

Chapter 4: Strengthening and implementing the global response

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1	Table of Content	
2		
3	Table of Content	2
4	Executive Summary	5
5	4.1 Accelerating the Global Response to Climate Change	10
6	4.2 Pathways Compatible with 1.5°C: Starting Points for Strengthening Implementation	11
7	4.2.1 Implications for Implementation of 1.5°C-consistent Pathways	11
8	4.2.1.1 Challenges and Opportunities for Mitigation Along the Reviewed Pathways	12
9	4.2.1.1.1 Greater scale, speed and change in investment patterns.....	12
10	4.2.1.1.2 Greater policy design and decision-making implications.....	13
11	4.2.1.1.3 Greater sustainable development implications.....	13
12	4.2.1.2 Implications for Adaptation Along the Reviewed Pathways.....	14
13	4.2.2 System Transitions and Rates of Change.....	14
14	4.2.2.1 Mitigation: Historical Rates of Change and State of Decoupling	14
15	4.2.2.2 Transformational Adaptation.....	15
16	4.2.2.3 Disruptive Innovation.....	16
17	4.3 Systemic Changes for 1.5°C-Consistent Pathways	17
18	4.3.1 Energy System Transitions.....	17
19	4.3.1.1 Renewable Electricity: Solar and Wind.....	17
20	4.3.1.2 Bioenergy and Biofuels	18
21	4.3.1.3 Nuclear Energy	19
22	4.3.1.4 Energy Storage	20
23	4.3.1.5 Options for Adapting Electricity Systems to 1.5°C.....	20
24	4.3.1.6 Carbon Dioxide Capture and Storage in the Power Sector	21
25	4.3.2 Land and Ecosystem Transitions.....	22
26	4.3.2.1 Agriculture and Food.....	22
27	4.3.2.2 Forests and Other Ecosystems.....	25
28	4.3.2.3 Coastal Systems.....	27
29	4.3.3 Urban and Infrastructure System Transitions.....	27
30	4.3.3.1 Urban Energy Systems	28
31	4.3.3.2 Urban Infrastructure, Buildings and Appliances	28
32	4.3.3.3 Urban Transport and Urban Planning.....	29
33	4.3.3.4 Electrification of Cities and Transport	30
34	4.3.3.5 Shipping, Freight and Aviation	31
35	4.3.3.6 Climate-Resilient Land Use	32
36	4.3.3.7 Green Urban Infrastructure and Ecosystem Services	32
37	4.3.3.8 Sustainable Urban Water and Environmental Services.....	33
38	4.3.4 Industrial Systems Transitions	33
39	4.3.4.1 Energy Efficiency.....	34
40	4.3.4.2 Substitution and Circularity.....	35
41	4.3.4.3 Bio-Based Feedstocks	35
42	4.3.4.4 Electrification and Hydrogen	35
43	4.3.4.5 CO ₂ Capture, Utilisation and Storage in Industry	36
44	4.3.5 Overarching Adaptation Options Supporting Adaptation Transitions	36
45	4.3.5.1 Disaster Risk Management (DRM).....	36
46	4.3.5.2 Risk Sharing and Spreading	36

1	4.3.5.3	Education and Learning.....	37
2	4.3.5.4	Population Health and Health System Adaptation Options.....	37
3	4.3.5.5	Indigenous Knowledge.....	37
4	4.3.5.6	Human Migration	37
5	4.3.5.7	Climate Services.....	38
6	Cross-Chapter Box 9: Risks, Adaptation Interventions, and Implications for Sustainable		
7	Development and Equity Across Four Social-Ecological Systems: Arctic, Caribbean, Amazon, and		
8	Urban 39		
9	4.3.6	Short Lived Climate Forcers.....	42
10	4.3.7	Carbon Dioxide Removal (CDR)	44
11	4.3.7.1	Bioenergy with carbon capture and storage (BECCS)	44
12	4.3.7.2	Afforestation and Reforestation (AR)	47
13	4.3.7.3	Soil Carbon Sequestration and Biochar.....	47
14	4.3.7.4	Enhanced Weathering (EW) and Ocean Alkalinisation	48
15	4.3.7.5	Direct Air Carbon Dioxide Capture and Storage (DACCS).....	49
16	4.3.7.6	Ocean Fertilisation	50
17	4.3.8	Solar Radiation Modification (SRM)	51
18	4.3.8.1	Governance and Institutional Feasibility	53
19	4.3.8.2	Economic and Technological Feasibility	54
20	4.3.8.3	Social Acceptability and Ethics.....	54
21	Cross-Chapter Box 10: Solar Radiation Modification in the Context of 1.5°C Mitigation		
22	Pathways 55		
23	4.4	Implementing Far-Reaching and Rapid Change	58
24	4.4.1	Enhancing Multi-Level Governance.....	58
25	4.4.1.1	Institutions and their Capacity to Invoke Far-Reaching and Rapid Change	58
26	4.4.1.2	International Governance	59
27	4.4.1.3	Sub-National Governance	61
28	4.4.1.4	Interactions and Processes for Multi-Level Governance.....	61
29	Box 4.1:	Multi-Level Governance in the EU Covenant of Mayors: Example of the Provincia di	
30	Foggia	62	
31	Box 4.2:	Watershed Management in a 1.5°C World.....	63
32	Cross-Chapter Box 11: Consistency Between Nationally Determined Contributions and 1.5°C		
33	Scenarios 64		
34	4.4.2	Enhancing Institutional Capacities	67
35	4.4.2.1	Capacity for Policy Design and Implementation.....	68
36	Box 4.3:	Indigenous Knowledge and Community Adaptation	68
37	Box 4.4:	Manizales, Colombia: Supportive National Government and Localised Planning and	
38	Integration as an Enabling Condition for Managing Climate and Development Risks	69	
39	4.4.2.2	Monitoring, Reporting, and Review Institutions	70
40	4.4.2.3	Financial Institutions	70
41	4.4.2.4	Co-Operative Institutions and Social Safety Nets	71
42	4.4.3	Enabling Lifestyle and Behavioural Change	71
43	4.4.3.1	Factors Related to Climate Actions	74
44	4.4.3.1.1	Ability to engage in climate action.....	74
45	4.4.3.1.2	Motivation to engage in climate action	75
46	4.4.3.1.3	Habits, heuristics and biases.....	76

1	4.4.3.2	Strategies and Policies to Promote Actions on Climate Change	77
2	Box 4.5:	How Pricing Policy has Reduced Car Use in Singapore, Stockholm and London.....	77
3	Box 4.6:	Bottom-up Initiatives: Adaptation Responses Initiated by Individuals and	
4	Communities	79	
5	4.4.3.3	Acceptability of Policy and System Changes.....	80
6	4.4.4	Enabling Technological Innovation.....	81
7	4.4.4.1	The Nature of Technological Innovations	81
8	4.4.4.2	Technologies as Enablers of Climate Action	82
9	4.4.4.3	The Role of Government in 1.5°C-Consistent Climate Technology Policy.....	83
10	Box 4.7:	Bioethanol in Brazil: Innovation and Lessons for Technology Transfer.....	84
11	4.4.4.4	Technology Transfer in the Paris Agreement.....	85
12	4.4.5	Strengthening Policy Instruments and Enabling Climate Finance	86
13	4.4.5.1	The Core Challenge: Cost Efficiency, Coordination of Expectations and Distributive Effects	
14		86	
15	Box 4.8:	Investment Needs and the Financial Challenge of Limiting Warming to 1.5°C	86
16	Box 4.9:	Emerging cities and ‘peak car use’: Evidence of decoupling in Beijing	90
17	4.4.5.2	Carbon Pricing: Necessity and Constraints	91
18	4.4.5.3	Regulatory measures and information flows	92
19	4.4.5.4	Scaling-up Climate Finance and De-Risking Low-Emission Investments.....	93
20	4.4.5.5	Financial Challenge for Basic Needs and Adaptation Finance	95
21	4.4.5.6	Towards Integrated Policy Packages and Innovative Forms of Financial Cooperation	96
22	4.5	Integration and Enabling Transformation.....	97
23	4.5.1	Assessing Feasibility of Options for Accelerated Transitions	97
24	4.5.2	Implementing Mitigation.....	98
25	4.5.2.1	Assessing of Mitigation Options for Limiting Warming to 1.5°C Against Feasibility	
26	Dimensions.....	98	
27	4.5.2.2	Enabling Conditions for Implementation of Mitigation Options Towards 1.5°C	103
28	4.5.3	Implementing Adaptation	103
29	4.5.3.1	Feasible Adaptation Options	104
30	4.5.3.2	Monitoring and Evaluation.....	108
31	4.5.4	Synergies and Trade-Offs Between Adaptation and Mitigation.....	108
32	Box 4.10:	Bhutan: Synergies and Trade-Offs in Economic Growth, Carbon Neutrality and	
33	Happiness	109	
34	4.6	Knowledge Gaps and Key Uncertainties	111
35	Frequently Asked Questions.....	119	
36	FAQ 4.1:	What transitions could enable limiting global warming to 1.5°C?	119
37	FAQ 4.2:	What are Carbon Dioxide Removal and negative emissions?.....	121
38	FAQ 4.3:	Why is adaptation important in a 1.5°C warmer world?	123
39	References	125	
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2
3
4
5
6
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17
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Executive Summary

Limiting warming to 1.5°C would require transformative systemic change, integrated with sustainable development. Such change would require the upscaling and acceleration of the implementation of far-reaching, multi-level and cross-sectoral climate mitigation and addressing barriers. Such systemic change would need to be linked to complementary adaptation actions, including transformational adaptation, especially for pathways that temporarily overshoot 1.5°C {Chapter 2, Chapter 3, 4.2.1, 4.4.5, 4.5} (medium evidence, high agreement). Current national pledges on mitigation and adaptation are not enough to stay below the Paris Agreement temperature limits and achieve its adaptation goals. While transitions in energy efficiency, carbon intensity of fuels, electrification and land use change are underway in various countries, limiting warming to 1.5°C will require a greater scale and pace of change to transform energy, land, urban and industrial systems globally. {4.3, 4.4, Cross-Chapter Box CB9 in this Chapter}

Although multiple communities around the world are demonstrating the possibility of implementation consistent with 1.5°C pathways {Boxes 4.1-4.10}, very few countries, regions, cities, communities or businesses can currently make such a claim (high confidence). To strengthen the global response, almost all countries would need to significantly raise their level of ambition. Implementation of this raised ambition would require enhanced institutional capabilities in all countries, including building the capability to utilise Indigenous and local knowledge (medium evidence, high agreement). In developing countries and for poor and vulnerable people, implementing the response would require financial, technological and other forms of support to build capacity, for which additional local, national and international resources would need to be mobilised (high confidence). However, public, financial, institutional and innovation capabilities currently fall short of implementing far-reaching measures at scale in all countries (high confidence). Transnational networks that support multi-level climate action are growing, but challenges in their scale-up remain. {4.4.1, 4.4.2, 4.4.4, 4.4.5, Box 4.1, Box 4.2, Box 4.7}

Adaptation needs will be lower in a 1.5°C world compared to a 2°C world (high confidence) {Chapter 3; Cross-Chapter Box CB11 in this Chapter}. Learning from current adaptation practices and strengthening them through adaptive governance {4.4.1}, lifestyle and behavioural change {4.4.3} and innovative financing mechanisms {4.4.5} can help their mainstreaming within sustainable development practices. Preventing maladaptation, drawing on bottom-up approaches {Box 4.6} and using Indigenous knowledge {Box 4.3} would effectively engage and protect vulnerable people and communities. While adaptation finance has increased quantitatively, significant further expansion would be needed to adapt to 1.5°C. Qualitative gaps in the distribution of adaptation finance, readiness to absorb resources and monitoring mechanisms undermine the potential of adaptation finance to reduce impacts. {Chapter 3, 4.4.2, 4.4.5, 4.6}

System transitions

The energy system transition that would be required to limit global warming to 1.5°C is underway in many sectors and regions around the world (medium evidence, high agreement). The political, economic, social and technical feasibility of solar energy, wind energy and electricity storage technologies has improved dramatically over the past few years, while that of nuclear energy and Carbon Dioxide Capture and Storage (CCS) in the electricity sector have not shown similar improvements. {4.3.1}

Electrification, hydrogen, bio-based feedstocks and substitution, and in several cases carbon dioxide capture, utilisation and storage (CCUS), would lead to the deep emissions reductions required in energy-intensive industry to limit warming to 1.5°C. However, those options are limited by institutional, economic and technical constraints, which increase financial risks to many incumbent firms (medium evidence, high agreement). Energy efficiency in industry is more economically feasible and an enabler of industrial system transitions but would have to be complemented with Greenhouse Gas (GHG)-neutral processes or Carbon Dioxide Removal (CDR) to make energy-intensive industry consistent with 1.5°C (high confidence). {4.3.1, 4.3.4}

1 **Global and regional land-use and ecosystems transitions and associated changes in behaviour that**
2 **would be required to limit warming to 1.5°C can enhance future adaptation and land-based**
3 **agricultural and forestry mitigation potential. Such transitions could, however, carry consequences for**
4 **livelihoods that depend on agriculture and natural resources {4.3.2, Cross-Chapter Box CB6 in**
5 **chapter 3}. Alterations of agriculture and forest systems to achieve mitigation goals could affect current**
6 **ecosystems and their services and potentially threaten food, water and livelihood security. While this could**
7 **limit the social and environmental feasibility of land-based mitigation options, careful design and**
8 **implementation could enhance their acceptability and support sustainable development objectives (*medium***
9 ***evidence, medium agreement*). {4.3.2, 4.5.3}**

10
11 **Changing agricultural practices can be an effective climate adaptation strategy.** A diversity of
12 adaptation options exists, including mixed crop-livestock production systems which can be a cost-effective
13 adaptation strategy in many global agriculture systems (*robust evidence, medium agreement*). Improving
14 irrigation efficiency could effectively deal with changing global water endowments, especially if achieved
15 via farmers adopting new behaviour and water-efficient practices rather than through large-scale
16 infrastructure (*medium evidence, medium agreement*). Well-designed adaptation processes such as
17 community-based adaptation can be effective depending upon context and levels of vulnerability. {4.3.2,
18 4.5.3}

19
20 **Improving the efficiency of food production and closing yield gaps have the potential to reduce**
21 **emissions from agriculture, reduce pressure on land and enhance food security and future mitigation**
22 **potential (*high confidence*).** Improving productivity of existing agricultural systems generally reduces the
23 emissions intensity of food production and offers strong synergies with rural development, poverty reduction
24 and food security objectives, but options to reduce absolute emissions are limited unless paired with demand-
25 side measures. Technological innovation including biotechnology, with adequate safeguards, could
26 contribute to resolving current feasibility constraints and expand the future mitigation potential of
27 agriculture. {4.3.2, 4.4.4}

28
29 **Dietary choices towards foods with lower emissions and requirements for land, along with reduced**
30 **food loss and waste, could reduce emissions and increase adaptation options (*high confidence*).**
31 Decreasing food loss and waste and behavioural change around diets could lead to effective mitigation and
32 adaptation options (*high confidence*) by reducing both emissions and pressure on land, with significant co-
33 benefits for food security, human health and sustainable development {4.3.2, 4.4.5, 4.5.2, 4.5.3, 5.4.2}, but
34 evidence of successful policies to modify dietary choices remains limited.

35 36 **Mitigation and Adaptation Options and other Measures**

37
38 **A mix of mitigation and adaptation options implemented in a participatory and integrated manner**
39 **can enable rapid, systemic transitions in urban and rural areas that are necessary elements of an**
40 **accelerated transition to 1.5°C worlds. Such options and changes are most effective when aligned with**
41 **economic and sustainable development, and when local and regional governments are supported by**
42 **national governments {4.3.3, 4.4.1, 4.4.3},** Various mitigation options are expanding rapidly across many
43 geographies. Although many have development synergies, not all income groups have so far benefited from
44 them. Electrification, end-use energy efficiency and increased share of renewables, amongst other options,
45 are lowering energy use and decarbonising energy supply in the built environment, especially in buildings.
46 Other rapid changes needed in urban environments include demotorisation and decarbonisation of transport,
47 including the expansion of electric vehicles, and greater use of energy-efficient appliances (*medium*
48 *evidence, high agreement*). Technological and social innovations can contribute to limiting warming to
49 1.5°C, e.g. by enabling the use of smart grids, energy storage technologies and general-purpose technologies,
50 such as Information and Communication Technology (ICT) that can be deployed to help reduce emissions.
51 Feasible adaptation options include green infrastructure, resilient water and urban ecosystem services, urban
52 and peri-urban agriculture, and adapting buildings and land use through regulation and planning (*medium*
53 *evidence, medium to high agreement*). {4.3.3}

1 **Synergies can be achieved across systemic transitions through several overarching adaptation options**
2 **in rural and urban areas.** Investments in health, social security and risk sharing and spreading are cost-
3 effective adaptation measures with high potential for scaling-up (*medium evidence, medium to high*
4 *agreement*). Disaster risk management and education-based adaptation have lower prospects of scalability
5 and cost-effectiveness (*medium evidence, high agreement*) but are critical for building adaptive capacity.
6 {4.3.5, 4.5.3}

7
8 **Converging adaptation and mitigation options can lead to synergies and potentially increase cost**
9 **effectiveness, but multiple trade-offs can limit the speed of and potential for scaling up.** Many examples
10 of synergies and trade-offs exist in all sectors and system transitions. For instance, sustainable water
11 management (*high evidence, medium agreement*) and investment in green infrastructure (*medium evidence,*
12 *high agreement*) to deliver sustainable water and environmental services and to support urban agriculture are
13 less cost-effective but can help build climate resilience. Achieving the governance, finance and social
14 support required to enable these synergies and to avoid trade-offs is often challenging, especially when
15 addressing multiple objectives, and appropriate sequencing and timing of interventions. {4.3.2, 4.3.4, 4.4.1,
16 4.5.2, 4.5.3, 4.5.4}

17
18 **Though CO₂ dominates long-term warming, the reduction of warming Short-Lived Climate Forcers**
19 **(SLCFs), such as methane and black carbon, can in the short term contribute significantly to limiting**
20 **warming to 1.5°C. Reductions of black carbon and methane would have substantial co-benefits (*high***
21 ***confidence*), including improved health due to reduced air pollution. This, in turn, enhances the**
22 **institutional and socio-cultural feasibility of such actions.** Reductions of several warming SLCFs are
23 constrained by economic and social feasibility (*low evidence, high agreement*). As they are often co-emitted
24 with CO₂, achieving the energy, land and urban transitions necessary to limit warming to 1.5°C would see
25 emissions of warming SLCFs greatly reduced. {2.3.3.2, 4.3.6}

26
27 **Most CDR options face multiple feasibility constraints, that differ between options, limiting the**
28 **potential for any single option to sustainably achieve the large-scale deployment in 1.5°C-consistent**
29 **pathways in Chapter 2 (*high confidence*).** Those 1.5°C pathways typically rely on Bioenergy with Carbon
30 Capture and Storage (BECCS), Afforestation and Reforestation (AR), or both, to neutralise emissions that
31 are expensive to avoid, or to draw down CO₂ emissions in excess of the carbon budget {Chapter 2}. Though
32 BECCS and AR may be technically and geophysically feasible, they face partially overlapping yet different
33 constraints related to land use. The land footprint per tonne CO₂ removed is higher for AR than for BECCS,
34 but in the light of low current deployment, the speed and scales required for limiting warming to 1.5°C pose
35 a considerable implementation challenge, even if the issues of public acceptance and missing economic
36 incentives were to be resolved (*high agreement, medium evidence*). The large potentials of afforestation and
37 their co-benefits if implemented appropriately (e.g. on biodiversity, soil quality) will diminish over time, as
38 forests saturate (*high confidence*). The energy requirements and economic costs of Direct Air Carbon
39 Capture and Storage (DACCS) and enhanced weathering remain high (*medium evidence, medium*
40 *agreement*). At the local scale, soil carbon sequestration has co-benefits with agriculture and is cost-effective
41 even without climate policy (*high confidence*). Its potential global feasibility and cost effectiveness appears
42 to be more limited. {4.3.7}

43
44 **Uncertainties surrounding Solar Radiation Modification (SRM) measures constrain their potential**
45 **deployment.** These uncertainties include: technological immaturity; limited physical understanding about
46 their effectiveness to limit global warming; and a weak capacity to govern, legitimise, and scale such measures.
47 Some recent model-based analysis suggests SRM would be effective but that it is too early to evaluate its
48 feasibility. Even in the uncertain case that the most adverse side-effects of SRM can be avoided, public
49 resistance, ethical concerns and potential impacts on sustainable development could render SRM
50 economically, socially and institutionally undesirable (*low agreement, medium evidence*). {4.3.8, Cross-
51 Chapter Box CB10 in this Chapter}

1 **Enabling Rapid and Far-reaching Change**

2
3 **The speed and scale of transitions and of technological change required to limit warming to 1.5°C has**
4 **been observed in the past within specific sectors and technologies {4.2.2.1}. But the geographical and**
5 **economic scales at which the required rates of change in the energy, land, urban, infrastructure and**
6 **industrial systems would need to take place, are larger and have no documented historic precedent**
7 *(limited evidence, medium agreement)*. To reduce inequality and alleviate poverty, such transformations
8 would require more planning and stronger institutions (including inclusive markets) than observed in the
9 past, as well as stronger coordination and disruptive innovation across actors and scales of governance. {4.3,
10 4.4}

11
12 **Governance consistent with limiting warming to 1.5°C and the political economy of adaptation and**
13 **mitigation can enable and accelerate systems transitions, behavioural change, innovation and**
14 **technology deployment** *(medium evidence, medium agreement)*. For 1.5°C-consistent actions, an effective
15 governance framework would include: accountable multi-level governance that includes non-state actors
16 such as industry, civil society and scientific institutions; coordinated sectoral and cross-sectoral policies that
17 enable collaborative multi-stakeholder partnerships; strengthened global-to-local financial architecture that
18 enables greater access to finance and technology; and addresses climate-related trade barriers; improved
19 climate education and greater public awareness; arrangements to enable accelerated behaviour change;
20 strengthened climate monitoring and evaluation systems; and reciprocal international agreements that are
21 sensitive to equity and the Sustainable Development Goals (SDGs). System transitions can be enabled by
22 enhancing the capacities of public, private and financial institutions to accelerate climate change policy
23 planning and implementation, along with accelerated technological innovation, deployment and upkeep.
24 {4.4.1, 4.4.2, 4.4.3, 4.4.4}

25
26 **Behaviour change and demand-side management can significantly reduce emissions, substantially**
27 **limiting the reliance on CDR to limit warming to 1.5°C {Chapter 2, 4.4.3}**. Political and financial
28 stakeholders may find climate actions more cost-effective and socially acceptable, if multiple factors
29 affecting behaviour are considered, including aligning them with people's core values *(medium evidence,*
30 *high agreement)*. Behaviour- and lifestyle-related measures and demand-side management have already led
31 to emission reductions around the world and can enable significant future reductions *(high confidence)*.
32 Social innovation through bottom-up initiatives can result in greater participation in the governance of
33 systems transitions and increase support for technologies, practices and policies that are part of the global
34 response to 1.5°C. {Chapter 2, 4.4.1, 4.4.3, Figure 4.3}

35
36 **This rapid and far-reaching response required to keep warming below 1.5°C and enhance the adaptive**
37 **capacity to climate risks needs large investments in low-emission infrastructure and buildings that are**
38 **currently underinvested, along with a redirection of financial flows towards low-emission investments**
39 *(robust evidence, high agreement)*. An estimated annual incremental investment of 1% to 1.5% of global
40 Gross Fixed Capital Formation (GFCF) for the energy sector is indicated; and 1.7% to 2.5% of global GFCF
41 for other development infrastructure that could also address SDG implementation. Though quality policy
42 design and effective implementation may enhance efficiency, they cannot substitute for these investments.
43 {2.5.2, 4.2.1}

44
45 **Enabling this investment requires the mobilisation and better integration of a range of policy**
46 **instruments** that include: the reduction of socially inefficient fossil fuel subsidy regimes and innovative
47 price and non-price national and international policy instruments and would need to be complemented by de-
48 risking financial instruments and the emergence of long-term low-emission assets. These instruments would
49 aim to reduce the demand for carbon-intensive services and shift market preferences away from fossil fuel-
50 based technology. Evidence and theory suggest that carbon pricing alone, in the absence of sufficient
51 transfers to compensate their unintended distributional cross-sector, cross-nation effects, cannot reach the
52 levels needed to trigger system transitions *(robust evidence, medium agreement)*. But, embedded in
53 consistent policy-packages, they can help mobilise incremental resources and provide flexible mechanisms
54 that help reduce the social and economic costs of the triggering phase of the transition *(robust evidence,*
55 *medium agreement)*. {4.4.3, 4.4.4, 4.4.5}

1 **Increasing evidence suggests that a climate-sensitive realignment of savings and expenditure towards**
2 **low-emission, climate-resilient infrastructure and services requires an evolution of global and national**
3 **financial systems.** Estimates suggest that, in addition to climate-friendly allocation of public investments, a
4 potential redirection of 5% to 10% of the annual capital revenues¹ is necessary {4.4.5, Table 1 in Box 4.8}.
5 This could be facilitated by a change of incentives for private day-to-day expenditure and the redirection of
6 savings from speculative and precautionary investments, towards long-term productive low-emission assets
7 and services. This implies the mobilisation of institutional investors and mainstreaming of climate finance
8 within financial and banking system regulation. Access by developing countries to low-risk and low-interest
9 finance through multilateral and national development banks would have to be facilitated (*medium evidence,*
10 *high agreement*). New forms of public-private partnerships may be needed with multilateral, sovereign and
11 sub-sovereign guarantees to de-risk climate-friendly investments, support new business models for small-scale
12 enterprises and help households with limited access to capital. Ultimately, the aim is to promote a portfolio
13 shift towards long-term low-emission assets, that would help redirect capital away from potential stranded
14 assets (*medium evidence, medium agreement*). {4.4.5}

16 Knowledge Gaps

17
18 **Knowledge gaps around implementing and strengthening the global response to climate change would**
19 **need to be urgently resolved if the transition to 1.5°C worlds is to become reality.** Remaining questions
20 include: how much can be realistically expected from innovation, behaviour and systemic political and
21 economic change in improving resilience, enhancing adaptation and reducing GHG emissions? How can
22 rates of changes be accelerated and scaled up? What is the outcome of realistic assessments of mitigation and
23 adaptation land transitions that are compliant with sustainable development, poverty eradication and
24 addressing inequality? What are life-cycle emissions and prospects of early-stage CDR options? How can
25 climate and sustainable development policies converge, and how can they be organised within a global
26 governance framework and financial system, based on principles of justice and ethics (including Common
27 But Differentiated Responsibilities and Respective Capabilities (CBDR-RC)), reciprocity and partnership?
28 To what extent limit warming to 1.5°C needs a harmonisation of macro-financial and fiscal policies, that
29 could include financial regulators such as central banks? How can different actors and processes in climate
30 governance reinforce each other, and hedge against the fragmentation of initiatives? {4.1, 4.4.1, 4.3.7, 4.4.5,
31 4.6}

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¹ Annual capital revenues are the paid interests plus the increase of the asset value.

4.1 Accelerating the Global Response to Climate Change

This chapter discusses how the global economy and socio-technical and socio-ecological systems can transition to 1.5°C-consistent pathways and adapt to warming of 1.5°C. In the context of systemic transitions, the chapter assesses adaptation and mitigation options, including Carbon Dioxide Removal (CDR), and potential Solar Radiation Modification (SRM) remediative measures (Section 4.3), as well as the enabling conditions that would facilitate implementing the rapid and far-reaching global response (Section 4.4), and render the options more or less feasible (Section 4.5).

The impacts of 1.5°C warmer worlds, while less than in a 2°C warmer world, would require complementary adaptation and development action, typically at local and national scale. From a mitigation perspective, 1.5°C-consistent pathways require immediate action on a greater and global scale so as to achieve net-zero emissions by mid-century, or earlier (Chapter 2). This chapter and Chapter 5 highlight the potential that combined mitigation, development and poverty reduction offer for accelerated decarbonisation.

The global context is an increasingly interconnected world, with the human population growing from the current 7.6 billion to over 9 billion by mid-century (UN, 2017). There has been a consistent growth of global economic output, wealth and trade with a significant reduction in extreme poverty. These trends could continue for the next few decades (Burt et al., 2014), potentially supported by new and disruptive information and communication, and nano- and bio-technologies. They however co-exist with rising inequality (Piketty, 2014), exclusion and social stratification, and regions locked in poverty traps (Deaton, 2013) that could fuel social and political tensions.

The aftermath of the 2008 financial crisis generated a challenging environment on which leading economists have issued repeated alerts about the ‘discontents of globalisation’ (Stiglitz, 2002), ‘depression economics’ (Krugman, 2009), an excessive reliance of export-led development strategies (Rajan, 2011), and risks of ‘secular stagnation’ due to the ‘saving glut’ that slows down the flow of global savings towards productive 1.5°C-consistent investments (Summers, 2016). Each of these impacts the implementation of both 1.5°C-consistent pathways and sustainable development (Chapter 5).

The range of mitigation and adaptation actions that can be deployed in the short run are well-known: for example, low-emission technologies, new infrastructure, energy efficiency measures in buildings, industry and transport; transformation of fiscal structures; reallocation of investments and human resources towards low-emission assets; sustainable land and water management, ecosystem restoration, enhancement of adaptive capacities to climate risks and impacts, disaster risk management; research and development; and mobilisation of new, traditional and Indigenous knowledge.

The convergence of short-term development co-benefits of mitigation and adaptation to address ‘everyday development failures’ (e.g., institutions, market structures and political processes) (Hallegatte et al., 2016; Pelling et al., 2018) could enhance the adaptive capacity of key systems at risk (e.g., water, energy, food, biodiversity, urban, regional and coastal systems) to 1.5°C climate impact (Chapter 3). The issue is whether aligning 1.5°C-consistent pathways with the Sustainable Development Goals (SDGs) will secure support for accelerated change and a new growth cycle (Stern, 2013, 2015). It is difficult to imagine how a 1.5°C world would be attained unless the SDG on cities and sustainable urbanisation is attained in developing countries (Revi, 2016), or without reforms in the global financial intermediation system.

Unless affordable and environmentally and socially acceptable CDR become feasible and available at scale well before 2050, 1.5°C-consistent pathways will be difficult to realise, especially in overshoot scenarios. The social costs and benefits of 1.5°C-consistent pathways depend on the depth and timing of policy responses and their alignment with short term and long-term development objectives, through policy packages that bring together a diversity of policy instruments, including public investment (Campiglio 2016; Winkler and Dubash 2015; Grubb et al. 2014).

Whatever its potential long-term benefits, a transition to a 1.5°C world may suffer from a lack of broad political and public support, if it exacerbates existing short-term economic and social tensions, including

1 unemployment, poverty, inequality, financial tensions, competitiveness issues and the loss of economic value
2 of carbon-intensive assets (Mercuri et al., 2018). The challenge is therefore how to strengthen climate
3 policies without inducing economic collapse or hardship, and to make them contribute to reducing some of
4 the ‘fault lines’ of the world economy (Rajan, 2011).

5
6 This chapter reviews literature addressing the alignment of climate with other public policies (e.g., fiscal,
7 trade, industrial, monetary, urban planning, infrastructure, innovation) and with a greater access to basic
8 needs and services, defined by the SDGs. It also reviews how de-risking low-emission investments and the
9 evolution of the financial intermediation system can help reduce the ‘savings glut’ (Arezki et al., 2016) and
10 the gap between cash balances and long-term assets (Aglietta et al., 2015b) to support more sustainable and
11 inclusive growth.

12
13 As the transitions associated with 1.5°C-consistent pathways require accelerated and coordinated action, in
14 multiple systems across all world regions, they are inherently exposed to risks of freeriding and moral
15 hazards. A key governance challenge is how the convergence of voluntary domestic policies can be
16 organised via aligned global, national and sub-national governance, based on reciprocity (Ostrom and
17 Walker, 2005) and partnership (UN, 2016), and how different actors and processes in climate governance
18 can reinforce each other to enable this (Gupta, 2014; Andonova et al., 2017). The emergence of polycentric
19 sources of climate action and transnational and subnational networks that link these efforts (Abbott et al.,
20 2012) offer the opportunity to experiment and learn from different approaches, thereby accelerating
21 approaches led by national governments (Cole, 2015; Jordan et al., 2015).

22
23 Section 4.2 of this chapter outlines existing rates of change and attributes of accelerated change. Section 4.3
24 identifies global systems, and their components, that offer options for this change. Section 4.4 documents the
25 enabling conditions that influence the feasibility of those options, including economic, financial and policy
26 instruments that could trigger the transition to 1.5°C-consistent pathways. Section 4.5 assesses mitigation
27 and adaptation options for feasibility, strategies for implementation and synergies and trade-offs between
28 mitigation and adaptation.

31 **4.2 Pathways Compatible with 1.5°C: Starting Points for Strengthening Implementation**

32 **4.2.1 Implications for Implementation of 1.5°C-consistent Pathways**

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35 The 1.5°C-consistent pathways assessed in Chapter 2 form the basis for the feasibility assessment in section
36 4.3. A wide range of 1.5°C-consistent pathways from both Integrated Assessment Modelling (IAM),
37 supplemented by other literature, are assessed by Chapter 2 (Sections 2.1, 2.3, 2.4, and 2.5). The most
38 common feature shared by these pathways is their requirement for faster and more radical changes compared
39 to 2°C and higher warming pathways.

40
41 A variety of 1.5°C-consistent technological options and policy targets is identified in the assessed modelling
42 literature (Sections 2.3, 2.4, 2.5). These technology and policy options include energy demand reduction,
43 greater penetration of low-emission and carbon-free technologies as well as electrification of transport and
44 industry, and reduction of land-use change. Both the detailed integrated modelling pathway literature and a
45 number of broader sectoral and bottom-up studies provide examples of how these sectoral technological and
46 policy characteristics can be broken down sectorally for 1.5°C-consistent pathways (see Table 4.1).

47
48 Both the integrated pathway literature and the sectoral studies agree on the need for rapid transitions in the
49 production and use of energy across various sectors, to be consistent with limiting global warming to 1.5°C.
50 The pace of these transitions are particularly significant for the supply mix and electrification, with sectoral
51 studies projecting a higher pace of change compared to IAMs (Table 4.1). These trends and transformation
52 patterns create opportunities and challenges for both mitigation and adaptation (Sections 4.2.1.1 and 4.2.1.2),
53 and have significant implications for the assessment of feasibility and enablers, including governance,
54 institutions, and policy instruments addressed in Sections 4.3 and 4.4.

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Table 4.1: Sectoral indicators of the pace of transformation in 1.5°C-consistent pathways, based on selected integrated pathways assessed in Chapter 2 (from the scenario database) and sectoral studies reviewed in Chapter 2 that assess mitigation transitions consistent with limiting warming to 1.5°C. Values for ‘1.5C low OS’ and ‘1.5C high OS’ indicate the median and the interquartile ranges for 1.5°C scenarios distinguishing high and low overshoot. S1, S2, S5 and LED represent the four illustrative pathway archetypes selected for this assessment (see Section 2.1 and Supplementary Material 4.SM.1 for detailed description).

		Energy		Buildings	Transport		Industry
		Share of renewable in primary energy [%]	Share of renewable in electricity [%]	Change in energy demand for buildings (2010 baseline) [%]	Share of low carbon fuels (electricity, hydrogen and biofuel) in transport [%]	Share of electricity in transport [%]	Industrial emissions reductions (based on current level) [%]
IAM Pathways 2030	1.5C low OS	29 (35; 25)	53 (59; 44)	-3 (5; -8)	10 (15; 8)	5 (7; 3)	40 (50; 30)
	1.5C high OS	24 (27; 20)	43 (54; 37)	-17 (-12; -20)	7 (8; 6)	3 (5; 3)	18 (28; -13)
	S1	29	58	-8	NA	4	49
	S2	29	48	-14	5	4	19
	S5	14	25	NA	3	1	NA
	LED	37	60	30	NA	21	42
Sectorial studies 2030	Löffler et al. (2017)	50	78				
	Rockström et al. (2017)	20					
	Kuramochi et al. (2017)						20
	IEA (2017)	20	47	7	16	6	14
	WBCSD (2017)			-11			
IAM Pathways 2050	1.5C low OS	58 (67; 50)	76 (85; 69)	-19 (2; -37)	53 (65; 34)	23 (30; 17)	79 (89; 71)
	1.5C high OS	62 (68; 47)	82 (88; 64)	-37 (-13; -51)	38 (44; 27)	18 (23; 14)	68 (81; 54)
	S1	58	81	-21	NA	34	74
	S2	53	63	-25	26	23	73
	S5	67	70	NA	53	10	NA
	LED	73	77	45	NA	59	91
Sectorial studies 2050	Löffler et al. (2017)	100	100		98		
	Rockström et al. (2017)		100				
	Figueres et al. (2017)						50
	Kuramochi et al. (2017)		100				
	IEA (2017)	29	74	11	59	31	20
	WBCSD (2017)						

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4.2.1.1 Challenges and Opportunities for Mitigation Along the Reviewed Pathways

4.2.1.1.1 Greater scale, speed and change in investment patterns

There is agreement in the literature reviewed by Chapter 2 that staying below 1.5°C would entail significantly greater transformation in terms of energy systems, lifestyles and investments patterns compared to 2°C-consistent pathways. Yet there is *limited evidence* and *low agreement* regarding the magnitudes and costs of the investments (Sections 2.5.1, 2.5.2 and 4.4.5). Based on the IAM literature reviewed in Chapter 2, climate policies in line with limiting warming to 1.5°C would require a marked upscaling of supply-side energy system investments between now and mid-century, reaching levels of between 1.6–3.8 trillion USD

1 yr⁻¹ globally with an average of about 3.5 trillion USD yr⁻¹ over 2016-2050 (see Figure 2.27). This can be
2 compared to an average of about 3.0 trillion USD yr⁻¹ over the same period for 2°C-consistent pathways
3 (also in Figure 2.27).
4

5 Not only the level of investment but also the type and speed of sectoral transformation would be impacted by
6 the transitions associated with 1.5°C-consistent pathways. IAM literature projects that investments in low-
7 emission energy overtake fossil-fuel investments globally by 2025 in 1.5°C-consistent pathways (Section
8 2.5.2). The projected low-emission investments in electricity generation allocations over the period 2016–
9 2050 are: solar (0.09–1.0 trillion USD yr⁻¹), wind (0.1–0.35 trillion USD yr⁻¹), nuclear (0.1–0.25 trillion
10 USD yr⁻¹), and transmission, distribution, and storage (0.3–1.3 trillion USD yr⁻¹). In contrast, investments in
11 fossil-fuel extraction and unabated fossil electricity generation along a 1.5°C-consistent pathway are
12 projected to drop by 0.3-0.85 trillion USD yr⁻¹ over the period 2016–2050, with investments in unabated coal
13 generation projected to halt by 2030 in most 1.5°C-consistent pathways (Section 2.5.2). Estimates of
14 investments in other infrastructure are currently unavailable, but they could be considerably larger in volume
15 than solely those in the energy sector (Section 4.4.5).
16
17

18 4.2.1.1.2 *Greater policy design and decision-making implications*

19 1.5°C-consistent pathways raise multiple challenges for effective policy design and responses to address the
20 scale, speed, and pace of mitigation technology, finance and capacity building needs. They also need to deal
21 with their distributional implications, while addressing adaptation to residual climate impacts (see
22 Chapter 5). The available literature indicates that 1.5°C-consistent pathways would require robust, stringent
23 and urgent transformative policy interventions targeting the decarbonisation of energy supply, electrification,
24 fuel switching, energy efficiency, land-use change, and lifestyles (Sections 2.5, 4.4.2, 4.4.3). Examples of
25 effective approaches to integrate mitigation with adaptation in the context of sustainable development and to
26 deal with distributional implications proposed in the literature include the utilisation of dynamic adaptive
27 policy pathways (Haasnoot et al., 2013; Mathy et al., 2016) and transdisciplinary knowledge systems
28 (Bendito and Barrios, 2016).
29

30 Yet, even with good policy design and effective implementation, 1.5°C-consistent pathways would incur
31 higher costs. Projections of the magnitudes of global economic costs associated with 1.5°C-consistent
32 pathways and their sectoral and regional distributions from the currently assessed literature are scant, yet
33 suggestive. For example, IAM simulations assessed in Chapter 2 project (with a probability greater than
34 50%) that marginal abatement costs, typically represented in IAMs through a carbon price, would increase
35 by about threefold by 2050 under a 1.5°C-consistent pathway compared to a 2°C-consistent pathway
36 (Section 2.5.2, Figure 2.26). Managing these costs and distributional effects would require an approach that
37 takes account of unintended cross-sector, cross-nation, and cross-policy trade-offs during the transition
38 (Droste et al., 2016; Stiglitz et al., 2017; Pollitt, 2018; Sands, 2018; Siegmeier et al., 2018).
39
40

41 4.2.1.1.3 *Greater sustainable development implications*

42 Few studies address the relations between the Shared Socioeconomic Pathways (SSPs) and the Sustainable
43 Developments Goals (SDGs) (O'Neill et al., 2015; Riahi et al., 2017). Nonetheless, literature on potential
44 synergies and trade-offs between 1.5°C-consistent mitigation pathways and sustainable development
45 dimensions is emerging (Sections 2.5.3, 5.4). Areas of potential trade-offs include reduction in final energy
46 demand in relation to SDG 7 (the universal clean energy access goal) and increase of biomass production in
47 relation to land use, water resources, food production, biodiversity and air quality (Sections 2.4.3, 2.5.3).
48 Strengthening the institutional and policy responses to deal with these challenges are discussed in Section 4.4
49 together with the linkage between disruptive changes in the energy sector and structural changes in other
50 infrastructure (transport, building, water and telecommunication) sectors. A more in-depth assessment of the
51 complexity and interfaces between 1.5°C-consistent pathways and sustainable development is presented in
52 Chapter 5.
53
54

4.2.1.2 *Implications for Adaptation Along the Reviewed Pathways*

Climate variability and uncertainties in the underlying assumptions in Chapter 2's IAMs as well as in model comparisons complicate discerning the implications for climate impacts, adaptation options and avoided adaptation investments at the global level of 2°C compared to 1.5°C warming (James et al., 2017; Mitchell et al., 2017).

Incremental warming from 1.5°C to 2°C would lead to significant increases in temperature and precipitation extremes in many regions (Section 3.3.2, 3.3.3). Those projected changes in climate extremes under both warming levels, however, depend on the emissions pathways, as they have different greenhouse gas (GHG)/aerosol forcing ratios. Impacts are sector-, system- and region-specific, as described in Chapter 3. For example, precipitation-related impacts reveal distinct regional differences (Sections 3.3.3, 3.3.4, 3.3.5, 3.4.2). Similarly, regional reduction in water availability and the lengthening of regional dry spells have negative implications for agricultural yields depending on crop types and world regions (see for example Sections 3.3.4, 3.4.2, 3.4.6).

Adaptation helps reduce impacts and risks. However, adaptation has limits. Not all systems can adapt, and not all impacts can be reversed (Cross-Chapter Box 12 in Chapter 5). For example, tropical coral reefs are projected to be at risk of severe degradation due to temperature-induced bleaching (Box 3.4).

4.2.2 *System Transitions and Rates of Change*

Society-wide transformation involves socio-technical transitions and social-ecological resilience (Gillard et al., 2016). Transitional adaptation pathways would need to respond to low-emission energy and economic systems, and the socio-technical transitions for mitigation involve removing barriers in social and institutional processes that could also benefit adaptation (Pant et al., 2015; Geels et al., 2017; Ickowitz et al., 2017). In this chapter, transformative change is framed in mitigation around socio-technical transitions, and in adaptation around socio-ecological transitions. In both instances, emphasis is placed on the enabling role of institutions (including markets, and formal and informal regulation). 1.5°C-consistent pathways and adaptation needs associated with warming of 1.5°C imply both incremental and rapid, disruptive and transformative changes.

4.2.2.1 *Mitigation: Historical Rates of Change and State of Decoupling*

Realising 1.5°C-consistent pathways would require rapid and systemic changes on unprecedented scales (see Chapter 2 and Section 4.2.1). This section examines whether the needed rates of change have historical precedents and are underway.

Some studies conduct a de-facto validation of IAM projections. For CO₂ emission intensity over 1990–2010, this resulted in the IAMs projecting declining emission intensities while actual observations showed an increase. For individual technologies (in particular solar energy), IAM projections have been conservative regarding deployment rates and cost reductions (Creutzig et al., 2017), suggesting that IAMs do not always impute actual rates of technological change resulting from influence of shocks, broader changes and mutually reinforcing factors in society and politics (Geels and Schot, 2007; Daron et al., 2015; Sovacool, 2016; Battiston et al., 2017).

Other studies extrapolate historical trends into the future (Höök et al., 2011; Fouquet, 2016), or contrast the rates of change associated with specific temperature limits in IAMs (such as those in Chapter 2) with historical trends to investigate plausibility of emission pathways and associated temperature limits (Wilson et al., 2013; Gambhir et al., 2017; Napp et al., 2017). When metrics are normalised to Gross Domestic Product (GDP; as opposed to other normalisation metrics such as primary energy), low-emission technology deployment rates used by IAMs over the course of the coming century are shown to be broadly consistent with past trends, but rates of change in emission intensity are typically overestimated (Wilson et al., 2013;

1 Loftus et al., 2014; van Sluisveld et al., 2015). This bias is consistent with the findings from the ‘validation’
2 studies cited above, suggesting that IAMs may under-report the potential for supply-side technological
3 change assumed in 1.5°-consistent pathways, but may be more optimistic about the systemic ability to realise
4 incremental changes in reduction of emission intensity as a consequence of favourable energy efficiency
5 payback times (Wilson et al., 2013). This finding suggests that barriers and enablers other than costs and
6 climate limits play a role in technological change, as also found in the innovation literature (Hekkert et al.,
7 2007; Bergek et al., 2008; Geels et al., 2016b).

8
9 One barrier to a greater rate of change in energy systems is that economic growth in the past has been
10 coupled to the use of fossil fuels. Disruptive innovation and socio-technical changes could enable the
11 decoupling of economic growth from a range of environmental drivers, including the consumption of fossil
12 fuels, as represented by 1.5°C-consistent pathways (UNEP, 2014; Newman, 2017). This may be relative
13 decoupling due to rebound effects that see financial savings generated by renewable energy used in the
14 consumption of new products and services (Jackson and Senker, 2011; Gillingham et al., 2013), but in 2015
15 and 2016 total global GHG emissions have decoupled absolutely from economic growth (IEA, 2017g; Peters
16 et al., 2017). A longer data trend would be needed before stable decoupling can be established. The observed
17 decoupling in 2015 and 2016 was driven by absolute declines in both coal and oil use since the early 2000s
18 in Europe, in the past seven years in the United States and Australia, and more recently in China (Newman,
19 2017). In 2017, decoupling in China reversed by 2% due to a drought and subsequent replacement of
20 hydropower with coal-fired power (Tollefson, 2017), but this reversal is expected to be temporary (IEA,
21 2017c). Oil consumption in China is still rising slowly, but absolute decoupling is ongoing in megacities like
22 Beijing (Gao and Newman, 2018) (see Box 4.9).

23 24 25 4.2.2.2 *Transformational Adaptation*

26
27 In some regions and places, incremental adaptation would not be sufficient to mitigate the impacts of climate
28 change on social-ecological systems (see Chapter 3). Transformational adaptation would then be required
29 (Bahadur and Tanner, 2014; Pant et al., 2015; Gillard, 2016; Gillard et al., 2016; Colloff et al., 2017;
30 Termeer et al., 2017). Transformational adaptation refers to actions aiming at adapting to climate change
31 resulting in significant changes in structure or function that go beyond adjusting existing practices (Dowd et
32 al., 2014; IPCC, 2014a; Few et al., 2017), including approaches that enable new ways of decision-making on
33 adaptation (Colloff et al., 2017). Few studies have assessed the potentially transformative character of
34 adaptation options (Pelling et al., 2015; Rippke et al., 2016; Solecki et al., 2017), especially in the context of
35 warming of 1.5°C.

36
37 Transformational adaptation can be adopted at a large scale, can lead to new strategies in a region or
38 resource system, transform places and potentially shifts locations (Kates et al., 2012). Some systems might
39 require transformational adaptation at 1.5°C. Implementing adaptation policies in anticipation of 1.5°C
40 would require transformation and flexible planning of adaptation (sometimes called adaptation pathways)
41 (Rothman et al., 2014; Smucker et al., 2015; Holland, 2017; Gajjar et al., 2018), an understanding of the
42 varied stakeholders involved and their motives, and knowledge of less visible aspects of vulnerability based
43 on social, cultural, political, and economic factors (Holland, 2017). Transformational adaptation would seek
44 deep and long-term societal changes that influence sustainable development (Chung Tiam Fook, 2017; Few
45 et al., 2017).

46
47 Adaptation requires multidisciplinary approaches integrating scientific, technological and social dimensions.
48 For example, a framework for transformational adaptation, and the integration of mitigation and adaptation
49 pathways can transform rural indigenous communities to address risks of climate change and other stressors
50 (Thornton and Comberti, 2017). In villages in rural Nepal, transformational adaptation has taken place with
51 villagers changing their agricultural and pastoralist livelihood strategies after years of lost crops due to
52 changing rain patterns and degradation of natural resources (Thornton and Comberti, 2017). Instead, they are
53 now opening stores, hotels, and tea shops. In another case, the arrival of an oil pipeline altered traditional
54 Alaskan communities’ livelihoods. With growth of oil production, investments were made for rural
55 development. A later drop in oil production decreased these investments. Alaskan Indigenous populations

1 are also dealing with impacts of climate change, such as sea level rise, which is altering their livelihood
2 sources. Transformational adaptation is taking place by changing the energy matrix to renewable energy, in
3 which indigenous people apply their knowledge to achieve environmental, economic, and social benefits
4 (Thornton and Comberti, 2017).

7 4.2.2.3 *Disruptive Innovation*

8
9 Demand-driven disruptive innovations that emerge as the product of political and social changes across
10 multiple scales can be transformative (Seba, 2014; Christensen et al., 2015; Green and Newman, 2017a).
11 Such innovations would lead to simultaneous, profound changes in behaviour, economies and societies
12 (Seba, 2014; Christensen et al. 2015), but are difficult to predict in supply-focussed economic models (Geels
13 et al., 2016a; Pindyck, 2017). Rapid socio-technical change has been observed in the solar industry (Creutzig
14 et al. (2017). Similar changes to socio-ecological systems can stimulate adaptation and mitigation options
15 that lead to more climate-resilient systems (Adger et al., 2005; Ostrom, 2009; Gillard et al., 2016) (see the
16 Alaska and Nepal examples in Section 4.2.2.2). The increase in roof-top solar and energy storage technology
17 as well as the increase in passive housing and net zero-emissions buildings are further examples of such
18 disruptions (Green and Newman, 2017b). Both roof-top solar and energy storage have benefitted from
19 countries' economic growth strategy and associated price declines in photovoltaic technologies, particularly
20 in China (Hsu et al., 2017; Shrivastava and Persson, 2018), as well as from new information and
21 communication technologies (Kooimey et al., 2013), rising demand for electricity in urban areas, and global
22 concern regarding greenhouse gas emissions (Azeiteiro et al., 2017; Lutz and Mutarak, 2017; Wamsler,
23 2017).

24
25 System co-benefits can create the potential for mutually enforcing and demand-driven climate responses
26 (Jordan et al., 2015; Hallegatte and Mach, 2016; Pelling et al., 2018), and rapid and transformational change
27 (Cole, 2015; Geels et al., 2016b; Hallegatte and Mach, 2016; Peters et al., 2017). Examples of co-benefits
28 include gender equality, agricultural productivity (Nyantakyi-Frimpong and Bezner-Kerr, 2015), reduced
29 indoor air pollution (Satterthwaite and Bartlett, 2017), flood buffering (Colenbrander et al., 2017), livelihood
30 support (Shaw et al., 2014; Üрге-Vorsatz et al., 2014), economic growth (GCEC, 2014; Stiglitz et al., 2017),
31 social progress (Steg et al., 2015; Hallegatte and Mach, 2016) and social justice (Ziervogel et al., 2017;
32 Patterson et al., 2018).

33
34 Innovations that disrupt entire systems may leave firms and utilities with stranded assets as the transition can
35 happen very quickly (IPCC, 2014b; Kossoy et al., 2015). This may have consequences for fossil fuels that
36 are rendered 'unburnable' (McGlade and Ekins, 2015) and fossil fuel-fired power and industry assets that
37 would become obsolete (Caldecott, 2017; Farfan and Breyer, 2017). The presence of multiple barriers and
38 enablers operating in a system implies that rapid change, whether the product of many small changes
39 (Sterling et al., 2017; Termeer et al., 2017) or large-scale disruptions, is seldom an insular or discrete
40 process. This finding informs the multi-dimensional nature of feasibility in Cross-Chapter Box 3 in
41 Chapter 1 which is applied in Section 4.5. Climate responses that are aligned with multiple feasibility
42 dimensions and combine adaptation and mitigation interventions with non-climate benefits can accelerate
43 change and reduce risks and costs (Fazey et al., 2018). Also political, social and technological influences on
44 energy transitions, for example, can accelerate them faster than narrow techno-economic analysis suggests is
45 possible (Kern and Rogge, 2016), but could also introduce new constraints and risks (Geels et al., 2016b;
46 Sovacool, 2016; Eyre et al., 2018).

47
48 Disruptive innovation and technological change may play a role in mitigation and in adaptation. The next
49 section assesses mitigation and adaption options in energy, land and ecosystem, urban and infrastructure and
50 industrial systems.

4.3 Systemic Changes for 1.5°C-Consistent Pathways

Section 4.2 emphasises the importance of systemic change for 1.5°C-consistent pathways. This section translates this into four main system transitions: energy, land and ecosystem, urban and infrastructure, and industrial system transitions. This section assesses the mitigation, adaptation and carbon dioxide removal options that offer the potential for such change within those systems, based on options identified by Chapter 2 and risks and impacts in Chapter 3.

The section puts more emphasis on those adaptation options (Sections 4.3.1-4.3.5) and mitigation options (Sections 4.3.1-4.3.4, 4.3.6 and 4.3.7) that are 1.5°C-relevant and have developed considerably since AR5. They also form the basis for the mitigation and adaptation feasibility assessments in Section 4.5. Section 4.3.8 discusses solar radiation modification methods.

This section emphasises that no single solution or option can enable a global transition to 1.5°C-consistent pathways or adapting to projected impacts. Rather, accelerating change, much of which is already starting or underway, in multiple global systems, simultaneously and at different scales, could provide the impetus for these system transition. The feasibility of individual options as well as the potential for synergies and reduce trade-offs will vary according to context and the local enabling conditions. These are explored at a high level in Section 4.4. Policy packages that bring together multiple enabling conditions can provide building blocks for a strategy to scale-up implementation and intervention impacts.

4.3.1 Energy System Transitions

This section discusses the feasibility of mitigation and adaptation options related to the energy system transition. As only options relevant to 1.5°C and with significant changes since AR5 are discussed, which means that for options like hydropower and geothermal energy, the chapter refers to AR5 and does not provide a discussion. Socio-technical inertia of energy options for 1.5°C-consistent pathways are increasingly being surmounted as fossil fuels start to be phased out. Supply-side mitigation and adaptation options, energy demand-side options, including energy efficiency in buildings and transportation, are discussed in Section 4.3.3, options around energy use in industry are discussed in Section 4.3.4.

Section 4.5 assesses the feasibility in a systematic manner based on the approach outlined in Cross-Chapter Box 3 in Chapter 1.

4.3.1.1 Renewable Electricity: Solar and Wind

All renewable energy options have seen considerable advances over the years since AR5, but solar energy and both onshore and offshore wind energy have had dramatic growth trajectories. They appear well underway to contribute to 1.5°C-consistent pathways (REN21, 2012; IEA, 2017c; IRENA, 2017b).

The largest growth driver for renewable energy since AR5 has been the dramatic reduction in the cost of solar PV (REN21, 2012). This has made rooftop solar competitive in sunny areas between 45° north and south (Green and Newman, 2017b), though IRENA (2018) suggests it is cost effective in many other places too. Solar Photovoltaics (PV) with batteries have been cost effective in many rural and developing areas (Pueyo and Hanna, 2015; Szabó et al., 2016; Jimenez, 2017), for example 19 million people in Bangladesh now have solar-battery electricity in remote villages and are reporting positive experiences on safety and ease of use (Kabir et al., 2017). Small-scale distributed energy projects are being implemented in developed and developing cities where residential and commercial rooftops offer potential for consumers becoming producers (called prosumers) (ACOLA, 2017; Kotilainen and Saari, 2018). Such prosumers could contribute significantly to electricity generation in sun-rich areas like California (Kurdgelashvili et al., 2016) or Sub-Saharan Africa in combination with micro-grids and mini-grids Bertheau et al. (2017). It could also contribute to universal energy access (SDG 7) as shown by (IEA, 2017c).

1
2 The feasibility of renewable energy options depends to a large extent on geophysical characteristics of the
3 area where the option is implemented. However, technological advances and policy instruments make
4 renewable energy options increasingly attractive in other areas. For example, solar PV is deployed
5 commercially in areas with low solar insolation, like North-Western Europe (Nyholm et al., 2017).
6 Feasibility also depends on grid adaptations (e.g., storage, see below) as renewables grow (IEA, 2017c). For
7 regions with high energy needs, such as industrial areas (see section 4.3.4), high-voltage DC transmission
8 across long distances would be needed (MacDonald et al., 2016).

9
10 Another important factor affecting feasibility is public acceptance, in particular for wind energy and other
11 large-scale renewable facilities (Yenneti and Day, 2016; Rand and Hoen, 2017; Gorayeb et al., 2018) that
12 raise landscape management (Nadaï and Labussière, 2017) and distributional justice (Yenneti and Day,
13 2016) challenges. Research indicates that financial participation and community engagement can be effective
14 in mitigating resistance (Brunes and Ohlhorst, 2011; Rand and Hoen, 2017) (see Section 4.4.3).

15
16 Bottom-up studies estimating the use of renewable energy in the future, either at the global or at the national
17 level, are plentiful, especially in the grey literature. It is hotly debated whether a fully renewable energy or
18 electricity system, with or without biomass, is possible (Jacobson et al., 2015, 2017) or not (Clack et al.,
19 2017; Heard et al., 2017), and by what year. Scale-up estimates vary with assumptions about costs and
20 technological maturity, as well as local geographical circumstances and the extent of storage used (REN21,
21 2012; Ghorbani et al., 2017). Several countries have adopted targets of 100% renewable electricity (IEA,
22 2017c) as this meets multiple social, economic and environmental goals and contribute to mitigation of
23 climate change (REN21, 2012).

24 25 26 4.3.1.2 *Bioenergy and Biofuels*

27
28 Bioenergy is renewable energy from biomass. Biofuel is biomass-based energy used in transport. Chapter 2
29 suggests that pathways limiting warming to 1.5°C would enable supply of 67–310 (median 150) EJ yr⁻¹ (see
30 Table 2.8) from biomass. Most scenarios find that Bioenergy is combined with Carbon Dioxide Capture and
31 Storage (CCS, BECCS) if it is available but also find robust deployment of bioenergy independent of the
32 availability of CCS (see Section 2.3.4.2 and 4.3.7 for a discussion of BECCS). Detailed assessments indicate
33 that deployment is similar for 2°C-consistent pathways (Chum et al., 2011; P. Smith et al., 2014; Creutzig et
34 al., 2015). There is however *high agreement* that the sustainable bioenergy potential in 2050 would be
35 restricted to around 100 EJ yr⁻¹ (Slade et al., 2014; Creutzig et al., 2015b). Sustainable deployment at this or
36 higher levels envisioned by 1.5°C-consistent pathways may put significant pressure on available land, food
37 production and prices (Popp et al., 2014b; Persson, 2015; Kline et al., 2017; Searchinger et al., 2017),
38 preservation of ecosystems and biodiversity (Creutzig et al., 2015b; Holland et al., 2015; Santangeli et al.,
39 2016) as well as potential water and nutrient constraints (Gerbens-Leenes et al., 2009; Gheewala et al., 2011;
40 Bows and Smith, 2012; Smith and Torn, 2013; Bonsch et al., 2016; Lampert et al., 2016; Mouratiadou et al.,
41 2016; Smith et al., 2016b; Wei et al., 2016; Mathioudakis et al., 2017); but there is still *low agreement* on
42 these interactions (Robledo-Abad et al., 2017). Some of the disagreement on the sustainable capacity for
43 bioenergy stems from global versus local assessments. Global assessments may mask local dynamics that
44 exacerbate negative impacts and shortages while at the same time niche contexts for deployment may avoid
45 trade-offs and exploit co-benefits more effectively. In some regions of the world (e.g., the case of Brazilian
46 ethanol, see Box 4.7, where land may be less of a constraint, the use of bioenergy is mature and the industry
47 is well developed), land transitions could be balanced with food production and biodiversity to enable a
48 global impact on CO₂ emissions (Jaiswal et al., 2017).

49
50 The carbon intensity of bioenergy, key for both bioenergy as an emission-neutral energy system and BECCS
51 as a Carbon Dioxide Removal (CDR) measure, is still a matter of debate (Buchholz et al., 2016; Liu et al.,
52 2018) and depends on management (Pyörälä et al., 2014; Torssonen et al., 2016; Baul et al., 2017;
53 Kilpeläinen et al., 2017); direct and indirect land use change emissions (Plevin et al., 2010; Schulze et al.,

1 2012; Harris et al., 2015; Repo et al., 2015; DeCicco et al., 2016; Qin et al., 2016)²; considered feedstock
2 and time frame (Zanchi et al., 2012; Daioglou et al., 2017; Booth, 2018; Sterman et al., 2018), as well as the
3 availability of coordinated policies and management to minimise negative side effects and trade-offs,
4 particularly those around food security (Stevanović et al., 2017) and livelihood and equity considerations
5 (Creutzig et al., 2013; Calvin et al., 2014) .
6

7 Biofuels are a part of the transport sector in some cities and countries, and may be deployed as a mitigation
8 option for aviation, shipping and freight transport (see Section 4.3.3.5) as well as industrial decarbonisation
9 (IEA, 2017g) (Section 4.3.4) though only Brazil has mainstreamed ethanol as a substantial, commercial
10 option. Lower emissions and reduced urban air pollution have been achieved there by use of ethanol and
11 biodiesel as fuels (Hill et al., 2006; Salvo et al., 2017) (see Box 4.7).
12

13 4.3.1.3 Nuclear Energy

14 Many scenarios in Chapter 2 and in AR5 (Bruckner et al., 2014) project an increase in the use of nuclear
15 power, while others project a decrease. The increase can be realised through existing mature nuclear
16 technologies or new options (generation III/IV reactors, breeder reactors, new uranium and thorium fuel
17 cycles, small reactors or nuclear cogeneration).
18

19 Even though historically scalability and speed of scaling of nuclear plants have been high in many nations,
20 such rates are currently not achieved anymore. In the 1960s and 1970s, France implemented a programme to
21 rapidly get 80% of its power from nuclear in about 25 years (IAEA, 2018), but the current time-lag between
22 the decision date and the commissioning of plants is observed to be 10-19 years (Lovins et al., 2018). The
23 current deployment pace of nuclear energy is constrained by social acceptability in many countries due to
24 concerns over risks of accidents and radioactive waste management (Bruckner et al., 2014). Though
25 comparative risk assessment shows health risks are low per unit of electricity production (Hirschberg et al.,
26 2016), and land requirement is lower than that of other power sources (Cheng and Hammond, 2017), the
27 political processes triggered by societal concerns depend on the country-specific means of managing the
28 political debates around technological choices and their environmental impacts (Gregory et al., 1993). Such
29 differences in perception (Kim and Chung, 2017) explain why the 2011 Fukushima incident resulted in a
30 confirmation or acceleration of phasing out nuclear energy in five countries (Roh, 2017) while 30 other
31 countries have continued using nuclear energy, amongst which 13 are building new nuclear capacity
32 including China, India and the United Kingdom (IAEA, 2017; Yuan et al., 2017).
33
34

35 Costs of nuclear power have increased over time in some developed nations, principally due to market
36 conditions where increased investment risks of high-capital expenditure technologies have become significant.
37 ‘Learning by doing’ processes often failed to compensate for this trend because they were slowed down by the
38 absence of standardisation and series effects (Grubler, 2010). What are and have been the costs of nuclear
39 power is debated in the literature (Lovering et al., 2016; Koomey et al., 2017). Countries with liberalised
40 markets that continue to develop nuclear employ de-risking instruments through long-term contracts with
41 guaranteed sale prices (Finon and Roques, 2013). For instance, the United Kingdom works with public
42 guarantees covering part of the upfront investment costs of newly planned nuclear capacity. This dynamic
43 differs in countries such as China and South Korea, where monopolistic conditions in the electric system allow
44 for reducing investment risks, deploying series effects and enhancing the engineering capacities of users due
45 to stable relations between the security authorities and builders (Schneider et al., 2017).
46

47 The safety of nuclear plants depends upon the public authorities of each country. However, because
48 accidents affect worldwide public acceptance of this industry, questions have been raised about the risk of
49 economic and political pressures weakening the safety of the plants (Finon, 2013; Budnitz, 2016). This raises
50 the issue of international governance of civil nuclear risks and reinforced international cooperation involving
51 governments, companies and engineering (Walker and Lönnroth, 1983; Thomas, 1988; Finon, 2013), based

² While there is high agreement that indirect Land Use Change (iLUC) could occur, there is low agreement about the actual extent of Iluc (P. Smith et al., 2014; Versteegen et al., 2015; David, 2017)

1 on the experience of the International Atomic Energy Agency.

4 4.3.1.4 Energy Storage

6 The growth in electricity storage for renewables has been around Grid Flexibility Resources (GFR) that
7 would enable several places to source more than half their power from non-hydro renewables (Komarnicki,
8 2016). Ten types of GFRs within smart grids have been developed largely since AR5 as renewables have
9 tested grid stability (Blaabjerg et al., 2004; IRENA, 2013; IEA, 2017d; Majzoobi and Khodaei, 2017) though
10 demonstrations of how to do this without hydro or natural gas-based power back-up are still needed. Pumped
11 hydro comprised 150 GW of storage capacity in 2016, and grid-connected battery storage just 1.7 GW, but
12 the latter grew between 2015 to 2016 by 50% (REN21, 2012). Battery storage has been the main growth
13 feature in energy storage since AR5 (Breyer et al., 2017). This appears to be the result of significant cost
14 reductions due to mass production for Electric Vehicles (EVs) (Nykqvist and Nilsson, 2015; Dhar et al.,
15 2017). Although costs and technical maturity look increasingly positive, the feasibility of battery storage is
16 challenged by concerns over the availability of resources and the environmental impacts of its production
17 (Peters et al., 2017). Lithium, a common element in the earth's crust, does not appear to be restricted and
18 large increases in production have happened in recent years with eight new mines in Western Australia
19 where most lithium is produced (GWA, 2016). Emerging battery technologies may provide greater
20 efficiency and recharge rates (Belmonte et al., 2016) but remain significantly more expensive due to speed
21 and scale issues compared to lithium ion batteries (Dhar et al., 2017; IRENA, 2017a).

23 Research and demonstration of energy storage in the form of thermal and chemical systems continues, but
24 large scale commercial systems are rare (Pardo et al., 2014). Renewably derived synthetic liquid (like
25 methanol and ammonia) and gas (like methane and hydrogen) are increasingly being seen as a feasible
26 storage options for renewable energy (producing fuel for use in industry during times when solar and wind
27 are abundant) (Bruce et al., 2010; Jiang et al., 2010; Ezeji, 2017) but, in the case of carbonaceous storage
28 media, would need a renewable source of carbon to make a positive contribution to GHG reduction (von der
29 Assen et al., 2013; Abanades et al., 2017) (see also Section 4.3.4.5). The use of electric vehicles as a form of
30 storage has been modelled and evaluated as an opportunity, and demonstrations are emerging (Dhar et al.,
31 2017; Green and Newman, 2017a), but challenges to upscaling remain.

34 4.3.1.5 Options for Adapting Electricity Systems to 1.5°C

36 Climate change has started to disrupt electricity generation and, if climate change adaptation options are not
37 considered, it is predicted that these disruptions will be lengthier and more frequent (Jahandideh-Tehrani et
38 al., 2014; Bartos and Chester, 2015; Kraucunas et al., 2015; van Vliet et al., 2016). Adaptation would both
39 secure vulnerable infrastructure and ensure the necessary generation capacity (Minville et al., 2009; Eisenack
40 and Stecker, 2012; Schaeffer et al., 2012; Cortekar and Groth, 2015; Murrant et al., 2015; Panteli and
41 Mancarella, 2015; Goytia et al., 2016). The literature shows *high agreement* that climate change impacts
42 need to be planned for in the design of any kind of infrastructure, especially in the energy sector (Nierop,
43 2014), including interdependencies with other sectors that require electricity to function, including water,
44 data, telecommunications and transport (Fryer, 2017).

46 Recent research has developed new frameworks and models that aim to assess and identify vulnerabilities in
47 energy infrastructure and create more proactive responses (Francis and Bekera, 2014; Ouyang and Dueñas-
48 Osorio, 2014; Arab et al., 2015; Bekera and Francis, 2015; Knight et al., 2015; Jeong and An, 2016; Panteli
49 et al., 2016; Perrier, 2016; Erker et al., 2017; Fu et al., 2017). Assessments of energy infrastructure
50 adaptation, while limited, emphasise the need for redundancy (Liu et al. 2017). The implementation of
51 controllable and islandable microgrids including the use of residential batteries, and can increase resiliency,
52 especially after extreme weather events (Qazi and Young Jr., 2014; Liu et al., 2017). Hybrid renewables-
53 based power systems with non-hydro capacity, such as with high-penetration wind generation, could provide
54 the required system flexibility (Canales et al., 2015). Overall, there is *high agreement* that hybrid systems,
55 taking advantage of an array of sources and time of use strategies, can help make electricity generation more

1 resilient (Parkinson and Djilali, 2015), given that energy security standards are in place (Almeida Prado et
2 al., 2016).

3
4 Interactions between water and energy are complex (IEA, 2017g). Water scarcity patterns and electricity
5 disruptions will differ across regions. There is *high agreement* that mitigation and adaptation options for
6 thermal electricity generation (if that remains fitted with CCS) need to consider increasing water shortages,
7 taking into account other factors such as ambient water resources and demand changes in irrigation water
8 (Hayashi et al., 2018). Increasing the efficiency of power plants can reduce emissions and water needs
9 (Eisenack and Stecker, 2012; van Vliet et al., 2016), but applying CCS would increase water consumption
10 (Koornneef et al 2012). The technological, economic, social and institutional feasibility of efficiency
11 improvements is high, but insufficient to limit temperature rise to 1.5°C (van Vliet et al., 2016).

12
13 In addition, a number of options for water cooling management systems have been proposed, such as
14 hydraulic measures (Eisenack and Stecker, 2012) and alternative cooling technologies (Chandel et al., 2011;
15 Eisenack and Stecker, 2012; Bartos and Chester, 2015; Murrant et al., 2015; Bustamante et al., 2016; van
16 Vliet et al., 2016; Huang et al., 2017b). There is *high agreement* on the technological and economic
17 feasibility of these technologies as their absence can severely impact the functioning of the power plant as
18 well as safety and security standards.

19 20 21 4.3.1.6 Carbon Dioxide Capture and Storage in the Power Sector

22
23 The AR5 (IPCC, 2014b) as well as Section 2.4.2 assign significant emission reductions over the course of
24 this century to CO₂ capture and storage (CCS) in the power sector. This section focuses on CCS in the fossil-
25 fuelled power sector; Section 4.3.4 discusses CCS in non-power industry, and Section 4.3.7 bioenergy with
26 CCS (BECCS). Section 2.4.2 puts the cumulative CO₂ stored from fossil-fuelled power at 410 (199–470
27 interquartile range) GtCO₂ over this century. Such modelling suggests that CCS in the power sector can
28 contribute to cost-effective achievement of emission reduction requirements for limiting warming to 1.5°C.
29 CCS may also offer employment and political advantages for fossil fuel-dependent economies (Kern et al.,
30 2016), but may entail more limited co-benefits than other mitigation options (that, e.g., generate power) and
31 therefore for its business case and economic feasibility relies on climate policy incentives. Since 2017, two
32 CCS projects in the power sector capture 2.4 MtCO₂ annually, while 30 MtCO₂ is captured annually in all
33 CCS projects (Global CCS Institute, 2017).

34
35 The technological maturity of CO₂ capture options in the power sectors has improved considerably
36 (Abanades et al., 2015; Bui et al., 2018), but costs have not come down between 2005 and 2015 due to
37 limited learning in commercial settings and increased energy and resources costs (Rubin et al., 2015).
38 Storage capacity estimates vary greatly, but Section 2.4.2 as well as literature (V. Scott et al., 2015) indicate
39 that perhaps 10,000 GtCO₂ could be stored in underground reservoirs. Regional availability of this may not
40 be sufficient, and it requires efforts to have this storage and the corresponding infrastructure available at the
41 necessary rates and times (de Coninck and Benson, 2014). CO₂ retention in the storage reservoir was
42 recently assessed as 98% over 10,000 years for well-managed reservoirs, and 78% for poorly regulated ones
43 Alcade et al 2018. A paper reviewing 42 studies on public perception of CCS (Seigo et al., 2014) found that
44 social acceptance of CCS is predicted by trust, perceived risks and benefits. The technology itself mattered
45 less than the social context of the project. Though insights on communication of CCS projects to the general
46 public and inhabitants of the area around the CO₂ storage sites have been documented over the years, project
47 stakeholders are not consistently implementing these lessons, although some projects have observed good
48 practices (Ashworth et al., 2015).

49
50 CCS in the power sector is hardly being realised at scale, mainly because the incremental costs of capture,
51 and the development of transport and storage infrastructures are not sufficiently compensated by market or
52 government incentives (IEA, 2017c). In both full-scale projects in the power sector, part of the capture costs
53 are compensated for by revenues from Enhanced Oil Recovery (EOR) (Global CCS Institute, 2017),
54 demonstrating that EOR helps developing CCS further. EOR is a technique that uses CO₂ to mobilise more
55 oil out of depleting oil fields, leading to additional CO₂ emissions by combusting the additionally recovered

1 oil (Cooney et al., 2015).

4 4.3.2 Land and Ecosystem Transitions

6 This section assesses the feasibility of mitigation and adaptation options related to land use and ecosystems.
7 Land transitions are grouped around agriculture and food, ecosystems and forests, and coastal systems.

10 4.3.2.1 Agriculture and Food

12 In a 1.5°C world, local yields are projected to decrease in tropical regions that are major food producing
13 areas of the world (West Africa, South-East Asia, South-Asia, and Central and northern South America)
14 (Schleussner et al., 2016). Some high-latitude regions may benefit from the combined effects of elevated
15 CO₂ and temperature because their average temperatures are below optimal temperature for crops. In both
16 cases there are consequences for food production and quality (Cross-Chapter Box 6 in Chapter 3 on Food
17 Security), conservation agriculture, irrigation, food wastage, bioenergy and the use of novel technologies.

19 **Food production and quality.** Increased temperatures, including 1.5°C warming, would affect the
20 production of cereals such as wheat and rice, impacting food security (Schleussner et al., 2016). There is
21 *medium agreement* that elevated CO₂ concentrations can change food composition, with implications for
22 nutritional security (Taub et al., 2008; Högy et al., 2009; DaMatta et al., 2010; Loladze, 2014; De Souza et
23 al., 2015), with the effects being different depending on the region (Medek et al., 2017).

25 Meta-analyses of the effects of drought, elevated CO₂, and temperature conclude that at 2°C local warming
26 and above, aggregate production of wheat, maize, and rice are expected to decrease in both temperate and
27 tropical areas (Challinor et al., 2014). These production losses could be lowered if adaptation measures are
28 taken (Challinor et al., 2014), such as developing varieties better adapted to changing climate conditions.

30 Adaptation options can help ensure access to sufficient, quality food. These include conservation agriculture,
31 improved livestock management, increasing irrigation efficiency, agroforestry and management of food loss
32 and waste. Complementary adaptation and mitigation options, for example, the use of climate services
33 (Section 4.3.5), bioenergy (Section 4.3.1) and biotechnology (Section 4.4.4) can also serve to reduce
34 emissions intensity and the carbon footprint of food production.

36 **Conservation Agriculture (CA).** Soil management that reduces the disruption of soil structure and biotic
37 processes by minimising tillage. A recent meta-analysis showed that no-till practices work well in water-
38 limited agroecosystems when implemented jointly with residue retention and crop rotation but may by
39 themselves decrease yields in other situations (Pittelkow et al., 2014). Additional climate adaptations
40 include adjusting planting times and crop varietal selection and improving irrigation efficiency. Adaptations
41 such as these may increase wheat and maize yields by 7–12% under climate change (Challinor et al., 2014).
42 CA can also help build adaptive capacity (*medium evidence, medium agreement*) (H. Smith et al., 2017;
43 Pradhan et al., 2018) and have mitigation co-benefits through improved fertiliser use or efficient use of
44 machinery and fossil fuels (Harvey et al., 2014; Cui et al., 2018; Pradhan et al., 2018). CA practices can also
45 raise soil carbon and therefore remove CO₂ from the atmosphere (Poeplau and Don 2015; Vicente-Vicente et
46 al. 2016; Aguilera et al. 2013). However, CA adoption can be constrained by inadequate institutional
47 arrangements and funding mechanisms (Harvey et al., 2014; Baudron et al., 2015; Li et al., 2016; Dougill et
48 al., 2017; Smith et al., 2017b).

50 **Sustainable intensification** of agriculture consists of agricultural systems with increased production per unit
51 area but with management of the range of potentially adverse impacts on the environment (Pretty and
52 Bharucha, 2014). Sustainable intensification can increase the efficiency of inputs and enhance health and
53 food security (Ramankutty et al., 2018).

55 **Livestock management.** Livestock are responsible for more GHG emissions than all other food sources.

1 Emissions are caused by feed production, enteric fermentation, animal waste, land-use change and livestock
2 transport and processing. Some estimates indicate that livestock supply chains could account for 7.1 GtCO₂,
3 equivalent to 14.5% of global anthropogenic greenhouse gas emissions (Gerber et al., 2013). Cattle (beef,
4 milk) are responsible for about two-thirds of that total, largely due to methane emissions resulting from
5 rumen fermentation (Gerber et al., 2013; Opio et al., 2013).

6
7 Despite ongoing gains in livestock productivity and volumes, the increase of animal products in global diets
8 is restricting overall agricultural efficiency gains because of inefficiencies in the conversion of agricultural
9 primary production (e.g., crops) in the feed-animal products pathway (Alexander et al., 2017), offsetting the
10 benefits of improvements in livestock production systems (Clark and Tilman, 2017).

11
12 There is increasing agreement that overall emissions from food systems could be reduced by targeting the
13 demand for meat and other livestock products, particularly where consumption is higher than suggested by
14 human health guidelines. Adjusting diets to meet nutritional targets could bring large co-benefits, through
15 GHG mitigation and improvements in the overall efficiency of food systems (Erb et al., 2009; Tukker et al.,
16 2011; Tilman and Clark, 2014; van Dooren et al., 2014; Ranganathan et al., 2016). Dietary shifts could
17 contribute one-fifth of the mitigation needed to hold warming below 2°C, with one-quarter of low-cost
18 options (Griscom et al., 2017). There, however, remains limited evidence of effective policy interventions to
19 achieve such large-scale shifts in dietary choices, and prevailing trends are for increasing rather than
20 decreasing demand for livestock products at the global scale (Alexandratos and Bruinsma, 2012;
21 OECD/FAO, 2017). How the role of dietary shift could change in 1.5°C-consistent pathways is also not clear
22 (see Chapter 2).

23
24 Adaptation of livestock systems can include a suite of strategies such as using different breeds and their wild
25 relatives to develop a genetic pool resilient to climatic shocks and longer-term temperature shifts (Thornton
26 and Herrero, 2014), improving fodder and feed management (Bell et al., 2014; Havet et al., 2014) and
27 disease prevention and control (Skuce et al., 2013; Nguyen et al., 2016). Most interventions that improve the
28 productivity of livestock systems and enhance adaptation to climate changes would also reduce the emissions
29 intensity of food production, with significant co-benefits for rural livelihoods and security of food supply
30 (Gerber et al., 2013; FAO & NZAGRC, 2017a, 2017b, 2017c). Whether such reductions in emission
31 intensity result in lower or higher absolute GHG emissions depends on overall demand for livestock
32 products, indicating the relevance of integrating supply-side with demand-side measures within food security
33 objectives (Gerber et al., 2013; Bajželj et al., 2014). Transitions in livestock production systems (e.g., from
34 extensive to intensive) can also result in significant emission reductions as part of broader land-based
35 mitigation strategies (Havlik et al., 2014).

36
37 Overall, there is *high agreement* that farm strategies that integrate mixed crop-livestock systems can improve
38 farm productivity and have positive sustainability outcomes (Havet et al., 2014; Thornton and Herrero, 2014;
39 Herrero et al., 2015; Weindl et al., 2015). Shifting towards mixed crop-livestock systems is estimated to
40 reduce agricultural adaptation costs to 0.3% of total production costs while abating deforestation by 76
41 million ha globally, making it a highly cost-effective adaptation option with mitigation co-benefits (Weindl
42 et al., 2015). Evidence from various regions supports this (Thornton and Herrero, 2015), although the
43 feasible scale varies between regions and systems, as well as being moderated by overall demand in specific
44 food products. In Australia, some farmers have successfully shifted to crop-livestock systems where, each
45 year, they allocate land and forage resources in response to climate and price trends (Bell et al., 2014).
46 However, there can be some unintended negative impacts of such integration, including an increased burdens
47 on women, higher requirements of capital, competing uses of crop residues (e.g., feed vs. mulching vs.
48 carbon sequestration) and higher requirements of management skills, which can be a challenge across several
49 low income countries (Thornton and Herrero, 2015; Thornton et al., 2018). Finally, the feasibility of
50 improving livestock efficiency is dependent on socio-cultural context and acceptability: there remain
51 significant issues around widespread adoption of crossbred animals, especially by smallholders (Thornton et
52 al., 2018).

53
54 **Irrigation efficiency.** Irrigation efficiency is especially critical since water endowments are expected to
55 change, with 20–60 Mha of global cropland being projected to revert from irrigated to rain fed land, while

1 other areas will receive higher precipitation in shorter time spans thus affecting irrigation demand (Elliott et
2 al., 2014). While increasing irrigation system efficiency is necessary, there is mixed evidence on how to
3 enact efficiency improvements (Fader et al., 2016; Herwehe and Scott, 2017). Physical and technical
4 strategies include building large-scale reservoirs or dams, renovating or deepening irrigation channels,
5 building on-farm rainwater harvesting structures, lining ponds, channels and tanks to reduce losses through
6 percolation and evaporation, and investing in small infrastructure such as sprinkler or drip irrigation sets
7 (Varela-Ortega et al., 2016; Sikka et al., 2018). Each strategy has differing costs and benefits relating to
8 unique biophysical, social, and economic contexts. Other concerns relating to the increase of irrigation
9 efficiency discuss fostering irrigation dependency, hence increasing climate sensitivity, which may be
10 maladaptive in the long-term (Lindoso et al., 2014).

11
12 Improvements in irrigation efficiency would need to be supplemented with ancillary activities, such as
13 shifting to crops that require less water, and improving soil and moisture conservation (Fader et al., 2016;
14 Hong and Yabe, 2017; Sikka et al., 2018). Currently, the feasibility of improving irrigation efficiency is
15 constrained by issues of replicability across scale and sustainability over time (Burney and Naylor, 2012),
16 institutional barriers and inadequate market linkages (Pittock et al., 2017).

17
18 Growing evidence suggests that investing in behavioural shifts towards using irrigation technology such as
19 micro-sprinklers or drip irrigation, is an effective and quick adaptation strategy (Varela-Ortega et al., 2016;
20 Herwehe and Scott, 2017; Sikka et al., 2018) as opposed to large dams which have high financial, ecological
21 and social costs (Varela-Ortega et al., 2016). While improving irrigation efficiency is technically feasible (R.
22 Fishman et al., 2015) and has clear benefits for environmental values (Pfeiffer and Lin, 2014; R. Fishman et
23 al., 2015), feasibility is regionally differentiated as shown by examples as diverse as Kansas (Jägermeyr et
24 al., 2015), India (R. Fishman et al., 2015) and Africa (Pittock et al., 2017).

25
26 **Agroforestry.** The integration of trees and shrubs into crop and livestock systems, when properly managed,
27 can potentially restrict soil erosion, facilitate water infiltration, improve soil physical properties and buffer
28 against extreme events (Lasco et al., 2014; Mbow et al., 2014; Quandt et al., 2017; Sida et al., 2018). There
29 is *medium evidence* and *high agreement* on the feasibility of agroforestry practices that enhance productivity,
30 livelihoods and carbon storage (Lusiana et al., 2012; K Murthy, 2013; Coulibaly et al., 2017; Sida et al.,
31 2018), including from indigenous production systems (Coq-Huelva et al., 2017), with variation by region,
32 agroforestry type, and climatic conditions (Place et al., 2012; Coe et al., 2014; Mbow et al., 2014; Iiyama et
33 al., 2017; Abdulai et al., 2018). Long-term studies examining the success of agroforestry, however, are rare
34 (Coe et al., 2014; Meijer et al., 2015; Brockington et al., 2016; Zomer et al., 2016).

35
36 The extent to which agroforestry practices at farm-level could be scaled up globally while satisfying growing
37 food demand is relatively unknown. Agroforestry adoption has been relatively low and uneven (Jacobi et al.,
38 2017; Hernández-Morcillo et al., 2018), with constraints including the expense of establishment and lack of
39 reliable financial support, insecure land tenure, landowner's lack of experience with trees, complexity of
40 management practices, fluctuating market demand and prices for different food and fibre products, the time
41 and knowledge required for management, low intermediate benefits to offset revenue lags, and inadequate
42 market access (Pattanayak et al., 2003; Mercer, 2004; Sendzimir et al., 2011; Valdivia et al., 2012; Coe et al.,
43 2014; Meijer et al., 2015; Coulibaly et al., 2017; Jacobi et al., 2017).

44
45 **Managing food loss and waste.** The way food is produced, processed and transported strongly influences
46 GHG emissions. Around one-third of the food produced on the planet is not consumed (FAO, 2013)
47 affecting food security and livelihoods (See Cross-Chapter Box 6 on Food Security in Chapter 3). Food
48 wastage is a combination of food loss—decrease in mass and nutritional value of food due to poor
49 infrastructure, logistics, and lack of storage technologies and management – and food waste that derives
50 from inappropriate human consumption that leads to food spoilage associated with inferior quality or
51 overproduction. Food wastage could lead to an increase in emissions estimated to 1.9–2.5 GtCO₂-eq yr⁻¹ (Hiç
52 et al., 2016).

53
54 Decreasing food wastage has high mitigation and adaptation potential and could play an important role in
55 land transitions towards 1.5°C, provided that reduced food waste results in lower production-side emissions

1 rather than increased consumption (Foley et al., 2011). There is *medium agreement* that a combination of
2 individual-institutional behaviour (Refsgaard and Magnussen, 2009; Thornton and Herrero, 2014), and
3 improved technologies and management (Lin et al., 2013; Papargyropoulou et al., 2014) can transform food
4 waste into products with marketable value. Institutional behaviour depends on investment and policies,
5 which if adequately addressed could enable mitigation and adaptation co-benefits, in a relatively short time.
6

7 **Novel technologies.** New molecular biology tools have been developed that can lead to fast and precise
8 genome modification (De Souza et al., 2016; Scheben et al., 2016) (e.g., CRISPR Cas 9 (Ran et al., 2013;
9 Schaeffer and Nakata, 2015). Such genome editing tools may moderately assist in mitigation and adaptation
10 of agriculture in relation to climate changes, CO₂ elevation, drought and flooding (DaMatta et al., 2010; De
11 Souza et al., 2015, 2016). These tools could contribute to developing new plant varieties that can adapt to
12 warming of 1.5°C and overshoot, potentially avoiding some of the costs of crop shifting (Schlenker and
13 Roberts, 2009; De Souza et al., 2016). However, biosafety concerns and government regulatory systems can
14 be a major barrier to the use of these tools as this increases the time and cost of turning scientific discoveries
15 into ready applicable technologies (Andow and Zwahlen, 2006; Maghari and Ardekani, 2011).
16

17 The strategy of reducing enteric methane emissions by ruminants through the development of inhibitors or
18 vaccines has already been attempted with some successes, although the potential for application at scale and
19 in different situations remains uncertain. A methane inhibitor has been demonstrated to reduce methane from
20 feedlot systems by 30% over a 12-week period (Hristov et al., 2015) with some productivity benefits but the
21 ability to apply it in grazing systems will depend on further technological developments as well as costs and
22 incentives. A vaccine could potentially modify the microbiota of the rumen and be applicable even in
23 extensive grazing systems by reducing the presence of methanogenic micro-organisms (Wedlock et al.,
24 2013) but has not yet been successfully demonstrated to reduce emissions in live animals. Selective breeding
25 for lower-emitting ruminants is becoming rapidly feasible, offering small but cumulative emissions
26 reductions without requiring substantial changes in farm systems (Pickering et al., 2015).
27

28 Technological innovation in culturing marine and freshwater micro and macro flora has significant potential
29 to expand food, fuel and fibre resources, and could reduce impacts on land and conventional agriculture
30 (Greene et al., 2017).
31

32 Technological innovation could assist in increased agricultural efficiency (e.g., via precision agriculture),
33 decrease food wastage and genetics that enhance plant adaptation traits (Section 4.4.4). Technological and
34 associated management improvements may be ways to increase the efficiency of contemporary agriculture to
35 help produce enough food to cope with population increases in a 1.5°C warmer world, and help reduce the
36 pressure on natural ecosystems and biodiversity.
37

38 39 4.3.2.2 *Forests and Other Ecosystems*

40
41 **Ecosystem restoration.** Biomass stocks in tropical, subtropical, temperate and boreal biomes currently hold
42 1085, 194, 176, 190 Gt CO₂, respectively. Conservation and restoration can enhance these natural carbon
43 sinks (Erb et al., 2017).
44

45 Recent studies explore options for conservation, restoration and improved land management estimating up to
46 23 GtCO₂ (Griscom et al., 2017). Mitigation potentials are dominated by reduced rates of deforestation,
47 reforestation and forest management, and concentrated in tropical regions (Houghton, 2013; Canadell and
48 Schulze, 2014; Grace et al., 2014; Houghton et al., 2015; Griscom et al., 2017). Much of the literature
49 focuses on REDD+ (Reducing Emissions from Deforestation and Degradation) as an institutional
50 mechanism. However, restoration and management activities need not be limited to REDD+ and locally
51 adapted implementation may keep costs low, capitalise on co-benefits and ensure consideration of competing
52 for socio-economic goals (Jantke et al., 2016; Ellison et al., 2017; Perugini et al., 2017; Spencer et al., 2017).
53

54 Half of the estimated potential can be achieved at <100 USD/tCO₂; a third of the cost-effective potential <10
55 USD/tCO₂ (Griscom et al., 2017). Variation of costs in projects aiming to reduce emissions from

1 deforestation is high when considering opportunity and transaction costs (Dang Phan et al., 2014; Overmars
2 et al., 2014; Ickowitz et al., 2017; Rakatama et al., 2017).

3
4 However, the focus on forests raises concerns of cross-biome leakage (*medium evidence, low agreement*)
5 (Popp et al., 2014a; Strassburg et al., 2014; Jayachandran et al., 2017) and encroachment on other
6 ecosystems (Veldman et al., 2015). Reducing rates of deforestation limits the land available for agriculture
7 and grazing with trade-offs between diets, higher yields and food prices (Erb et al., 2016a; Kreidenweis et
8 al., 2016). Restoration and conservation are compatible with biodiversity (Rey Benayas et al., 2009; Jantke et
9 al., 2016) and water resources; in the tropics, reducing rates of deforestation maintains cooler surface
10 temperatures (Perugini et al., 2017) and rainfall (Ellison et al., 2017).

11
12 Its multiple potential co-benefits have made REDD+ important for local communities, biodiversity and
13 sustainable landscapes (Ngendakumana et al., 2017; Turnhout et al., 2017). There is *low agreement* on
14 whether climate impacts will reverse mitigation benefits of restoration (Le Page et al., 2013) by increasing
15 the likelihood of disturbance (Anderegg 2015), or reinforce them through carbon fertilisation (P. Smith et al.,
16 2014).

17
18 Emerging regional assessments offer new perspectives for upscaling. Strengthening coordination, additional
19 funding sources, and access and disbursement points increase the potential of REDD+ in working towards
20 2°C and 1.5°C targets (Well and Carrapatoso, 2017). While there are indications that land tenure (Sunderlin
21 et al., 2014) has a positive impact, a meta-analysis by (Wehkamp et al., 2018a) shows that there is *medium*
22 *evidence* and *low agreement* on which aspects of governance improvements are supportive of conservation.
23 Local benefits, especially for indigenous communities, will only be accrued if land tenure is respected and
24 legally protected, which is not often the case (Sunderlin et al., 2014; Brugnach et al., 2017). Although
25 payments for reduced rates of deforestation may benefit the poor, the most vulnerable populations could
26 have limited, uneven access (Atela et al., 2014) and face lower opportunity costs from deforestation
27 (Ickowitz et al., 2017).

28
29 **Community-based Adaptation (CbA).** There is *medium evidence* and *high agreement* for the use of CbA.
30 The specific actions to take will depend upon the location, context, and vulnerability of the specific
31 community. CbA is defined as ‘a community-led process, based on communities’ priorities, needs,
32 knowledge, and capacities, which aim to empower people to plan for and cope with the impacts of climate
33 change’ (Reid et al., 2009). The integration of CbA with Ecosystems-based Adaptation (EbA) has been
34 increasingly promoted, especially in efforts to alleviate poverty (Mannke, 2011; Reid, 2016).

35
36 Despite the potential and advantages of both CbA and EbA, including knowledge exchange, information
37 access and increased social capital and equity; institutional and governance barriers still constitute a
38 challenge for local adaptation efforts (Wright et al., 2014; Fernández-Giménez et al., 2015).

39
40 **Wetland management.** In wetland ecosystems, temperature rise has direct and irreversible impacts on
41 species functioning and distribution, ecosystem equilibrium and services, and second order impacts on local
42 livelihoods (see Section 3.4.3). The structure and function of wetland systems are changing due to climate
43 change. Wetland management strategies, including adjustments in infrastructural, behavioural, and
44 institutional practices have clear implications for adaptation (Colloff et al., 2016b; Finlayson et al., 2017;
45 Wigand et al., 2017)

46
47 Despite international initiatives on wetland restoration and management through the Ramsar Convention on
48 Wetlands, policies have not been effective (Finlayson, 2012; Finlayson et al., 2017). Institutional reform
49 such as flexible, locally relevant governance, drawing on principles of adaptive co-management, and multi-
50 stakeholder participation becomes increasingly necessary for effective wetland management (Capon et al.,
51 2013; Finlayson et al., 2017).

4.3.2.3 Coastal Systems

Managing coastal stress. Particularly to allow for the landward relocation of coastal ecosystems under a transition to 1.5°C, planning for climate change would need to be integrated with the use of coastlines by humans (Saunders et al., 2014; Kelleway et al., 2017). Adaptation options for managing coastal stress include coastal hardening through the building of seawalls and the re-establishment of coastal ecosystems such as mangroves (André et al., 2016; Cooper et al., 2016). While the feasibility of the solutions is high, they are expensive to scale (*robust evidence, medium agreement*).

There is *low evidence* and *high agreement* that reducing the impact of local stresses (Halpern et al., 2015) will improve the resilience of marine ecosystems as they transition to a 1.5°C world (O’Leary et al., 2017). Approaches to reducing local stresses are considered feasible, cost-effective and highly scalable. Ecosystem resilience may be increased through alternative livelihoods (e.g., sustainable aquaculture), which are among a suite of options for building resilience in coastal ecosystems. These options enjoy high levels of feasibility yet are expensive, which stands in the way of scalability (*robust evidence, medium agreement*) (Hiwasaki et al., 2015; Brugnach et al., 2017).

Working with coastal communities has the potential for improving the resilience of coastal ecosystems. Combined with the advantages of using Indigenous knowledge to guide transitions, solutions can be more effective when undertaken in partnership local communities, cultures, and knowledge (See Box 4.3).

Restoration of coastal ecosystems and fisheries. Marine restoration is expensive compared to terrestrial restoration, and the survival of projects is currently low, with success depending on the ecosystem and site, rather than the size of the financial investment (Bayraktarov et al., 2016). Mangrove replanting shows evidence of success globally, with numerous examples of projects that have established forests (Kimball et al., 2015; Bayraktarov et al., 2016).

Efforts with reef-building corals have been attempted with a low level of success (Bayraktarov et al., 2016). Technologies to help re-establish coral communities are limited (Rinkevich, 2014), as are largely untested disruptive technologies (e.g., genetic manipulation, assisted evolution) (van Oppen et al., 2015). Current technologies also have trouble scaling given the substantial costs and investment required (Bayraktarov et al., 2016).

(Johannessen and Macdonald, 2016) report the ‘blue carbon’ sink to be 0.4–0.8% of global anthropogenic emissions. However, this does not adequately account for post-depositional processes and could overestimate removal potentials, subject to a risk of reversal. Seagrass beds will thus not contribute significantly to enabling 1.5°C-consistent pathways.

4.3.3 Urban and Infrastructure System Transitions

There will be approximately 70 million additional urban residents every year through to the mid part of this century (UN, 2014). The majority of these new urban citizens will reside in small and medium sized cities in low- and middle-income countries (Cross-Chapter Box13 in Chapter 5). The combination of urbanisation and economic and infrastructure development could account for an additional 226 GtCO₂ by 2050 (Bai et al. 2018). However, urban systems can harness the mega-trends of urbanisation, digitalisation, financialisation and growing sub-national commitment to smart cities, green cities, resilient cities, sustainable cities and adaptive cities, for the type of transformative change required by 1.5°C-consistent pathways (Revi and Rosenzweig, 2013; Parag and Sovacool, 2016; Roberts, 2016; Wachsmuth et al., 2016; Revi, 2017; Solecki et al., 2018). There is a growing number of urban climate responses driven by cost-effectiveness, development, work creation and inclusivity considerations (Floater et al., 2014; Revi et al., 2014a; Villarroel Walker et al., 2014; Kennedy et al., 2015; Rodríguez, 2015; Newman et al., 2017; UN-Habitat, 2017; Westphal et al., 2017) (Solecki et al. 2013; Ahern et al. 2014; McGranahan et al. 2016; Dodman et al. 2017a).

1 In addition, low-carbon cities could reduce the need to deploy Carbon Dioxide Removal (CDR) and Solar
2 Radiation Modification (SRM) (Fink, 2013; Thomson and Newman, 2016).

3
4 Cities are also places in which the risks associated with warming of 1.5°C, such as heat stress, terrestrial and
5 coastal flooding, new disease vectors, air pollution and water scarcity, will coalesce (see Section 3.3)
6 (Dodman et al., 2017a; Satterthwaite and Bartlett, 2017). Unless adaptation and mitigation efforts are
7 designed around the need to decarbonise urban societies in the developed world and provide low-carbon
8 solutions to the needs of growing urban populations in developing countries, they will struggle to deliver the
9 pace or scale of change required by 1.5°C-consistent pathways (Hallegatte et al., 2013; Villarroel Walker et
10 al., 2014; Roberts, 2016; Solecki et al., 2018). The pace and scale of urban climate responses can be
11 enhanced by attention to social equity (including gender equity), urban ecology (Brown and McGranahan,
12 2016; Wachsmuth et al., 2016; Ziervogel et al., 2016a) and participation in sub-national networks for climate
13 action (Cole, 2015; Jordan et al., 2015).

14
15 The long-lived urban transport, water and energy systems that will be constructed in the next three decades
16 to support urban populations in developing countries and to retrofit cities in developed countries will have to
17 be different to that built in Europe and North America in the 20th century, if they are to support the required
18 transitions (Freire et al., 2014; Cartwright, 2015; McPhearson et al., 2016; Roberts, 2016; Lwasa, 2017).
19 Recent literature identifies energy, infrastructure, appliances, urban planning, transport and adaptation
20 options as capable of facilitating systemic change. It is these aspects of the urban system that are discussed
21 below and from which options in Section 4.5 are selected.

22 23 24 4.3.3.1 *Urban Energy Systems*

25
26 Urban economies tend to be more energy intensive than national economies due to higher levels of *per*
27 *capita* income, mobility and consumption (Kennedy et al., 2015; Broto, 2017; Gota et al., 2018). However,
28 some urban systems have begun decoupling development from the consumption of fossil fuel powered
29 energy through energy efficiency, renewable energy and locally managed smart-grids (Dodman, 2009; Freire
30 et al., 2014; Eyre et al., 2018; Glazebrook and Newman, 2018a).

31
32 The rapidly expanding cities of Africa and Asia, where energy poverty currently undermines adaptive capacity
33 (Westphal et al., 2017; Satterthwaite et al., 2018), have the opportunity to benefit from recent price changes in
34 renewable energy technologies to enable clean energy access to citizens (SDG 7) (Cartwright, 2015; Watkins,
35 2015; Lwasa, 2017; Kennedy et al., 2018; Teferi and Newman, 2018). This will require strengthened energy
36 governance in these countries (Eberhard et al., 2017). Where renewable energy displaces paraffin, wood fuel
37 or charcoal feedstocks in informal urban settlements, it provides the co-benefits of improved indoor air quality,
38 reduced fire-risk and reduced deforestation, all of which can enhance adaptive capacity and strengthen demand
39 for this energy (Newham and Conradie, 2013; Winkler, 2017; Kennedy et al., 2018; Teferi and Newman,
40 2018).

41 42 43 4.3.3.2 *Urban Infrastructure, Buildings and Appliances*

44
45 Buildings are responsible for 32% of global energy consumption (IEA, 2016c) and have a large energy
46 saving potential with available and demonstrated technologies such as energy efficiency improvements in
47 technical installations and in thermal insulation (Toleikyte et al., 2018) and energy sufficiency (Thomas et
48 al., 2017). (Kuramochi et al., 2017) show that 1.5°C-consistent pathways require building emissions to be
49 reduced by 80–90% by 2050, new construction to be fossil-free and near-zero energy by 2020, and an
50 increased rate of energy refurbishment of existing buildings to 5% per annum in OECD (Organisation for
51 Economic Co-operation and Development) countries (see also Section 4.2.1).

52
53 Chapter 2 based on the IEA-ETP (IEA, 2017g) identifies large saving potential in heating and cooling
54 through improved building design, efficient equipment, lighting and appliances. Several examples of net zero
55 energy in buildings are now available (Wells et al., 2018). In existing buildings, refurbishment enables

1 energy saving (Semprini et al., 2017; Brambilla et al., 2018; D'Agostino and Parker, 2018; Sun et al., 2018)
2 and cost savings (Toleikyte et al., 2018; Zangheri et al., 2018).

3
4 Reducing the embodied energy in buildings material provides further energy and GHG savings (Cabeza et
5 al., 2013; Oliver and Morecroft, 2014; Koezjakov et al., 2018), in particular through bio-based materials
6 (Lupíšek et al., 2015) and wood construction (Ramage et al., 2017). The United Nations Environment
7 Programme (UNEP³) estimates that improving embodied energy, thermal performance, and direct energy use
8 of buildings can reduce emissions by 1.9 GtCO₂e yr⁻¹ (UNEP, 2017b), with an additional reduction of
9 3 GtCO₂e yr⁻¹ through energy efficient appliances and lighting (UNEP, 2017b). Further increasing the
10 energy efficiency of appliances and lighting, heating and cooling offers the potential for further savings
11 (Parikh and Parikh, 2016; Garg et al., 2017).

12
13 Smart technology, drawing on the Internet of Things (IoT) and building information modelling, offer
14 opportunities to accelerate energy efficiency in buildings and cities (Moreno-Cruz and Keith, 2013; Hoy,
15 2016) (see also Section 4.4.4). Some developing country cities are drawing on these technologies to adopt
16 'leapfrog' infrastructure, buildings and appliances to pursue low-carbon development (Newman et al., 2017;
17 Teferi and Newman, 2017) (Cross-Chapter Box 13 in Chapter 5).

18 19 20 4.3.3.3 *Urban Transport and Urban Planning*

21
22 Urban form impacts demand for energy (Sims et al., 2014) and other welfare related factors: a meta-analysis
23 of 300 papers reported energy savings of 26 USD per person per year attributable to a 10% increase in urban
24 population density (Ahlfeldt and Pietrostefani, 2017). Significant reductions in car use are associated with
25 dense, pedestrianised cities and towns and medium-density transit corridors (Newman and Kenworthy, 2015;
26 Newman et al., 2017) relative to low-density cities in which car dependency is high (Kenworthy and
27 Schiller, 2018). Combined dense urban forms and new mass transit systems in Shanghai and Beijing have
28 yielded less car use (Gao and Newman, 2018) (see Box 4.9). Compact cities also create the passenger density
29 required to make public transport more financially viable (Ahlfeldt and Pietrostefani, 2017; Rode et al.,
30 2017) and enable combinations of cleaner fuel feed stocks and urban smart-grids, in which vehicles form
31 part of the storage capacity (Oldenbroek et al., 2017). Similarly, the spatial organisation of urban energy
32 influenced the trajectories of urban development in cities as diverse as Hong Kong, Bengaluru and Maputo
33 (Broto, 2017).

34
35 The informal settlements of middle- and low-income cities where urban density is more typically associated
36 with a range of water- and vector-borne health risks, may provide a notable exception to the adaptive
37 advantages of urban density (Mitlin and Satterthwaite, 2013; Lilford et al., 2017) unless new approaches and
38 technologies are harnessed to accelerate slum upgrading (Teferi and Newman, 2017)

39
40 Scenarios consistent with 1.5°C pathways, depend on an almost 40% reduction in final energy use by the
41 transport sector by 2050 (Chapter 2, Figure 2.12). In one analysis the phasing out of fossil fuel passenger
42 vehicle sales by 2035-2050 was identified as a benchmark for aligning with 1.5°C-consistent pathways
43 (Kuramochi et al., 2017). Reducing emissions from transport has lagged the power sector (Sims et al., 2014;
44 Creutzig et al., 2015a) but evidence since AR5 suggests that cities are urbanising and re-urbanising in ways
45 that co-ordinate transport sector adaptation and mitigation (Colenbrander et al., 2017; Newman et al., 2017;
46 Salvo et al., 2017; Gota et al., 2018). The global transport sector could reduce 4.7GtCO₂e yr⁻¹ (4.1–5.3) by
47 2030. This is significantly more than is predicted by Integrated Assessment Models (IAMs; UNEP, 2017b).
48 Such a transition depends on cities that enable modal shifts, avoided journeys, provide incentives for uptake
49 of improved fuel efficiency and changes in urban design that encourage walkable cities, non-motorised
50 transport and shorter commuter distances (IEA, 2016a; Mittal et al., 2016; Zhang et al., 2016; Li and Loo,
51 2017). In at least four African cities, 43 Asian cities and 54 Latin American cities, Transit Oriented
52 Development (TOD), has emerged as an organising principle for urban growth and spatial planning
53 (Colenbrander et al., 2017; Lwasa, 2017; BRT Data, 2018). This trend is important to counter the rising

³ Currently called UN Environment.

1 demand for private cars in developing country cities (OECD, 2016b). In India TOD has been combined with
2 localized solar PV installations and new ways of financing rail expansion (Sharma, 2018).

3
4 Cities pursuing sustainable transport benefit from reduced air pollution, congestion and road fatalities and
5 are able to harness the relationship between transport systems, urban form, urban energy intensity and social
6 cohesion (Goodwin and Van Dender, 2013; Newman and Kenworthy, 2015; Wee, 2015)

7
8 Technology and electrification trends since AR5 make carbon efficient urban transport easier (Newman et
9 al., 2016), but realising urban transport's contribution to a 1.5°C-consistent pathways will require the type of
10 governance that can overcome the financial, institutional, behavioural and legal barriers to change (Geels,
11 2014; Bakker et al., 2017).

12
13 Adaptation to a 1.5°C world is enabled by urban design and spatial planning policies that consider extreme
14 weather conditions and reduce displacement by climate related disasters (UNISDR, 2009; UN-Habitat, 2011;
15 Mitlin and Satterthwaite, 2013).

16
17 Building codes and technology standards for public lighting, including traffic lights (Beccali et al., 2015),
18 play a critical role in reducing carbon emissions, enhancing urban climate resilience and managing climate
19 risk (Steenhof and Sparling, 2011; Parnell, 2015; Shapiro, 2016; Evans et al., 2017). Building codes can
20 support the convergence to zero emissions from buildings (Wells et al., 2018), and can be used retrofit the
21 existing building stock for energy efficiency (Ruparathna et al., 2016).

22
23 The application of building codes and standards for 1.5°C-consistent pathways will require improved
24 enforcement, which can be a challenge in developing countries where inspection resources are often limited
25 and codes are poorly tailored to local conditions (Ford et al., 2015c; Chandel et al., 2016; Eisenberg, 2016;
26 Shapiro, 2016; Hess and Kelman, 2017; Mavhura et al., 2017). In all countries, building codes can be
27 undermined by industry interests, and can be maladaptive if they prevent buildings or land use from evolving
28 to reduce climate impacts (Eisenberg, 2016; Shapiro, 2016).

29
30 The deficit in building codes and standards in middle-income and developing country cities need not be a
31 constraint to more energy-efficient and resilient buildings (Tait and Euston-Brown, 2017). For example, the
32 relatively high price that poor households pay for unreliable and at times dangerous household energy in
33 African cities has driven the uptake of renewable energy and energy efficiency technologies in the absence
34 of regulations or fiscal incentives (Eberhard et al., 2011, 2016; Cartwright, 2015; Watkins, 2015). The
35 Kuyasa Housing Project in Khayelitsha, one of Cape Town's poorest suburbs, created significant mitigation
36 and adaptation benefits by installing ceilings, solar water heaters and energy efficient lightbulbs in houses
37 independent of the formal housing or electrification programme (Winkler, 2017).

38 39 40 4.3.3.4 *Electrification of Cities and Transport*

41
42 The electrification of urban systems, including transport, has shown global progress since AR5 (IEA, 2016a;
43 Kennedy et al., 2018; Kenworthy and Schiller, 2018). High growth rates are now appearing in electric
44 vehicles (Figure 4.1), electric bikes and electric transit (IEA, 2018), which would need to displace fossil-fuel
45 powered passenger vehicles by 2035–2050 to remain in line with 1.5°C-consistent pathways. China's 2017
46 Road Map calls for 20% of new vehicle sales to be electric. India is aiming for exclusively electric vehicles
47 (EVs) by 2032 (NITI Aayog and RMI, 2017). Globally, EV sales were up 42% in 2016 relative to 2015, and
48 in the United States EV sales were up 36% over the same period (Johnson and Walker, 2016).

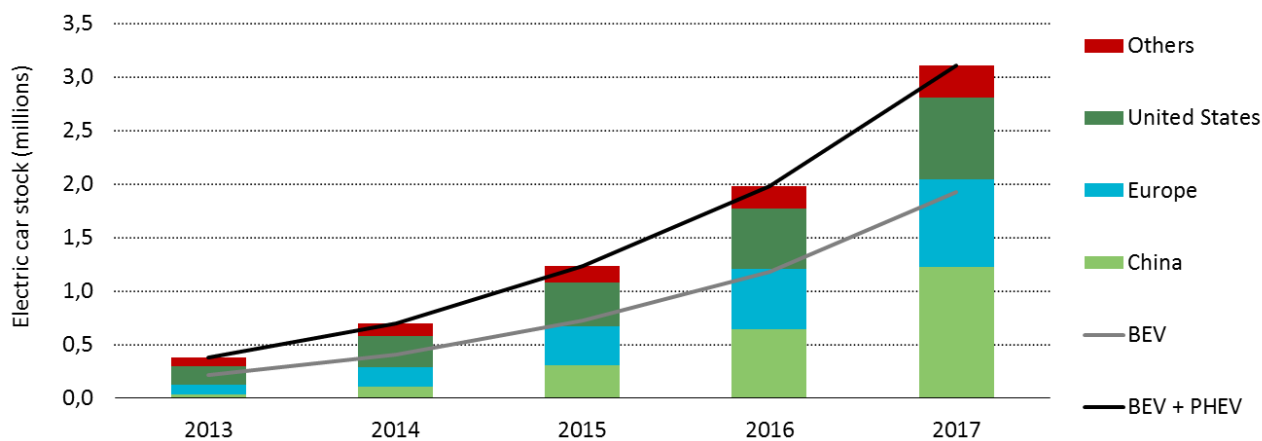


Figure 4.1: Increase of the global electric car stock by country (2013–2017). Source: (IEA, 2018). Based on IEA data from Global EV Outlook 2018 © OECD/IEA 2018, IEA Publishing.

The extent of electric railways in and between cities has expanded since AR5 (IEA, 2016a; Mittal et al., 2016; Zhang et al., 2016; Li and Loo, 2017). In high income cities there is *medium evidence* for the decoupling of car use and wealth since AR5 (Newman, 2017). In cities where private vehicle ownership is expected to increase, less carbon-intensive fuel sources and reduced car journeys will be necessary as well as electrification of all modes of transport (Mittal et al., 2016; van Vuuren et al., 2017). Some recent urban data show a decoupling of urban growth and GHG emissions (Newman and Kenworthy, 2015) and that ‘peak car’ has been reached in Shanghai and Beijing (Gao and Kenworthy, 2017) and beyond (Manville et al., 2017) (also see Box 4.9).

An estimated 800 cities globally have operational bike-share schemes (E. Fishman et al., 2015) and China had 250 million e-bikes in 2017 (Newman et al., 2017). Advances in Information and Communication Technologies (ICT) offer cities the chance to reduce urban transport congestion and fuel consumption by making better use of the urban vehicle fleet through car sharing, driverless cars and coordinated public transport, especially when electrified (Wee, 2015; Glazebrook and Newman, 2018b). Advances in ‘big-data’ can assist in creating a better understanding of the connections between cities, green infrastructure, environmental services and health (Jennings et al., 2016) and improve decision-making in urban development (Lin et al., 2017).

4.3.3.5 Shipping, Freight and Aviation

International transport hubs, including airports and ports and the associated mobility of people, are major economic contributors to most large cities even while under the governance of national authorities and international legislation. Shipping, freight and aviation systems have grown rapidly and little progress has been made since AR5 on replacing fossil fuels, though some trials are continuing (Zhang, 2016; Bouman et al., 2017; EEA, 2017). Aviation emissions do not yet feature in IAMs (Bows-Larkin, 2015), but could be reduced by between a third and two-thirds through energy efficiency measures and operational changes (Dahlmann et al., 2016). On shorter inter-city trips, aviation could be replaced by high-speed electric trains drawing on renewable energy (Åkerman, 2011). Some progress has been made on the use of electricity in planes and shipping (Grewe et al., 2017) though no commercial applications have arisen. Studies indicate that biofuels are the most viable means of decarbonising intercontinental travel, given their technical characteristics, energy content and affordability (Wise et al., 2017). The lifecycle emissions of bio-based jet fuels and marine fuels can be considerable (Cox et al., 2014; IEA, 2017g) depending on their location (Elshout et al., 2014), but can be reduced by feedstock and conversion technology choices (de Jong et al., 2017).

In recent years the potential for transport to use synfuels, such as ethanol, methanol, methane, ammonia and hydrogen, created from renewable electricity and CO₂, has gained momentum but has not yet demonstrated benefits on a scale consistent with 1.5°C pathways (Ezeji, 2017; Fasihi et al., 2017). Decarbonising the fuel

1 used by the world's 60,000 large vessels faces governance barriers and the need for a global policy (Bows
2 and Smith, 2012; IRENA, 2015; Rehmatulla and Smith, 2015). Low-emission marine fuels could
3 simultaneously address sulphur and black carbon issues in ports and around waterways and accelerate the
4 electrification of all large ports (Bouman et al., 2017; IEA, 2017g).

7 4.3.3.6 *Climate-Resilient Land Use*

9 Urban land use influences energy intensity, risk exposure and adaptive capacity (Carter et al., 2015; Araos et
10 al., 2016a; Ewing et al., 2016; Newman et al., 2016; Broto, 2017). Accordingly, urban land-use planning can
11 contribute to climate mitigation and adaptation (Parnell, 2015; Francesch-Huidobro et al., 2017) and the
12 growing number of urban climate adaptation plans provide instruments for planning (Carter et al., 2015;
13 Dhar and Khirfan, 2017; Siders, 2017; Stults and Woodruff, 2017). Adaptation plans can reduce exposure to
14 urban flood risk that, in a 1.5°C world, could double relative to 1976–2005 (Alfieri et al., 2017), reduce heat
15 stress (Section 3.5.5.8), fire risk (Section 3.4.3.4) and sea-level rise (Section 3.4.5.1) (Schleussner et al.,
16 2016).

18 Cities can reduce their risk exposure by considering investment in infrastructure and buildings that are more
19 resilient to warming of 1.5°C or beyond. Where adaptation planning and urban planning generate the type of
20 local participation that enhances capacity to cope with risks, they can be mutually supportive processes
21 (Archer et al., 2014; Kettle et al., 2014; Campos et al., 2016; Chu et al., 2017; Siders, 2017; Underwood et
22 al., 2017). Not all adaptation plans are reported as effective (Measham et al., 2011; Hetz, 2016; Woodruff
23 and Stults, 2016; Mahlkow and Donner, 2017), especially in developing country cities (Kiunsi, 2013). Where
24 adaptation planning further marginalises poor citizens through limited local control over establishing
25 adaptation priorities, or the displacement of impacts onto poorer communities, justice, equity, and broad
26 participation would need to be considered in the dimensions of successful urban risk reduction, and
27 recognition of the political economy of adaptation (Archer, 2016; Shi et al., 2016; Ziervogel et al., 2016a,
28 2017; Chu et al., 2017).

31 4.3.3.7 *Green Urban Infrastructure and Ecosystem Services*

33 Integrating and promoting green urban infrastructure (including street trees, parks, green roofs and facades,
34 water features) into city planning can be difficult (Leck et al., 2015) and increases urban resilience to
35 impacts of 1.5°C warming (Table 4.2) in ways that can be more cost effective than conventional
36 infrastructure (Culwick and Bobbins (2016) (Cartwright et al., 2013).

38 **Table 4.2:** Green urban infrastructure and benefits.

Green infrastructure	Adaptation benefits	Mitigation benefits	References
Urban trees planting, urban parks	Reduced heat island effect, psychological benefits	Less cement, reduced air-conditioning	(Demuzere et al., 2014; Mullaney et al., 2015; Soderlund and Newman, 2015; Beaudoin and Gosselin, 2016; Green et al., 2016; Lin et al., 2017)
Permeable surfaces	Water recharge	Less cement in city, some bio-sequestration, less water pumping	(Liu et al., 2014; Lamond et al., 2015; Skougaard Kaspersen et al., 2015; Voskamp and Van de Ven, 2015; Costa et al., 2016; Mguni et al., 2016; Xie et al., 2017)
Forest retention, and urban agricultural land	Flood mediation, healthy lifestyles	Air pollution reduction	(Nowak et al., 2006; Tallis et al., 2011; Elmqvist et al., 2013; Buckeridge, 2015; Culwick and Bobbins, 2016; Panagopoulos et al., 2016; Stevenson et al., 2016; White et al., 2017)
Wetland restoration,	Reduced urban flooding, Low	Some bio-sequestration, Less	(Cartwright et al., 2013; Elmqvist et al., 2015; Brown and McGranahan, 2016; Camps-Calvet et al., 2016;

riparian buffer zones	skilled local work, Sense of place	energy spent on water treatment	Culwick and Bobbins, 2016; McPhearson et al., 2016; Ziervogel et al., 2016b; Collas et al., 2017; F. Li et al., 2017)
Biodiverse urban habitat	Psychological benefits, inner-city recreation	Carbon sequestration	(Beatley, 2011; Elmqvist et al., 2015; Brown and McGranahan, 2016; Camps-Calvet et al., 2016; McPhearson et al., 2016; Collas et al., 2017; F. Li et al., 2017)

1
2 Realising climate benefits from urban green infrastructure sometimes requires a city-region perspective
3 (Wachsmuth et al., 2016). Where the urban impact on ecological systems in and beyond the city is
4 appreciated, the potential for transformative change exists (Soderlund and Newman, 2015; Ziervogel et al.,
5 2016a), and a locally appropriate combination of green space, ecosystem goods and services and the built
6 environment can increase the set of urban adaptation options (Puppim de Oliveira et al., 2013).
7

8 Milan, Italy, a city with deliberate urban greening policies, planted 10,000 hectares of new forest and green
9 areas over the last two decades (Sanesi et al., 2017). The accelerated growth of urban trees, relative to rural
10 trees, in several regions of the world is expected to decrease tree longevity (Pretzsch et al., 2017), requiring
11 monitoring and additional management of urban trees if their contribution to urban ecosystem based
12 adaptation and mitigation is to be maintained in a 1.5°C world (Buckeridge, 2015; Pretzsch et al., 2017).
13

14 15 4.3.3.8 *Sustainable Urban Water and Environmental Services*

16
17 Urban water supply and wastewater treatment is energy intensive, and currently accounts for significant
18 GHG emissions (Nair et al., 2014). Cities can integrate sustainable water resource management and the
19 supply of water services in ways that support mitigation, adaptation and development through waste-water
20 recycling and storm water diversion (Xue et al., 2015; Poff et al., 2016). Governance and finance challenges
21 complicate balancing sustainable water supply and rising urban demand, particularly in low-income cities
22 (Bettini et al., 2015; Deng and Zhao, 2015; Hill Clarvis and Engle, 2015; Lemos, 2015; Margerum and
23 Robinson, 2015).

24 Urban surface sealing with impervious materials affects the volume and velocity of run-off and flooding
25 during intense rainfall (Skougaard Kaspersen et al., 2015), but urban design in many cities now seeks to
26 mediate run-off, encourage groundwater recharge and enhance water quality (Liu et al., 2014; Lamond et al.,
27 2015; Voskamp and Van de Ven, 2015; Costa et al., 2016; Mguni et al., 2016; Xie et al., 2017). Challenges
28 remain for managing intense rainfall events that are reported to be increasing in frequency and intensity in
29 some locations (Ziervogel et al., 2016b) and urban flooding is expected to increase at 1.5°C warming (Alfieri
30 et al., 2017). This risk falls disproportionately on women and poor people in cities (Mitlin, 2005; Chu et al.,
31 2016; Ziervogel et al., 2016b; Chant et al., 2017; Dodman et al., 2017a, b).

32 Nexus approaches that highlight urban areas as socio-ecological systems, can support policy coherence
33 (Rasul and Sharma, 2016) and sustainable urban livelihoods (Biggs et al., 2015). The Water-Energy-Food
34 (WEF) nexus is especially important to growing urban populations (Tacoli et al., 2013; Lwasa et al., 2014;
35 Villarroel Walker et al., 2014).
36
37

38 4.3.4 *Industrial Systems Transitions*

39
40 Industry consumes about one third of global final energy and contributes, directly and indirectly, about one
41 third of global GHG emissions (IPCC, 2014b). If global temperatures are to remain under 1.5°C, modelling
42 indicates that industry cannot emit more than 2 GtCO₂ in 2050, corresponding > 70% GHG emission
43 reduction compared to 2010 (see Figures 2.20 and 2.21). Moreover, the consequences of climate change of
44 1.5°C or more pose substantial challenges for industrial diversity. This section will first briefly discuss the
45 limited literature on adaptation options for industry. Subsequently, new literature since AR5 on the
46 feasibility of industrial mitigation options will be discussed.
47

48 Research assessing adaptation actions by industry indicates that only a small fraction of corporations have

1 developed adaptation measures. Studies of adaptation in the private sector remain limited (Agrawala et al.,
2 2011; Linnenluecke et al., 2015; Averchenkova et al., 2016; Bremer and Linnenluecke, 2016; Pauw et al.,
3 2016a) and for 1.5°C are largely absent. This knowledge gap is particularly evident for medium-sized
4 enterprises and in low- and middle-income nations (Surminski, 2013).
5

6 Depending on the industrial sector, mitigation consistent with 1.5°C would mean, across industries, a
7 reduction of final energy demand by one-third, an increase of the rate of recycling of materials and the
8 development of a circular economy in industry (Lewandowski, 2016; Linder and Williander, 2017), the
9 substitution of materials in high-carbon products with those made up of renewable materials (e.g., wood
10 instead of steel or cement in the construction sector, natural textile fibres instead of plastics), and a range of
11 deep emission reduction options, including use of bio-based feedstocks, low-emission heat sources,
12 electrification of production processes, and/or capture and storage of all CO₂ emissions by 2050 (Åhman et
13 al., 2016). Some of the choices for mitigation options and routes for GHG-intensive industry are discrete and
14 potentially subject to path dependency: if an industry goes one way (e.g., in keeping existing processes), it
15 will be harder to transition to process change (e.g., electrification) (Bataille et al., 2018). In the context of
16 rising demand for construction, an increasing share of industrial production may be based in developing
17 countries (N. Li et al., 2017), where current efficiencies may be lower than in developed countries, and
18 technical and institutional feasibility may differ (Ma et al., 2015).
19

20 Except for energy efficiency, costs of disruptive change associated with hydrogen- or electricity-based
21 production, bio-based feedstocks and Carbon Dioxide Capture, (Utilisation) and Storage (CC(U)S) for trade-
22 sensitive industrial sectors (in particular the iron and steel, petrochemical and refining industries) make
23 policy action by individual countries challenging because of competitiveness concerns (Åhman et al., 2016;
24 Nabernegg et al., 2017).
25

26 Table 4.3 provides an overview of applicable mitigation options for key industrial sectors.
27

28 **Table 4.3:** Overview of different mitigation options potentially consistent with 1.5°C and applicable to main industrial
29 sectors, including examples of application (Napp et al., 2014; Boulamanti and Moya, 2017; Wesseling et
30 al., 2017).
31

	Iron/steel	Cement	Refineries and petrochemicals	Chemicals
Process and energy efficiency	Can make a difference on of between 10% and 50%, depending on the plant. Relevant but not enough for 1.5°C			
Bio-based	Coke can be made from biomass instead of coal	Partial (only energy-related emissions)	Biomass can replace fossil feedstocks	
Circularity & substitution	More recycling and replacement by low-emission materials, including alternative chemistries for cement		Limited potential	
Electrification & hydrogen	Direct reduction with hydrogen. Heat generation through electricity	Partial (only electrified heat generation)	Electrified heat and hydrogen generation	
CCS	Possible for process emissions and energy. Reduces emissions by 80-95%, and become negative when combined with biofuel		Can be applied to energy emissions and different stacks but not on emissions of products in the use phase (e.g., gasoline)	

32 33 34 35 4.3.4.1 Energy Efficiency

36 Isolated efficiency implementation in energy-intensive industries is a necessary but insufficient condition for
37 deep emission reductions (Napp et al., 2014; Aden, 2017). Various options specific to different industries are
38 available. In general, their feasibility depends on lowering capital costs and raising awareness and expertise
39 (Wesseling et al., 2017). General purpose technologies, such as ICT, and energy management tools can

1 improve the prospects of energy efficiency in industry (see Section 4.4.4).

2
3 Cross-sector technologies and practices, which play a role in all industrial sectors including Small- and
4 Medium-sized Enterprises (SMEs) and non-energy intensive industry, also offer potential for considerable
5 energy efficiency improvements. They include motor systems (for example electric motors, variable speed
6 drives, pumps, compressors and fans), responsible for about 10% of industrial energy consumption with an
7 energy efficiency improvement potential of around 20–25%, worldwide (Napp et al., 2014); steam systems,
8 responsible for about 30% of industrial energy consumption and energy saving potentials of about 10%
9 (Hasanbeigi et al., 2014; Napp et al., 2014). Waste heat recovery from industry has substantial potential for
10 energy efficiency and emission reduction (Forman et al., 2016). Low awareness and competition from other
11 investments limit the feasibility of such options (Napp et al., 2014).

12 13 14 4.3.4.2 *Substitution and Circularity*

15
16 Recycling materials and developing a circular economy can be institutionally challenging as it requires
17 advanced capabilities (Henry et al., 2006) and organisational changes (Cooper- Searle et al., 2018), but has
18 advantages in terms of cost, health, governance and environment (Ali et al., 2017). An assessment of the
19 impacts on energy use and environmental issues is not available, but substitution could play a large role in
20 reducing emissions (Åhman et al., 2016) although its potential depends on the demand for material, and the
21 turnover of for example in buildings (Haas et al., 2015). Material substitution and CO₂ storage options are
22 under development, for example, the use of algae and renewable energy for carbon fibre production, which
23 could become a net sink of CO₂ (Arnold et al., 2018).

24 25 26 4.3.4.3 *Bio-Based Feedstocks*

27
28 Bio-based feedstock processes could be partly seen as part of the circular materials economy (see Section
29 above). In several sectors, bio-based feedstocks would leave the production process of materials relatively
30 untouched, and a switch would not affect the product quality, making the option more attractive. However,
31 energy requirements for processing bio-based feedstocks are often high, costs are also still higher, and the
32 emissions over the full lifecycle, both upstream and downstream, could be significant (Wesseling et al.,
33 2017). Bio-based feedstocks may put pressure on natural resources by increasing land demand, biodiversity
34 impacts beyond bioenergy demand for electricity, transport and buildings (Slade et al., 2014), and, partly as a
35 result, face barriers in public acceptance (Sleehoff et al., 2015).

36 37 38 4.3.4.4 *Electrification and Hydrogen*

39
40 Electrification of manufacturing processes would constitute a significant technological challenge and a more
41 disruptive innovation in industry than bio-based or CCS options, to get to very low or zero emissions, except
42 potentially in steel-making (Philibert, 2017). The disruptive characteristics could potentially lead to stranded
43 assets, and could reduce political feasibility and industry support (Åhman et al., 2016). Electrification of
44 manufacturing would require further technological development in industry, as well as an ample supply of
45 cost-effective low-emission electricity (Philibert, 2017).

46
47 Low-emission hydrogen can be produced either by natural gas with CCS, by electrolysis of water powered
48 by zero-emission electricity, or potentially in the future by generation IV nuclear reactors. Feasibility of
49 electrification and use of hydrogen in production processes or fuel cells is affected by technical development
50 in terms of efficient hydrogen production and electrification of processes, by geophysical factors related to
51 the availability of low-emission electricity (MacKay, 2013), by associated public perception and by
52 economic feasibility, except in areas with ample solar and/or wind resources (Philibert, 2017; Wesseling et
53 al., 2017).

4.3.4.5 *CO₂ Capture, Utilisation and Storage in Industry*

CO₂ capture in industry is generally considered more feasible than CCS in the power sector (Section 4.3.1) or from bioenergy sources (Section 4.3.7), although CCS in industry faces similar barriers. Almost all of the current full-scale (>1MtCO₂ yr⁻¹) CCS projects capture CO₂ from industrial sources, including the Sleipner project in Norway, which has been injecting CO₂ from a gas facility in an offshore saline formation since 1996 (Global CCS Institute, 2017). Compared to the power sector, retrofitting CCS on existing industrial plants would leave the production process of materials relatively untouched (Åhman et al., 2016), though significant investments and modifications still have to be made. Some industries, in particular cement, emit CO₂ as inherent process emissions and can therefore not reduce emissions to zero without CC(U)S. CO₂ stacks in some industries have a high economic and technical feasibility for CO₂ capture as the CO₂ concentration in the exhaust gases is relatively high (IPCC, 2005; Leeson et al., 2017), but others require strong modifications in the production process, limiting technical and economic feasibility, though costs remain lower than other deep GHG reduction options (Rubin et al., 2015). There are indications that the energy use in CO₂ capture through amine solvents (for solvent regeneration) can decrease by around 60%, from 5 GJ tCO₂⁻¹ in 2005 to 2 GJ tCO₂⁻¹ in the best-performing pilot plants (Idem et al., 2015), increasing both technical and economic potential for this option. The heterogeneity of industrial production processes might point to the need for specific institutional arrangements to incentivise industrial CCS (Mikunda et al., 2014), and may decrease institutional feasibility.

The contribution of Carbon Dioxide Utilisation (CCU) to limiting warming to 1.5°C depends on the origin of CO₂ (fossil, biogenic or atmospheric), the source of electricity for converting the CO₂ or regenerating catalysts, and the lifetime of the product. Review studies indicate that carbon dioxide utilisation in industry has a small role to play in limiting warming to 1.5°C because of the limited potential of re-using CO₂ with currently available technologies and the re-emission of CO₂ when used as a fuel (IPCC, 2005; Mac Dowell et al., 2017). However, there are new developments, in particular in CO₂ use as a feedstock for carbon-based materials that would isolate CO₂ from the atmosphere for a long time and greater availability of low-cost, low-emission electricity. The conversion of CO₂ to fuels using zero-emission electricity has a lower technical, economic and environmental feasibility than direct CO₂ capture and storage from industry (Abanades et al., 2017), although the economic prospects have improved recently (Philibert, 2017).

4.3.5 *Overarching Adaptation Options Supporting Adaptation Transitions*

This section assesses overarching adaptation options, which are specific solutions from which actors can choose and make decisions to reduce climate vulnerability and build resilience. We examine their feasibility in the context of transitions of energy, land and ecosystem, urban and infrastructure, and industrial systems here, and further in Section 4.5. These options can contribute to creating an enabling environment for adaptation (see Table 4.4 and Section 4.4).

4.3.5.1 *Disaster Risk Management (DRM)*

DRM is a process for designing, implementing and evaluating strategies, policies and measures to improve the understanding of disaster risk, and promoting improvement in disaster preparedness, response and recovery (IPCC, 2012). There is increased demand to integrate DRM and adaptation (Howes et al., 2015; Kelman et al., 2015; Serrao-Neumann et al., 2015; Archer, 2016; Rose, 2016; van der Keur et al., 2016; Kelman, 2017; Wallace, 2017) to reduce vulnerability, but institutional, technical and financial capacity challenges in frontline agencies constitute constraints (*medium evidence, high agreement*) (Eakin et al., 2015; Kita, 2017; Wallace, 2017).

4.3.5.2 *Risk Sharing and Spreading*

Risks associated with 1.5°C warming (Section 3.4) have the potential to increase the demand for options that

1 share and spread financial burdens. Formal, market-based (re)insurance spreads risk and provides a financial
2 buffer against the impact of climate hazards (Linnerooth-Bayer and Hochrainer-Stigler, 2015; Wolfrom and
3 Yokoi-Arai, 2015; O'Hare et al., 2016; Glaas et al., 2017; Patel et al., 2017). As an alternative to traditional
4 indemnity-based insurance, index-based micro-crop and livestock insurance programmes have been rolled
5 out in regions with less developed insurance markets (Aker et al., 2016, 2017; Jensen and Barrett, 2017).
6 There is *medium evidence* and *medium agreement* on the feasibility of insurance for adaptation, with
7 financial, social, and institutional barriers to implementation and uptake, especially in low-income nations
8 (García Romero and Molina, 2015; Joyette et al., 2015; Lashley and Warner, 2015; Jin et al., 2016). Social
9 protection programmes include cash and in-kind transfers to protect poor and vulnerable households from the
10 impact of economic shocks, natural disasters and other crises (World Bank, 2017b), and can build generic
11 adaptive capacity and reduce vulnerability when combined with a comprehensive climate risk management
12 approach (*medium evidence, medium agreement*) (Devereux, 2016; Lemos et al., 2016).

15 4.3.5.3 *Education and Learning*

16 Educational adaptation options motivate adaptation through building awareness (Butler et al., 2016; Myers et
17 al., 2017), leveraging multiple knowledge systems (Pearce et al., 2015; Janif et al., 2016), developing
18 participatory action research and social learning processes (Butler and Adamowski, 2015; Ensor and Harvey,
19 2015; Butler et al., 2016; Thi Hong Phuong et al., 2017; Ford et al., 2018), strengthening extension services,
20 and building learning and knowledge sharing mechanisms through community-based platforms, international
21 conferences and knowledge networks (Vinke-de Kruijf and Pahl-Wostl, 2016) (*medium evidence, high
22 agreement*).

26 4.3.5.4 *Population Health and Health System Adaptation Options*

27 Until mid-century, climate change will exacerbate existing health challenges (Section 3.4.7). Enhancing
28 current health services includes providing access to safe water and improved sanitation, enhancing access to
29 essential services such as vaccination, and developing or strengthening integrated surveillance systems
30 (WHO, 2015). Combining these with iterative management can facilitate effective adaptation (*medium
31 evidence, high agreement*).

35 4.3.5.5 *Indigenous Knowledge*

36 There is *medium evidence* and *high agreement* that Indigenous knowledge is critical for adaptation,
37 underpinning adaptive capacity through the diversity of Indigenous agro-ecological and forest management
38 systems, collective social memory, repository of accumulated experience, and social networks (Hiwasaki et
39 al., 2015; Pearce et al., 2015; Mapfumo et al., 2016; Sherman et al., 2016; Ingty, 2017) (Box 4.3). It is
40 threatened by acculturation, dispossession of land rights and land grabbing, rapid environmental changes,
41 colonisation, and social change, increasing vulnerability to climate change, which climate policy can
42 exacerbate if based on limited understanding of Indigenous worldviews (Thornton and Manasfi, 2010; Ford,
43 2012; Nakashima et al., 2012; McNamara and Prasad, 2014). Many scholars argue that recognition of
44 Indigenous rights, governance systems and laws is central to adaptation, mitigation and sustainable
45 development (Magni, 2017; Thornton and Comberti, 2017; Pearce, 2018).

49 4.3.5.6 *Human Migration*

50 Human migration, whether planned, forced or voluntary, is increasingly gaining attention as a response,
51 particularly where climatic risks are becoming severe (Section 3.4.10.2). There is *medium evidence* and *low
52 agreement* as to whether migration is adaptive, in relation to cost effectiveness (Grecequet et al., 2017) and
53 scalability (Brzoska and Fröhlich, 2016; Gemenne and Blocher, 2017; Grecequet et al., 2017) concerns.
54 Migrating can have mixed outcomes on reducing socio-economic vulnerability (Birk and Rasmussen, 2014;
55

1 Kothari, 2014; Adger et al., 2015; Betzold, 2015; Kelman, 2015; Grecequet et al., 2017; Melde et al., 2017;
 2 World Bank, 2017a, 2018b) and its feasibility is constrained by low political and legal acceptability, and
 3 inadequate institutional capacity (Betzold, 2015; Methmann and Oels, 2015; Brzoska and Fröhlich, 2016;
 4 Gemenne and Blocher, 2017; Grecequet et al., 2017; Yamamoto et al., 2017).

7 4.3.5.7 Climate Services

8
 9 There is *medium evidence* and *high agreement* that climate services can play a critical role in aiding
 10 adaptation decision making (Vaughan and Dessai, 2014; Wood et al., 2014; Lourenço et al., 2016; Trenberth
 11 et al., 2016; Singh et al., 2017; Vaughan et al., 2018). The higher uptake of short-term climate information
 12 such as weather advisories and daily forecasts contrast with lesser use of longer-term information such as
 13 seasonal forecasts and multi-decadal projections (Singh et al., 2017; Vaughan et al., 2018). Climate service
 14 interventions have met challenges with scaling-up due to low capacity, inadequate institutions, and
 15 difficulties in maintaining systems beyond pilot project stage (Sivakumar et al., 2014; Tall et al., 2014;
 16 Gebru et al., 2015; Singh et al., 2016b), and technical, institutional, design, financial and capacity barriers to
 17 the application of climate information for better decision-making remain (WMO, 2015; Briley et al., 2015;
 18 L. Jones et al., 2016; Lourenço et al., 2016; Snow et al., 2016; Harjanne, 2017; Singh et al., 2017; C.J. White
 19 et al., 2017).

20
 21 **Table 4.4:** Assessment of overarching adaptation options in relation to enabling conditions. For more details, see
 22 Supplementary Material 4.SM.2.
 23

Option	Enabling Conditions	Examples
Disaster risk management (DRM)	Governance and institutional capacity: supports post-disaster recovery and reconstruction (Kelman et al., 2015; Kull et al., 2016).	Early warning systems (Anaconda et al., 2015), and monitoring of dangerous lakes and surrounding slopes (including using remote sensing) offer DRM opportunities (Emmer et al., 2016; Milner et al., 2017).
Risk sharing and spreading: insurance	Institutional capacity and finance: buffers climate risk (Wolfrom and Yokoi-Arai, 2015; O'Hare et al., 2016; Glaas et al., 2017; Jenkins et al., 2017; Patel et al., 2017).	In 2007, the Caribbean Catastrophe Risk Insurance Facility was formed to pool risk from tropical cyclones, earthquakes, and excess rainfalls (Murphy et al., 2012; CCRIF, 2017).
Risk sharing and spreading: social protection programmes	Institutional capacity and finance: builds generic adaptive capacity and reduces social vulnerability (Weldegebriel and Prowse, 2013; Eakin et al., 2014; Lemos et al., 2016; Schwan and Yu, 2017).	In sub-Saharan Africa, cash transfer programmes targeting poor communities have proven successful in smoothing household welfare and food security during droughts, strengthening community ties, and reducing debt levels (del Ninno et al., 2016; Asfaw et al., 2017; Asfaw and Davis, 2018).
Education and learning	Behavioural change and institutional capacity: social learning strengthens adaptation and affects longer-term change (Clemens et al., 2015; Ensor and Harvey, 2015; Henly-Shepard et al., 2015).	Participatory scenario planning is a process by which multiple stakeholders work together to envision future scenarios under a range of climatic conditions (Oteros-Rozas et al., 2015; Butler et al., 2016; Flynn et al., 2018).
Population health and health system	Institutional capacity: 1.5°C warming will primarily exacerbate existing health challenges (K.R. Smith et al., 2014), which can be targeted by enhancing health services.	Heat wave early warning and response systems coordinate the implementation of multiple measures in response to predicted extreme temperatures (e.g. public announcements, opening public cooling shelters, distributing information on heat stress symptoms) (Knowlton et al., 2014; Takahashi et al., 2015; Nitschke et al., 2016, 2017).
Indigenous knowledge	Institutional capacity and behavioural change: knowledge of environmental conditions helps communities detect and monitor change (Johnson et al., 2015; Mistry and Berardi, 2016; Williams et al., 2017).	Options such as integration of Indigenous knowledge into resource management systems and school curricula, are identified as potential adaptations (Cunsolo Willox et al., 2013; McNamara and Prasad, 2014; MacDonald et al., 2015; Pearce et al., 2015; Chambers et al., 2017; Inamara and Thomas, 2017).

Human migration	Governance: revising and adopting migration issues in national disaster risk management policies, National Adaptation Plans and NDCs (Kuruppu and Willie, 2015; Yamamoto et al., 2017).	In dryland India, populations in rural regions already experiencing 1.5°C warming are migrating to cities (Gajjar et al., 2018) but are inadequately covered by existing policies (Bhagat, 2017).
Climate services	Technological innovation: rapid technical development (due to increased financial inputs and growing demand) is enabling quality of climate information provided (WMO, 2015; Rogers and Tsirkunov, 2010; Clements et al., 2013; Perrels et al., 2013; Gasc et al., 2014; Roudier et al., 2016).	Climate services are seeing wide application in sectors such as agriculture, health, disaster management, insurance (Lourenço et al., 2016; Vaughan et al., 2018) with implications for adaptation decision-making (Singh et al., 2017).

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[START CROSS-CHAPTER BOX 9 HERE]

Cross-Chapter Box 9: Risks, Adaptation Interventions, and Implications for Sustainable Development and Equity Across Four Social-Ecological Systems: Arctic, Caribbean, Amazon, and Urban

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This box presents four case studies from different social-ecological systems as examples of risks of 1.5°C warming and higher (Chapter 3); adaptation options that respond to these risks (Chapter 4); and their implications for poverty, livelihoods and sustainability (Chapter 5). It is not yet possible to generalise adaptation effectiveness across regions due to a lack of empirical studies and monitoring and evaluation of current efforts.

Arctic

The Arctic is undergoing the most rapid climate change globally (Larsen et al., 2014), warming by 1.9°C over the last 30 years (Walsh, 2014; Grosse et al., 2016). For 2°C warming relative to pre-industrial levels, chances of an ice-free Arctic during summer are substantially higher than at 1.5°C (see Sections 3.3.5 and 3.3.8), with permafrost melt, increased instances of storm surge, and extreme weather events anticipated along with later ice freeze up, earlier break up, and a longer ice free open water season (Bring et al., 2016; DeBeer et al., 2016; Jiang et al., 2016; Chadburn et al., 2017; Melvin et al., 2017). Negative impacts on health, infrastructure, and economic sectors (AMAP, 2017a, b, 2018) are projected, although the extension of the summer ocean shipping season has potential economic opportunities (Ford et al., 2015b; Dawson et al., 2016; K.Y. et al., 2018).

Communities, many with Indigenous roots, have adapted to environmental change, developing or shifting harvesting activities and patterns of travel and transitioning economic systems (Forbes et al., 2009; Wenzel, 2009; Ford et al., 2015a; Pearce et al., 2015), although emotional and psychological effects have been documented (Cunsolo Willox et al., 2012; Cunsolo and Ellis, 2018). Besides climate change (Keskitalo et al., 2011; Loring et al., 2016), economic and social conditions can constrain the capacity to adapt unless resources and cooperation are available from public and private sector actors (AMAP, 2017a, 2018)(see Box 5.3Section). In Alaska, the economic impacts of climate change on public infrastructure are significant, estimated at 5.5 billion USD to 4.2 billion USD from 2015 to 2099, with adaptation efforts halving these estimates (Melvin et al., 2017). Marginalisation, colonisation, and land dispossession provide broader underlying challenges facing many communities across the circumpolar north in adapting to change (Ford et al., 2015a; Sejersen, 2015) (see Section 4.3.5).

Adaptation opportunities include alterations to building codes and infrastructure design, disaster risk management, and surveillance (Ford et al., 2014a; AMAP, 2017a, b; Labbé et al., 2017). Most adaptation initiatives are currently occurring at local levels in response to both observed and projected environmental

1 changes as well as social and economic stresses (Ford et al., 2015a). In a recent study of Canada, most
2 adaptations were found to be in the planning stages (Labbé et al., 2017). Studies have suggested that a
3 number of the adaptation actions are not sustainable, lack evaluation frameworks, and hold potential for
4 maladaptation (Loboda, 2014; Ford et al., 2015a; Larsson et al., 2016). Utilising Indigenous and local
5 knowledge and stakeholder engagement can aid the development of adaptation policies and broader
6 sustainable development, along with more proactive and regionally coherent adaptation plans and actions,
7 and regional cooperation (e.g. through the Arctic Council) (Larsson et al., 2016; AMAP, 2017a; Melvin et
8 al., 2017; Forbis Jr and Hayhoe, 2018) (see Section 4.3.5).

9 10 **Caribbean SIDS and Territories**

11 Extreme weather, linked to tropical storms and hurricanes, represent one of the largest risks facing Caribbean
12 island nations (Section 3.4.5.3). Non-economic damages include detrimental health impacts, forced
13 displacement and destruction of cultural heritages. Projections of increased frequency of the most intense
14 storms at 1.5°C and higher warming levels (Wehner et al., 2018; Section 3.3.6; Box 3.5) are a significant
15 cause for concern, making adaptation a matter of survival (Mycoo, 2017).

16
17 Despite a shared vulnerability arising from commonalities in location, circumstance and size (Bishop and
18 Payne, 2012; Nurse et al., 2014), adaptation approaches are nuanced by differences in climate governance,
19 affecting vulnerability and adaptive capacity (see Section 4.4.1). Three cases exemplify differences in
20 disaster risk management.

21
22 **Cuba:** Together with a robust physical infrastructure and human resource base (Kirk, 2017), Cuba has
23 implemented an effective civil defence system for emergency preparedness and disaster response, centred
24 around community mobilisation and preparedness (Kirk, 2017). Legislation to manage disasters, an efficient
25 and robust early warning system, emergency stockpiles, adequate shelter system and continuous training and
26 education of the population help create a ‘culture of risk’ (Isayama and Ono, 2015; Lizarralde et al., 2015)
27 which reduces vulnerability to extreme events (Pichler and Striessnig, 2013). Cuba’s infrastructure is still
28 susceptible to devastation, as seen in the aftermath of the 2017 hurricane season.

29
30 **United Kingdom Outer Territories (UKOT):** All UKOT have developed National Disaster Preparedness
31 Plans (PAHO/WHO, 2016) and are part of the Caribbean Disaster Risk Management Program which aims to
32 improve disaster risk management within the health sector. Different vulnerability levels across the UKOT
33 (Lam et al., 2015) indicate the benefits of greater regional cooperation and capacity-building, not only within
34 UKOT, but throughout the Caribbean (Forster et al., 2011). While sovereign states in the region can directly
35 access climate funds and international support, Dependent Territories are reliant on their controlling states
36 (Bishop and Payne, 2012). There tends to be low-scale management for environmental issues in UKOT,
37 which increases UKOT’s vulnerability. Institutional limitations, lack of human and financial resources, and
38 limited long-term planning are identified as barriers to adaptation (Forster et al., 2011).

39
40 **Jamaica:** Disaster management is coordinated through a hierarchy of national, parish and community
41 disaster committees under the leadership of the Office of Disaster Preparedness and Emergency Management
42 (ODPEM). ODPEM coordinates disaster preparedness and risk reduction efforts among key state and non-
43 state agencies (Grove, 2013). A National Disaster Committee provides technical and policy oversight to the
44 ODPEM and is comprised of representatives from multiple stakeholders (Osei, 2007). Most initiatives are
45 primarily funded through a mix of multi-lateral and bi-lateral loan and grant funding focusing on
46 strengthening technical and institutional capacities of state and research-based institutions and supporting
47 integration of climate change considerations into national and sectoral development plans (Robinson, 2017).

48
49 To improve climate change governance in the region, Pittman et al 2015 suggest incorporating holistic and
50 integrated management systems, improving flexibility in collaborative processes, implementing monitoring
51 programs, and increasing the capacity of local authorities. Implementation of the 2030 Sustainable
52 Development Agenda and the Sustainable Development Goals (SDGs) can contribute to addressing the risks
53 related with extreme events (Box 5.3).

The Amazon

1 Terrestrial forests, such as the Amazon, are sensitive to changes in the climate, particularly drought
2 (Laurance and Williamson, 2001) which might intensify through the 21st century (Marengo and Espinoza,
3 2016) (Section 3.5.5.6).
4

5
6 The poorest communities in the region face substantial risks with climate change, and barriers and limits to
7 adaptive capacity (Maru et al., 2014; Pinho et al., 2014, 2015; Brondízio et al., 2016). The Amazon is
8 considered a hotspot with interconnections between increasing temperature, decreased precipitation and
9 hydrological flow (Betts et al., 2018) (Sections 3.3.2.2, 3.3.3.2 and 3.3.5), low levels of socioeconomic
10 development (Pinho et al., 2014), and high levels of climate vulnerability (Darela et al., 2016). Limiting
11 temperature warming to 1.5°C could increase food and water security in the region compared to 2°C (Betts
12 et al., 2018), reduce the impact on poor people and sustainable development, and make adaptation easier
13 (O'Neill et al., 2017) particularly in the Amazon (Bathiany et al., 2018) (Section 5.2.2).
14

15 Climate policy in many Amazonian nations has focused on forests as carbon sinks (Soares-Filho et al.,
16 2010). In 2009, the Brazilian National Policy on Climate Change acknowledged adaptation as a concern and
17 the government sought to mainstream adaptation into public administration. Brazil's National Adaptation
18 Plan sets guidelines for sectoral adaptation measures, primarily by developing capacity building, plans,
19 assessments and tools to support adaptive decision making. Adaptation is increasingly being presented as
20 having mitigation co-benefits in the Brazilian Amazon (Gregorio et al., 2016), especially within ecosystem-
21 based adaptation (Locatelli et al., 2011). In Peru's Framework Law for Climate Change, every governmental
22 sector will consider climatic conditions as potential risks and/or opportunities to promote economic
23 development and to plan adaptation.
24

25 Drought and flood policies have had limited effectiveness in reducing vulnerability (Marengo et al., 2013).
26 In the absence of effective adaptation, achieving the SDGs will be challenging, mainly in poverty, health,
27 water and sanitation, inequality and gender equality (Section 5.2.3).
28

Urban systems

29 Around 360 million people reside in urban coastal areas where precipitation variability is exposing
30 inadequacies of urban infrastructure and governance, with the poor especially vulnerable (Reckien et al.,
31 2017)(Cross-Chapter Box 13 in Chapter 5). Urban systems have seen growing adaptation action (Revi et al.,
32 2014b; Araos et al., 2016b; Amundsen et al., 2018). Developing cities spend more on health and agriculture-
33 related adaptation options while developed cities spend more on energy and water (Georgeson et al., 2016).
34 Current adaptation activities are lagging in emerging economies which are major centres of population
35 growth facing complex interrelated pressures on investment in health, housing and education (Georgeson et
36 al., 2016; Reckien et al., 2017).
37

38
39 **New York:** Adaptation plans are undertaken across government levels, sectors and departments (NYC
40 Parks, 2010; Vision 2020 Project Team, 2011; The City of New York, 2013), and have been advanced by an
41 expert science panel that is obligated by local city law to provide regular updates on policy relevant climate
42 science (NPCC, 2015). Federal initiatives include 2013's Rebuild By Design competition to promote
43 resilience through infrastructural projects (HUD, 2013). In 2013 the Mayor's office, in response to Hurricane
44 Sandy, published the city's adaptation strategy (The City of New York, 2013). In 2015, the OneNYC Plan
45 for a Strong and Just City (OneNYC Team, 2015) laid out a strategy for urban planning through a justice and
46 equity lens. In 2017, new climate resiliency guidelines proposed that new construction must include sea level
47 rise projections into planning and development (The City of New York, 2017). Although this attention to
48 climate-resilient development may help reduce income inequality, its full effect could be constrained, if a
49 policy focus on resilience obscures analysis of income redistribution for the poor (Fainstein, 2018).
50

51 **Kampala:** Kampala Capital City Authority (KCCA) has the statutory responsibility for managing the city.
52 The Kampala Climate Change Action Strategy (KCCAS) is responding to climatic impacts of elevated
53 temperature and more intense, erratic rain. KCCAS has considered multi-scale and temporal aspects of
54 response (Chelleri et al., 2015; Douglas, 2017; Fraser et al., 2017), strengthened community adaptation
55 (Lwasa, 2010; Dobson, 2017), responded to differential adaptive capacities (Waters and Adger, 2017) and

believes in participatory processes and bridging of citywide linkages (KCCA, 2016). Analysis of the implications of uniquely adapted local solutions (e.g., motorcycle taxis) suggests sustainability can be enhanced when planning recognises the need to adapt to uniquely local solutions (Evans et al., 2018).

Rotterdam: The Rotterdam Climate Initiative (RCI) was launched to reduce Greenhouse Gas (GHG) emissions and climate-proof Rotterdam (RCI, 2017). Rotterdam has an integrated adaptation strategy, built on flood management, accessibility, adaptive building, urban water systems and urban climate, defined through Rotterdam Climate Proof and Rotterdam Climate Change Adaptation Strategy (RCI, 2008, 2013). Governance mechanisms that enabled integration of flood risk management plans with other policies, citizen participation, institutional eco-innovation, and focussing on green infrastructure (Albers et al., 2015; Dircke and Molenaar, 2015; de Boer et al., 2016a; Huang-Lachmann and Lovett, 2016) have contributed to effective adaptation (Ward et al., 2013). Entrenched institutional characteristics constrain the response framework (Francesch-Huidobro et al., 2017) but emerging evidence suggests that new governance arrangements and structures can potentially overcome these barriers in Rotterdam (Hölscher et al., 2018).

[END CROSS-CHAPTER BOX 9 HERE]

4.3.6 Short Lived Climate Forcers

The main Short-Lived Climate Forcer (SLCF) emissions that cause warming are methane (CH₄), other precursors of tropospheric ozone (i.e., carbon monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOC)), black carbon (BC) and hydrofluorocarbons (HFCs) (Myhre et al., 2013). SLCFs also include emissions that lead to cooling, such as sulphur dioxide (SO₂) and organic carbon (OC). Nitrogen oxides (NO_x) can have both warming and cooling effects, by affecting ozone (O₃) and CH₄, depending on timescale and location (Myhre et al., 2013).

Cross-Chapter Box 2 in Chapter 1 provides a discussion of role of SLCFs in comparison to long-lived GHGs. Chapter 2 shows that 1.5°C-consistent pathways require stringent reductions in CO₂ and CH₄, and that non-CO₂ climate forcers reduce carbon budgets by ~2200 GtCO₂ per degree of warming attributed to them (see Chapter 2 Annex).

Reducing non-CO₂ emissions is part of most mitigation pathways (IPCC, 2014c). All current GHG emissions and other forcing agents affect the rate and magnitude of climate change over the next few decades, while long-term warming is mainly driven by CO₂ emissions. CO₂ emissions result in a virtually permanent warming, while temperature change from SLCFs disappears within decades after emissions of SLCFs are ceased. Any scenario that fails to reduce CO₂ emissions to net zero would not limit global warming, even if SLCFs are reduced, due to accumulating CO₂-induced warming that overwhelms SLCFs' mitigation benefits in a couple of decades (Shindell et al., 2012; Schmale et al., 2014) and see Section 2.3.3.1).

Mitigation options for warming SLCFs often overlap with other mitigation options, especially since many warming SLCFs are co-emitted with CO₂. SLCFs are generally mitigated in 1.5°C- or 2°C-consistent pathways as an integral part of an overall mitigation strategy (Chapter 2). For example, section 2.3 indicates that most very low-emissions pathways include a transition away from the use of coal and natural gas in the energy sector and oil in transportation, which coincides with emission reduction strategies related to methane from the fossil fuel sector and BC from the transportation sector. Much SLCF emission reduction aims at BC-rich sectors and considers the impacts of several co-emitted SLCFs (Bond et al., 2013; Sand et al., 2015; Stohl et al., 2015). However, it is uncertain whether such strategies would lead to additional long-term climate benefits compared to BC emissions reductions achieved through CO₂ mitigation and associated co-control on BC-rich sectors in 1.5°C and 2°C pathways (Rogelj et al., 2014).

Some studies have evaluated the focus on SLCFs in mitigation strategies and point towards trade-offs between short-term SLCF benefits and lock in of long-term CO₂ warming (Smith and Mizrahi, 2013; Pierrehumbert, 2014). Reducing fossil fuel combustion will reduce aerosols levels, and thereby cause warming from removal of cooling effects (Myhre et al., 2013; Xu and Ramanathan, 2017; Samset et al.,

2018). Recent studies have also found lower temperature effects of BC than what can be expected from the direct radiative forcing alone, thus questioning the effectiveness of targeted BC mitigation for climate change mitigation (Myhre et al., 2013; Baker et al., 2015; Stjern et al., 2017; Samset et al., 2018).

Table 4.5 provides an overview of three warming SLCFs and their emission sources, with examples of options for emission reductions and associated co-benefits.

Table 4.5: Overview of main characteristics of three warming Short-Lived Climate Forcers (SLCFs) (core information based on (Pierrehumbert, 2014) and (Schmale et al., 2014); rest of the details as referenced).

SLCF compound	Atmospheric lifetime	Annual global emission	Main anthropogenic emission sources	Examples of options to reduce emissions consistent with 1.5°C	Examples of co-benefits based on (Haines et al., 2017) unless specified otherwise
Methane	On the order of 10 years	0.3 GtCH ₄ (2010) (Pierrehumbert, 2014)	Fossil fuel extraction and transportation Land-use change Livestock and rice cultivation Waste and wastewater	Managing manure from livestock Intermittent irrigation of rice Capture and usage of fugitive methane Dietary change For more: see Sections 4.3.2 and 4.3.3.	Reduction of tropospheric ozone (Shindell et al., 2017a) Health benefits of dietary changes Increased crop yields Improved access to drinking water
HFCs	Months to decades, depending on the gas	0.35 GtCO ₂ -eq (2010) (Velders et al., 2015)	Air conditioning Refrigeration Construction material	Alternatives to HFCs in air-conditioning and refrigeration applications	Greater energy efficiency (Mota-Babiloni et al., 2017)
Black carbon	Days	~7 Mt (2010) (Klimont et al., 2017)	Incomplete combustion of fossil fuels or biomass in vehicles (esp. diesel), cook stoves or kerosene lamps Field and biomass burning	Fewer and cleaner vehicles Reducing agricultural biomass burning Cleaner cook stoves, gas-based or electric cooking Replacing brick and coke ovens Solar lamps For more see Section 4.3.4	Health benefits of better air quality Increased education opportunities Reduced coal consumption for modern brick kilns Reduced deforestation

A wide range of options to reduce SLCF emissions was extensively discussed in AR5 (IPCC, 2014b). Fossil fuel and waste sector methane mitigation options have high cost-effectiveness, producing a net profit over a few years, considering market costs only. Moreover, reducing roughly one-third to one-half of all human-caused emissions has societal benefits greater than mitigation costs when considering environmental impacts only (UNEP, 2011; Höglund-Isaksson, 2012; IEA, 2017b; Shindell et al., 2017a). Since AR5, new options for methane, such as those related to shale gas, have been included in mitigation portfolios (e.g., Shindell et al. 2017b).

Reducing BC emissions and co-emissions has sustainable development co-benefits, especially around human health (Stohl et al., 2015; Haines et al., 2017; Aakre et al., 2018), avoiding premature deaths and increasing crop yields (Scovronick et al., 2015; Peng et al., 2016). Additional benefits include lower likelihood of non-linear climate changes and feedbacks (Shindell et al., 2017a) and temporarily slowing down the rate of sea level rise (Hu et al., 2013). Interventions to reduce BC offer tangible local air quality benefits, increasing the

1 likelihood of local public support (Eliasson, 2014; Venkataraman et al., 2016) (see Section 5.4.1.2). Limited
 2 interagency co-ordination, poor science-policy interactions (Zusman et al., 2015), and weak policy and
 3 absence of inspections and enforcement (Kholod and Evans, 2016) are among barriers that reduce the
 4 institutional feasibility of options to reduce vehicle-induced BC emissions. A case study for India shows that
 5 switching from biomass cook stoves to cleaner gas stoves (based on liquefied petroleum gas or natural gas)
 6 or to electric cooking stoves is technically and economically feasible in most areas, but faces barriers in user
 7 preferences, costs and the organisation of supply chains (Jeuland et al., 2015). Similar feasibility
 8 considerations emerge in switching in lighting from kerosene wick lamps to solar lanterns, from current low-
 9 efficiency brick kilns and coke ovens to cleaner production technologies; and from field burning of crop
 10 residues to agricultural practices using deep-sowing and mulching technologies (Williams et al., 2011;
 11 Wong, 2012).

12
 13 The radiative forcing from HFCs are currently small but have been growing rapidly (Myhre et al., 2013). The
 14 Kigali amendment (from 2016) to the Montreal Protocol set out a global accord for phasing out these
 15 compounds (Höglund-Isaksson et al., 2017). HFC mitigation options include alternatives with reduced
 16 warming effects, ideally combined with improved energy efficiency so as to simultaneously reduce CO₂ and
 17 co-emissions (Shah et al., 2015). Costs for most of HFC's mitigation potential are estimated to be below
 18 USD₂₀₁₀ 60 tCO₂-eq⁻¹, and the remainder below roughly double that number (Höglund-Isaksson et al., 2017).

19
 20 Reductions in SLCFs can provide large benefits towards sustainable development, beneficial for social,
 21 institutional and economic feasibility. Strategies that reduce SLCFs can provide benefits that include
 22 improved air quality (for example (Anenberg et al., 2012)) and crop yields (for example (Shindell et al.,
 23 2012)), energy access, gender equality and poverty eradication (for example (Shindell et al., 2012; Haines et
 24 al., 2017)). Institutional feasibility can be negatively affected by an information deficit, with the absence of
 25 international frameworks for integrating SLCFs into emissions accounting and reporting mechanisms being a
 26 barrier for policy-making to address SLCF emissions (Venkataraman et al., 2016). The incentives for
 27 reducing SLCFs are particularly strong for small groups of countries, and such a collaboration could increase
 28 feasibility and effectiveness of SLCF mitigation options (Aakre et al., 2018).

31 4.3.7 Carbon Dioxide Removal (CDR)

32
 33 CDR methods refer to a set of techniques for removing CO₂ from the atmosphere. In the context of 1.5°C-
 34 consistent pathways (Chapter 2), they serve to offset residual emissions that take longer to abate or to
 35 compensate for emissions occurring after running out of the 1.5°C carbon budget. See Cross-Chapter Box 7
 36 in Chapter 3 for a synthesis of land-based CDR options. Cross-cutting issues and uncertainties are
 37 summarised in Table 4.6.

40 4.3.7.1 Bioenergy with carbon capture and storage (BECCS)

41
 42 BECCS has been assessed in previous IPCC reports (IPCC, 2005; P. Smith et al., 2014; Minx et al., 2017)
 43 and has been incorporated into integrated assessment models (Clarke et al., 2014). In the meantime, 1.5°C
 44 pathways without BECCS have emerged (Bauer et al., 2018; Grübler, 2018; Mousavi and Blesl, 2018; van
 45 Vuuren et al., 2018). Still, models indicate that 3.7–8 GtCO₂ yr⁻¹ (interquartile range) and 14 GtCO₂ yr⁻¹
 46 (median) would be removed by BECCS by 2050 and 2100, respectively, with some models starting BECCS
 47 in 2030 already (Section 2.3.4). BECCS is constrained by sustainable bioenergy potentials (Sections 4.3.1.2,
 48 5.4.3 and Cross-Chapter Box 6 in Chapter 3), and availability of safe storage for CO₂ (Section 4.3.1.6).
 49 Literature estimates for BECCS mitigation potentials in 2050 range from 1–85 GtCO₂⁴. Fuss et al. (2018)
 50 narrow this range to 0.5–5 GtCO₂ yr⁻¹ (*medium agreement, high evidence*) (Figure 4.3), thus falling below
 51 the upper end of 1.5°C pathways. This is, among other things, related to sustainability concerns (Boysen et

⁴ As more bottom-up literature exists on bioenergy potentials, this exercise explored the bioenergy literature and converted those estimates to BECCS potential with 1EJ of bioenergy yielding 0.02–0.05 GtCO₂ emission reduction. For the bottom-up literature references for the potentials range, please refer to Supplementary Material 4.SM.3 Table 1.

1 al., 2017; Heck et al., 2018; Henry et al., 2018).

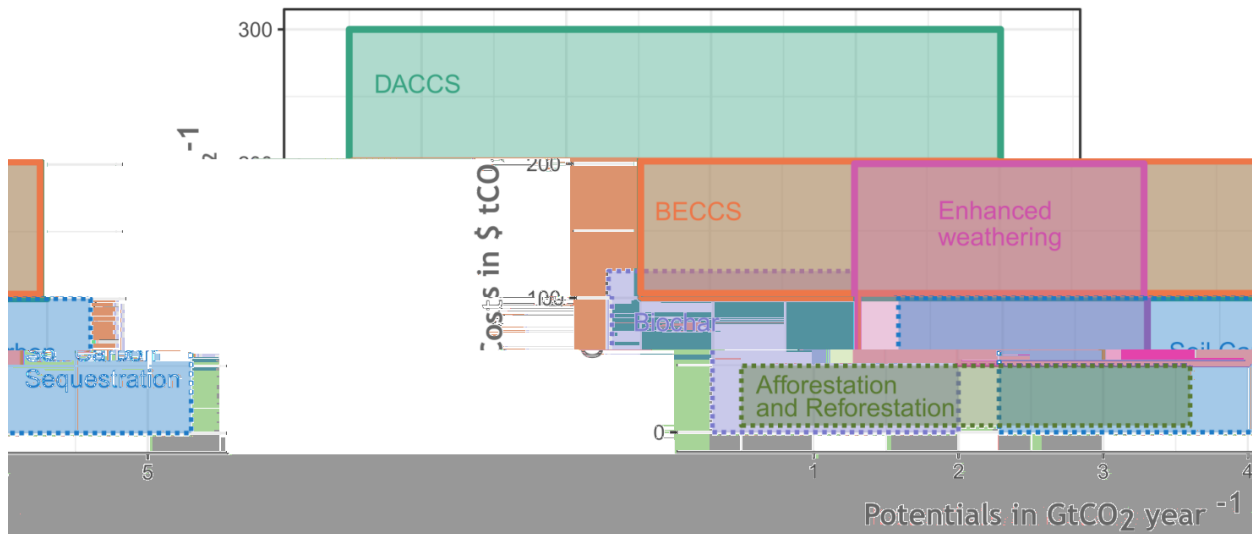
2
3 Assessing BECCS deployment in 2°C pathways (of about 12 GtCO₂-eq yr⁻¹, here considered as a lower
4 deployment limit for 1.5°C, Smith et al. (2016b) estimate a land-use intensity of 0.3–0.5 ha tCO₂-eq⁻¹ yr⁻¹
5 using forest residues, 0.16 ha CO₂-eq⁻¹ yr⁻¹ for agricultural residues, and 0.03–0.1 ha tCO₂-eq⁻¹ yr⁻¹ for
6 purpose-grown energy crops. The average amount of BECCS in these pathways requires 25–46% of arable
7 and permanent crop area in 2100. Land area estimates differ in scale and are not necessarily a good indicator
8 of competition with, e.g., food production, because requiring a smaller land area for the same potential could
9 indicate that high-productivity agricultural land is used. In general, the literature shows *low agreement* on
10 the availability of land (Fritz et al., 2011); see (Erb et al., 2016b) for recent advances. Productivity, food
11 production and competition with other ecosystem services and land use by local communities are important
12 factors for the design of regulation. These potentials and trade-offs are not homogeneously distributed across
13 regions. However, (Robledo-Abad et al., 2017) find that regions with higher potentials are understudied,
14 given their potential contribution. Researchers have expressed the need to complement global assessments
15 with regional, geographically explicit bottom-up studies of biomass potentials and socio-economic impacts
16 (e.g., de Wit and Faaij 2010; Kraxner et al., 2014; Baik et al., 2018).

17
18 Energy production, land and water footprints show wide ranges in bottom-up assessments due to differences
19 in technology, feedstock and other parameters (–1–150 EJ yr⁻¹ of energy, 109–990 Mha, 6–79 MtN, 218–
20 4758 km³ yr⁻¹ of water per GtCO₂ yr⁻¹ (Smith and Torn, 2013; Smith et al., 2016b; Fajardy and Mac Dowell,
21 2017) and are not comparable to IAM pathways which consider system effects (Bauer et al., 2018). Global
22 impacts on nutrients and albedo are difficult to quantify (Smith et al., 2016b). BECCS competes with other
23 land-based CDR and mitigation measures for resources (Chapter 2).

24
25 There is uncertainty about the feasibility of timely upscaling. CCS (see Section 4.3.1) is largely absent from
26 the nationally determined contributions (Spencer et al., 2015) and lowly ranked in investment priorities
27 (Fridahl, 2017). Although there are dozens of small-scale BECCS demonstrations (Kemper, 2015) and a full
28 scale project capturing 1 MtCO₂ exists (Finley, 2014), this is well below the numbers associated with 1.5°C
29 or 2°C-compatible pathways (IEA, 2016a; Peters et al., 2017). Although the majority of BECCS cost
30 estimates are below 200 USD tCO₂⁻¹ (Figure 4.3), estimates vary widely. Economic incentives for ramping
31 up large CCS or BECCS infrastructure are weak (Bhave et al., 2017). The 2050 average investment costs for
32 such a BECCS infrastructure for bio-electricity and biofuels are estimated at 138 and 123 billion USD yr⁻¹,
33 respectively (Smith et al., 2016b).

34
35 BECCS deployment is further constrained by bioenergy's carbon accounting, land, water and nutrient
36 requirements (Section 4.3.1), its compatibility with other policy goals and limited public acceptance of both
37 bioenergy and CCS (Section 4.3.1). Current pathways are believed to have inadequate assumptions on the
38 development of societal support and governance structures (Vaughan and Gough, 2016).
39 However, removing BECCS and CCS from the portfolio of available options significantly raises mitigation
40 costs (Kriegler et al., 2013) (Bauer et al., 2018).

Panel A - Estimated costs and 2050 potentials



Panel B - Literature estimates on costs, potentials (2050) and side effects



Figure 4.2: Evidence on Carbon Dioxide Removal (CDR) abatement costs, 2050 deployment potentials, and key side effects. Panel A presents estimates based on a systematic review of the bottom up literature (Fuss et al., 2018), corresponding to dashed blue boxes in Panel B. Dashed lines represent saturation limits for the corresponding technology. Panel B shows the percentage of papers at a given cost or potential estimate. Reference year for all potential estimates is 2050, while all cost estimates preceding 2050 have been

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2
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7

1 included (as early as 2030, older estimates are excluded if they lack a base year and thus cannot be made
2 comparable). Ranges have been trimmed to show detail (see Fuss et al., 2018) for the full range). Costs
3 refer only to abatement costs. Icons for side-effects are allocated only if a critical mass of papers
4 corroborates their occurrence

5 *Notes: For references please see Supplementary Material Table 4.SM.3. Direct Air Carbon Dioxide*
6 *Capture and Storage (DACCS) is theoretically only constrained by geological storage capacity, estimates*
7 *presented are considering upscaling and cost challenges. BECCS potential estimates are based on*
8 *bioenergy estimates in the literature ($EJ\ yr^{-1}$), converted to $GtCO_2$ following footnote 3. Potentials cannot*
9 *be added up, as CDR options would compete for resources (e.g., land). SCS - Soil Carbon Sequestration;*
10 *OA - Ocean Alkalinisation; EW- Enhanced Weathering; DACCS - Direct Air Carbon Dioxide Capture*
11 *and Storage; BECCS - Bioenergy with Carbon Capture and Storage; AR - Afforestation*
12

13 14 4.3.7.2 Afforestation and Reforestation (AR)

15
16 Afforestation implies planting trees on land not forested for a long time (e.g., over the last 50 years in the
17 context of the Kyoto Protocol), while reforestation implies re-establishment of forest formations after a
18 temporary condition with less than 10% canopy cover due to human-induced or natural perturbations.
19 Houghton et al. (2015) estimate about 500 Mha could be available for the re-establishment of forests on
20 lands previously forested, but not currently used productively. This could sequester at least $3.7\ GtCO_2\ yr^{-1}$
21 for decades. The full literature range gives 2050 potentials of $1\text{--}7\ GtCO_2\ yr^{-1}$ (*low evidence, medium*
22 *agreement*), narrowed down to $0.5\text{--}3.6\ GtCO_2\ yr^{-1}$ based on a number of constraints (Fuss et al., 2018).
23 Abatement costs are estimated to be low compared to other CDR options, $5\text{--}50\ USD\ tCO_2\ eq^{-1}$ (*robust*
24 *evidence, high agreement*). Yet, realising such large potentials comes at higher land and water footprints than
25 BECCS, although there would be a positive impact on nutrients, and the energy requirement would be
26 negligible (Smith et al., 2016b; Cross-Chapter Box 7 in Chapter 3). The 2030 estimate by Griscom et al.
27 (2017) is up to $17.9\ GtCO_2\ yr^{-1}$ for reforestation with significant co-benefits (Cross-Chapter Box 7 in Chapter
28 3).
29

30 Biogenic storage is not as permanent as emission reductions of geological storage. In addition, forest sinks
31 saturate, a process which typically occurs in decades to centuries compared to the thousands of years of
32 residence time of CO_2 stored geologically (Smith et al., 2016a) and is subject to disturbances that can be
33 exacerbated by climate change (e.g. drought, forest fires and pests) (Seidl et al., 2017). Handling this
34 requires careful forest management. There is much practical experience with AR, facilitating upscaling but
35 with two caveats: AR potentials are heterogeneously distributed (Bala et al., 2007), partly because the
36 planting of less reflective forests results in higher net-absorbed radiation and localised surface warming in
37 higher latitudes (Bright et al., 2015; Jones et al., 2015), and forest governance structures and monitoring
38 capacities can be bottlenecks and are usually not considered in models (Wang et al., 2016; Wehkamp et al.,
39 2018b). There is *medium agreement* on the positive impacts of AR on ecosystems and biodiversity due to
40 different forms of afforestation discussed in the literature: afforestation of grassland ecosystems or
41 diversified agricultural landscapes with monocultures or invasive alien species can have significant negative
42 impacts on biodiversity, water resources, etc. (P. Smith et al., 2014), while forest ecosystem restoration
43 (forestry and agroforestry) with native species have positive social and environmental impacts (Cunningham
44 et al., 2015; Locatelli et al., 2015; Paul et al., 2016); See Section 4.3.2).
45

46 Synergies with other policy goals are possible (see also Section 4.5.4); for example land spared by diet shifts
47 could be afforested (Röös et al., 2017) or used for energy crops (Grübler, 2018). Such land-sparing strategies
48 could also benefit other land-based CDR options.
49

50 51 4.3.7.3 Soil Carbon Sequestration and Biochar

52
53 At local scales there is *robust evidence* that Soil Carbon Sequestration (SCS, e.g., agroforestry, De Stefano
54 and Jacobson, 2018), restoration of degraded land (Griscom et al., 2017), or conservation agriculture
55 management practices (Aguilera et al., 2013; Poelplau and Don, 2015; Vicente-Vicente et al., 2016) have co-
56 benefits in agriculture and that many measures are cost-effective even without supportive climate policy.

1 Evidence at global scale for potentials and especially costs is much lower. The literature spans cost ranges of
2 –40–100 USD tCO₂⁻¹ (negative costs relating to the multiple co-benefits of SCS, such as increased
3 productivity and resilience of soils (P. Smith et al., 2014) and 2050 potentials are estimated between 1–11
4 GtCO₂ yr⁻¹, narrowed down to 2–5 GtCO₂ yr⁻¹ considering that studies above 5 GtCO₂ yr⁻¹ often do not apply
5 constraints, while estimates lower than 2 GtCO₂ yr⁻¹ mostly focus on single practices (Fuss et al., 2018).
6

7 SCS has negligible water and energy requirements (Smith, 2016), affects nutrients and food security
8 favourably (*high agreement, robust evidence*) and can be applied without changing current land use thus
9 making it socially more acceptable than CDR options with a high land footprint. However, soil sinks saturate
10 after 10–100 years, depending on the SCS option, soil type and climate zone (Smith, 2016).
11

12 Biochar is formed by recalcitrant (i.e., very stable) organic carbon obtained from pyrolysis which applied to
13 soil can increase soil carbon sequestration leading to improved soil fertility properties.⁵ Looking at the full
14 literature range, the global potential in 2050 lies between 1–35 Gt CO₂ yr⁻¹ (*low agreement, low evidence*),
15 but considering limitations in biomass availability and uncertainties due to a lack of large-scale trials of
16 biochar application to agricultural soils under field conditions, Fuss et al. (2018) lower the 2050 range to
17 0.3–2 GtCO₂ yr⁻¹. This potential is below previous estimates (e.g., Woolf et al., 2010), which additionally
18 consider the displacement of fossil fuels through biochar. Permanence depends on soil type and biochar
19 production temperatures, varying between a few decades and several centuries (Fang et al., 2014). Costs are
20 30–120 USD tCO₂⁻¹ (*medium agreement, medium evidence*) (McCarl et al., 2009; McGlashan et al., 2012;
21 McLaren, 2012; Smith, 2016).
22

23 Water requirements are low and at full theoretical deployment, up to 65 EJ yr⁻¹ of energy could be generated
24 as a side product (Smith, 2016). Positive side effects include a favourable effect on nutrients and reduced
25 N₂O emissions (Cayuela et al., 2014; Kammann et al., 2017). However, 40–260 Mha are needed to grow the
26 biomass for biochar for implementation at 0.3 GtCO₂-eq yr⁻¹ (Smith, 2016), even though it is also possible to
27 use residues (e.g., Windeatt et al., 2014). Biochar is further constrained by the maximum safe holding
28 capacity of soils (Lenton, 2010) and the labile nature of carbon sequestered in plants and soil at higher
29 temperatures (Wang et al., 2013).
30
31

32 4.3.7.4 Enhanced Weathering (EW) and Ocean Alkalinisation

33

34 Weathering is the natural process of rock decomposition via chemical and physical processes in which CO₂
35 is spontaneously consumed and converted to solid or dissolved alkaline bicarbonates and/or carbonates
36 (IPCC 2005). The process is controlled by temperature, reactive surface area, interactions with biota and, in
37 particular, water solution composition. CDR can be achieved by accelerating mineral weathering through the
38 distribution of ground-up rock material over land (Hartmann and Kempe, 2008; Wilson et al., 2009; Köhler
39 et al., 2010; Renforth, 2012; ten Berge et al., 2012; Manning and Renforth, 2013; Taylor et al., 2016),
40 shorelines (Hangx and Spiers, 2009; Montserrat et al., 2017) or the open ocean (House et al., 2007; Harvey,
41 2008; Köhler et al., 2013; Hauck et al., 2016). Ocean alkalinisation adds alkalinity to marine areas to locally
42 increase the CO₂ buffering capacity of the ocean (González and Ilyina, 2016; Renforth and Henderson,
43 2017).
44

45 In the case of land application of ground minerals, the estimated CDR potential range is 0.72–95 GtCO₂ yr⁻¹
46 (Hartmann and Kempe, 2008; Köhler et al., 2010; Hartmann et al., 2013; Taylor et al., 2016; Strefler et al.,
47 2018) (*low evidence, low agreement*). Marine application of ground minerals is limited by feasible rates of
48 mineral extraction, grinding and delivery, with estimates of 1–6 GtCO₂ yr⁻¹ (Köhler et al., 2013; Hauck et
49 al., 2016; Renforth and Henderson, 2017) (*low evidence, low agreement*). Agreement is low due to a variety
50 of assumptions and unknown parameter ranges in the applied modelling procedures that would need to be
51 verified by field experiments (Fuss et al., 2018). As with other CDR options, scaling and maturity are

⁵ Other pyrolysis products that can achieve net CO₂ removals are bio-oil (pumped into geological storages) and permanent-pyrogas (capture and storage of CO₂ from gas combustion) (Werner et al., 2018)

1 challenges, with deployment at scale potentially requiring decades (NRC, 2015a), considerable costs in
2 transport and disposal (Hangx and Spiers, 2009; Strefler et al., 2018) and mining (NRC, 2015a; Strefler et
3 al., 2018)⁶.

4
5 Site-specific cost estimates vary depending on the chosen technology for rock grinding – an energy-intensive
6 process (Köhler et al., 2013; Hauck et al., 2016) – material transport and rock source (Renforth, 2012;
7 Hartmann et al., 2013), ranging from 15–40 USD tCO₂⁻¹ to 3,460 USD tCO₂⁻¹ (Schuiling and Krijgsman,
8 2006; Köhler et al., 2010; Taylor et al., 2016, *limited evidence, low agreement*; Figure 4.2). The evidence
9 base for costs of ocean alkalisation and marine enhanced weathering is sparser than the land applications.
10 The ocean alkalisation potential is assessed to be 0.1–10 GtCO₂ yr⁻¹ with costs of 14– >500 USD tCO₂⁻¹
11 (Renforth and Henderson, 2017).

12
13 The main side effects of terrestrial EW are an increase in water pH (Taylor et al., 2016), the release of heavy
14 metals like Ni and Cr, and plant nutrients like K, Ca, Mg, P and Si (Hartmann et al., 2013), and changes in
15 hydrological soil properties. Respirable particle sizes, though resulting in higher potentials, can have impacts
16 on health (Schuiling and Krijgsman, 2006; Taylor et al., 2016); utilisation of wave-assisted decomposition
17 through deployment on coasts could avert the need for fine grinding (Hangx and Spiers, 2009; Schuiling and
18 de Boer, 2010). Side effects of marine EW and ocean alkalisation are the potential release of heavy metals
19 like Ni and Cr (Montserrat et al., 2017). Increasing ocean alkalinity helps counter ocean acidification
20 (Albright et al., 2016; Feng et al., 2016). Ocean alkalisation could affect ocean biogeochemical functioning
21 (González and Ilyina, 2016). A further caveat of relates to saturation state and the potential to trigger
22 spontaneous carbonate precipitation.⁷ While the geochemical potential to remove and store CO₂ is quite
23 large, *limited evidence* on the preceding topics makes it difficult to assess the true capacity, net benefits and
24 desirability of EW and ocean alkalinity addition in the context of CDR.

25 26 27 4.3.7.5 Direct Air Carbon Dioxide Capture and Storage (DACCS)

28
29 Capturing CO₂ from ambient air through chemical processes with subsequent storage of the CO₂ in
30 geological formations is independent of source and timing of emissions, and can avoid competition for land.
31 Yet, this is also the main challenge: while the theoretical potential for DACCS is mainly limited by the
32 availability of safe and accessible geological storage, the CO₂ concentration in ambient air is 100–300 times
33 lower than at gas- or coal-fired power plants (Sanz-Pérez et al., 2016) thus requiring more energy than flue
34 gas CO₂ capture (Pritchard et al., 2015). This appears to be the main challenge to DACCS (Sanz-Pérez et al.,
35 2016; Barkakaty et al., 2017).

36
37 Studies explore alternative techniques to reduce the energy penalty of DACCS (van der Giesen et al., 2017).
38 Energy consumption could be up to 12.9 GJ tCO₂-eq⁻¹; translating into an average of 156 EJ yr⁻¹ by 2100
39 (current annual global primary energy supply is 600 EJ); water requirements are estimated to average 0.8–
40 24.8 km³ GtCO₂-eq⁻¹ yr⁻¹ (Smith et al., 2016, based on Socolow et al., 2011).

41
42 However, the literature shows *low agreement* and is fragmented (Broehm et al., 2015). This fragmentation is
43 reflected in a large range of cost estimates: from 20–1,000 USD tCO₂⁻¹ (Keith et al., 2006; Pielke, 2009;
44 House et al., 2011; Ranjan and Herzog, 2011; Simon et al., 2011; Goepfert et al., 2012; Holmes and Keith,
45 2012; Zeman, 2014; Sanz-Pérez et al., 2016; Sinha et al., 2017). The interquartile range (see Figure 4.2) is
46 40–449 USD tCO₂⁻¹; there is lower agreement and a smaller evidence base at the lower end of the cost range.

47
48 Research and efforts by small-scale commercialisation projects focus on utilisation of captured CO₂ (Wilcox

⁶ It has also been suggested that ocean alkalinity can be increased through accelerated weathering of limestone (Rau and Caldeira, 1999; Rau, 2011; Chou et al., 2015) or electrochemical processes (House et al., 2007; Rau, 2008; Rau et al., 2013b; Lu et al., 2015). However, these techniques have not been proven at large scale either (Renforth and Henderson, 2017).

⁷ This analysis relies on the assessment in Fuss et al. (2018b), which provides more detail on saturation and permanence.

et al., 2018). Given that only a few IAM scenarios incorporate DACCS (e.g., Chen and Tavoni 2013; Strefler et al. 2018a) its possible role in cost-optimised 1.5°C scenarios is not yet fully explored. Given the technology's early stage of development (McLaren, 2012; NRC, 2015a; Nemet et al., 2018) and few demonstrations (Holmes et al., 2013; Rau et al., 2013; Agee et al., 2016), deploying the technology at scale is still a considerable challenge though both optimistic (Lackner et al., 2012) and pessimistic outlooks exist (Pritchard et al., 2015).

4.3.7.6 Ocean Fertilisation

Nutrients can be added to the ocean resulting in increased biologic production, leading to carbon fixation in the sunlit ocean and subsequent sequestration in the deep ocean or sea floor sediments. The added nutrients can be either micronutrients (such as iron) or macronutrients (such as nitrogen and/or phosphorous) (Harrison 2017). There is *limited evidence* and *low agreement* on the readiness of this technology to contribute to rapid decarbonisation (Williamson et al. 2012). Only small-scale field experiments and theoretical modelling have been conducted (e.g., McLaren (2012)). The full range of CDR potential estimates is 15.2 ktCO₂ yr⁻¹ (Bakker et al. 2001) for a spatially constrained field experiment to 4.4 GtCO₂ yr⁻¹ (Sarmiento and Orr 1991) following a modelling approach, but Fuss et al. (2018b) consider the potential to be extremely limited given the evidence and existing barriers. Due to scavenging of iron, the iron addition only leads to inefficient use of the nitrogen in exporting carbon (Aumont and Bopp 2006; Zahariev et al. 2008; Zeebe 2005).

Cost estimates range from 2 USD tCO₂⁻¹ (for iron fertilization) (Boyd and Denman 2008) to 457 USD tCO₂⁻¹ (Harrison 2013). Jones (2014) proposed values greater than 20 USD tCO₂⁻¹ for nitrogen fertilisation. Fertilisation is expected to impact food webs by stimulating its base organisms (Matear 2004), and extensive algal blooms may cause anoxia (Matear 2004; Russell et al. 2012; Sarmiento and Orr 1991) and deep water oxygen decline (Matear 2004), with negative impacts on biodiversity. Nutrient inputs can shift ecosystem production from an iron-limited system to a P, N-, or Si-limited system depending on the location (Bertram 2010; Matear 2004) and non-CO₂ GHGs may increase (Bertram 2010; Sarmiento and Orr 1991; Matear 2004). The greatest theoretical potential for this practice is the Southern Ocean, posing challenges for monitoring and governance (Robinson et al. 2014). The London Protocol of the International Maritime Organization has asserted authority for regulation of ocean fertilisation (Strong et al. 2009), which is widely viewed as a, *de facto moratorium* on commercial ocean fertilisation activities.

There is *low agreement* in the technical literature on the permanence of CO₂ in the ocean, with estimated residence times of 1,600 years to millennia, especially if injected or buried in or below the sea floor (Williams and Druffel, 1987; Jones, 2014). Storage at the surface would mean that the carbon would be rapidly released after cessation (Aumont and Bopp 2006; Zeebe 2005).

Table 4.6: Cross-cutting issues and uncertainties across Carbon Dioxide Removal (CDR) options aspects and uncertainties

<i>Area of uncertainty</i>	<i>Cross-cutting issues and uncertainties</i>
Technology upscaling	<ul style="list-style-type: none"> CDR options are at different stages of technological readiness (McLaren, 2012) and differ with respect to scalability. Nemet et al. (2018) find >50% of the CDR innovation literature concerned with the earliest stages of the innovation process (R&D) identifying a dissonance between the large CO₂ removals needed in 1.5°C pathways and the long-time periods involved in scaling up novel technologies. Lack of post-R&D literature, including incentives for early deployment, niche markets, scale-up, demand, and public acceptance.
Emerging and niche technologies	<ul style="list-style-type: none"> For BECCS, there are niche opportunities with high efficiencies and fewer trade-offs (e.g., sugar and paper processing facilities (Möllersten et al., 2003), district heating (Kärki et al., 2013; Ericsson and Werner, 2016), industrial and municipal waste (Sanna et al., 2012). Turner et al. (2018) constrain potential using

	<p>sustainability considerations and overlap with storage basins to avoid the CO₂ transportation challenge, providing a possible, though limited entry point for BECCS.</p> <ul style="list-style-type: none"> • The impacts on land use, water, nutrients and albedo of BECCS could be alleviated using marine sources of biomass that could include aqua-cultured micro and macro flora (Hughes et al., 2012; Lenton, 2014) • Regarding captured CO₂ as a resource is discussed as an entry point for CDR. However, this does not necessarily lead to carbon removals, particularly if the CO₂ is sourced from fossil fuels and/or if the products do not store the CO₂ for climate-relevant horizons (von der Assen et al. 2013) (see also Section 4.3.4.5). • Methane⁸ is a much more potent GHG than CO₂ (Montzka et al., 2011), associated with difficult-to-abate emissions in industry and agriculture, outgassing from lakes, wetlands, and oceans (Lockley, 2012; Stolaroff et al., 2012). Enhancing processes that naturally remove methane, either by chemical or biological decomposition (Sundqvist et al., 2012), has been proposed to remove CH₄. There is low confidence that existing technologies for methane removal are economically or energetically suitable for large-scale air capture (Boucher and Folberth, 2010). Methane removal potentials are limited due to its low atmospheric concentration and its low chemical reactivity at ambient conditions.
Ethical aspects	<ul style="list-style-type: none"> • Preston (2013) identifies distributive and procedural justice, permissibility, moral hazard (Shue, 2018), and hubris as ethical aspects that could apply to large-scale CDR deployment. • There is a lack of reflection on the climate futures produced by recent modelling and implying very different ethical costs/risks and benefits (Minx et al., 2018).
Governance	<ul style="list-style-type: none"> • Existing governance mechanisms are scarce and either targeted at particular CDR options (e.g., ocean-based) or aspects (e.g., concerning indirect land-use change (iLUC) associated with bioenergy upscaling) and often the mechanisms are at national or regional scale (e.g., EU). Regulation accounting for iLUC by formulating sustainability criteria (e.g., the EU Renewable Energy Directive) has been assessed as insufficient in avoiding leakage (e.g., Frank et al., 2013) • An international governance mechanism is only in place for R&D of Ocean Fertilisation within the Convention on Biological Diversity (IMO, 1972, 1996, CBD, 2008, 2010). • Burns and Nicholson (2017) propose a human rights-based approach to protect those potentially adversely impacted by CDR options.
Policy	<ul style="list-style-type: none"> • The CDR potentials that can be realised are constrained by the lack of policy portfolios incentivising large-scale CDR (Peters and Geden, 2017). • Near-term opportunities could be supported through modifying existing policy mechanisms (Lomax et al., 2015). • Scott and Geden (2018) sketch three possible routes for limited progress, (1) at EU-level, (2) at EU Member State level, and (3) at private sector level, noting the implied paradigm shift this would entail. • EU may struggle to adopt policies for CDR deployment on the scale or time-frame envisioned by IAMs (Geden et al., 2018). • Social impacts of large-scale CDR deployment (Buck, 2016) require policies taking these into account.
Carbon cycle	<ul style="list-style-type: none"> • On long time scales, natural sinks could reverse (C.D. Jones et al., 2016) • No robust assessments yet of the effectiveness of CDR in reverting climate change (Tokarska and Zickfeld, 2015; Wu et al., 2015; Keller et al., 2018), see also Section 2.2.2 and 2.6.2.

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4.3.8 Solar Radiation Modification (SRM)

⁸ Current work (e.g. de Richter et al. 2017) examines other technologies considering non-CO₂ GHGs like N₂O.

1 This report refrains from using the term ‘geoengineering’ and separates SRM from CDR and other
2 mitigation options (see Section 1.4.1 and Glossary).

3
4 Table 4.6 gives an overview of SRM methods and characteristics. For a more comprehensive discussion of
5 currently proposed SRM methods, and their implications for geophysical quantities and sustainable
6 development, see Cross-Chapter Box 10 in this Chapter. This section assesses the feasibility, from an
7 institutional, technological, economic and social-cultural viewpoint, focusing on Stratospheric Aerosol
8 Injection (SAI) unless otherwise indicated, as most available literature is about SAI.

9
10 Some of the literature on SRM appears in the forms of commentaries, policy briefs, viewpoints and opinions
11 (e.g., (Horton et al., 2016; Keith et al., 2017; Parson, 2017)). This assessment covers original research rather
12 than viewpoints, even if the latter appear in peer-reviewed journals.

13
14
15 **Table 4.7:** Overview of the main characteristics of the most-studied SRM methods
16

	Stratospheric aerosol injection (SAI)	Marine cloud brightening (MCB)	Cirrus cloud thinning (CCT)	Ground-based albedo modification (GBAM)
Description of SRM method	Injection of a gas in the stratosphere, which then converts to aerosols. Injection of other particles also considered.	Spraying sea salt or other particles into marine clouds, making them more reflective.	Seeding to promote nucleation, reducing optical thickness and cloud lifetime, to allow more outgoing longwave radiation to escape into space.	Whitening roofs, changes in land use management (e.g., no-till farming), change of albedo at a larger scale (covering glaciers or deserts with reflective sheeting and changes in ocean albedo).
Radiative forcing efficiencies	1–4 TgS W ⁻¹ m ² yr ⁻¹	100–295 Tg dry sea salt W ⁻¹ m ² yr ⁻¹	Not known	Small on global scale, up to 1–3°C on regional scale
Amount needed for 1°C overshoot	2–8 TgS yr ⁻¹	70 Tg dry sea salt yr ⁻¹	Not known	0.04–0.1 albedo change in agricultural and urban areas
SRM specific impacts on climate variables	Changes in precipitation patterns and circulation regimes; in case of SO ₂ injection disruption to stratospheric chemistry (for instance NO _x depletion and changes in methane lifetime); increase in stratospheric water vapour and tropospheric-stratospheric ice formation affecting cloud microphysics.	Regional rainfall responses; reduction in hurricane intensity	Low-level cloud changes; tropospheric drying; intensification of the hydrological cycle	Impacts on precipitation in monsoon areas; could target hot extremes
SRM specific impacts on human/natural systems	In case of SO ₂ injection - stratospheric ozone loss (which could also have a positive effect – a net reduction in global mortality due	Reduction in the number of mild crop failures		

	to competing health impact pathways) and significant increase of surface UV			
Maturity of science	Volcanic analogues <i>High agreement</i> amongst simulations <i>Robust evidence</i> on ethical, governance and sustainable development limitations	Observed in ships tracks Several simulations confirm mechanism Regionally limited	No clear physical mechanism <i>Limited evidence and low agreement</i> several simulations	Natural and land-use analogues Several simulations confirm mechanism <i>High agreement</i> to influence on regional temperature Land use costly
Key references	(Robock et al., 2008; Heckendorn et al., 2009; Tilmes et al., 2012, 2016; Pitari et al., 2014; Crook et al., 2015; C.J. Smith et al., 2017; Visioni et al., 2017a, b; Eastham et al., 2018; Plazzotta et al., 2018)	(Salter et al., 2008; Alterskjær et al., 2012; Jones and Haywood, 2012; Latham et al., 2012, 2013; Kravitz et al., 2013; Crook et al., 2015; Parkes et al., 2015; Ahlm et al., 2017)	(Storelvmo et al., 2014; Kristjánsson et al., 2015; Jackson et al., 2016; Kärcher, 2017; Lohmann and Gasparini, 2017)	(Irvine et al., 2011; Akbari et al., 2012; Jacobson and Ten Hoeve, 2012; Davin et al., 2014; Crook et al., 2015, 2016; Seneviratne et al., 2018)

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SRM could reduce some of the global risks of climate change related to temperature rise (Izrael et al., 2014; MacMartin et al., 2014), rate of sea level rise (Moore et al., 2010), sea-ice loss (Berdahl et al., 2014) and frequency of extreme storms in the North Atlantic and heatwaves in Europe (Jones et al., 2018). SRM also holds risks of changing precipitation and ozone concentrations and potentially reductions in biodiversity (Pitari et al., 2014; Visioni et al., 2017a; Trisos et al., 2018). Literature only supports SRM as a supplement to deep mitigation, for example in overshoot scenarios (Smith and Rasch, 2013; MacMartin et al., 2018).

4.3.8.1 Governance and Institutional Feasibility

There is *robust evidence* but *medium agreement* for unilateral action potentially becoming a serious SRM governance issue (Weitzman, 2015; Rabitz, 2016), as some argue that enhanced collaboration might emerge around SRM (Horton, 2011). An equitable institutional or governance arrangement around SRM would have to reflect views of different countries (Heyen et al., 2015; Robock, 2016) and be multilateral because of the risk of termination, and risks that implementation or unilateral action by one country or organisation will produce negative precipitation or extreme weather effects across borders (Lempert and Prosnitz, 2011; Dilling and Hauser, 2013; NRC, 2015b). Some have suggested that the governance of research and field experimentation can help clarify uncertainties surrounding deployment of SRM (Long and Shepherd, 2014; Parker, 2014; NRC, 2015c; Caldeira and Bala, 2017; Lawrence and Crutzen, 2017), and that SRM is compatible with democratic processes (Horton et al., 2018) or not (Szerszynski et al., 2013; Owen, 2014).

Several possible institutional arrangements have been considered for SRM governance: under the UNFCCC (in particular under the Subsidiary Body on Scientific and Technological Advice (SBSTA)) or the United Nations Convention on Biological Diversity (UNCBD) (Honegger et al., 2013; Nicholson et al., 2018), or through a consortium of states (Bodansky, 2013; Sandler, 2017). Voice in SRM diplomacy, prevention of unilateral action by others and benefits from research collaboration might be reasons for states to join an international governance framework for SRM (Lloyd and Oppenheimer, 2014).

Alongside SBSTA, the WMO, UNESCO and UN Environment could play a role in governance of SRM (Nicholson et al., 2018). Each of these organisations has relevance with respect to the regulatory framework (Bodley et al., 2012; Williamson and Bodley, 2016). The UNCBD gives guidance that ‘that no climate-related geo-engineering activities that may affect biodiversity take place’ (UNCBD, 2010).

4.3.8.2 *Economic and Technological Feasibility*

The literature on engineering cost of SRM is limited and may be unreliable in the absence of testing or deployment. There is *high agreement* that cost of SAI (not taking into account indirect and social costs, research and development costs and monitoring expenses) may be in the range of 1–10 billion USD yr⁻¹ for injection of 1–5 MtS to achieve cooling of 1–2 W m⁻² (Robock et al., 2009; McClellan et al., 2012; Ryaboshapko and Revokatova, 2015; Moriyama et al., 2016), suggesting that cost-effectiveness may be high if side-effects are low or neglected (McClellan et al., 2012). The overall economic feasibility of SRM also depends on externalities and social costs (Moreno-Cruz and Keith, 2013; Mackerron, 2014), climate sensitivity (Kosugi, 2013), option value (Arino et al., 2016), presence of climate tipping points (Eric Bickel, 2013) and damage costs as a function of the level of SRM (Bahn et al., 2015; Heutel et al., 2018). Modelling of game-theoretic, strategic interactions of states under heterogeneous climatic impacts shows *low agreement* on the outcome and viability of a cost-benefit analysis for SRM (Ricke et al., 2015; Weitzman, 2015).

For SAI, there is *high agreement* that aircrafts after some modifications could inject millions of tons of SO₂ in the lower stratosphere (~20 km; (Davidson et al., 2012; McClellan et al., 2012; Irvine et al., 2016).

4.3.8.3 *Social Acceptability and Ethics*

Ethical questions around SRM include those of international responsibilities for implementation, financing, compensation for negative effects, the procedural justice questions of who is involved in decisions, privatisation and patenting, welfare, informed consent by affected publics, intergenerational ethics (because SRM requires sustained action in order to avoid termination hazards), and the so-called ‘moral hazard’ (Burns, 2011; Whyte, 2012; Gardiner, 2013; Lin, 2013; Buck et al., 2014; Klepper and Rickels, 2014; Morrow, 2014; Wong, 2014; Reynolds, 2015; Lockley and Coffman, 2016; McLaren, 2016; Suarez and van Aalst, 2017; Reynolds et al., 2018). The literature shows *low agreement* on whether SRM research and deployment may lead policy-makers to reduce mitigation efforts and thus imply a moral hazard (Linnér and Wibeck, 2015). SRM might motivate individuals (as opposed to policymakers) to reduce their GHG emissions (Merk et al., 2016), but even a subtle difference in the articulation of information about SRM can influence subsequent judgements of favourability (Corner and Pidgeon, 2014). The argument that SRM research increases the likelihood of deployment (the ‘slippery slope’ argument), is also made (Parker, 2014; Quaas et al., 2017; Bellamy and Healey, 2018).

Unequal representation and deliberate exclusion are plausible in decision-making on SRM, given diverging regional interests and the anticipated low resource requirements to deploy SRM (Ricke et al., 2013). Whyte (2012) argues that the concerns, sovereignties, and experiences of Indigenous peoples may particularly be at risk.

The general public can be characterised as ignorant and worried about SRM (Carr et al., 2013; Parkhill et al., 2013; Wibeck et al., 2017). An emerging literature discusses public perception of SRM, showing a lack of knowledge and unstable opinions (Scheer and Renn, 2014). The perception of controllability affects legitimacy and public acceptability of SRM experiments (Bellamy et al., 2017). In Germany, laboratory work on SRM is generally approved of, field research much less so, and immediate deployment is largely rejected (Merk et al., 2015; Braun et al., 2017). Various factors could explain variations in the degree of rejection of SRM between Canada, China, Germany, Switzerland, the United Kingdom, and the United States (Visschers et al., 2017).

[START CROSS-CHAPTER BOX 10 HERE]

Cross-Chapter Box 10: Solar Radiation Modification in the Context of 1.5°C Mitigation Pathways

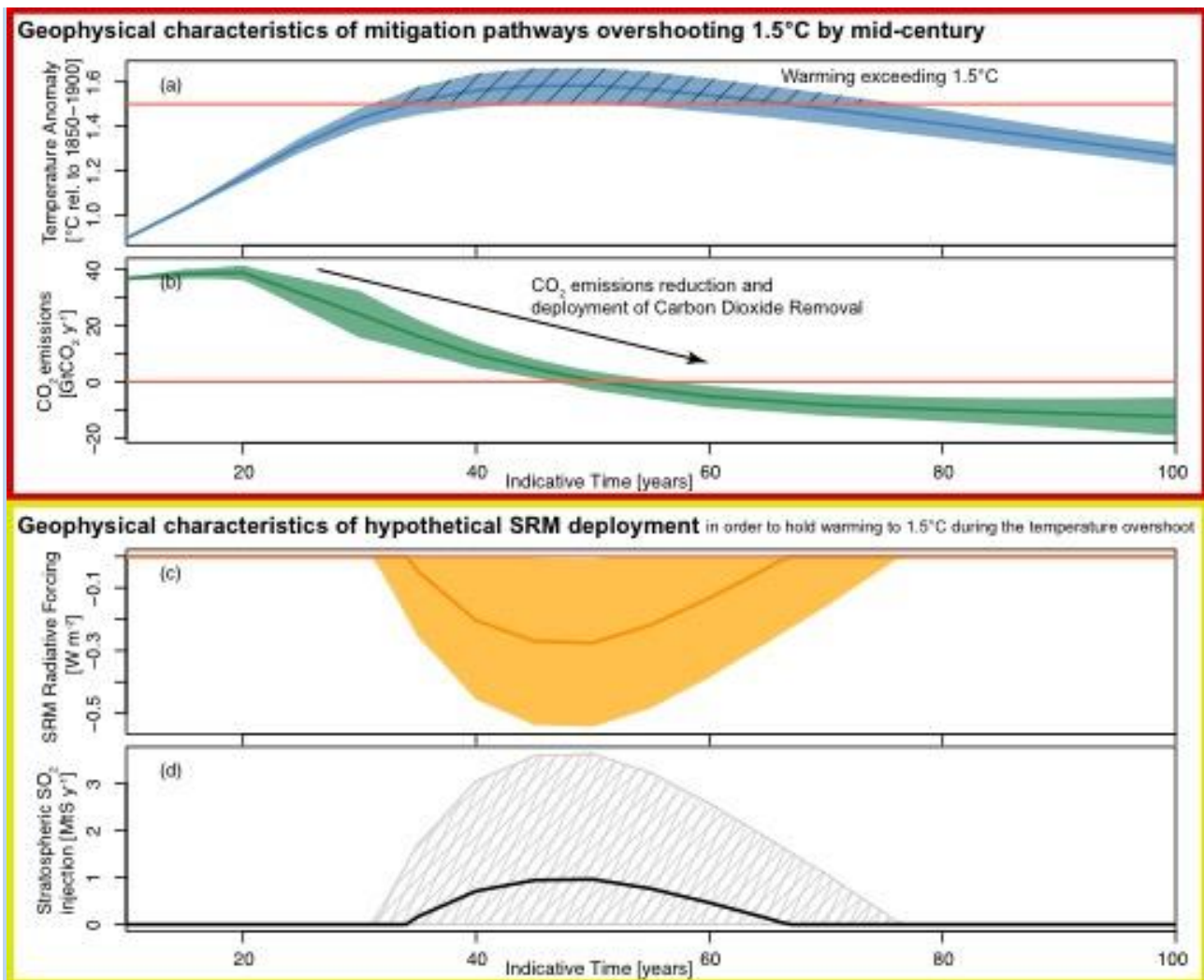
Authors: Anastasia Revokatova (Russian Federation), Heleen de Coninck (The Netherlands), Piers Forster (UK), Veronika Ginzburg (Russian Federation), Jatin Kala (Australia), Diana Liverman (USA), Maxime Plazzotta (France), Roland Séférian (France), Sonia I. Seneviratne (Switzerland), Jana Sillmann (Norway).

Solar Radiation Modification (SRM) refers to a range of radiation modification measures not related to Greenhouse Gas (GHG) mitigation, which seek to limit global warming (see Section 1.4.1). Most methods involve reducing the solar incoming radiation reaching the surface, but others also act on the longwave radiation budget reducing optical thickness and cloud lifetime (see Table 4.6). In the context of this report, SRM is assessed in terms of its potential to limiting warming below 1.5°C in temporary overshoot scenarios as a way to reduce elevated temperatures and associated impacts (Irvine et al., 2016; Keith and Irvine, 2016; Chen and Xin, 2017; Sugiyama et al., 2017a; Vioni et al., 2017a; MacMartin et al., 2018). The inherent variability of the climate system would make it difficult to detect the efficacy or side-effects of SRM intervention when deployed in such a temporary scenario (Jackson et al., 2015).

A. Potential SRM timing and magnitude

Published SRM approaches are summarised in Table 4.6. The timing and magnitude of potential SRM deployment depends on the temperature overshoot associated with mitigation pathways. All overshooting pathways make use of carbon dioxide removal. Therefore, if considered, SRM would only be deployed as a supplement measure to large-scale carbon dioxide removal (Section 2.3).

Cross-Chapter Box 10, Figure 1 below illustrates an example of how a hypothetical SRM deployment based on Stratospheric Aerosols Injection (SAI) could be used to limit warming below 1.5°C using an ‘adaptive SRM’ approach (e.g., Kravitz et al. 2011; Tilmes et al., 2016), where global mean temperature exceeds 1.5°C compared to pre-industrial level by mid-century and returns below before 2100 with a 66% likelihood (see Chapter 2). In all such limited adaptive deployment scenarios, deployment of SRM only commences under conditions in which CO₂ emissions have already fallen substantially below their peak level and are continuing to fall. In order to hold warming to 1.5°C, a hypothetical SRM deployment could span from one to several decades with the earliest possible threshold exceedance occurring before mid-century. Over this duration, SRM has to compensate for warming that exceeds 1.5°C (displayed with hatching on panel a) with a decrease in radiative forcing (panel b) which could be achieved with a rate of SAI varying between 0–5.9 MtSO₂ yr⁻¹ (panel c) (Robock et al., 2008; Heckendorn et al., 2009).



Cross-Chapter Box 10, Figure 1: Evolution of hypothetical SRM deployment (based on SAI) in the context of 1.5°C-consistent pathways. (a) Range of median temperature outcomes as simulated by MAGICC (see in Section 2.2) given the range of CO₂ emissions (b) and other climate forcers for mitigation pathways exceeding 1.5°C at mid-century and returning below by 2100 with a 66% likelihood. Geophysical characteristics are represented by the magnitude of radiative forcing (c) and the amount of stratospheric SO₂ injection (d) that are required to keep the global median temperature below 1.5°C during the temperature overshoot (given by the blue hatching on panel a). SRM surface radiative forcing has been diagnosed using a mean cooling efficiency of 0.3°C (W⁻¹ m²) of Plazzotta et al. (2018). Magnitude and timing of SO₂ injection have been derived from published estimates of Heckendorn et al. (2009) and Robock et al. (2008).

SAI is the most researched SRM method with *high agreement* that it could limit warming to below 1.5°C (Tilmes et al., 2016; Jones et al., 2018). The response of global temperature to SO₂ injection, however, is uncertain and varies depending on the model parametrisation and emission scenarios (Jones et al., 2011; Kravitz et al., 2011; Izrael et al., 2014; Crook et al., 2015; Niemeier and Timmreck, 2015; Tilmes et al., 2016; Kashimura et al., 2017). Uncertainty also arises due to the nature and the optical properties of injected aerosols.

Other approaches are less well researched but the literature suggests that Ground-Based Albedo Modification (GBAM), Marine Cloud Brightening (MCB) or Cirrus Cloud Thinning (CCT) are not assessed to be able to substantially reduce overall global temperature (Irvine et al., 2011; Seneviratne et al., 2018). However, these SRM approaches are known to create spatially heterogeneous forcing and potentially more spatially heterogeneous climate effects, which may be used to mitigate regional climate impacts. This may be of most relevance in the case of GBAM when applied to crop and urban areas (Seneviratne et al. 2018). Most of the literature on regional mitigation has focused on GBAM in relationship with land-use land cover changes scenarios. Both models and observations suggest that there is a *high agreement* that GBAM would result in

1 cooling over the region of changed albedo, and in particular reduce hot extremes (Irvine et al., 2011; Akbari
2 et al., 2012; Jacobson and Ten Hoeve, 2012; Davin et al., 2014; Crook et al., 2015, 2016; Alkama and
3 Cescatti, 2016; Seneviratne et al., 2018). In comparison, there is a *limited evidence* on the ability of MCB or
4 CCT to mitigate regional climate impacts of 1.5°C warming because the magnitude of the climate response
5 to MCB or CCT remains uncertain and the processes are not fully understood (Lohmann and Gasparini,
6 2017).

8 **B. General consequence and impacts of solar radiation modification**

9 It has been proposed that deploying SRM as a supplement to mitigation may reduce increases in global
10 temperature-related extremes and rainfall intensity, and lessen the loss of coral reefs from increasing sea-
11 surface temperatures (Keith and Irvine, 2016), but it would not address or even worsen (Tjiputra et al., 2016)
12 negative effects from continued ocean acidification.

13
14 Another concern with SRM is the risk of a ‘termination shock’ or ‘termination effect’ when suddenly
15 stopping SRM, which might cause rapid temperature rise and associated impacts (Jones et al., 2013; Izrael et
16 al., 2014; McCusker et al., 2014; Robock, 2016), most noticeably biodiversity loss (Trisos et al., 2018). The
17 severity of the termination effect has recently been debated (Parker and Irvine, 2018) and depends on the
18 degree of SRM cooling. This report only considers limited SRM in the context of mitigation pathways to
19 1.5°C. Other risks of SRM deployment could be associated with the lack of testing of the proposed
20 deployment schemes (*e.g.* (Schäfer et al., 2013)). Ethical aspects and issues related to the governance and
21 economics are discussed in Section 4.3.8.

23 **C. Consequences and impacts of SRM on the carbon budget**

24 Because of its effects on surface temperature, precipitation and surface shortwave radiation, SRM would also
25 alter the carbon budget pathways to 1.5°C or 2°C (Eliseev, 2012; Keller et al., 2014; Keith et al., 2017;
26 Lauvset et al., 2017).

27
28 Despite the large uncertainties in the simulated climate response to SRM, current model simulations suggest
29 that SRM would lead to altered carbon budgets compatible with 1.5°C or 2°C. The 6 CMIP5 models
30 investigated simulated an increase of natural carbon uptake by land biosphere and, to a smaller extent, by the
31 oceans (*high agreement*). The multi-model mean of this response suggests an increase of the RCP4.5 carbon
32 budget of about 150 GtCO₂ after 50 years of SO₂ injection with a rate of 4 TgS yr⁻¹, which represents about 4
33 years of CO₂ emissions at the current rate (36 GtCO₂ yr⁻¹). However, there is uncertainty around quantitative
34 determination of the effects that SRM or its cessation has on the carbon budget due to a lack of
35 understanding of the radiative processes driving the global carbon cycle response to SRM (Ramachandran et
36 al., 2000; Mercado et al., 2009; Eliseev, 2012; Xia et al., 2016), uncertainties about how the carbon cycle
37 will respond to termination effects of SRM, and uncertainties in climate-carbon cycle feedbacks
38 (Friedlingstein et al., 2014).

40 **D. Sustainable development and SRM**

41 There are few studies investigating potential implications of SRM for sustainable development. These are
42 based on a limited number of scenarios and hypothetical considerations, mainly referring to benefits from
43 lower temperatures (Irvine et al., 2011; Nicholson, 2013; Anshelm and Hansson, 2014; Harding and Moreno-
44 Cruz, 2016). Other studies suggest negative impacts from SRM implementation concerning issues related to
45 regional disparities (Heyen et al., 2015), equity (Buck, 2012), fisheries, ecosystems, agriculture, and
46 termination effects (Robock, 2012; Morrow, 2014; Wong, 2014). If SRM is initiated by the richer nations,
47 there might be issues with local agency, and possibly worsening conditions for those suffering most under
48 climate change (Buck et al., 2014). In addition, ethical issues related to testing SRM have been raised (*e.g.*,
49 (Lenferna et al., 2017)). Overall, there is *high agreement* that SRM would affect many development issues
50 but *limited evidence* on the degree of influence, and how it manifests itself across regions and different levels
51 of society.

53 **E. Overall feasibility of SRM**

54 If mitigation efforts do not keep global mean temperature below 1.5°C, SRM can potentially reduce the
55 climate impacts of a temporary temperature overshoot, in particular extreme temperatures, rate of sea level

1 rise and intensity of tropical cyclones, alongside intense mitigation and adaptation efforts. While theoretical
2 developments show that SRM is technically feasible (see Section 4.3.8.2), global field experiments have not
3 been conducted and most of the knowledge about SRM is based on imperfect model simulations and some
4 natural analogues. There are also considerable challenges to the implementation of SRM associated with
5 disagreements over the governance, ethics, public perception, and distributional development impacts (Boyd,
6 2016; Preston, 2016; Asayama et al., 2017; Sugiyama et al., 2017b; Svoboda, 2017; McKinnon, 2018;
7 Talberg et al., 2018) (see Section 4.3.8). Overall, the combined uncertainties surrounding the various SRM
8 approaches, including technological maturity, physical understanding, potential impacts, and challenges of
9 governance, constrain the ability to implement SRM in the near future.

10
11
12 **[END CROSS-CHAPTER BOX 10 HERE]**

13 14 15 **4.4 Implementing Far-Reaching and Rapid Change**

16
17 The feasibility of 1.5°C-compatible pathways is contingent upon enabling conditions for systemic change
18 (see Cross Chapter Box 3 in Chapter 1). Section 4.3 identifies the major systems, and options within those
19 systems, that offer the potential for change to align with 1.5°C pathways.

20
21 AR5 identifies enabling conditions as influencing the feasibility of climate responses (Kolstad et al., 2014).
22 This section draws on 1.5°C-specific and related literature on rapid and scale-up change, to identify the
23 enabling conditions that influence the feasibility of adaptation and mitigation options assessed in Section 4.5.
24 Examples from diverse regions and sectors are provided to illustrate how these conditions could enable or
25 constrain the implementation of incremental, rapid, disruptive and transformative mitigation and adaptation
26 consistent with 1.5°C pathways.

27
28 Coherence between the enabling conditions holds potential to enhance feasibility of 1.5°C-consistent
29 pathways and adapting to the consequences. This includes better alignment across governance scales
30 (OECD/IEA/NEA/ITF, 2015; Geels et al., 2017), enabling multi-level governance (Cheshmehzangi, 2016;
31 Revi, 2017; Tait and Euston-Brown, 2017) and nested institutions (Abbott, 2012). It also includes inter-
32 disciplinary actions, combined adaptation and mitigation action (Göpfert et al., 2018) and science-policy
33 partnerships (Vogel et al., 2007; Hering et al., 2014; Roberts, 2016; Figueres et al., 2017; Leal Filho et al.,
34 2018). These partnerships are difficult to establish and sustain, but can generate trust (Cole, 2015; Jordan et
35 al., 2015) and inclusivity that ultimately can provide durability and the realisation of co-benefits for
36 sustained rapid change (Blanchet, 2015; Ziervogel et al., 2016a).

37 38 **4.4.1 Enhancing Multi-Level Governance**

39
40 Addressing climate change and implementing responses to 1.5°C-consistent pathways will need to engage
41 with various levels and types of governance (Betsill and Bulkeley, 2006; Kern and Alber, 2009;
42 Christoforidis et al., 2013; Romero-Lankao et al., 2018). AR5 highlighted the significance of governance as
43 a means of strengthening adaptation and mitigation and advancing sustainable development (Fleurbaey et al.,
44 2014). Governance is defined in the broadest sense as the ‘processes of interaction and decision making
45 among actors involved in a common problem’ (Kooiman 2003, Hufty 2011) (Fleurbaey et al., 2014). This
46 definition goes beyond notions of formal government or political authority and integrates other actors,
47 networks, informal institutions and communities.

48 49 50 **4.4.1.1 Institutions and their Capacity to Invoke Far-Reaching and Rapid Change**

51
52 Institutions, the rules and norms that guide human interactions (Section 4.4.2), enable or impede the
53 structures, mechanisms and measures that guide mitigation and adaptation. Institutions, understood as the
54 ‘rules of the game’ (North, 1990), exert direct and indirect influence over the viability of 1.5°C-consistent
55 pathways (Munck et al., 2014; Willis, 2017). Governance would be needed to support wide-scale and

1 effective adoption of mitigation and adaptation options. Institutions and governance structures are
2 strengthened when the principle of the ‘commons’ is explored as a way of sharing management and
3 responsibilities (Ostrom et al., 1999; Chaffin et al., 2014; Young, 2016). Institutions would need to be
4 strengthened to interact amongst themselves, and to share responsibilities for the development and
5 implementation of rules, regulations and policies (Ostrom et al., 1999; Wejs et al., 2014; Craig et al., 2017),
6 with the goal of ensuring that these embrace equity, justice, poverty alleviation and sustainable development,
7 enabling a 1.5°C world (Reckien et al., 2017; Wood et al., 2017).

8
9 Several authors have identified different modes of cross-stakeholder interaction in climate policy, including
10 the role played by large multinational corporations, small enterprises, civil society and non-state actors.
11 Ciplet et al. (2015) argue that civil society is to a great extent the only reliable motor for driving institutions
12 to change at the pace required. Kern and Alber (2009) recognise different forms of collaboration relevant to
13 successful climate policies beyond the local level. Horizontal collaboration (e.g., transnational city networks)
14 and vertical collaboration within nation-states can play an enabling role (Ringel, 2017). Vertical and
15 horizontal collaboration requires synergistic relationships between stakeholders (Ingold and Fischer, 2014;
16 Hsu et al., 2017). The importance of community participation is emphasised in literature, and in particular
17 the need to take into account equity and gender considerations (Chapter 5) (Graham et al., 2015; Bryan et al.,
18 2017; Wangui and Smucker, 2017). Participation often faces implementation challenges and may not always
19 result in better policy outcomes. Stakeholders, for example, may not view climate change as a priority and
20 may not share the same preferences, potentially creating a policy deadlock (Preston et al., 2013, 2015; Ford
21 et al., 2016).

22 23 24 4.4.1.2 *International Governance*

25
26 International treaties help strengthen policy implementation, providing a medium and long-term vision
27 (Obergassel et al., 2016). International climate governance is organised via many mechanisms, including
28 international organisations, treaties and conventions, for example, UNFCCC, the Paris Agreement and the
29 Montreal Protocol. Other multilateral and bilateral agreements, such as trade agreements, also have a bearing
30 on climate change.

31
32 There are significant differences between global mitigation and adaptation governance frames. Mitigation
33 tends to be global by its nature and it is based on the principle of the climate system as a global commons
34 (Ostrom et al., 1999). Adaptation has traditionally been viewed as a local process, involving local authorities,
35 communities, and stakeholders (Khan, 2013; Preston et al., 2015), although is now recognised to be a multi-
36 scaled, multi-actor process that transcends from local and sub-national, to national and international scales
37 (Mimura et al., 2014; UNEP, 2017a). National governments provide a central pivot for coordination,
38 planning, determining policy (Section 4.4.5) priorities and distributing resources. National governments are
39 accountable to the international community through international agreements. Yet, many of the impacts of
40 climate change are transboundary, so that bilateral and multilateral cooperation are needed (Nalau et al.,
41 2015; Donner et al., 2016; Magnan and Ribera, 2016; Tilleard and Ford, 2016; Lesnikowski et al., 2017).
42 The Kigali Amendment to the Montreal Protocol demonstrates that a global environmental agreement
43 facilitating common but differentiated responsibilities is possible (Sharadin, 2018). This was operationalised
44 by developed countries acting first, with developing countries following and benefiting from leap-frogging
45 the trial-and-error stages of innovative technology development.

46
47 Work on international climate governance has focused on the nature of ‘climate regimes’ and coordinating
48 the action of nation-states (Aykut, 2016) organised around a diverse set of instruments: i) binding limits
49 allocated by principles of historical responsibility and equity, ii) carbon prices, emissions quotas, iii) pledges
50 and review of policies and measures or iv) a combination of these options (Stavins, 1988; Grubb, 1990;
51 Pizer, 2002; Newell and Pizer, 2003).

52
53 Literature on the Kyoto Protocol provides two important insights for 1.5°C transition: the challenge of
54 agreeing on rules to allocate emissions quotas (Shukla, 2005; Caney, 2012; Winkler et al., 2013; Gupta,
55 2014; Méjean et al., 2015) and a climate-centric vision (Shukla, 2005; Winkler et al., 2011), separated from

1 development issues which drove resistance from many developing nations (Roberts and Parks, 2006). For the
2 former, a burden sharing approach led to an adversarial process among nations to decide who shall be
3 allocated ‘how much’ of the remainder of the emissions budget (Caney, 2014; Ohndorf et al., 2015; Roser et
4 al., 2015; Giménez-Gómez et al., 2016). Industry group lobbying, further contributed to reducing space for
5 manoeuvre of some major emitting nations (Newell and Paterson, 1998; Levy and Egan, 2003; Dunlap and
6 McCright, 2011; Michaelowa, 2013; Geels, 2014).

7
8 Given the political unwillingness to continue with the Kyoto Protocol approach a new approach was
9 introduced in the Copenhagen Accord, the Cancun Agreements, and finally in the Paris Agreement. The
10 transition to 1.5°C requires carbon neutrality and thus going beyond the traditional framing of climate as a
11 ‘tragedy of the commons’ to be addressed via cost-optimal allocation rules, which demonstrated a low
12 probability of enabling a transition to 1.5°C consistent pathways (Patt, 2017). The Paris Agreement, built on
13 a ‘pledge and review’-system is thought to be more effective in securing trust (Dagnet et al., 2016), enables
14 effective monitoring and timely reporting on national actions (including adaptation), allowing for
15 international scrutiny and persistent efforts of civil society and non-state actors to encourage action in both
16 national and international contexts (Allan and Hadden, 2017; Bäckstrand and Kuypers, 2017; Höhne et al.,
17 2017; Lesnikowski et al., 2017; Maor et al., 2017; UNEP, 2017a), with some limitations (Nieto et al., 2018).

18
19 The paradigm shift enabled at Cancun succeeded by focusing on the objective of ‘equitable access to
20 sustainable development’ (Hourcade et al., 2015). The use of ‘pledge and review’ now underpins the Paris
21 Agreement. This consolidates multiple attempts to define a governance approach that relies on National
22 Determined Contributions (NDCs) and on means for a ‘facilitative model’ (Bodansky and Diring, 2014) to
23 reinforce them. This enables a regular, iterative, review of NDCs allowing countries to set their own
24 ambitions after a global stocktake and more flexible, experimental forms of climate governance, which may
25 provide room for higher ambition, and be consistent with the needs of governing for a rapid transition to
26 close the emission gap (Cléménçon, 2016; Falkner, 2016) (Cross-Chapter Box 11 in this Chapter). Beyond a
27 general consensus on the necessity of Measurement, Reporting and Verification (MRV) mechanisms as a
28 key element of a climate regime (Ford et al., 2015b; van Asselt et al., 2015), some authors emphasise
29 different governance approaches to implement the Paris Agreement. Through market mechanisms under
30 Article 6 of the Paris Agreement and the new proposed sustainable development mechanism, it allows the
31 space to harness the lowest cost mitigation options worldwide. This may incentivise policymakers to
32 enhance mitigation ambition by speeding up climate action as part of ‘climate regime complex’ (Keohane
33 and Victor, 2011) of loosely interrelated global governance institutions. In the Paris Agreement, the
34 Common But Differentiated Responsibilities and Respective Capabilities (CBDR-RC) principle could be
35 expanded and revisited under a ‘sharing the pie’ paradigm (Ji and Sha, 2015) as a tool to open innovation
36 processes towards alternative development pathways (Chapter 5).

37
38 COP16 in Cancun was also the first time in the UNFCCC that adaptation was recognised to have similar
39 priority as mitigation. The Paris Agreement recognises the importance of adaptation action and cooperation
40 to enhance such action. (Chung Tiam Fook, 2017; Lesnikowski et al., 2017) suggest that the Paris
41 Agreement is explicit about multilevel adaptation governance, outlines stronger transparency mechanisms,
42 links adaptation to development and climate justice, and is hence, suggestive of greater inclusiveness of non-
43 state voices and the broader contexts of social change.

44
45 1.5°C-consistent pathways require further exploration of conditions of trust and reciprocity amongst nation
46 states (Schelling, 1991; Ostrom and Walker, 2005). Some authors (Colman et al., 2011; Courtois et al., 2015)
47 suggest a departure from the vision of actors acting individually in the pursuit of self-interest to that of
48 iterated games with actors interacting over time showing that reciprocity, with occasional forgiveness and
49 initial good faith, can lead to win-win outcomes and to cooperation as a stable strategy (Axelrod and
50 Hamilton, 1981).

51
52 Regional cooperation plays an important role in the context of global governance. Literature on climate
53 regimes has only started exploring innovative governance arrangements including: coalitions of transnational
54 actors including state, market and non-state actors (Bulkeley et al., 2012; Hovi et al., 2016; Hagen et al.,
55 2017; Hermwille et al., 2017; Roelfsema et al., 2018) and groupings of countries, as a complement to the

1 UNFCCC (Abbott and Snidal, 2009; Biermann, 2010; Zelli, 2011; Nordhaus, 2015). Climate action requires
2 multi-level governance from the local and community level to national, regional and international levels.
3 Box 4.1 shows the role of sub-national authorities, e.g. regions and provinces in facilitating urban climate
4 action, while Box 4.2 shows that climate governance can be organised across hydrological and not only
5 political units as well.

8 *4.4.1.3 Sub-National Governance*

10 Local governments can play a key role (Melica et al., 2018; Romero-Lankao et al., 2018) in influencing
11 mitigation and adaptation strategies. It is important to understand how rural and urban areas, small islands,
12 informal settlements and communities might intervene to reduce climate impacts (Bulkeley et al., 2011),
13 either by implementing climate objectives defined at higher government levels, taking initiative
14 autonomously or collectively (Aall et al., 2007; Reckien et al., 2014; Araos et al., 2016a; Heidrich et al.,
15 2016). Local governance faces the challenge of reconciling local concerns with global objectives. Local
16 governments could coordinate and develop effective local responses, and could pursue procedural justice in
17 ensuring community engagement and more effective policies around energy and vulnerability reduction
18 (Moss et al., 2013; Fudge et al., 2016). They can enable more participative decision-making (Barrett, 2015;
19 Hesse, 2016). Fudge et al. (2016) argue that local authorities are well-positioned to involve the wider
20 community in: designing and implementing climate policies, engaging with sustainable energy generation,
21 e.g., by supporting energy communities (Slee, 2015), and the delivery of demand-side measures and
22 adaptation implementation.

24 By 2050, it is estimated three billion people will be living in slums and informal settlements:
25 neighbourhoods without formal governance, on un-zoned land developments and in places that are exposed
26 to climate-related hazards (Bai et al., 2018). Emerging research is examining how citizens can contribute
27 informally to governance with rapid urbanisation and weaker government regulation (Sarmiento and Tilly,
28 2018). It remains to be seen how the possibilities and consequences of alternative urban governance models
29 for large, complex problems and addressing inequality and urban adaptation will be managed (Amin and
30 Cirolia, 2018; Bai et al., 2018; Sarmiento and Tilly, 2018).

32 Expanding networks of cities sharing experiences on coping with climate change and drawing economic and
33 development benefits from climate change responses represent a recent institutional innovation. This could
34 be complemented by efforts of national governments through national urban policies to enhance local
35 climate action (Broekhoff et al., 2018). Over the years, non-state actors have set up several transnational
36 climate governance initiatives to accelerate the climate response, for example ICLEI (1990), C-40 (2005),
37 the Global Island Partnership (2006) and the Covenant of Mayors (2008) (Gordon and Johnson, 2017; Hsu et
38 al., 2017; Ringel, 2017; Kona et al., 2018; Melica et al., 2018) and to exert influence on national
39 governments and the UNFCCC (Bulkeley, 2005). However, (Michaelowa and Michaelowa, 2017) find low
40 effectiveness of over 100 of such mitigation initiatives.

43 *4.4.1.4 Interactions and Processes for Multi-Level Governance*

45 Literature has proposed multi-level governance in climate change as an enabler for systemic transformation
46 and effective governance, as the concept is thought to allow for combining decisions across levels, sectors
47 and institutional types at the same level (Romero-Lankao et al., 2018) with multi-level reinforcement and the
48 mobilisation of economic interests at different levels of governance (Janicke and Quitzow, 2017). These
49 governance mechanisms are based on accountability and transparency rules and participation and
50 coordination across and within these levels.

52 A study of 29 European countries showed that the rapid adoption and diffusion of adaptation policymaking is
53 largely driven by internal factors, at the national and sub-national levels (Massey et al., 2014). An
54 assessment of national level adaptation in 117 countries (Berrang-Ford et al., 2014), find good governance to
55 be the one of the strongest predictors of national adaptation policy. An analysis of climate response by 200

1 large and medium-sized cities across eleven European countries find that factors such as membership of
2 climate networks, population size, Gross Domestic Product (GDP) per capita and adaptive capacity act as
3 drivers of mitigation and adaptation plans (Reckien et al., 2015).

4
5 Adaptation policy has seen growth in some areas (Massey et al., 2014; Lesnikowski et al., 2016), although
6 efforts to track adaptation progress are constrained by an absence of data sources on adaptation (Berrang-
7 Ford et al. 2011; Ford and Berrang-Ford 2016; Magnan and Ribera 2016; Magnan 2016). Many developing
8 countries have made progress in formulating national policies, plans and strategies on responding to climate
9 change. The NDCs have been identified as one such institutional mechanism (Magnan et al., 2015; Kato and
10 Ellis, 2016; Peters et al., 2017) (Cross-Chapter Box 11 in this Chapter).

11
12 To overcome barriers to policy implementation, local conflicts of interest or vested interests, strong
13 leadership and agency is needed by political leaders. As shown by the Covenant of Mayors initiative (Box
14 4.1), political leaders with a vision for the future of the local community can succeed in reducing GHG
15 emissions, when they are supported by civil society (Rivas et al., 2015; Croci et al., 2017; Kona et al., 2018).
16 Any political vision would need to be translated into an action plan, of which elements could be describing
17 policies and measures needed to achieve transition, the human and financial resources needed, milestones,
18 and appropriate measurement and verification processes (Azevedo and Leal, 2017). Discussing the plan with
19 stakeholders and civil society, including citizens and right of participation for minorities, and having them
20 provide input and endorse it, is found to increase the likelihood of success (Rivas et al., 2015; Wamsler,
21 2017). However, as described by Nightingale (2017) and Green (2016), struggles over natural resources and
22 adaptation governance both at the national and community levels would need to be addressed too, ‘in
23 politically unstable contexts, where power and politics shape adaptation outcomes’.

24
25 **[START BOX 4.1 HERE]**

26
27 **Box 4.1: Multi-Level Governance in the EU Covenant of Mayors: Example of the Provincia di**
28 **Foggia**

29
30 Since 2005, cities have emerged as a locus of institutional and governance climate innovation (Melica et al.,
31 2018) and are driving responses to climate change (Roberts, 2016). Many cities have adopted more
32 ambitious Greenhouse Gas (GHG) emission reduction targets than countries (Kona et al., 2018), with an
33 overall commitment of GHG emission reduction targets by 2020 of 27%, almost 7 percentage points higher
34 than the minimum target for 2020 (Kona et al., 2018). The Covenant of Mayors (CoM) is an initiative in
35 which municipalities voluntarily commit to CO₂ emission reduction. The participation of small
36 municipalities has been facilitated by the development and testing of a new multi-level governance model
37 involving Covenant Territorial Coordinators (CTCs), i.e., provinces and regions, which commit to providing
38 strategic guidance, financial and technical support to municipalities in their territories. Results from the 315
39 monitoring inventories submitted shows an achievement of 23% reduction in emissions (compared to an
40 average year 2005) of more than half of the cities under a CTC schema (Kona et al., 2018).

41
42 The Province of Foggia, acting as a CTC, gave support to 36 municipalities to participate in the CoM and to
43 prepare Sustainable Energy Action Plans (SEAPs). The Province developed a common approach to prepare
44 SEAPs, provided data to compile municipal emission inventories (Bertoldi et al., 2018) and guided the
45 signatory to identify an appropriate combination of measures to curb GHG emissions programme. The local
46 Chamber of Commerce had a key role also in the implementation of these projects by the municipalities
47 (Lombardi et al., 2016). The joint action by the province and the municipalities in collaboration with the
48 local business community could be seen as an example of multi-level governance (Lombardi et al., 2016).

49
50 Researchers have investigated local forms of collaboration within local government, with the active
51 involvement of citizens and stakeholders, and acknowledge that public acceptance is key to the successful
52 implementation of policies (Larsen and Gunnarsson-Östling, 2009; Musall and Kuik, 2011; Pollak et al.,
53 2011; Christoforidis et al., 2013; Pasimeni et al., 2014; Lee and Painter, 2015). Achieving ambitious targets
54 would need leadership, enhanced multi-level governance, vision and widespread participation in
55 transformative change (Castán Broto and Bulkeley, 2013; Rosenzweig et al., 2015; Castán Broto, 2017;

1 Fazey et al., 2017; Wamsler, 2017; Romero-Lankao et al., 2018). The Section 5.6.4 case studies of climate-
2 resilient development pathways, at state and community scales, show that participation, social learning and
3 iterative decision-making are governance features of strategies that deliver mitigation, adaptation, and
4 sustainable development in a fair and equitable manner. Other insights include that incremental voluntary
5 changes are amplified through community networking, poly-centric governance (Dorsch and Flachsland,
6 2017) and partnerships and long-term change to governance systems at multiple levels (Stevenson and
7 Dryzek, 2014; Lövbrand et al., 2017; Pichler et al., 2017; Termeer et al., 2017).

8
9 **[END BOX 4.1 HERE]**

10
11 Multilevel governance includes adaptation across local, regional, and national scales (Adger et al., 2005).
12 The whole-of-government approach to understanding and influencing climate change policy design and
13 implementation puts analytical emphasis on how different levels of government and different types of actors
14 (e.g., public and private) can constrain or support local adaptive capacity (Corfee-Morlot et al., 2011),
15 including the role of the civil society. National governments, for example, have been associated with
16 enhancing adaptive capacity through building awareness of climate impacts, encouraging economic growth,
17 providing incentives, establishing legislative frameworks conducive to adaptation, and communicating
18 climate change information (Berrang-Ford et al., 2014; Massey et al., 2014; Austin et al., 2015; Henstra,
19 2016; Massey and Huitema, 2016). Local governments, on the other hand, are responsible for delivering
20 basic services and utilities to the urban population, and protecting their integrity from the impacts of extreme
21 weather (Austin et al., 2015; Cloutier et al., 2015; Nalau et al., 2015; Araos et al., 2016b). National policies
22 and transnational governance could be seen as complementary, rather than competitors, and strong national
23 policies favour sub- and non-state actors to engage transnationally (Andonova et al., 2017). Local initiatives
24 are complementary with higher level policies and can be integrated in the multi-level governance system
25 (Fuhr et al., 2018).

26
27 A multilevel approach considers that adaptation planning is affected by scale mismatches between the local
28 manifestation of climate impacts and the diverse scales at which the problem is driven (Shi et al., 2016).
29 Multilevel approaches may be relevant in low-income countries where limited financial resources and human
30 capabilities within local governments often lead to greater dependency on national governments and other
31 (donor) organisations, to strengthen adaptation responses (Donner et al., 2016; Adenle et al., 2017). National
32 governments or international organisations may motivate urban adaptation externally through broad policy
33 directives or projects by international donors. Municipal governments on the other hand work within the city
34 to spur progress on adaptation. Individual political leadership in municipal government, for example, has
35 been cited as a factor driving adaptation policy of early adapters in Quito, Ecuador, and Durban, South
36 Africa (Anguelovski et al., 2014), and for adaptation more generally (Smith et al., 2009). Adaptation
37 pathways can help identify maladaptive actions (Juhola et al., 2016; Magnan et al., 2016; Gajjar et al., 2018)
38 and encourage social learning approaches across multiple levels of stakeholders in sectors such as marine
39 biodiversity and water supply (Bosomworth et al., 2015; Butler et al., 2015; van der Brugge and Roosjen,
40 2015).

41
42 Box 4.2 exemplifies how multilevel governance has been used for watershed management in different
43 basins, given the impacts on water sources (Section 3.4.2).

44
45 **[START BOX 4.2 HERE]**

46
47 **Box 4.2: Watershed Management in a 1.5°C World**

48
49 Water management is necessary if the global community would adapt to 1.5°C-consistent pathways.
50 Cohesive planning that includes numerous stakeholders will be required to improve access, utilisation and
51 efficiency of water use and ensure hydrologic viability.

52
53 **Response to drought and El Niño Southern Oscillation (ENSO) in Southern Guatemala**

54 Hydro-meteorological events, including the ENSO, have impacted Central America (Steinhoff et al., 2014;
55 Chang et al., 2015; Maggioni et al., 2016) and are projected to increase in frequency during a 1.5°C

1 transition (Wang et al., 2017). The 2014–2016 ENSO damaged agriculture, seriously impacting rural
2 communities.

3
4 In 2016, the Climate Change Institute, in conjunction with local governments, the private sector,
5 communities and human rights organisations, established dialogue tables for different watersheds to discuss
6 water usage amongst stakeholders and plans to mitigate the effects of drought, ameliorate social tension, and
7 map water use of watersheds at risk. The goal was to encourage better water resource management and to
8 enhance ecological flow through improved communication, transparency, and coordination amongst users.
9 These goals were achieved in 2017 when each previously affected river reached the Pacific Ocean with at
10 least its minimum ecological flow (Guerra, 2017).

11 **Drought management through the Limpopo Watercourse Commission**

12 The governments sharing the Limpopo river basin (Botswana, Mozambique, South Africa and Zimbabwe)
13 formed the Limpopo Watercourse Commission in 2003 (Nyagwambo et al., 2008; Mitchell, 2013). It has an
14 advisory body comprised of working groups that assess water use and sustainability, decides national level
15 distribution of water access, and supports disaster and emergency planning. The Limpopo basin delta is
16 highly vulnerable (Tessler et al., 2015), and is associated with a lack of infrastructure and investment
17 capacity, requiring increased economic development together with plans for vulnerability reduction (Tessler
18 et al., 2015) and water rights (Swatuk, 2015). The high vulnerability is influenced by gender inequality,
19 limited stakeholder participation and institutions to address unequal water access (Mehta et al., 2014). The
20 implementation of Integrated Water Resources Management (IWRM) would need to consider pre-existing
21 social, economic, historical and cultural contexts (Merrey, 2009; Mehta et al., 2014). The Commission
22 therefore could play a role in improving participation and in providing an adaptable and equitable strategy
23 for cross-border water sharing (Ekblom et al., 2017).

24 **Flood management in the Danube**

25
26 The Danube River Protection Convention is the official instrument for cooperation on transboundary water
27 governance between the countries that share the Danube Basin. The International Commission for the
28 Protection of the Danube River (ICPDR) provides a strong science-policy link through expert working
29 groups dealing with issues including governance, monitoring and assessment and flood protection (Schmeier,
30 2014). The Trans-National Monitoring Network (TNMN) was developed to undertake comprehensive
31 monitoring of water quality (Schmeier, 2014). Monitoring of water quality constitutes almost 50% of
32 ICPDR's scientific publications, which also works on governance, basin planning, monitoring, and IWRM,
33 indicating the importance. The ICPDR is an example of IWRM 'coordinating groundwater, surface water
34 abstractions, flood management, energy production, navigation, and water quality' (Hering et al., 2014).

35
36
37 **[END BOX 4.2 HERE]**

38
39
40
41 **[START CROSS-CHAPTER BOX 11 HERE]**

42 **Cross-Chapter Box 11: Consistency Between Nationally Determined Contributions and 1.5°C Scenarios**

43
44
45 **Authors:** Paolo Bertoldi (Italy), Michel den Elzen (Netherlands), James Ford (Canada/UK), Richard Klein
46 (Netherlands/Germany), Debora Ley (Guatemala/Mexico), Timmons Roberts (USA), Joeri Rogelj
47 (Austria/Belgium).

48 **Mitigation**

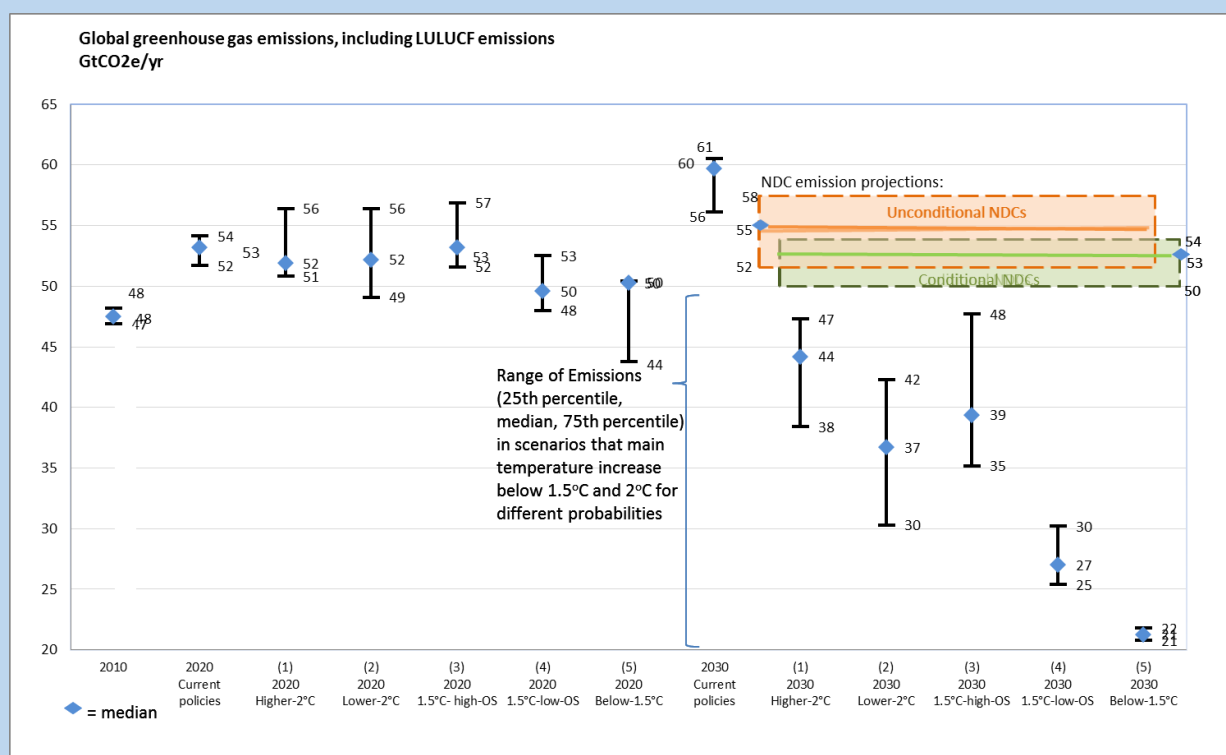
49 *1. Introduction*

50
51 There is *high agreement* that Nationally Determined Contributions (NDCs) are important for the global
52 response to climate change and represent an innovative bottom-up instrument in climate change governance
53 (Section 4.4.1), with contributions from all signatory countries (den Elzen et al., 2016; Rogelj et al., 2016;
54 Vandyck et al., 2016; Luderer et al., 2018; Vrontisi et al., 2018). The global emission projection resulting

1 from full implementation of the NDCs represent an improvement compared to business as usual (Rogelj et
 2 al., 2016) and current policies scenarios to 2030 (den Elzen et al., 2016; Vrontisi et al., 2018). Most G20
 3 economies would require new policies and actions to achieve their NDC targets (den Elzen et al., 2016;
 4 Vandyck et al., 2016; Kuramochi et al., 2017; UNEP, 2017b).

6 2. The effect of NDCs on global Greenhouse Gas (GHG) emissions

7 Several studies estimate global emission levels that would be achieved under the NDCs (e.g., den Elzen et
 8 al., 2016; Luderer et al., 2016; Rogelj et al., 2016, 2017; Vandyck et al., 2016; Rose et al., 2017; Vrontisi et
 9 al., 2018). Rogelj et al. (2016) and (UNEP, 2017b) concluded that the full implementation of the
 10 unconditional and conditional NDCs are expected to result in global GHG emissions of about 55 (52–58) and
 11 53 (50–54) GtCO₂-eq yr⁻¹, respectively (Cross-Chapter Box 11, Figure 1 below).



15
16
17 **Cross-Chapter Box 11, Figure 1:** GHG emissions are all expressed in units of CO₂-equivalence computed with 100-
 18 year Global Warming Potentials (GWPs) reported in IPCC SAR, while the emissions of the 1.5°C and 2°C scenarios in Table 2.4 are reported using the 100-
 19 year GWPs reported in IPCC AR4, and are hence about 3% higher. Using IPCC
 20 AR4 instead of SAR GWP values is estimated to result in a 2-3% increase in
 21 estimated 1.5°C and 2°C emissions levels in 2030. Source: based on Rogelj et al.
 22 (2016) and UNEP (2017b).
 23
 24

25 3. The effect of NDCs on temperature increase and carbon budget

26 Estimates of global average temperature increase are 2.9–3.4°C above preindustrial levels with a greater than
 27 66% probability by 2100 (Rogelj et al., 2016; UNEP, 2017b), under a full implementation of unconditional
 28 NDCs and a continuation of climate action similar to that of the NDCs. Full implementation of the
 29 conditional NDCs would lower the estimates by about 0.2°C by 2100. As an indication of the carbon budget
 30 implications of NDC scenarios, Rogelj et al. (2016) estimated cumulative emissions in the range of 690 to
 31 850 GtCO₂ for the period 2011–2030 if the NDCs are successfully implemented. The carbon budget for post-
 32 2010 till 2100 emissions compatible with staying below 1.5°C with a 50–66% probability was estimated at
 33 550–600 GtCO₂ (Clarke et al., 2014; Rogelj et al., 2016), which will be well exceeded by 2030 at full
 34 implementation of the NDCs. This estimate has been updated (Section 2.2 and Section 2.3.1).

4. *The 2030 emissions gap with 1.5°C and urgency of action*

As the 1.5°C pathways require reaching carbon neutrality by mid-century, the NDCs alone are not sufficient, as they have a time horizon until 2030. (Rogelj et al., 2016; Hof et al., 2017) have used results or compared NDC pathways with emissions pathways produced by Integrated Assessment Models (IAMs) assessing the contribution of NDCs to achieve the 1.5°C targets. There is *high agreement* that current NDC emission levels are not in line with pathways that limit warming to 1.5°C by the end of the century (Rogelj et al., 2016, 2017; Hof et al., 2017; UNEP, 2017b; Vrontisi et al., 2018). The median 1.5°C emissions gap (>66% chance) for the full implementation of both the conditional and unconditional NDCs for 2030 is 26 (19–29) to 28 (22–33) GtCO₂-eq (Cross-Chapter Box 11, Figure 1 above).

Studies indicate important trade-offs of delaying global emissions reductions (Sections 2.3.5 and 2.5.1). AR5 identified flexibility in 2030 emission levels when pursuing a 2°C objective (Clarke et al., 2014) indicating that strongest trade-offs for 2°C pathways could be avoided if emissions are limited to below 50 GtCO₂-eq yr⁻¹ in 2030 (here computed with the GWP-100 metric of the IPCC SAR). New scenario studies show that full implementation of the NDCs by 2030 would imply much deeper and faster emission reductions beyond 2030 in order to meet 2°C, and also higher costs and efforts of negative emissions (Fujimori et al., 2016; Sanderson et al., 2016; Rose et al., 2017; van Soest et al., 2017; Luderer et al., 2018). However, no flexibility has been found for 1.5°C pathways (Luderer et al., 2016; Rogelj et al., 2017) indicating that post-2030 emissions reductions required to remain within a 1.5°C compatible carbon budget during the 21st century (Section 2.2) are not within the feasible operating space of IAMs. This indicates that failing to reach a 1.5°C pathway are significantly increased (Riahi et al., 2015), if near-term ambition is not strengthened beyond the level implied by current NDCs.

Accelerated and stronger short-term action and enhanced longer-term national ambition going beyond the NDCs would be needed for 1.5°C-consistent pathways. Implementing deeper emissions reduction than current NDCs would imply action towards levels identified in Section 2.3.3, either as part of or over-delivering on NDCs.

5. *The impact of uncertainties on NDC emission levels*

The measures proposed in NDCs are not legally binding (Nemet et al., 2017), further impacting estimates of anticipated 2030 emission levels. The aggregation of targets results in high uncertainty (Rogelj et al., 2017), which could be reduced with clearer guidelines for compiling future NDCs focused more on energy accounting (Rogelj et al., 2017) and increased transparency and comparability (Pauw et al., 2018).

Many factors would influence NDCs global aggregated effects, including: (1) variations in socioeconomic conditions, (Gross Domestic Product, GDP, and population growth), (2) uncertainties in historical emission inventories, (3) conditionality of certain NDCs, (4) definition of NDC targets as ranges instead of single values, (5) the way in which renewable energy targets are expressed, and (6) the way in which traditional biomass use is accounted for. Additionally, there are land-use mitigation uncertainties (Forsell et al., 2016; Grassi et al., 2017). Land-use options play a key role in many country NDCs, however, many analyses on NDCs do not use country estimates on land-use emissions, but use model estimates, mainly because of the large difference in estimating the "anthropogenic" forest sink between countries and models (Grassi et al., 2017).

7. *Comparing countries' NDC ambition (equity, cost optimal allocation and other indicators)*

Various assessment frameworks have been proposed to analyse, benchmark and compare NDCs, and indicate possible strengthening, based on equity and other indicators (Aldy et al., 2016; den Elzen et al., 2016; Höhne et al., 2017; Jiang et al., 2017; Holz et al., 2018). There is large variation in conformity/fulfillment with equity principles across NDCs and countries. Studies use assessment frameworks based on six effort sharing categories in the AR5 (Clarke et al., 2014) with the principles of 'responsibility', 'capability' and 'equity' (Höhne et al., 2017; Pan et al., 2017; Robiou du Pont et al., 2017). There is an important methodological gap in the assessment of the NDCs' fairness and equity implications, partly due to lack of information on countries' own assessment (Winkler et al., 2017). Implementation of Article 2.2 of the Paris Agreement could reflect equity and the principle of common but differentiated

responsibilities and respective capabilities, due to different national circumstances and different interpretations of equity principles (Lahn, 2017; Lahn and Sundqvist, 2017).

Adaptation

The Paris Agreement recognises adaptation by establishing a global goal for adaptation (Kato and Ellis, 2016; Rajamani, 2016; Kinley, 2017; Lesnikowski et al., 2017; UNEP, 2017a). This is assessed qualitatively, as achieve a temperature goal, would determine the level of ambition of addressing adaptation to consequent risks and impacts (Rajamani, 2016). Countries can include domestic adaptation goals in their NDCs, which together with National Adaptation Plans (NAPs) give countries flexibility to design and adjust their adaptation trajectories as their needs evolve and as progress is evaluated over time. A challenge for assessing progress on adaptation globally is the aggregation of many national adaptation actions and approaches. Knowledge gaps still remain about how to design measurement frameworks that generate and integrate national adaptation data without placing undue burdens on countries (UNEP, 2017a).

The Paris Agreement stipulates that adaptation communications shall be submitted as a component of or in conjunction with other communications, such as an NDC, a NAP, or a National Communication. Of the 197 Parties to the UNFCCC, 140 NDCs have an adaptation component, almost exclusively from developing countries. NDC adaptation components could be an opportunity for enhancing adaptation planning and implementation by highlighting priorities and goals (Kato and Ellis, 2016). At the national level they provide momentum for the development of NAPs and raise the profile of adaptation (Pauw et al., 2016b, 2018). The Paris Agreement's transparency framework includes adaptation, through which 'adaptation communication' and accelerated adaptation actions are submitted and reviewed every five years (Hermwille, 2016; Kato and Ellis, 2016). This framework, unlike others used in the past, is applicable to all countries taking into account differing capacities amongst Parties (Rajamani, 2016).

Adaptation measures presented in qualitative terms include sectors, risks and vulnerabilities that are seen as priorities by the Parties. Sectoral coverage of adaptation actions identified in NDCs is uneven, with adaptation primarily reported to focus on the water sector (71% of NDCs with adaptation component), agriculture (63%), and health (54%), and biodiversity/ecosystems (50%) (Pauw et al., 2016b, 2018).

[END CROSS-CHAPTER BOX 11 HERE]

4.4.2 *Enhancing Institutional Capacities*

The implementation of sound responses and strategies to enable a transition to 1.5°C world would require strengthening governance and scaling up institutional capacities, particularly in developing countries (Adenle et al., 2017; Rosenbloom, 2017). Building on the characterisation of governance in Section 4.4.1, this section examines the necessary institutional capacity to implement actions to limit warming to 1.5°C and adapt to the consequences. This takes into account a plurality of regional and local responses, as institutional capacity is highly context-dependent (North, 1990; Lustick et al., 2011).

Institutions would need to interact with one another and align across scales to ensure that rules and regulations are followed (Chaffin and Gunderson, 2016; Young, 2016). The institutional architecture required for a 1.5°C world would include the growing proportion of the world's population that live in peri-urban and informal settlements and engage in informal economic activity (Simone and Pieterse, 2017). This population, amongst the most exposed to perturbed climates in the world (Hallegatte et al., 2017), is also beyond the direct reach of some policy instruments (Jaglin, 2014; Thieme, 2017). Strategies that accommodate the informal rules of the game adopted by these populations have large chances of success (McGranahan et al., 2016; Kaika, 2017).

The goal for strengthening implementation is to ensure that these rules and regulations embrace equity, equality and poverty alleviation along 1.5°C-consistent pathways (mitigation) and enables the building of

1 adaptive capacity that together, will enable sustainable development and poverty reduction.

2
3 Rising to the challenge of a transition to a 1.5°C world would require enhancing institutional climate change
4 capacities along multiple dimensions presented below.

7 *4.4.2.1 Capacity for Policy Design and Implementation*

8
9 The enhancement of institutional capacity for integrated policy design and implementation has long been
10 among the top items on the UN agenda of addressing global environmental problems and sustainable
11 development (UNEP, 2005) (see Section 5.5).

12
13 Political stability, an effective regulatory and enforcement framework (e.g., institutions to impose sanctions,
14 collect taxes and to verify building codes), access to a knowledge base and the availability of resources,
15 would be needed at various governance levels, to address a wide range of stakeholders, and their concerns.
16 The strengthening of the global response would need to support these with different interventions, in the
17 context of sustainable development (Pasquini et al., 2015) (Section 5.5.1).

18
19 Given the scale of change needed to achieve 1.5°C, strengthening the response capacity of relevant
20 institutions are best addressed in ways that take advantage of existing decision-making processes in local and
21 regional governments and within cities and communities (Romero-Lankao et al., 2013), and draw upon
22 diverse knowledge sources including Indigenous and local knowledge (Nakashima et al., 2012; Smith and
23 Sharp, 2012; Mistry and Berardi, 2016; Tschakert et al., 2017). Examples of successful local institutional
24 processes and the integration of local knowledge in climate-related decisions making are provided in Box 4.3
25 and Box 4.4.

26
27 Implementing 1.5°C-relevant strategies would require well-functioning legal frameworks to be in place, in
28 conjunction with clearly defined mandates, rights and responsibilities to enable the institutional capacity to
29 deliver (Romero-Lankao et al., 2013). As an example, current rates of urbanisation occurring in cities with a
30 lack of institutional capacity for effective land-use planning, zoning and infrastructure development, result in
31 unplanned, informal urban settlements which are vulnerable to climate impacts. It is common for 30–50% of
32 urban populations in low-income nations to live in informal settlements with no regulatory infrastructure
33 (Revi et al., 2014b). For example, in Huambo (Angola), a classified ‘urban’ area extends 20km west of the
34 city and is predominantly made up of ‘unplanned’ urban settlements (Smith and Jenkins, 2015).

35
36 Internationally, the Paris Agreement process has aimed at enhancing the capacity of decision-making
37 institutions in developing countries to support effective implementation. These efforts are particularly
38 reflected in Article 11 of the Paris Agreement on capacity building (the creation of the Paris Committee on
39 Capacity Building), Article 13 (the creation of the Capacity Building Initiative on Transparency), as well as
40 Article 15 on compliance (UNFCCC, 2015).

41
42 **[START BOX 4.3 HERE]**

44 **Box 4.3: Indigenous Knowledge and Community Adaptation**

45
46 Indigenous knowledge refers to the understandings, skills and philosophies developed by societies with long
47 histories of interaction with their natural surroundings (UNESCO, 2017). This knowledge can underpin the
48 development of adaptation and mitigation strategies (Ford et al., 2014b; Green and Minchin, 2014; Pearce et
49 al., 2015; Savo et al., 2016).

50
51 Climate change is an important concern for the Maya, who depend on climate knowledge for their
52 livelihood. In Guatemala, the collaboration between the Mayan K'iché population of the Nahualate river
53 basin and the Climate Change Institute has resulted in a catalogue of Indigenous knowledge, used to identify
54 indicators for watershed meteorological forecasts (Yax L. and Álvarez, 2016). These indicators are relevant
55 but would need continuous assessment if their continued reliability is to be confirmed (Nyong et al., 2007;

Alexander et al., 2011; Mistry and Berardi, 2016). For more than ten years, Guatemala has maintained an ‘Indigenous Table for Climate Change’, to enable the consideration of indigenous knowledge in disaster management and adaptation development.

In Tanzania, increased variability of rainfall is challenging Indigenous and local communities (Mahoo et al., 2015; Sewando et al., 2016). The majority of agro-pastoralists use Indigenous knowledge to forecast seasonal rainfall, relying on observations of plant phenology, bird, animal, and insect behaviour, the sun and moon, and wind (Chang'a et al., 2010; Elia et al., 2014; Shaffer, 2014). Increased climate variability has raised concerns about the reliability of these indicators (Shaffer, 2014), therefore, initiatives have focused on the co-production of knowledge, through involving local communities in monitoring and discussing the implications of indigenous knowledge and meteorological forecasts (Shaffer, 2014), and creating local forecasts by utilising the two sources of knowledge (Mahoo et al., 2013). This has resulted in increased documentation of Indigenous knowledge, understanding of relevant climate information amongst stakeholders, and adaptive capacity at the community-level (Mahoo et al., 2013, 2015; Shaffer, 2014).

The Pacific Islands and Small Island Developing States (SIDS) are vulnerable to the effects of climate change, but the cultural resilience of Pacific Island inhabitants is also recognized (Nunn et al., 2017). In Fiji and Vanuatu, strategies used to prepare for cyclones include building reserve emergency supplies, and utilising farming techniques to ensure adequate crop yield to combat potential losses from a cyclone or drought (McNamara and Prasad, 2014; Granderson, 2017; Pearce et al., 2017). Social cohesion and kinship are important in responding and preparing for climate-related hazards, including the role of resource sharing, communal labour, and remittances (McMillen et al., 2014; Gawith et al., 2016; Granderson, 2017). There is a concern that Indigenous knowledge will weaken, a process driven by westernisation and disruptions in established bioclimatic indicators and traditional planning calendars (Granderson, 2017). In some urban settlements, it has been noted that cultural practices (e.g., prioritising the quantity of food over the quality of food) can lower food security through dispersing limited resources and by encouraging the consumption of cheap but nutrient-poor foods (Mccubbin et al., 2017) (See Cross-Chapter Box 6 on Food Security in Chapter 3). Indigenous practices also encounter limitations, particularly in relating to sea level rise (Nunn et al., 2017).

[END BOX 4.3 HERE]

[START BOX 4.4 HERE]

Box 4.4: Manizales, Colombia: Supportive National Government and Localised Planning and Integration as an Enabling Condition for Managing Climate and Development Risks

Institutional reform in the city of Manizales, Colombia helps identify three important features of an enabling environment: integrating climate change adaptation, mitigation and disaster risk management at the city-scale; the importance of decentralised planning and policy formulation within a supportive national policy environment; and the role of a multi-sectoral framework in mainstreaming climate action in development activities.

Manizales is exposed to risks caused by rapid development and expansion in a mountainous terrain exposed to seismic activity and periodic wet and dry spells. Local assessments expect climate change to amplify the risk of disasters (Carreño et al., 2017). The city is widely recognised for its longstanding urban environmental policy (Biomanizales) and local environmental action plan (Bioplan), and has been integrating environmental planning in its development agenda for nearly two decades (Velásquez Barrero, 1998; Hardoy and Velásquez Barrero, 2014). When the city’s environmental agenda was updated in 2014 to reflect climate change risks, assessments were conducted in a participatory manner at the street and neighbourhood level (Hardoy and Velásquez Barrero, 2016).

The creation of a new Environmental Secretariat assisted in coordination and integration of environmental policies, disaster risk management, development and climate change (Leck and Roberts, 2015).

Planning in Manizales remains mindful of steep gradients, through its longstanding Slope Guardian

1 programme that trains women and keeps records of vulnerable households. Planning also looks to include
2 mitigation opportunities and enhance local capacity through participatory engagement (Hardoy and
3 Velásquez Barrero, 2016).

4
5 Manizales' mayors were identified as important champions for much of these early integration and
6 innovation efforts. Their role may have been enabled by Colombia's history of decentralised approaches to
7 planning and policy formulation, including establishing environmental observatories (for continuous
8 environmental assessment) and participatory tracking of environmental indicators. Multi-stakeholder
9 involvement has both enabled and driven progress, and has enabled the integration of climate risks in
10 development planning (Hardoy and Velásquez Barrero, 2016).

11
12 **[END BOX 4.4 HERE]**

13 14 15 4.4.2.2 *Monitoring, Reporting, and Review Institutions*

16
17 One of the novel features of the new climate governance architecture emerging from the 2015 Paris
18 Agreement is the transparency framework in Article 13 committing countries, based on capacity, to provide
19 regular progress reports on national pledges to address climate change (UNFCCC, 2015). Many countries
20 will rely on public policies and existing national reporting channels to deliver on their NDCs under the Paris
21 Agreement. Scaling up the mitigation and adaptation efforts in these countries to be consistent with 1.5°C
22 would put significant pressure on the need to develop, enhance and streamline local, national and
23 international climate change reporting and monitoring methodologies and institutional capacity in relation to
24 mitigation, adaptation, finance, and Greenhouse Gases (GHGs) inventories (Ford et al., 2015b; Lesnikowski
25 et al., 2015; Schoenefeld et al., 2016). Consistent with this direction, the provision of the information to the
26 stocktake under Article 14 of the Paris Agreement would contribute to enhancing reporting and transparency
27 (UNFCCC, 2015). Nonetheless, approaches, reporting procedures, reference points, and data sources to
28 assess progress on implementation across and within nations are still largely underdeveloped (Ford et al.,
29 2015b; Araos et al., 2016b; Magnan and Ribera, 2016; Lesnikowski et al., 2017). The availability of
30 independent private and public reporting and statistical institutions is integral to oversight, effective
31 monitoring, reporting and review. The creation and enhancement of these institutions would be an important
32 contribution to an effective transition to a low-emission world.

33 34 35 4.4.2.3 *Financial Institutions*

36
37 IPCC AR5 assessed that to enable a transition to a 2°C pathway, the volume of climate investments would
38 need to be transformed along with changes in the pattern of general investment behaviour towards low-
39 emissions. The report argued that, compared to 2012, annually up to a trillion dollars in additional
40 investment in low-emission energy and energy efficiency measures may be required until 2050 (Blanco et
41 al., 2014; IEA, 2014a). Financing of 1.5°C would present an even greater challenge, addressing financing of
42 both existing and new assets, which would require significant transitions to the type and structure of
43 financial institutions as well as to the method of financing (Cochrani et al., 2014; Ma, 2014). Both public and
44 private financial institutions would be needed to contribute to the large resource mobilisation needed for
45 1.5°C, yet, in the ordinary course of business, these transitions may not be expected. On one hand, private
46 financial institutions could face the scale-up risk, for example the risks associated with commercialisation
47 and scaling up of renewable technologies to accelerate mitigation (Wilson, 2012; Hartley and Medlock,
48 2013) and/or price risk, such as carbon price volatility that carbon markets could face. In contrast, traditional
49 public financial institutions are limited by both structure and instruments, while concessional financing
50 would require taxpayer support for subsidisation. Special efforts and innovative approaches would be needed
51 to address these challenges, for example the creation of special institutions that underwrite the value of
52 emission reductions using auctioned price floors (Bodnar et al., 2018) to deal with price volatility.

53
54 Financial institutions are equally important for adaptation. Linnerooth-Bayer and Hochrainer-Stigler (2015)
55 discuss the benefits of financial instruments in adaptation, including the provision of post-disaster finances

1 for recovery and pre-disaster security necessary for climate adaptation and poverty reduction. Pre-disaster
2 financial instruments and options include insurance, such as index-based weather insurance schemes,
3 catastrophe bonds, and laws to encourage insurance purchasing. The development and enhancement of
4 microfinance institutions to ensure social resilience and smooth transitions in the adaptation to climate
5 change impacts could be an important local institutional innovation (Hammill et al., 2008).

8 *4.4.2.4 Co-Operative Institutions and Social Safety Nets*

10 Effective co-operative institutions and social safety nets may help address energy access, adaptation, as well
11 as distributional impacts during the transition to 1.5°C-consistent pathways and enabling sustainable
12 development. Not all countries have the institutional capabilities to design and manage these. Social capital
13 for adaptation in the form of bonding, bridging, and linking social institutions has proved to be effective in
14 dealing with climate crises at the local, regional, and national levels (Aldrich et al., 2016).

16 The shift towards sustainable energy systems in transitioning economies could impact the livelihoods of
17 large populations, in traditional and legacy employment sectors. The transition of selected EU Member
18 States to biofuels, for example, caused anxiety among farmers, who lacked confidence in the biofuel crop
19 market. Enabling contracts between farmers and energy companies, involving local governments, helped
20 create an atmosphere of confidence during the transition (McCormick and Käberger, 2007).

22 How do broader socio-economic processes influence urban vulnerabilities and thereby underpin climate
23 change adaptation? This is a systemic challenge originating from a lack of collective societal ownership of
24 the responsibility for climate risk management. Numerous explanations, help explain this from competing
25 time-horizons due to self-interest of stakeholders to a more ‘rational’ conception of risk assessment,
26 measured across a risk-tolerance spectrum (Moffatt, 2014).

28 Self-governing and self-organised institutional settings where equipment and resource systems are
29 commonly owned and managed can potentially generate a much higher diversity of administration solutions,
30 than other institutional arrangements where energy technology and resource systems are either owned and
31 administered individually in market settings or via a central authority (e.g., the state). They can also increase
32 the adaptability of technological systems, while reducing their burden on the environment (Labanca, 2017).
33 Educational, learning and awareness-building institutions can help strengthen the societal response to climate
34 change (Butler et al., 2016; Thi Hong Phuong et al., 2017).

37 *4.4.3 Enabling Lifestyle and Behavioural Change*

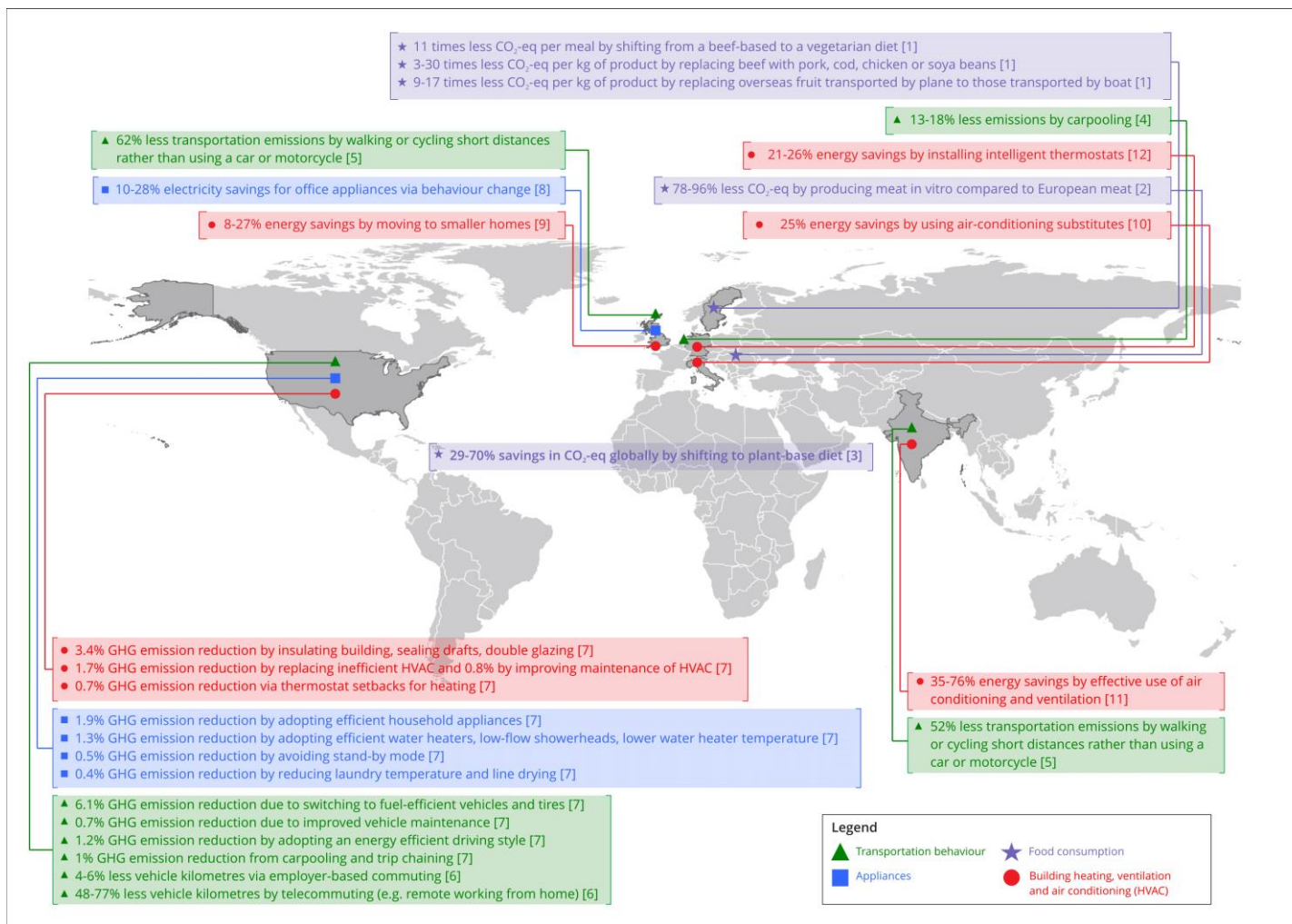
39 Humans are at the centre of global climate change: their actions cause anthropogenic climate change, and
40 social change is key to effectively respond to climate change (Vlek and Steg, 2007; Dietz et al., 2013; ISSC
41 and UNESCO, 2013; Hackmann et al., 2014). Chapter 2 shows that 1.5°C-consistent pathways assume
42 substantial changes in behaviour. This section assesses the potential of behaviour change, as the Integrated
43 Assessment Models (IAMs) applied in Chapter 2 do not comprehensively assess this potential.

45 Table 4.8 shows examples of mitigation and adaptation actions relevant for 1.5°C-consistent pathways.
46 Reductions in population growth can reduce overall carbon demand and mitigate climate change
47 (Bridgeman, 2017), particularly when population growth is accompanied with increases in affluence and
48 carbon-intensive consumption (Rosa and Dietz, 2012; Clayton et al., 2017). Mitigation actions with a
49 substantial carbon emission reduction potential (see Figure 4.3) that individuals may readily adopt would
50 have the most climate impact (Dietz et al., 2009).

1 **Table 4.8:** Examples of mitigation and adaptation behaviours relevant for 1.5°C (Dietz et al., 2009; Jabeen, 2014;
 2 Taylor et al., 2014; Araos et al., 2016b; Steg, 2016; Stern et al., 2016b; Creutzig et al., 2018)
 3

Climate action	Type of action	Examples
Mitigation	Implementing resource efficiency in building	Insulation Low-carbon building materials
	Adopting low-emission innovations	Electric vehicles Heat pumps, district heating and cooling
	Adopting energy efficient appliances	Energy-efficient heating or cooling Energy-efficient appliances
	Energy-saving behaviour	Walking or cycling rather than drive short distances Using mass transit rather than flying Lower temperature for space heating Line drying of laundry Reducing food waste
	Buying products and materials with low GHG emissions during production and transport	Reducing meat and dairy consumption Buying local, seasonal food Replacing aluminium products by low-GHG alternatives
	Organisational behaviour	Designing low-emission products and procedures Replacing business travel by videoconferencing
Adaptation	Growing different crops and raising different animal varieties	Using crops with higher tolerance for higher temperatures or CO ₂ elevation
	Flood protective behaviour	Elevating barriers between rooms Building elevated storage spaces Building drainage channels outside the home
	Heat protective behaviour	Staying hydrated Moving to cooler places Installing green roofs
	Efficient water use during water shortage crisis	Rationing water Constructing wells or rainwater tanks
Mitigation & adaptation	Adoption of renewable energy sources	Solar PV Solar water heaters
	Citizenship behaviour	Engage through civic channels to encourage or support planning for low-carbon climate-resilient development

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Figure 4.3: Examples of mitigation behaviour and their GHG emission reduction potential. Mitigation potential assessments are printed in different units. Based on [1] Carlsson-Kanyama and González (2009); [2] Tuomisto and Teixeira de Mattos (2011); [3] Springmann et al. (2016); [4] Nijland and Meerkerk (2017); [5] Woodcock et al. (2009); [6] Salon et al. (2012); [7] Dietz et al. (2009); [8] Mulville et al. (2017); [9] Huebner and Shipworth (2017); [10] Jaboyedoff et al. (2004); [11] Pellegrino et al. (2016); [12] Nägele et al. (2017).

1 Various policy approaches and strategies can encourage and enable climate actions by individuals and
2 organisations. Policy approaches would be more effective when they address key contextual and psycho-
3 social factors influencing climate actions, which differ across contexts and individuals (Steg and Vlek, 2009;
4 Stern, 2011). This suggests that diverse policy approaches would be needed in 1.5°C-consistent pathways in
5 different contexts and regions. Combinations of policies that target multiple barriers and enabling factors
6 simultaneously can be more effective (Nissinen et al., 2015).

7
8 In the US and Europe, GHG emissions are lower when legislators have strong environmental records (Jensen
9 and Spoon, 2011; Dietz et al., 2015). Political elites affect public concern about climate change: pro-climate
10 action statements increased concern, while anti-climate action statements and anti-environment voting
11 reduced public concern about climate change (Brulle et al., 2012). In the European Union, individuals worry
12 more about climate change and engage more in climate actions in countries where political party elites are
13 united rather than divided in their support for environmental issues (Sohlberg, 2017).

14
15 This section discusses how to enable and encourage behaviour and lifestyle changes that strengthen
16 implementation of 1.5°C-consistent pathways by assessing psycho-social factors related to climate action, as
17 well as the effects and acceptability of policy approaches targeting climate actions that are consistent with
18 1.5°C. Box 4.5 and Box 4.6 illustrate how these have worked in practice.

19 20 21 *4.4.3.1 Factors Related to Climate Actions*

22
23 Mitigation and adaptation behaviour is affected by many factors that shape which options are feasible and
24 considered by individuals. Besides contextual factors (see other sub-sections in Section 4.4), these include
25 abilities and different types of motivation to engage in behaviour.

26 27 *4.4.3.1.1 Ability to engage in climate action*

28 Individuals more often engage in adaptation (Gebrehiwot and van der Veen, 2015; Koerth et al., 2017) and
29 mitigation behaviour (Pisano and Lubell, 2017) when they are or feel more capable to do so. Hence, it is
30 important to enhance ability to act on climate change, which depends on income and knowledge, among
31 other things. A higher income is related to higher CO₂ emissions; higher income groups can afford more
32 carbon-intensive lifestyles (Lamb et al., 2014; Dietz et al., 2015; Wang et al., 2015). Yet, low-income groups
33 may lack resources to invest in energy efficient technology and refurbishments (Andrews-Speed and Ma,
34 2016) and adaptation options (Wamsler, 2007; Fleming et al., 2015b; Takahashi et al., 2016). Adaptive
35 capacity further depends on gender roles (Jabeen, 2014; Bunce and Ford, 2015), technical capacities and
36 knowledge (Feola et al., 2015; Eakin et al., 2016; Singh et al., 2016b).

37
38 Knowledge of the causes and consequences of climate change and on ways to reduce GHG emissions is not
39 always accurate (Bord et al., 2000; Whitmarsh et al., 2011; Tobler et al., 2012), which can inhibit climate
40 actions, even when people would be motivated to act. For example, people overestimate savings from low-
41 energy activities, and underestimate savings from high-energy activities (Attari et al., 2010). They know
42 little about ‘embodied’ energy (i.e., energy needed to produce products; Tobler et al., 2011), including meat
43 (de Boer et al., 2016b). Some people mistake weather for climate (Reynolds et al., 2010), or conflate climate
44 risks with other hazards, which can inhibit adequate adaptation (Taylor et al., 2014).

45
46 More knowledge on adaptation is related to higher engagement in adaptation actions in some circumstances
47 (Bates et al., 2009; van Kasteren, 2014; Hagen et al., 2016). How adaptation is framed in the media can
48 influence the types of options viewed as important in different contexts (Boykoff et al., 2013; Moser, 2014;
49 Ford and King, 2015).

50
51 Knowledge is important, but is often not sufficient to motivate action (Trenberth et al., 2016). Climate
52 change knowledge and perceptions are not strongly related to mitigation actions (Hornsey et al., 2016).
53 Direct experience of events related to climate change influences climate concerns and actions (Blennow et
54 al., 2012; Taylor et al., 2014), more so than second-hand information (Spence et al., 2011; Myers et al.,

1 2012; Demski et al., 2017); high impact events with low frequency are remembered more than low impact
2 regular events (Meze-Hausken, 2004; Singh et al., 2016b; Sullivan-Wiley and Short Gianotti, 2017).
3 Personal experience with climate hazards strengthens motivation to protect oneself (Jabeen, 2014) and
4 enhances adaptation actions (Bryan et al., 2009; Berrang-Ford et al., 2011; Demski et al., 2017), although
5 this does not always translate into proactive adaptation (Taylor et al., 2014). Collectively constructed notions
6 of risk and expectations of future climate variability shape risk perception and adaptation behaviour (Singh
7 et al., 2016b). People with particular political views and those who emphasise individual autonomy may
8 reject climate science knowledge and believe that there is widespread scientific disagreement about climate
9 change (Kahan, 2010; O'Neill et al., 2013), inhibiting support for climate policy (Ding et al., 2011;
10 McCright et al., 2013). This may explain why extreme weather experiences enhances preparedness to reduce
11 energy use among left- but not right-leaning voters (Ogunbode et al., 2017).

14 4.4.3.1.2 *Motivation to engage in climate action*

15 Climate actions are more strongly related to motivational factors, reflecting individuals' reasons for actions,
16 such as values, ideology and worldviews than to knowledge (Hornsey et al., 2016). People consider various
17 types of costs and benefits of actions (Gözl and Hahnel, 2016), and focus on consequences that have
18 implications for the values they find most important (Dietz et al., 2013; Hahnel et al., 2015; Steg, 2016). This
19 implies that different individuals consider different consequences when making choices. People who
20 strongly value protecting the environment and other people generally more strongly consider climate impact
21 and act more on climate change than those who strongly endorse hedonic and egoistic values (Taylor et al.,
22 2014; Steg, 2016). People are more prone to adopt sustainable innovations when they are more open to new
23 ideas (Jansson, 2011; Wolske et al., 2017). Further, a free-market ideology is associated with weaker climate
24 change beliefs (McCright and Dunlap, 2011; Hornsey et al., 2016), and a capital-oriented culture tends to
25 promote activity associated with GHG emissions (Kasser et al., 2007).

27 Some Indigenous populations believe it is arrogant to predict the future, and some cultures have belief
28 systems that interpret natural phenomena as sentient, where thoughts and words are believed to influence the
29 future, with people reluctant to talk about negative future possibilities (Natcher et al., 2007; Flynn et al.,
30 2018). Integrating these considerations into the design of adaptation and mitigation policy is important
31 (Cochran et al., 2013; Chapin et al., 2016; Brugnach et al., 2017; Flynn et al., 2018).

33 People are more prone to act on climate change when individual benefits of actions exceed costs (Steg and
34 Vlek, 2009; Kardooni et al., 2016; Wolske et al., 2017). For this reason, people generally prefer adoption of
35 energy-efficient appliances above energy consumption reductions; the latter is perceived as more costly
36 (Poortinga et al., 2003; Steg et al., 2006), although transaction costs can inhibit the uptake of mitigation
37 technology (Mundaca, 2007). Decentralised renewable energy systems are evaluated most favourably when
38 they guarantee independence, autonomy, control and supply security (Ecker, 2017).

40 Besides, social costs and benefits affect climate action (Farrow et al., 2017). People engage more in climate
41 actions when they think others expect them to do so and when others act as well (Nolan et al., 2008; Le Dang
42 et al., 2014; Truelove et al., 2015; Rai et al., 2016), and when they experience social support (Singh et al.,
43 2016a; Burnham and Ma, 2017; Wolske et al., 2017). Discussing effective actions with peers also
44 encourages climate action (Esham and Garforth, 2013), particularly when individuals strongly identify with
45 their peers (Biddau et al., 2012; Fielding and Hornsey, 2016). Further, individuals may engage in mitigation
46 actions when they think doing so would enhance their reputation (Milinski et al., 2006; Noppers et al., 2014;
47 Kastner and Stern, 2015). Such social costs and benefits can be addressed in climate policy (see Section
48 4.4.3.2).

50 Feelings affect climate action (Brosch et al., 2014). Negative feelings related to climate change can
51 encourage adaptation action (Kerstholt et al., 2017; Zhang et al., 2017), while positive feelings associated
52 with climate risks may inhibit protective behaviour (Lefevre et al., 2015). Individuals are more prone to
53 engage in mitigation actions when they worry about climate change (Verplanken and Roy, 2013), and when
54 they expect to derive positive feelings from such actions (Pelletier et al., 1998; Taufik et al., 2016).

1 Furthermore, collective consequences affect climate actions (Balcombe et al., 2013; Dóci and Vasileiadou,
2 2015; Kastner and Stern, 2015). People are motivated to see themselves as morally right, which encourages
3 mitigation actions (Steg et al., 2015), particularly when long-term goals are salient (Zaval et al., 2015) and
4 behavioural costs are not too high (Diekmann and Preisendörfer, 2003). Individuals are more prone to
5 engage in climate actions when they believe climate change is occurring, when they are aware of threats
6 caused by climate change and by their inaction, and when they think they can engage in actions that will
7 reduce these threats (Esham and Garforth, 2013; Arunrat et al., 2017; Chatrchyan et al., 2017). The more
8 individuals are concerned about climate change and aware of the negative climate impact of their behaviour,
9 the more they feel responsible for and think their actions can help reduce such negative impacts, which can
10 strengthen their moral norms to act accordingly (Steg and de Groot, 2010; Jakovcevic and Steg, 2013; Chen,
11 2015; Ray et al., 2017; Wolske et al., 2017; Woods et al., 2017). Individuals may engage in mitigation
12 actions when they see themselves as supportive of the environment (i.e. strong environmental self-identity)
13 (Fielding et al., 2008; van der Werff et al., 2013b; Kashima et al., 2014; Barbarossa et al., 2017); a strong
14 environmental identity strengthens intrinsic motivation to engage in mitigation actions both at home (van der
15 Werff et al., 2013a) and at work (Ruepert et al., 2016). Environmental self-identity is strengthened when
16 people realise they engaged in mitigation actions, which can in turn promote further mitigation actions (van
17 der Werff et al., 2014b).

18
19 Individuals are less prone to engage in adaptation behaviour themselves when they rely on external measures
20 such as government interventions (Grothmann and Reusswig, 2006; Wamsler and Brink, 2014a; Armah et
21 al., 2015; Burnham and Ma, 2017) or perceive themselves as protected by god (Gandure et al., 2013; Dang et
22 al., 2014; Cannon, 2015).

23 24 25 4.4.3.1.3 *Habits, heuristics and biases*

26 Decisions are often not based on weighing costs and benefits, but on habit or automaticity, both of
27 individuals (Aarts and Dijksterhuis, 2000; Kloeckner et al., 2003) and within organisations (Dooley, 2017)
28 and institutions (Munck et al., 2014). When habits are strong, individuals are less perceptive of information
29 (Verplanken et al., 1997; Aarts et al., 1998), and may not consider alternatives as long as outcomes are good
30 enough (Maréchal, 2010). Habits are mostly only reconsidered when the situation changed significantly
31 (Fujii and Kitamura, 2003; Maréchal, 2010; Verplanken and Roy, 2016). Hence, strategies that create the
32 opportunity for reflection and encourage active decisions can break habits (Steg et al., 2017).

33
34 Individuals can follow heuristics, or ‘rules of thumb’, in making inferences rather than thinking through all
35 implications of actions, which demands less cognitive resources, knowledge and time (Preston et al., 2013;
36 Frederiks et al., 2015; Gillingham and Palmer, 2017). For example, people tend to think that larger and
37 visible appliances use more energy, which is not always accurate (Cowen and Gatersleben, 2017). They
38 underestimate energy used for water heating and overestimate energy used for lighting (Stern, 2014). When
39 facing choice overload, people may choose the easiest or first available option, which can inhibit energy
40 saving behaviour (Stern and Gardner, 1981; Frederiks et al., 2015). As a result, individuals and firms often
41 strive for satisficing (‘good enough’) outcomes with regard to energy decisions (Wilson and Dowlatabadi,
42 2007; Klotz, 2011), which can inhibit investments in energy efficiency (Decanio, 1993; Frederiks et al.,
43 2015).

44
45 Besides, biases play a role. In Mozambique, farmers displayed omission biases (unwillingness to take
46 adaptation actions with potentially negative consequences to avoid personal responsibility for losses), while
47 policymakers displayed action biases (wanting to demonstrate positive action despite potential negative
48 consequences; Patt and Schröter, 2008). People tend to place greater value on relative losses than gains
49 (Kahneman, 2003). Perceived gains and losses depend on the reference point or status-quo (Kahneman,
50 2003). Loss aversion and the status-quo bias prevent consumers from switching electricity suppliers (Ek and
51 Söderholm, 2008), to time-of-use electricity tariffs (Nicolson et al., 2017), and to accept new energy systems
52 (Leijten et al., 2014).

53
54 Owned inefficient appliances and fossil fuel-based electricity can act as endowments, increasing their value
55 compared to alternatives (Pichert and Katsikopoulos, 2008; Dinner et al., 2011). Uncertainty and loss

1 aversion lead consumers to undervalue future energy savings (Greene, 2011) and savings from energy
2 efficient technologies (Kolstad et al., 2014). Uncertainties about the performance of products and illiquidity
3 of investments can drive consumers to postpone (profitable) energy efficient investments (Sutherland, 1991;
4 van Soest and Bulte, 2001). People with a higher tendency to delay decisions may engage less in energy
5 saving actions (Lillemo, 2014). Training energy auditors in loss-aversion increased their clients' investments
6 in energy efficiency improvements (Gonzales et al., 1988). Engagement in energy saving and renewable
7 energy programmes can be enhanced if participation is set as a default option (Pichert and Katsikopoulos,
8 2008; Ölander and Thøgersen, 2014; Ebeling and Lotz, 2015).

11 4.4.3.2 *Strategies and Policies to Promote Actions on Climate Change*

13 Policy can enable and strengthen motivation to act on climate change via top-down or bottom-up approaches,
14 through informational campaigns, regulatory measures, financial (dis)incentives, and infrastructural and
15 technological changes (Adger et al., 2003; Steg and Vlek, 2009; Henstra, 2016).

17 Adaptation efforts tend to focus on infrastructural and technological solutions (Ford and King, 2015) with
18 lower emphasis on socio-cognitive and finance aspects of adaptation. For example, flooding policies in cities
19 focus on infrastructure projects and regulation such as building codes, and hardly target individual or
20 household behaviour (Araos et al., 2016b; Georgeson et al., 2016).

22 Current mitigation policies emphasise infrastructural and technology development, regulation, financial
23 incentives and information provision (Mundaca and Markandya, 2016) that can create conditions enabling
24 climate action, but target only some of the many factors influencing climate actions (see Section 4.4.5.1).
25 They fall short of their true potential if their social and psychological implications are overlooked (Stern et
26 al., 2016a). For example, promising energy-saving or low carbon technology may not be adopted or not be
27 used as intended (Pritoni et al., 2015) when people lack resources and trustworthy information (Stern, 2011;
28 Balcombe et al., 2013).

30 Financial incentives or feedback on financial savings can encourage climate action (Santos, 2008; Bolderdijk
31 et al., 2011; Maki et al., 2016) (see Box 4.5), but are not always effective (Delmas et al., 2013), and can be
32 less effective than social rewards (Handgraaf et al., 2013) or emphasising benefits for people and the
33 environment (Bolderdijk et al., 2013b; Asensio and Delmas, 2015; Schwartz et al., 2015). The latter can
34 happen when financial incentives reduce a focus on environmental considerations and weaken intrinsic
35 motivation to engage in climate action (Evans et al., 2012; Agrawal et al., 2015; Schwartz et al., 2015).
36 Besides, pursuing small financial gains is perceived to be less worth the effort than pursuing equivalent CO₂
37 emission reductions (Bolderdijk et al., 2013b; Dogan et al., 2014). Also, people may not respond to financial
38 incentives (e.g., to improve energy efficiency) because they do not trust the organisation sponsoring
39 incentive programmes (Mundaca, 2007) or when it takes too much effort to receive the incentive (Stern et
40 al., 2016a).

42 [START BOX 4.5 HERE]

44 **Box 4.5: How Pricing Policy has Reduced Car Use in Singapore, Stockholm and London**

46 In Singapore, Stockholm and London, car ownership, car use, and Greenhouse Gas (GHG) emissions have
47 reduced because of pricing and regulatory policies and policies facilitating behaviour change. Notably,
48 acceptability of these policies has increased as people experienced their positive effects.

50 Singapore implemented electronic road pricing in the central business district and at major expressways, a
51 vehicle quota and registration fee system, and investments in mass transit. In the vehicle quota system
52 introduced in 1990, registration of new vehicles is conditional upon a successful bid (via auctioning) (Chu,
53 2015), costing about 50,000 USD in 2014 (LTA, 2015). The registration tax incentivises purchases of low-
54 emission vehicles via a feebate system. As a result, per capita transport emissions (approximately 1.25
55 tCO₂/yr⁻¹) and car ownership (107 vehicles per 1000 capita) (LTA, 2017) are substantially lower than in

1 cities with comparable income levels. Modal share of public transport was 63% during peak hours in 2013
2 (LTA, 2013).

3
4 The Stockholm congestion charge implemented in 2007 (after a trial in 2006) reduced kilometres driven in
5 the inner city by 16%, and outside the city by 5%; traffic volumes reduced by 20% and remained constant
6 across time despite economic and population growth (Eliasson, 2014). CO₂ emissions from traffic reduced
7 by 2–3% in Stockholm county. Vehicles entering or leaving the city centre were charged during weekdays
8 (except for holidays). Charges were 1–2€ (maximum 6€ per day), being higher during peak hours; taxis,
9 emergency vehicles and busses were exempted. Before introducing the charge, public transport and parking
10 places near mass transit stations were extended. The aim and effects of the charge were extensively
11 communicated to the public. Acceptability of the congestion charge was initially low, but gained support of
12 about two-thirds of the population and all political parties after the scheme was implemented (Eliasson,
13 2014), which may be related to earmarking the revenues to constructing a motorway tunnel. After the trial,
14 people believed that the charge had more positive effects on environmental, congestion and parking
15 problems while costs increased less than they anticipated beforehand (Schuitema et al., 2010a). The initially
16 hostile media eventually declared the scheme to be a success.

17
18 In 2003, a congestion charge was implemented in the Greater London area, with an enforcement and
19 compliance scheme and an information campaign on the functioning of the scheme. Vehicles entering,
20 leaving, driving or parking on a public road in the zone at weekdays at daytime pay a congestion charge of
21 8£ (until 2005 5£), with some exemptions. Revenues were invested in London's bus network (80%), cycling
22 facilities, and road safety measures (Leape, 2006). The number of cars entering the zone decreased by 18%
23 in 2003 and 2004. In the charging zone, vehicle kilometres driven decreased by 15% in the first year and a
24 further 6% a year later, while CO₂ emissions from road traffic reduced by 20% (Santos, 2008).

25 26 **[END BOX 4.5 HERE]**

27
28 While providing information on the causes and consequences of climate change or on effective climate
29 actions, generally increases knowledge, it often does not encourage engagement in climate actions by
30 individuals (Abrahamse et al., 2005; Ünal et al., 2017) or organisations (Anderson and Newell, 2004).
31 Similarly, media coverage on the UN Climate Summit slightly increased knowledge about the conference
32 but did not enhance motivation to engage personally in climate protection (Brüggemann et al., 2017). Fear-
33 inducing representations of climate change may inhibit action when they make people feel helpless and
34 overwhelmed (O'Neill and Nicholson-Cole, 2009). Energy-related recommendations and feedback (e.g., via
35 performance contracts, energy audits, smart metering) are more effective to promote energy conservation,
36 load shifting in electricity use and sustainable travel choices when framed in terms of losses rather than gains
37 (Gonzales et al., 1988; Wolak, 2011; Bradley et al., 2016; Bager and Mundaca, 2017).

38
39 Credible and targeted information at the point of decision can promote climate action (Stern et al., 2016a).
40 For example, communicating the impacts of climate change is more effective when provided right before
41 adaptation decisions are taken (e.g., before the agricultural season) and when bundled with information on
42 potential actions to ameliorate impacts, rather than just providing information on climate projections with
43 little meaning to end users (e.g., weather forecasts, seasonal forecasts, decadal climate trends) (Dorward et
44 al., 2015; Singh et al., 2017). Similarly, heat action plans that provide early alerts and advisories combined
45 with emergency public health measures can reduce heat-related morbidity and mortality (Benmarhnia et al.,
46 2016).

47
48 Information provision is more effective when tailored to the personal situation of individuals, demonstrating
49 clear impacts, and resonating with individuals' core values (Daamen et al., 2001; Abrahamse et al., 2007;
50 Bolderdijk et al., 2013a; Dorward et al., 2015; Singh et al., 2017). Tailored information prevents information
51 overload, and people are more motivated to consider and act upon information that aligns with their core
52 values and beliefs (Campbell and Kay, 2014; Hornsey et al., 2016). Also, tailored information can remove
53 barriers to receive and interpret information faced by vulnerable groups, such as the elderly during heat
54 waves (Vandentorren et al., 2006; Keim, 2008). Further, prompts can be effective when they serve as
55 reminders to perform a planned action (Osbaldiston and Schott, 2012).

1
2 Feedback provision is generally effective in promoting mitigation behaviour within households (Abrahamse
3 et al., 2005; Delmas et al., 2013; Karlin et al., 2015) and at work (Young et al., 2015), particularly when
4 provided in real-time or immediately after the action (Abrahamse et al., 2005), which makes the implications
5 of one's behaviour more salient (Tiefenbeck et al., 2016). Simple information is more effective than detailed
6 and technical data (Wilson and Dowlatabadi, 2007; Ek and Söderholm, 2010; Frederiks et al., 2015). Energy
7 labels (Banerjee and Solomon, 2003; Stadelmann, 2017), visualisation techniques (Pahl et al., 2016), and
8 ambient persuasive technology (Midden and Ham, 2012) can encourage mitigation actions by providing
9 information and feedback in a format that immediately makes sense and hardly requires users' conscious
10 attention.

11
12 Social influence approaches that emphasise what other people do or think can encourage climate action
13 (Clayton et al., 2015), particularly when they involve face-to-face interaction (Abrahamse and Steg, 2013).
14 For example, community approaches, where change is initiated from the bottom-up, can promote adaptation
15 (see Box 4.6) and mitigation actions (Middlemiss, 2011; Seyfang and Haxeltine, 2012; Abrahamse and Steg,
16 2013), especially when community ties are strong (Weenig and Midden, 1991). Furthermore, providing
17 social models of desired actions can encourage mitigation action (Osbaldiston and Schott, 2012; Abrahamse
18 and Steg, 2013). Social influence approaches that do not involve social interaction, such as social norm,
19 social comparison and group feedback, are less effective, but can be easily administered on a large scale at
20 low costs (Allcott, 2011; Abrahamse and Steg, 2013).

21
22 **[START BOX 4.6 HERE]**

23 **Box 4.6: Bottom-up Initiatives: Adaptation Responses Initiated by Individuals and Communities**

24
25
26 To effectively adapt to climate change, bottom-up initiatives by individuals and communities are essential, in
27 addition to efforts of governments, organisations, and institutions (Wamsler and Brink, 2014a). This box
28 presents examples of bottom-up adaptation responses and behavioural change.

29
30 Fiji increasingly faces a lack of freshwater due to decreasing rainfall and rising temperatures (Deo, 2011;
31 IPCC, 2014a). While some villages have access to boreholes, these are not sufficient to supply the
32 population with freshwater. Villagers are adapting by rationing water, changing diets, and setting up inter-
33 village sharing networks (Pearce et al., 2017). Some villagers take up wage employment to buy food instead
34 of growing it themselves (Pearce et al., 2017). In Kiribati, residents adapt to drought by purchasing rainwater
35 tanks and constructing additional wells (Kuruppu and Liverman, 2011). An important factor that motivated
36 residents of Kiribati to adapt to drought was the perception that they could effectively adapt to the negative
37 consequences of climate change (Kuruppu and Liverman, 2011).

38
39 In the Philippines, seismic activity has caused some islands to flood during high tide. While the municipal
40 government offered affected island communities the possibility to relocate to the mainland, residents
41 preferred to stay and implement measures themselves in their local community to reduce flood damage
42 (Laurice Jamero et al., 2017). Migration is perceived as undesirable because island communities have strong
43 place-based identities (Mortreux and Barnett, 2009). Instead, these island communities have adapted to
44 flooding by constructing stilted houses and raising floors, furniture, and roads to prevent water damage
45 (Laurice Jamero et al., 2017). While inundation was in this case caused by seismic activity, this example
46 indicates how island-based communities may respond to rising sea levels caused by climate change.

47
48 Adaptation initiatives by individuals may temporarily reduce the impacts of climate change and enable
49 residents to cope with changing environmental circumstances. However, they may not be sufficient to sustain
50 communities' way of life in the long term. For instance, in Fiji and Kiribati, freshwater and food are
51 projected to become even scarcer in the future, rendering individual adaptations ineffective. Moreover,
52 individuals can sometimes engage in behaviour that may be maladaptive over larger spatio-temporal scales.
53 For example, in the Philippines, many islanders adapt to flooding by elevating their floors using coral stone
54 (Laurice Jamero et al., 2017). Over time, this can harm the survivability of their community, as coral reefs
55 are critical for reducing flood vulnerability (Ferrario et al., 2014). In Maharashtra, India, on-farm ponds are

1 promoted as rainwater harvesting structures to adapt to dry spells during the monsoon season. However,
2 some individuals fill these ponds with groundwater, leading to depletion of water tables and potentially
3 maladaptive outcomes in the long run (Kale, 2015).
4

5 Integration of individuals' adaptation initiatives with top-down adaptation policy is critical (Butler et al.,
6 2015), as failing to do so may lead individual actors to mistrust authority and can discourage them from
7 undertaking adequate adaptive actions (Wamsler and Brink, 2014a).
8

9 **[END BOX 4.6 HERE]**

10
11 Goal setting can promote mitigation action, when goals are not set too low or too high (Loock et al., 2013).
12 Commitment strategies where people make a pledge to engage in climate actions can encourage mitigation
13 behaviour (Abrahamse and Steg, 2013; Lokhorst et al., 2013), particularly when individuals also indicate
14 how and when they will perform the relevant action and anticipate how to cope with possible barriers (i.e.,
15 implementation intentions) (Bamberg, 2000, 2002). Such strategies take advantage of individuals' desire to
16 be consistent (Steg, 2016). Similarly, hypocrisy strategies that make people aware of inconsistencies between
17 their attitudes and behaviour can encourage mitigation actions (Osbaldiston and Schott, 2012).
18

19 Actions that reduce climate risks can be rewarded and facilitated, while actions that increase climate risks
20 can be punished and inhibited, and behaviour change can be voluntary (e.g., information provision) or
21 imposed (e.g., by law); voluntary changes that involve rewards are more acceptable than imposed changes
22 that restrict choices (Eriksson et al., 2006, 2008; Steg et al., 2006; Dietz et al., 2007). Policies punishing
23 maladaptive behaviour can increase vulnerability when they reinforce socio-economic inequalities that
24 typically produce the maladaptive behaviour in the first place (W.N. Adger et al., 2003). Change can be
25 initiated by governments at various levels, but also by individuals, communities, profit-making
26 organisations, trade organisations, and other non-governmental actors (Lindenberg and Steg, 2013;
27 Robertson and Barling, 2015; Stern et al., 2016b).
28

29 Strategies can target intrinsic versus extrinsic motivation. It may be particularly important to enhance
30 intrinsic motivation so that people voluntarily engage in climate action over and again (Steg, 2016).
31 Endorsement of mitigation and adaptation actions are positively related (Brügger et al., 2015; Carrico et al.,
32 2015); both are positively related to concern about climate change (Brügger et al., 2015). Strategies that
33 target general antecedents that affect a wide range of actions, such as values, identities, worldviews, climate
34 change beliefs, awareness of climate impacts of one's actions and feelings of responsibility to act on climate
35 change, can encourage consistent actions on climate change (van Der Werff and Steg, 2015; Hornsey et al.,
36 2016; Steg, 2016). Initial climate actions can lead to further commitment to climate action (Juhl et al., 2017),
37 when people learn that such actions are easy and effective (Lauren et al., 2016), when they engaged in the
38 initial behaviour for environmental reasons (Peters et al., 2018), hold strong pro-environmental values and
39 norms (Thøgersen, J., Ölander, 2003), and when initial actions make them realise they are an
40 environmentally-sensitive person, motivating them to act on climate change in subsequent situations so as to
41 be consistent (van der Werff et al., 2014a; Lacasse, 2015, 2016). Yet, some studies suggest that people may
42 feel licensed not to engage in further mitigation actions when they believe they already did their bit
43 (Truelove et al., 2014).
44
45

46 *4.4.3.3 Acceptability of Policy and System Changes*

47
48 Public acceptability can shape, enable or prevent policy and system changes. Acceptability reflects the extent
49 to which policy or system changes are evaluated (un)favourably. Acceptability is higher when people expect
50 more positive and less negative effects of policy and system changes (Perlaviciute and Steg, 2014; Demski et
51 al., 2015; Drews and Van den Bergh, 2016), including climate impacts (Schuitema et al., 2010b). Because of
52 this, policy 'rewarding' climate actions is more acceptable than policy 'punishing' actions that increase
53 climate risks (Steg et al., 2006; Eriksson et al., 2008). Pricing policy is more acceptable when revenues are
54 earmarked for environmental purposes (Steg et al., 2006; Sælen and Kallbekken, 2011), or redistributed
55 towards those affected (Schuitema and Steg, 2008). Acceptability can increase when people experience

1 positive effects after a policy has been implemented (Schuitema et al., 2010a; Eliasson, 2014; Weber, 2015);
2 effective policy trials can thus build public support for climate policy.

3
4 Climate policy and renewable energy systems are more acceptable when people strongly value other people
5 and the environment, or support egalitarian worldviews, left-wing or green political ideologies (Drews and
6 Van den Bergh, 2016), and less acceptable when people strongly endorse self-enhancement values, or
7 support individualistic and hierarchical worldviews (Dietz et al., 2007; Perlaviciute and Steg, 2014; Drews
8 and Van den Bergh, 2016). Solar radiation modification is more acceptable when people strongly endorse
9 self-enhancement values, and less acceptable when they strongly value other people and the environment
10 (Vischers et al., 2017). Climate policy is more acceptable when people believe climate change is real, when
11 they are concerned about climate change (Hornsey et al., 2016), when they think their actions may reduce
12 climate risks, and when they feel responsible to act on climate change (Steg et al., 2005; Eriksson et al.,
13 2006; Jakovcevic and Steg, 2013; Drews and Van den Bergh, 2016; Kim and Shin, 2017). Stronger
14 environmental awareness is associated with a preference for governmental regulation and behaviour change,
15 rather than free market and technological solutions (Poortinga et al., 2002).

16
17 Climate policy is more acceptable when costs and benefits are distributed equally, when nature and future
18 generations are protected (Sjöberg and Drottz-Sjöberg, 2001; Schuitema et al., 2011; Drews and Van den
19 Bergh, 2016), and when fair procedures have been followed, including participation by the public (Dietz,
20 2013; Bernauer et al., 2016a; Bidwell, 2016) or public society organisations (Bernauer and Gampfer, 2013).
21 Providing benefits to compensate affected communities for losses due to policy or systems changes enhanced
22 public acceptability in some cases (Perlaviciute and Steg, 2014), although people may disagree on what
23 would be a worthwhile compensation (Aitken, 2010; Cass et al., 2010), or feel they are being bribed (Cass et
24 al., 2010; Perlaviciute and Steg, 2014).

25
26 Public support is higher when individuals trust responsible parties (Perlaviciute and Steg, 2014; Drews and
27 Van den Bergh, 2016). Yet, public support for multilateral climate policy is not higher than for unilateral
28 policy (Bernauer and Gampfer, 2015); public support for unilateral, non-reciprocal climate policy is rather
29 strong and robust (Bernauer et al., 2016b). Public opposition may result from a culturally valued landscape
30 being affected by adaptation or mitigation options, such as renewable energy development (Warren et al.,
31 2005; Devine-wright and Howes, 2010) or coastal protection measures (Kimura, 2016), particularly when
32 people have formed strong emotional bonds with the place (Devine-Wright, 2009, 2013).

33
34 Climate actions may reduce human wellbeing when such actions involve more costs, effort or discomfort.
35 Yet, some climate actions enhance wellbeing, such as technology that improves daily comfort and nature-
36 based solutions for climate adaptation (Wamsler and Brink, 2014b). Further, climate action may enhance
37 wellbeing (Kasser and Sheldon, 2002; Xiao et al., 2011; Schmitt et al., 2018) because pursuing meaning by
38 acting on climate change can make people feel good (Venhoeven et al., 2013, 2016; Taufik et al., 2015),
39 more so than merely pursuing pleasure.

40 41 42 **4.4.4 Enabling Technological Innovation**

43
44 This section focuses on the role of technological innovation in limiting warming to 1.5°C, and how
45 innovation can contribute to strengthening implementation to move towards or to adapt to 1.5°C worlds. This
46 assessment builds on information of technological innovation and related policy debates in and after AR5
47 (Somanathan et al., 2014).

48 49 50 **4.4.4.1 The Nature of Technological Innovations**

51
52 Technological systems have their own dynamics. New technologies have been described as emerging as part
53 of a 'socio-technical system' that is integrated with social structures and that itself evolves over time (Geels
54 and Schot, 2007). This progress is cumulative and accelerating (Kauffman, 2002; Arthur, 2009). To illustrate
55 such a process of co-evolution: the progress of computer simulation enables us to understand climate,

1 agriculture, and material sciences better, contributing to upgrading food production and quality, microscale
2 manufacturing techniques, and leading to much faster computing technologies, resulting for instance in
3 better performing Photovoltaic (PV) cells.
4

5 A variety of technological developments have and will, contribute to 1.5°C-consistent climate action or the
6 lack of it. They can do this, e.g., in the form of applications such as smart lighting systems, more efficient
7 drilling techniques making fossil fuels cheaper, or precision agriculture. As discussed in Section 4.3.1, costs
8 of PV (IEA, 2017f) and batteries (Nykqvist and Nilsson, 2015) have sharply dropped. In addition, costs of
9 fuel cells (Iguma and Kidoshi, 2015; Wei et al., 2017) and shale gas and oil (Wang et al., 2014; Mills, 2015)
10 have come down as a consequence of innovation.
11

12 13 4.4.4.2 *Technologies as Enablers of Climate Action* 14

15 Since AR5, literature has emerged as to how much future GHG emission reductions can be enabled by the
16 rapid progress of General Purpose Technologies (GPTs), consisting of Information and Communication
17 Technologies (ICT) including Artificial Intelligence (AI) and Internet-of-Things (IoT), nanotechnologies,
18 biotechnologies, robotics, and so forth (World Economic Forum, 2015; OECD, 2017c). Although these may
19 contribute to limiting warming to 1.5°C, the potential environmental, social and economic impacts of new
20 technologies are uncertain.
21

22 Rapid improvement of performance and cost reduction is observed for many GPTs. They include AI,
23 sensors, internet, memory storage and micro-electro mechanical systems. The latter GPTs are not usually
24 categorised as climate technologies, but they can impact GHG emissions.
25

26 Progress of GPT could help reducing GHG emissions more cost-effectively. Examples are shown in Table
27 4.9. It may however, result in more emissions by increasing the volume of economic activities, with
28 unintended negative consequence on sustainable development. While ICT increases electricity consumption
29 (Aebischer and Hilty, 2015), the energy consumption of ICT is usually dwarfed by the energy saving by ICT
30 (Koomey et al., 2013; Malmodin et al., 2014), but rebound effects and other sustainable development
31 impacts may be significant. An appropriate policy framework that accommodates such impacts and their
32 uncertainties could address the potential negative impacts by GPT (Jasanoff, 2007).
33

34 GHG emission reduction potentials in relation to GPTs were estimated for passenger cars using a
35 combination of three emerging technologies: electric vehicles, car sharing, and self-driving. GHG emission
36 reduction potential is reported, assuming generation of electricity with low GHG emissions (Greenblatt and
37 Saxena, 2015; ITF, 2015; Viegas et al., 2016; Fulton et al., 2017). It is also possible that GHG emissions
38 increase due to an incentive to car use. Appropriate policies such as urban planning and efficiency
39 regulations could contain such rebound effects (Wadud et al., 2016).
40

41 Estimating emission reductions by GPT is difficult due to substantial uncertainties, including projections of
42 future technological performance, costs, penetration rates, and induced human activity. Even if a technology
43 is available, the establishment of business models might not be feasible (Linder and Williander, 2017).
44 Indeed, studies show a wide range of estimates, ranging from deep emission reductions to possible increases
45 in the emissions due to the rebound effect (Larson and Zhao, 2017).
46

47 GPT could also enable climate adaptation, in particular through more effective climate disaster risk
48 management and improved weather forecasting.
49
50
51
52
53

Table 4.9: Examples of technological innovations relevant to 1.5°C enabled by General Purpose Technologies (GPT).
 Note: Lists of enabling GPT or adaptation/mitigation options are not exhaustive, and the GPTs by themselves do not reduce emissions or increase climate change resilience.

Sector	Examples of mitigation/adaptation technological innovation	Enabling GPT
Buildings	Energy and CO ₂ efficiency of logistics, warehouse and shops (GeSI, 2015; IEA, 2017a)	IoT, AI
	Smart lighting and air conditioning (IEA, 2016b, 2017a)	IoT, AI, nanotechnology
Industry	Energy efficiency improvement by industrial process optimisation (IEA, 2017a)	Robots, IoT
	Bio-based plastic production by bio-refinery (OECD, 2017c)	Biotechnology
	New materials from bio-refineries (Fornell et al., 2013; McKay et al., 2016)	ICT, Biotechnology
Transport	Electric vehicles, car sharing, automation (Greenblatt and Saxena, 2015; Fulton et al., 2017)	IoT, AI, nanotechnology
	Bio-based diesel fuel by bio-refinery (OECD, 2017c)	Biotechnology
	Second Generation Bioethanol potentially coupled to Carbon Capture Systems (de Souza et al., 2014; Rochedo et al., 2016)	ICT, Biotechnology
	Logistical optimisation, and electrification of trucks by overhead line (IEA, 2017e)	IoT, AI
	Reduction of transport needs by remote education, health, and other services (GeSI, 2015; IEA, 2017a)	ICT
	Energy saving by lightweight aircraft components (Beyer, 2014; Faludi et al., 2015; Verhoef et al., 2018)	Additive manufacturing (3D printing)
Electricity	Solar PV manufacturing (Nemet, 2014)	Nanotechnology
	Smart grids and grid flexibility to accommodate intermittent renewables (Heard et al., 2017)	IoT, AI
	Plasma confinement for nuclear fusion (Baltz et al., 2017)	AI
Agriculture	Precision agriculture (improvement of energy and resource efficiency including reduction of fertiliser use and N ₂ O emissions) (Pierpaoli et al., 2013; Brown et al., 2016; Schimmelpfennig and Ebel, 2016)	Biotechnology ICT, AI
	Methane inhibitors (methanogenic vaccines) that reduce dairy livestock emissions (Wollenberg et al., 2016)	Biotechnology
	Engineering C3 into C4 photosynthesis to improve agricultural production and productivity (Schuler et al., 2016)	Biotechnology
	Genome editing using CRISPR to improve/adapt crops to a changing climate (Gao, 2018)	Biotechnology
Disaster reduction and adaptation	Weather forecasting and early warning systems, in combination with user knowledge (Hewitt et al., 2012; Lourenço et al., 2016)	ICT
	Climate risk reduction (Upadhyay and Bijalwan, 2015)	ICT
	Rapid assessment of disaster damage (Kryvasheyev et al., 2016)	ICT

Government policy usually plays a role in promoting or limiting GPTs, or science and technology in general. It has impacts on climate action, because the performance of further climate technologies will partly depend on the progress of GPTs. Governments have established institutions for achieving many social, and sometimes conflicting goals, including economic growth and addressing climate change (OECD, 2017c), which include investment in basic R&D that can help develop game changing technologies (Shayegh et al., 2017). Governments are also needed to create an enabling environment for the growth of scientific and technological ecosystems necessary for GPT development (Tassey, 2014).

4.4.4.3 The Role of Government in 1.5°C-Consistent Climate Technology Policy

While literature on 1.5°C-specific innovation policy is absent, a growing body of literature indicates that governments aim to achieve social, economic and environmental goals by promoting science and a broad range of technologies through ‘mission-driven’ innovation policies, based on differentiated national priorities

1 (Edler and Fagerberg, 2017). Governments can play a role in advancing climate technology via a
2 ‘technology push’ policy on the technology supply side (e.g., R&D subsidies), and by ‘demand pull’ policy
3 on the demand side (e.g., energy efficiency regulation), and these policies can be complemented by enabling
4 environments (Somanathan et al., 2014). Governments may also play a role in removing existent support for
5 incumbents (Kivimaa and Kern, 2016). A growing literature indicates that policy mixes, rather than single
6 policy instruments, are more effective in addressing climate innovation challenges ranging from technologies
7 in the R&D phase to those ready for diffusion (Veugelers, 2012; Quitzow, 2015; Rogge et al., 2017;
8 Rosenow et al., 2017). Such innovation policies can help address two kinds of externalities: environmental
9 externalities and proprietary problems (GEA, 2012; IPCC, 2014b; Mazzucato and Semieniuk, 2017). To
10 avoid ‘picking winners’, governments often maintain a broad portfolio of technological options (Kverndokk
11 and Rosendahl, 2007) and work in close collaboration with the industrial sector and society in general. Some
12 governments have achieved relative success in supporting innovation policies (Grubler et al., 2012;
13 Mazzucato, 2013) that addressed climate-related R&D (see Box 4.7 on bioethanol in Brazil).

14
15 **[START BOX 4.7 HERE]**

16 **Box 4.7: Bioethanol in Brazil: Innovation and Lessons for Technology Transfer**

17
18 The use of sugarcane as a bioenergy source started in Brazil in the 1970s. Government and multinational car
19 factories modified car engines nationwide so that vehicles running only on ethanol could be produced. As
20 demand grew, production and distribution systems matured and costs came down (Soccol et al., 2010). After
21 a transition period in which ethanol-only and gasoline-only cars were used, the flex-fuel era started in 2003,
22 when all gasoline was blended with 25% ethanol (de Freitas and Kaneko, 2011). By 2010, around 80% of the
23 car fleet in Brazil had been converted to use flex-fuel (Goldemberg, 2011; Su et al., 2015).

24
25 More than forty years of combining technology push and market pull measures led to the deployment of
26 ethanol production, transportation and distribution systems across Brazil, leading to a significant decrease in
27 CO₂ emissions (Macedo et al., 2008). Examples of innovations include: 1) the development of
28 environmentally well-adapted varieties of sugarcane; 2) the development and scaling up of sugar
29 fermentation in a non-sterile environment, and 3) the development of adaptations of car engines to use
30 ethanol as a fuel isolated or in combination with gasoline (Amorim et al., 2011; de Freitas and Kaneko,
31 2011; de Souza et al., 2014). Public procurement, public investment in R&D and mandated fuel blends
32 accompanying these innovations were also crucial (Hogarth, 2017). In the future, innovation could lead to
33 viable partial carbon dioxide removal through deployment of BECCS associated with the bioethanol
34 refineries (Fuss et al., 2014; Rochedo et al., 2016) (see Section 4.3.7).

35
36 Ethanol appears to reduce urban car emission of health-affecting ultrafine particles by 30% compared to
37 gasoline-based cars, but increases ozone (Salvo et al., 2017). During the 1990s, when sugarcane burning was
38 still prevalent, particulate pollution had negative consequences for human health and the environment
39 (Ribeiro, 2008; Paraiso and Gouveia, 2015). While (Jaiswal et al., 2017) report bioethanol’s limited impact
40 on food production and forests in Brazil, despite the large scale, and attribute this to specific agro-ecological
41 zoning legislation, various studies report adverse effects of bioenergy production through forest substitution
42 by croplands (Searchinger et al., 2008), as well as impacts on biodiversity, water resources, and food security
43 (Rathore et al., 2016). For new generation biofuels, feasibility and life cycle assessment studies can provide
44 information on their impacts on environmental, economic, and social factors (Rathore et al., 2016).

45
46 Brazil and the European Union have tried to replicate Brazil’s bioethanol experience in climatically suitable
47 African countries. Although such technology transfer achieved relative success in Angola and Sudan, the
48 attempts to set up bioethanol value chains did not pass the phase of political deliberations and feasibility
49 studies elsewhere in Africa. Lessons learned include the need of political and economic stability of the donor
50 country (Brazil) and the necessity of market creation to attract investments in first-generation biofuels
51 alongside a safe legal and policy environment for improved technologies (Afionis et al., 2014; Favretto et al.,
52 2017).

53
54 **[END BOX 4.7 HERE]**

1 Funding for R&D could come from various sources, including the general budget, energy or resource
2 taxation, or emission trading schemes (see Section 4.4.5). Investing in climate-related R&D has as an
3 additional benefit of building capabilities to implement climate mitigation and adaptation technologies
4 (Ockwell et al., 2015). Countries regard innovation in general and climate technology specifically as a
5 national interests issue, and addressing climate change primarily as in the global interest. Reframing part of
6 climate policy as technology or industrial policy might therefore contribute to resolving the difficulties that
7 continue to plague emission target negotiations (Faehn and Isaksen, 2016; Fischer et al., 2017; Lachapelle et
8 al., 2017).

9
10 Climate technology transfer to emerging economies has happened regardless of international treaties, as
11 these countries have been keen to acquire them, and companies have an incentive to access emerging
12 markets to remain competitive (Glachant and Dechezleprêtre, 2016). However, the complexity of this
13 transfer processes is high and they have to be conducted carefully by governments and institutions (Favretto
14 et al., 2017). It is noticeable that the impact of the EU Emission Trading Scheme (EU ETS) on innovation is
15 contested; recent work (based on lower carbon prices than anticipated for 1.5°C-consistent pathways)
16 indicates that it is limited (Calel and Dechezleprêtre, 2016) but earlier assessments (Blanco et al., 2014)
17 indicate otherwise.

18 19 20 4.4.4.4 *Technology Transfer in the Paris Agreement*

21
22 Technology development and transfer is recognised as an enabler of both mitigation and adaptation in
23 Article 10 in the Paris Agreement (UNFCCC, 2015) as well as in Article 4.5 of the original text of the
24 UNFCCC (UNFCCC, 1992). As previous sections have focussed on technology development and diffusion,
25 this section focuses on technology transfer. Technology transfer can adapt technologies to local
26 circumstances, reduce financing costs, develop indigenous technology, and build capabilities to operate,
27 maintain, adapt and innovate on technology globally (Ockwell et al., 2015; de Coninck and Sagar, 2017).
28 Technology cooperation could decrease global mitigation cost, and enhance developing countries' mitigation
29 contributions (Huang et al., 2017a).

30
31 The international institutional landscape around technology development and transfer includes the UNFCCC
32 (via its technology framework and technology mechanism including the Climate Technology Centre and
33 Network (CTCN)), the United Nations (a technology facilitation mechanism for the SDGs) and a variety of
34 non-UN multilateral and bilateral cooperation initiatives such as the Consultative Group on International
35 Agricultural Research (CGIAR, founded in the 1970s), and numerous initiatives of companies, foundations,
36 governments and non-governmental and academic organisations. Moreover, in 2015, twenty countries
37 launched an initiative called 'Mission Innovation', seeking to double their energy R&D funding. At this
38 point it is difficult to evaluate whether Mission Innovation achieved its objective (Sanchez and Sivaram,
39 2017). At the same time, the private sector started an initiative called the 'Breakthrough Energy Coalition'.

40
41 Most technology transfer is driven by through markets by the interests of technology seekers and technology
42 holders, in particular in regions with well-developed institutional and technological capabilities such as
43 developed and emerging nations (Glachant and Dechezleprêtre, 2016). However, the current international
44 technology transfer landscape has gaps, in particular in reaching out to least-developed countries, where
45 institutional and technology capabilities are limited (de Coninck and Puig, 2015; Ockwell and Byrne, 2016).
46 On the one hand, literature suggests that the management or even monitoring of all these UN, bilateral,
47 private and public initiatives may fail to lead to better results. On the other hand, it is probably more cost-
48 effective to adopt a strategy of 'letting a thousand flowers bloom', by challenging and enticing researchers in
49 the public and the private sector to direct innovation towards low-emission and adaptation options (Haselip
50 et al., 2015). This can be done at the same time as mission-oriented research is adopted in parallel by the
51 scientific community (Mazzucato, 2018).

52
53 At COP 21, the UNFCCC requested the Subsidiary Body for Scientific and Technological Advice (SBSTA)
54 to initiate the elaboration of the technology framework established under the Paris Agreement (UNFCCC,
55 2015). Among other things, the technology framework would 'provide overarching guidance for the work of

1 the Technology Mechanism in promoting and facilitating enhanced action on technology development and
2 transfer in order to support the implementation of this Agreement' (this Agreement being the Paris
3 Agreement). An enhanced guidance issued by the Technology Executive Committee (TEC) for preparing a
4 Technology Action Plan (TAP) supports the new technology framework as well as Parties' long-term vision
5 on technology development and transfer, reflected in the Paris Agreement (TEC, 2016).
6
7

8 **4.4.5 Strengthening Policy Instruments and Enabling Climate Finance**

9

10 Triggering rapid and far-reaching change in technical choices and institutional arrangements, consumption
11 and lifestyles, infrastructure, land use and spatial patterns implies the ability to scale-up policy signals to
12 enable the decoupling of GHGs emission, and economic growth and development (Section 4.2.2.3). Such a
13 scale-up would also imply that potential short-term negative responses by populations and interest groups,
14 that could block these changes from the outset, would need to be prevented or overcome. This section
15 describes the size and nature of investment needs and the financial challenge over the coming two decades in
16 the context of 1.5°C warmer worlds, assesses the potential and constraints of three categories of policy
17 instruments that respond to the challenge, and explains the conditions for using them synergistically. The
18 policy and finance instruments discussed in this section relate to Section 4.4.1 (on governance) and other
19 Sections in 4.4.
20
21

22 **4.4.5.1 The Core Challenge: Cost Efficiency, Coordination of Expectations and Distributive Effects**

23

24 Box 4.8 shows that the average estimates by seven models of annual investments needs in the energy system
25 is around 2.38 trillion USD₂₀₁₀ (1,38 to 3,25) between 2016 and 2035. This represents between 2.53% (1.6%
26 to 4%) of the world GDP in Market Exchange Rates (MER) and 1.7% of the world GDP in purchasing
27 power parity (PPP). OECD investment assessments for a 2°C-consistent transition suggest that including
28 investments in transportation and in other infrastructure would increase the investment needs by a factor of
29 three. Other studies not included in Box 4.8, in particular by the World Economic Forum (World Economic
30 Forum, 2013) and the Global Commission on the Economy and Climate (GCEC, 2014) confirm these orders
31 of magnitude of investment.
32

33 **[START BOX 4.8 HERE]**
34

35 **Box 4.8: Investment Needs and the Financial Challenge of Limiting Warming to 1.5°C**

36

37 The peer-reviewed literature that estimates the investment needs to scale up the response to limit warming to
38 1.5°C is limited (see Section 4.6). This box attempts to bring together available estimates of the order of
39 magnitude of these investments to provide the context for global and national financial mobilisation policy
40 and related institutional arrangements.
41

42 Table 1 in this box presents mean annual investments up to 2035, based on three studies (after clarifying
43 their scope and harmonising their metrics): an ensemble of six integrated assessment models (See Chapter
44 2); an OECD (Organisation for Economic Co-operation and Development) scenario for a 2°C limit (OECD,
45 2017a) and scenarios from the International Energy Agency (IEA) (IEA, 2016c). All three sources provide
46 estimates for the energy sector for various for mitigation scenarios. The OECD estimate also covers
47 transportation and other infrastructure (water, sanitation, and telecommunication), which are essential to
48 deliver the Sustainable Development Goals (SDGs), including SDG7 on clean energy access, and enhance
49 the adaptive capacity to climate change.
50
51
52
53
54

Box 4.8, Table 1: Estimated annualised mitigation investment needed to stay well below 2°C (2015–2035 in trillion USD at market exchange rates)

	Energy investments	Of which demand side	Transport	Other infra-structures	Total	Ratio to MER GDP
IAM Baseline (mean)	1.96	0.24			1.96	1.8%
IAM NDC (mean)	2.04	0.28			2.04	1.9%
IAM 2°C (mean)	2.19	0.38			2.19	2.1%
IAM 1.5°C (mean)	2.32	0.45			2.32	2.2%
IEA NDC	2.40	0.72	0.35		2.40	2.3%
IEA 1.5°C	2.76	1.13	0.55		2.76	2.7%
Mean IAM-IEA, 1.5°C	2.38	0.54			2.38	2.53%
Min IAM-IEA, 1.5°C	1.38	0.38			1.38	1.6%
Max IAM-IEA, 1.5°C	3.25	1.13			3.25	4.0%
<i>OECD Baseline</i>	<i>1.91</i>	<i>0.36</i>	<i>2.46</i>	<i>1.37</i>	<i>5.74</i>	<i>5.4%</i>
<i>OECD 2°C</i>	<i>2.13</i>	<i>0.40</i>	<i>2.73</i>	<i>1.52</i>	<i>6.38</i>	<i>6.0%</i>

The mean incremental share of annual mitigation investments to stay well below 2°C is 0.36% (between 0.2–1%) of global Gross Domestic Product (GDP) over 2015–2035. Since Gross Fixed Capital Formation (GFCF) is about 24% of global GDP, the estimated incremental energy investments between a baseline and a 1.5°C transition would be approximately 1.5% (between 0.8–4.2%) of projected total world investments. Given the uncertainty in these estimates, decision-makers could lower the probability of the most pessimistic assumptions by implementing policies to accelerate technical change (Section 4.4.5).

While total incremental investment for a 2°C-consistent pathway, including for transportation and other infrastructure, is estimated at 2.5% of global GFCF, there is no comprehensive study or estimate of these investments for a 1.5°C limit. For a 1.5°C-consistent pathway, the anticipated incremental ‘other investments’ might be lower thanks to lower investment needs in adaptation.

The issue, from a macroeconomic perspective, is whether these investments would be funded by higher savings at the costs of lower consumption. This would mean a 0.5% reduction in consumption for the energy sector for 1.5°C. Note that for a 2°C scenario, this reduction would be 0.8% if we account for the investment needs of all infrastructure sectors. Assuming a constant saving ratio, this can be enabled by reallocating existing capital flows towards infrastructure. In addition to these incremental investments, the amount of redirected investments is relevant from a financial perspective. In the reported Integrated Assessment Model (IAM) energy sector scenarios, about three times the incremental investments is redirected. There is no such assessment for the other sectors. The OECD report suggests that these ratios might be higher.

These orders of magnitude of investment can be compared to the available statistics of the global stock of 386 trillion USD of financial capital, which consists of 100 trillion USD in bonds (SIFMA, 2017), around 60 trillion USD in equity (The World Bank Data, 2018), and 226 trillion USD of loans managed by the banking system (IIF, 2017)(World Bank, 2018a). The long term rate of return (interest plus increase of shareholder value) is about 3% on bonds, 5% on bank lending, 7% on equity, leading to a weighted mean cost of capital of 3.4% in real terms (5.4% in nominal terms). Using 3.4% as a lower bound and 5% as a higher bound (following (Piketty, 2014)) and taking a conservative assumption that global financial capital grows at the same rate as global GDP, the estimated financial capital revenues would be between 16.8 and 25.4 trillion USD.

Assuming that a quarter of these investments comes from public funds (as estimated by the World Bank (World Bank, 2018a)), the amount of private resources needed to enable an energy sector transition is between 3.3% and 5.3% of annual capital income and between 5.6% and 8.3% of these revenues for all

1 infrastructure to meet the 2°C target and the SDGs.

2
3 Since the financial system has limited fungibility across budget lines, changing the partitioning of
4 investments is not a zero-sum game. An effective policy regime could encourage investment managers to
5 change their asset allocation. Part of the challenge may lie in increasing the pace of financing of low-
6 emission assets to compensate for a possible 38% decrease, by 2035, in the value of fossil fuel assets (energy
7 sector and indirect holdings in downstream uses like automobiles) (Mercure et al., 2018).

8
9
10 **[END BOX 4.8 HERE]**

11
12 The average increase of investment in the energy sector resulting from Box 4.8 represents a mean value of
13 1.5% of the global Gross Fixed Capital Formation (GFCF) compared with the baselines scenario in Market
14 Exchange Rate (MER) and a little over 1% in Purchasing Power Parity (PPP). Including infrastructure
15 investments would raise this to 2.5% and 1.7% respectively⁹.

16
17 These incremental investments could be funded through a drain on consumption (Bowen et al., 2017) which
18 would necessitate between 0.68% and 0.45% lower global consumption than in the baseline. But,
19 consumption at constant savings/consumption ratio can alternatively be funded by shifting savings towards
20 productive adaptation and mitigation investments, instead of real-estate sector and liquid financial products.
21 This response depends upon whether it is possible to close the global investment funding gap for
22 infrastructure that potentially inhibits growth, through structural changes in the global economy. In this case,
23 investing more in infrastructures would not be an incremental cost in terms of development and welfare
24 (IMF, 2014; Gurara et al., 2017)

25
26 Investments in other (non-energy system) infrastructure to meet development and poverty reduction goals
27 can strengthen the adaptive capacity to address climate change, and is difficult to separate from overall
28 sustainable development and poverty alleviation investments (Hallegatte and Rozenberg, 2017). The
29 magnitude of potential climate change damages is related to pre-existing fragility of impacted societies
30 (Hallegatte et al., 2007). Enhancing infrastructure and service provision would lower this fragility, for
31 example through the provision of universal (water, sanitation, telecommunication) service access (Arezki et
32 al., 2016).

33
34 The main challenge is thus not just a lack of mobilisation of aggregate resources but of redirection of savings
35 towards infrastructure, and the further redirection of these infrastructure investments towards low-emission
36 options. If emission-free assets emerge fast enough to compensate for the devaluation of high-emission
37 assets, the sum of the required incremental and redirected investments in the energy sector would (up to
38 2035) be equivalent to between 3.3% and 5.3% of the average annual revenues of the private capital stock
39 (see Box 4.8) and to 5.6% and 8.3%, including all infrastructure investments.

40
41 The interplay between mechanisms of financial intermediation and the private risk-return calculus is a major
42 barrier to realising these investments (Sirkis et al., 2015). This obstacle is not specific to climate mitigation
43 investments but also affects infrastructure and has been characterised as the gap between the ‘propensity to
44 save’ and the ‘propensity to invest’ (Summers, 2016). The issue is whether new financial instruments could
45 close this gap and inject liquidity into the low-emission transition, thereby unlocking new economic
46 opportunities (GCEC, 2014; NCE, 2016). By offsetting the crowding-out of other private and public
47 investments (Pollitt and Mercure, 2017) the ensuing ripple effect could reinforce growth and the
48 sustainability of development (King, 2011; Teulings and Baldwin, 2014) and potentially triggering a new
49 growth cycle (Stern, 2013, 2015). In this case, a massive mobilisation of low-emission investments would

⁹ A calculation in MER tends indeed to underestimate the world GDP and its growth by giving a lower weight to fast growing developing countries whereas a calculation in PPP tends to overestimate it. The difference between the value of two currencies in PPP and MER should vanish as the gap of the income levels of the two concerned countries decreases. Accounting for this trend in modelling is challenging.

1 require a significant effort, but may be complementary to sustainable development investments.

2 This uncertain but potentially positive outcome might be constrained by the higher energy costs of low-
3 emission options in the energy and transportation sectors. The price envelope of worldwide marginal
4 abatement costs for 1.5°C-consistent pathways reported in Chapter 2 is 135–475 USD tCO₂⁻¹ in 2030 and
5 245–1100 USD tCO₂⁻¹ in 2050, which is between two or three times higher than for a 2°C limit.

6 These figures are consistent with the dramatic reduction in the unit costs of some low-emission technical
7 options (for example solar PV, LED lighting) over the past decade (OECD, 2017c) (see Section 4.3.1). Yet,
8 there are multiple constraints to a system-wide energy transition. Lower costs of some supply and demand-
9 side options does not always result in a proportional decrease in energy system costs. The adoption of
10 alternative options can be slowed down by increasing costs of decommissioning existing infrastructure,
11 inertia of market structures, cultural habits and by risk-adverse user behaviour (see Sections 4.4.1 to 4.4.3).
12 Learning-by-doing processes and R&D can accelerate the cost-efficiency of low-emission technology but
13 often imply higher early-phase costs. The German energy transition resulted in high consumer prices for
14 electricity in Germany (Kreuz and Müsgens, 2017) and needed strong accompanying measures to succeed.

15
16 One key issue is that energy costs can propagate across sectors amplifying overall production costs. During
17 the early stage of a low-emission transition, an increase in the prices of non-energy goods could cause lower
18 consumer purchasing power and final demand. A rise of energy prices has a proportionally greater impact in
19 developing countries that are in a catch-up phase, with strong dependence on energy-intensive sectors
20 (Crassous et al., 2006; Luderer et al., 2012) and a higher ratio of energy to labour cost (Waisman et al.,
21 2012). This explains why with lower carbon prices, similar emission reductions are reached in South Africa
22 (Altieri et al., 2016) and Brazil (La Rovere et al., 2017a) compared to developed countries. However, three
23 distributional issues emerge.

24
25 First, in the absence of countervailing policies, higher energy costs have an adverse effect on the distribution
26 of welfare (see also Chapter 5). The negative impact is inversely correlated with the level of income
27 (Harberger, 1984; Fleurbaey and Hammond, 2004) and positively correlated with the share of energy in the
28 households budget, which is high for low- and middle- income households (Proost and Van Regemorter,
29 1995; Barker and Kohler, 1998; West and Williams, 2004; Chiroleu-Assouline and Fodha, 2011). Moreover,
30 climatic conditions and the geographical conditions of human settlements matter for heating and mobility
31 needs (see Chapter 5). Medium-income populations in the suburbs, remote and low-density regions can be as
32 vulnerable as residents of low-income urban areas. Poor households with low levels of energy consumption
33 are also impacted by price increases of non-energy goods caused by the propagation of energy costs (Combet
34 et al., 2010; Dubois, 2012). These impacts are generally not offset by non-market co-benefits of climate
35 policies for the poor (Baumgärtner et al., 2017).

36
37 A second matter of concern is the distortion of international competition and employment implications in
38 case of uneven carbon constraints, especially for energy-intensive industries (Demailly and Quirion, 2008).
39 Some of these industries are not highly exposed to international competition because of their very high
40 transportation costs per unit value added (Sartor, 2013; Branger et al., 2016), but other industries could suffer
41 severe shocks, generate ‘carbon leakage’ through cheaper imports from countries with lower carbon
42 constraints (Branger and Quirion, 2014) and weaken the surrounding regional industrial fabric with
43 economy-wide and employment implications.

44
45 A third challenge is the depreciation of assets whose value is based on the valuation of fossil energy
46 resources of which future revenues may decline precipitously with higher carbon prices (Waisman et al.,
47 2013; Jakob and Hilaire, 2015; McGlade and Ekins, 2015) and on emission-intensive capital stocks
48 (Guivarch and Hallegatte, 2011; OECD/IEA/NEA/ITF, 2015; Pfeiffer et al., 2016). This raises issues of
49 changes in industrial structure, adaptation of worker skills and of stability of financial, insurance and social
50 security systems. These systems are in part based on current holdings of carbon-based assets whose value
51 might decrease by 38% by the mid-2030s (Mercure et al., 2018). This stranded asset challenge may be
52 exacerbated by a decline of export revenues of fossil fuel producing countries and regions (Waisman et al.,
53 2013; Jakob and Hilaire, 2015; McGlade and Ekins, 2015).

54

1 These distributional issues, if addressed carefully and expeditiously, could affect popular sensitivity towards
 2 climate policies. Addressing them could mitigate adverse macroeconomic effects on economic growth and
 3 employment that could undermine the potential benefits of a redirection of savings and investments towards
 4 1.5°C-consistent pathways.

5 Strengthening policy instruments for a low-emission transition would thus need to reconcile three objectives:
 6 i) handling the short-term frictions inherent to this transition in an equitable way, ii) minimising these
 7 frictions by lowering the cost of avoided GHGs emissions, and iii) coordinating expectations of multiple
 8 stakeholders at various decision-making levels to accelerate the decline in costs of emission reduction,
 9 efficiency and decoupling options and maximising their co-benefits (see the practical example of lowering
 10 car use in cities in Box 4.9).

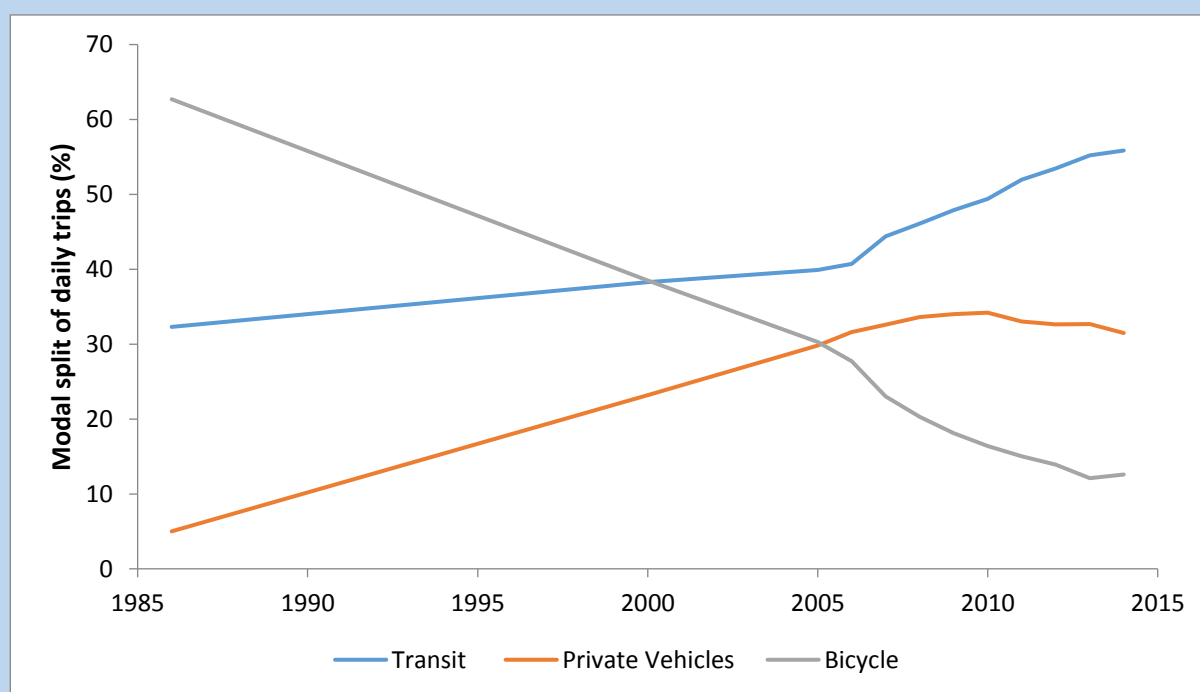
11
 12 Three categories of policy tools would be available to meet the distributional challenges: carbon pricing,
 13 regulatory instruments and information and financial tools,. Each of them has its own strength and
 14 weaknesses, and in a 1.5°C perspective, policy tools would have to be both upscale and better coordinated in
 15 packages in a synergistic manner.

16
 17 **[START BOX 4.9 HERE]**

18 **Box 4.9: Emerging cities and ‘peak car use’: Evidence of decoupling in Beijing**

19
 20 The phenomenon of ‘peak car use’, or reductions in per capita car use, provides hope for continuing
 21 reductions in greenhouse gas from oil consumption (Millard-Ball and Schipper, 2011; Newman and
 22 Kenworthy, 2011; Goodwin and Van Dender, 2013). The phenomenon has been mostly associated with
 23 developed cities apart from some early signs in Eastern Europe, Latin America and China (Newman and
 24 Kenworthy, 2015). New research indicates that peak car is now also underway in China (Gao and Newman,
 25 2018).

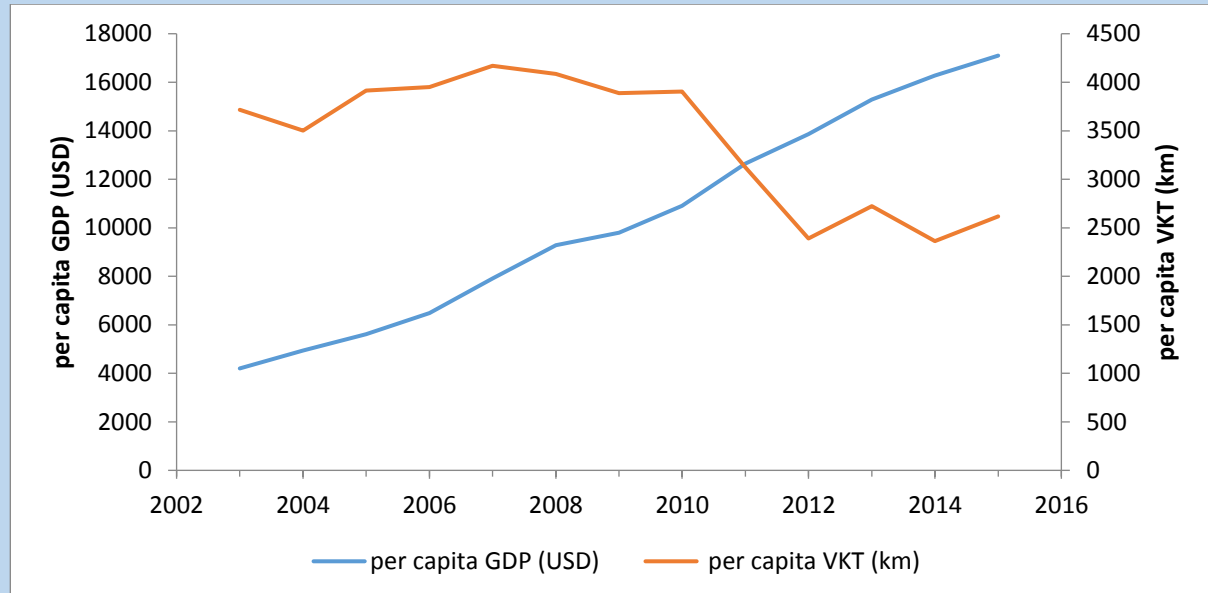
26
 27 China’s rapid urban motorisation has resulted from strong economic growth, fast urban development and the
 28 prosperity of the Chinese automobile industry (Gao and Kenworthy, 2015). However, recent data (Gao and
 29 Newman, 2018) suggest the first signs of a break in the growth of car use expressed in percentage of daily
 30 trips as the growth in mass transit, primarily caused by the expansion of Metro systems, is becoming more
 31 significant (see Box 4.9, Figure 1).



32

1 **Box 4.9, Figure 1:** The modal split data in Beijing between 1986 and 2014. Source: (Gao and Newman, 2018).

2
3 Chinese urban fabrics, featuring traditional dense linear forms and mixed land use, favour mass transit
4 systems over automobiles (Gao and Newman, 2018). The data show that the decline in car use did not
5 impede economic development but Vehicle Kilometres of Travel (VKT) growth has decoupled absolutely
6 from GDP as shown in Box 4.9, Figure 2 below.
7



8
9 **Box 4.9, Figure 2:** Peak car in Beijing: relationships between economic performance and private automobile use in
10 Beijing from 1986 to 2014. VKT is Vehicle Kilometres of Travel. Source: (Gao and Newman, 2018).

11 **[END BOX 4.9 HERE]**

12 4.4.5.2 Carbon Pricing: Necessity and Constraints

13
14
15 For long, economic literature has argued that climate and energy policy only grounded in regulation,
16 standards and public funding of R&D is at risk of being influenced by political and administrative
17 arbitrariness, which could raise the costs of implementation. This literature has argued that it may be more
18 efficient to make these costs explicit through carbon taxes and carbon trading, securing the abatement of
19 emissions in places and sectors where it is cheapest (IPCC, 1995, 2001; Gupta et al., 2007; Somanathan et
20 al., 2014).
21
22

23 In a frictionless world, a unique world carbon price could minimise the social costs of the low carbon
24 transition by equating the marginal costs of abatement across all sources of emissions. This implies that
25 investors will be able to make the right choices under perfect foresight and that domestic and international
26 compensatory transfers offset the adverse distributional impacts of higher energy prices and their
27 consequences on economic activity. In the absence of transfers targeted in function of countries market
28 structures (Boeters, 2014), carbon prices are no longer optimal (Böhringer et al. 2009; Böhringer and
29 Alexeeva-Talebi 2013) and need to be differentiated by jurisdiction (Chichilnisky and Heal, 2000; Sheeran,
30 2006) in function of the countries' social welfare function. This differentiation could in turn raise concerns
31 of distortions in international competition (Hourcade et al., 2001; Stavins et al., 2014).

32 Obstacles to enforcing a unique world carbon price in the short-run would not necessarily crowd out explicit
33 national carbon pricing, for three reasons. First, it could restrain an emissions rebound due to a higher
34 consumption of energy services enabled by efficiency gains, if energy prices do not change (Greening et al.,
35 2000; Fleurbaey and Hammond, 2004; Sorrell et al., 2009; Guivarch and Hallegatte, 2011; Chitnis and
36 Sorrell, 2015; Freire-González, 2017). Second, it could hedge against the arbitrariness of regulatory policies.
37 Third, 'revenue neutral' recycling, at a constant share of taxes on GDP, into lowering some existing taxes

1 compensates at least part of the propagation effect of higher energy costs (Stiglitz et al., 2017). The
2 substitution by carbon taxes of taxes that cause distortions on the economy can counteract the regressive
3 effect of higher energy prices. For example, offsetting increased carbon prices with lower labour taxes can
4 potentially decrease labour costs (without affecting salaries), enhance employment and reduce the
5 attractiveness of informal economic activity (Goulder, 2013).

6
7 The conditions under which an economic gain along with climate benefit (a ‘double dividend’) can be
8 expected are well documented (Goulder, 1995; Bovenberg, 1999; Mooij, 2000)
9 . In the context of OECD countries, the literature examines how carbon taxation could substitute for other
10 taxes to fund the social security system (Combet, 2013). The same general principles apply for countries that
11 are building their social welfare system such as China (Li and Wang, 2012) or Brazil (La Rovere et al.,
12 2017a) but an optimal recycling scheme could differ based on the structure of the economy (Lefèvre et al.
13 2018).

14
15 In every country the design of carbon pricing policy implies a balance between incentivising low-carbon
16 behaviour and mitigating the adverse distributional consequences of higher energy prices (Combet et al.,
17 2010). Carbon taxes can offset these effects if their revenues are redistributed through rebates to poor
18 households. Other options include the reduction of value added taxes for basic products or direct benefit
19 transfers to enable poverty reduction (see (Winkler et al., 2017) for South Africa and (Grottera et al., 2016)
20 for Brazil). This is possible because higher income households pay more in absolute terms, even though their
21 carbon tax burden is a relatively smaller share of their income (Arze del Granado et al., 2012).

22
23 Ultimately, the pace of increase of carbon prices would depend on the pace at which they can be embedded
24 in a consistent set of fiscal and social policies. This is why, after a quarter century of academic debate and
25 experimentation (see IPCC WGIII reports since the SAR), a gap persists with respect to ‘switching carbon
26 prices’ needed to trigger rapid changes. In 2016, only 15% of global emissions are covered by carbon
27 pricing, three-quarters of which with prices below 10 USD tCO₂⁻¹ (World Bank, 2016). This is too low to
28 outweigh the ‘noise’ from the volatility of oil markets (in the range of 100 USD tCO₂⁻¹ over the past decade),
29 of other price dynamics (interest rates, currency exchange rates and real estate prices) and of regulatory
30 policies in energy, transportation and industry. For example, the dynamics of mobility depend upon a trade-
31 off between housing prices and transportation costs in which the price of real estate and the inert
32 endowments in public transport play as important a role as liquid fuel prices (Lampin et al., 2013).

33
34 These considerations apply to attempts to secure a minimum price in carbon trading systems (Wood and
35 Jotzo, 2011; Fell et al., 2012; Fuss et al., 2018) and to the reduction of fossil fuel subsidies. Estimated at 650
36 billion USD in 2015 (Coady et al., 2017), they represent 25–30% of government revenues in forty (mostly
37 developing) countries (IEA, 2014b). Reducing these subsidies would contribute to reaching 1.5°C-consistent
38 pathways, but raises similar issues as carbon pricing around long-term benefits and short-term costs (Jakob et
39 al., 2015; Zeng and Chen, 2016), as well as social impacts.

40
41 Explicit carbon prices are thus a necessary ‘lubricant’ to accommodate the general equilibrium effects
42 of higher energy prices but may not suffice to trigger the low-carbon transition because of a persistent
43 ‘implementation gap’ between the aspirational carbon prices and those that can practically be
44 enforced. When systemic changes, such as those needed for 1.5°C-consistent pathways, are at play on
45 many dimensions of development, price levels ‘depend on the path and the path depends on political
46 decisions’ (Dréze and Stern, 1990).

47 48 49 *4.4.5.3 Regulatory measures and information flows*

50
51 Regulatory instruments are a common tool for improving energy efficiency and enhancing renewable energy
52 in OECD countries (e.g., US, Japan, Korea, Australia, the EU) and, more recently, in developing countries
53 (M.H. Scott et al., 2015; Brown et al., 2017) including constraints on the import of products banned in other
54 countries (Knoop and Lechtenböhmer, 2017).

1 For energy efficiency, these instruments include end-use standards and labelling for domestic appliances,
2 lighting, electric motors, water heaters and air-conditioners. They are often complemented by mandatory
3 efficiency labels to attract consumers' attention and stimulate the manufacture of more efficient products
4 (Girod et al., 2017). Experience shows that these policy instruments are effective only if they are regularly
5 reviewed to follow technological developments, as in the 'Top Runner' programme for domestic appliances
6 in Japan (Sunikka-Blank and Iwafune, 2011).
7

8 In four countries, efficiency standards (e.g. miles/gallon or level of CO₂ emission per km) have been used in
9 the transport sector, for light and heavy-duty vehicles, which have spill-overs for the global car industry. In
10 the EU (Ajanovic and Haas, 2017) and the US (Sen et al., 2017) vehicle manufacturers need to meet an
11 annual CO₂ emission target for their entire new vehicle fleet. This allows them to compensate through the
12 introduction of low-emission vehicles for the high-emission ones in the fleet. This leads to increasingly
13 efficient fleets of vehicles over time, but does not necessarily limit the driven distance.
14

15 Building codes that prescribe efficiency requirements for new and existing buildings have been adopted in
16 many OECD countries (Evans et al., 2017) and are regularly revised to increase their efficiency per unit of
17 floor space. Building codes can avoid the lock-in of rapidly urbanising countries to poorly performing
18 buildings that remain in use for the next 50–100 years (Ürge-Vorsatz et al., 2014). In OECD countries,
19 however, their main role is to incentivise the retrofit of existing buildings. In addition of the convergence of
20 these codes to Net Zero Energy Buildings (D'Agostino, 2015), a new focus should be placed, in the context
21 of 1.5°C-consistent pathways, on public and private co-ordination to achieve better integration of building
22 policies with the promotion of low-emission transportation modes (Bertoldi, 2017).
23

24 The efficacy of regulatory instruments can be reinforced by economic incentives, such as feed-in tariffs
25 based on the quantity of renewable energy produced, subsidies or tax exemptions for energy savings
26 (Bertoldi et al., 2013; Ritzenhofen and Spinler, 2016; García-Álvarez et al., 2017; Pablo-Romero et al.,
27 2017), fee-bates, and 'bonus-malus' that foster the penetration of low-emission options (Butler and Neuhoff,
28 2008). Economic incentives can also be combined with direct use market-based instruments, for example
29 combining, in the United States and, in some EU countries, carbon trading schemes with Energy Savings
30 Obligations for energy retailers (Haoqi et al., 2017), or with Green Certificates for renewable energy
31 portfolio standards (Upton and Snyder, 2017). Scholars have investigated caps on utilities' energy sales
32 (Thomas et al., 2017) and emission caps at a personal level (Fawcett et al., 2010).
33

34 In combination with the funding of public research institutes, grants or subsidies also support R&D, where
35 risk and the uncertainty about long-term perspectives can reduce the private sector's willingness to invest in
36 low-emission innovation (see also Section 4.4.4). Subsidies can take the form of rebates on Value-Added
37 Tax (VAT), of direct support to investments (e.g. renewable energy or refurbishment of buildings) or feed-in
38 tariffs (Mir-Artigues and del Río, 2014). They can be provided by the public budget, via consumption levies,
39 or via the revenues of carbon taxes or pricing. Fee-bates, introduced in some countries (for example for cars),
40 have had a neutral impact on public budgets by incentivising low-emission products and penalising high-
41 emission ones (de Haan et al., 2009).
42

43 All policy instruments can benefit from information campaigns (e.g., TV ads) tailored to specific end-users.
44 A vast majority of public campaigns on energy and climate have been delivered through mass-media
45 channels, and advertising-based approaches (Corner and Randall, 2011; Doyle, 2011). Although some
46 authors report large savings obtained by such campaigns, most agree that the effects are short-lived and
47 decrease over time (Bertoldi et al., 2016). Recently, focus has been placed on the use of social norms to
48 motivate behavioural changes (Allcott, 2011; Alló and Loureiro, 2014). More on strategies to change
49 behaviour can be found in section 4.4.3.
50

51 4.4.5.4 *Scaling-up Climate Finance and De-Risking Low-Emission Investments*

52 The redirection of savings towards low-emission investments may be constrained by enforceable carbon
53 prices, implementation of technical standards and the short-term bias financial systems (Miles, 1993;
54
55

1 Bushee, 2001; Black and Fraser, 2002). The many causes of this bias are extensively analysed in economic
2 literature (Tehrani and Waagelein, 1985; Shleifer and Vishny, 1990; Bikhchandani and Sharma, 2000)
3 including their link with prevailing patterns of economic globalisation (Krugman, 2009; Rajan, 2011) and the
4 chronic under-investment in long-term infrastructure (IMF, 2014). Emerging literature explores how to
5 overcome this through reforms targeted to bridge the gap between short-term cash balances and long-term
6 low-emission assets and to reduce the risk-weighted capital costs of climate-resilient investments. This gap
7 was qualified by the Governor of the Bank of England as a Tragedy of the Horizons (Carney, 2016) that
8 constitutes a threat to the stability of the financial system, is confirmed by the literature (Arezki et al., 2016;
9 Christophers, 2017). This potential threat would encompass the impact of climate events on the value of
10 assets (Battiston et al., 2017), liability risks (Heede, 2014) and the transition risk due to devaluation of
11 certain classes of assets (Platinga and Scholtens, 2016).

12
13 The financial community's attention to climate change grew after COP 15 (ESRB ASC, 2016). This led to
14 the introduction of climate-related risk disclosure in financial portfolios (UNEP, 2015) placing it on the
15 agenda of G20 Green Finance Study Group and of the Financial Stability Board. This led to the creation of
16 low-carbon financial indices that investors could consider as a 'free option on carbon' to hedge against risks
17 of stranded carbon intensive assets (Andersson et al., 2016). This could also accelerate the emergence of
18 climate-friendly financial products such as green or climate bonds, The estimated value of the Green bonds
19 market in 2017 is USD 200 billion (BNEF, 2017). The bulk of these investments are in renewable energy,
20 energy efficiency and low-emission transport (Lazurko and Venema, 2017), with only 4% for adaptation
21 (OECD, 2017b). One major issue is whether individual strategies based on improved climate-related
22 information alone will enable the financial system to allocate capital in an optimal way (Christophers, 2017)
23 since climate change is a systemic risk (Schoenmaker and van Tilburg, 2016) (CISL, 2015).

24
25 The readiness of financial actors to reduce investments in fossil fuels is a real trend (Platinga and
26 Scholtens, 2016; Ayling and Gunningham, 2017) but they may not resist the attractiveness of carbon-
27 intensive investments in many regions. Hence, decarbonising an investment portfolio is not synonymous
28 with investing massively in low-emission infrastructure. Scaling up climate-friendly financial products
29 may depend upon a business context conducive to the reduction of the risk-weighted capital costs of low-
30 emission projects. The typical leverage of public funding mechanisms for low-emission investment is low
31 (2 to 4) compared with (10 to 15) in other sectors (Maclean et al., 2008; Ward et al., 2009; MDB, 2016).
32 This is due to the interplay of the uncertainty of emerging low-emission technologies in the midst of their
33 learning-by-doing cycle, and of uncertain future revenues due to volatility of fossil fuel prices (Roques et
34 al., 2008; Gross et al., 2010) and of uncertainty around regulatory policies. This inhibits low-emission
35 investments by corporations functioning under a 'shareholder value business regime' (Berle and Means,
36 1932; Froud et al., 2000; Roe, 2001) and actors with restricted access to capital (e.g. cities, local
37 authorities, SMEs and households).

38
39 De-risking policy instruments to enable low-emission investment encompass interest rate subsidies, fee-
40 bates, tax breaks, concessional loans from development banks, and public investment funds, including
41 revolving funds. Given the constraints on public budgets, public guarantees can be used to secure high
42 leverage of public financing. They imply a full direct burden on public budgets only in case of default of
43 the project. They could back for example various forms of Green Infrastructure Funds (De Gouvello and
44 Zelenko, 2010; Emin et al., 2014; Studart and Gallagher, 2015)¹⁰.

45
46 The risk of defaulting can be mitigated by strong Measurement, Reporting and Verifying (MRV) systems
47 (Bellassen et al., 2015) and by the use of notional prices recommended in public economics and currently
48 in use in France and the UK, to calibrate public support to the provision of public goods in case of
49 persisting distortions in pricing (Stiglitz et al., 2017). Some suggest linking these notional prices to
50 'social, economic and environmental value of voluntary mitigation actions' recognised by the COP21
51 Decision accompanying the Paris Agreement (paragraph 108) (Hourcade et al., 2015; La Rovere et al.,
52 2017b; Shukla et al., 2017), in order to incorporate the co-benefits of mitigation.

53

¹⁰ One prototype is the World Bank's Pilot Auction Facility on Methane and Climate Change

1 Such public guarantees ultimately amount to money issuance backed by low-emission projects as
2 collateral. This explains the potentially strong link between global climate finance and the evolution of
3 the financial and monetary system. Amongst suggested mechanisms for this evolution are the use of
4 International Monetary Fund's (IMF's) Special Drawing Rights to fund the paid-in capital of the Green
5 Climate Fund (Bredenkamp and Pattillo, 2010) and the creation of carbon remediation assets at a
6 predetermined face value per avoided tonne of emissions (Aglietta et al., 2015a, b). Such a predetermined
7 value could hedge against the fragmentation of climate finance initiatives and support the emergence of
8 financial products backed by a new class of long-term assets.

9
10 Combining public guarantees at a predetermined value of avoided emissions, in addition to improving the
11 consistency of non-price measures, could support the emergence of financial products backed by a new
12 class of certified assets to attract savers in search of safe and ethical investments (Aglietta et al., 2015b).
13 It could hedge against the fragmentation of climate finance initiatives and provide a mechanism to
14 compensate for the 'stranded' assets caused by divestment in carbon-based activities and in lowering the
15 systemic risk of stranded assets (Safarzyńska and van den Bergh, 2017). These new assets could also
16 facilitate a low-carbon transition for fossil-fuel producers and help them to overcome the 'resource curse'
17 (Ross, 2015; Venables, 2016).

18
19 Blended injection of liquidity has monetary implications. Some argue that this questions the premise that
20 money should remain neutral (Annicchiarico and Di Dio, 2015, 2016; Nikiforos and Zezza, 2017).
21 Central Banks or financial regulators could act as a facilitator of last resort for low-emission financing
22 instruments, that could in turn lower the systemic risk of stranded assets (Safarzyńska and van den Bergh,
23 2017). This may, in time, lead to the use of carbon-based monetary instruments to diversify reserve
24 currencies (Jaeger et al., 2013) and differentiate reserve requirements (Rozenberg et al., 2013) in the
25 perspective of a Climate Friendly Bretton Woods (Sirkis et al., 2015; Stua, 2017).

26 27 28 *4.4.5.5 Financial Challenge for Basic Needs and Adaptation Finance*

29
30 Adaptation finance is difficult to quantify for two reasons. The first is that it is very difficult to isolate
31 specific investment needs to enhance climate resilience from the provision of basic infrastructure that are
32 currently underinvested (IMF, 2014; Gurara et al., 2017). The UNEP (2016) estimate of investment needs on
33 adaptation in developing countries between 140–300 billion USD yr⁻¹ in 2030, a major part being investment
34 expenditures that are complementary with SDG-related investments focussed on universal access to
35 infrastructure and services and meeting basic needs. Many climate adaptation-centric financial incentives are
36 relevant to non-market services, offering fewer opportunities for market revenues while they contribute to
37 creating resilience to climate impacts.

38 Hence, adaptation investments and the provision of basic needs would typically have to be supported by
39 national and sub-national government budgets together with support from overseas development assistance
40 and multilateral development banks (Fankhauser and Schmidt-Traub, 2011; Adenle et al., 2017; Robinson
41 and Dornan, 2017), and a slow increase of dedicated NGO and private climate funds (Nakhoda and Watson,
42 2016). Even though the UNEP estimates of the costs of adaptation might be lower in a 1.5°C world (Climate
43 Analytics, 2015) they would be higher than the UNEP 22.5 USD billion estimates of the bilateral and
44 multilateral funding for climate change adaptation in 2014. Currently, 18–25% of climate finance flows to
45 adaptation in developing countries (OECD, 2015, 2016a; Shine and Campillo, 2016). It remains fragmented,
46 with small proportions flowing through UNFCCC channels (AdaptationWatch, 2015; Roberts and
47 Weikmans, 2017).

48
49 Means of raising resources for adaptation, achieving the SDG and meeting basic needs (Durand et al., 2016;
50 Roberts et al., 2017) include the reduction of fossil fuel subsidies (Jakob et al., 2016), increasing revenues
51 from carbon taxes (Jakob et al., 2016), levies on international aviation and maritime transport and share of
52 the proceeds of financial arrangements supporting mitigation activities (Keen et al., 2013). Each have
53 different redistribution implications. Challenges, however, include the efficient use of resources, the
54 emergence of long-term assets using infrastructure as collateral and the capacity to implement small-scale

1 adaptation and the mainstreaming of adaptation in overall development policies. There is thus a need for
2 greater policy coordination (Fankhauser and McDermott, 2014; Morita and Matsumoto, 2015; Sovacool
3 et al., 2015, 2017; Lemos et al., 2016; Adenle et al., 2017; Peake and Ekins, 2017) that includes robust
4 mechanisms for tracking, reporting, and ensuring transparency of adaptation finance (Donner et al., 2016;
5 Pauw et al., 2016a; Roberts and Weikmans, 2017; Trabacchi and Buchner, 2017) and its consistency with the
6 provision of basic needs (Hallegatte et al., 2016).

9 *4.4.5.6 Towards Integrated Policy Packages and Innovative Forms of Financial Cooperation*

10 Carbon prices, regulation and standards, improved information and appropriate financial instruments can
11 work synergistically to meet the challenge of ‘making finance flows consistent with a pathway towards
12 low greenhouse gas emissions and climate-resilient development’, as in Article 2 in the Paris Agreement.
13

14
15 There is growing attention to combine the use of policy instruments that actually address three
16 domains of action: the behavioural changes, the economic optimisation and the long-term strategies
17 (Grubb et al., 2014). For example, de-risking low-emission investments would result in higher
18 volumes of low-emission investments, and would in turn lead to a lower switching price for the
19 same climate ambition (Hirth and Steckel, 2016). In the reverse direction, higher explicit carbon
20 prices may generate more low-emission projects for a given quantum of de-risking. For example,
21 efficiency standards for housing can increase the efficacy of carbon prices and overcome the barriers
22 coming from the high discount rates used by households (Parry et al., 2014), while explicit and
23 notional carbon prices can lower the risk of arbitrary standards. The calibration of innovative
24 financial instruments to notional carbon prices could encourage large multinational companies to
25 increase their level of internal carbon prices (UNEP, 2016). These notional prices could be higher than
26 explicit carbon prices because they redirect new hardware investments without an immediate impact
27 on existing capital stocks and associated interests.

28
29 Literature however shows that conflicts between poorly articulated policy instruments can undermine
30 their efficiency (Lecuyer and Quirion, 2013; Bhattacharya et al., 2017; García-Álvarez et al., 2017). As has
31 been illustrated in Europe, commitment uncertainty and lack of credibility of regulation have consistently led
32 to low carbon prices in the case of the EU Emission Trading System (ETS; Koch et al., 2014; 2016). A
33 comparative study shows how these conflicts can be avoided by policy packages that integrate many
34 dimensions of public policies and are designed to match institutional and social context of each country and
35 region (Bataille et al., 2015).

36
37 Even though policy packages depend upon domestic political processes, they might not reinforce the NDCs
38 at a level consistent with the 1.5°C transition without a conducive international setting where international
39 development finance plays a critical role. Section 4.4.1 explores the means of mainstreaming climate finance
40 in the current evolution of the lending practices of national and multilateral bank (Badré, 2018). This could
41 facilitate the access of developing countries to loans via bond markets at low interest rates,
42 encouragement of the emergence of new business models for infrastructure, and encouragement of
43 financial markets to support small-scale investments (Déau and Touati, 2017).

44
45 These financial innovations may involve non-state public actors like cities and regional public authorities
46 that govern infrastructure investment, enable energy and food systems transitions and manage urban
47 dynamics (Cartwright, 2015). They would help for example in raising USD 4.5–5.4 trillion yr⁻¹ from 2015 to
48 2030 announced by the Cities Climate Finance Leadership Alliance (CCFLA, 2016) to achieve the
49 commitments by the Covenant of Mayors of many cities to long-term climate targets (Kona et al., 2018).

50
51 The evolution of global climate financial cooperation may involve Central Banks, financial regulatory
52 authorities, multilateral and commercial banks. There are still knowledge gaps about the form,
53 structure and potential of these arrangements. They could be viewed as a form of a burden-sharing
54 between high, medium and low-income countries to enhance, the deployment of ambitious Nationally

1 Determined Contributions (NDCs), and new forms of Common But Differentiated Responsibility and
 2 Respective Capabilities (Edenhofer et al., 2015; Hourcade et al., 2015; Ji and Sha, 2015).
 3
 4

5 **4.5 Integration and Enabling Transformation**

7 **4.5.1 Assessing Feasibility of Options for Accelerated Transitions**

9 Chapter 2 shows that 1.5°C-consistent pathways involve rapid, global climate responses to reach net-zero
 10 emissions by mid-century or earlier. Chapter 3 identifies climate change risks and impacts to which the
 11 world would need to adapt to, during these transitions and additional risks and impacts during potential
 12 1.5°C overshoot pathways. The feasibility of these pathways is contingent upon systemic change (Section
 13 4.3) and enabling conditions (Section 4.4), including policy packages. This section assesses the feasibility of
 14 options (technologies, actions and measures) that form parts of global systems under transition that make up
 15 1.5°C-consistent pathways (Section 4.3).
 16

17 Following the assessment framework developed in Chapter 1, economic and technological; institutional and
 18 socio-cultural; and environmental and geophysical feasibility are considered, and applied in to system
 19 transitions (Sections 4.3.1–4.3.4), overarching adaptation options (Section 4.3.5) and to Carbon Dioxide
 20 Removal (CDR) options (Section 4.3.7). This is done to assess the multi-dimensional feasibility of
 21 mitigation and adaptation options that have seen considerable development and change since AR5. In the
 22 case of adaptation, the assessed AR5 options are typically clustered, for example, all options related to
 23 energy infrastructure resilience, independently of the generation source, are categorised as ‘resilience of
 24 power infrastructure’.
 25

26 Table 4.10 presents sets of indicators against which the multi-dimensional feasibility of individual adaptation
 27 options relevant to limiting warming of 1.5°C, and mitigation options along 1.5°C-consistent pathways, are
 28 assessed.
 29

30 **Table 4.10:** Sets of indicators against which the feasibility of adaptation and mitigation are assessed, for each feasibility
 31 dimension (in Sections 4.3.1-4.3.4, 4.3.5 and 4.3.7)
 32

	Characteristics	Adaptation indicators	Mitigation indicators
	Economic	Micro-economic viability Macro-economic viability Socio-economic vulnerability reduction potential Employment & productivity enhancement potential	Cost-effectiveness Absence of distributional effects Employment & productivity enhancement potential
	Technological	Technical resource availability Risks mitigation potential	Technical scalability Maturity Simplicity Absence of risk
	Institutional	Political acceptability Legal & regulatory feasibility Institutional capacity & administrative feasibility Transparency & accountability potential	Political acceptability Legal & administrative feasibility Institutional capacity Transparency & accountability potential
	Socio-cultural	Social co-benefits (health, education) Socio-cultural acceptability Social & regional inclusiveness Intergenerational equity	Social co-benefits (health, education) Public acceptance Social & regional inclusiveness Intergenerational equity Human capabilities

	Environmental/ecological	Ecological capacity Adaptive capacity/ resilience building potential	Reduction of air pollution Reduction of toxic waste Reduction of water use Improved biodiversity
	Geophysical	Physical feasibility Land use change enhancement potential Hazard risk reduction potential	Physical feasibility (physical potentials) Limited use of land Limited use of scarce (geo)physical resources Global spread

1 The feasibility assessment takes the following steps. First, each of the mitigation and adaptation options is
 2 assessed along the relevant indicators grouped around six feasibility dimensions: economic, technological,
 3 institutional, socio-cultural, environmental/ecological and geophysical. Three types feasibility groupings
 4 were assessed from the underlying literature: first, if the indicator could block the feasibility of this option,
 5 second, if the indicator has neither a positive, nor a negative effect on the feasibility of the option or the
 6 evidence is mixed, and third if the indicator does not pose any barrier to the feasibility of this option. The full
 7 assessment of each option under each indicator, including the literature references on which the assessment
 8 is based, can be found in supplementary materials 4.SM.4.2 and 4.SM.4.3. When appropriate, it is indicated
 9 that there is no evidence (NE), limited evidence (LE) or that the indicator is not applicable to the option
 10 (NA).

11 Next, for each feasibility dimension and option, the overall feasibility for a given dimension is assessed as
 12 the mean of combined scores of the relevant underlying indicators, and classified into ‘insignificant barriers’
 13 (2.5 to 3), ‘mixed or moderate but still existent barriers’ (1.5 to 2.5) or ‘significant barriers’ (below 1.5) to
 14 feasibility. Indicators assessed as NA, LE or NE are not included in this overall assessment (see
 15 supplementary material 4.SM.4.1 for the averaging and weighing guidance).

16 The results are summarised in Table 4.11 (for mitigation options) and Table 4.12 (for adaptation options) for
 17 each of the six feasibility dimensions: where dark shading indicates few feasibility barriers; moderate
 18 shading indicates that there are some barriers and light shading that multiple barriers, in this dimension, may
 19 block implementation.

20 A three-step process of independent validation and discussion by authors and reviewers was undertaken to
 21 make this assessment as robust as possible within the scope of this special report. It must however, be
 22 recognised that this is an indicative assessment at global scale, and both policy and implementation at
 23 regional, national and local level would need to adapt and build on this knowledge, within the particular
 24 local context and constraints.

27 **4.5.2 Implementing Mitigation**

29 This section builds on the insights on mitigation options in Section 4.3, applies the assessment methodology
 30 along feasibility dimensions and indicators explained in Section 4.5.1, and synthesises the assessment of the
 31 enabling conditions in Section 4.4.

34 **4.5.2.1 Assessing of Mitigation Options for Limiting Warming to 1.5°C Against Feasibility Dimensions**

36 An assessment of the degree to which examples of 1.5°C-relevant mitigation options face barriers to
 37 implementation, and on which contexts this depends, is summarised in Table 4.11. An explanation of the
 38 approach is given in Section 4.5.1 and in supplementary material 4.SM.4.1. Selected options were mapped
 39 onto system transitions and clustered through an iterative process of literature review, expert feedback, and
 40 responses to reviewer comments. The detailed assessment and the literature underpinning the assessment can

1 be found in supplementary material 4.SM.4.2.

2

3 The feasibility framework in Cross-Chapter Box 3 in Chapter 1 highlights that the feasibility of mitigation
4 and adaptation options depends on many factors. Many of those are captured in the indicators in Table 4.10,
5 but many depend on the specific context in which an option features. Since this Special Report did not have
6 the mandate, space nor the literature base to undertake a regionally specific assessment. Hence the
7 assessment is caveated as providing a broad indication of where the global barriers are likely to ignoring
8 significant regional diversity. Regional and context-specific literature is also just emerging as recorded in
9 knowledge gaps (Section 4.6). Nevertheless, in Table 4.11, an indicative attempt has been made to capture
10 some relevant contextual information. The 'context' column indicates what contextual factors may affect the
11 feasibility of an option, including regional differences. For instance, solar irradiation in an area impacts the
12 cost-effectiveness of solar Photovoltaic (PV), so solar irradiation is mentioned in this column.

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Table 4.11: Feasibility assessment of examples of 1.5°C-relevant mitigation options with dark shading signifying the absence of barriers in the feasibility dimension, moderate shading that on average, the dimension does not have a positive, nor a negative effect on the feasibility of the option, and faint shading the presence of potentially blocking barriers. No shading means that not sufficient literature could be found to make the assessment. Evidence and agreement assessment is undertaken at the option level. The context column on the far right indicates how the assessment might change if contextual factors are different. For the methodology and literature basis, see supplementary material 4.SM.4.1 and 4.SM.4.2.

System	Mitigation option	Evidence	Agreement	Ec	Tec	Inst	Soc	Env	Geo	Context
Energy system transitions	Wind energy (on-shore & off-shore)	Robust	Medium							Wind regime, economic status, space for windfarms and enhanced by legal framework for independent power producers affect uptake; cost-effectiveness affected by incentive regime.
	Solar PV	Robust	High							Cost-effectiveness affected by solar irradiation and incentive regime. Also enhanced by legal framework for independent power producers affect uptake.
	Bioenergy	Robust	Medium							Depends on availability of biomass and land and capability to manage sustainable land use. Distributional effects depend on the agrarian (or other) system used to produce feedstock.
	Electricity storage	Robust	High							Batteries universal but grid flexible resources vary with area's level of development
	Power sector CCS	Robust	High							Varies with local CO2 storage capacity, presence of legal framework, level of development and quality of public engagement
	Nuclear energy	Robust	High							Electricity market organisation, legal framework, standardisation & know-how, country's 'democratic fabric', institutional and technical capacity, and safety culture of public and private institutions
Land & ecosystem transitions	Reduced food wastage & efficient food production	Robust	High							Will depend on the combination of individual and institutional behaviour
	Dietary shifts	Medium	High							Depends on individual behaviour, education, cultural factors and institutional support
	Sustainable intensification of agriculture	Medium	High							Depends on development and deployment of new technologies
	Ecosystems restoration	Medium	High							Depends on location and institutional factors
Urban	Land-use & urban planning	Robust	Medium							Varies with urban fabric, not geography or economy; requires capacitated local government and legitimate tenure system

	Electric cars and buses	Medium	High							Varies with degree of government intervention; requires capacity to retrofit “fuelling” stations
	Sharing schemes	Limited	Medium							Historic schemes universal new ones depend on ICT status; undermined by high crime and low levels of law enforcement
	Public transport	Robust	Medium							Depends on presence of existing ‘informal’ taxi systems, which may be more cost effective and affordable than capital intensive new build schemes, as well as (local) government capabilities
	Non-motorised transport	Robust	High							Viability rests on linkages with public transport, cultural factors, climate and geography
	Aviation & shipping	Medium	Medium							Varies with technology, governance and accountability
	Smart Grids	Medium	Medium							Varies with economic status and presence or quality of existing grid
	Efficient appliances	Medium	High							Adoption varies with economic status and policy framework
	Low/zero-energy buildings	Medium	High							Depends on size of existing building stock and growth of building stock
Industrial system transitions	Energy efficiency	Robust	High							Potentials and adoption depends on existing efficiency, energy prices and interest rates, as well as government incentives.
	Bio-based & circularity	Medium	Medium							Faces barriers in terms of pressure on natural resources and biodiversity. Product substitution depends on market organisation and government incentivisation.
	Electrification & hydrogen	Medium	High							Depends on availability of large-scale, cheap, emission-free electricity (electrification, hydrogen) or CO2 storage nearby (hydrogen). Manufacturers' appetite to embrace disruptive innovations
	Industrial CCUS	Robust	High							High concentration of CO2 in exhaust gas improve economic and technical feasibility of CCUS in industry. CO2 storage or reuse possibilities.
Carbon dioxide removal	BECCS	Robust	Medium							Depends on biomass availability, CO2 storage capacity, legal framework, economic status and social acceptance
	DACCS	Medium	Medium							Depends on CO2-free energy, CO2 storage capacity, legal framework, economic status and social acceptance
	Afforestation & reforestation	Robust	High							Depends on location, mode of implementation, and economic and institutional factors

Soil carbon sequestration & biochar	Robust	High	■	■				■	Depends on location, soil properties, time span
Enhanced weathering	Medium	Low		■				■	Depends on CO2-free energy, economic status and social acceptance

1

1 4.5.2.2 *Enabling Conditions for Implementation of Mitigation Options Towards 1.5°C*

2
3 The feasibility assessment highlights six dimensions that could help inform an agenda that could be
4 addressed by the areas discussed in Section 4.4: governance, behaviour and lifestyles, innovation, enhancing
5 institutional capacities, policy and finance. For instance, Section 4.4.3 on behaviour offers strategies for
6 addressing public acceptance problems, and how changes can be more effective when communication and
7 the actions relate to people's values. This section synthesises the findings in Section 4.4 in an attempt to link
8 them to the assessment in Table 4.11. The literature on which the discussion is based is found in Section 4.4.
9

10 From Section 4.4, including the case studies presented in the Boxes 4.1 to 4.10, several main messages can
11 be constructed. For instance, governance would have to be multi-level and engaging different actors, while
12 being efficient, and choosing the type of cooperation based on the specific systemic challenge or option at
13 hand. If institutional capacity for financing and governing the various transitions is not urgently built, many
14 countries would lack the ability to change pathways from a high-emission scenario to a low- or zero-
15 emission scenario. In terms of innovation, governments, both national and multilateral, can contribute to the
16 mitigation-purposed application of general purpose technologies. If this is not managed, some emission
17 reduction could happen autonomously, but it may not lead to a 1.5°C-consistent pathway. International
18 cooperation on technology, including technology transfer where this does not happen autonomously, is
19 needed and can help creating the innovation capabilities in all countries to be able to operate, maintain, adapt
20 and regulate a portfolio of mitigation technologies. Case studies in the various sub-sections highlight the
21 opportunities and challenges of doing this in practice. They indicate that it can be done in specific
22 circumstances .
23

24 A combination of behaviour-oriented pricing policies and financing options can help change technologies
25 and social behaviour as it challenges the existing, high-emission socio-technical regime on multiple levels
26 across feasibility characteristics. For instance, for dietary change, a combination of supply-side measures
27 with value-driven communication and economic instruments may help make a lasting transition, while only
28 an economic instrument, such as enhanced prices or taxation, may not be as robust.
29

30 Governments could benefit from enhanced carbon prices, as a price and innovation incentive and also source
31 of additional revenue to correct distributional effects and subsidise the development of new, cost-effective
32 negative-emission technology and infrastructure. However, there is *high evidence* and *medium agreement*
33 that pricing alone is insufficient. Even if prices rise significantly, they typically incentivise incremental
34 change, but typically fail to provide the impetus for private actors to take the risk of engaging in the
35 transformational changes that would be needed to limit warming to 1.5°C. Apart from the incentives to
36 change behaviour and technology, financial systems are an indispensable element of a systemic transition. If
37 financial markets do not acknowledge climate risk and the risk of transitions, they could be organised by
38 regulatory financial institutions, such as central banks.
39

40 Strengthening implementation revolves around more than addressing barriers to feasibility. A system
41 transition, be it in energy, industry, land or a city, requires changing the core parameters of a system. These
42 relate, as introduced in Section 4.2 and further elaborated in Section 4.4, to how actors cooperate, how
43 technologies are embedded, how resources are linked, how cultures relate and what values people associate
44 with the transition and the current regime.
45

46 4.5.3 *Implementing Adaptation*

47 Article 7 of the Paris Agreement provides an aspirational global goal for adaptation, of 'enhancing adaptive
48 capacity, strengthening resilience, and reducing vulnerability' (UNFCCC, 2015). Adaptation implementation
49 is gathering momentum in many regions, guided by national NDC's and National Adaptation Plans (see
50 Cross-Chapter Box 11 in this Chapter).
51
52

53
54 Operationalising adaptation in a set of regional environments on pathways to a 1.5°C world, requires
55 strengthened global and differentiated regional and local capacities. It also needs rapid and decisive

1 adaptation actions to reduce the costs and magnitude of potential climate impacts (Vergara et al., 2015).

2
3 This could be facilitated by: i) enabling conditions, especially improved governance, economic measures and
4 financing (Section 4.4); ii) enhanced clarity on adaptation options to help identify strategic priorities,
5 sequencing and timing of implementation (Section 4.3); iii) robust monitoring and evaluation frameworks;
6 and iv) political leadership (Magnan et al., 2015; Magnan and Ribera, 2016; Lesnikowski et al., 2017;
7 UNEP, 2017a).

8 9 10 *4.5.3.1 Feasible Adaptation Options*

11 This section summarises the feasibility (defined in Cross-Chapter Box 3, Table 1 in Chapter 1 and Table 4.4)
12 of select adaptation options using evidence presented across this chapter and in supplementary material
13 4.SM.4.3 and the expert-judgement of its authors (Table 4.12). The options assessed respond to risks and
14 impacts identified in Chapter 3. They were selected based on options identified in AR5 (Noble et al., 2014),
15 focusing on those relevant to 1.5°C-compatible pathways, where sufficient literature exists. Selected options
16 were mapped onto system transitions and clustered through an iterative process of literature review, expert
17 feedback, and responses to reviewer comments.

18
19 Besides gaps in the literature around crucial adaptation questions on the transition to a 1.5°C world (Section
20 4.6), there is inadequate current literature to undertake a spatially differentiated assessment (Cross-Chapter
21 Box 3 in Chapter 1). There are also limited baselines for exposure, vulnerability and risk to help policy and
22 implementation prioritisation. Hence, the compiled results can at best provide a broad framework to inform
23 policymaking. Given the bottom-up nature of most adaptation implementation evidence, care needs to be
24 taken in generalising these findings.

25
26 Options are considered as part of a systemic approach, recognising that no single solution exists to limit
27 warming to 1.5°C and adapting to its impacts. To respond to the local and regional context, and synergies
28 and trade-offs between adaptation, mitigation and sustainable development, packages of options suited to
29 local enabling conditions, can be implemented.

30
31 Table 4.12 summarises the feasibility assessment through its six dimensions with levels of evidence and
32 agreement, and indicates how the feasibility of an adaptation option may be differentiated by certain
33 contextual factors (last column).
34
35

Table 4.12: Feasibility assessment of examples of 1.5°C-relevant adaptation options with dark shading signifying the absence of barriers in the feasibility dimension, moderate shading that on average, the dimension does not have a positive, nor a negative effect on the feasibility of the option, and light shading the presence of potentially blocking barriers. No shading means that not sufficient literature could be found to make the assessment. NA signifies that the dimension is not applicable to that adaptation option. For methodology and literature basis, see supplementary material 4.SM.4.

System	Adaptation option	Evidence	Agreement	Ec	Tec	Inst	Soc	Env	Geo	Context
Energy system transitions	Power infrastructure, including water	Medium	High							Depends on existing power infrastructure, all generation sources and with intensive water requirements
Land & ecosystem transitions	Conservation agriculture	Medium	Medium							Depends on irrigated/rainfed system, ecosystem characteristics, crop type, other farming practices
	Efficient irrigation	Medium	Medium							Depends on agricultural system, technology used, regional institutional and biophysical context
	Efficient livestock	Limited	High							Dependent on livestock breeds, feed practices, and biophysical context (e.g. carrying capacity)
	Agroforestry	Medium	High							Depends on knowledge, financial support, and market conditions
	Community-based adaptation	Medium	High							Focus on rural areas and combined with ecosystems-based adaptation, does not include urban settings
	Ecosystem restoration & avoided deforestation	Robust	Medium							Mostly focused on existing and evaluated REDD+ projects
	Biodiversity management	Medium	Medium							Focus on hotspots of biodiversity vulnerability and high connectivity
	Coastal defense & hardening	Robust	Medium							Depends on locations that require it as a first adaptation option
	Sustainable aquaculture	Limited	Medium							Depends on locations at risk and socio-cultural context
Urban & infrastructure system transitions	Sustainable land-use & urban planning	Medium	Medium							Depends on nature of planning systems and enforcement mechanisms
	Sustainable water management	Robust	Medium							Balancing sustainable water supply and rising demand especially in low-income countries
	Green infrastructure & ecosystem services	Medium	High							Depends on reconciliation of urban development with green infrastructure

	Approval Session			IPCC SR1.5						Chapter 4
	Building codes & standards	Limited	Medium							Adoption requires legal, educational, and enforcement mechanisms to regulate buildings
Industrial system transitions	Intensive industry infrastructure resilience and water management	Limited	High							Depends on intensive industry, existing infrastructure and using or requiring high demand of water
Overarching adaptation options	Disaster risk management	Medium	High							Requires institutional, technical, and financial capacity in frontline agencies and government
	Risk spreading and sharing	Medium	Medium							Requires well developed financial structures and public understanding
	Climate services	Medium	High							Depends on climate information availability and usability, local infrastructure and institutions, national priorities
	Indigenous knowledge	Medium	High							Dependent on recognition of Indigenous rights, laws, and governance systems
	Education and learning	Medium	High							Existing education system, funding
	Population health and health system	Medium	High							Requires basic health services and infrastructure
	Social safety nets	Medium	Medium							Type and mechanism of safety net, political priorities, institutional transparency
	Human migration	Medium	Low							Hazard exposure, political and socio-cultural acceptability (in destination), migrant skills and social networks

1

1
2 When considered jointly, the description of adaptation options (Section 4.3), the feasibility assessment
3 (summarised in Table 4.12), and discussion of enabling conditions (Section 4.4) show us how options can be
4 implemented and lead towards transformational adaptation if and when needed.
5

6 The adaptation options for energy system transitions focus on existing power infrastructure resilience and
7 water management, when required, for any type of generation source. These options are not sufficient for the
8 far-reaching transformations required in the energy sector, which have tended to focus on technologies to
9 shift from a fossil-based to a renewable energy system (Erlinghagen and Markard, 2012; Muench et al.,
10 2014; Brand and von Gleich, 2015; Monstadt and Wolff, 2015; Child and Breyer, 2017; Hermwille et al.,
11 2017). There is also need for integration of this with social-ecological systems transformations to
12 increase the resilience of the energy sector, for which appropriate enabling conditions, such as for
13 technological innovations, are fundamentally important. Institutional capacities can be enhanced by
14 expanding the role of actors as transformation catalysts (Erlinghagen and Markard, 2012). The integration of
15 ethics and justice within these transformations can help attain the SDG7 on clean energy access (Jenkins et
16 al., 2018), while inclusion of the cultural dimension and cultural legitimacy (Amars et al., 2017) can provide
17 a more substantial base for societal transformation. Strengthening policy instruments and regulatory
18 frameworks and enhancing multi-level governance that focusses on resilience components can help secure
19 these transitions (Exner et al., 2016).
20

21 For land and ecosystem transitions, conservation agriculture, efficient irrigation, agroforestry, ecosystem
22 restoration and avoided deforestation, and coastal defence and hardening have between *medium and robust*
23 *evidence* with *medium to high agreement*. The other options assessed have limited or no evidence across one
24 or more of the feasibility dimensions. Community-based adaptation is assessed as an option many
25 opportunities with *medium evidence* and *high agreement* though faces scaling barriers. Given the structural
26 changes these options may require, transformational adaptation may be implied in some regions, involving
27 enhanced multi-level governance and institutional capacities by enabling anticipatory and flexible decision-
28 making systems that access and develop collaborative networks (Dowd et al., 2014), tackling root causes of
29 vulnerability (Chung Tiam Fook, 2017), and developing synergies between development and climate change
30 (Burch et al., 2017). Case studies show the use of transformational adaptation approaches for fire
31 management (Colloff et al., 2016a), floodplain and wetland management (Colloff et al., 2016b), and forest
32 management (Chung Tiam Fook, 2017), in which the strengthening of policy instruments and climate
33 finance are also required.
34

35 There is growing recognition of the need for transformational adaptation within the agricultural sector but
36 limited evidence on how to facilitate processes of deep, systemic change (Dowd et al., 2014). Case studies
37 demonstrate that transformational adaptation in agriculture requires a sequencing and overlap between
38 incremental and transformational adaptation actions (Hadarits et al., 2017; Termeer et al., 2017), e.g.,
39 incremental improvements to crop management while new crop varieties are being researched and field
40 tested (Rippke et al., 2016). Broader considerations include addressing stakeholder values and attitudes
41 (Fleming et al., 2015a), understanding and leveraging the role of social capital, collaborative networks, and
42 information (Dowd et al., 2014), and being inclusive with rural and urban communities, and the social,
43 political, and cultural environment (Rickards and Howden, 2012). Transformational adaptation in agriculture
44 systems could have significant economic and institutional costs (Mushtaq, 2016), along with potential
45 unintended negative consequences (Davidson, 2016; Rippke et al., 2016; Gajjar et al., 2018; Mushtaq, 2018),
46 and a need to focus on the transitional space between incremental and transformational adaptation (Hadarits
47 et al., 2017), as well as the timing of the shift from one to the other (Läderach et al., 2017).
48

49 Within urban and infrastructure transitions, green infrastructure and sustainable water management are
50 assessed as the most feasible options, followed by sustainable land-use and urban planning. The need for
51 transformational adaptation in urban settings arises from the root causes of poverty, failures in sustainable
52 development, and a lack of focus on social justice (Revi et al., 2014a; Parnell, 2015; Simon and Leck, 2015;
53 Shi et al., 2016; Ziervogel et al., 2016a; Burch et al., 2017), with the focus on governance structures and the
54 inclusion of equity and justice (Bos et al., 2015; Shi et al., 2016; Hölscher et al., 2018).
55

1 Current implementation of Urban Ecosystems-based Adaptation (EbA) lacks a systems perspective of
2 transformations and consideration of the normative and ethical aspects of EbA (Brink et al., 2016).
3 Flexibility within urban planning could help deal with the multiple uncertainties of implementing adaptation
4 (Radhakrishnan et al., 2018) (Rosenzweig and Solecki, 2014), for example, urban adaptation pathways were
5 implemented in the aftermath of Hurricane Sandy in New York, which is considered as tipping point that led
6 to the implementation of transformational adaptation practices.

7
8 Adaptation options for industry focus on infrastructure resilience and water management. Like with energy
9 system transitions, technological innovation would be required, but also the enhancement of institutional
10 capacities. Recent research illustrates transformational adaptation within industrial transitions focusing on
11 the role of different actors and tools driving innovation, and points to the role of Nationally Appropriate
12 Mitigation Actions in avoiding lock-ins and promoting system innovation (Boodoo and Olsen, 2017), the
13 role of private sector in sustainability governance in the socio-political context (Burch et al., 2016), and of
14 green entrepreneurs driving transformative change in the green economy (Gibbs and O'Neill, 2014). (Lim-
15 Camacho et al., 2015) suggest an analysis of the complete lifecycle of supply chains as a means of
16 identifying additional adaptation strategies, as opposed to the current focus on a part of the supply chain.
17 Chain-wide strategies can modify the rest of the chain and present a win-win with commercial objectives.

18
19 The assessed adaptation options also have mitigation synergies and tradeoffs (assessed in Section 4.5.4) that
20 need to be carefully considered, while planning climate action.

21 22 23 *4.5.3.2 Monitoring and Evaluation*

24
25 Monitoring and Evaluation (M&E) in adaptation implementation can promote accountability and
26 transparency of adaptation financing, facilitate policy learning and the share good practices, pressure
27 laggards, and guide adaptation planning. The majority of research on M&E focuses on specific policies or
28 programmes, and has typically been driven by the needs of development organisations, donors, and
29 governments to measure the impact and attribution of adaptation initiatives (Ford and Berrang-Ford, 2016).
30 There is growing research examining adaptation progress across nations, sectors, and scales (Austin et al.
31 2016; Heidrich et al. 2016; Lesnikowski et al. 2016; Reckien et al. 2014; Robinson 2017; Araos et al.
32 2016a,b). Responding to need for global, regional and local adaptation, developing indicators and
33 standardised approaches to evaluate and compare adaptation over time and across regions, countries, and
34 sectors would enhance comparability and learning. A number of constraints continue to hamper progress on
35 adaptation M&E, including a debate on what actually constitutes adaptation for purposes of assessing
36 progress (Dupuis and Biesbroek 2013; Biesbroek et al. 2015), absence of comprehensive and systematically
37 collected data on adaptation to support longitudinal assessment and comparison (Lesnikowski et al. 2016;
38 Ford et al. 2015), lack of agreement on indicators to measure (Lesnikowski et al. 2015; Bours et al. 2015;
39 Brooks et al. 2013), and challenges of attributing altered vulnerability to adaptation actions (UNEP 2017;
40 Bours et al. 2015; Ford et al. 2013).

41 42 43 *4.5.4 Synergies and Trade-Offs Between Adaptation and Mitigation*

44
45 Implementing a particular mitigation or adaptation option may affect the feasibility and effectiveness of
46 other mitigation and adaptation options. Supplementary Material 4.SM.5.1 provides examples of possible
47 positive impacts (synergies) and negative impacts (trade-offs) of mitigation options for adaptation. For
48 example, renewable energy sources such as wind energy and solar PV combined with electricity storage can
49 increase resilience due to distributed grids, thereby enhancing both mitigation and adaptation. Yet, as another
50 example, urban densification may reduce Greenhouse Gas (GHG) emissions, enhancing mitigation, but can
51 also intensify heat island effects and inhibit restoration of local ecosystems if not accounted for, thereby
52 increasing adaptation challenges.

53 The table in Supplementary Material 4.SM.5.2 provides examples of synergies and trade-offs of adaptation
54 options for mitigation. It shows, for example, that conservation agriculture can reduce some GHG emissions

1 and thus enhance mitigation, but at the same time increase other GHG emissions thereby reducing mitigation
2 potential. As another example, agroforestry can reduce GHG emissions through reduced deforestation and
3 fossil fuel consumption, but has a lower carbon sequestration potential compared with natural and secondary
4 forest.

5 Maladaptive actions could increase the risk of adverse climate-related outcomes, for example, biofuel targets
6 could lead to indirect land use change and influence local food security, through a shift in land use abroad in
7 response to increased domestic biofuel demand, increasing global GHG emissions, rather than decreasing it.

8 Various options enhance both climate change mitigation and adaptation, and would hence serve two 1.5°C-
9 related goals: reducing emissions while adapting to the associated climate change. Examples of such options
10 are reforestation, urban and spatial planning, and land and water management.

11 Synergies between mitigation and adaptation may be enhanced, and trade-offs reduced, by considering
12 enabling conditions (Section 4.4), while trade-offs can be amplified when enabling conditions are not
13 considered (C.A. Scott et al., 2015). For example, information that is tailored to the personal situation of
14 individuals and communities, including climate services, that are credible and targeted at the point of
15 decision making, can enable and promote both mitigation and adaptation actions (Section 4.4.3). Similarly,
16 multi-level governance and community participation, respectively, can enable and promote both adaptation
17 and mitigation actions (Section 4.4.1). Governance, policies and institutions can facilitate the implementation
18 of the Water-Energy-Food (WEF) nexus (Rasul and Sharma, 2016). The WEF can enhance food, water and
19 energy security, particularly in cities with agricultural production areas (Biggs et al., 2015), electricity
20 generation with intensive water requirements (Conway et al 2015), and in agriculture (El Gafy et al., 2017)
21 and livelihoods (Biggs et al., 2015). Such a nexus approach can reduce the transport energy that is embedded
22 in food value chains (Villaruel Walker et al., 2014), providing diverse sources of food in the face of
23 changing climates (Tacoli et al., 2013). Urban agriculture, where integrated, can mitigate climate change and
24 support urban flood management (Angotti, 2015; Bell et al., 2015; Biggs et al., 2015; Gwedla and
25 Shackleton, 2015; Lwasa et al., 2015; Y.C.E. Yang et al., 2016; Sanesi et al., 2017). In the case of electricity
26 generation, enabling conditions through a combination of carefully selected policy instruments can maximize
27 the synergic benefits between low GHG energy production and water for energy (Shang et al., 2018).
28 Despite the multiple benefits of maximising synergies between mitigation and adaptations options through
29 the WEF nexus approach (Chen and Chen, 2016), there are implementation challenges given institutional
30 complexity, political economy, and interdependencies between actors (Leck et al., 2015).

31 **[START BOX 4.10 HERE]**

32

33 **Box 4.10: Bhutan: Synergies and Trade-Offs in Economic Growth, Carbon Neutrality and Happiness**

34

35 Bhutan has three national goals, improving: its Gross National Happiness Index (GNHI), economic growth
36 (Gross Domestic Product, GDP) and carbon neutrality. These goals increasingly interact and raise questions
37 about whether they can be sustainably maintained into the future. Interventions in this enabling environment
38 are required to comply with all three goals.

39

40 Bhutan is well known for its GNHI, which is based on a variety of indicators covering psychological well-
41 being, health, education, cultural and community vitality, living standards, ecological issues and good
42 governance (RGoB, 2012; Schroeder and Schroeder, 2014; Ura, 2015). The GNHI is a precursor to the
43 Sustainable Development Goals (SDGs) (Allison, 2012; Brooks, 2013) and reflects local enabling
44 environments. The GNHI has been measured twice, in 2010 and 2015, and this showed an increase of 1.8%
45 (CBS, 2016). Like most emerging countries, Bhutan wants to increase its wealth and become a middle-
46 income country (RGoB, 2013, 2016), while it remains carbon-neutral, a goal which has been in place since
47 2011 at COP 19 and was reiterated in its Intended Nationally Determined Contribution (NEC, 2015). Bhutan
48 achieves its current carbon-neutral status through hydropower and forest cover (Yangka and Diesendorf,
49 2016) which are part of their resilience and adaptation strategy.

50

51 Nevertheless, Bhutan faces rising Greenhouse Gas (GHG) emissions. Transport and industry are the largest

1 growth areas (NEC, 2011). Bhutan's carbon-neutral status would be threatened by 2037 by business-as-usual
2 approaches to economic growth (Yangka and Newman, 2018). Increases in hydropower are being planned
3 based on climate change scenarios that suggest sufficient water supply will be available (NEC, 2011). Forest
4 cover is expected to remain sufficient to maintain co-benefits. The biggest challenge is to electrify both
5 freight and passenger transport (ADB, 2013). Bhutan wants to be a model for achieving economic growth
6 consistent with limiting climate change to 1.5°C and improving its Gross National Happiness (Michaelowa
7 et al., 2018) through synthesizing all three goals and improving its adaptive capacity.

8
9 **[END BOX 4.10 HERE]**

10

4.6 Knowledge Gaps and Key Uncertainties

The global response to limiting warming to 1.5°C is a new knowledge area, that has emerged after the Paris Agreement. This sections presents a number of knowledge gaps that have emerged from the assessment of mitigation, adaptation and Carbon Dioxide Removal (CDR) options and Solar Radiation Modification (SRM) measures, enabling conditions, and synergies and tradeoffs. Illustrative questions that emerge synthesising the more comprehensive Table 4.14 below include: how much can be realistically expected from innovation, behaviour and systemic political and economic change in improving resilience, enhancing adaptation and reducing GHG emissions? How can rates of changes be accelerated and scaled up? What is the outcome of realistic assessments of mitigation and adaptation land transitions that are compliant with sustainable development, poverty eradication and addressing inequality? What are life-cycle emissions and prospects of early-stage CDR options? How can climate and sustainable development policies converge, and how can they be organised within a global governance framework and financial system, based on principles of justice and ethics (CBDR-RC), reciprocity and partnership? To what extent limit warming to 1.5°C needs a harmonization of macro-financial and fiscal policies, that could include Central banks? How can different actors and processes in climate governance reinforce each other, and hedge against the fragmentation of initiatives?

These knowledge gaps are highlighted in Table 4.13 along with a cross-reference to the respective sections in the last column.

Table 4.13: Knowledge gaps and uncertainties

<i>Knowledge area</i>		<i>Mitigation</i>	<i>Adaptation</i>	<i>Reference</i>
1.5°C pathways and ensuing change		<ul style="list-style-type: none"> Lack of literature specific to 1.5°C on investment costs with detailed breakdown by technology. Lack of literature specific to 1.5°C on mitigation costs in terms of GDP and welfare. Lack of literature on distributional implications of 1.5°C compared to 2°C or business-as-usual at sectoral and regional levels. Limited 1.5°C-specific case studies for mitigation Limited knowledge on the systemic and dynamic aspects of transitions to 1.5°C, including how vicious or virtuous circles might work, how self-reinforcing aspects can be actively introduced and managed. 	<ul style="list-style-type: none"> Lack of literature specific to 1.5°C on adaptation costs and need Lack of literature on what overshoot means for adaptation Lack of knowledge on avoided adaptation investments associated with limiting warming to 1.5°C, 2°C or business-as-usual Limited 1.5°C-specific case studies for adaptation Scant literature examining current or future adaptation options, or examining what different climate pathways mean for adaptation success Need for transformational adaptation at 1.5°C and beyond remains largely unexplored 	4.2
Options to achieve and	Energy	<ul style="list-style-type: none"> The shift to variable renewables that many countries are implementing is just reaching a level where large-scale storage systems or other grid 	<ul style="list-style-type: none"> Relatively little literature on individual adaptation options since AR5 	4.3.1

adapt to 1.5°C		<p>flexibility options, e.g., demand response, are required to enable resilient grid systems, thus, new knowledge on the opportunities and issues associated with scaling up zero carbon grids would be needed including knowledge about how zero carbon electric grids can integrate with the full scale electrification of transport systems.</p> <ul style="list-style-type: none"> • CCS suffers mostly from uncertainty about the feasibility of timely upscaling, both due to lack of regulatory capacity and concerns about storage safety and cost. • There is not much literature on the distributional implications of large-scale bioenergy deployment, the assessment of environmental feasibility is hampered by a diversity of contexts of individual studies (type of feedstock, technology, land availability), which could be improved through emerging meta-studies 	<ul style="list-style-type: none"> • No evidence on socio-cultural acceptability of adaptation options • Lack of regional research on the implementation of adaptation options. 	
	Land & ecosystems	<ul style="list-style-type: none"> • More knowledge would be needed on how land-based mitigation can be reconciled with land demands for adaptation and development. • While there is now more literature on the underlying mechanisms of land transitions, data is often insufficient to draw robust conclusions, and uncertainty about land availability • The lack of data counts on social and institutional information (largest knowledge gap indicated for ecosystems restoration in Table 4.11), which is therefore not widely integrated in land use modelling. • Examples of successful policy implementation and institutions related to land-based mitigation leading to co-benefits for adaptation and development are missing from the literature 	<ul style="list-style-type: none"> • Regional information on some options does not exist, especially in the case of land use transitions. • Limited research examining socio-cultural perspectives and impacts of adaptation options, especially for efficient irrigation, coastal defense and hardening, agroforestry and biodiversity management • Lack of longitudinal, regional studies assessing the impacts of certain adaptation options such as conservation agriculture and shifting to efficient livestock systems. • More knowledge is needed on the cost-effectiveness and scalability of various adaptation options. For example, there is no evidence for the macro-economic viability of Community-based Adaptation (CbA) and biodiversity management, nor on employment and productivity enhancement 	4.3.2

		<ul style="list-style-type: none"> • There is relatively little scientific literature on the effects of dietary shifts and reduction of food wastage on mitigation, especially regarding the institutional, technical and environmental concerns 	<p>potential for biodiversity management and coastal defense and hardening.</p> <ul style="list-style-type: none"> • More knowledge is needed on risk mitigation and the potential of biodiversity management. • Lack of evidence of the political acceptability of efficient livestock • Limited evidence on legal and regulatory feasibility of conservation agriculture and no evidence on coastal defense and hardening • For transparency and accountability potential, there is limited evidence for conservation agriculture and no evidence for biodiversity management, coastal defense and hardening and sustainable aquaculture • No evidence on hazard risk reduction potential of conservation agriculture and biodiversity management. 	
Urban systems & infrastructure	<ul style="list-style-type: none"> • Limited evidence of effective land use planning in low income cities where tenure and land zoning is contested, and the risks of trying to implement land use planning under communal tenure. • Limited evidence on the governance of public transport from an accountability and transparency perspective • Limited evidence on relationship between toxic waste and public transport. • Limited evidence on the impacts of electric vehicles and non-motorised urban transport as most schemes are too new. • As changes in shipping and aviation have been limited to date, limited evidence of social impacts. • Knowledge about how to facilitate disruptive, demand-based innovations that may be transformative in urban systems, is needed. 	<ul style="list-style-type: none"> • Regional and sectoral adaptation cost assessments are missing, particularly in the context of welfare losses of households, across time and space. • More knowledge is needed on the political economy of adaptation, particularly on how to impute different types of cost and benefit in a consistent manner, on adaptation performance indicators that could stimulate investment, and the impact of adaptation interventions on socio-economic, and other types, of inequality. • More evidence would be needed on hot-spots, for example the growth of peri-urban areas populated by large informal settlements. • Major uncertainties emanate from the lack of knowledge on the integration of climate adaptation and mitigation, disaster risk management, and urban poverty alleviation. • There is limited evidence on the institutional, technological and economic feasibility of green 	4.3.3	

	<ul style="list-style-type: none"> • The urban form implications of combined changes from electric, autonomous and shared/public mobility systems, is needed. • Considering distributional consequences of climate responses is an on-going need. • Knowledge gaps in the application and scale-up of combinations of new smart technologies, sustainable design, advanced construction techniques and new insulation materials, renewable energy and behaviour change in urban settlements. • The potential for leapfrog technologies to be applied to slums and new urban developments in developing countries is weak. 	<p>infrastructure and environmental services and for socio-cultural and environmental feasibility of codes and standards</p> <ul style="list-style-type: none"> • In general, there is no evidence for the employment and productivity enhancement potential of most adaptation options. • There is limited evidence on the economic feasibility of sustainable water management. 	
Industry	<ul style="list-style-type: none"> • Lack of knowledge on potential for scaling up and global diffusion of zero- and low-emission technologies in industry • Questions remain on the socio-cultural feasibility of industry options, including human capacity and private sector acceptance of new, radically different technologies from current well-developed practices, as well as distributional effects of potential new business models • As the industrial transition unfolds, lack of knowledge on its dynamic interactions with other sectors, in particular with the power sector (and infrastructure) for electrification of industry, with food production and other users of biomass in case of bio-based industry developments, and with CDR technologies in the case of CC(U)S. • Life-cycle assessment-based comparative analysis of CCUS options are missing, as well as life-cycle information on electrification and hydrogen. • Impacts of industrial system transitions are not well understood, especially on employment, identity and well-being, in particular in the case of substitution 	<ul style="list-style-type: none"> • Very limited evidence on how industry would adapt to the consequences of 1.5 or 2°C temperature increases, in particular large and immobile industrial clusters in low-lying areas and availability of transportation and (cooling) water resources and infrastructure. • There is limited evidence on the economic, institutional and socio-cultural feasibility of adaptation options available to industry. 	4.3.4

		of conventional , high-carbon industrial products with lower-carbon alternatives, as well as electrification and use of hydrogen.		
	Short-lived climate forcers	<ul style="list-style-type: none"> Limited evidence of co-benefits and trade-offs of SLCF reduction (e.g., better health outcomes, agricultural productivity improvements). Integration of SLCFs into emissions accounting and international reporting mechanisms enabling a better understanding of the links between black carbon, air pollution, climate change and agricultural productivity. 		4.3.6
	CDR	<ul style="list-style-type: none"> A bottom-up analysis of CDR options, indicates that there are still key uncertainties around the individual technologies. This – includes Ocean-based options will be assessed in depth in the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC). Assessments of environmental aspects are missing, especially for ‘newer’ options like Enhanced Weathering or Direct Air Carbon Capture. In order to obtain more information on realistically available and sustainable removal potentials, more bottom-up, regional studies, also taking into account also social issues, would be needed. These can better inform the modeling of 1.5°C pathways. Knowledge gaps on issues of governance and public acceptance, the impacts of large-scale removals on the carbon cycle, the potential to accelerate deployment and upscaling, and means of incentivisation. Knowledge gaps on integrated systems of renewable energy and CDR technologies such as enhanced weathering and DACCS 		4.3.7

		<ul style="list-style-type: none"> • Knowledge gaps on the use of captured CO₂ is generating negative emissions and as mitigation option. 		
	Overarching Adaptation Options	<ul style="list-style-type: none"> • There is no evidence on technical and institutional feasibility of educational options • There is limited evidence on employment and productivity enforcement potential of climate services • There is limited evidence on socio-cultural acceptability of social safety nets • There is a small but growing literature on human migration as an adaptation strategy. Scant literature on the cost effectiveness of migration. 		4.3.5
Enabling conditions	Governance	<ul style="list-style-type: none"> • As technological changes have begun to accelerate, there is lack of knowledge on new mechanisms that can enable private enterprise to mainstream this activity and reasons for success and failure need to be researched. • Research is thin on effective multi-level governance in particular in developing countries, including participation by civil society, women and minorities Gaps in knowledge remain pertaining to partnerships within local governance arrangements that may act as mediators and drivers for achieving global ambition and local action. • Methods for assessing contribution and aggregation of non-state actors in limiting warming to 1.5°C • Knowledge gap on an enhanced framework for assessment of the ambition of NDCs 	<ul style="list-style-type: none"> • The ability to identify explanatory factors affecting the progress of climate policy is constrained by a lack of data on adaptation actions across nations, regions, and sectors, compounded by an absence of frameworks for assessing progress. Most hypotheses on what drives adaptation remain untested. • Limited empirical assessment of how governance affects adaptation across cases • Focus on ‘success’ stories and leading adaptors overlooks lessons from situations where no or unsuccessful adaptation is taking place 	4.4.1
	Institutions	<ul style="list-style-type: none"> • Lack of 1.5°C-specific literature • Role of regulatory financial institutions and their capacity to guarantee financial stability of economies when investments potentially face risks both because of climate impacts and because of the systems transitions if lower temperature scenarios are pursued. • Knowledge gaps on how to build capabilities across all countries and regions globally to implement, maintain, manage, govern and further develop mitigation options for 1.5°C. • While importance of Indigenous and local knowledge is recognized, the ability to scale up beyond the local remains challenging and little examined • There is a lack of monitoring and evaluation (M&E) of adaptation measures, with most studies enumerating M&E challenges and emphasising the importance of context and social learning. Very few studies evaluate 		4.4.2

		whether and why an adaptation initiative has been effective. One of the challenges of M&E for both mitigation and adaptation is a lack of high quality information for modellings. Adaptation M&E is additionally challenged by limited understanding on what indicators to measure and how to attribute altered vulnerability to adaptation actions.	
Lifestyle and behavioural change	<ul style="list-style-type: none"> Whereas mitigation pathways studies address (implicitly or explicitly) the reduction or elimination of market failures (e.g., external costs, information asymmetries) <i>via</i> climate or energy policies, no study addresses behavioural change strategies in the relationship with mitigation and adaptation actions in the 1.5°C context. Limited knowledge on GHG emission reduction potential of diverse mitigation behaviour across the world. Most studies on factors enabling lifestyle changes have been conducted in high income countries, more knowledge needed from low- and middle-income countries, and the focus is typically on enabling individual behavior change, far less on enabling change in organisations and political systems Limited understanding and treatment of behavioural change and the potential effects of related policies in ambitious mitigation pathways, e.g., in Integrated Assessment Models. 	<ul style="list-style-type: none"> Knowledge gaps on factors enabling adaptation behaviour, except for behaviour in agriculture. Little is known about cognitive and motivational factors promoting adaptive behavior. Little is known about how potential adaptation actions might affect behavior to influence vulnerability outcomes 	4.4.3
	Lack of insight on what can enable changes in adaptation and mitigation behaviour in organisations and political systems.		
Technological innovation	<ul style="list-style-type: none"> Quantitative estimates for mitigation and adaptation potentials at economy or sector scale as a result of the combination of general purpose technologies and mitigation technologies have been scarce, except for some evidence in the transport sector. Evidence on the role of international organisations, including the UNFCCC, in building capabilities and enhancing technological innovation for 1.5°C, except for some parts of the transport sector. Technology transfer trials to enable leapfrog applications in developing countries have limited evidence 		4.4.4
Policy	<ul style="list-style-type: none"> More empirical research would be needed to derive robust conclusions on effectiveness of policies for 	<ul style="list-style-type: none"> Understanding of what policies work (and do not work) is limited for adaptation in general and for 	4.4.5

		enabling transition to 1.5°C and on which factors aid decision-makers seeking to ratchet up their NDCs	1.5°C in particular, beyond specific case studies.	
	Finance	Knowledge gaps persist with respect to the instruments to match finance to its most effective use in mitigation and adaptation.		4.4.5
Synergies and tradeoffs between adaptation and mitigation		<ul style="list-style-type: none"> • Strong claims are made with respect to synergies and trade-offs, but there is little knowledge to underpin these, especially of co-benefits by region. • Water-energy conservation relationships of individual conservation measures in industries other than the water and energy sectors have not been investigated in detail. • There is no evidence on synergies with adaptation of CCS in the power sector and of enhanced weathering under carbon dioxide removal. • There is no evidence on trade-offs with adaptation of low and zero-energy buildings, and circularity and substitution and bio-based industrial system transitions. • There is no evidence of synergies or trade-offs with mitigation of CbA • There is no evidence of trade-offs with mitigation of the built environment, on adaptation options for industrial energy, and climate services 		4.5.4
SRM		<ul style="list-style-type: none"> • In spite of increasing attention to the different SRM measures and their potential to keep global temperature below 1.5°C, knowledge gaps remain not only with respect to the physical understanding of SRM options, but also concerning ethical issues. • We do not know how to govern SRM in order to avoid unilateral action and how to prevent possible reductions in mitigation ('moral hazard'). 		4.3.8

1
2

1 **Frequently Asked Questions**

2 3 **FAQ 4.1: What transitions could enable limiting global warming to 1.5°C?**

4
5 ***Summary:** In order to limit warming to 1.5°C above preindustrial levels, the world would need to transform*
6 *in a number of complex and connected ways. While transitions towards lower greenhouse gas emissions are*
7 *underway in some cities, regions, countries, businesses and communities, there are few that are currently*
8 *consistent with limiting warming to 1.5°C. Meeting this challenge would require a rapid escalation in the*
9 *current scale and pace of change, particularly in the coming decades. There are many factors that affect the*
10 *feasibility of different adaptation and mitigation options that could help limit warming to 1.5°C and*
11 *adapting to the consequences.*

12 There are actions across all sectors can substantially reduce greenhouse gas emissions. This Special Report
13 assesses energy, land and ecosystems, urban and infrastructure, and industry in developed and developing
14 nations to see how they would need to be transformed to limit warming to 1.5°C. Examples of actions
15 include shifting to low- or zero-emission power generation, such as renewables; changing food systems, such
16 as diet changes away from land-intensive animal products; electrifying transport and developing ‘green
17 infrastructure’, such as building green roofs, or improving energy efficiency by smart urban planning, which
18 will change the layout of many cities.

19 Because these different actions are connected, a ‘whole systems’ approach would be needed for the type of
20 transformations that could limit warming to 1.5°C. This means that all relevant companies, industries and
21 stakeholders would need to be involved to increase the support and chance of successful implementation. As
22 an illustration, the deployment of low-emission technology (e.g., renewable energy projects or a bio-based
23 chemical plants) would depend upon economic conditions (e.g., employment generation or capacity to
24 mobilise investment), but also on social/cultural conditions (e.g., awareness and acceptability) and
25 institutional conditions (e.g., political support and understanding).

26 To limit warming to 1.5°C, mitigation would have to be large-scale and rapid. Transitions can be
27 transformative or incremental, and they often, but not always, go hand in hand. Transformative change can
28 arise from growth in demand for a new product or market, such that it displaces an existing one. This is
29 sometimes called ‘disruptive innovation’. For example, high demand for LED lighting is now making more
30 energy-intensive, incandescent lighting near-obsolete, with the support of policy action that spurred rapid
31 industry innovation. Similarly, smart phones have become global in use within ten years. But electric cars,
32 which were released around the same time, have not been adopted so quickly because the bigger, more
33 connected transport and energy systems are harder to change. Renewable energy, especially solar and wind,
34 is considered to be disruptive by some as it is rapidly being adopted and is transitioning faster than predicted.
35 But its demand is not yet uniform. Urban systems that are moving towards transformation are coupling solar
36 and wind with battery storage and electric vehicles in a more incremental transition, though this would still
37 require changes in regulations, tax incentives, new standards, demonstration projects and education
38 programmes to enable markets for this system to work.

39 Transitional changes are already underway in many systems but limiting warming to 1.5°C would require a
40 rapid escalation in the scale and pace of transition, particularly in the next 10-20 years. While limiting
41 warming to 1.5°C would involve many of the same types of transitions as limiting warming to 2°C, the pace
42 of change would need to be much faster. While the *pace* of change that would be required to limit warming
43 to 1.5°C can be found in the past, there is no historical precedent for the *scale* of the necessary transitions, in
44 particular in a socially and economically sustainable way. Resolving such speed and scale issues would
45 require people’s support, public-sector interventions and private-sector cooperation.

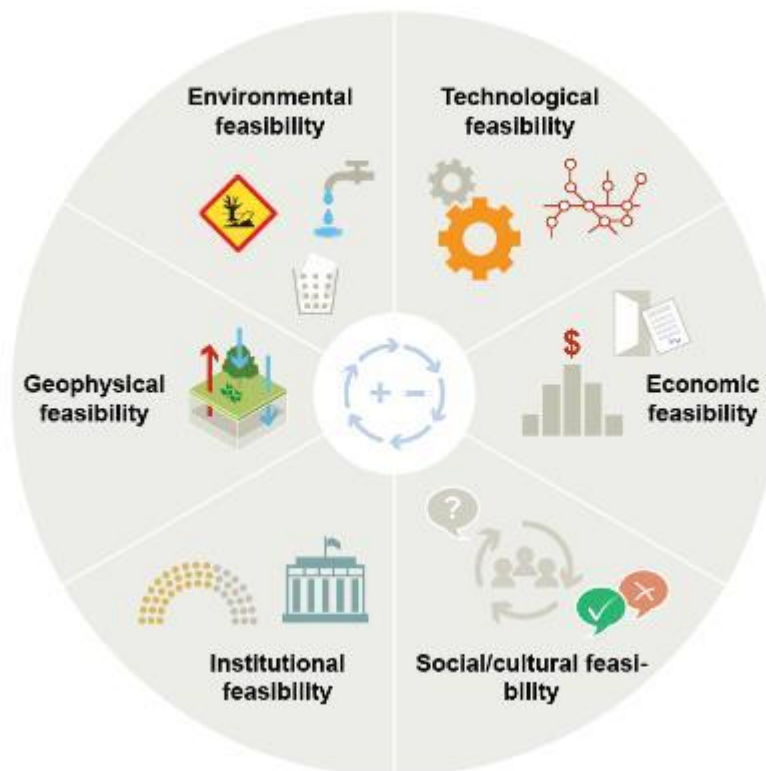
46 Different types of transitions carry with them different associated costs and requirements for institutional or
47 governmental support. Some are also easier to scale up than others, and some need more government support
48 than others. Transitions between, and within, these systems are connected and none would be sufficient on
49 its own to limit warming to 1.5°C.

1 The ‘feasibility’ of adaptation and mitigation options or actions within each system that together can limit
 2 warming to 1.5°C within the context of sustainable development and efforts to eradicate poverty requires
 3 careful consideration of multiple different factors. These factors include: (i) whether sufficient natural
 4 systems and resources are available to support the various options for transitioning (known as *environmental*
 5 *feasibility*); (ii) the degree to which the required technologies are developed and available (known as
 6 *technological feasibility*); (iii) the economic conditions and implications (known as *economic feasibility*);
 7 (iv) what are the implications for human behaviour and health (known as *social/cultural feasibility*); and (v)
 8 what type of institutional support would be needed, such as governance, institutional capacity and political
 9 support (known as *institutional feasibility*). An additional factor (vi - known as the *geophysical feasibility*)
 10 addresses the capacity of physical systems to carry the option, for example whether it is geophysically
 11 possible to implement large-scale afforestation consistent with 1.5°C.

12 Promoting enabling conditions, such as finance, innovation and behaviour change, would reduce barriers to
 13 the options, make the required speed and scale of the system transitions more likely, and therefore would
 14 increase the overall feasibility limiting warming to 1.5°C.

FAQ4.1: The different feasibility dimensions towards limiting warming to 1.5°C

Assessing the feasibility of different adaptation and mitigation options/actions requires consideration across six dimensions.



15

16

17 **FAQ4.1, Figure 1:** The different dimensions to consider when assessing the ‘feasibility’ of adaptation and mitigation
 18 options or actions within each system that can help to limit warming to 1.5°C. These are: (i) the environmental
 19 feasibility; (ii) the technological feasibility; (iii) the economic feasibility; (iv) the social/cultural feasibility; (v) the
 20 institutional feasibility; and (vi) the geophysical feasibility.

21

1 FAQ 4.2: What are Carbon Dioxide Removal and negative emissions?

2

3 **Summary:** *Carbon Dioxide Removal (CDR) refers to the process of removing CO₂ from the atmosphere. Since this is the opposite of emissions, practices or technologies that remove CO₂ are often described as achieving ‘negative emissions’. The process is sometimes referred to more broadly as Greenhouse Gas Removal if it involves removing gases other than CO₂. There are two main types of CDR: either enhancing existing natural processes that remove carbon from the atmosphere (e.g., by increasing its uptake by trees, soil, or other ‘carbon sinks’) or using chemical processes to, for example, capture CO₂ directly from the ambient air and storing it elsewhere (i.e., underground). All CDR methods are at different stages of development and some are more conceptual than others, as they have not been tested at scale.*

11 Limiting warming to 1.5°C above preindustrial levels would require unprecedented rates of transformation in many areas, including in the energy and industrial sectors, for example. Conceptually, it is possible that techniques to draw CO₂ out of the atmosphere (known as Carbon Dioxide Removal, or CDR) could contribute to limiting warming to 1.5°C. One use of CDR could be to compensate for greenhouse gas emissions from sectors that cannot completely decarbonise, or which may take a long time to do so.

16 If global temperature temporarily overshoots 1.5°C, CDR would be required to reduce the atmospheric concentration of CO₂ to bring global temperature back down. To achieve this temperature reduction, the amount of CO₂ drawn out of the atmosphere would need to be greater than the amount entering the atmosphere, resulting in ‘net negative emissions’. This would involve a greater amount of CDR than stabilising atmospheric CO₂ concentration – and, therefore, global temperature – at a certain level. The larger and longer an overshoot, the greater the reliance on practices that remove CO₂ from the atmosphere.

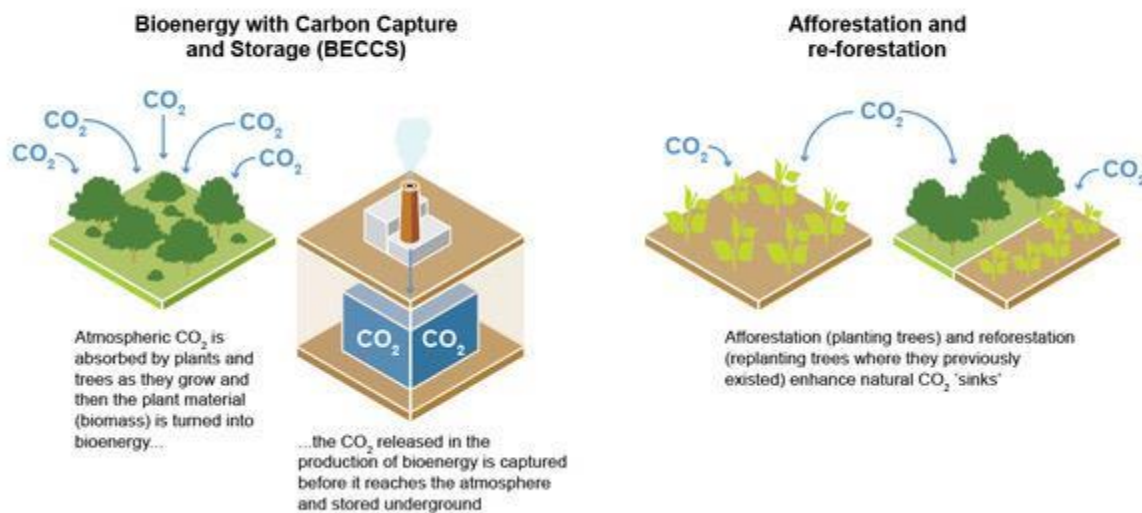
22 There are a number of CDR methods, each with different potentials for achieving negative emissions, as well as different associated costs and side effects. They are also at differing levels of development, with some more conceptual than others. One example of a CDR method in the demonstration phase is a process known as Bioenergy with Carbon Capture and Storage (BECCS), in which atmospheric CO₂ is absorbed by plants and trees as they grow and then the plant material (biomass) is burned to produce bioenergy. The CO₂ released in the production of bioenergy is captured before it reaches the atmosphere and stored in geological formations deep underground on very long timescales. Since the plants absorb CO₂ as they grow and the process does not emit CO₂, the overall effect can be to reduce atmospheric CO₂.

30 Afforestation (planting new trees) and reforestation (replanting trees where they previously existed) are also considered forms of CDR because they enhance natural CO₂ ‘sinks’. Another category of CDR techniques uses chemical processes to capture CO₂ from the air and store it away on very long timescales. In a process known as Direct Air Carbon Capture and Storage (DACCS), CO₂ is extracted directly from the air and stored in geological formations deep underground. Converting waste plant material into a charcoal-like substance called biochar and burying it in soil can also be used to store carbon away from the atmosphere for decades to centuries.

37 There can be beneficial side effects of some types of CDR, other than removing CO₂ from the atmosphere. For example, restoring forests or mangroves can enhance biodiversity and protect against flooding and storms. But there could also be risks involved with some CDR methods. For example, deploying BECCS at large scale would require a large amount of land to cultivate the biomass required for bioenergy. This could have consequences for sustainable development if the use of land competes with producing food to support a growing population, biodiversity conservation, or land rights. There are also other considerations. For example, there are uncertainties about how much it would cost to deploy DACCS as a CDR technique, given that removing CO₂ from the air requires considerable energy.

FAQ4.2: Carbon dioxide removal and negative emissions

Examples of some CDR / negative emissions techniques and practices



1

2 **FAQ4.2, Figure 1:** Carbon Dioxide Removal (CDR) refers to the process of removing CO₂ from the atmosphere.
 3 There are a number of CDR techniques, each with different potential for achieving 'negative emissions', as well as
 4 different associated costs and side effects.

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1 FAQ 4.3: Why is adaptation important in a 1.5°C warmer world?

2 **Summary:** *Adaptation is the adjustment process to current or expected changes in climate and its effects.*
3 *Even though climate change is a global problem, its impacts are experienced differently across the world.*
4 *This means that responses are often specific to the local context, and so people in different regions are*
5 *adapting in different ways. A rise in global temperature from 1°C to 1.5°C, and beyond, increases the need*
6 *for adaptation. Therefore, stabilising global temperatures at 1.5°C above pre-industrial levels would require*
7 *a smaller adaptation effort than for 2°C. Despite many successful examples around the world, progress in*
8 *adaptation is, in many regions, in its infancy and unevenly distributed globally.*

9 Adaptation refers to the process of adjustment to actual or expected changes in climate and its effects. Since
10 different parts of the world are experiencing the impacts of climate change differently, there is similar
11 diversity in how people in a given region are adapting to those impacts.

12 The world is already experiencing the impacts from 1°C of global warming above preindustrial levels and
13 there are many examples of adaptation to impacts associated with this warming. Examples of adaptation
14 efforts taking place around the world include investing in flood defences such as building sea walls or
15 restoring mangroves, efforts to guide development away from high risk areas, modifying crops to avoid yield
16 reductions, and using social learning (social interactions that changes understanding on the community level)
17 to modify agricultural practices, amongst many others. Adaptation also involves building capacity to respond
18 better to climate change impacts, including making governance more flexible and strengthening financing
19 mechanisms such as providing different types of insurance.

20 In general, an increase in global temperature from present day to 1.5°C or 2°C (or higher) above
21 preindustrial temperatures would increase the need for adaptation. Therefore, stabilising global temperature
22 increase at 1.5°C would require a smaller adaptation effort than for 2°C.

23 Since adaptation is still in early stages in many regions, this raises questions about the capacity of vulnerable
24 communities to cope with any amount of further warming. Successful adaptation can be supported at the
25 national and sub-national levels, with national governments playing an important role in coordination,
26 planning, determining policy priorities, and distributing resources and support. Given that the need for
27 adaptation can be very different from one community to the next, the kinds of measures that can successfully
28 reduce climate risks will also depend heavily on the local context.

29 When done successfully, adaptation can allow individuals to adjust to the impacts of climate change in ways
30 that minimise negative consequences and maintain their livelihoods. This could involve, for example, a
31 farmer switching drought-tolerant crops to deal with increasing occurrences of heat waves. In some cases,
32 however, the impacts of climate change could result in entire systems changing significantly, such as moving
33 to an entirely new agricultural system in areas where the climate is no longer suitable for current practices.
34 Constructing sea walls to stop flooding due to sea level rising from climate change is another example of
35 adaptation, but developing city planning to change how flood water is managed throughout the city would be
36 an example of transformational adaptation. These actions require significantly more institutional, structural,
37 and financial support. While this kind of transformational adaptation wouldn't be needed everywhere in a
38 1.5°C world, the scale of change needed would be challenging to implement, as it requires additional support
39 such as through financial assistance and behavioural change. Few empirical examples exist to date.

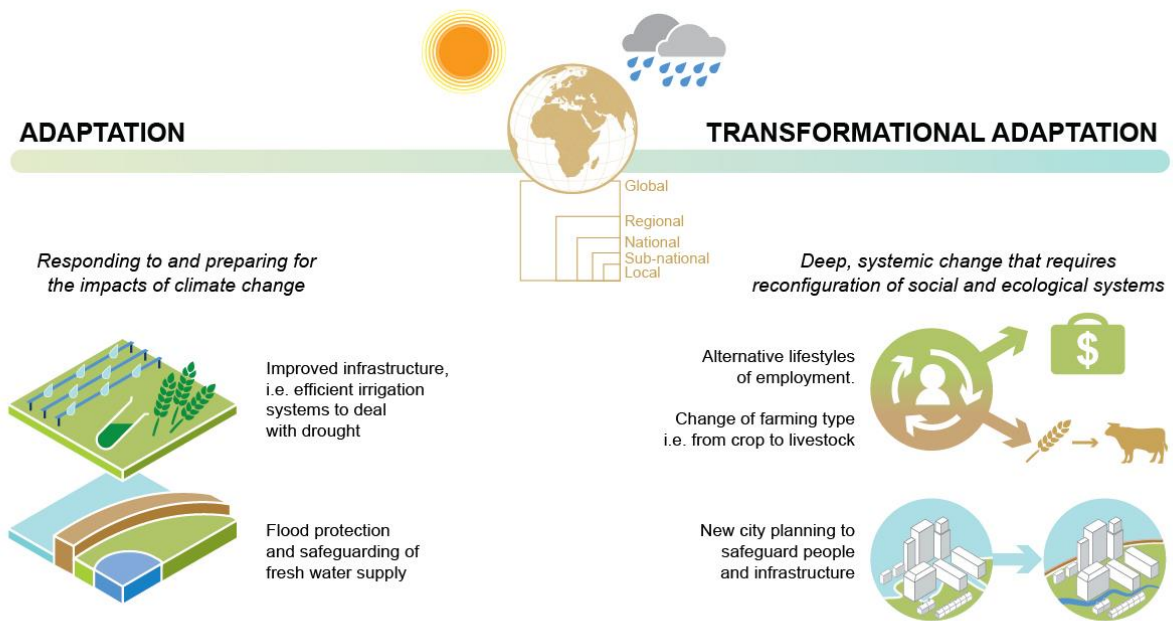
40 Examples from around the world show that adaptation is an iterative process. Adaptation pathways describe
41 how communities can make decisions about adaptation in an ongoing and flexible way. Such pathways allow
42 for pausing, evaluating the outcomes of specific adaptation actions, and modifying the strategy as
43 appropriate. Due to their flexible nature, adaptation pathways can help to identify the most effective ways to
44 minimise the impacts of present and future climate change for a given local context. This is important since
45 adaptation can sometimes exacerbate vulnerabilities and existing inequalities if poorly designed. The
46 unintended negative consequences of adaptation that can sometimes occur is known as 'maladaptation'.
47 Maladaptation can be seen if a particular adaptation option has negative consequences for some (e.g.,

1 rainwater harvesting upstream might reduce water availability downstream) or if an adaptation intervention
 2 in the present has trade-offs in the future (e.g., desalination plants may improve water availability in the
 3 present but have large energy demands over time).

4 While adaptation is important to reduce the negative impacts from climate change, adaptation measures on
 5 their own are not enough to prevent climate change impacts entirely. The more global temperature rises, the
 6 more frequent, severe, and erratic the impacts will be, and adaptation may not protect against all risks.
 7 Examples of where limits may be reached include substantial loss of coral reefs, massive range losses for
 8 terrestrial species, more human deaths from extreme heat, and losses of coastal-dependent livelihoods in low
 9 lying islands and coasts.

FAQ4.3: Adaptation in a warming world

Adapting to further warming requires action at national & sub-national levels and can mean different things to different people in different contexts



10

11 **FAQ4.3, Figure 1:** Examples of adaptation and transformational adaptation. Adapting to further warming requires
 12 action at national & sub-national levels and can mean different things to different people in different contexts. While
 13 transformational adaptation wouldn't be needed everywhere in a world limited to 1.5°C warming, the scale of change
 14 needed would be challenging to implement.

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1 **References**

- 2
- 3 Aakre, S., S. Kallbekken, R. Van Dingenen, and D.G. Victor, 2018: Incentives for small clubs of Arctic countries to
4 limit black carbon and methane emissions. *Nature Climate Change*, **8(1)**, 85-90, doi:10.1038/s41558-017-
5 0030-8.
- 6 Aall, C., K. Groven, and G. Lindseth, 2007: The Scope of Action for Local Climate Policy: The Case of Norway.
7 *Global Environmental Politics*, **7(2)**, 83-101, doi:10.1162/glep.2007.7.2.83.
- 8 Aarts, H. and A.P. Dijksterhuis, 2000: The Automatic Activation of Goal-directed Behaviour: The case of travel habit.
9 *Journal of Environmental Psychology*, **20(1)**, 75-82, doi:10.1006/jevp.1999.0156.
- 10 Aarts, H., B. Verplanken, and A. Knippenberg, 1998: Predicting Behavior From Actions in the Past: Repeated Decision
11 Making or a Matter of Habit? *Journal of Applied Social Psychology*, **28(15)**, 1355-1374, doi:10.1111/j.1559-
12 1816.1998.tb01681.x.
- 13 Abanades, J.C., E.S. Rubin, M. Mazzotti, and H.J. Herzog, 2017: On the climate change mitigation potential of CO2
14 conversion to fuels. *Energy Environ. Sci.*, **10(12)**, 2491-2499, doi:10.1039/C7EE02819A.
- 15 Abanades, J.C. et al., 2015: Emerging CO2 capture systems. *International Journal of Greenhouse Gas Control*, **40**,
16 126-166, doi:10.1016/j.ijggc.2015.04.018.
- 17 Abbott, K.W., 2012: The transnational regime complex for climate change. *Environment and Planning C: Government
18 and Policy*, **30(4)**, 571-590, doi:10.1068/c11127.
- 19 Abbott, K.W. and D. Snidal, 2009: Strengthening International Regulation Through Transnational New Governance:
20 Overcoming the Orchestration Deficit.. *Vanderbilt Journal of Transnational Law*, **42**, 501-578.
- 21 Abbott, K.W., S. Day, O.C. College, and S.M. Ave, 2012: The transnational regime complex for climate change. ,
22 **30(1)**, 571-590, doi:10.1068/c11127.
- 23 Abdulai, I. et al., 2018: Cocoa agroforestry is less resilient to sub-optimal and extreme climate than cocoa in full sun.
24 *Global Change Biology*, **24(1)**, 273-286, doi:10.1111/gcb.13885.
- 25 Abrahamse, W. and L. Steg, 2013: Social influence approaches to encourage resource conservation: A meta-analysis.
26 *Global Environmental Change*, **23**, 1773-1785, doi:10.1016/j.gloenvcha.2013.07.029.
- 27 Abrahamse, W., L. Steg, C. Vlek, and T. Rothengatter, 2005: A review of intervention studies aimed at household
28 energy conservation. *Journal of Environmental Psychology*, **25(3)**, 273-291, doi:10.1016/j.jenvp.2005.08.002.
- 29 Abrahamse, W., L. Steg, C. Vlek, and T. Rothengatter, 2007: The effect of tailored information, goal setting, and
30 tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents. *Journal of
31 Environmental Psychology*, **27**, 265-276, doi:10.1016/j.jenvp.2007.08.002.
- 32 ACOLA, 2017: *The Role of Energy Storage in Australia's Future Energy Supply Mix*. Australian Council of Learned
33 Academics, Melbourne, VIC, 158 pp.
- 34 AdaptationWatch, 2015: *Toward Mutual Accountability: The 2015 Adaptation Finance Transparency Gap Report*.
35 AdaptationWatch.
- 36 ADB, 2013: *Bhutan transport 2040: integrated strategic vision*. Asian Development Bank (ADB), Mandaluyong City,
37 Philippines, 24 pp.
- 38 Aden, N., 2017: Necessary but not sufficient: the role of energy efficiency in industrial sector low-carbon
39 transformation. *Energy Efficiency*, doi:https://doi.org/10.1007/s12053-017-9570-z.
- 40 Adenle, A.A. et al., 2017: Managing Climate Change Risks in Africa - A Global Perspective. *Ecological Economics*,
41 **141**, 190-201, doi:10.1016/j.ecolecon.2017.06.004.
- 42 Adger et al., 2003: Adaptation to climate change in the developing world. *Progress in Development Studies*, **3**, 179-
43 195.
- 44 Adger, W.N., N.W. Arnell, and E.L. Tompkins, 2005: Successful adaptation to climate change across scales. *Global
45 environmental change*, **15(2)**, 77-86.
- 46 Adger, W.N. et al., 2003: Adaptation to climate change in the developing world. *Progress in Development Studies*, **3**,
47 179-195.
- 48 Adger, W.N. et al., 2015: Focus on environmental risks and migration: causes and consequences. *Environmental
49 Research Letters*, **10(6)**, 60201, doi:10.1088/1748-9326/10/6/060201.
- 50 Aebischer, B. and L.M. Hilty, 2015: The Energy Demand of ICT: A Historical Perspective and Current Methodological
51 Challenges. *ICT Innovations for Sustainability*, 71-103.
- 52 Afionis, S., L.C. Stringer, N. Favretto, J. Tomei, and M.S. Buckneridge, 2014: Unpacking Brazil's Leadership in the
53 Global Biofuels Arena: Brazilian Ethanol Diplomacy in Africa. *Global Environmental Politics*, **14(2)**, 82-101,
54 doi:10.1162/GLEP.
- 55 Agee, E.M., A. Orton, E.M. Agee, and A. Orton, 2016: An Initial Laboratory Prototype Experiment for Sequestration of
56 Atmospheric CO 2. *Journal of Applied Meteorology and Climatology*, **55(8)**, 1763-1770, doi:10.1175/JAMC-
57 D-16-0135.1.
- 58 Aglietta, M., E. Espagne, and B. Perrissin Fabert, 2015a: *A proposal to finance low carbon investment in Europe*.
59 France Stratégie, Paris, France, 1-12 pp.
- 60 Aglietta, M., J.-C. Hourcade, C. Jaeger, and B.P. Fabert, 2015b: Financing transition in an adverse context: climate

- 1 finance beyond carbon finance. *International Environmental Agreements: Politics, Law and Economics*, **15(4)**,
2 403-420, doi:10.1007/s10784-015-9298-1.
- 3 Agrawal, A., C. E.R., and E.R. Gerber, 2015: Motivational Crowding in Sustainable Development Interventions.
4 *American Political Science Review*, **109(3)**, 470-487.
- 5 Agrawala, S., M. Carraro, N. Kingsmill, E. Lanzi, and G. Prudent-richard, 2011: Private Sector Engagement in
6 Adaptation to Climate Change: Approaches to Managing Climate Risks. OECD Environment Working Paper
7 No 39, 56 pp.
- 8 Aguilera, E., L. Lassaletta, A. Gattinger, and B.S. Gimeno, 2013: Managing soil carbon for climate change mitigation
9 and adaptation in Mediterranean cropping systems: A meta-analysis. *Agriculture, Ecosystems & Environment*,
10 **168**, 25-36, doi:10.1016/j.agee.2013.02.003.
- 11 Ahern, J., S. Cilliers, and J. Niemelä, 2014: The concept of ecosystem services in adaptive urban planning and design:
12 A framework for supporting innovation. *Landscape and Urban Planning*, **125(Supplement C)**, 254-259,
13 doi:https://doi.org/10.1016/j.landurbplan.2014.01.020.
- 14 Ahlfeldt, G. and E. Pietrostefani, 2017: *Demystifying Compact Urban Growth: Evidence From 300 Studies From*
15 *Across the World*. Coalition for Urban Transitions, OECD, 1-84 pp.
- 16 Ahlm, L. et al., 2017: Marine cloud brightening – as effective without clouds. *Atmospheric Chemistry*
17 *and Physics Discussions*, **17**, 13071-13087, doi:10.5194/acp-2017-484.
- 18 Åhman, M., L.J. Nilsson, and B. Johansson, 2016: Global climate policy and deep decarbonization of energy-intensive
19 industries. *Climate Policy*, **17(5)**, 634-649, doi:10.1080/14693062.2016.1167009.
- 20 Aitken, M., 2010: Wind power and community benefits: Challenges and opportunities. *Energy Policy*, **38(10)**, 6066-
21 6075, doi:10.1016/j.enpol.2010.05.062.
- 22 Ajanovic, A. and R. Haas, 2017: The impact of energy policies in scenarios on GHG emission reduction in passenger
23 car mobility in the EU-15. *Renewable and Sustainable Energy Reviews*, **68**, 1088-1096,
24 doi:10.1016/j.rser.2016.02.013.
- 25 Akbari, H., H.D. Matthews, and D. Seto, 2012: The long-term effect of increasing the albedo of urban areas.
26 *Environmental Research Letters*, **7(2)**, 024004, doi:10.1088/1748-9326/7/2/024004.
- 27 Åkerman, J., 2011: The role of high-speed rail in mitigating climate change - The Swedish case Europabanan from a
28 life cycle perspective. *Transportation Research Part D: Transport and Environment*, **16(3)**, 208-217,
29 doi:https://doi.org/10.1016/j.trd.2010.12.004.
- 30 Akter, S., T.J. Krupnik, and F. Khanam, 2017: Climate change skepticism and index versus standard crop insurance
31 demand in coastal Bangladesh. *Regional Environmental Change*, **17(8)**, 2455-2466, doi:10.1007/s10113-017-
32 1174-9.
- 33 Akter, S., T.J. Krupnik, F. Rossi, and F. Khanam, 2016: The influence of gender and product design on farmers'
34 preferences for weather-indexed crop insurance. *Global Environmental Change*, **38**, 217-229,
35 doi:10.1016/j.gloenvcha.2016.03.010.
- 36 Albers, R.A.W. et al., 2015: Overview of challenges and achievements in the climate adaptation of cities and in the
37 Climate Proof Cities program. *Building and Environment*, **83**, 1-10, doi:10.1016/j.buildenv.2014.09.006.
- 38 Albright, R. et al., 2016: Reversal of ocean acidification enhances net coral reef calcification. *Nature*, **531(7594)**, 362-
39 365, doi:10.1038/nature17155.
- 40 Aldrich, D.P., C. Page, and C.J. Paul, 2016: Social Capital and Climate Change Adaptation. *Oxford Research*
41 *Encyclopedia of Climate Science*, **1**, doi:10.1093/acrefore/9780190228620.013.342.
- 42 Aldy, J. et al., 2016: Economic tools to promote transparency and comparability in the Paris Agreement. *Nature*
43 *Climate Change*, **6**, 1000, doi:10.1038/nclimate3106.
- 44 Alexander, C. et al., 2011: Linking indigenous and scientific knowledge of climate change. *BioScience*, **61(6)**, 477-484,
45 doi:10.1525/bio.2011.61.6.10.
- 46 Alexander, P. et al., 2017: Losses, inefficiencies and waste in the global food system. *Agricultural Systems*, **153**, 190-
47 200, doi:10.1016/j.agry.2017.01.014.
- 48 Alexandratos, N. and J. Bruinsma, 2012: World Agriculture Towards 2030/2050. The 2012 Revision. .
- 49 Alfieri, L. et al., 2017: Global projections of river flood risk in a warmer world. *Earth's Future*, **5(2)**, 171-182,
50 doi:10.1002/2016EF000485.
- 51 Ali, S.H. et al., 2017: Mineral supply for sustainable development requires resource governance. *Nature*, **543**, 367,
52 doi:10.1038/nature21359.
- 53 Alkama, R. and A. Cescatti, 2016: Biophysical climate impacts of recent changes in global forest cover. *Science*,
54 **351(6273)**, 600-604, doi:10.1126/science.aac8083.
- 55 Allan, J.I. and J. Hadden, 2017: Exploring the framing power of NGOs in global climate politics. *Environmental*
56 *Politics*, **26(4)**, 600-620, doi:10.1080/09644016.2017.1319017.
- 57 Allcott, H., 2011: Social norms and energy conservation. *Journal of Public Economics*, **95(9-10)**, 1082-1095,
58 doi:10.1016/j.jpubeco.2011.03.003.
- 59 Allison, E., 2012: Gross National Happiness. In: *The Berkshire Encyclopedia of Sustainability: Measurements,*
60 *Indicators, and Research Methods for Sustainability* [Spellerberg, I., D.S. Fogel, L.M. Butler Harrington, and

- 1 S.E. Fredericks (eds.)). Berkshire Publishing Group, Great Barrington, MA, USA, pp. 180-184.
- 2 Alló, M. and M.L. Loureiro, 2014: The role of social norms on preferences towards climate change policies: A meta-
3 analysis. *Energy Policy*, **73**, 563-574, doi:10.1016/j.enpol.2014.04.042.
- 4 Almeida Prado, F. et al., 2016: How much is enough? An integrated examination of energy security, economic growth
5 and climate change related to hydropower expansion in Brazil. *Renewable and Sustainable Energy Reviews*,
6 **53**, 1132-1136, doi:10.1016/j.rser.2015.09.050.
- 7 Alterskjær, K., J.E. Kristjánsson, and O. Seland, 2012: Sensitivity to deliberate sea salt seeding of marine clouds -
8 Observations and model simulations. *Atmospheric Chemistry and Physics*, **12(5)**, 2795-2807, doi:10.5194/acp-
9 12-2795-2012.
- 10 Altieri, K.E. et al., 2016: Achieving development and mitigation objectives through a decarbonization development
11 pathway in South Africa. *Climate Policy*, **16(Sup 1)**, s78-s91, doi:10.1080/14693062.2016.1150250.
- 12 AMAP, 2017a: *Adaptation Actions for a Changing Arctic: Barents Area Overview Report*. Arctic Monitoring and
13 Assessment Programme (AMAP), Oslo, Norway, 24 pp.
- 14 AMAP, 2017b: *Adaptation Actions for a Changing Arctic: Perspectives from the Bering-Chukchi-Beaufort Region*.
15 Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway, xiv + 255 pp.
- 16 AMAP, 2018: *Adaptation Actions for a Changing Arctic: Perspectives from the Baffin Bay/Davis Strait Region*. Arctic
17 Monitoring and Assessment Programme (AMAP), Oslo, Norway, xvi + 354 pp.
- 18 Amars, L., M. Fridahl, M. Hagemann, F. Röser, and B.-O. Linnér, 2017: The transformational potential of Nationally
19 Appropriate Mitigation Actions in Tanzania: assessing the concept's cultural legitimacy among stakeholders in
20 the solar energy sector. *Local Environment*, **22(1)**, 86-105, doi:10.1080/13549839.2016.1161607.
- 21 Amin, A. and L.R. Cirolia, 2018: Politics/matter: Governing Cape Town's informal settlements. *Urban Studies*, **55(2)**,
22 274-295, doi:10.1177/0042098017694133.
- 23 Amorim, H., M.L. Lopes, J.V. De Castro Oliveira, M.S. Buckeridge, and G.H. Goldman, 2011: Scientific challenges of
24 bioethanol production in Brazil. *Applied Microbiology and Biotechnology*, **91(5)**, 1267-1275,
25 doi:10.1007/s00253-011-3437-6.
- 26 Amundsen, H., G.K. Hovelsrud, C. Aall, M. Karlsson, and H. Westskog, 2018: Local governments as drivers for
27 societal transformation: towards the 1.5 °C ambition. *Current Opinion in Environmental Sustainability*, **31**, 23-
28 29, doi:10.1016/j.cosust.2017.12.004.
- 29 Anaconda, P.I., A. Mackintosh, and K. Norton, 2015: Reconstruction of a glacial lake outburst flood (GLOF) in the
30 Engaño Valley, Chilean Patagonia: Lessons for GLOF risk management. *Science of The Total Environment*,
31 **527-528(Supplement C)**, 1-11, doi:https://doi.org/10.1016/j.scitotenv.2015.04.096.
- 32 Anderson, S.T. and R.G. Newell, 2004: Information programs for technology adoption: the case of energy-efficiency
33 audits. *Resource and Energy Economics*, **26(1)**, 27-50.
- 34 Andersson, M., P. Bolton, and F. Samama, 2016: Hedging Climate Risk. *Financial Analysts Journal*, **72(3)**.
- 35 Andonova, L., T.N. Hale, and C. Roger, 2017: National Policies and Transnational Governance of Climate Change:
36 Substitutes or Complements? *International Studies Quarterly*, 1-16, doi:10.1093/isq/sqx014.
- 37 Andow, D.A. and C. Zwahlen, 2006: Assessing environmental risks of transgenic plants. *Ecology Letters*, **9(2)**, 196-
38 214, doi:10.1111/j.1461-0248.2005.00846.x.
- 39 André, C., D. Boulet, H. Rey-Valette, and B. Rulleau, 2016: Protection by hard defence structures or relocation of
40 assets exposed to coastal risks: Contributions and drawbacks of cost-benefit analysis for long-term adaptation
41 choices to climate change. *Ocean and Coastal Management*, **134**, 173-182,
42 doi:10.1016/j.ocecoaman.2016.10.003.
- 43 Andrews-Speed, P. and G. Ma, 2016: Household Energy Saving in China: The Challenge of Changing Behaviour. In:
44 *China's Energy Efficiency and Conservation: Household Behaviour, Legislation, Regional Analysis and*
45 *Impacts* [Su, B. and E. Thomson (eds.)]. SpringerBriefs in Environment, Security, Development and Peace,
46 pp. 23-39.
- 47 Anenberg, S.C. et al., 2012: Global Air Quality and Health Co-benefits of Mitigating Near-Term Climate Change
48 through Methane and Black Carbon Emission Controls. *Environmental Health Perspectives*, **120(6)**, 831-839,
49 doi:10.1289/ehp.1104301.
- 50 Angotti, T., 2015: Urban agriculture: long-term strategy or impossible dream? *Public Health*, **129(4)**, 336-341,
51 doi:10.1016/j.puhe.2014.12.008.
- 52 Anguelovski, I., E. Chu, and J.A. Carmin, 2014: Variations in approaches to urban climate adaptation: Experiences and
53 experimentation from the global South. *Global Environmental Change*, **27(1)**, 156-167,
54 doi:10.1016/j.gloenvcha.2014.05.010.
- 55 Annicchiarico, B. and F. Di Dio, 2015: Environmental policy and macroeconomic dynamics in a new Keynesian model.
56 *Journal of Environmental Economics and Management*, **69(1)**, 1-21, doi:10.1016/j.jeem.2014.10.002.
- 57 Annicchiarico, B. and F. Di Dio, 2016: GHG Emissions Control and Monetary Policy. *Environmental and Resource*
58 *Economics*, 1-29, doi:10.1007/s10640-016-0007-5.
- 59 Anshelm, J. and A. Hansson, 2014: Battling Promethean dreams and Trojan horses: Revealing the critical discourses of
60 geoengineering. *Energy Research and Social Science*, **2**, 135-144, doi:10.1016/j.erss.2014.04.001.

- 1 Arab, A., A. Khodaei, Z. Han, and S.K. Khator, 2015: Proactive Recovery of Electric Power Assets for Resiliency
2 Enhancement. *IEEE Access*, **3**, 99-109, doi:10.1109/ACCESS.2015.2404215.
- 3 Araos, M., J. Ford, L. Berrang-Ford, R. Biesbroek, and S. Moser, 2016a: Climate change adaptation planning for
4 Global South megacities: the case of Dhaka. *Journal of Environmental Policy and Planning*, **19(6)**, 682-696,
5 doi:10.1080/1523908X.2016.1264873.
- 6 Araos, M. et al., 2016b: Climate change adaptation planning in large cities: A systematic global assessment.
7 *Environmental Science and Policy*, **66**, 375-382, doi:10.1016/j.envsci.2016.06.009.
- 8 Archer, D., 2016: Building urban climate resilience through community-driven approaches to development.
9 *International Journal of Climate Change Strategies and Management*, **8(5)**, 654-669, doi:10.1108/IJCCSM-
10 03-2014-0035.
- 11 Archer, D. et al., 2014: Moving towards inclusive urban adaptation: approaches to integrating community-based
12 adaptation to climate change at city and national scale. *Climate and Development*, **6(4)**, 345-356,
13 doi:10.1080/17565529.2014.918868.
- 14 Arezki, R., P. Bolton, S. Peters, F. Samama, and J. Stiglitz, 2016: From Global Savings Glut to Financing
15 Infrastructure: The Advent of Investment Platforms. WP/16/18.
- 16 Arino, Y. et al., 2016: Estimating option values of solar radiation management assuming that climate sensitivity is
17 uncertain. *Proceedings of the National Academy of Sciences of the United States of America*, **113(21)**, 5886-
18 91, doi:10.1073/pnas.1520795113.
- 19 Armah, F.A., I. Luginaah, H. Hambati, R. Chuenpagdee, and G. Campbell, 2015: Assessing barriers to adaptation to
20 climate change in coastal Tanzania: Does where you live matter? *Population and Environment*, **37(2)**, 231-
21 263, doi:10.1007/s11111-015-0232-9.
- 22 Arnold, U., A. De Palmenaer, T.B. Brück, and K. Kuse, 2018: Energy Efficient Carbon Fiber Production with
23 Concentrated Solar Power: Process-Design and Techno-Economic Analysis. *Industrial & Engineering
24 Chemistry Research* (in press), doi:10.1021/acs.iecr.7b04841.
- 25 Arthur, W.B., 2009: The nature of technology: What it is and how it evolves. .
- 26 Arunrat, N., C. Wang, N. Pumijumnong, S. Sreenonchai, and W. Cai, 2017: Farmers' intention and decision to adapt to
27 climate change: A case study in the Yom and Nan basins, Phichit province of Thailand. *Journal of Cleaner
28 Production*, **143**, 672-685, doi:10.1016/j.jclepro.2016.12.058.
- 29 Arze del Granado, F.J., D. Coady, and R. Gillingham, 2012: The Unequal Benefits of Fuel Subsidies: A Review of
30 Evidence for Developing Countries. *World Development*, **40(11)**, 2234-2248,
31 doi:10.1016/j.worlddev.2012.05.005.
- 32 Asayama, S., M. Sugiyama, and A. Ishii, 2017: Ambivalent climate of opinions: Tensions and dilemmas in
33 understanding geoengineering experimentation. *Geoforum*, **80**, 82-92, doi:10.1016/j.geoforum.2017.01.012.
- 34 Asensio, O.I. and M.A. Delmas, 2015: Nonprice incentives and energy conservation. *Proceedings of the National
35 Academy of Sciences*, **112(6)**, 1-6, doi:10.1073/pnas.1401880112.
- 36 Asfaw, S. and B. Davis, 2018: Can Cash Transfer Programmes Promote Household Resilience? Cross-Country
37 Evidence from Sub-Saharan Africa. *Climate Smart Agriculture : Building Resilience to Climate Change*, 227-
38 250, doi:10.1007/978-3-319-61194-5_11.
- 39 Asfaw, S., A. Carraro, B. Davis, S. Handa, and D. Seidenfeld, 2017: Cash transfer programmes, weather shocks and
40 household welfare: evidence from a randomised experiment in Zambia. *Journal of Development Effectiveness*,
41 **9(4)**, 419-442, doi:10.1080/19439342.2017.1377751.
- 42 Ashworth, P., S. Wade, D. Reiner, and X. Liang, 2015: Developments in public communications on CCS. *International
43 Journal of Greenhouse Gas Control*, **40**, 449-458, doi:10.1016/j.ijggc.2015.06.002.
- 44 Atela, J.O., C.H. Quinn, and P.A. Minang, 2014: Are REDD projects pro-poor in their spatial targeting? Evidence from
45 Kenya. *Applied Geography*, **52**, 14-24, doi:10.1016/J.APGEOG.2014.04.009.
- 46 Aumont, O. and L. Bopp, 2006: Globalizing results from ocean in situ iron fertilization studies. *Global Biogeochemical
47 Cycles*, **20(2)**, doi:10.1029/2005GB002591.
- 48 Austin, S.E. et al., 2015: Public health adaptation to climate change in canadian jurisdictions. *International Journal of
49 Environmental Research and Public Health*, **12(1)**, doi:10.3390/ijerph120100623.
- 50 Averchenkova, A., F. Crick, A. Kocornik-Mina, H. Leck, and S. Surminski, 2016: Multinational and large national
51 corporations and climate adaptation: are we asking the right questions? A review of current knowledge and a
52 new research perspective. *Wiley Interdisciplinary Reviews: Climate Change*, **7(4)**, 517-536,
53 doi:10.1002/wcc.402.
- 54 Axelrod, R. and W.D. Hamilton, 1981: The Evolution of Cooperation. *Science*, **211(4489)**, 1390-1396.
- 55 Aykut, S.C., 2016: Taking a wider view on climate governance: moving beyond the 'iceberg,' the 'elephant,' and the
56 'forest'. *Wiley Interdisciplinary Reviews: Climate Change*, **7(3)**, doi:10.1002/wcc.391.
- 57 Ayling, J. and N. Gunningham, 2017: Non-state governance and climate policy: the fossil fuel divestment movement.
58 *Climate Policy*, **17(2)**, 131-149, doi:10.1080/14693062.2015.1094729.
- 59 Azeiteiro, U.M., W. Leal Filho, and L. Aires, 2017: Climate Literacy and Innovations in Climate Change Education.
60 *International Journal of Global Warming*, **12(3)**.

- 1 Azevedo, I. and V.M.S. Leal, 2017: Methodologies for the evaluation of local climate change mitigation actions: A
2 review. *Renewable and Sustainable Energy Reviews*, **79**, 681-690, doi:10.1016/j.rser.2017.05.100.
- 3 Bäckstrand, K. and J.W. Kuyper, 2017: The democratic legitimacy of orchestration: the UNFCCC, non-state actors, and
4 transnational climate governance. *Environmental Politics*, **26(4)**, 764-788,
5 doi:10.1080/09644016.2017.1323579.
- 6 Badré, B., 2018: *Can Finance Save the World?: Regaining Power over Money to Serve the Common Good*. 288 pp.
- 7 Bager, S. and L. Mundaca, 2017: Energy Research & Social Science Making 'Smart Meters' smarter ? Insights from a
8 behavioural economics pilot field experiment in Copenhagen , Denmark. *Energy Research & Social Science*,
9 **28(April)**, 68-76, doi:10.1016/j.erss.2017.04.008.
- 10 Bahadur, A. and T. Tanner, 2014: Transformational resilience thinking: putting people, power and politics at the heart
11 of urban climate resilience. *Environment and Urbanization*, **26(1)**, 200-214, doi:10.1177/0956247814522154.
- 12 Bahn, O., M. Chesney, J. Gheysens, R. Knutti, and A.C. Pana, 2015: Is there room for geoengineering in the optimal
13 climate policy mix? *Environmental Science and Policy*, **48(i)**, 67-76, doi:10.1016/j.envsci.2014.12.014.
- 14 Bai, X. et al., 2018: Six research priorities for cities and climate change. *Nature*, **555(7694)**, 23-25,
15 doi:10.1038/d41586-018-02409-z.
- 16 Baik, E. et al., 2018: Geospatial analysis of near-term potential for carbon-negative bioenergy in the United States.
17 *Proceedings of the National Academy of Sciences of the United States of America*, **115(13)**, 3290-3295,
18 doi:10.1073/pnas.1720338115.
- 19 Bajželj, B. et al., 2014: Importance of food-demand management for climate mitigation. *Nature Climate Change*, **4(10)**,
20 924-929, doi:10.1038/nclimate2353.
- 21 Baker, L.H. et al., 2015: Climate responses to anthropogenic emissions of short-lived climate pollutants. *Atmospheric
22 Chemistry and Physics*, **15(14)**, 8201-8216, doi:10.5194/acp-15-8201-2015.
- 23 Bakker, D.C.E., A.J. Watson, and C.S. Law, 2001: Southern Ocean iron enrichment promotes inorganic carbon
24 drawdown. *Deep Sea Research Part II: Topical Studies in Oceanography*, **48(11)**, 2483-2507,
25 doi:10.1016/S0967-0645(01)00005-4.
- 26 Bakker, S. et al., 2017: Low-Carbon Transport Policy in Four ASEAN Countries: Developments in Indonesia, the
27 Philippines, Thailand and Vietnam. *Sustainability*, **9(7)**, 1217, doi:10.3390/su9071217.
- 28 Bala, G. et al., 2007: Combined climate and carbon-cycle effects of large-scale deforestation. *Proceedings of the
29 National Academy of Sciences*, **104(16)**, 6550-6555, doi:10.1073/pnas.0608998104.
- 30 Balcombe, P., D. Rigby, and A. Azapagic, 2013: Motivations and barriers associated with adopting microgeneration
31 energy technologies in the UK. *Renewable and Sustainable Energy Reviews*, **22**, 655-666,
32 doi:10.1016/j.rser.2013.02.012.
- 33 Baltz, E.A. et al., 2017: Achievement of Sustained Net Plasma Heating in a Fusion Experiment with the Optometrist
34 Algorithm. *Scientific Reports*, **7(1)**, 6425, doi:10.1038/s41598-017-06645-7.
- 35 Bamberg, S., 2000: The Promotion of New Behavior by Forming an Implementation Intention: Results of a Field
36 Experiment in the Domain of Travel Mode Choice. *Journal of Applied Social Psychology*, **30**, 1903-1922.
- 37 Bamberg, S., 2002: Implementation intention versus monetary incentive comparing the effects of interventions to
38 promote the purchase of organically produced food. *Journal of Economic Psychology*, **23**, 573-587.
- 39 Banerjee, A. and B.D. Solomon, 2003: Eco-labeling for energy efficiency and sustainability: a meta-evaluation of US
40 programs. *Energy Policy*, **31**, 109-123.
- 41 Barbarossa, C., P. De Pelsmacker, and I. Moons, 2017: Personal Values, Green Self-identity and Electric Car Adoption.
42 *Ecological Economics*, **140**, 190-200, doi:10.1016/j.ecolecon.2017.05.015.
- 43 Barkakaty, B. et al., 2017: Emerging materials for lowering atmospheric carbon. *Environmental Technology &
44 Innovation*, **7**, 30-43.
- 45 Barker, T. and J. Kohler, 1998: Equity and Ecotax Reform in the EU: Achieving a 10 per cent Reduction in CO2
46 Emissions Using Excise Duties. *Fiscal Studies*, **19(4)**, 375-402, doi:10.1111/j.1475-5890.1998.tb00292.x.
- 47 Barrett, S., 2015: Subnational Adaptation Finance Allocation: Comparing Decentralized and Devolved Political
48 Institutions in Kenya. *Global Environmental Politics*, **15(3)**, 118-139, doi:10.1162/GLEP_a_00314.
- 49 Bartos, M.D. and M. Chester, 2015: Impacts of climate change on electric power supply in the Western United States.
50 *Nature Climate Change*, **5(8)**, 748-752, doi:10.1038/nclimate2648.
- 51 Bataille, C., D. Sawyer, and N. Melton, 2015: *Pathways to deep decarbonization in Canada*. SDSN-IDDRI, 54 pp.
- 52 Bataille, C. et al., 2018: Technology and policy options for making heavy industry products consistent with 1.5-2°C
53 compatible deep decarbonization pathways. *Journal of Cleaner Production*, **187**, 960-973.
- 54 Bates, B.R., B.L. Quick, and A.A. Kloss, 2009: Antecedents of intention to help mitigate wildfire: Implications for
55 campaigns promoting wildfire mitigation to the general public in the wildland-urban interface. *Safety Science*,
56 **47(3)**, 374-381, doi:10.1016/j.ssci.2008.06.002.
- 57 Bathiany, S., V. Dakos, M. Scheffer, and T.M. Lenton, 2018: Climate models predict increasing temperature variability
58 in poor countries. *Science Advances*, **4(5)**, eaar5809, doi:10.1126/sciadv.aar5809.
- 59 Battiston, S. et al., 2017: A climate stress-test of the financial system. *Nature Climate Change*, **7(4)**, 283-288,
60 doi:10.1038/nclimate3255.

- 1 Baudron, F., C. Thierfelder, I. Nyagumbo, and B. Gérard, 2015: Where to target conservation agriculture for African
2 smallholders? How to overcome challenges associated with its implementation? Experience from Eastern and
3 Southern Africa. *Environments*, **2(3)**, 338-357.
- 4 Bauer, N., S.K. Rose, S. Fujimori, D.P. Vuuren, and J. Weyant, 2018: Global energy sector emission reductions and
5 bioenergy use : overview of the bioenergy demand phase of the EMF-33 model comparison. *Climate Change*.
- 6 Baul, T.K., A. Alam, H. Strandman, and A. Kilpelä, 2017: Net climate impacts and economic profitability of
7 forest biomass production and utilization in fossil fuel and fossil-based material substitution under alternative
8 forest management. *Biomass and Bioenergy*, **98**, 291-305, doi:10.1016/j.biombioe.2017.02.007.
- 9 Baumgärtner, S., M.A. Drupp, J.N. Meya, J.M. Munz, and M.F. Quaas, 2017: Income inequality and willingness to pay
10 for environmental public goods. *Journal of Environmental Economics and Management*, **85**, 35-61.
- 11 Bayraktarov, E. et al., 2016: The cost and feasibility of marine coastal restoration. *Ecological Applications*, **26(4)**,
12 1055-1074, doi:10.1890/15-1077.
- 13 Beatley, T., 2011: *Biophilic Cities: Integrating Nature into Urban Design and Planning*. Island Press, Washington DC,
14 USA, 208 pp.
- 15 Beaudoin, M. and P. Gosselin, 2016: An effective public health program to reduce urban heat islands in Québec,
16 Canada. *Revista Panamericana de Salud Publica*, **40(3)**, 160-166.
- 17 Beccali, M., M. Bonomolo, G. Ciulla, A. Galatioto, and V. Brano, 2015: Improvement of energy efficiency and quality
18 of street lighting in South Italy as an action of Sustainable Energy Action Plans. The case study of Comiso
19 (RG). *Energy, Volume*, **92(3)**, 394-408.
- 20 Bekera, B. and R.A. Francis, 2015: A Bayesian method for thermo-electric power generation drought risk assessment.
21 In: *Safety and Reliability of Complex Engineered Systems - Proceedings of the 25th European Safety and*
22 *Reliability Conference, ESREL 2015*.
- 23 Bell, L.W., A.D. Moore, and J.A. Kirkegaard, 2014: Evolution in crop-livestock integration systems that improve farm
24 productivity and environmental performance in Australia. *European Journal of Agronomy*, **57**, 10-20.
- 25 Bell, T., R. Briggs, R. Bachmayer, and S. Li, 2015: Augmenting Inuit knowledge for safe sea-ice travel - The SmartICE
26 information system. In: *2014 Oceans - St. John's, OCEANS 2014*.
- 27 Bellamy, R. and P. Healey, 2018: Slippery slope' or 'uphill struggle'? Broadening out expert scenarios of climate
28 engineering research and development. *Environmental Science and Policy*, **83(January)**, 1-10,
29 doi:10.1016/j.envsci.2018.01.021.
- 30 Bellamy, R., J. Lezaun, and J. Palmer, 2017: Public perceptions of geoengineering research governance: An
31 experimental deliberative approach. *Global Environmental Change*, **45(June)**, 194-202,
32 doi:10.1016/j.gloenvcha.2017.06.004.
- 33 Belmonte, N. et al., 2016: A comparison of energy storage from renewable sources through batteries and fuel cells: A
34 case study in Turin, Italy. *International Journal of Hydrogen Energy*, **41(46)**, 21427-21438,
35 doi:10.1016/j.ijhydene.2016.07.260.
- 36 Bendito, A. and E. Barrios, 2016: Convergent Agency: Encouraging Transdisciplinary Approaches for Effective
37 Climate Change Adaptation and Disaster Risk Reduction. *International Journal of Disaster Risk Science*, **7(4)**,
38 430-435, doi:10.1007/s13753-016-0102-9.
- 39 Benmarhnia, T. et al., 2016: A Difference-in-Differences Approach to Assess the Effect of a Heat Action Plan on Heat-
40 Related Mortality, and Differences in Effectiveness According. *Environmental health perspectives*, **124(11)**,
41 1694-1699.
- 42 Berdahl, M. et al., 2014: Arctic cryosphere response in the Geoengineering Model Intercomparison Project G3 and G4
43 scenarios. *Journal of Geophysical Research: Atmospheres*, **119**, 1308-1321,
44 doi:10.1002/2013JD021264.Received.
- 45 Bergek, A., S. Jacobsson, B. Carlsson, S. Lindmark, and A. Rickne, 2008: Analyzing the functional dynamics of
46 technological innovation systems: A scheme of analysis. *Research Policy*, **37(3)**, 407-429,
47 doi:10.1016/j.respol.2007.12.003.
- 48 Berle, A.A. and G.C. Means, 1932: *The Modern Corporation and Private Property*. Harcourt, Brace and World, New
49 York, NY, USA.
- 50 Bernauer, T. and R. Gampfer, 2013: Effects of civil society involvement on popular legitimacy of global environmental
51 governance. *Global Environmental Change*, **23(2)**, 439-449, doi:10.1016/j.gloenvcha.2013.01.001.
- 52 Bernauer, T. and R. Gampfer, 2015: How robust is public support for unilateral climate policy? *Environmental Science*
53 *& Policy*, **54**, 316-330, doi:10.1016/j.envsci.2015.07.010.
- 54 Bernauer, T., R. Gampfer, T. Meng, and Y.– Su, 2016a: Could more civil society involvement increase public support
55 for climate policy-making ? Evidence from a survey experiment in China. *Global Environmental Change*, **40**,
56 1-12, doi:10.1016/j.gloenvcha.2016.06.001.
- 57 Bernauer, T., L. Dong, L.F. McGrath, I. Shaymerdenova, and H. Zhang, 2016b: Unilateral or Reciprocal Climate
58 Policy? Experimental Evidence from China. *Politics and Governance*, **4(3)**, 152-171,
59 doi:10.17645/pag.v4i3.650.
- 60 Berrang-Ford, L., J.D. Ford, and J. Paterson, 2011: Are we adapting to climate change? *Global Environmental Change*,

- 1 **21(1)**, 25-33, doi:10.1016/j.gloenvcha.2010.09.012.
- 2 Berrang-Ford, L. et al., 2014: What drives national adaptation? A global assessment. *Climatic Change*, **124(1-2)**, 441-
- 3 450, doi:10.1007/s10584-014-1078-3.
- 4 Bertoldi, P., 2017: Are current policies promoting a change in behaviour, conservation and sufficiency? An analysis of
- 5 existing policies and recommendations for new and effective policies. In: *Proceedings of the ECEEE 2017*
- 6 *Summer Study on Consumption, Efficiency & Limits*. ECEEE, Stockholm, Sweden, pp. 201-211.
- 7 Bertoldi, P., S. Rezessy, and V. Oikonomou, 2013: Rewarding energy savings rather than energy efficiency: Exploring
- 8 the concept of a feed-in tariff for energy savings. *Energy Policy*, **56**, 526-535,
- 9 doi:10.1016/j.enpol.2013.01.019.
- 10 Bertoldi, P., T. Ribeiro Serrenho, and P. Zangheri, 2016: Consumer Feedback Systems: How Much Energy Saving Will
- 11 They Deliver and for How Long? In: *Proceedings of the 2016 ACEEE Summer Study on Energy Efficiency in*
- 12 *Buildings*. ACEEE, Washington DC, USA.
- 13 Bertoldi, P., A. Kona, S. Rivas, and J.F. Dallemand, 2018: Towards a global comprehensive and transparent framework
- 14 for cities and local governments enabling an effective contribution to the Paris climate agreement. *Current*
- 15 *Opinion in Environmental Sustainability*, **30**, 67-74, doi:10.1016/j.cosust.2018.03.009.
- 16 Betsill, M.M. and H. Bulkeley, 2006: Cities and the Multilevel Governance of Global Climate Change. *Global*
- 17 *Governance*, **12(2)**, 141-159, doi:10.2307/27800607.
- 18 Bettini, Y., R.R. Brown, and F.J. de Haan, 2015: Exploring institutional adaptive capacity in practice: examining water
- 19 governance adaptation in Australia. *Ecology and Society*, **20(1)**, art47, doi:10.5751/ES-07291-200147.
- 20 Betts, R.A. et al., 2018: Changes in climate extremes, fresh water availability and vulnerability to food insecurity
- 21 projected at 1.5°C and 2°C global warming with a higher-resolution global climate model. *Philosophical*
- 22 *Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, **376(2119)**, 20160452,
- 23 doi:10.1098/rsta.2016.0452.
- 24 Betzold, C., 2015: Adapting to climate change in small island developing states. *Climatic Change*, **133(3)**, 481-489,
- 25 doi:10.1007/s10584-015-1408-0.
- 26 Beyer, C., 2014: Strategic Implications of Current Trends in Additive Manufacturing. *Journal of Manufacturing*
- 27 *Science and Engineering*, **136(6)**, 064701, doi:10.1115/1.4028599.
- 28 Bhagat, R., 2017: Migration, Gender and Right to the City. *Economic & Political Weekly*, **LII(32)**, 35-40.
- 29 Bhattacharya, S., K. Giannakas, and K. Schoengold, 2017: Market and welfare effects of renewable portfolio standards
- 30 in United States electricity markets. *Energy Economics*, **64**, 384-401, doi:10.1016/j.eneco.2017.03.011.
- 31 Bhawe, A. et al., 2017: Screening and techno-economic assessment of biomass-based power generation with CCS
- 32 technologies to meet 2050 CO2 targets. *Applied Energy*, **190**, 481-489,
- 33 doi:10.1016/J.APENERGY.2016.12.120.
- 34 Biddau, F., A. Armenti, and P. Cottone, 2012: Special Thematic Section on " Rethinking Prefigurative Politics " Socio-
- 35 Psychological Aspects of Grassroots Participation in the Transition Movement : An Italian Case Study.
- 36 *Journal of Social and Political Psychology*, **4(1)**, 142-165, doi:10.5964/jspp.v4i1.518.
- 37 Bidwell, D., 2016: Thinking through participation in renewable energy decisions. *Nature Energy*, **1(5)**,
- 38 doi:10.1038/nenergy.2016.51.
- 39 Biermann, F., 2010: Beyond the intergovernmental regime: Recent trends in global carbon governance. *Current*
- 40 *Opinion in Environmental Sustainability*, **2(4)**, 284-288, doi:10.1016/j.cosust.2010.05.002.
- 41 Biggs, E.M. et al., 2015: Sustainable development and the water-energy-food nexus: A perspective on livelihoods.
- 42 *Environmental Science & Policy*, **54**, 389-397, doi:10.1016/j.envsci.2015.08.002.
- 43 Bikhchandani, S. and S. Sharma, 2000: Herd Behavior in Financial Markets. , **47(3)**, 279-310.
- 44 Birk, T. and K. Rasmussen, 2014: Migration from atolls as climate change adaptation: Current practices, barriers and
- 45 options in Solomon Islands. *Natural Resources Forum*, **38(1)**, 1-13, doi:10.1111/1477-8947.12038.
- 46 Bishop, M.L. and A. Payne, 2012: Climate change and the future of Caribbean development. *The Journal of*
- 47 *Development Studies*, **48(10)**, 1536-1553.
- 48 Blaabjerg, F., Z. Chen, and S.B. Kjaer, 2004: Power Electronics as Efficient Interface in Dispersed Power Generation
- 49 Systems. *IEEE Transactions on Power Electronics*, **19(5)**, 1184-1194, doi:10.1109/TPEL.2004.833453.
- 50 Black, A. and P. Fraser, 2002: Stock market short-termism-an international perspective. *Journal of Multinational*
- 51 *Financial Management*, **12(2)**, 135-158, doi:10.1016/S1042-444X(01)00044-5.
- 52 Blanchet, T., 2015: Struggle over energy transition in Berlin: How do grassroots initiatives affect local energy policy-
- 53 making? *Energy Policy*, **78**, 246-254, doi:10.1016/j.enpol.2014.11.001.
- 54 Blanco, G. et al., 2014: Drivers, Trends and Mitigation. In: *Climate Change 2014: Mitigation of climate change.*
- 55 *Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate*
- 56 *Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum,
- 57 S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, and J.C.
- 58 Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 351-
- 59 411.
- 60 Blennow, K., J. Persson, M. Tomé, and M. Hanewinkel, 2012: Climate Change: Believing and Seeing Implies

- 1 Adapting. *Plos ONE*, **7(11)**, 1435-1439.
- 2 BNEF, 2017: *Bloomberg New Energy Outlook*. Bloomberg New Energy Finance, New York, NY, USA.
- 3 Bodansky, D., 2013: The who, what, and wherefore of geoengineering governance. *Climatic Change*, **121(3)**, 539-551,
4 doi:10.1007/s10584-013-0759-7.
- 5 Bodansky, D. and E. Diringer, 2014: Alternative Models for the 2015 Climate Change Agreement. *FNI Climate Policy*
6 *Perspectives*, **13**.
- 7 Bodle, R., G. Homan, S. Schiele, and T. E., 2012: *The Regulatory Framework for Climate-Related Geoengineering*
8 *Relevant to the Convention on Biological Diversity. Part II of: Geoengineering in Relation to the Convention*
9 *on Biological Diversity: Technical and Regulatory Matters..* 152 pp.
- 10 Bodnar, P, et al., 2018: Underwriting 1.5°C: competitive approaches to financing accelerated climate change mitigation.
11 *Climate Policy*, **18(3)**, 368-382, doi:10.1080/14693062.2017.1389687.
- 12 Böhringer, C., A., Löschel, U. Moslener, and, T.F. Rutherford et al. 2009: EU climate policy up to 2020: An economic
13 impact assessment. *Energy Economics*.
- 14 Bolderdijk, J.W., J. Knockaert, E.M. Steg, and E.T. Verhoef, 2011: Author 's personal copy Effects of Pay-As-You-
15 Drive vehicle insurance on young drivers' speed choice: Results of a Dutch field experiment. *Accident Analysis*
16 *& Prevention*, **43**, 1181-1186, doi:10.1016/j.aap.2010.12.032.
- 17 Bolderdijk, J.W., M. Gorsira, K. Keizer, and L. Steg, 2013a: Values determine the (in)effectiveness of informational
18 interventions in promoting pro-environmental behavior. *PLoS ONE*, **8(12)**, e83911,
19 doi:10.1371/journal.pone.0083911.
- 20 Bolderdijk, J.W., L. Steg, E.S. Geller, P.K. Lehman, and T. Postmes, 2013b: Comparing the effectiveness of monetary
21 versus moral motives in environmental campaigning. *Nature Climate Change*, **3(1)**, 1-4,
22 doi:10.1038/nclimate1767.
- 23 Bond, T.C. et al., 2013: Bounding the role of black carbon in the climate system: A scientific assessment. *Journal of*
24 *Geophysical Research: Atmospheres*, **118(11)**, 5380-5552, doi:10.1002/jgrd.50171.
- 25 Bonsch, M. et al., 2016: Trade-offs between land and water requirements for large-scale bioenergy production. *GCB*
26 *Bioenergy*, **8(1)**, 11-24, doi:10.1111/gcbb.12226.
- 27 Boodoo, Z. and K.H. Olsen, 2017: Assessing transformational change potential: the case of the Tunisian cement
28 Nationally Appropriate Mitigation Action (NAMA). *Climate Policy*, 1-19,
29 doi:10.1080/14693062.2017.1386081.
- 30 Booth, M.S., 2018: Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy.
31 *Environmental Research Letters*, **13(3)**, 035001, doi:10.1088/1748-9326/aaac88.
- 32 Bord, R.J., R.E. O'Connor, and A. Fisher, 2000: In what sense does the public need to understand global climate
33 change? *Public Understanding of Science*, **9(3)**, 205-218.
- 34 Bos, J.J., R.R. Brown, and M.A. Farrelly, 2015: Building networks and coalitions to promote transformational change:
35 Insights from an Australian urban water planning case study. *Environmental Innovation and Societal*
36 *Transitions*, **15**, 11-25, doi:10.1016/J.EIST.2014.10.002.
- 37 Bosomworth, K., A. Harwood, P. Leith, and P. Wallis, 2015: *Adaptation Pathways: a playbook for developing options*
38 *for climate change adaptation in NRM*. Southern Slopes Climate Adaptation Research Partnership (SCARP):
39 RMIT University, University of Tasmania, and Monash University, 26 pp.
- 40 Boucher, O. and G.A. Folberth, 2010: New Directions: Atmospheric methane removal as a way to mitigate climate
41 change? *Atmospheric Environment*, **44(27)**, 3343-3345, doi:10.1016/j.atmosenv.2010.04.032.
- 42 Boulamanti, A. and J.A. Moya, 2017: *Energy efficiency and GHG emissions: Prospective scenarios for the Chemical*
43 *and Petrochemical Industry*. 237 pp.
- 44 Bouman, E.A., E. Lindstad, A.I. Riialand, and A.H. Strømman, 2017: State-of-the-art technologies, measures, and
45 potential for reducing GHG emissions from shipping - A review. *Transportation Research Part D: Transport*
46 *and Environment*, **52(Part A)**, 408-421, doi:https://doi.org/10.1016/j.trd.2017.03.022.
- 47 Bowen, K.J. et al., 2017: Implementing the "Sustainable Development Goals": towards addressing three key
48 governance challenges - collective action, trade-offs, and accountability. *Current Opinion in Environmental*
49 *Sustainability*, **26-27(May)**, 90-96, doi:10.1016/j.cosust.2017.05.002.
- 50 Bows, A. and T. Smith, 2012: The (low-carbon) shipping forecast: opportunities on the high seas. *Carbon Management*,
51 **3(6)**, 525-528, doi:10.4155/cmt.12.68.
- 52 Bows-Larkin, A., 2015: All adrift: aviation, shipping, and climate change policy. *Climate Policy*, **15(6)**, 681-702,
53 doi:10.1080/14693062.2014.965125.
- 54 Boyd, P.W., 2016: Development of geopolitically relevant ranking criteria for geoengineering methods. *Earth's Future*,
55 **4(11)**, 523-531, doi:10.1002/2016EF000447.
- 56 Boykoff, M.T., A. Ghoshi, and K. Venkateswaran, 2013: Media discourse on adaption: competing vision of "success"
57 in the Indian context. In: *Successful Adaptation to Climate Change: Linking Science and Policy in a Rapidly*
58 *Changing World* [Moser, S.C. and M.T. Boykoff (eds.)]. Routledge, Abingdon, Oxon, UK and New York,
59 NY, USA, pp. 237-252.
- 60 Boysen, L.R. et al., 2017: The limits to global-warming mitigation by terrestrial carbon removal. *Earth's Future*, **5(5)**,

- 1 463-474, doi:10.1002/2016EF000469.
- 2 Bradley, P., A. Coke, and M. Leach, 2016: Financial incentive approaches for reducing peak electricity demand,
3 experience from pilot trials with a UK energy provider. *Energy Policy*, **98**, 108-120,
4 doi:10.1016/j.enpol.2016.07.022.
- 5 Brambilla, A., G. Salvalai, M. Imperadori, and M.M. Sesana, 2018: Nearly zero energy building renovation: From
6 energy efficiency to environmental efficiency, a pilot case study. *Energy and Buildings*, **166**, 271-283,
7 doi:10.1016/j.enbuild.2018.02.002.
- 8 Brand, U. and A. von Gleich, 2015: Transformation toward a Secure and Precaution - Oriented Energy System with the
9 Guiding Concept of Resilience - Implementation of Low-Exergy Solutions in Northwestern Germany.
10 *Energies*, **8(7)**, 6995-7019, doi:10.3390/en8076995.
- 11 Branger, F. and P. Quirion, 2014: Climate policy and the 'carbon haven' effect. *Wiley Interdisciplinary Reviews:*
12 *Climate Change*, **5(1)**, 53-71, doi:10.1002/wcc.245.
- 13 Branger, F., P. Quirion, and J. Chevallier, 2016: Carbon leakage and competitiveness of cement and steel industries
14 under the EU ETS: Much ado about nothing. *Energy Journal*, **37(3)**, 109-135,
15 doi:10.5547/01956574.37.3.fbra.
- 16 Braun, C., C. Merk, G. Pönitzsch, K. Rehdanz, and U. Schmidt, 2017: Public perception of climate engineering and
17 carbon capture and storage in Germany: survey evidence. *Climate Policy*, **3062(August)**, 1-14,
18 doi:10.1080/14693062.2017.1304888.
- 19 Bredenkamp, H. and C. Pattillo, 2010: Financing the Response to Climate Change. IMF Station Position Note
20 SPN10/06, 14 pp.
- 21 Bremer, J. and M.K. Linnenluecke, 2016: Determinants of the perceived importance of organisational adaptation to
22 climate change in the Australian energy industry. *Australian Journal of Management*, **42(3)**, 502-521,
23 doi:10.1177/0312896216672273.
- 24 Breyer, C. et al., 2017: On the role of solar photovoltaics in global energy transition scenarios. *Progress in*
25 *Photovoltaics: Research and Applications*, **25(8)**, 727-745, doi:10.1002/pip.2885.
- 26 Bridgeman, B., 2017: Population growth underlies most other environmental problems: Comment on Clayton et al.
27 (2016). *American Psychologist*, **72(4)**, 386-387, doi:10.1037/amp0000137.
- 28 Bright, R.M., K. Zhao, R.B. Jackson, and F. Cherubini, 2015: Quantifying surface albedo and other direct
29 biogeophysical climate forcings of forestry activities. *Global Change Biology*, **21(9)**, 3246-3266,
30 doi:10.1111/gcb.12951.
- 31 Briley, L., D. Brown, and S.E. Kalafatis, 2015: Overcoming barriers during the co-production of climate information
32 for decision-making. *Climate Risk Management*, **9**, 41-49, doi:10.1016/j.crm.2015.04.004.
- 33 Bring, A. et al., 2016: Arctic terrestrial hydrology: A synthesis of processes, regional effects, and research challenges.
34 *Journal of Geophysical Research: Biogeosciences*, **121(3)**, 621-649, doi:10.1002/2015JG003131.
- 35 Brink, E. et al., 2016: Cascades of green: A review of ecosystem-based adaptation in urban areas. *Global*
36 *Environmental Change*, **36**, 111-123, doi:10.1016/j.gloenvcha.2015.11.003.
- 37 Brockington, J.D., I.M. Harris, and R.M. Brook, 2016: Beyond the project cycle: a medium-term evaluation of
38 agroforestry adoption and diffusion in a south Indian village. *Agroforestry Systems*, **90(3)**, 489-508,
39 doi:10.1007/s10457-015-9872-0.
- 40 Broehm, M., J. Strefler, and N. Bauer, 2015: *Techno-Economic Review of Direct Air Capture Systems for Large Scale*
41 *Mitigation of Atmospheric CO2*. 28 pp.
- 42 Broekhoff, D., G. Piggot, and P. Erickson, 2018: Building Thriving, Low-Carbon Cities: An Overview of Policy
43 Options for National Governments. 124 pp.
- 44 Brondízio, E.S., A.C.B. de Lima, S. Schramski, and C. Adams, 2016: Social and health dimensions of climate change in
45 the Amazon. *Annals of Human Biology*, **43(4)**, 405-414, doi:10.1080/03014460.2016.1193222.
- 46 Brooks, S.J., 2013: Avoiding the Limits to Growth: Gross National Happiness in Bhutan as a Model for Sustainable
47 Development. *Sustainability*, **5(9)**, doi:10.3390/su5093640.
- 48 Brosch, T., M.K. Patel, and D. Sander, 2014: Affective influences on energy-related decisions and behaviors. *Frontiers*
49 *in Energy Research*, **2(March)**, 1-12, doi:10.3389/fenrg.2014.00011.
- 50 Broto, V.C., 2017: Energy landscapes and urban trajectories towards sustainability. *Energy Policy*, **108(December**
51 **2016)**, 755-764, doi:10.1016/j.enpol.2017.01.009.
- 52 Brown, D. and G. McGranahan, 2016: The urban informal economy, local inclusion and achieving a global green
53 transformation. *Habitat International*, **53**, 97-105, doi:10.1016/j.habitatint.2015.11.002.
- 54 Brown, M.A., G. Kim, A.M. Smith, and K. Southworth, 2017: Exploring the impact of energy efficiency as a carbon
55 mitigation strategy in the U.S.. *Energy Policy*, **109**, 249-259, doi:10.1016/j.enpol.2017.06.044.
- 56 Brown, R.M., C.R. Dillon, J. Schieffer, and J.M. Shockley, 2016: The carbon footprint and economic impact of
57 precision agriculture technology on a corn and soybean farm. *Journal of Environmental Economics and*
58 *Policy*, **5(3)**, 335-348, doi:10.1080/21606544.2015.1090932.
- 59 BRT Data, 2018: Key Indicators Per Region. <https://brtdata.org> (Accessed: 15 May 2018).
- 60 Bruce, P., R. Catlow, and P. Edwards, 2010: Energy materials to combat climate change. *Philosophical Transactions of*

- 1 *the Royal Society A: Mathematical, Physical and Engineering Sciences*, **368(1923)**, 3225 LP - 3225.
- 2 Bruckner, T. et al., 2014: Energy Systems. In: *Climate Change 2014: Mitigation of Climate Change. Contribution of*
3 *Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*
4 [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S.
5 Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, and J.C. Minx
6 (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, United Kingdom
7 and New York, NY, USA.
- 8 Brüggemann, M., F. De Silva-Schmidt, I. Hoppe, D. Arlt, and J.B. Schmitt, 2017: The appeasement effect of a United
9 Nations climate summit on the German public. *Nature Climate Change*, 1-7, doi:10.1038/nclimate3409.
- 10 Brügger, A., T.A. Morton, and S. Dessai, 2015: Hand in hand: Public endorsement of climate change mitigation and
11 adaptation. *PLoS ONE*, **10(4)**, 1-18, doi:10.1371/journal.pone.0124843.
- 12 Brugnach, M., M. Craps, and A. Dewulf, 2017: Including indigenous peoples in climate change mitigation: addressing
13 issues of scale, knowledge and power. *Climatic Change*, **140(1)**, 19-32, doi:10.1007/s10584-014-1280-3.
- 14 Brulle, R.J., J. Carmichael, and J.C. Jenkins, 2012: Shifting public opinion on climate change: an empirical assessment
15 of factors influencing concern over climate change in the U.S., 2002-2010. *Climatic Change*, **114(2)**, 169-188,
16 doi:10.1007/s10584-012-0403-y.
- 17 Brunes, E. and D. Ohlhorst, 2011: Wind power generation in Germany: a transdisciplinary view on the innovation
18 biography. *J. Transdiscipl. Environ. Stud.*, **10**, 45-67.
- 19 Bryan, E., T.T. Deressa, G.A. Gbetibouo, and C. Ringler, 2009: Adaptation to climate change in Ethiopia and South
20 Africa: options and constraints. *Environmental Science and Policy*, **12(4)**, 413-426,
21 doi:10.1016/j.envsci.2008.11.002.
- 22 Bryan, E., Q. Bernier, M. Espinal, and C. Ringler, 2017: Making climate change adaptation programmes in sub-Saharan
23 Africa more gender responsive: insights from implementing organizations on the barriers and opportunities.
24 *Climate and Development*, 1-15, doi:10.1080/17565529.2017.1301870.
- 25 Brzoska, M. and C. Fröhlich, 2016: Climate change, migration and violent conflict: vulnerabilities, pathways and
26 adaptation strategies. *Migration and Development*, **5(2)**, 190-210, doi:10.1080/21632324.2015.1022973.
- 27 Buchholz, T., M.D. Hurteau, J. Gunn, and D. Saah, 2016: A global meta-analysis of forest bioenergy greenhouse gas
28 emission accounting studies. *GCB Bioenergy*, **8(2)**, 281-289, doi:10.1111/gcbb.12245.
- 29 Buck, H.J., 2012: Geoengineering: Re-making Climate for Profit or Humanitarian Intervention? *Development and*
30 *Change*, **43(1)**, 253-270, doi:10.1111/j.1467-7660.2011.01744.x.
- 31 Buck, H.J., 2016: Rapid scale-up of negative emissions technologies: social barriers and social implications. *Climatic*
32 *Change*, **139(2)**, 155-167, doi:10.1007/s10584-016-1770-6.
- 33 Buck, H.J., A.R. Gammon, and C.J. Preston, 2014: Gender and geoengineering. *Hypatia*, **29(3)**, 651-669,
34 doi:10.1111/hypa.12083.
- 35 Buckeridge, M., 2015: Árvores urbanas em São Paulo: planejamento, economia e água. *Estudos Avançados*, **29(84)**, 85-
36 101, doi:10.1590/S0103-40142015000200006.
- 37 Budnitz, R.J., 2016: Nuclear power: Status report and future prospects. *Energy Policy*, **96(Supplement C)**, 735-739,
38 doi:https://doi.org/10.1016/j.enpol.2016.03.011.
- 39 Bui, M. et al., 2018: Carbon capture and storage (CCS): the way forward. *Energy & Environmental Science* (in press),
40 doi:10.1039/C7EE02342A.
- 41 Bulkeley, H., 2005: Reconfiguring environmental governance: Towards a politics of scales and networks. *Political*
42 *Geography*, **24(8)**, 875-902, doi:10.1016/j.polgeo.2005.07.002.
- 43 Bulkeley, H. et al., 2011: The Role of Institutions, Governance, and Urban Planning for Mitigation and Adaptation. In:
44 *Cities and Climate Change*. The World Bank, pp. 125-159.
- 45 Bulkeley, H. et al., 2012: Governing climate change transnationally: Assessing the evidence from a database of sixty
46 initiatives. *Environment and Planning C: Government and Policy*, **30(4)**, 591-612, doi:10.1068/c11126.
- 47 Bunce, A. and J. Ford, 2015: How is adaptation, resilience, and vulnerability research engaging with gender? *Environ.*
48 *Res. Lett. Environ. Res. Lett.*, **10(10)**, 123003, doi:10.1088/1748-9326/10/12/123003.
- 49 Burch, S., C. Mitchell, M. Berbes-Blazquez, and J. Wandel, 2017: Tipping Toward Transformation: Progress, Patterns
50 and Potential for Climate Change Adaptation in the Global South. *Journal of Extreme Events*, **04(01)**,
51 1750003, doi:10.1142/S2345737617500038.
- 52 Burch, S. et al., 2016: Governing and accelerating transformative entrepreneurship: exploring the potential for small
53 business innovation on urban sustainability transitions. *Current Opinion in Environmental Sustainability*, **22**,
54 26-32, doi:10.1016/J.COSUST.2017.04.002.
- 55 Burney, J.A. and R.L. Naylor, 2012: Smallholder Irrigation as a Poverty Alleviation Tool in Sub-Saharan Africa. *World*
56 *Development*, **40(1)**, 110-123, doi:10.1016/j.worlddev.2011.05.007.
- 57 Burnham, M. and Z. Ma, 2017: Climate change adaptation: factors influencing Chinese smallholder farmers' perceived
58 self-efficacy and adaptation intent. *Regional Environmental Change*, **17(1)**, 171-186, doi:10.1007/s10113-016-
59 0975-6.
- 60 Burns, W. and S. Nicholson, 2017: Bioenergy and carbon capture with storage (BECCS): the prospects and challenges

- 1 of an emerging climate policy response. *Journal of Environmental Studies and Sciences*, **15(2)**,
2 doi:10.1007/s13412-017-0445-6.
- 3 Burns, W.C.G., 2011: Climate geoengineering: solar radiation management and its implications for intergenerational
4 equity. *Stanford Journal of Law, Science & Policy*, **4**, 39-55.
- 5 Burt, A., B. Hughes, and G. Milante, 2014: Eradicating Poverty in Fragile States: Prospects of Reaching The 'High-
6 Hanging' Fruit by 2030. WPS7002, 35 pp.
- 7 Bushee, B.J., 2001: Do Institutional Investors Prefer Near-Term Earnings over Long-Run Value? *Contemporary*
8 *Accounting Research*, **18(2)**, 207-246, doi:10.1506/J4GU-BHWH-8HME-LEOX.
- 9 Bustamante, J.G., A.S. Rattner, and S. Garimella, 2016: Achieving near-water-cooled power plant performance with
10 air-cooled condensers. *Applied Thermal Engineering*, **105**, 362-371,
11 doi:10.1016/j.applthermaleng.2015.05.065.
- 12 Butler, C. and J. Adamowski, 2015: Empowering marginalized communities in water resources management:
13 Addressing inequitable practices in Participatory Model Building. *Journal of Environmental Management*,
14 **153**, 153-162, doi:10.1016/j.jenvman.2015.02.010.
- 15 Butler, J.R.A. et al., 2015: Integrating Top-Down and Bottom-Up Adaptation Planning to Build Adaptive Capacity: A
16 Structured Learning Approach. *Coastal Management*, **43(4)**, 346-364, doi:10.1080/08920753.2015.1046802.
- 17 Butler, J.R.A. et al., 2016: Scenario planning to leap-frog the Sustainable Development Goals: An adaptation pathways
18 approach. *Climate Risk Management*, **12**, 83-99, doi:10.1016/j.crm.2015.11.003.
- 19 Butler, L. and K. Neuhoff, 2008: Comparison of feed-in tariff, quota and auction mechanisms to support wind power
20 development. *Renewable Energy*, **33(8)**, 1854-1867, doi:10.1016/j.renene.2007.10.008.
- 21 Cabeza, L.F. et al., 2013: Affordable construction towards sustainable buildings: review on embodied energy in
22 building materials. *Current Opinion in Environmental Sustainability*, **5(2)**, 229-236,
23 doi:10.1016/j.cosust.2013.05.005.
- 24 Caldecott, B., 2017: Introduction to special issue: stranded assets and the environment. *Journal of Sustainable Finance*
25 *& Investment*, **7(1)**, 1-13, doi:10.1080/20430795.2016.1266748.
- 26 Caldeira, K. and G. Bala, 2017: Reflecting on 50 years of geoengineering research. *Earth's Future*, **5(1)**, 10-17,
27 doi:10.1002/2016EF000454.
- 28 Calel, R. and A. Dechezleprêtre, 2016: Environmental Policy and Directed Technological Change: Evidence from the
29 European Carbon Market. *Review of Economics and Statistics*, **98(1)**, 173-191, doi:10.1162/REST_a_00470.
- 30 Calvin, K. et al., 2014: Trade-offs of different land and bioenergy policies on the path to achieving climate targets.
31 *Climatic Change*, **123(3-4)**, 691-704, doi:10.1007/s10584-013-0897-y.
- 32 Campbell, T.H. and A.C. Kay, 2014: Solution aversion: On the relation between ideology and motivated disbelief.
33 *Journal of Personality and Social Psychology*, **107(5)**, 809-824, doi:10.1037/a0037963.
- 34 Campiglio, E., 2016: Beyond Carbon Pricing: The Role of Banking and Monetary Policy in Financing the Transition to
35 a Low- Carbon Economy. *Ecological Economics*, **121(C)**, 220-230.
- 36 Campos, I.S. et al., 2016: Climate adaptation, transitions, and socially innovative action-research approaches. *Ecology*
37 *and Society*, **21(1)**, art13, doi:10.5751/ES-08059-210113.
- 38 Camps-Calvet, M., J. Langemeyer, L. Calvet-Mir, and E. Gómez-Baggethun, 2016: Ecosystem services provided by
39 urban gardens in Barcelona, Spain: Insights for policy and planning. *Environmental Science & Policy*, **62**, 14-
40 23, doi:10.1016/j.envsci.2016.01.007.
- 41 Canadell, J.G. and E.D. Schulze, 2014: Global potential of biospheric carbon management for climate mitigation.
42 *Nature Communications*, **5**, 1-12, doi:10.1038/ncomms6282.
- 43 Canales, F.A., A. Beluco, and C.A.B. Mendes, 2015: A comparative study of a wind hydro hybrid system with water
44 storage capacity: Conventional reservoir or pumped storage plant? *Journal of Energy Storage*, **4**, 96-105,
45 doi:10.1016/j.est.2015.09.007.
- 46 Caney, S., 2012: Just Emissions. *Philosophy & Public Affairs*, **40(4)**, 255-300, doi:10.1111/papa.12005.
- 47 Caney, S., 2014: Two Kinds of Climate Justice: Avoiding Harm and Sharing Burdens. *Journal of Political Philosophy*,
48 **22(2)**, 125-149, doi:10.1111/jopp.12030.
- 49 Cannon, T., 2015: Disasters, vulnerability and the significance of culture. In: *Cultures and Disasters: Understanding*
50 *Cultural Framings in Disaster Risk Reduction*. Routledge.
- 51 Capon, S.J. et al., 2013: Riparian Ecosystems in the 21st Century: Hotspots for Climate Change Adaptation?
52 *Ecosystems*, **16(3)**, 359-381, doi:10.1007/s10021-013-9656-1.
- 53 Carlsson-Kanyama, A. and A.D. González, 2009: Potential contributions of food consumption patterns to climate
54 change. *The American Journal of Clinical Nutrition*, **89(5)**, 1704S-1709S, doi:10.3945/ajcn.2009.26736AA.
- 55 Carney, M., 2016: Breaking the tragedy of the horizon climate change and financial stability.
56 <http://www.bankofengland.co.uk/publications/Pages/speeches/2015/844.aspx> (Accessed: 25 July 2017).
- 57 Carr, W.A. et al., 2013: Public engagement on solar radiation management and why it needs to happen now. *Climatic*
58 *Change*, **121(3)**, 567-577, doi:10.1007/s10584-013-0763-y.
- 59 Carreño, M.L. et al., 2017: Holistic disaster risk evaluation for the urban risk management plan of Manizales,
60 Colombia. *International Journal of Disaster Risk Science*, **8(3)**, 258-269.

- 1 Carrico, A.R., H.B. Truelove, M.P. Vandenberg, and D. Dana, 2015: Does learning about climate change adaptation
2 change support for mitigation? *Journal of Environmental Psychology*, **41**, 19-29,
3 doi:10.1016/j.jenvp.2014.10.009.
- 4 Carter, J.G. et al., 2015: Climate change and the city: Building capacity for urban adaptation. *Progress in Planning*, **95**,
5 1-66, doi:10.1016/j.progress.2013.08.001.
- 6 Cartwright, A., 2015: Better Growth, Better Cities: Rethinking and Redirecting Urbanisation in Africa. 44 pp.
- 7 Cartwright, A. et al., 2013: Economics of climate change adaptation at the local scale under conditions of uncertainty
8 and resource constraints: the case of Durban, South Africa. *Environment and Urbanization*, **25(1)**, 139-156,
9 doi:10.1177/0956247813477814.
- 10 Cass, N., G. Walker, and P. Devine-Wright, 2010: Good neighbours, public relations and bribes: The politics and
11 perceptions of community benefit provision in renewable energy development in the UK. *Journal of*
12 *Environmental Policy and Planning*, **12(3)**, 255-275, doi:10.1080/1523908x.2010.509558.
- 13 Castán Broto, V., 2017: Urban Governance and the Politics of Climate change. *World Development*, **93**, 1-15,
14 doi:10.1016/j.worlddev.2016.12.031.
- 15 Castán Broto, V. and H. Bulkeley, 2013: A survey of urban climate change experiments in 100 cities. *Global*
16 *Environmental Change*, **23(1)**, 92-102, doi:10.1016/j.gloenvcha.2012.07.005.
- 17 Cayuela, M.L. et al., 2014: Biochar's role in mitigating soil nitrous oxide emissions: A review and meta-analysis.
18 *Agriculture, Ecosystems & Environment*, **191**, 5-16, doi:https://doi.org/10.1016/j.agee.2013.10.009.
- 19 CBD, 2008: Decision IX/16: Biodiversity and Climate Change. In: *Ninth meeting of the Conference of the Parties to the*
20 *Convention on Biological Diversity, COP 9*. Convention on Biological Diversity (CBD), Nagoya, Japan.
- 21 CBD, 2010: Decision X/33: Biodiversity and climate change. In: *Tenth meeting of the Conference of the Parties to the*
22 *Convention on Biological Diversity, COP 10*. Convention on Biological Diversity (CBD), Bonn, Germany.
- 23 CBS, 2016: *A Compass Towards a Just and Harmonious Society: 2015 GNH Survey Report*. Centre for Bhutan Studies
24 & GNH Research, Thimphu, Bhutan, 342 pp.
- 25 CCFLA, 2016: *Localizing Climate Finance: Mapping Gaps and Opportunities, Designing solutions*. 29 pp.
- 26 CCRIF, 2017: *Annual Report 2016-2017*. 107 pp.
- 27 Chadburn, S.E. et al., 2017: An observation-based constraint on permafrost loss as a function of global warming.
28 *Nature Climate Change*, **7(0316)**, doi:10.1038/nclimate3262.
- 29 Chaffin, B.C. and L.H. Gunderson, 2016: Emergence, institutionalization and renewal: Rhythms of adaptive
30 governance in complex social-ecological systems. *Journal of Environmental Management*, **165**, 81-87,
31 doi:10.1016/j.jenvman.2015.09.003.
- 32 Chaffin, B.C., H. Gosnell, and B.A. Cosens, 2014: A Decade of Adaptive Governance Scholarship: Synthesis and
33 Future Directions. *Ecology and Society*, **19(3)**, 56.
- 34 Challinor, A.J. et al., 2014: A meta-analysis of crop yield under climate change and adaptation. *Nature Climate*
35 *Change*, **4(4)**, 287-291, doi:10.1038/nclimate2153.
- 36 Chambers, L.E. et al., 2017: A database for traditional knowledge of weather and climate in the Pacific. *Meteorological*
37 *Applications*, **24(3)**, 491-502, doi:10.1002/met.1648.
- 38 Chandel, M.K., L.F. Pratson, and R.B. Jackson, 2011: The potential impacts of climate-change policy on freshwater use
39 in thermoelectric power generation. *Energy Policy*, **39(10)**, 6234-6242, doi:10.1016/j.enpol.2011.07.022.
- 40 Chandel, S.S., A. Sharma, and B.M. Marwaha, 2016: Review of energy efficiency initiatives and regulations for
41 residential buildings in India. *Renewable and Sustainable Energy Reviews*, **54**, 1443-1458,
42 doi:10.1016/j.rser.2015.10.060.
- 43 Chang, N., M.V. Vasquez, C.F. Chen, S. Imen, and L. Mullon, 2015: Global nonlinear and nonstationary climate
44 change effects on regional precipitation and forest phenology in Panama, Central America. *Hydrological*
45 *Processes*, **29(3)**, 339-355, doi:10.1002/hyp.10151.
- 46 Chang'a, L.B., P.Z. Yanda, and J. Ngana, 2010: Indigenous knowledge in seasonal rainfall prediction in Tanzania : A
47 case of the South-western Highland of Tanzania. *Journal of Geography and Regional Planning*, **3(April)**, 66-
48 72.
- 49 Chant, S., M. Klett-davies, and J. Ramalho, 2017: *Challenges and potential solutions for adolescent girls in urban*
50 *settings: a rapid evidence review*.
- 51 Chapin, F.S., C.N. Knapp, T.J. Brinkman, R. Bronen, and P. Cochran, 2016: Community-empowered adaptation for
52 self-reliance. *Current Opinion in Environmental Sustainability*, **19**, 67-75, doi:10.1016/j.cosust.2015.12.008.
- 53 Chatrchyan, A.M. et al., 2017: United States agricultural stakeholder views and decisions on climate change. *Wiley*
54 *Interdisciplinary Reviews: Climate Change*, e469, doi:10.1002/wcc.469.
- 55 Chelleri, L., J.J. Waters, M. Olazabal, and G. Minucci, 2015: Resilience trade-offs: addressing multiple scales and
56 temporal aspects of urban resilience. *Environment and Urbanization*, **27(1)**, 181-198,
57 doi:10.1177/0956247814550780.
- 58 Chen, C. and M. Tavoni, 2013: Direct air capture of CO2 and climate stabilization: A model based assessment.
59 *Climatic Change*, **118(1)**, 59-72, doi:10.1007/s10584-013-0714-7.
- 60 Chen, M., 2015: An examination of the value-belief-norm theory model in predicting pro-environmental behaviour in

- 1 Taiwan. *Asian Journal of Social Psychology*, **18**, 145-151, doi:10.1111/ajsp.12096.
- 2 Chen, S. and B. Chen, 2016: Urban energy-water nexus: A network perspective. *Applied Energy*, **184**, 905-914,
3 doi:10.1016/j.apenergy.2016.03.042.
- 4 Chen, Y. and Y. Xin, 2017: Implications of geoengineering under the 1.5°C target: Analysis and policy suggestions.
5 *Advances in Climate Change Research*, **7**, 1-7, doi:10.1016/j.accr.2017.05.003.
- 6 Cheng, V.K.M. and G.P. Hammond, 2017: Life-cycle energy densities and land-take requirements of various power
7 generators: A UK perspective. *Journal of the Energy Institute*, **90(2)**, 201-213,
8 doi:10.1016/J.JOEI.2016.02.003.
- 9 Cheshmehzangi, A., 2016: China's New-type Urbanisation Plan (NUP) and the Foreseeing Challenges for
10 Decarbonization of Cities: A Review. *Energy Procedia*, **104(5)**, 146-152, doi:10.1016/j.egypro.2016.12.026.
- 11 Chichilnisky, G. and G. Heal (eds.), 2000: *Equity and Efficiency in Environmental Markets: Global Trade in Carbon*
12 *Dioxide Emissions*. Columbia University Press, 280 pp.
- 13 Child, M. and C. Breyer, 2017: Transition and transformation: A review of the concept of change in the progress
14 towards future sustainable energy systems. *Energy Policy*, **107**, 11-26, doi:10.1016/J.ENPOL.2017.04.022.
- 15 Chiroleu-Assouline, M. and M. Fodha, 2011: Environmental Tax and the Distribution of Income among Heterogeneous
16 Workers. *Annals of Economics and Statistics*, **103/104(103)**, 71-92, doi:10.2307/41615494.
- 17 Chitnis, M. and S. Sorrell, 2015: Living up to expectations: Estimating direct and indirect rebound effects for UK
18 households. *Energy Economics*, **52**, S100-S116, doi:10.1016/j.eneco.2015.08.026.
- 19 Christensen, C., M. Raynor, and R. McDonald, 2015: What is Disruptive Innovation? *Harvard Business Review*.
- 20 Christoforidis, G.C., K.C. Chatzisavvas, S. Lazarou, and C. Parisses, 2013: Covenant of Mayors initiative - Public
21 perception issues and barriers in Greece. *Energy Policy*, **60**, 643-655, doi:10.1016/j.enpol.2013.05.079.
- 22 Christophers, B., 2017: Climate Change and Financial Instability: Risk Disclosure and the Problematics of Neoliberal
23 Governance. *Annals of the American Association of Geographers*, **107(5)**, 1108-1127,
24 doi:10.1080/24694452.2017.1293502.
- 25 Chu, E., I. Anguelovski, and J.A. Carmin, 2016: Inclusive approaches to urban climate adaptation planning and
26 implementation in the Global South. *Climate Policy*, **16(3)**, 372-392, doi:10.1080/14693062.2015.1019822.
- 27 Chu, E., I. Anguelovski, and D. Roberts, 2017: Climate adaptation as strategic urbanism: assessing opportunities and
28 uncertainties for equity and inclusive development in cities. *Cities*, **60**, 378-387,
29 doi:10.1016/j.cities.2016.10.016.
- 30 Chu, S., 2015: Car restraint policies and mileage in Singapore. *Transportation Research Part A: Policy and Practice*,
31 **77(C)**, 404-412.
- 32 Chum, H. et al., 2011: Bioenergy. In: *IPCC Special Report on Renewable Energy Sources and Climate Change*
33 *Mitigation* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P.
34 Eickemeier, G. Hansen, S. Schlömer, and C. von Stechow (eds.)]. Cambridge University Press, Cambridge,
35 United Kingdom and New York, NY, USA.
- 36 Chung Tiam Fook, T., 2017: Transformational processes for community-focused adaptation and social change: a
37 synthesis. *Climate and Development*, **9(1)**, 5-21, doi:10.1080/17565529.2015.1086294.
- 38 Ciplet, D., J.T. Roberts, and M.R. Khan, 2015: *Power in a warming world: The new global politics of climate change*
39 *and the remaking of environmental inequality*. MIT Press.
- 40 CISL, 2015: *Unhedgeable Risk: How climate change sentiment impacts investment*. 64 pp.
- 41 Clack, C.T.M. et al., 2017: Evaluation of a proposal for reliable low-cost grid power with 100% wind, water, and solar.
42 *Proceedings of the National Academy of Sciences of the United States of America*, **114(26)**, 6722-6727,
43 doi:10.1073/pnas.1610381114.
- 44 Clark, M. and D. Tilman, 2017: Comparative analysis of environmental impacts of agricultural production systems ,
45 agricultural input efficiency, and food choice Comparative analysis of environmental impacts of agricultural
46 production systems , agricultural input efficiency , and food. *Environ. Res. Lett*, **12**,
47 doi:https://doi.org/10.1088/1748-9326/aa6cd5.
- 48 Clarke, L. et al., 2014: Assessing transformation pathways. In: *Climate Change 2014: Mitigation of Climate Change.*
49 *Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate*
50 *Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum,
51 S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, and J.C.
52 Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 413-
53 510.
- 54 Clayton, S. et al., 2015: Psychological research and global climate change. *Nature Climate Change*, **5(7)**, 640-646,
55 doi:10.1038/nclimate2622.
- 56 Clayton, S. et al., 2017: Psychologists and the Problem of Population Growth : Reply to Bridgeman (2017). *American*
57 *Psychologist*, **72(4)**, 388-389, doi:10.1037/amp0000152.
- 58 Cléménçon, R., 2016: The two sides of the Paris climate agreement: Dismal failure or historic breakthrough? *Journal of*
59 *Environment & Development*, **25(1)**, 3-24.
- 60 Clemens, M., J. Rijke, A. Pathirana, J. Evers, and N. Hong Quan, 2015: Social learning for adaptation to climate change

- 1 in developing countries: insights from Vietnam. *Journal of Water and Climate Change*, **8(4)**,
2 doi:10.2166/wcc.2015.004.
- 3 Clements, J., A. Ray, and G. Anderson, 2013: *The Value of Climate Services Across Economic and Public Sectors: A*
4 *Review of Relevant Literature*. United States Agency for International Development (USAID).
- 5 Climate Analytics, 2015: *Africa's Adaptation Gap 2: Bridging the gap - mobilising sources*.
- 6 Cloutier, G. et al., 2015: Planning adaptation based on local actors' knowledge and participation: a climate governance
7 experiment. *Climate Policy*, **15(4)**, 458-474, doi:10.1080/14693062.2014.937388.
- 8 Coady, D., I. Parry, L. Sears, and B. Shang, 2017: How Large Are Global Fossil Fuel Subsidies? *World Development*,
9 **91**, 11-27, doi:10.1016/j.worlddev.2016.10.004.
- 10 Cochran, P. et al., 2013: Indigenous frameworks for observing and responding to climate change in Alaska. *Climatic*
11 *Change*, **120(3)**, 557-567, doi:10.1007/s10584-013-0735-2.
- 12 Cochrani, I., R. Hubert, V. Marchal, and R. Youngman, 2014: *Public Financial Institutions and the Low-carbon*
13 *Transition: Five Case Studies on Low-Carbon Infrastructure and Project Investment*. OECD Environment
14 Working Papers, No. 72, OECD Publishing, Paris.
- 15 Coe, R., F. Sinclair, and E. Barrios, 2014: Scaling up agroforestry requires research 'in' rather than 'for' development.
16 *Current Opinion in Environmental Sustainability*, **6(1)**, 73-77, doi:10.1016/j.cosust.2013.10.013.
- 17 Cole, D.H., 2015: Advantages of a polycentric approach to climate change policy. *Nature Climate Change*, **5(2)**, 114-
18 118, doi:10.1038/nclimate2490.
- 19 Colenbrander, S. et al., 2017: Can low-carbon urban development be pro-poor? The case of Kolkata, India.
20 *Environment and Urbanization*, **29(1)**, 139-158, doi:10.1177/0956247816677775.
- 21 Collas, L., R.E. Green, A. Ross, J.H. Wastell, and A. Balmford, 2017: Urban development, land sharing and land
22 sparing: the importance of considering restoration. *Journal of Applied Ecology*, **54(6)**, 1865-1873,
23 doi:10.1111/1365-2664.12908.
- 24 Colloff, M.J. et al., 2016a: Adaptation services and pathways for the management of temperate montane forests under
25 transformational climate change. *Climatic Change*, **138(1-2)**, 267-282, doi:10.1007/s10584-016-1724-z.
- 26 Colloff, M.J. et al., 2016b: Adaptation services of floodplains and wetlands under transformational climate change.
27 *Ecological Applications*, **26(4)**, 1003-1017, doi:10.1890/15-0848.
- 28 Colloff, M.J. et al., 2017: An integrative research framework for enabling transformative adaptation. *Environmental*
29 *Science & Policy*, **68**, 87-96, doi:10.1016/j.envsci.2016.11.007.
- 30 Combet, E., 2013: Fiscalité carbone et progrès social. Application au cas français., École des Hautes Études en Sciences
31 Sociales (EHESS), 412 pp.
- 32 Combet, E., F. Ghersi, J.C. Hourcade, and D. Théry, 2010: Carbon Tax and Equity: The Importance of Policy Design.
33 In: *Critical Issues In Environmental Taxation* [Dias Soares, C., J. Milne, H. Ashiabor, K. Deketelaere, and L.
34 Kreiser (eds.)]. Oxford University Press, pp. 277-295.
- 35 Cooney, G., J. Littlefield, J. Marriott, and T.J. Skone, 2015: Evaluating the Climate Benefits of CO₂-Enhanced Oil
36 Recovery Using Life Cycle Analysis. *Environmental Science & Technology*, **49(12)**, 7491-7500,
37 doi:10.1021/acs.est.5b00700.
- 38 Cooper, J.A.G., M.C. O'Connor, and S. McIvor, 2016: Coastal defences versus coastal ecosystems: A regional
39 appraisal. *Marine Policy* (in press), doi:10.1016/j.marpol.2016.02.021.
- 40 Cooper-Searle, S., F. Livesey, and J.M. Allwood, 2018: Why are Material Efficiency Solutions a Limited Part of the
41 Climate Policy Agenda? An application of the Multiple Streams Framework to UK policy on CO₂ emissions
42 from cars. *Environmental Policy and Governance*, **28(1)**, 51-64, doi:10.1002/eet.1782.
- 43 Coq-Huelva, D., A. Higuchi, R. Alfalla-Luque, R. Burgos-Morán, and R. Arias-Gutiérrez, 2017: Co-Evolution and Bio-
44 Social Construction: The Kichwa Agroforestry Systems (Chakras) in the Ecuadorian Amazonia. *Sustainability*,
45 **9(11)**, 1920, doi:10.3390/su9101920.
- 46 Corfee-Morlot, J., I. Cochran, S. Hallegatte, and P.J. Teasdale, 2011: Multilevel risk governance and urban adaptation
47 policy. *Climatic Change*, **104(1)**, 169-197.
- 48 Corner, A. and A. Randall, 2011: Selling climate change? The limitations of social marketing as a strategy for climate
49 change public engagement. *Global environmental change*, **21(3)**, 1005-1014.
- 50 Corner, A. and N. Pidgeon, 2014: Geoengineering, climate change scepticism and the 'moral hazard' argument: an
51 experimental study of UK public perceptions. *Philosophical Transactions of the Royal Society A:*
52 *Mathematical, Physical and Engineering Sciences*, **372(2031)**, 20140063-20140063,
53 doi:10.1098/rsta.2014.0063.
- 54 Cortekar, J. and M. Groth, 2015: Adapting energy infrastructure to climate change - Is there a need for government
55 interventions and legal obligations within the German "energiewende"? *Energy Procedia*, **73**, 12-17,
56 doi:10.1016/j.egypro.2015.07.552.
- 57 Costa, D., P. Burlando, and C. Priadi, 2016: The importance of integrated solutions to flooding and water quality
58 problems in the tropical megacity of Jakarta. *Sustainable Cities and Society*, **20(Supplement C)**, 199-209,
59 doi:10.1016/j.scs.2015.09.009.
- 60 Coulibaly, J.Y., B. Chiputwa, T. Nakelse, and G. Kundhlande, 2017: Adoption of agroforestry and the impact on

- 1 household food security among farmers in Malawi. *Agricultural Systems*, **155**, 52-69,
2 doi:10.1016/j.agry.2017.03.017.
- 3 Cowen, L. and B. Gatersleben, 2017: Testing for the size heuristic in householders' perceptions of energy consumption.
4 *Journal of Environmental Psychology*, **54**, 103-115, doi:10.1016/j.jenvp.2017.10.002.
- 5 Cox, K., M. Renouf, A. Dargan, C. Turner, and D. Klein-Marcuschamer, 2014: Environmental life cycle assessment
6 (LCA) of aviation biofuel from microalgae, *Pongamia pinnata*, and sugarcane molasses. *Biofuels, Bioproducts
7 and Biorefining*, **8(4)**, 579-593, doi:10.1002/bbb.1488.
- 8 Craig, R.K. et al., 2017: Balancing stability and flexibility in adaptive governance: an analysis of tools available in U.S.
9 environmental law. *Ecology and Society*, **22(2)**, art3, doi:10.5751/ES-08983-220203.
- 10 Crassous, R., J.C. Hourcade, and O. Sassi, 2006: Endogenous Structural Change and Climate Targets. *The Energy
11 Journal*, **27**, 259-276.
- 12 Creutzig, F., E. Corbera, S. Bolwig, and C. Hunsberger, 2013: Integrating place-specific livelihood and equity
13 outcomes into global assessments of bioenergy deployment. *Environmental Research Letters*, **8(3)**, 035047,
14 doi:10.1088/1748-9326/8/3/035047.
- 15 Creutzig, F., G. Baiocchi, R. Bierkandt, P.-P. Pichler, and K.C. Seto, 2015a: Global typology of urban energy use and
16 potentials for an urbanization mitigation wedge. *Proceedings of the National Academy of Sciences*, **112(20)**,
17 6283-6288, doi:10.1073/pnas.1315545112.
- 18 Creutzig, F. et al., 2015b: Bioenergy and climate change mitigation: an assessment. *GCB Bioenergy*, **7(5)**, 916-944,
19 doi:10.1111/gcbb.12205.
- 20 Creutzig, F. et al., 2017: The underestimated potential of solar energy to mitigate climate change. *Nature Energy*, **2**,
21 17140, doi:10.1038/nenergy.2017.140.
- 22 Creutzig, F. et al., 2018: Towards demand-side solutions for mitigating climate change. *Nature Climate Change*, **8(4)**,
23 268-271, doi:10.1038/s41558-018-0121-1.
- 24 Croci, E., B. Lucchitta, G. Janssens-Maenhout, S. Martelli, and T. Molteni, 2017: Urban CO2 mitigation strategies
25 under the Covenant of Mayors: An assessment of 124 European cities. *Journal of Cleaner Production*, **169**,
26 161-177, doi:10.1016/j.jclepro.2017.05.165.
- 27 Crook, J.A., L.S. Jackson, and P.M. Forster, 2016: Can increasing albedo of existing ship wakes reduce climate
28 change? *Journal of Geophysical Research: Atmospheres*, **121(4)**, 1549-1558, doi:10.1002/2015JD024201.
- 29 Crook, J.A., L.S. Jackson, S.M. Osprey, and P.M. Forster, 2015: A comparison of temperature and precipitation
30 responses to different Earth radiation management geoengineering schemes. *Journal of Geophysical Research:
31 Atmospheres*, **120(18)**, doi:10.1002/2015JD023269.
- 32 Cui, Z. et al., 2018: Pursuing sustainable productivity with millions of smallholder farmers. *Nature*,
33 doi:10.1038/nature25785.
- 34 Culwick, C. and K. Bobbins, 2016: A Framework for a Green Infrastructure Planning Approach in the Gauteng City-
35 Region. , 132.
- 36 Cunningham, S.C. et al., 2015: Balancing the environmental benefits of reforestation in agricultural regions.
37 *Perspectives in Plant Ecology, Evolution and Systematics*, **17(4)**, 301-317, doi:10.1016/j.ppees.2015.06.001.
- 38 Cunsolo, A. and N.R. Ellis, 2018: Ecological grief as a mental health response to climate change-related loss. *Nature
39 Climate Change*, **8(4)**, 275-281, doi:10.1038/s41558-018-0092-2.
- 40 Cunsolo Willox, A., S.L. Harper, and V.L. Edge, 2013: Storytelling in a digital age: digital storytelling as an emerging
41 narrative method for preserving and promoting indigenous oral wisdom. *Qualitative Research*, **13(2)**, 127-147,
42 doi:10.1177/1468794112446105.
- 43 Cunsolo Willox, A. et al., 2012: "From this place and of this place:" Climate change, sense of place, and health in
44 Nunatsiavut, Canada. *Social Science and Medicine*, **75(3)**, 538-547, doi:10.1016/j.socscimed.2012.03.043.
- 45 D'Agostino, D., 2015: Assessment of the progress towards the establishment of definitions of Nearly Zero Energy
46 Buildings (nZEBs) in European Member States. *Journal of Building Engineering*, **1**, 20-32,
47 doi:10.1016/j.jobee.2015.01.002.
- 48 Daamen, D.D.L., H. Staats, H.A.M. Wilke, and M. Engelen, 2001: Improving Environmental Behavior in Companies.
49 *Environment and Behavior*, **33(2)**, 229-248, doi:10.1177/00139160121972963.
- 50 Dagnet, Y. et al., 2016: Staying on Track from Paris: Advancing the Key Elements of the Paris Agreement. World
51 Resources Institute, Washington DC, USA.
- 52 D'Agostino, D. and D. Parker, 2018: A framework for the cost-optimal design of nearly zero energy buildings (NZEBS)
53 in representative climates across Europe. *Energy*, **149**, 814-829, doi:10.1016/j.energy.2018.02.020.
- 54 Dahlmann, K. et al., 2016: Climate-Compatible Air Transport System-Climate Impact Mitigation Potential for Actual
55 and Future Aircraft. *Aerospace*, **3(4)**, 38, doi:10.3390/aerospace3040038.
- 56 Daioglou, V. et al., 2017: Greenhouse gas emission curves for advanced biofuel supply chains. *Nature Climate Change*,
57 **7(12)**, 920-924, doi:10.1038/s41558-017-0006-8.
- 58 DaMatta, F.M., A. Grandis, B.C. Arenque, and M.S. Buckeridge, 2010: Impacts of climate changes on crop physiology
59 and food quality. *Food Research International*, **43(7)**, 1814-1823, doi:10.1016/j.foodres.2009.11.001.
- 60 Dang, H., E. Li, I. Nuberg, and J. Bruwer, 2014: Understanding farmers' adaptation intention to climate change: A

- 1 structural equation modelling study in the Mekong Delta, Vietnam. *Environmental Science and Policy*, **41**, 11-
2 22, doi:10.1016/j.envsci.2014.04.002.
- 3 Dang Phan, T.-H., R. Brouwer, and M. Davidson, 2014: The economic costs of avoided deforestation in the developing
4 world: A meta-analysis. *Journal of Forest Economics*, **20(1)**, 1-16, doi:10.1016/j.jfe.2013.06.004.
- 5 Darela, J.P., D.M. Lapola, R.R. Torres, and M.C. Lemos, 2016: Socio-climatic hotspots in Brazil: how do changes
6 driven by the new set of IPCC climatic projections affect their relevance for policy? *Climatic Change*, **136(3-4)**,
7 413-425, doi:10.1007/s10584-016-1635-z.
- 8 Daron, J.D., K. Sutherland, C. Jack, and B.C. Hewitson, 2015: The role of regional climate projections in managing
9 complex socio-ecological systems. *Regional Environmental Change*, **15(1)**, 1-12, doi:10.1007/s10113-014-
10 0631-y.
- 11 David, Z., 2017: Indirect land use change: much ado about (almost) nothing. *GCB Bioenergy*, **9(3)**, 485-488,
12 doi:10.1111/gcbb.12368.
- 13 Davidson, D., 2016: Gaps in agricultural climate adaptation research. *Nature Climate Change*, **6(5)**, 433-435,
14 doi:10.1038/nclimate3007.
- 15 Davidson, P., C. Burgoyne, H. Hunt, and M. Causier, 2012: Lifting options for stratospheric aerosol geoengineering:
16 advantages of tethered balloon systems. *Philosophical Transactions of the Royal Society A: Mathematical,*
17 *Physical and Engineering Sciences*, 4263-4300, doi:10.1098/rsta.2011.0639.
- 18 Davin, E.L., S.I. Seneviratne, P. Ciais, A. Olioso, and T. Wang, 2014: Preferential cooling of hot extremes from
19 cropland albedo management. *Proceedings of the National Academy of Sciences of the United States of*
20 *America*, **111(27)**, 9757-9761, doi:10.1073/pnas.1317323111.
- 21 Dawson, J., E.J. Stewart, M.E. Johnston, and C.J. Lemieux, 2016: Identifying and evaluating adaptation strategies for
22 cruise tourism in Arctic Canada. *Journal of Sustainable Tourism*, **24(10)**, 1425-1441,
23 doi:10.1080/09669582.2015.1125358.
- 24 de Boer, J., W.J.W. Botzen, and T. Terpstra, 2016a: Flood risk and climate change in the Rotterdam area, The
25 Netherlands: enhancing citizen's climate risk perceptions and prevention responses despite skepticism.
26 *Regional environmental change*, **16(6)**, 1613-1622.
- 27 de Boer, J., A. de Witt, and H. Aiking, 2016b: Help the climate, change your diet: A cross-sectional study on how to
28 involve consumers in a transition to a low-carbon society. *Appetite*, **98**, 19-27,
29 doi:10.1016/j.appet.2015.12.001.
- 30 de Coninck, H.C. and S.M. Benson, 2014: Carbon Dioxide Capture and Storage: Issues and Prospects. *Annual Review*
31 *of Environment and Resources*, **39**, 243-70, doi:10.1146/annurev-environ-032112-095222.
- 32 de Coninck, H.C. and D. Puig, 2015: Assessing climate change mitigation technology interventions by international
33 institutions. *Climatic Change*, **131(3)**, 417-433, doi:10.1007/s10584-015-1344-z.
- 34 de Coninck, H.C. and A. Sagar, 2017: Technology Development and Transfer (Article 10). In: *The Paris Agreement on*
35 *Climate Change* [Klein, D., M.P. Carazo, M. Doelle, J. Bulmer, and A. Higham (eds.)]. Oxford University
36 Press, Oxford, U.K. pp. 258-276.
- 37 de Freitas, L.C. and S. Kaneko, 2011: Ethanol demand under the flex-fuel technology regime in Brazil. *Energy*
38 *Economics*, **33(6)**, 1146-1154, doi:https://doi.org/10.1016/j.eneco.2011.03.011.
- 39 De Gouvello, C. and I. Zelenko, 2010: *Scaling up the Financing of Emissions Reduction Projects for Low Carbon*
40 *Development in Developing Countries. Proposal for a Low-carbon Development Facility*. World Bank Paper
41 No. 203, World Bank, Washington DC, USA.
- 42 de Haan, P., M.G. Mueller, and R.W. Scholz, 2009: How much do incentives affect car purchase? Agent-based
43 microsimulation of consumer choice of new cars - Part II: Forecasting effects of feebates based on energy-
44 efficiency. *Energy Policy*, **37(3)**, 1083-1094, doi:10.1016/j.enpol.2008.11.003.
- 45 de Jong, S. et al., 2017: Life-cycle analysis of greenhouse gas emissions from renewable jet fuel production.
46 *Biotechnology for Biofuels*, **10(1)**, 64, doi:10.1186/s13068-017-0739-7.
- 47 de Souza, A.P., A. Grandis, D.C.C. Leite, and M.S. Buckeridge, 2014: Sugarcane as a Bioenergy Source: History,
48 Performance, and Perspectives for Second-Generation Bioethanol. *Bioenergy Research*, **7(1)**, 24-35,
49 doi:10.1007/s12155-013-9366-8.
- 50 De Souza, A.P., B.C. Arenque, E.Q.P. Tavares, and M.S. Buckeridge, 2016: Transcriptomics and Genetics Associated
51 with Plant Responses to Elevated CO2 Atmospheric Concentrations. In: *Plant Genomics and Climate Change*
52 [Edwards, D. and J. Batley (eds.)]. Springer New York, New York, NY, USA, pp. 67-83.
- 53 De Souza, A.P., J.-C. Cocuron, A.C. Garcia, A.P. Alonso, and M.S. Buckeridge, 2015: Changes in Whole-Plant
54 Metabolism during the Grain-Filling Stage in Sorghum Grown under Elevated CO2 and Drought.. *Plant*
55 *physiology*, **169(3)**, 1755-65, doi:10.1104/pp.15.01054.
- 56 De Stefano, A. and M.G. Jacobson, 2018: Soil carbon sequestration in agroforestry systems: a meta-analysis.
57 *Agroforestry Systems*, **92(2)**, 285-299, doi:10.1007/s10457-017-0147-9.
- 58 de Wit, M. and A. Faaij, 2010: European biomass resource potential and costs. *Biomass and Bioenergy*, **34(2)**, 188-202,
59 doi:10.1016/J.BIOMBIOE.2009.07.011.
- 60 Deaton, A., 2013: *The Great Escape Health, Wealth, and the Origins of Inequality*. Princeton University Press,

- 1 Princeton, NJ, USA.
- 2 Déau, T. and J. Touati, 2017: Financing Sustainable Infrastructure. In: *Coping with the Climate Crisis Mitigation*
- 3 *Policies and Global Coordination* []. pp. 167-178.
- 4 DeBeer, C.M., H.S. Wheeler, S.K. Carey, and K.P. Chun, 2016: Recent climatic, cryospheric, and hydrological changes
- 5 over the interior of western Canada: A review and synthesis. *Hydrology and Earth System Sciences*, **20(4)**,
- 6 1573-1598, doi:10.5194/hess-20-1573-2016.
- 7 Decanio, S.J., 1993: Barriers within firms to energy- efficient investments. *Energy Policy*, **21(9)**, 906-914.
- 8 DeCicco, J.M. et al., 2016: Carbon balance effects of U.S. biofuel production and use. *Climatic Change*, **138(3-4)**, 667-
- 9 680, doi:10.1007/s10584-016-1764-4.
- 10 del Ninno, C., S. Coll-Black, and P. Fallavier, 2016: Social Protection: Building Resilience Among the Poor and
- 11 Protecting the Most Vulnerable. *Confronting Drought in Africa's Drylands: Opportunities for Enhancing*
- 12 *Resilience*, 165-184, doi:doi:10.1596/978-1-4648-0817-3_ch10.
- 13 Delmas, M.A., M. Fischlein, and O.I. Asensio, 2013: Information strategies and energy conservation behavior: A meta-
- 14 analysis of experimental studies from 1975 to 2012. *Energy Policy*, **61**, 729-739,
- 15 doi:10.1016/j.enpol.2013.05.109.
- 16 Demailly, D. and P. Quirion, 2008: European Emission Trading Scheme and competitiveness: A case study on the iron
- 17 and steel industry. *Energy Economics*, **30(4)**, 2009-2027, doi:10.1016/j.eneco.2007.01.020.
- 18 Demski, C., C. Butler, K.A. Parkhill, A. Spence, and N.F. Pidgeon, 2015: Public values for energy system change.
- 19 *Global Environmental Change*, **34**, 59-69, doi:10.1016/j.gloenvcha.2015.06.014.
- 20 Demski, C., S. Capstick, N. Pidgeon, N. Frank, and A. Spence, 2017: Experience of extreme weather affects climate
- 21 change mitigation and adaptation responses. *Climatic Change*, **140(2)**, 149-1164, doi:10.1007/s10584-016-
- 22 1837-4.
- 23 Demuzere, M. et al., 2014: Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of
- 24 green urban infrastructure. *Journal of Environmental Management*, **146**, 107-115,
- 25 doi:10.1016/j.jenvman.2014.07.025.
- 26 den Elzen, M. et al., 2016: Contribution of the G20 economies to the global impact of the Paris agreement climate
- 27 proposals. *Climatic Change*, **137(3-4)**, 655-665, doi:10.1007/s10584-016-1700-7.
- 28 Deng, X. and C. Zhao, 2015: Identification of Water Scarcity and Providing Solutions for Adapting to Climate Changes
- 29 in the Heihe River Basin of China. *Advances in Meteorology*, **2015**, 1-13, doi:10.1155/2015/279173.
- 30 Deo, R.C., 2011: On meteorological droughts in tropical Pacific Islands: Time-series analysis of observed rainfall using
- 31 Fiji as a case study. *Meteorological Applications*, **18(2)**, 171-180, doi:10.1002/met.216.
- 32 Devereux, S., 2016: Social protection for enhanced food security in sub-Saharan Africa. *Food Policy*, **60**, 52-62,
- 33 doi:10.1016/j.foodpol.2015.03.009.
- 34 Devine-Wright, P., 2009: Rethinking NIMBYism: The role of place attachment and place identity in explaining place-
- 35 protective action. *Journal of Community & Applied Social Psychology*, **19(6)**, 426-441,
- 36 doi:10.1002/casp.1004.
- 37 Devine-Wright, P., 2013: Think global, act local? The relevance of place attachments and place identities in a climate
- 38 changed world. *Global Environmental Change*, **23(1)**, 61-69, doi:10.1016/j.gloenvcha.2012.08.003.
- 39 Devine-wright, P. and Y. Howes, 2010: Disruption to place attachment and the protection of restorative environments:
- 40 A wind energy case study. *Journal of Environmental Psychology*, **30(3)**, 271-280,
- 41 doi:10.1016/j.jenvp.2010.01.008.
- 42 Dhar, S., M. Pathak, and P.R. Shukla, 2017: Electric vehicles and India's low carbon passenger transport: a long-term
- 43 co-benefits assessment. *Journal of Cleaner Production*, **146(Supplement C)**, 139-148,
- 44 doi:10.1016/j.jclepro.2016.05.111.
- 45 Dhar, T.K. and L. Khirfan, 2017: Climate change adaptation in the urban planning and design research: missing links
- 46 and research agenda. *Journal of Environmental Planning and Management*, **60(4)**, 602-627,
- 47 doi:10.1080/09640568.2016.1178107.
- 48 Diekmann, A. and P. Preisendörfer, 2003: Rationality and Society. *Rational*, **15**, 441-472,
- 49 doi:10.1177/1043463103154002.
- 50 Dietz, T., 2013: Bringing values and deliberation to science communication. *Proceeding of the National Academy of*
- 51 *Sciences of the United States of America (PNAS)*, **110**, 14081-14087, doi:10.1073/pnas.1212740110.
- 52 Dietz, T., A. Dan, and R. Shwom, 2007: Support for Climate Change Policy: Social Psychological and Social Structural
- 53 Influences. *Rural Sociology*, **72(2)**, 185-214.
- 54 Dietz, T., P.C. Stern, and E.U. Weber, 2013: Reducing Carbon-Based Energy Consumption through Changes in
- 55 Household Behavior. *Daedalus*, **142(1)**, 78-89, doi:10.1162/DAED_a_00186.
- 56 Dietz, T., G.T. Gardner, J. Gilligan, P.C. Stern, and M.P. Vandenbergh, 2009: Household actions can provide a
- 57 behavioral wedge to rapidly reduce US carbon emissions. *Proceedings of the National Academy of Sciences*,
- 58 **106(44)**, 18452-18456, doi:10.1073/pnas.0908738106.
- 59 Dietz, T., K.A. Frank, C.T. Whitley, J. Kelly, and R. Kelly, 2015: Political influences on greenhouse gas emissions
- 60 from US states. *Proceeding of the National Academy of Sciences of the United States of America (PNAS)*,

- 1 **112(27)**, 8254-8259, doi:10.1073/pnas.1417806112.
- 2 Dilling, L. and R. Hauser, 2013: Governing geoengineering research: Why, when and how? *Climatic Change*, **121(3)**,
3 553-565, doi:10.1007/s10584-013-0835-z.
- 4 Ding, D., E.W. Maibach, X. Zhao, C. Roser-Renouf, and A. Leiserowitz, 2011: Support for climate policy and societal
5 action are linked to perceptions about scientific agreement. *Nature Climate Change*, **1(9)**, 462-466,
6 doi:10.1038/nclimate1295.
- 7 Dinner, I., E.J. Johnson, D.G. Goldstein, and K. Liu, 2011: Partitioning default effects: Why people choose not to
8 choose. *Journal of Experimental Psychology: Applied*, **17(4)**, 432-432, doi:10.1037/a0026470.
- 9 Dircke, P. and A. Molenaar, 2015: Climate change adaptation; innovative tools and strategies in Delta City Rotterdam.
10 *Water Practice and Technology*, **10(4)**, 674-680.
- 11 Dobson, S., 2017: Community-driven pathways for implementation of global urban resilience goals in Africa.
12 *International Journal of Disaster Risk Reduction*, **26**, 78-84, doi:10.1016/j.ijdr.2017.09.028.
- 13 Dóci, G. and E. Vasileiadou, 2015: "Let's do it ourselves" Individual motivations for investing in renewables at
14 community level. *Renewable and Sustainable Energy Reviews*, **49**, 41-50, doi:10.1016/j.rser.2015.04.051.
- 15 Dodman, D., 2009: Blaming cities for climate change? An analysis of urban greenhouse gas emissions inventories.
16 *Environment and Urbanization*, **21(1)**, 185-201, doi:10.1177/0956247809103016.
- 17 Dodman, D., S. Colenbrander, and D. Archer, 2017a: Conclusion. In: *Responding to climate change in Asian cities:
18 Governance for a more resilient urban future* [Archer, D., S. Colenbrander, and D. Dodman (eds.)]. Routledge
19 Earthscan, Abingdon, UK.
- 20 Dodman, D., H. Leck, M. Rusca, and S. Colenbrander, 2017b: African Urbanisation and Urbanism: Implications for
21 risk accumulation and reduction. *International Journal of Disaster Risk Reduction*, **26(June)**, 7-15,
22 doi:10.1016/j.ijdr.2017.06.029.
- 23 Dogan, E., J.W. Bolderdijk, and L. Steg, 2014: Making Small Numbers Count: Environmental and Financial Feedback
24 in Promoting Eco-driving Behaviours. *Journal of Consumer Policy*, **37(3)**, 413-422, doi:10.1007/s10603-014-
25 9259-z.
- 26 Donner, S.D., M. Kandlikar, and S. Webber, 2016: Measuring and tracking the flow of climate change adaptation aid to
27 the developing world. *Environmental Research Letters*, **11(5)**, 054006, doi:10.1088/1748-9326/11/5/054006.
- 28 Dooley, K., 2017: Routines, Rigidity and Real Estate: Organisational Innovations in the Workplace. *Sustainability*,
29 **9(6)**, 998, doi:10.3390/su9060998.
- 30 Dorsch, M.J. and C. Flachslan, 2017: A Polycentric Approach to Global Climate Governance. *Global Environmental
31 Politics*, **17(2)**, 45-64, doi:10.1162/GLEP_a_00400.
- 32 Dorward, P., G. Clarkson, and R. Stern, 2015: *Participatory integrated climate services for agriculture (PICSA): Field
33 manual*. 65 pp.
- 34 Dougill, A.J. et al., 2017: Mainstreaming conservation agriculture in Malawi: Knowledge gaps and institutional
35 barriers. *Journal of Environmental Management*, **195**, 25-34, doi:10.1016/j.jenvman.2016.09.076.
- 36 Douglas, I., 2017: Flooding in African cities, scales of causes, teleconnections, risks, vulnerability and impacts.
37 *International Journal of Disaster Risk Reduction*, **26**, 34-42, doi:10.1016/j.ijdr.2017.09.024.
- 38 Dowd, A.-M. et al., 2014: The role of networks in transforming Australian agriculture. *Nature Climate Change*, **4(7)**,
39 558-563, doi:10.1038/nclimate2275.
- 40 Doyle, J., 2011: Acclimatizing nuclear? Climate change, nuclear power and the reframing of risk in the UK news
41 media. *International Communication Gazette*, **73(1-2)**, 107-125.
- 42 Drews, S. and J.C.J.M. Van den Bergh, 2016: What explains public support for climate policies ? A review of empirical
43 and experimental studies review of empirical and experimental studies. *Climate Policy*, **16(7)**, 855-876,
44 doi:10.1080/14693062.2015.1058240.
- 45 Dréze, J. and N. Stern, 1990: Policy Reform, Shadow Prices, and Market Prices. *Journal of Public Economics*, **42**, 1-45.
- 46 Droste, N. et al., 2016: Steering innovations towards a green economy: Understanding government intervention.
47 *Journal of Cleaner Production*, **135**, 426-434, doi:10.1016/j.jclepro.2016.06.123.
- 48 Dubois, U., 2012: From targeting to implementation: The role of identification of fuel poor households. *Energy Policy*,
49 **49**, 107-115, doi:https://doi.org/10.1016/j.enpol.2011.11.087.
- 50 Dunlap, R.E. and A.M. McCright, 2011: Organized climate change denial. In: *The Oxford handbook of climate change
51 and society* []. pp. 144-160.
- 52 Durand, A. et al., 2016: *Financing Options for Loss and Damage: a Review and Roadmap*. Deutsches Institut für
53 Entwicklungspolitik gGmbH.
- 54 Eakin, H. et al., 2015: Information and communication technologies and climate change adaptation in Latin America
55 and the Caribbean: a framework for action. *Climate and Development*, **7(3)**, 208-222,
56 doi:10.1080/17565529.2014.951021.
- 57 Eakin, H. et al., 2016: Cognitive and institutional influences on farmers' adaptive capacity: insights into barriers and
58 opportunities for transformative change in central Arizona. *Regional Environmental Change*, **16(3)**, 801-814,
59 doi:10.1007/s10113-015-0789-y.
- 60 Eakin, H.C.C., M.C.C. Lemos, and D.R.R. Nelson, 2014: Differentiating capacities as a means to sustainable climate

- 1 change adaptation. *Global Environmental Change*, **27(1)**, 1-8, doi:10.1016/j.gloenvcha.2014.04.013.
- 2 Eastham, S.D., D.W. Keith, and S.R.H. Barrett, 2018: Mortality tradeoff between air quality and skin cancer from
3 changes in stratospheric ozone. *Environmental Research Letters*, **13(3)**, 34035, doi:10.1088/1748-
4 9326/aaad2e.
- 5 Ebeling, F. and S. Lotz, 2015: Domestic uptake of green energy promoted by opt-out tariffs. *Nature Climate Change*,
6 **5(June)**, 868-871, doi:10.1038/NCLIMATE2681.
- 7 Eberhard, A., O. Rosnes, M. Shkaratan, and H. Vennemo, 2011: *Africa's Power Infrastructure: Investment, Integration,*
8 *Efficiency*. 352 pp.
- 9 Eberhard, A., K. Gratwick, E. Morella, and P. Antmann, 2016: *Independent Power Projects in Sub-Saharan Africa:*
10 *Lessons from Five Key Countries*. The World Bank, Washington, DC, 382 pp.
- 11 Eberhard, A., K. Gratwick, E. Morella, and P. Antmann, 2017: Accelerating investments in power in sub-Saharan
12 Africa. *Nature Energy*, **2(2)**, 17005, doi:10.1038/nenergy.2017.5.
- 13 Ecker, F., 2017: Promoting Decentralized Sustainable Energy Systems in Different Supply Scenarios: The Role of
14 Autarky Aspiration Promoting Decentralized sustainable energy systems in Different supply scenarios : The
15 role of autarky aspiration. *Frontiers in Energy Research*, **5**, 14, doi:10.3389/fenrg.2017.00014.
- 16 Edenhofer, O. et al., 2015: Closing the emission price gap. *Global Environmental Change*, **31**, 132-143,
17 doi:10.1016/j.gloenvcha.2015.01.003.
- 18 Edler, J. and J. Fagerberg, 2017: Innovation policy: what, why, and how. *Oxford Review of Economic Policy*, **33(1)**, 2-
19 23, doi:10.1093/oxrep/grx001.
- 20 EEA, 2017: *Aviation and shipping - impacts on Europe's environment: TERM 2017: Transport and Environment*
21 *Reporting Mechanism (TERM) report*. European Environment Agency (EEA), Copenhagen, 70 pp.
- 22 Eisenack, K. and R. Stecker, 2012: A framework for analyzing climate change adaptations as actions. *Mitigation and*
23 *Adaptation Strategies for Global Change*, **17(3)**, 243-260, doi:10.1007/s11027-011-9323-9.
- 24 Eisenberg, D.A., 2016: Transforming building regulatory systems to address climate change. *Building Research &*
25 *Information*, **44(5-6)**, 468-473, doi:10.1080/09613218.2016.1126943.
- 26 Ek, K. and P. Söderholm, 2008: Households' switching behavior between electricity suppliers in Sweden. *Utilities*
27 *Policy*, **16(4)**, 254-261, doi:10.1016/j.jup.2008.04.005.
- 28 Ek, K. and P. Söderholm, 2010: The devil is in the details: Household electricity saving behavior and the role of
29 information. *Energy Policy*, **38(3)**, 1578-1587, doi:10.1016/j.enpol.2009.11.041.
- 30 Ekblom, A., L. Gillson, and M. Notelid, 2017: Water flow, ecological dynamics, and management in the lower
31 Limpopo Valley: a long-term view. *Wiley Interdisciplinary Reviews: Water*, **4(5)**, e1228,
32 doi:10.1002/wat2.1228.
- 33 El Gafy, I., N. Grigg, and W. Reagan, 2017: Dynamic Behaviour of the Water-Food-Energy Nexus: Focus on Crop
34 Production and Consumption. *Irrigation and Drainage*, **66(1)**, 19-33, doi:10.1002/ird.2060.
- 35 Elia, E.F., S. Mutula, and C. Stilwell, 2014: Indigenous Knowledge use in seasonal weather forecasting in Tanzania :
36 the case of semi-arid central Tanzania. *South African Journal of Libraries and Information Science*, **80(1)**, 18-
37 27, doi:10.7553/80-1-180.
- 38 Eliasson, J., 2014: The role of attitude structures, direct experience and reframing for the success of congestion pricing.
39 *Transportation Research Part A: Policy and Practice*, **67**, 81-95, doi:10.1016/j.tra.2014.06.007.
- 40 Eliseev, A., 2012: Climate change mitigation via sulfate injection to the stratosphere: impact on the global carbon cycle
41 and terrestrial biosphere. *Atmospheric and Oceanic Optics*, **25(6)**, 405-413, doi:10.1134/S1024856012060024.
- 42 Elliott, J. et al., 2014: Constraints and potentials of future irrigation water availability on agricultural production under
43 climate change. *Proceedings of the National Academy of Sciences*, **111(9)**, 3239-3244,
44 doi:10.1073/pnas.1222474110.
- 45 Ellison, D. et al., 2017: Trees, forests and water: Cool insights for a hot world. *Global Environmental Change*, **43**, 51-
46 61, doi:10.1016/j.gloenvcha.2017.01.002.
- 47 Elmqvist, T. et al., 2013: *The world's first global assessment of the effects of urbanization on biodiversity and*
48 *ecosystem services*.
- 49 Elmqvist, T. et al., 2015: Benefits of restoring ecosystem services in urban areas. *Current Opinion in Environmental*
50 *Sustainability*, **14(Supplement C)**, 101-108, doi:10.1016/j.cosust.2015.05.001.
- 51 Elshout, P.M.F., R. van Zelm, R. Karuppiyah, I.J. Laurenzi, and M.A.J. Huijbregts, 2014: A spatially explicit data-driven
52 approach to assess the effect of agricultural land occupation on species groups. *The International Journal of*
53 *Life Cycle Assessment*, **19(4)**, 758-769, doi:10.1007/s11367-014-0701-x.
- 54 Emin, G., M. Lepetit, A. Grandjean, and O. Ortega, 2014: *Massive financing of the energy transition (SFTE feasibility*
55 *study: synthesis report Energy renovation of public buildings)*.
- 56 Emmer, A., J. Klimeš, M. Mergili, V. Vilimek, and A. Cochachin, 2016: 882 lakes of the Cordillera Blanca: An
57 inventory, classification, evolution and assessment of susceptibility to outburst floods. *CATENA*,
58 **147(Supplement C)**, 269-279, doi:https://doi.org/10.1016/j.catena.2016.07.032.
- 59 Ensor, J. and B. Harvey, 2015: Social learning and climate change adaptation: evidence for international development
60 practice. *Wiley Interdisciplinary Reviews: Climate Change*, **6(5)**, 509-522, doi:10.1002/wcc.348.

- 1 Erb, K.–H. et al., 2009: Eating the Planet: Feeding and fuelling the world sustainably, fairly and humanely - a scoping
2 study. , 1-132.
- 3 Erb, K.–H. et al., 2016a: Exploring the biophysical option space for feeding the world without deforestation. *Nature*
4 *Communications*, **7**, 11382, doi:10.1038/NCOMMS11382.
- 5 Erb, K.–H. et al., 2016b: Land management: data availability and process understanding for global change studies.
6 *Global Change Biology*, **23(2)**, 512-533, doi:10.1111/gcb.13443.
- 7 Erb, K.–H. et al., 2017: Unexpectedly large impact of forest management and grazing on global vegetation biomass.
8 *Nature*, **553(7686)**, 73-76, doi:10.1038/nature25138.
- 9 Eric Bickel, J., 2013: Climate engineering and climate tipping-point scenarios. *Environment Systems & Decisions*,
10 **33(1)**, 152-167, doi:10.1007/s10669-013-9435-8.
- 11 Ericsson, K. and S. Werner, 2016: The introduction and expansion of biomass use in Swedish district heating systems.
12 *Biomass and Bioenergy*, **94**, 57-65, doi:10.1016/J.BIOMBIOE.2016.08.011.
- 13 Eriksson, L., J. Garvill, and A.M. Nordlund, 2006: Acceptability of travel demand management measures : The
14 importance of problem awareness, personal norm, freedom, and fairness. *Journal of Environmental*
15 *Psychology*, **26**, 15-26, doi:10.1016/j.jenvp.2006.05.003.
- 16 Eriksson, L., J. Garvill, and A.M. Nordlund, 2008: Acceptability of single and combined transport policy measures: The
17 importance of environmental and policy specific beliefs. *Transportation Research Part A: Policy and*
18 *Practice*, **42(8)**, 1117-1128, doi:10.1016/j.tra.2008.03.006.
- 19 Erker, S., R. Stangl, and G. Stoeglehner, 2017: Resilience in the light of energy crises - Part II: Application of the
20 regional energy resilience assessment. *Journal of Cleaner Production*, **164**, doi:10.1016/j.jclepro.2017.06.162.
- 21 Erlinghagen, S. and J. Markard, 2012: Smart grids and the transformation of the electricity sector: ICT firms as
22 potential catalysts for sectoral change. *Energy Policy*, **51**, 895-906, doi:10.1016/J.ENPOL.2012.09.045.
- 23 Esham, M. and C. Garforth, 2013: Agricultural adaptation to climate change: insights from a farming community in Sri
24 Lanka. *Mitigation and Adaptation Strategies for Global Change*, **18(5)**, 535-549, doi:10.1007/s11027-012-
25 9374-6.
- 26 ESRB ASC, 2016: *Too late, too sudden: Transition to a low-carbon economy and systemic risk*. ESRB ASC Report No
27 6, 22 pp.
- 28 Evans, J., J. O'Brien, and B. Ch Ng, 2018: Towards a geography of informal transport: Mobility, infrastructure and
29 urban sustainability from the back of a motorbike. *Transactions of the Institute of British Geographers*,
30 doi:10.1111/tran.12239.
- 31 Evans, L. et al., 2012: Self-interest and pro-environmental behaviour. *Nature Climate Change*, **3(2)**, 122-125,
32 doi:10.1038/nclimate1662.
- 33 Evans, M., V. Roshchanka, and P. Graham, 2017: An international survey of building energy codes and their
34 implementation. *Journal of Cleaner Production*, **158**, 382-389, doi:10.1016/j.jclepro.2017.01.007.
- 35 Ewing, R., S. Hamidi, and J.B. Grace, 2016: Compact development and VMT-Environmental determinism, self-
36 selection, or some of both? *Environment and Planning B: Planning and Design*, **43(4)**, 737-755,
37 doi:10.1177/0265813515594811.
- 38 Exner, A. et al., 2016: Measuring regional resilience towards fossil fuel supply constraints. Adaptability and
39 vulnerability in socio-ecological Transformations-the case of Austria. *Energy Policy*, **91**, 128-137,
40 doi:10.1016/j.enpol.2015.12.031.
- 41 Eyre, N., S.J. Darby, P. Grünewald, E. McKenna, and R. Ford, 2018: Reaching a 1.5°C target: socio-technical
42 challenges for a rapid transition to low-carbon electricity systems. *Philosophical Transactions of the Royal*
43 *Society A: Mathematical, Physical and Engineering Sciences*, **376(2119)**, 20160462,
44 doi:10.1098/rsta.2016.0462.
- 45 Ezeji, T., 2017: Production of Bio-Derived Fuels and Chemicals. *Fermentation*, **3(3)**, 42,
46 doi:10.3390/fermentation3030042.
- 47 Fader, M., S. Shi, W. von Bloh, A. Bondeau, and W. Cramer, 2016: Mediterranean irrigation under climate change:
48 more efficient irrigation needed to compensate for increases in irrigation water requirements. *Hydrology and*
49 *Earth System Sciences*, **20(2)**, 953-973, doi:10.5194/hess-20-953-2016.
- 50 Faehn, T. and E.T. Isaksen, 2016: Diffusion of Climate Technologies in the Presence of Commitment Problems. *The*
51 *Energy Journal*, **37(2)**, 155-180, doi:10.5547/01956574.37.2.tfae.
- 52 Fainstein, S.S., 2018: Resilience and justice: planning for New York City. *Urban Geography*, 1-8,
53 doi:10.1080/02723638.2018.1448571.
- 54 Fajardy, M. and N. Mac Dowell, 2017: Can BECCS deliver sustainable and resource efficient negative emissions?
55 *Energy & Environmental Science*, **10(6)**, 1389-1426, doi:10.1039/C7EE00465F.
- 56 Falkner, R., 2016: The Paris Agreement and the new logic of international climate politics. *International Affairs*, **92(5)**,
57 1107-1125.
- 58 Faludi, J., C. Bayley, S. Bhogal, and M. Iribarne, 2015: Comparing environmental impacts of additive manufacturing vs
59 traditional machining via life-cycle assessment. *Rapid Prototyping Journal*, **21(1)**, 14-33, doi:10.1108/RPJ-07-
60 2013-0067.

- 1 Fang, Y., B. Singh, B.P. Singh, and E. Krull, 2014: Biochar carbon stability in four contrasting soils. *European Journal*
2 *of Soil Science*, **65**(1), 60-71, doi:10.1111/ejss.12094.
- 3 Fankhauser, S. and G. Schmidt-Traub, 2011: From adaptation to climate-resilient development: The costs of climate-
4 proofing the Millennium Development Goals in Africa. *Climate and Development*, **3**(2), 94-113,
5 doi:10.1080/17565529.2011.582267.
- 6 Fankhauser, S. and T.K.J. McDermott, 2014: Understanding the adaptation deficit: Why are poor countries more
7 vulnerable to climate events than rich countries? *Global Environmental Change*, **27**(1), 9-18,
8 doi:10.1016/j.gloenvcha.2014.04.014.
- 9 FAO, 2013: Food wastage footprint. Impacts on natural resources. Summary Report. *Food wastage footprint Impacts*
10 *on natural resources*, 63.
- 11 FAO & NZAGRC, 2017a: *Low emissions development of the beef cattle sector in Uruguay - reducing enteric methane*
12 *for food security and livelihoods*. 34 pp.
- 13 FAO & NZAGRC, 2017b: *Options for low emission development in the Kenya dairy sector - reducing enteric methane*
14 *for food security and livelihoods*. 43 pp.
- 15 FAO & NZAGRC, 2017c: *Supporting low emissions development in the Ethiopian dairy cattle sector - reducing enteric*
16 *methane for food security and livelihoods*. 34 pp.
- 17 Farfan, J. and C. Breyer, 2017: Structural changes of global power generation capacity towards sustainability and the
18 risk of stranded investments supported by a sustainability indicator. *Journal of Cleaner Production*, **141**, 370-
19 384, doi:10.1016/j.jclepro.2016.09.068.
- 20 Farrow, K., G. Grolleau, and L. Ibanez, 2017: Social Norms and Pro-environmental Behavior: A Review of the
21 Evidence. *Ecological Economics*, **140**, 1-13, doi:10.1016/j.ecolecon.2017.04.017.
- 22 Fasihi, M., D. Bogdanov, and C. Breyer, 2017: Long-Term Hydrocarbon Trade Options for the Maghreb Region and
23 Europe-Renewable Energy Based Synthetic Fuels for a Net Zero Emissions World. *Sustainability*, **9**(2),
24 doi:10.3390/su9020306.
- 25 Favretto, N., L.C. Stringer, M.S. Buckeridge, and S. Afionis, 2017: Policy and Diplomacy in the Production of Second
26 Generation Ethanol in Brazil: International Relations with the EU, the USA and Africa BT - Advances of
27 Basic Science for Second Generation Bioethanol from Sugarcane. *Advances of Basic Science for Second*
28 *Generation from Sugarcane*, 197-212, doi:10.1007/978-3-319-49826-3_11.
- 29 Fawcett, T., F. Hvelplund, and N.I. Meyer, 2010: Making It Personal: Per Capita Carbon Allowances. In: *Generating*
30 *Electricity in a Carbon-Constrained World* [Sioshansi, F.P. (ed.)]. Academic Press, Boston, MA, USA, pp. 87-
31 107.
- 32 Fazey, I. et al., 2017: Transformation in a changing climate: a research agenda. *Climate and Development*, 1-21,
33 doi:10.1080/17565529.2017.1301864.
- 34 Fazey, I. et al., 2018: Energy Research & Social Science Ten essentials for action-oriented and second order energy
35 transitions, transformations and climate change research. *Energy Research & Social Science*, **40**(April 2017),
36 54-70, doi:10.1016/j.erss.2017.11.026.
- 37 Fell, H., D. Burtraw, R.D. Morgenstern, and K.L. Palmer, 2012: Soft and hard price collars in a cap-and-trade system:
38 A comparative analysis. *Journal of Environmental Economics and Management*, **64**(2), 183-198,
39 doi:10.1016/j.jeem.2011.11.004.
- 40 Feng, E.Y., D.P. Keller, W. Koeve, and A. Oschlies, 2016: Could artificial ocean alkalization protect tropical coral
41 ecosystems from ocean acidification? *Environmental Research Letters*, **11**(7), 074008, doi:10.1088/1748-
42 9326/11/7/074008.
- 43 Feola, G., A.M. Lerner, M. Jain, M.J.F. Montefrio, and K. Nicholas, 2015: Researching farmer behaviour in climate
44 change adaptation and sustainable agriculture: Lessons learned from five case studies. *Journal of Rural*
45 *Studies*, **39**, 74-84, doi:10.1016/j.jrurstud.2015.03.009.
- 46 Fernández-Giménez, M.E., B. Batkhisig, B. Batbuyan, and T. Ulambayar, 2015: Lessons from the Dzud: Community-
47 Based Rangeland Management Increases the Adaptive Capacity of Mongolian Herders to Winter Disasters.
48 *World Development*, **68**, 48-65, doi:10.1016/j.worlddev.2014.11.015.
- 49 Ferrario, F. et al., 2014: The effectiveness of coral reefs for coastal hazard risk reduction and adaptation. *Nature*
50 *Communications*, **5**(May), 1-9, doi:10.1038/ncomms4794.
- 51 Few, R., D. Morchain, D. Spear, A. Mensah, and R. Bendapudi, 2017: Transformation, adaptation and development:
52 relating concepts to practice. *Palgrave Communications*, **3**, 17092, doi:10.1057/palcomms.2017.92.
- 53 Fielding, K.S. and M.J. Hornsey, 2016: A Social Identity Analysis of Climate Change and Environmental Attitudes and
54 Behaviors: Insights and Opportunities. *Frontiers in Psychology*, **7**(FEB), 1-12, doi:10.3389/fpsyg.2016.00121.
- 55 Fielding, K.S., R. McDonald, and W.R. Louis, 2008: Theory of planned behaviour, identity and intentions to engage in
56 environmental activism. *Journal of Environmental Psychology*, **28**, 318-326, doi:10.1016/j.jenvp.2008.03.003.
- 57 Figueres, C. et al., 2017: Three years to safeguard our climate. *Nature*, **546**(7660), 593-595.
- 58 Fink, J.H., 2013: Geoengineering cities to stabilise climate. *Proceedings of the Institution of Civil Engineers -*
59 *Engineering Sustainability*, **166**(5), 242-248, doi:10.1680/ensu.13.00002.
- 60 Finlayson, C., 2012: Forty years of wetland conservation and wise use. *Aquatic Conservation: Marine and Freshwater*

- 1 *Ecosystems*, **22(2)**, 139-143, doi:10.1002/aqc.2233.
- 2 Finlayson, C.M. et al., 2017: Policy considerations for managing wetlands under a changing climate. *Marine and*
3 *Freshwater Research*, **68(10)**, 1803-1815, doi:10.1071/MF16244.
- 4 Finley, R.J., 2014: An overview of the Illinois Basin - Decatur Project. *Greenhouse Gases: Science and Technology*,
5 **4(5)**, 571-579, doi:10.1002/ghg.1433.
- 6 Finon, D., 2013: Towards a global governance of nuclear safety: an impossible quest ? *Revue de l'Energie*, **616**, 440-
7 450.
- 8 Finon, D. and F.A. Roques, 2013: European Electricity Market Reforms: The "Visible Hand" of Public Coordination.
9 *Economics of Energy & Environmental Policy*.
- 10 Fischer, C., M. Greaker, and K.E. Rosendahl, 2017: Robust technology policy against emission leakage: The case of
11 upstream subsidies. *Journal of Environmental Economics and Management*, **84**, 44-61,
12 doi:10.1016/j.jeem.2017.02.001.
- 13 Fishman, E., S. Washington, and N. Haworth, 2015: Bikeshare's impact on active travel: Evidence from the United
14 States, Great Britain, and Australia. *Journal of Transport & Health*, **2(2)**, 135-142,
15 doi:10.1016/j.jth.2015.03.004.
- 16 Fishman, R., N. Devineni, and S. Raman, 2015: Can improved agricultural water use efficiency save India's
17 groundwater? *Environmental Research Letters*, **10(8)**, 84022.
- 18 Fleming, A., S.E. Park, and N.A. Marshall, 2015a: Enhancing adaptation outcomes for transformation: climate change
19 in the Australian wine industry. *Journal of Wine Research*, **26(2)**, 99-114,
20 doi:10.1080/09571264.2015.1031883.
- 21 Fleming, A., A.M. Dowd, E. Gaillard, S. Park, and M. Howden, 2015b: "Climate change is the least of my worries":
22 Stress limitations on adaptive capacity. *Rural Society*, **24(1)**, 24-41, doi:10.1080/10371656.2014.1001481.
- 23 Fleurbaey, M. and P.J. Hammond, 2004: Interpersonally Comparable Utility. In: *Handbook of Utility Theory: Volume 2*
24 *Extensions* [Barbera, S., P.J. Hammond, and C. Seidl (eds.)]. Kluwer Academic Publishers, Dordrecht, The
25 Netherlands, pp. 1179-1285.
- 26 Fleurbaey, M. et al., 2014: Sustainable Development and Equity. In: *Climate Change 2014: Mitigation of Climate*
27 *Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum,
28 S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, and J.C.
29 Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 283-
30 350.
- 31 Flynn, M., J. Ford, T. Pearce, S. Harper, and IHACC Research Team, 2018: Participatory scenario planning and climate
32 change impacts, adaptation, and vulnerability research in the Arctic. *Environmental Science & Policy*, **79**, 45-
33 53.
- 34 Foley, J.A. et al., 2011: Solutions for a cultivated planet. *Nature*, doi:10.1038/nature10452.
- 35 Forbes, B.C. et al., 2009: High resilience in the Yamal-Nenets social-ecological system, West Siberian Arctic, Russia.
36 *Proceedings of the National Academy of Sciences*, **106(52)**, 22041-22048, doi:10.1073/pnas.0908286106.
- 37 Forbis Jr, R. and K. Hayhoe, 2018: Does Arctic governance hold the key to achieving climate policy targets?
38 *Environmental Research Letters*, **13(2)**, 20201.
- 39 Ford, J.D., 2012: Indigenous health and climate change. *American Journal of Public Health*, **102(7)**, 1260-1266,
40 doi:10.2105/AJPH.2012.300752.
- 41 Ford, J.D. and D. King, 2015: Coverage and framing of climate change adaptation in the media: A review of influential
42 North American newspapers during 1993-2013. *Environmental Science and Policy*, **48**, 137-146,
43 doi:10.1016/j.envsci.2014.12.003.
- 44 Ford, J.D. and L. Berrang-Ford, 2016: The 4Cs of adaptation tracking: consistency, comparability, comprehensiveness,
45 coherency. *Mitigation and Adaptation Strategies for Global Change*, **21(6)**, 839-859, doi:10.1007/s11027-014-
46 9627-7.
- 47 Ford, J.D., G. McDowell, and J. Jones, 2014a: The state of climate change adaptation in the Arctic. *Environmental*
48 *Research Letters*, **9(10)**, 104005, doi:10.1088/1748-9326/9/10/104005.
- 49 Ford, J.D., G. McDowell, and T. Pearce, 2015a: The adaptation challenge in the Arctic. *Nature Climate Change*, **5(12)**,
50 1046-1053, doi:10.1038/nclimate2723.
- 51 Ford, J.D. et al., 2014b: Adapting to the effects of climate change on inuit health. *American Journal of Public Health*,
52 **104(SUPPL. 3)**, e9-e17, doi:10.2105/AJPH.2013.301724.
- 53 Ford, J.D. et al., 2015b: Adaptation tracking for a post-2015 climate agreement. *Nature Climate Change*, **5(11)**, 967-
54 969, doi:10.1038/nclimate2744.
- 55 Ford, J.D. et al., 2015c: Evaluating climate change vulnerability assessments: a case study of research focusing on the
56 built environment in northern Canada. *Mitigation and Adaptation Strategies for Global Change*, **20(8)**, 1267-
57 1288, doi:10.1007/s11027-014-9543-x.
- 58 Ford, J.D. et al., 2016: Community-based adaptation research in the Canadian Arctic. *Wiley Interdisciplinary Reviews:*
59 *Climate Change*, **7(2)**, 175-191, doi:10.1002/wcc.376.
- 60 Ford, J.D. et al., 2018: Preparing for the health impacts of climate change in Indigenous communities: The role of

- 1 community-based adaptation. *Global Environmental Change*, **49**, 129-139.
- 2 Forman, C., I.K. Muritala, R. Pardemann, and B. Meyer, 2016: Estimating the global waste heat potential. *Renewable*
3 *and Sustainable Energy Reviews*, **57(Supplement C)**, 1568-1579,
4 doi:<https://doi.org/10.1016/j.rser.2015.12.192>.
- 5 Fornell, R., T. Berntsson, and A. Åsblad, 2013: Techno-economic analysis of a kraft pulp-mill-based biorefinery
6 producing both ethanol and dimethyl ether. *Energy*, **50(1)**, 83-92, doi:10.1016/j.energy.2012.11.041.
- 7 Forsell, N. et al., 2016: Assessing the INDCs' land use, land use change, and forest emission projections. *Carbon*
8 *Balance and Management*, **11(1)**, 26, doi:10.1186/s13021-016-0068-3.
- 9 Forster, J., I.R. Lake, A.R. Watkinson, and J.A. Gill, 2011: Marine biodiversity in the Caribbean UK overseas
10 territories: Perceived threats and constraints to environmental management. *Marine Policy*, **35(5)**, 647-657,
11 doi:10.1016/j.marpol.2011.02.005.
- 12 Fouquet, R., 2016: Lessons from energy history for climate policy: Technological change, demand and economic
13 development. *Energy Research & Social Science*, **22**, 79-93, doi:10.1016/j.erss.2016.09.001.
- 14 Francesch-Huidobro, M., M. Dabrowski, Y. Tai, F. Chan, and D. Stead, 2017: Governance challenges of flood-prone
15 delta cities: Integrating flood risk management and climate change in spatial planning. *Progress in Planning*,
16 **114**, 1-27, doi:10.1016/j.progress.2015.11.001.
- 17 Francis, R. and B. Bekera, 2014: A metric and frameworks for resilience analysis of engineered and infrastructure
18 systems. *Reliability Engineering & System Safety*, **121**, 90-103, doi:10.1016/j.res.2013.07.004.
- 19 Frank, S. et al., 2013: How effective are the sustainability criteria accompanying the European Union 2020 biofuel
20 targets? *GCB Bioenergy*, **5(3)**, 306-314, doi:10.1111/j.1757-1707.2012.01188.x.
- 21 Fraser, A. et al., 2017: Meeting the challenge of risk-sensitive and resilient urban development in sub-Saharan Africa:
22 Directions for future research and practice. *International Journal of Disaster Risk Reduction*, **26**, 106-109,
23 doi:10.1016/j.ijdr.2017.10.001.
- 24 Frederiks, E.R., K. Stenner, and E. Hobman, 2015: Household energy use: Applying behavioural economics to
25 understand consumer decision-making and behaviour. *Renewable and Sustainable Energy Reviews*, **41**, 1385-
26 1394, doi:10.1016/j.rser.2014.09.026.
- 27 Freire, M.E., S. Lall, and D. Leipziger, 2014: *Africa's urbanization: challenges and opportunities*. Working Paper No.
28 7, The Growth Dialogue, Washington DC, USA, 44 pp.
- 29 Freire-González, J., 2017: Evidence of direct and indirect rebound effect in households in EU-27 countries. *Energy*
30 *Policy*, **102**, 270-276, doi:10.1016/j.enpol.2016.12.002.
- 31 Fridahl, M., 2017: Socio-political prioritization of bioenergy with carbon capture and storage. *Energy Policy*, **104**, 89-
32 99, doi:10.1016/J.ENPOL.2017.01.050.
- 33 Friedlingstein, P. et al., 2014: Uncertainties in CMIP5 climate projections due to carbon cycle feedbacks. *Journal of*
34 *Climate*, **27(2)**, 511-526, doi:10.1175/JCLI-D-12-00579.1.
- 35 Fritz, S. et al., 2011: Highlighting continued uncertainty in global land cover maps for the user community.
36 *Environmental Research Letters*, **6(4)**, 044005, doi:10.1088/1748-9326/6/4/044005.
- 37 Froud, J., C. Haslam, S. Johal, and K. Williams, 2000: Shareholder value and Financialization: consultancy promises,
38 management moves. *Economy and Society*, **29(1)**, 80-110, doi:10.1080/030851400360578.
- 39 Fryer, E., 2017: Digital infrastructure: And the impacts of climate change. *Journal of the Institute of*
40 *Telecommunications Professionals*, **11(2)**, 8-13.
- 41 Fu, G. et al., 2017: Integrated Approach to Assess the Resilience of Future Electricity Infrastructure Networks to
42 Climate Hazards. *IEEE Systems Journal*, doi:10.1109/JSYST.2017.2700791.
- 43 Fudge, S., M. Peters, and B. Woodman, 2016: Local authorities as niche actors: the case of energy governance in the
44 UK. *Environmental Innovation and Societal Transitions*, **18**, 1-17, doi:10.1016/j.eist.2015.06.004.
- 45 Fuhr, H., T. Hickmann, and K. Kern, 2018: The role of cities in multi-level climate governance: local climate policies
46 and the 1.5 °C target. *Current Opinion in Environmental Sustainability*, **30**, 1-6,
47 doi:10.1016/j.cosust.2017.10.006.
- 48 Fujii, S. and R. Kitamura, 2003: What does a one-month free bus ticket do to habitual drivers? An experimental
49 analysis of habit and attitude change. *Transportation*, **30(1)**, 81-95, doi:10.1023/A:1021234607980.
- 50 Fujimori, S. et al., 2016: Implication of Paris Agreement in the context of long-term climate mitigation goals.
51 *SpringerPlus*, **5(1)**, 1620, doi:10.1186/s40064-016-3235-9.
- 52 Fulton, L. et al., 2017: Three Revolutions in Urban Transportation. .
- 53 Fuss, S. et al., 2014: Betting on negative emissions. *Nature Climate Change*, **4(10)**, 850-853,
54 doi:10.1038/nclimate2392.
- 55 Fuss, S. et al., 2018: Negative emissions - Part 2: Costs, potentials and side effects. *Environmental Research Letters* (in
56 press), doi:<https://doi.org/10.1088/1748-9326/aabf9f>.
- 57 Gajjar, S.P., C. Singh, and T. Deshpande, 2018: Tracing back to move ahead: a review of development pathways that
58 constrain adaptation futures. *Climate and Development*, 1-15, doi:10.1080/17565529.2018.1442793.
- 59 Gambhir, A. et al., 2017: Assessing the Feasibility of Global Long-Term Mitigation Scenarios. *Energies*, **10(1)**.
- 60 Gandure, S., S. Walker, and J.J. Botha, 2013: Farmers' perceptions of adaptation to climate change and water stress in a

- 1 South African rural community. *Environmental Development*, **5(1)**, 39-53, doi:10.1016/j.envdev.2012.11.004.
- 2 Gao, C., 2018: The future of CRISPR technologies in agriculture. *Nature Reviews Molecular Cell Biology*, **19(5)**, 275-
3 276, doi:10.1038/nrm.2018.2.
- 4 Gao, Y. and J. Kenworthy, 2015: Growth of a Giant: A Historical and Current Perspective on the Chinese Automobile
5 Industry. *World Transport Policy and Practice*, **21**, 40-55.
- 6 Gao, Y. and J. Kenworthy, 2017: China. In: *The Urban Transport Crisis in Emerging Economies* [Pojani, D. and D.
7 Stead (eds.)]. Springer, New York, NY, USA, pp. 33-58.
- 8 Gao, Y. and P. Newman, 2018: Beijing's Peak Car Transition: Hope for Emerging Cities in the 1.5 °C Agenda. *Urban
9 Planning*, **3(2)**, 82, doi:10.17645/up.v3i2.1246.
- 10 García Romero, H. and A. Molina, 2015: *Agriculture and Adaptation to Climate Change: The Role of Insurance in Risk
11 Management: The Case of Colombia*. Inter-American Development Bank, 49 pp.
- 12 García-Álvarez, M.T., L. Cabeza-García, and I. Soares, 2017: Analysis of the promotion of onshore wind energy in the
13 EU: Feed-in tariff or renewable portfolio standard? *Renewable Energy*, **111**, 256-264,
14 doi:10.1016/j.renene.2017.03.067.
- 15 Gardiner, S.M., 2013: Why geoengineering is not a 'global public good', and why it is ethically misleading to frame it as
16 one. *Climatic Change*, **121(3)**, 513-525, doi:10.1007/s10584-013-0764-x.
- 17 Garg, A., J. Maheshwari, P.R. Shukla, and R. Rawal, 2017: Energy appliance transformation in commercial buildings in
18 India under alternate policy scenarios. *Energy*, **140**, 952-965, doi:10.1016/j.energy.2017.09.004.
- 19 Gasc, F., D. Guerrier, S. Barrett, and S. Anderson, 2014: *Assessing the effectiveness of investments in climate
20 information services*. IIED, London.
- 21 Gawith, D., A. Daigneault, and P. Brown, 2016: Does community resilience mitigate loss and damage from
22 climaterelated disasters? Evidence based on survey data. *Journal of Environmental Planning and
23 Management*, **59(12)**, 2102-2123, doi:10.1080/09640568.2015.1126241.
- 24 GCEC, 2014: *Better growth, Better Climate: The New Climate Economy Report*. The Global Commission of the
25 Economy and Climate, New Climate Economy, Washington, DC, USA, 308 pp.
- 26 GEA, 2012: *Global Energy Assessment - Toward a sustainable future*. Global Energy Assessment (GEA). Cambridge
27 University Press, Cambridge UK and New York, NY, USA and the International Institute for Applied Systems
28 Analysis, Laxenburg, Austria, 113 pp.
- 29 Gebrehiwot, T. and A. van der Veen, 2015: Farmers Prone to Drought Risk: Why Some Farmers Undertake Farm-Level
30 Risk-Reduction Measures While Others Not? *Environmental Management*, **55(3)**, 588-602,
31 doi:10.1007/s00267-014-0415-7.
- 32 Gebru, B., P. Kibaya, T. Ramahaleo, K. Kwena, and P. Mapfumo, 2015: *Improving access to climate-related
33 information for adaptation*. IDRC, Canada, 1-4 pp.
- 34 Geden, O., V. Scott, and J. Palmer, 2018: Integrating carbon dioxide removal into EU climate policy: Prospects for a
35 paradigm shift. , 1-10, doi:10.1002/wcc.521.
- 36 Geels, F.W., 2014: Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-
37 Level Perspective. *Theory, Culture & Society*, **31(5)**, 21-40, doi:10.1177/0263276414531627.
- 38 Geels, F.W. and J. Schot, 2007: Typology of sociotechnical transition pathways. *Research Policy*, **36(3)**, 399-417,
39 doi:10.1016/j.respol.2007.01.003.
- 40 Geels, F.W., F. Berkhout, and D.P. van Vuuren, 2016a: Bridging analytical approaches for low-carbon transitions.
41 *Nature Climate Change*, **6(6)**, 576-583, doi:10.1038/nclimate2980.
- 42 Geels, F.W., B.K. Sovacool, T. Schwanen, and S. Sorrell, 2017: Sociotechnical transitions for deep decarbonization.
43 *Science*, **357(6357)**, 1242-1244, doi:10.1126/science.aao3760.
- 44 Geels, F.W. et al., 2016b: The enactment of socio-technical transition pathways: A reformulated typology and a
45 comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990-2014).
46 *Research Policy*, **45(4)**, 896-913, doi:10.1016/j.respol.2016.01.015.
- 47 Gemenne, F. and J. Blocher, 2017: How can migration serve adaptation to climate change? Challenges to fleshing out a
48 policy ideal. *Geographical Journal*, doi:10.1111/geoj.12205.
- 49 Georgeson, L., M. Maslin, M. Poessinouw, and S. Howard, 2016: Adaptation responses to climate change differ
50 between global megacities. *Nature Climate Change*, **6(6)**, 584-588.
- 51 Gerbens-Leenes, W., A.Y. Hoekstra, and T.H. van der Meer, 2009: The water footprint of bioenergy. *Proceedings of
52 the National Academy of Sciences*, **106(25)**, 10219-10223, doi:10.1073/pnas.0812619106.
- 53 Gerber, P.J. et al., 2013: Tackling climate change through livestock - A global assessment of emissions and mitigation
54 opportunities. , 133.
- 55 GeSI, 2015: *SMARTEer2030: ICT Solutions for 21st Century Challenges*. Global e-Sustainability Initiative (GeSI),
56 Brussels, Belgium, 134 pp.
- 57 Gheewala, S.H., G. Berndes, and G. Jewitt, 2011: The bioenergy and water nexus. *Biofuels, Bioproducts and
58 Biorefining*, **5(4)**, 353-360, doi:10.1002/bbb.295.
- 59 Ghorbani, N., A. Aghahosseini, and C. Breyer, 2017: Transition towards a 100% Renewable Energy System and the
60 Role of Storage Technologies: A Case Study of Iran. *Energy Procedia*, **135(Supplement C)**, 23-36,

- 1 doi:<https://doi.org/10.1016/j.egypro.2017.09.484>.
- 2 Gibbs, D. and K. O'Neill, 2014: Rethinking Sociotechnical Transitions and Green Entrepreneurship: The Potential for
3 Transformative Change in the Green Building Sector. *Environment and Planning A*, **46(5)**, 1088-1107,
4 doi:10.1068/a46259.
- 5 Gillard, R., 2016: Questioning the Diffusion of Resilience Discourses in Pursuit of Transformational Change. *Global
6 Environmental Politics*, **16(1)**, 13-20, doi:10.1162/GLEP_a_00334.
- 7 Gillard, R., A. Gouldson, J. Paavola, and J. Van Alstine, 2016: Transformational responses to climate change: beyond a
8 systems perspective of social change in mitigation and adaptation. *Wiley Interdisciplinary Reviews: Climate
9 Change*, **7(2)**, 251-265, doi:10.1002/wcc.384.
- 10 Gillingham, K. and K. Palmer, 2017: Bridging the Energy Efficiency Gap: Policy Insights from Economic Theory and
11 Empirical Evidence. *Review of Environmental Economics and Policy*, **8(1)**, 18-38, doi:10.1093/leep/ret021.
- 12 Gillingham, K., M.J. Kotchen, D.S. Rapson, and G. Wagner, 2013: Energy policy: The rebound effect is overplayed.
13 *Nature*, **493(7433)**, 475-476, doi:10.1038/493475a.
- 14 Giménez-Gómez, J.-M., J. Teixidó-Figueras, and C. Vilella, 2016: The global carbon budget: a conflicting claims
15 problem. *Climatic Change*, **136(3-4)**, 693-703, doi:10.1007/s10584-016-1633-1.
- 16 Girod, B., T. Stucki, and M. Woerter, 2017: How do policies for efficient energy use in the household sector induce
17 energy-efficiency innovation? An evaluation of European countries. *Energy Policy*, **103**, 223-237,
18 doi:10.1016/j.enpol.2016.12.054.
- 19 Glaas, E., E.C.H. Keskitalo, and M. Hjerpe, 2017: Insurance sector management of climate change adaptation in three
20 Nordic countries: the influence of policy and market factors. *Journal of Environmental Planning and
21 Management*, **60(9)**, 1601-1621, doi:10.1080/09640568.2016.1245654.
- 22 Glachant, M. and A. Dechezleprêtre, 2016: What role for climate negotiations on technology transfer? *Climate Policy*,
23 1-15, doi:10.1080/14693062.2016.1222257.
- 24 Glazebrook, G. and P. Newman, 2018a: The City of the Future. *Urban Planning*, **3(2)**, 1, doi:10.17645/up.v3i2.1247.
- 25 Glazebrook, G. and P. Newman, 2018b: The City of the Future. *Urban Planning*, **3(2)**, 1, doi:10.17645/up.v3i2.1247.
- 26 Global CCS Institute, 2017: *The Global Status of CCS 2016 Summary Report*. 28 pp.
- 27 Goeppert, A., M. Czaun, G.K. Surya Prakash, and G.A. Olah, 2012: Air as the renewable carbon source of the future:
28 an overview of CO2 capture from the atmosphere. *Energy & Environmental Science*, **5(7)**, 7833,
29 doi:10.1039/c2ee21586a.
- 30 Goldemberg, J., 2011: The Role of Biomass in the World's Energy System. In: *Routes to Cellulosic Ethanol*
31 [Buckeridge, M.S. and G.H. Goldman (eds.)]. Springer, New York, NY, USA, pp. 3-14.
- 32 Gölz, S. and U.J.J. Hahnel, 2016: What motivates people to use energy feedback systems ? A multiple goal approach to
33 predict long-term usage behaviour in daily life. *Energy Research & Social Science*, **21**, 155-166,
34 doi:10.1016/j.erss.2016.07.006.
- 35 Gonzales, M.H., E. Aronson, and M.A. Costanzo, 1988: Using Social Cognition and Persuasion to Promote Energy
36 Conservation: A Quasi-Experiment. *Journal of Applied Social Psychology*, **18(12)**, 1049-1066.
- 37 González, M.F. and T. Ilyina, 2016: Impacts of artificial ocean alkalization on the carbon cycle and climate in Earth
38 system simulations. *Geophysical Research Letters*, **43(12)**, 6493-6502, doi:10.1002/2016GL068576.
- 39 Goodwin, P. and K. Van Dender, 2013: Peak Car' - Themes and Issues. *Transport Reviews*, **33(3)**, 243-254,
40 doi:10.1080/01441647.2013.804133.
- 41 Göpfert, C., C. Wamsler, and W. Lang, 2018: A framework for the joint institutionalization of climate change
42 mitigation and adaptation in city administrations. *Mitigation and Adaptation Strategies for Global Change*,
43 doi:10.1007/s11027-018-9789-9.
- 44 Gorayeb, A., C. Brannstrom, A.J. de Andrade Meireles, and J. de Sousa Mendes, 2018: Wind power gone bad:
45 Critiquing wind power planning processes in northeastern Brazil. *Energy Research & Social Science*, **40**, 82-
46 88, doi:<https://doi.org/10.1016/j.erss.2017.11.027>.
- 47 Gordon, D.J. and C.A. Johnson, 2017: The orchestration of global urban climate governance: conducting power in the
48 post-Paris climate regime. *Environmental Politics*, **26(4)**, 694-714, doi:10.1080/09644016.2017.1320829.
- 49 Gota, S., C. Huizenga, K. Peet, N. Medimorec, and S. Bakker, 2018: Decarbonising transport to achieve Paris
50 Agreement targets. *Energy Efficiency*, doi:10.1007/s12053-018-9671-3.
- 51 Goulder, L.H., 1995: Effects of Carbon Taxes in an Economy with Prior Tax Distortions: An Intertemporal General
52 Equilibrium Analysis. *Journal of Environmental Economics and Management*, **29(3)**, 271-297,
53 doi:10.1006/jeem.1995.1047.
- 54 Goulder, L.H., 2013: Climate change policy's interactions with the tax system. *Energy Economics*, **40, Supple**, S3-S11,
55 doi:10.1016/j.eneco.2013.09.017.
- 56 Goytia, S., M. Pettersson, T. Schellenberger, W.J. van Doorn-Hoekveld, and S. Priest, 2016: Dealing with change and
57 uncertainty within the regulatory frameworks for flood defense infrastructure in selected European countries.
58 *Ecology and Society*, **21(4)**, doi:10.5751/ES-08908-210423.
- 59 Grace, J., E. Mitchard, and E. Gloor, 2014: Perturbations in the carbon budget of the tropics. *Global Change Biology*,
60 **20(10)**, 3238-3255, doi:10.1111/gcb.12600.

- 1 Graham, S., J. Barnett, R. Fincher, C. Mortreux, and A. Hurlimann, 2015: Towards fair local outcomes in adaptation to
2 sea-level rise. *Climatic Change*, **130(3)**, 411-424, doi:10.1007/s10584-014-1171-7.
- 3 Granderson, A.A., 2017: The Role of Traditional Knowledge in Building Adaptive Capacity for Climate Change:
4 Perspectives from Vanuatu. *Weather, Climate, and Society*, **9(3)**, 545-561, doi:10.1175/WCAS-D-16-0094.1.
- 5 Grassi, G. et al., 2017: The key role of forests in meeting climate targets requires science for credible mitigation. *Nature*
6 *Climate Change*, **7(3)**, 220-226, doi:10.1038/nclimate3227.
- 7 Grecequet, M., J. DeWaard, J.J. Hellmann, and G.J. Abel, 2017: Climate Vulnerability and Human Migration in Global
8 Perspective. *Sustainability*, **9(5)**, 720, doi:10.3390/su9050720.
- 9 Green, D. and L. Minchin, 2014: Living on climate-changed country: Indigenous health, well-being and climate change
10 in remote Australian communities. *EcoHealth*, **11(2)**, 263-272, doi:10.1007/s10393-013-0892-9.
- 11 Green, J. and P. Newman, 2017a: Citizen utilities: The emerging power paradigm. *Energy Policy*, **105(February)**, 283-
12 293, doi:10.1016/j.enpol.2017.02.004.
- 13 Green, J. and P. Newman, 2017b: Disruptive innovation, stranded assets and forecasting: the rise and rise of renewable
14 energy. *Journal of Sustainable Finance & Investment*, **7(2)**, 169-187, doi:10.1080/20430795.2016.1265410.
- 15 Green, K.E., 2016: A political ecology of scaling: Struggles over power, land and authority. *Geoforum*, **74**, 88-97,
16 doi:10.1016/j.geoforum.2016.05.007.
- 17 Green, O.O. et al., 2016: Adaptive governance to promote ecosystem services in urban green spaces. *Urban*
18 *Ecosystems*, **19(1)**, 77-93, doi:10.1007/s11252-015-0476-2.
- 19 Greenblatt, J.B. and S. Saxena, 2015: Autonomous taxis could greatly reduce greenhouse-gas emissions of US light-
20 duty vehicles. *Nature Climate Change*, **5(9)**, 860-863, doi:10.1038/nclimate2685.
- 21 Greene, C.H. et al., 2017: Earth 's Future Geoengineering , marine microalgae , and climate stabilization in the 21st
22 century Earth 's Future. , doi:10.1002/ef2.194.
- 23 Greene, D.L., 2011: Uncertainty, loss aversion, and markets for energy efficiency. *Energy Economics*, **33(4)**, 608-616,
24 doi:10.1016/j.eneco.2010.08.009.
- 25 Greening, L.A., D.L. Greene, and C. Difiglio, 2000: Energy efficiency and consumption - the rebound effect - a survey.
26 *Energy Policy*, **28(6-7)**, 389-401, doi:10.1016/S0301-4215(00)00021-5.
- 27 Gregorio, M. et al., 2016: Integrating Mitigation and Adaptation in Climate and Land Use Policies in Brazil: A Policy
28 Document Analysis. .
- 29 Gregory, R., S. Lichtenstein, and P. Slovic, 1993: Valuing environmental resources: A constructive approach. *Journal*
30 *of Risk and Uncertainty*, **7(2)**, 177-197.
- 31 Grewe, V., E. Tsati, M. Mertens, C. Frömming, and P. Jöckel, 2017: Contribution of emissions to concentrations: the
32 TAGGING 1.0 submodel based on the Modular Earth Submodel System (MESSy 2.52). *Geoscientific Model*
33 *Development*, **10(7)**, 2615-2633, doi:10.5194/gmd-10-2615-2017.
- 34 Griscom, B.W. et al., 2017: Natural climate solutions. *Proceedings of the National Academy of Sciences*, **114(44)**,
35 11645-11650, doi:10.1073/pnas.1710465114.
- 36 Gross, R., W. Blyth, and P. Heptonstall, 2010: Risks, revenues and investment in electricity generation: Why policy
37 needs to look beyond costs. *Energy Economics*, **32(4)**, 796-804, doi:10.1016/j.eneco.2009.09.017.
- 38 Grosse, G., S. Goetz, A.D. McGuire, V.E. Romanovsky, and E.A.G. Schuur, 2016: Changing permafrost in a warming
39 world and feedbacks to the Earth system. *Environmental Research Letters*, **11(4)**, doi:10.1088/1748-
40 9326/11/4/040201.
- 41 Grothmann, T. and F. Reusswig, 2006: People at risk of flooding: Why some residents take precautionary action while
42 others do not. *Natural hazards*, **38(1)**, 101-120.
- 43 Grottera, C., W. Wills, and E.L. La Rovere, 2016: The Transition to a Low Carbon Economy and Its Effects on Jobs
44 and Welfare - A Long-Term Scenario for Brazil. In: *The Fourth Green Growth Knowledge Platform Annual*
45 *Conference, 6-7 September 2016, Jeju, Republic of Korea*. The Fourth Green Growth Knowledge Platform
46 Annual Conference, 6-7 September 2016. Jeju, Republic of Korea, Geneva, Switzerland, pp. 7.
- 47 Grove, K.J., 2013: From emergency management to managing emergence: A genealogy of disaster management in
48 Jamaica. *Annals of the Association of American Geographers*, **103(3)**, 570-588.
- 49 Grubb, M., 1990: The Greenhouse Effect: Negotiating Targets. *International Affairs*, **66(1)**, 67-89.
- 50 Grubb, M., J.C. Hourcade, and K. Neuhoﬀ, 2014: *Planetary economics: energy, climate change and the three domains*
51 *of sustainable development*. Routledge, Abingdon, Oxon, UK, 548 pp.
- 52 Grubler, A., 2010: The costs of the French nuclear scale-up: A case of negative learning by doing. *Energy Policy*,
53 **38(9)**, 5174-5188, doi:https://doi.org/10.1016/j.enpol.2010.05.003.
- 54 Grubler, A. et al., 2012: Chapter 24 - Policies for the Energy Technology Innovation System (ETIS). In: *Global Energy*
55 *Assessment - Toward a Sustainable Future*. Cambridge University Press, Cambridge, UK and New York, NY,
56 USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria, pp. 1665-1744.
- 57 Grubler, A., 2018: A Global Scenario of Low Energy Demand for Sustainable Development below 1.5°C without
58 Negative Emission Technologies. *Nature Energy* (in press).
- 59 Guerra, A., 2017: La Crisis como Oportunidad, Análisis de la sequía en la costa sur de Guatemala en 2016. *Red*
60 *Nacional de Formacion e Investigacion Ambiental*, 21-27 pp.

- 1 Guivarch, C. and S. Hallegatte, 2011: Existing infrastructure and the 2°C target. *Climatic Change*, **109(3-4)**, 801-805,
2 doi:10.1007/s10584-011-0268-5.
- 3 Gupta, J., 2014: *The History of Global Climate Governance*. Cambridge University Press, Cambridge, UK and New
4 York, NY, USA, 262 pp.
- 5 Gupta, S. et al., 2007: Policies, Instruments and Co-operative Arrangements. In: *Climate Change 2007: Mitigation.*
6 *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on*
7 *Climate Change* [Metz, B., O.R. Davidson, P.R. Bosch, R. Dave, and L.A. Meyer (eds.)]. pp. 746-807.
- 8 Gurara, D. et al., 2017: Trends and Challenges in Infrastructure Investment in Low-Income Developing Countries. IMF
9 Working Paper, 31 pp.
- 10 GWA, 2016: *Statistics Digest 2015-16*. Department of Mines and Petroleum, Government of Western Australia
11 (GWA), Perth, Australia, 74 pp.
- 12 Gwedla, N. and C.M. Shackleton, 2015: The development visions and attitudes towards urban forestry of officials
13 responsible for greening in South African towns. *Land Use Policy*, **42**, 17-26,
14 doi:10.1016/j.landusepol.2014.07.004.
- 15 Haas, W., F. Krausmann, D. Wiedenhofer, and M. Heinz, 2015: How Circular is the Global Economy?: An Assessment
16 of Material Flows, Waste Production, and Recycling in the European Union and the World in 2005. *Journal of*
17 *Industrial Ecology*, **19(5)**, 765-777, doi:10.1111/jiec.12244.
- 18 Haasnoot, M., J.H.J.H. Kwakkel, W.E.W.E. Walker, and J. ter Maat, 2013: Dynamic adaptive policy pathways: A
19 method for crafting robust decisions for a deeply uncertain world. *Global Environmental Change*, **23(2)**, 485-
20 498, doi:10.1016/j.gloenvcha.2012.12.006.
- 21 Hackmann, H., S.C. Moser, and A.L. St. Clair, 2014: The social heart of global environmental change. *Nature Climate*
22 *Change*, **4(8)**, 653-655, doi:10.1038/nclimate2320.
- 23 Hadarits, M. et al., 2017: The interplay between incremental, transitional, and transformational adaptation: a case study
24 of Canadian agriculture. *Regional Environmental Change*, **17(5)**, 1515-1525, doi:10.1007/s10113-017-1111-y.
- 25 Hagen, A., L. Kähler, and K. Eisenack, 2017: *Transnational environmental agreements with heterogeneous actors*.
26 Routledge.
- 27 Hagen, B., A. Middel, and D. Pijawka, 2016: European Climate Change Perceptions: Public support for mitigation and
28 adaptation policies. *Environmental Policy and Governance*, **26(3)**, 170-183, doi:10.1002/eet.1701.
- 29 Hahnel, U.J.J. et al., 2015: The power of putting a label on it : green labels weigh heavier than contradicting product
30 information for consumers ' purchase decisions and post-purchase behavior. *Frontiers in Psychology*,
31 **6(September)**, 1392, doi:10.3389/fpsyg.2015.01392.
- 32 Haines, A. et al., 2017: Short-lived climate pollutant mitigation and the Sustainable Development Goals. *Nature*
33 *Climate Change*, **7(12)**, 863-869, doi:10.1038/s41558-017-0012-x.
- 34 Hallegatte, S. and K.J. Mach, 2016: Make climate-change assessments more relevant. *Nature*, **534(7609)**, 613-615,
35 doi:10.1038/534613a.
- 36 Hallegatte, S. and J. Rozenberg, 2017: Climate change through a poverty lens. *Nature Climate Change*, **7**, 250-256,
37 doi:10.1038/nclimate3253.
- 38 Hallegatte, S., J.-C. Hourcade, and P. Dumas, 2007: Why economic dynamics matter in assessing climate change
39 damages: Illustration on extreme events. *Ecological Economics*, **62(2)**, 330-340,
40 doi:10.1016/j.ecolecon.2006.06.006.
- 41 Hallegatte, S., C. Green, R.J. Nicholls, and J. Corfee-Morlot, 2013: Future flood losses in major coastal cities. *Nature*
42 *Climate Change*, **3(9)**, 802-806, doi:10.1038/nclimate1979.
- 43 Hallegatte, S., A. Vogt-Schilb, M. Bangalore, and J. Rozenberg, 2017: *Unbreakable: Building the Resilience of the*
44 *Poor in the Face of Natural Disasters*. The World Bank, Washington DC, USA, 201 pp.
- 45 Hallegatte, S. et al., 2016: *Shock waves: Managing the Impacts of Climate Change on Poverty*. World Bank Group,
46 Washington DC, USA, 227 pp.
- 47 Halpern, B.S. et al., 2015: Spatial and temporal changes in cumulative human impacts on the world's ocean. *Nature*
48 *Communications*, **6**, 7615, doi:10.1038/ncomms8615.
- 49 Hammill, A., R. Matthew, and E. McCarter, 2008: Microfinance and climate change adaptation. *IDS bulletin*, **39(4)**,
50 113-122.
- 51 Handgraaf, M.J.J., M.A. Lidth, D. Jeude, and K.C. Appelt, 2013: Public praise vs . private pay : Effects of rewards on
52 energy conservation in the workplace. *Ecological Economics*, **86**, 86-92, doi:10.1016/j.ecolecon.2012.11.008.
- 53 Hangx, S.J.T. and C.J. Spiers, 2009: Coastal spreading of olivine to control atmospheric CO2 concentrations: A critical
54 analysis of viability. *International Journal of Greenhouse Gas Control*, **3(6)**, 757-767,
55 doi:10.1016/j.ijggc.2009.07.001.
- 56 Haoqi, Q., W. Libo, and T. Weiqi, 2017: "Lock-in" effect of emission standard and its impact on the choice of market
57 based instruments. *Energy Economics*, **63**, 41-50, doi:10.1016/j.eneco.2017.01.005.
- 58 Harberger, A.C., 1984: Basic Needs versus Distributional Weights in Social Cost-Benefit Analysis. *Economic*
59 *Development and Cultural Change*, **32(3)**, 455-474, doi:10.1086/451400.
- 60 Harding, A. and J.B. Moreno-Cruz, 2016: Solar geoengineering economics: From incredible to inevitable and half-way

- 1 back. *Earth's Future*, **4(12)**, 569-577, doi:10.1002/2016EF000462.
- 2 Hardoy, J. and L.S. Velásquez Barrero, 2014: Re-thinking "Biomanzales": addressing climate change adaptation in
3 Manzales, Colombia. *Environment and Urbanization*, **26(1)**, 53-68.
- 4 Hardoy, J. and L.S. Velásquez Barrero, 2016: Manzales, Colombia. *Cities on a finite planet: Towards transformative
5 responses to climate change*, 274.
- 6 Harjanne, A., 2017: Servitizing climate science-Institutional analysis of climate services discourse and its implications.
7 *Global Environmental Change*, **46(November 2016)**, 1-16, doi:10.1016/j.gloenvcha.2017.06.008.
- 8 Harris, Z.M., R. Spake, and G. Taylor, 2015: Land use change to bioenergy: A meta-analysis of soil carbon and GHG
9 emissions. *Biomass and Bioenergy*, **82**, 27-39, doi:10.1016/J.BIOMBIOE.2015.05.008.
- 10 Harrison, D.P., 2017: Global negative emissions capacity of ocean macronutrient fertilization. *Environmental Research
11 Letters*, **12(3)**, doi:10.1088/1748-9326/aa5ef5.
- 12 Hartley, P.R. and K.B. Medlock, 2013: The Valley of Death for New Energy Technologies. *The Energy Journal*, **38(3)**,
13 1-61.
- 14 Hartmann, J. and S. Kempe, 2008: What is the maximum potential for CO₂ sequestration by "stimulated" weathering
15 on the global scale? *Naturwissenschaften*, **95(12)**, 1159-1164, doi:10.1007/s00114-008-0434-4.
- 16 Hartmann, J. et al., 2013: Enhanced chemical weathering as a geoengineering strategy to reduce atmospheric carbon
17 dioxide, supply nutrients, and mitigate ocean acidification: Enhanced weathering. *Reviews of Geophysics*,
18 **51(2)**, 113-149, doi:10.1002/rog.20004.
- 19 Harvey, C.A. et al., 2014: Climate-Smart Landscapes: Opportunities and Challenges for Integrating Adaptation and
20 Mitigation in Tropical Agriculture. *Conservation Letters*, **7(2)**, 77-90, doi:10.1111/conl.12066.
- 21 Harvey, L.D.D., 2008: Mitigating the atmospheric CO₂ increase and ocean acidification by adding limestone powder
22 to upwelling regions. *Journal of Geophysical Research*, **113(C4)**, C04028, doi:10.1029/2007JC004373.
- 23 Hasanbeigi, A., M. Arens, and L. Price, 2014: Alternative emerging ironmaking technologies for energy-efficiency and
24 carbon dioxide emissions reduction: A technical review. *Renewable and Sustainable Energy Reviews*,
25 **33(Supplement C)**, 645-658, doi:https://doi.org/10.1016/j.rser.2014.02.031.
- 26 Haselip, J., U.E. Hansen, D. Puig, S. Trærup, and S. Dhar, 2015: Governance, enabling frameworks and policies for the
27 transfer and diffusion of low carbon and climate adaptation technologies in developing countries. *Climatic
28 Change*, **131(3)**, 363-370, doi:10.1007/s10584-015-1440-0.
- 29 Hauck, J., P. Köhler, D. Wolf-Gladrow, and C. Völker, 2016: Iron fertilisation and century-scale effects of open ocean
30 dissolution of olivine in a simulated CO₂ removal experiment. *Environmental Research Letters*, **11(2)**,
31 doi:10.1088/1748-9326/11/2/024007.
- 32 Havet, A. et al., 2014: Review of livestock farmer adaptations to increase forages in crop rotations in western France.
33 *Agriculture, ecosystems & environment*, **190**, 120-127.
- 34 Havlik, P. et al., 2014: Climate change mitigation through livestock system transitions. *Proceedings of the National
35 Academy of Sciences*, **111(10)**, 3709-3714, doi:10.1073/pnas.1308044111.
- 36 Hayashi, A., F. Sano, Y. Nakagami, and K. Akimoto, 2018: Changes in terrestrial water stress and contributions of
37 major factors under temperature rise constraint scenarios. *Mitigation and Adaptation Strategies for Global
38 Change*, 1-27, doi:10.1007/s11027-018-9780-5.
- 39 Heard, B.P., B.W. Brook, T.M.L. Wigley, and C.J.A. Bradshaw, 2017: Burden of proof: A comprehensive review of the
40 feasibility of 100% renewable-electricity systems. *Renewable and Sustainable Energy Reviews*, **76(March)**,
41 1122-1133, doi:10.1016/j.rser.2017.03.114.
- 42 Heck, V., D. Gerten, W. Lucht, and A. Popp, 2018: Biomass-based negative emissions difficult to reconcile with
43 planetary boundaries. *Nature Climate Change*, **8(2)**, 151-155, doi:10.1038/s41558-017-0064-y.
- 44 Heckendorn, P. et al., 2009: The impact of geoengineering aerosols on stratospheric temperature and ozone.
45 *Environmental Research Letters*, **4(4)**, 045108, doi:10.1088/1748-9326/4/4/045108.
- 46 Heede, R., 2014: Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers,
47 1854-2010. *Climatic Change*, **122(1)**, 229-241, doi:10.1007/s10584-013-0986-y.
- 48 Heidrich, O. et al., 2016: National climate policies across Europe and their impacts on cities strategies. *Journal of
49 Environmental Management*, **168**, 36-45.
- 50 Hekkert, M.P., R.A.A. Suurs, S.O. Negro, S. Kuhlmann, and R.E.H.M. Smits, 2007: Functions of innovation systems:
51 A new approach for analysing technological change. *Technological Forecasting and Social Change*, **74(4)**,
52 413-432, doi:10.1016/j.techfore.2006.03.002.
- 53 Henly-Shepard, S., S.A. Gray, and L.J. Cox, 2015: The use of participatory modeling to promote social learning and
54 facilitate community disaster planning. *Environmental Science & Policy*, **45**, 109-122,
55 doi:10.1016/j.envsci.2014.10.004.
- 56 Henry, R.C. et al., 2018: Food supply and bioenergy production within the global cropland planetary boundary. *PLOS
57 ONE*, **13(3)**, e0194695, doi:10.1371/journal.pone.0194695.
- 58 Henry, R.K., Z. Yongsheng, and D. Jun, 2006: Municipal solid waste management challenges in developing countries -
59 Kenyan case study. *Waste Management*, **26(1)**, 92-100, doi:10.1016/j.wasman.2005.03.007.
- 60 Henstra, D., 2016: The tools of climate adaptation policy : analysing instruments and instrument selection The tools of

- 1 climate adaptation policy : analysing instruments and instrument selection. *Climate Policy*, **16(4)**, 496-521,
2 doi:10.1080/14693062.2015.1015946.
- 3 Hering, J.G., D.A. Dzombak, S.A. Green, R.G. Luthy, and D. Swackhamer, 2014: Engagement at the Science-Policy
4 Interface. *Environmental Science and Technology*, **48(19)**, 1031-11033, doi:10.1021/es504225t.
- 5 Hermwille, L., 2016: Climate Change as a Transformation Challenge. A New Climate Policy Paradigm? *GAIA -
6 Ecological Perspectives for Science and Society*, **25(1)**, 19-22, doi:10.14512/gaia.25.1.6.
- 7 Hermwille, L., W. Obergassel, H.E. Ott, and C. Beuermann, 2017: UNFCCC before and after Paris - what's necessary
8 for an effective climate regime? *Climate Policy*, **17(2)**, 150-170, doi:10.1080/14693062.2015.1115231.
- 9 Hernández-Morcillo, M., P. Burgess, J. Mirck, A. Pantera, and T. Plieninger, 2018: Scanning agroforestry-based
10 solutions for climate change mitigation and adaptation in Europe. *Environmental Science and Policy*, **80**, 44-
11 52, doi:10.1016/j.envsci.2017.11.013.
- 12 Herrero, M. et al., 2015: Livestock and the Environment: What Have We Learned in the Past Decade? *Annual Review
13 of Environment and Resources*, **40(1)**, 177-202, doi:10.1146/annurev-environ-031113-093503.
- 14 Herwehe, L. and C.A. Scott, 2017: Drought adaptation and development: small-scale irrigated agriculture in northeast
15 Brazil. *Climate and Development*, 1-10, doi:10.1080/17565529.2017.1301862.
- 16 Hess, J. and I. Kelman, 2017: Tourism Industry Financing of Climate Change Adaptation: Exploring the Potential in
17 Small Island Developing States. *Climate, Disaster and Development Journal*, **2(2)**, 34-45,
18 doi:10.18783/cddj.v002.i02.a04.
- 19 Hesse, C., 2016: Decentralising climate finance to reach the most vulnerable. , 4.
- 20 Hetz, K., 2016: Contesting adaptation synergies: political realities in reconciling climate change adaptation with urban
21 development in Johannesburg, South Africa. *Regional Environmental Change*, **16(4)**, 1171-1182,
22 doi:10.1007/s10113-015-0840-z.
- 23 Heutel, G., J. Moreno-Cruz, and S. Shayegh, 2018: Solar geoengineering, uncertainty, and the price of carbon. *Journal
24 of Environmental Economics and Management*, **87**, 24-41, doi:10.1016/j.jeem.2017.11.002.
- 25 Hewitt, C., S. Mason, and D. Walland, 2012: The Global Framework for Climate Services. *Nature Climate Change*,
26 **2(12)**, 831-832, doi:10.1038/nclimate1745.
- 27 Heyen, D., T. Wiertz, and P.J. Irvine, 2015: Regional disparities in SRM impacts: the challenge of diverging
28 preferences. *Climatic Change*, **133(4)**, 557-563, doi:10.1007/s10584-015-1526-8.
- 29 Hiç, C., P. Pradhan, D. Rybski, and J.P. Kropp, 2016: Food Surplus and Its Climate Burdens. *Environmental Science
30 and Technology*, doi:10.1021/acs.est.5b05088.
- 31 Hill, J., E. Nelson, D. Tilman, S. Polasky, and D. Tiffany, 2006: Environmental, economic, and energetic costs and
32 benefits of biodiesel and ethanol biofuels. *Proceedings of the National Academy of Sciences*, **103(30)**, 11206-
33 11210, doi:10.1073/pnas.0604600103.
- 34 Hill Clarvis, M. and N.L. Engle, 2015: Adaptive capacity of water governance arrangements: a comparative study of
35 barriers and opportunities in Swiss and US states. *Regional Environmental Change*, **15(3)**, 517-527,
36 doi:10.1007/s10113-013-0547-y.
- 37 Hirschberg, S. et al., 2016: Health effects of technologies for power generation: Contributions from normal operation,
38 severe accidents and terrorist threat. *Reliability Engineering and System Safety*, **145**, 373-387,
39 doi:10.1016/j.ress.2015.09.013.
- 40 Hirth, L. and J.C. Steckel, 2016: The role of capital costs in decarbonizing the electricity sector. *Environmental
41 Research Letters*, **11(11)**, 114010, doi:10.1088/1748-9326/11/11/114010.
- 42 Hiwasaki, L., E. Luna, Syamsidik, and J.A. Marçal, 2015: Local and indigenous knowledge on climate-related hazards
43 of coastal and small island communities in Southeast Asia. *Climatic Change*, **128(1-2)**, 35-56,
44 doi:10.1007/s10584-014-1288-8.
- 45 Hof, A.F. et al., 2017: Global and regional abatement costs of Nationally Determined Contributions (NDCs) and of
46 enhanced action to levels well below 2 °C and 1.5 °C. *Environmental Science & Policy*, **71**, 30-40,
47 doi:10.1016/j.envsci.2017.02.008.
- 48 Hogarth, J.R., 2017: Evolutionary models of sustainable economic change in Brazil: No-till agriculture, reduced
49 deforestation and ethanol biofuels. *Environmental Innovation and Societal Transitions*, **24**, 130-141,
50 doi:https://doi.org/10.1016/j.eist.2016.08.001.
- 51 Höglund-Isaksson, L., 2012: Global anthropogenic methane emissions 2005-2030: technical mitigation potentials and
52 costs. *Atmospheric Chemistry and Physics*, **12(19)**, 9079-9096, doi:10.5194/acp-12-9079-2012.
- 53 Höglund-Isaksson, L. et al., 2017: Cost estimates of the Kigali Amendment to phase-down hydrofluorocarbons.
54 *Environmental Science & Policy*, **75**, 138-147, doi:10.1016/j.envsci.2017.05.006.
- 55 Högy, P. et al., 2009: Effects of elevated CO2 on grain yield and quality of wheat: results from a 3-year free-air CO2
56 enrichment experiment. *Plant Biology*, **11(s1)**, 60-69, doi:10.1111/j.1438-8677.2009.00230.x.
- 57 Höhne, N., H. Fekete, M.G.J. den Elzen, A.F. Hof, and T. Kuramochi, 2017: Assessing the ambition of post-2020
58 climate targets: a comprehensive framework. *Climate Policy*, 1-16, doi:10.1080/14693062.2017.1294046.
- 59 Holland, B., 2017: Procedural justice in local climate adaptation: political capabilities and transformational change.
60 *Environmental Politics*, **26(3)**, 391-412, doi:10.1080/09644016.2017.1287625.

- 1 Holland, R.A. et al., 2015: A synthesis of the ecosystem services impact of second generation bioenergy crop
2 production. *Renewable and Sustainable Energy Reviews*, **46**, 30-40, doi:10.1016/J.RSER.2015.02.003.
- 3 Holmes, G. and D.W. Keith, 2012: An air-liquid contactor for large-scale capture of CO₂ from air. *Philosophical*
4 *transactions. Series A, Mathematical, Physical, and Engineering sciences*, **370(1974)**, 4380-403,
5 doi:10.1098/rsta.2012.0137.
- 6 Holmes, G. et al., 2013: Outdoor prototype results for direct atmospheric capture of carbon dioxide. *Energy Procedia*,
7 **37**, 6079-6095.
- 8 Hölscher, K., N. Frantzeskaki, and D. Loorbach, 2018: Steering transformations under climate change: capacities for
9 transformatory climate governance and the case of Rotterdam, the Netherlands. *Regional Environmental*
10 *Change*, 1-15, doi:10.1007/s10113-018-1329-3.
- 11 Holz, C., S. Kartha, and T. Athanasiou, 2018: Fairly sharing 1.5: national fair shares of a 1.5 °C-compliant global
12 mitigation effort. *International Environmental Agreements: Politics, Law and Economics*, **18(1)**, 117-134,
13 doi:10.1007/s10784-017-9371-z.
- 14 Honegger, M., K. Sugathapala, and A. Michaelowa, 2013: Tackling climate change: where can the generic framework
15 be located? *Carbon & Climate Law Review*, **7(2)**, 125-135, doi:10.5167/uzh-86551.
- 16 Hong, N.B. and M. Yabe, 2017: Improvement in irrigation water use efficiency: a strategy for climate change
17 adaptation and sustainable development of Vietnamese tea production. *Environment, Development and*
18 *Sustainability*, **19(4)**, 1247-1263, doi:10.1007/s10668-016-9793-8.
- 19 Höök, M., J. Li, N. Oba, and S. Snowden, 2011: Descriptive and Predictive Growth Curves in Energy System Analysis.
20 *Natural Resources Research*, **20(2)**, 103-116, doi:10.1007/s11053-011-9139-z.
- 21 Hornsey, M.J., E.A. Harris, P.G. Bain, and K.S. Fielding, 2016: Meta-analyses of the determinants and outcomes of
22 belief in climate change. *Nature Climate Change*, **6(6)**, 622-626, doi:10.1038/nclimate2943.
- 23 Horton, J.B., 2011: Geoengineering and the Myth of Unilateralism: Pressures and Prospects for International
24 Cooperation. *Stanford Journal of Law Science Policy*, **IV(May)**, 56-69,
25 doi:10.1017/CBO9781139161824.010.
- 26 Horton, J.B., D.W. Keith, and M. Honegger, 2016: Implications of the Paris Agreement for Carbon Dioxide Removal
27 and Solar Geoengineering. 1-10 pp.
- 28 Horton, J.B., J.L. Reynolds, and D.W. Keith, 2018: Solar Geoengineering and Democracy. *Global Environmental*
29 *Politics*, 1-18.
- 30 Houghton, R.A., 2013: The emissions of carbon from deforestation and degradation in the tropics: past trends and
31 future potential. *Carbon Management*, **4(5)**, 539-546, doi:10.4155/cmt.13.41.
- 32 Houghton, R.A., B. Byers, and A.A. Nassikas, 2015: A role for tropical forests in stabilizing atmospheric CO₂. *Nature*
33 *Clim. Change*, **5(12)**, 1022-1023.
- 34 Hourcade, J.-C., P.-R. Shukla, and C. Cassen, 2015: Climate policy architecture for the Cancun paradigm shift:
35 building on the lessons from history. *International Environmental Agreements: Politics, Law and Economics*,
36 **15(4)**, 353-367, doi:10.1007/s10784-015-9301-x.
- 37 Hourcade, J.-C. et al., 2001: Global, Regional, and National Costs and Ancillary Benefits of Mitigation. *Climate*
38 *Change 2001: Mitigation. Contribution of Working Group III to the Third Assessment Report of the*
39 *Intergovernmental Panel on Climate Change*.
- 40 House, K.Z., C.H. House, D.P. Schrag, and M.J. Aziz, 2007: Electrochemical acceleration of chemical weathering as an
41 energetically feasible approach to mitigating anthropogenic climate change. *Environmental Science &*
42 *Technology*, **41(24)**, 8464-8470, doi:10.1021/es0701816.
- 43 House, K.Z. et al., 2011: Economic and energetic analysis of capturing CO₂ from ambient air. *Proceedings of the*
44 *National Academy of Sciences*, **108(51)**, 20428-20433, doi:10.1073/pnas.1012253108.
- 45 Hovi, J., D.F. Sprinz, H. Sælen, and A. Underdal, 2016: Climate change mitigation: a role for climate clubs? *Palgrave*
46 *Communications*, **2**, 16020.
- 47 Howes, M. et al., 2015: Towards networked governance: improving interagency communication and collaboration for
48 disaster risk management and climate change adaptation in Australia. *Journal of Environmental Planning and*
49 *Management*, **58(5)**, 757-776, doi:10.1080/09640568.2014.891974.
- 50 Hoy, M.B., 2016: Smart Buildings: An Introduction to the Library of the Future. *Medical Reference Services Quarterly*,
51 **35(3)**, 326-331, doi:10.1080/02763869.2016.1189787.
- 52 Hristov, A.N. et al., 2015: An inhibitor persistently decreased enteric methane emission from dairy cows with no
53 negative effect on milk production. *Proceedings of the National Academy of Sciences*, **112(34)**, 10663-10668,
54 doi:10.1073/pnas.1504124112.
- 55 Hsu, A., A.J. Weinfurter, and K. Xu, 2017: Aligning subnational climate actions for the new post-Paris climate regime.
56 *Climatic Change*, **142(3-4)**, 419-432, doi:10.1007/s10584-017-1957-5.
- 57 Hu, A., Y. Xu, C. Tebaldi, W.M. Washington, and V. Ramanathan, 2013: Mitigation of short-lived climate pollutants
58 slows sea-level rise. *Nature Climate Change*, **3**, 730.
- 59 Huang, W., W. Chen, and G. Anandarajah, 2017a: The role of technology diffusion in a decarbonizing world to limit
60 global warming to well below 2 °C: An assessment with application of Global TIMES model. *Applied Energy*,

- 1 208, 291-301, doi:<https://doi.org/10.1016/j.apenergy.2017.10.040>.
- 2 Huang, W., D. Ma, and W. Chen, 2017b: Connecting water and energy: Assessing the impacts of carbon and water
3 constraints on China's power sector. *Applied Energy*, **185**, 1497-1505,
4 doi:10.1016/J.APENERGY.2015.12.048.
- 5 Huang-Lachmann, J.-T. and J.C. Lovett, 2016: How cities prepare for climate change: Comparing Hamburg and
6 Rotterdam. *Cities*, **54**, 36-44.
- 7 HUD, 2013: Rebuild by Design Competition. <http://www.rebuildbydesign.org>.
- 8 Huebner, G.M. and D. Shipworth, 2017: All about size? - The potential of downsizing in reducing energy demand.
9 *Applied Energy*, **186**, 226-233, doi:10.1016/j.apenergy.2016.02.066.
- 10 Hughes, A.D. et al., 2012: Does seaweed offer a solution for bioenergy with biological carbon capture and storage?
11 *Greenhouse Gases: Science and Technology*, **2(6)**, 402-407, doi:10.1002/ghg.1319.
- 12 IAEA, 2017: *Nuclear Technology Review 2017*. IAEA.
- 13 IAEA, 2018: Power Reactor Information System - Country Statistics: France.
14 <https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=FR> (Accessed: 12 April 2018).
- 15 Ickowitz, A., E. Sills, and C. de Sassi, 2017: Estimating Smallholder Opportunity Costs of REDD+: A Pantropical
16 Analysis from Households to Carbon and Back. *World Development*, **95**, 15-26,
17 doi:10.1016/J.WORLDDEV.2017.02.022.
- 18 Idem, R. et al., 2015: Practical experience in post-combustion CO₂ capture using reactive solvents in large pilot and
19 demonstration plants. *International Journal of Greenhouse Gas Control*, **40(Supplement C)**, 6-25,
20 doi:<https://doi.org/10.1016/j.ijggc.2015.06.005>.
- 21 IEA, 2014a: *World Energy Investment Outlook Special Report*. 190 pp.
- 22 IEA, 2014b: *World Energy Outlook 2014*. OECD, Paris, France, 748 pp.
- 23 IEA, 2016a: *20 Years of Carbon Capture and Storage - Accelerating Future Deployment*. International Energy Agency,
24 Paris, France, 115 pp.
- 25 IEA, 2016b: *IEA 4E Solid State Lighting Annex Task 7: Smart Lighting - New Features Impacting Energy Consumption*
26 *First Status Report*. 41 pp.
- 27 IEA, 2016c: *World Energy Outlook 2016*.
- 28 IEA, 2017a: *Digitalization & Energy*. 188 pp.
- 29 IEA, 2017b: *Energy Access Outlook 2017*. International Energy Agency, Paris, France, 144 pp.
- 30 IEA, 2017c: *Energy Technology Perspectives 2017: Catalysing Energy Technology Transformations*. IEA, Paris,
31 France, 443 pp.
- 32 IEA, 2017d: *Getting Wind and Sun onto the Grid A Manual for Policy Makers*. 64 pp.
- 33 IEA, 2017e: *The Future of Trucks*. International Energy Agency, Paris, France.
- 34 IEA, 2017f: *Tracking Clean Energy Progress 2017*. 1-82 pp.
- 35 IEA, 2017g: *World Energy Outlook 2017*. International Energy Agency, Paris, France, 748 pp.
- 36 IEA, 2018: *Global EV Outlook 2018: Towards cross-modal electrification*. International Energy Agency (IEA), Paris,
37 France, 141 pp.
- 38 Iguma, H. and H. Kidoshi, 2015: *Why Toyota can sell Mirai at 7 million Yen?* Nikkan-Kogyo Press.
- 39 IIF, 2017: Global Debt Monitor. <https://www.iif.com/publication/global-debt-monitor/global-debt-monitor-april-2018>
40 (Accessed: 18 May 2018).
- 41 Iiyama, M. et al., 2017: Understanding patterns of tree adoption on farms in semi-arid and sub-humid Ethiopia.
42 *Agroforestry Systems*, **91(2)**, 271-293, doi:10.1007/s10457-016-9926-y.
- 43 IMF, 2014: *World Economic Outlook October 2014: Legacies, Clouds, Uncertainties*. 243 pp.
- 44 IMO, 1972: *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*. International
45 Maritime Organization (IMO).
- 46 IMO, 1996: *1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other*
47 *Matter, 1972*. International Maritime Organization (IMO).
- 48 Inamara, A. and V. Thomas, 2017: Pacific climate change adaptation: The use of participatory media to promote
49 indigenous knowledge. *Pacific Journalism Review*, **23(1)**, 113-132.
- 50 Ingold, K. and M. Fischer, 2014: Drivers of collaboration to mitigate climate change: An illustration of Swiss climate
51 policy over 15 years. *Global Environmental Change*, **24**, 88-98, doi:10.1016/j.gloenvcha.2013.11.021.
- 52 Ingty, T., 2017: High mountain communities and climate change: adaptation, traditional ecological knowledge, and
53 institutions. *Climatic Change*, **145(1-2)**, 41-55, doi:10.1007/s10584-017-2080-3.
- 54 IPCC, 1995: Climate Change 1995. , 339, doi:10.1016/S0959-3780(97)82915-9.
- 55 IPCC, 2001: Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II, and III to the Third
56 Assessment Report of the Intergovernmental Panel on Climate Change. []. 398 pp.
- 57 IPCC, 2005: Special Report on Carbon Dioxide Capture and Storage. [Metz, B., O. Davidson, H.C. de Coninck, M.
58 Loos, and L.A. Meyer (eds.)]. Cambridge University Press, Cambridge, UK, Cambridge, United Kingdom and
59 New York, NY, USA, UK and New York, NY, USA, 442 pp.
- 60 IPCC, 2012: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special

- 1 Report of Working Groups I and II of IPCC Intergovernmental Panel on Climate Change. [Field, C.B., V.
2 Barros, T.F. Stocker, Q. Dahe, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K.
3 Allen, and Others (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY,
4 USA, 594 pp.
- 5 IPCC, 2014a: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the
6 Fifth Assessment Report of the Intergovernmental Panel on Climate Change. [Barros, V.R., C.B. Field, D.J.
7 Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B.
8 Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge
9 University Press, Cambridge, United Kingdom and New York, NY, USA.
- 10 IPCC, 2014b: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth
11 Assessment Report of the Intergovernmental Panel on Climate Change. [Edenhofer, O., R. Pichs-Madruga, Y.
12 Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J.
13 Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, and J.C. Minx (eds.)]. Cambridge University Press,
14 Cambridge, United Kingdom and New York, NY, USA, 1454 pp.
- 15 IPCC, 2014c: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth
16 Assessment Report of the Intergovernmental Panel on Climate Change. [Core Writing Team, R.K. Pachauri,
17 and L.A. Meyer (eds.)]. 169 pp.
- 18 IRENA, 2013: *Smart Grids and Renewables - A Guide for Effective Deployment*. International Renewable Energy
19 Agency, Abu Dhabi, United Arab Emirates, 47 pp.
- 20 IRENA, 2015: *Renewable energy options for shipping: Technology Brief*. International Renewable Energy Agency
21 (IRENA), Bonn, Germany, 1-58 pp.
- 22 IRENA, 2017a: *Electricity storage and renewables: Costs and markets to 2030*. International Renewable Energy
23 Agency (IRENA), Abu Dhabi, United Arab Emirates.
- 24 IRENA, 2017b: *Renewable Energy and Jobs: Annual Review 2017*. , 24.
- 25 IRENA, 2018: *Renewable Power Generation Costs in 2017*.
- 26 Irvine, P.J., A. Ridgwell, and D.J. Lunt, 2011: Climatic effects of surface albedo geoengineering. *Journal of*
27 *Geophysical Research Atmospheres*, **116(24)**, n/a-n/a, doi:10.1029/2011JD016281.
- 28 Irvine, P.J., B. Kravitz, M.G. Lawrence, and H. Muri, 2016: An overview of the Earth system science of solar
29 geoengineering. *Wiley Interdisciplinary Reviews: Climate Change*, **7(6)**, 815-833, doi:10.1002/wcc.423.
- 30 Isayama, K. and N. Ono, 2015: Steps towards sustainable and resilient disaster management in Japan: Lessons from
31 Cuba. *International Journal of Health System and Disaster Management*, **3(2)**, 54, doi:10.4103/2347-
32 9019.151300.
- 33 ISSC and UNESCO, 2013: *World Social Science Report 2013: Changing Global Environments*. 612 pp.
- 34 ITF, 2015: *Urban Mobility System Upgrade: How shared self-driving cars could change city traffic*. OECD Publishing,
35 Paris, 1-36 pp.
- 36 Izrael, Y.A., E.M. Volodin, S. Kostykin, A.P. Revokatova, and A.G. Ryaboshapko, 2014: The ability of stratospheric
37 climate engineering in stabilizing global mean temperatures and an assessment of possible side effects.
38 *Atmospheric Science Letters*, **15(2)**, 140-148, doi:10.1002/asl2.481.
- 39 Jabeen, H., 2014: Adapting the built environment : the role of gender in shaping vulnerability and resilience to climate
40 extremes in Dhaka. *Environment & Urbanization*, **26(1)**, 147-165, doi:10.1177/0956247813517851.
- 41 Jaboyedoff, P., C.A. Roulet, V. Dorer, A. Weber, and A. Pfeiffer, 2004: Energy in air-handling units - results of the
42 AIRLESS European Project. *Energy and Buildings*, **36(4)**, 391-399, doi:10.1016/j.enbuild.2004.01.047.
- 43 Jackson, L.S., J.A. Crook, and P.M. Forster, 2016: An intensified hydrological cycle in the simulation of
44 geoengineering by cirrus cloud thinning using ice crystal fall speed changes. *Journal of Geophysical Research*,
45 **121(12)**, 6822-6840, doi:10.1002/2015JD024304.
- 46 Jackson, L.S. et al., 2015: Assessing the controllability of Arctic sea ice extent by sulfate aerosol geoengineering.
47 *Geophysical Research Letters*, **42(4)**, doi:10.1002/2014GL062240.
- 48 Jackson, T. and P. Senker, 2011: Prosperity without growth: Economics for a finite planet. *Energy & Environment*,
49 **22(7)**, 1013-1016.
- 50 Jacobi, J., S. Rist, and M.A. Altieri, 2017: Incentives and disincentives for diversified agroforestry systems from
51 different actors' perspectives in Bolivia. *International Journal of Agricultural Sustainability*, **15(4)**, 365-379,
52 doi:10.1080/14735903.2017.1332140.
- 53 Jacobson, M.Z. and J.E. Ten Hoeve, 2012: Effects of urban surfaces and white roofs on global and regional climate.
54 *Journal of Climate*, **25(3)**, 1028-1044, doi:10.1175/JCLI-D-11-00032.1.
- 55 Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, B.A. Frew, and S. Polasky, 2015: Low-cost solution to the grid
56 reliability problem with 100% penetration of intermittent wind, water, and solar for all purposes. *Proceeding*
57 *of the National Academy of Sciences of the United States of America*, 15060-15065,
58 doi:10.1073/pnas.1510028112.
- 59 Jacobson, M.Z. et al., 2017: 100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for
60 139 Countries of the World. *Joule*, **1(1)**, 108-121, doi:10.1016/j.joule.2017.07.005.

- 1 Jaeger, C.C., A. Haas, and K. Töpfer, 2013: Sustainability, Finance, and a Proposal from China. 1-35 pp.
- 2 Jägermeyr, J. et al., 2015: Water savings potentials of irrigation systems: global simulation of processes and linkages.
- 3 *Hydrology and Earth System Sciences*, **19(7)**, 3073-3091, doi:10.5194/hess-19-3073-2015.
- 4 Jaglin, S., 2014: Regulating Service Delivery in Southern Cities: Rethinking urban heterogeneity. In: *The Routledge*
- 5 *Handbook on Cities of the Global South* [Parnell, S. and S. Oldfield (eds.)]. Routledge, Abingdon, UK, pp.
- 6 636.
- 7 Jahandideh-Tehrani, M., O. Bozorg Haddad, and H.A. Loáiciga, 2014: Hydropower Reservoir Management Under
- 8 Climate Change: The Karoon Reservoir System. *Water Resources Management*, **29(3)**, 749-770,
- 9 doi:10.1007/s11269-014-0840-7.
- 10 Jaiswal, D. et al., 2017: Brazilian sugarcane ethanol as an expandable green alternative to crude oil use. *Nature Climate*
- 11 *Change*, **7(11)**, 788-792, doi:10.1038/nclimate3410.
- 12 Jakob, M. and J. Hilaire, 2015: Climate science: Unburnable fossil-fuel reserves. *Nature*, **517(7533)**, 150-152,
- 13 doi:10.1038/517150a.
- 14 Jakob, M., C. Chen, S. Fuss, A. Marxen, and O. Edenhofer, 2015: Development incentives for fossil fuel subsidy
- 15 reform. *Nature Climate Change*, **5(8)**, 709-712, doi:10.1038/nclimate2679.
- 16 Jakob, M. et al., 2016: Carbon Pricing Revenues Could Close Infrastructure Access Gaps. *World Development*, **84**, 254-
- 17 265, doi:10.1016/j.worlddev.2016.03.001.
- 18 Jakovcevic, A. and L. Steg, 2013: Sustainable transportation in Argentina: Values, beliefs, norms and car use reduction.
- 19 *Transportation Research Part F: Traffic Psychology and Behaviour*, **20**, 70-79, doi:10.1016/j.trf.2013.05.005.
- 20 James, R., R. Washington, C.-F. Schleussner, J. Rogelj, and D. Conway, 2017: Characterizing half-a-degree difference:
- 21 a review of methods for identifying regional climate responses to global warming targets. *Wiley*
- 22 *Interdisciplinary Reviews: Climate Change*, **8(2)**, e457, doi:10.1002/wcc.457.
- 23 Janif, S.Z. et al., 2016: Value of traditional oral narratives in building climate-change resilience: insights from rural
- 24 communities in Fiji. *Ecology and Society*, **21(2)**, doi:10.5751/ES-08100-210207.
- 25 Jansson, J., 2011: Consumer eco-innovation adoption: Assessing attitudinal factors and perceived product
- 26 characteristics. *Business Strategy and the Environment*, **20(3)**, 192-210, doi:10.1002/bse.690.
- 27 Jantke, K., J. Müller, N. Trapp, and B. Blanz, 2016: Is climate-smart conservation feasible in Europe? Spatial relations
- 28 of protected areas, soil carbon, and land values. *Environmental Science & Policy*, **57(Supplement C)**, 40-49,
- 29 doi:10.1016/j.envsci.2015.11.013.
- 30 Jasanoff, S., 2007: Technologies of humility. *Nature*, **450(7166)**, 33-33, doi:10.1038/450033a.
- 31 Jayachandran, S. et al., 2017: Cash for carbon: A randomized trial of payments for ecosystem services to reduce
- 32 deforestation. *Science (New York, N.Y.)*, **357(6348)**, 267-273, doi:10.1126/science.aan0568.
- 33 Jenkins, K., B.K. Sovacool, and D. McCauley, 2018: Humanizing sociotechnical transitions through energy justice: An
- 34 ethical framework for global transformative change. *Energy Policy*, **117**, 66-74,
- 35 doi:10.1016/J.ENPOL.2018.02.036.
- 36 Jenkins, K., S. Surminski, J. Hall, and F. Crick, 2017: Assessing surface water flood risk and management strategies
- 37 under future climate change: Insights from an Agent-Based Model. *Science of the Total Environment*, **595**,
- 38 159-168, doi:10.1016/j.scitotenv.2017.03.242.
- 39 Jennings, V., L. Larson, and J. Yun, 2016: Advancing Sustainability through Urban Green Space: Cultural Ecosystem
- 40 Services, Equity, and Social Determinants of Health. *International Journal of Environmental Research and*
- 41 *Public Health*, **13(2)**, 196, doi:10.3390/ijerph13020196.
- 42 Jensen, C.B. and J.J. Spoon, 2011: Testing the 'Party Matters' Thesis: Explaining Progress towards Kyoto Protocol
- 43 Targets. *Political Studies*, **59(1)**, 99-115, doi:10.1111/j.1467-9248.2010.00852.x.
- 44 Jensen, N. and C. Barrett, 2017: Agricultural index insurance for development. *Applied Economic Perspectives and*
- 45 *Policy*, **39(2)**, 199-219, doi:10.1093/aep/ppw022.
- 46 Jeong, S. and Y.-Y. An, 2016: Climate change risk assessment method for electrical facility. In: *2016 International*
- 47 *Conference on Information and Communication Technology Convergence, ICTC 2016*.
- 48 Jeuland, M., S.K. Pattanayak, and R. Bluffstone, 2015: The Economics of Household Air Pollution. *Annual Review of*
- 49 *Resource Economics*, **7(1)**, 81-108, doi:10.1146/annurev-resource-100814-125048.
- 50 Ji, Z. and F. Sha, 2015: The challenges of the post-COP21 regime: interpreting CBDR in the INDC context.
- 51 *International Environmental Agreements: Politics, Law and Economics*, **15**, 421-430, doi:10.1007/s10784-
- 52 015-9303-8.
- 53 Jiang, K., K. Tamura, and T. Hanaoka, 2017: Can we go beyond INDCs: Analysis of a future mitigation possibility in
- 54 China, Japan, EU and the U.S.. *Advances in Climate Change Research*, **8(2)**, 117-122,
- 55 doi:10.1016/j.accre.2017.05.005.
- 56 Jiang, Y. et al., 2016: Importance of soil thermal regime in terrestrial ecosystem carbon dynamics in the circumpolar
- 57 north. *Global and Planetary Change*, **142**, 28-40, doi:10.1016/j.gloplacha.2016.04.011.
- 58 Jiang, Z., T. Xiao, V.L. Kuznetsov, and P.P. Edwards, 2010: Turning carbon dioxide into fuel. *Philosophical*
- 59 *transactions. Series A, Mathematical, physical, and engineering sciences*, **368(1923)**, 3343-3364,
- 60 doi:10.1098/rsta.2010.0119.

- 1 Jimenez, R., 2017: *Development Effects of Rural Electrification*. Policy Brief No IDB-PB-261, Infrastructure and
2 Energy Sector - Energy Division, Inter-American Development Bank, Washington DC, USA.
- 3 Jin, J., W. Wang, and X. Wang, 2016: Farmers' Risk Preferences and Agricultural Weather Index Insurance Uptake in
4 Rural China. *International Journal of Disaster Risk Science*, **7(4)**, 366-373, doi:10.1007/s13753-016-0108-3.
- 5 Johannessen, S.C. and R.W. Macdonald, 2016: Geoengineering with seagrasses: is credit due where credit is given?
6 *Environmental Research Letters*, **11(11)**, 113001, doi:10.1088/1748-9326/11/11/113001.
- 7 Johnson, C. and J. Walker, 2016: *Peak car ownership report*. 30 pp.
- 8 Johnson, N. et al., 2015: The contributions of Community-Based monitoring and traditional knowledge to Arctic
9 observing networks: Reflections on the state of the field. *Arctic*, **68(5)**, 1-13, doi:10.14430/arctic4447.
- 10 Jones, A. and J.M. Haywood, 2012: Sea-spray geoengineering in the HadGEM2-ES earth-system model: Radiative
11 impact and climate response. *Atmospheric Chemistry and Physics*, **12(22)**, 10887-10898, doi:10.5194/acp-12-
12 10887-2012.
- 13 Jones, A., J. Haywood, and O. Boucher, 2011: A comparison of the climate impacts of geoengineering by stratospheric
14 SO₂ injection and by brightening of marine stratocumulus cloud. *Atmospheric Science Letters*, **12(2)**, 176-183,
15 doi:10.1002/asl.291.
- 16 Jones, A. et al., 2013: The impact of abrupt suspension of solar radiation management (termination effect) in
17 experiment G2 of the Geoengineering Model Intercomparison Project (GeoMIP). *Journal of Geophysical*
18 *Research: Atmospheres*, **118(17)**, 9743-9752, doi:10.1002/jgrd.50762.
- 19 Jones, A.C. et al., 2018: Regional climate impacts of stabilizing global warming at 1.5 K using solar geoengineering.
20 *Earth's Future*, 1-22, doi:10.1002/2017EF000720.
- 21 Jones, A.D., K. Calvin, W.D. Collins, and J. Edmonds, 2015: Accounting for radiative forcing from albedo change in
22 future global land-use scenarios. *Climatic Change*, **131(4)**, 691-703, doi:10.1007/s10584-015-1411-5.
- 23 Jones, C.D. et al., 2016: Simulating the Earth system response to negative emissions. *Environmental Research Letters*,
24 **11(9)**, 095012, doi:10.1088/1748-9326/11/9/095012.
- 25 Jones, I.S.F., 2014: The cost of carbon management using ocean nourishment. *International Journal of Climate Change*
26 *Strategies and Management*, **6(4)**, 391-400, doi:10.1108/ijccsm-11-2012-0063.
- 27 Jones, L., B. Harvey, and R. Godfrey-Wood, 2016: *The changing role of NGOs in supporting climate services*. 24 pp.
- 28 Jordan, A.J. et al., 2015: Emergence of polycentric climate governance and its future prospects. *Nature Climate*
29 *Change*, **5(11)**, 977-982, doi:10.1038/nclimate2725.
- 30 Joyette, A.R.T., L.A. Nurse, and R.S. Pulwarty, 2015: Disaster risk insurance and catastrophe models in risk-prone
31 small Caribbean islands. *Disasters*, **39(3)**, 467-492, doi:10.1111/disa.12118.
- 32 Juhl, H.J., M.H.J. Fenger, and J. Thøgersen, 2017: Will the Consistent Organic Food Consumer Step Forward? An
33 Empirical Analysis. *Journal of Consumer Research*, 1-17, doi:10.1093/jcr/ucx052.
- 34 Juhola, S., E. Glaas, B.O. Linnér, and T.S. Neset, 2016: Redefining maladaptation. *Environmental Science and Policy*,
35 **55**, 135-140, doi:10.1016/j.envsci.2015.09.014.
- 36 K Murthy, I., 2013: Carbon Sequestration Potential of Agroforestry Systems in India. *Journal of Earth Science &*
37 *Climatic Change*, **04(01)**, 1-7, doi:10.4172/2157-7617.1000131.
- 38 K.Y., N.A., A. Jonathan, B. David, L. Yufeng, and B. Austin, 2018: Implications of climate change for shipping:
39 Opening the Arctic seas. *Wiley Interdisciplinary Reviews: Climate Change*, **9(2)**, e507, doi:10.1002/wcc.507.
- 40 Kabir, E., K.-H. Kim, and J. Szulejko, 2017: Social Impacts of Solar Home Systems in Rural Areas: A Case Study in
41 Bangladesh. *Energies*, **10(10)**, 1615, doi:10.3390/en10101615.
- 42 Kahan, D., 2010: Fixing the communications failure. *Nature*, **463(7279)**, 296-297, doi:10.1038/463296a.
- 43 Kahneman, D., 2003: A perspective on judgment and choice: Mapping bounded rationality. *American Psychologist*,
44 **58(9)**, 697-720, doi:10.1037/0003-066X.58.9.697.
- 45 Kaika, M., 2017: Don't call me resilient again! The New Urban Agenda as immunology ... or ... what happens when
46 communities refuse to be vaccinated with 'smart cities' and indicators. *Environment & Urbanization*, **29(1)**, 89-
47 102, doi:10.1177/0956247816684763.
- 48 Kale, E., 2015: Problematic Uses and Practices of Farm Ponds in Maharashtra. *Economic and Political Weekly*, **52(3)**,
49 7-8.
- 50 Kammann, C. et al., 2017: Biochar as a tool to reduce the agricultural greenhouse-gas burden - knowns, unknowns and
51 future research needs. *Journal of Environmental Engineering and Landscape Management*, **25(2)**, 114-139,
52 doi:10.3846/16486897.2017.1319375.
- 53 Kärcher, B., 2017: Cirrus Clouds and Their Response to Anthropogenic Activities. *Current Climate Change Reports*,
54 **3(1)**, 45-57, doi:10.1007/s40641-017-0060-3.
- 55 Kardooni, R., S.B. Yusoff, and F.B. Kari, 2016: Renewable energy technology acceptance in Peninsular Malaysia.
56 *Energy Policy*, **88**, 1-10, doi:10.1016/j.enpol.2015.10.005.
- 57 Kärki, J., E. Tsupari, and A. Arasto, 2013: CCS feasibility improvement in industrial and municipal applications by
58 heat utilization. *Energy Procedia*, **37**, 2611-2621, doi:10.1016/j.egypro.2013.06.145.
- 59 Karlin, B., J.F. Zinger, and R. Ford, 2015: The effects of feedback on energy conservation: A meta-analysis..
60 *Psychological Bulletin*, **141(6)**, 1205-1227, doi:10.1037/a0039650.

- 1 Kashima, Y., A. Paladino, and E.A. Margetts, 2014: Environmentalist identity and environmental striving. *Journal of*
2 *Environmental Psychology*, **38**, 64-75, doi:10.1016/j.jenvp.2013.12.014.
- 3 Kashimura, H. et al., 2017: Shortwave radiative forcing, rapid adjustment, and feedback to the surface by sulfate
4 geoengineering: Analysis of the Geoengineering Model Intercomparison Project G4 scenario. *Atmospheric*
5 *Chemistry and Physics*, **17(5)**, 3339-3356, doi:10.5194/acp-17-3339-2017.
- 6 Kasser, T. and K.M. Sheldon, 2002: What Makes for a Merry Christmas? *Journal of Happiness Studies*, **3(4)**, 313-329,
7 doi:10.1023/A:1021516410457.
- 8 Kasser, T., S. Cohn, A.D. Kanner, and R.M. Ryan, 2007: Some Costs of American Corporate Capitalism: A
9 Psychological Exploration of Value and Goal Conflicts. *Psychological Inquiry*, **18(1)**, 1-22,
10 doi:10.1080/10478400701386579.
- 11 Kastner, I. and P.C. Stern, 2015: Examining the decision-making processes behind household energy investments: A
12 review. *Energy Research and Social Science*, **10**, 72-89, doi:10.1016/j.erss.2015.07.008.
- 13 Kates, R.W., W.R. Travis, and T.J. Wilbanks, 2012: Transformational adaptation when incremental adaptations to
14 climate change are insufficient. *Proceedings of the National Academy of Sciences of the United States of*
15 *America*, **109(19)**, 7156-61, doi:10.1073/pnas.1115521109.
- 16 Kato, T. and J. Ellis, 2016: Communicating Progress in National and Global Adaptation to Climate Change.
17 OECD/IEA Climate Change Expert Group Papers No. 47, 47 pp.
- 18 Kauffman, S.A., 2002: Investigations. , 308.
- 19 KCCA, 2016: *Kampala Climate Change Action Plan*. Kampala Capital City Authority, Kampala, Uganda.
- 20 Keen, M., I. Parry, and J. Strand, 2013: Planes, ships and taxes: charging for international aviation and maritime
21 emissions. *Economic Policy*, **28(76)**, 701-749, doi:10.1111/1468-0327.12019.
- 22 Keim, M.E., 2008: Adaptation to Climate Change. *American Journal of Preventive Medicine*, **35(5)**, 508-516,
23 doi:10.1016/j.amepre.2008.08.022.
- 24 Keith, D.W. and P.J. Irvine, 2016: Solar geoengineering could substantially reduce climate risks - a research hypothesis
25 for the next decade. *Earth's Future*, **4(11)**, 549-559, doi:10.1002/2016EF000465.
- 26 Keith, D.W., M. Ha-Duong, and J.K. Stolaroff, 2006: Climate Strategy with CO2 Capture from the Air. *Climatic*
27 *Change*, **74(1-3)**, 17-45, doi:10.1007/s10584-005-9026-x.
- 28 Keith, D.W., G. Wagner, and C.L. Zabel, 2017: Solar geoengineering reduces atmospheric carbon burden. *Nature*
29 *Climate Change*, **7(9)**, 617-619, doi:10.1038/nclimate3376.
- 30 Keller, D.P., E.Y. Feng, and A. Oschlies, 2014: Potential climate engineering effectiveness and side effects during a
31 high carbon dioxide-emission scenario. *Nature Communications*, **5**, 3304, doi:10.1038/ncomms4304.
- 32 Keller, D.P. et al., 2018: The Carbon Dioxide Removal Model Intercomparison Project (CDRMIP): rationale and
33 experimental protocol for CMIP6. *Geoscientific Model Development*, **11(3)**, 1133-1160, doi:10.5194/gmd-11-
34 1133-2018.
- 35 Kelleway, J.J. et al., 2017: Review of the ecosystem service implications of mangrove encroachment into salt marshes.
36 *Global Change Biology*, **23(10)**, 3967-3983, doi:10.1111/gcb.13727.
- 37 Kelman, I., 2015: Difficult decisions: Migration from Small Island Developing States under climate change. *Earth's*
38 *Future*, **3(4)**, 133-142, doi:10.1002/2014EF000278.
- 39 Kelman, I., 2017: Linking disaster risk reduction, climate change, and the sustainable development goals. *Disaster*
40 *Prevention and Management: An International Journal*, **26(3)**, 254-258, doi:10.1108/DPM-02-2017-0043.
- 41 Kelman, I., J.C. Gaillard, and J. Mercer, 2015: Climate Change's Role in Disaster Risk Reduction's Future: Beyond
42 Vulnerability and Resilience. *International Journal of Disaster Risk Science*, **6(1)**, 21-27, doi:10.1007/s13753-
43 015-0038-5.
- 44 Kemper, J., 2015: Biomass and carbon dioxide capture and storage: A review. *International Journal of Greenhouse Gas*
45 *Control*, **40**, 401-430, doi:10.1016/j.ijggc.2015.06.012.
- 46 Kennedy, C., I.D. Stewart, M.I. Westphal, A. Facchini, and R. Mele, 2018: Keeping global climate change within 1.5
47 °C through net negative electric cities. *Current Opinion in Environmental Sustainability*, **30**, 18-25,
48 doi:10.1016/j.cosust.2018.02.009.
- 49 Kennedy, C.A. et al., 2015: Energy and material flows of megacities. *Proceedings of the National Academy of Sciences*,
50 **112(19)**, 5985-5990, doi:10.1073/pnas.1504315112.
- 51 Kenworthy, J. and P.L. Schiller, 2018: *An Introduction to Sustainable Transportortation: Policy, Planning and*
52 *Implementation*. Routledge, Abingdon, Oxon; New York, NY, 442 pp.
- 53 Keohane, R.O. and D.G. Victor, 2011: The Regime Complex for Climate Change. *Perspectives on Politics*, **9(1)**, 7-23,
54 doi:10.1017/S1537592710004068.
- 55 Kern, F. and K.S. Rogge, 2016: The pace of governed energy transitions: Agency, international dynamics and the
56 global Paris agreement accelerating decarbonisation processes? *Energy Research and Social Science*, **22**, 13-
57 17, doi:10.1016/j.erss.2016.08.016.
- 58 Kern, F., J. Gaede, J. Meadowcroft, and J. Watson, 2016: The political economy of carbon capture and storage: An
59 analysis of two demonstration projects. *Technological Forecasting and Social Change*, **102**, 250-260,
60 doi:10.1016/j.techfore.2015.09.010.

- 1 Kern, K. and G. Alber, 2009: Governing Climate Change in Cities: Modes of Urban Climate Governance in Multi-level
2 Systems. In: *The international conference on Competitive Cities and Climate Change, Milan, Italy*. OECD,
3 Paris, France, pp. 171-196.
- 4 Kerstholt, J., H. Duijnhoven, and D. Paton, 2017: Flooding in The Netherlands: How people's interpretation of
5 personal, social and institutional resources influence flooding preparedness. *International Journal of Disaster*
6 *Risk Reduction*, **24(August 2016)**, 52-57, doi:10.1016/j.ijdr.2017.05.013.
- 7 Keskitalo, E.C.H., H. Dannevig, G.K. Hovelsrud, J.J. West, and G. Swartling, 2011: Adaptive capacity determinants in
8 developed states: Examples from the Nordic countries and Russia. *Regional Environmental Change*, **11(3)**,
9 579-592, doi:10.1007/s10113-010-0182-9.
- 10 Kettle, N.P. et al., 2014: Integrating scientific and local knowledge to inform risk-based management approaches for
11 climate adaptation. *Climate Risk Management*, **4**, 17-31.
- 12 Khan, M.R., 2013: Toward a binding climate change adaptation regime: a proposed framework. .
- 13 Kholod, N. and M. Evans, 2016: Reducing black carbon emissions from diesel vehicles in Russia: An assessment and
14 policy recommendations. *Environmental Science & Policy*, **56**, 1-8, doi:10.1016/j.envsci.2015.10.017.
- 15 Kilpeläinen, A. et al., 2017: Effects of Initial Age Structure of Managed Norway Spruce Forest Area on Net Climate
16 Impact of Using Forest Biomass for Energy. *BioEnergy Research*, **10(2)**, 499-508, doi:10.1007/s12155-017-
17 9821-z.
- 18 Kim, S. and W. Shin, 2017: Understanding American and Korean Students ' Support for Pro-environmental Tax Policy
19 : The Application of the Value - Belief - Norm Theory of Environmentalism. *Environmental Communication*,
20 **11**, 311-331, doi:10.1080/17524032.2015.1088458.
- 21 Kim, S.C. and Y. Chung, 2017: Dynamics of Nuclear Power Policy in the Post-Fukushima Era: Interest Structure and
22 Politicisation in Japan, Taiwan and Korea. *Asian Studies Review*, **42(1)**, 107-124,
23 doi:10.1080/10357823.2017.1408569.
- 24 Kimball, S. et al., 2015: Cost-effective ecological restoration. *Restoration Ecology*, **23(6)**, 800-810,
25 doi:10.1111/rec.12261.
- 26 Kimura, S., 2016: When a Seawall Is Visible: Infrastructure and Obstruction in Post-tsunami Reconstruction in Japan.
27 *Science as Culture*, **25(1)**, 23-43, doi:10.1080/09505431.2015.1081501.
- 28 King, S.D., 2011: *Losing control: the emerging threats to Western prosperity*. Yale University Press, New Haven, CT,
29 USA and London, UK, 304 pp.
- 30 Kinley, R., 2017: Climate change after Paris: from turning point to transformation. *Climate Policy*, **17(1)**, 9-15,
31 doi:10.1080/14693062.2016.1191009.
- 32 Kirk, E.J., 2017: Alternatives-Dealing with the perfect storm: Cuban disaster management. *Studies in Political*
33 *Economy*, **98(1)**, 93-103, doi:10.1080/07078552.2017.1297047.
- 34 Kita, S.M., 2017: "Government Doesn't Have the Muscle": State, NGOs, Local Politics, and Disaster Risk Governance
35 in Malawi. *Risk, Hazards & Crisis in Public Policy*, **8(3)**, 244-267, doi:10.1002/rhc3.12118.
- 36 Kiunsi, R., 2013: The constraints on climate change adaptation in a city with a large development deficit: the case of
37 Dar es Salaam. *Environment and Urbanization*, **25(2)**, 321-337, doi:10.1177/0956247813489617.
- 38 Kivimaa, P. and F. Kern, 2016: Creative destruction or mere niche support? Innovation policy mixes for sustainability
39 transitions. *Research Policy*, **45(1)**, 205-217, doi:10.1016/j.respol.2015.09.008.
- 40 Klepper, G. and W. Rickels, 2014: Climate Engineering: Economic Considerations and Research Challenges. *Review of*
41 *Environmental Economics and Policy*, **8(2)**, 270-289, doi:10.1093/reep/reu010.
- 42 Klimont, Z. et al., 2017: Global anthropogenic emissions of particulate matter including black carbon. *Atmospheric*
43 *Chemistry and Physics*, **17(14)**, 8681-8723, doi:10.5194/acp-17-8681-2017.
- 44 Kline, K.L. et al., 2017: Reconciling food security and bioenergy: priorities for action. *GCB Bioenergy*, **9(3)**, 557-576,
45 doi:10.1111/gcbb.12366.
- 46 Kloeckner, C.A., E. Matthies, and M. Hunecke, 2003: Operationalizing Habits and Integrating Habits in Normative
47 Decision-Making Models. *Journal of Applied Social Psychology*, **33(2)**, 396-417.
- 48 Klotz, L., 2011: Cognitive biases in energy decisions during the planning, design, and construction of commercial
49 buildings in the United States: An analytical framework and research needs. *Energy Efficiency*, **4(2)**, 271-284,
50 doi:10.1007/s12053-010-9089-z.
- 51 Knight, P.J., T. Prime, J.M. Brown, K. Morrissey, and A.J. Plater, 2015: Application of flood risk modelling in a web-
52 based geospatial decision support tool for coastal adaptation to climate change. *Natural Hazards and Earth*
53 *System Sciences*, **15(7)**, doi:10.5194/nhess-15-1457-2015.
- 54 Knoop, K. and S. Lechtenböhrer, 2017: The potential for energy efficiency in the EU Member States - A comparison
55 of studies. *Renewable and Sustainable Energy Reviews*, **68**, 1097-1105, doi:10.1016/j.rser.2016.05.090.
- 56 Knowlton, K. et al., 2014: Development and Implementation of South Asia's First Heat-Health Action Plan in
57 Ahmedabad (Gujarat, India). *International Journal of Environmental Research and Public Health*, **11(4)**,
58 doi:10.3390/ijerph110403473.
- 59 Koch, N., S. Fuss, G. Grosjean, and O. Edenhofer, 2014: Causes of the EU ETS price drop: Recession, CDM,
60 renewable policies or a bit of everything? - New evidence. *Energy Policy*, **73**, 676-685,

- 1 doi:10.1016/j.enpol.2014.06.024.
- 2 Koch, N., G. Grosjean, S. Fuss, and O. Edenhofer, 2016: Politics matters: Regulatory events as catalysts for price
3 formation under cap-and-trade. *Journal of Environmental Economics and Management*, **78**, 121-139,
4 doi:10.1016/j.jeem.2016.03.004.
- 5 Koerth, J., A.T. Vafeidis, and J. Hinkel, 2017: Household-Level Coastal Adaptation and Its Drivers: A Systematic Case
6 Study Review. *Risk Analysis*, **37(4)**, 629-646, doi:10.1111/risa.12663.
- 7 Koezjakov, A., D. Urge-Vorsatz, W. Crijns-Graus, and M. van den Broek, 2018: The relationship between operational
8 energy demand and embodied energy in Dutch residential buildings. *Energy and Buildings*, **165**, 233-245,
9 doi:10.1016/j.enbuild.2018.01.036.
- 10 Köhler, P., J. Hartmann, and D.A. Wolf-Gladrow, 2010: Geoengineering potential of artificially enhanced silicate
11 weathering of olivine. *Proc Natl Acad Sci U S A*, **107(47)**, 20228-20233, doi:10.1073/pnas.1000545107.
- 12 Köhler, P., J.F. Abrams, C. Volker, J. Hauck, and D.A. Wolf-Gladrow, 2013: Geoengineering impact of open ocean
13 dissolution of olivine on atmospheric CO₂, surface ocean pH and marine biology. *Environmental Research
14 Letters*, **8(1)**, doi:Artn 014009 10.1088/1748-9326/8/1/014009.
- 15 Kolstad, C. et al., 2014: Social, Economic and Ethical Concepts and Methods. In: *Climate Change 2014: Mitigation of
16 Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental
17 Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth,
18 A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T.
19 Zwickel, and J.C. Minx (eds.)]. pp. 207-282.
- 20 Komarnicki, P., 2016: Energy storage systems: power grid and energy market use cases. *Archives of Electrical
21 Engineering*, **65**, 495, doi:10.1515/aee-2016-0036.
- 22 Kona, A., P. Bertoldi, G. Melica, and S. Rivas, 2018: Covenant of Mayors signatories leading the way towards 1.5
23 degree global warming pathway. *Sustainable Cities and Society* (in press).
- 24 Koomey, J., N.E. Hultman, and A. Grubler, 2017: A reply to "Historical construction costs of global nuclear power
25 reactors". *Energy Policy*, **102**, 640-643, doi:https://doi.org/10.1016/j.enpol.2016.03.052.
- 26 Koomey, J.G., H.S. Matthews, and E. Williams, 2013: Smart everything: Will intelligent systems reduce resource use?
27 *Annual Review of Environment and Resources*, **38**, 17.1-17.33.
- 28 Kossoy, A. et al., 2015: *State and Trends of Carbon Pricing October 2015*. The World Bank, Washington DC, 140 pp.
- 29 Kosugi, T., 2013: Fail-safe solar radiation management geoengineering. *Mitigation and Adaptation Strategies for
30 Global Change*, **18(8)**, 1141-1166, doi:10.1007/s11027-012-9414-2.
- 31 Kothari, U., 2014: Political discourses of climate change and migration: resettlement policies in the Maldives. *The
32 Geographical Journal*, **180(2)**, 130-140, doi:10.1111/geoj.12032.
- 33 Kotilainen, K. and U.A. Saari, 2018: Policy Influence on Consumers' Evolution into Prosumers-Empirical Findings
34 from an Exploratory Survey in Europe. *Sustainability*, **2018(10)**, doi:10.3390/su10010186.
- 35 Kraucunas, I. et al., 2015: Investigating the nexus of climate, energy, water, and land at decision-relevant scales: the
36 Platform for Regional Integrated Modeling and Analysis (PRIMA). *Climatic Change*, **129(3-4)**, 573-588,
37 doi:10.1007/s10584-014-1064-9.
- 38 Kravitz, B. et al., 2011: The Geoengineering Model Intercomparison Project (GeoMIP). *Atmospheric Science Letters*,
39 **12(2)**, 162-167, doi:10.1002/asl.316.
- 40 Kravitz, B. et al., 2013: Sea spray geoengineering experiments in the geoengineering model intercomparison project
41 (GeoMIP): Experimental design and preliminary results. *Journal of Geophysical Research Atmospheres*,
42 **118(19)**, 11175-11186, doi:10.1002/jgrd.50856.
- 43 Kraxner, F. et al., 2014: BECCS in South Korea - Analyzing the negative emissions potential of bioenergy as a
44 mitigation tool. *Renewable Energy*, **61**, 102-108, doi:10.1016/J.RENENE.2012.09.064.
- 45 Kreidenweis, U. et al., 2016: Afforestation to mitigate climate change: impacts on food prices under consideration of
46 albedo effects. *Environmental Research Letters*, **11(8)**, 085001, doi:10.1088/1748-9326/11/8/085001.
- 47 Kreuz, S. and F. Müsgens, 2017: The German Energiewende and its roll-out of renewable energies: An economic
48 perspective. *Frontiers in Energy*, 1-9.
- 49 Kriegler, E., O. Edenhofer, L. Reuster, G. Luderer, and D. Klein, 2013: Is atmospheric carbon dioxide removal a game
50 changer for climate change mitigation? *Climatic Change*, **118(1)**, 45-57, doi:10.1007/s10584-012-0681-4.
- 51 Kristjánsson, J.E., H. Muri, and H. Schmidt, 2015: The hydrological cycle response to cirrus cloud thinning.
52 *Geophysical Research Letters*, **42(24)**, 10807-10815, doi:10.1002/2015GL066795.
- 53 Krugman, P., 2009: *The Return of Depression Economics and the Crisis of 2008*. W.W. Norton & Company Inc, New
54 York, NY, USA, 207 pp.
- 55 Kryvasheyev, Y. et al., 2016: Rapid assessment of disaster damage using social media activity. *Science Advances*, **2(3)**,
56 e1500779-e1500779, doi:10.1126/sciadv.1500779.
- 57 Kull, D. et al., 2016: Building Resilience: World Bank Group Experience in Climate and Disaster Resilient
58 Development. *Climate Change Adaptation Strategies -- An Upstream-downstream Perspective*, 255-270,
59 doi:10.1007/978-3-319-40773-9_14.
- 60 Kuramochi, T. et al., 2018: Ten key short-term sectoral benchmarks to limit warming to 1.5°C. *Climate Policy*, **18(3)**,

- 1 287-305, doi:10.1080/14693062.2017.1397495.
- 2 Kurdgelashvili, L., J. Li, C.–H. Shih, and B. Attia, 2016: Estimating technical potential for rooftop photovoltaics in
3 California, Arizona and New Jersey. *Renewable Energy*, **95(Supplement C)**, 286-302,
4 doi:https://doi.org/10.1016/j.renene.2016.03.105.
- 5 Kuruppu, N. and D. Liverman, 2011: Mental preparation for climate adaptation: The role of cognition and culture in
6 enhancing adaptive capacity of water management in Kiribati. *Global Environmental Change*, **21(2)**, 657-669,
7 doi:10.1016/j.gloenvcha.2010.12.002.
- 8 Kuruppu, N. and R. Willie, 2015: Barriers to reducing climate enhanced disaster risks in Least Developed Country-
9 Small Islands through anticipatory adaptation. *Weather and Climate Extremes*, **7**, 72-83,
10 doi:10.1016/j.wace.2014.06.001.
- 11 Kverndokk, S. and K.E. Rosendahl, 2007: Climate policies and learning by doing: Impacts and timing of technology
12 subsidies. *Resource and Energy Economics*, **29(1)**, 58-82, doi:10.1016/j.reseneeco.2006.02.007.
- 13 La Rovere, E.L., C. Gesteira, C. Grottera, and W. William, 2017a: Pathways to a low carbon economy in Brazil. In:
14 *Brazil in the Anthropocene: Conflicts between predatory development and environmental policies* [Issberner,
15 L.–R. and P. Léna (eds.)]. pp. 243-266.
- 16 La Rovere, E.L., J.–C. Hourcade, S. Priyadarshi, E. Espagne, and B. Perrissin-Fabert, 2017b: Social Value of
17 Mitigation Activities and forms of Carbon Pricing. CIRED Working Papers: 2017-60, 8 pp.
- 18 Labanca, N. (ed.), 2017: *Complex Systems and Social Practices in Energy Transitions: Framing Energy Sustainability*
19 *in the Time of Renewables*. Springer, 337 pp.
- 20 Labbé, J., J.D. Ford, M. Araos, and M. Flynn, 2017: The government-led climate change adaptation landscape in
21 Nunavut, Canada. *Environmental Reviews*, **25(1)**, 12-25, doi:10.1139/er-2016-0032.
- 22 Lacasse, K., 2015: The Importance of Being Green. *Environment and Behavior*, **47(7)**, 754-781,
23 doi:10.1177/0013916513520491.
- 24 Lacasse, K., 2016: Don't be satisfied, identify! Strengthening positive spillover by connecting pro-environmental
25 behaviors to an "environmentalist" label. *Journal of Environmental Psychology*, **48**, 149-158,
26 doi:10.1016/j.jenvp.2016.09.006.
- 27 Lachapelle, E., R. MacNeil, and M. Paterson, 2017: The political economy of decarbonisation: from green energy 'race'
28 to green 'division of labour'. *New Political Economy*, **22(3)**, 311-327, doi:10.1080/13563467.2017.1240669.
- 29 Lackner, K.S. et al., 2012: The urgency of the development of CO2 capture from ambient air. *Proceedings of the*
30 *National Academy of Sciences*, **109(33)**, 13156-13162, doi:10.1073/pnas.1108765109.
- 31 Läderach, P. et al., 2017: Climate change adaptation of coffee production in space and time. *Climatic Change*, **141(1)**,
32 47-62, doi:10.1007/s10584-016-1788-9.
- 33 Lahn, B., 2017: In the light of equity and science: scientific expertise and climate justice after Paris. *International*
34 *Environmental Agreements: Politics, Law and Economics*, doi:10.1007/s10784-017-9375-8.
- 35 Lahn, B. and G. Sundqvist, 2017: Science as a "fixed point"? Quantification and boundary objects in international
36 climate politics. *Environmental Science & Policy*, **67(Supplement C)**, 8-15,
37 doi:https://doi.org/10.1016/j.envsci.2016.11.001.
- 38 Lam, N.S.–N., Y. Qiang, H. Arenas, P. Brito, and K.–Liu, 2015: Mapping and assessing coastal resilience in the
39 Caribbean region. *Cartography and Geographic Information Science*, **42(4)**, 315-322,
40 doi:10.1080/15230406.2015.1040999.
- 41 Lamb, W.F. et al., 2014: Transitions in pathways of human development and carbon emissions. *Environmental*
42 *Research Letters*, **9(1)**, 014011, doi:10.1088/1748-9326/9/1/014011.
- 43 Lamond, J.E., C.B. Rose, and C.A. Booth, 2015: Evidence for improved urban flood resilience by sustainable drainage
44 retrofit. *Proceedings of the Institution of Civil Engineers - Urban Design and Planning*, **168(2)**, 101-111,
45 doi:10.1680/udap.13.00022.
- 46 Lampert, D.J., H. Cai, and A. Elgowainy, 2016: Wells to wheels: water consumption for transportation fuels in the
47 United States. *Energy & Environmental Science*, **9(3)**, 787-802, doi:10.1039/C5EE03254G.
- 48 Lampin, L.B.A., F. Nadaud, F. Grazi, and J.–C. Hourcade, 2013: Long-term fuel demand: Not only a matter of fuel
49 price. *Energy Policy*, **62**, 780-787, doi:10.1016/j.enpol.2013.05.021.
- 50 Larsen, J.N. et al., 2014: Polar Regions. *Climate Change 2014: Impacts, Adaptation and Vulnerability*, 1567-1612,
51 doi:10.1017/CBO9781107415386.008.
- 52 Larsen, K. and U. Gunnarsson-Östling, 2009: Climate change scenarios and citizen-participation: Mitigation and
53 adaptation perspectives in constructing sustainable futures. *Habitat International*, **33(3)**, 260-266,
54 doi:10.1016/j.habitatint.2008.10.007.
- 55 Larson, W. and W. Zhao, 2017: Telework: Urban Form, Energy Consumption, and Greenhouse Gas Implications.
56 *Economic Inquiry*, **55(2)**, 714-735, doi:10.1111/ecin.12399.
- 57 Larsson, L., E.C.H. Keskitalo, and J. Åkermark, 2016: Climate Change Adaptation and Vulnerability Planning within
58 the Municipal and Regional System: Examples from Northern Sweden. *Journal of Northern Studies*, **10(1)**, 61-
59 90.
- 60 Lasco, R.D., R.J.P. Delfino, and M.L.O. Espaldon, 2014: Agroforestry systems: helping smallholders adapt to climate

- 1 risks while mitigating climate change. *Wiley Interdisciplinary Reviews: Climate Change*, **5(6)**, 825-833,
2 doi:10.1002/wcc.301.
- 3 Lashley, J.G. and K. Warner, 2015: Evidence of demand for microinsurance for coping and adaptation to weather
4 extremes in the Caribbean. *Climatic Change*, **133(1)**, 101-112, doi:10.1007/s10584-013-0922-1.
- 5 Latham, J., B. Parkes, A. Gadian, and S. Salter, 2012: Weakening of hurricanes via marine cloud brightening (MCB).
6 *Atmospheric Science Letters*, **13(4)**, 231-237, doi:10.1002/asl.402.
- 7 Latham, J., J. Kleypas, R. Hauser, B. Parkes, and A. Gadian, 2013: Can marine cloud brightening reduce coral
8 bleaching? *Atmospheric Science Letters*, **14(4)**, 214-219, doi:10.1002/asl2.442.
- 9 Laurance, W.F. and G.B. Williamson, 2001: Positive Feedbacks among Forest Fragmentation, Drought, and Climate
10 Change in the Amazon. *Conservation Biology*, **15(6)**, 1529-1535, doi:10.1046/j.1523-1739.2001.01093.x.
- 11 Lauren, N., K.S. Fielding, L. Smith, and W.R. Louis, 2016: You did, so you can and you will: Self-efficacy as a
12 mediator of spillover from easy to more difficult pro-environmental behaviour. *Journal of Environmental*
13 *Psychology*, **48**, 191-199, doi:10.1016/j.jenvp.2016.10.004.
- 14 Laurice Jamero, M. et al., 2017: Small-island communities in the Philippines prefer local measures to relocation in
15 response to sea-level rise. *Nature Climate Change*, **7**, 581-586, doi:10.1038/nclimate3344.
- 16 Lauvset, S.K., J. Tjiputra, and H. Muri, 2017: Climate engineering and the ocean: effects on biogeochemistry and
17 primary production. *Biogeosciences*, **14(24)**, 5675-5691, doi:10.5194/bg-14-5675-2017.
- 18 Lawrence, M.G. and P.J. Crutzen, 2017: Was breaking the taboo on research on climate engineering via albedo
19 modification a moral hazard, or a moral imperative? *Earth's Future*, **5(2)**, 136-143,
20 doi:10.1002/2016EF000463.
- 21 Lazurko, A. and H.D. Venema, 2017: Financing high performance climate adaptation in agriculture: Climate bonds for
22 multi-functional water harvesting infrastructure on the Canadian Prairies. *Sustainability*, **9(7)**,
23 doi:10.3390/su9071237.
- 24 Le Dang, H., E. Li, J. Bruwer, and I. Nuberg, 2014: Farmers' perceptions of climate variability and barriers to
25 adaptation: lessons learned from an exploratory study in Vietnam. *Mitigation and adaptation strategies for*
26 *global change*, **19(5)**, 531-548.
- 27 Le Page, Y. et al., 2013: Sensitivity of climate mitigation strategies to natural disturbances. *Environmental Research*
28 *Letters*, **8(1)**, doi:10.1088/1748-9326/8/1/015018.
- 29 Leal Filho, W. et al., 2018: Implementing climate change research at universities: Barriers, potential and actions.
30 *Journal of Cleaner Production*, **170(1)**, 269-277, doi:10.1016/j.jclepro.2017.09.105.
- 31 Leape, J., 2006: The London Congestion Charge. *Journal of Economic Perspectives*, **20(4)**, 157-176,
32 doi:10.1257/jep.20.4.157.
- 33 Leck, H. and D. Roberts, 2015: What lies beneath: understanding the invisible aspects of municipal climate change
34 governance. *Current Opinion in Environmental Sustainability*, **13**, 61-67, doi:10.1016/j.cosust.2015.02.004.
- 35 Leck, H., D. Conway, M. Bradshaw, and J. Rees, 2015: Tracing the Water-Energy-Food Nexus: Description, Theory
36 and Practice. *Geography Compass*, **9(8)**, 445-460, doi:10.1111/gec3.12222.
- 37 Lecuyer, O. and P. Quirion, 2013: Can uncertainty justify overlapping policy instruments to mitigate emissions?
38 *Ecological Economics*, **93**, 177-191, doi:10.1016/j.ecolecon.2013.05.009.
- 39 Lee, T. and M. Painter, 2015: Comprehensive local climate policy: The role of urban governance. *Urban Climate*, **14**,
40 566-577, doi:10.1016/j.uclim.2015.09.003.
- 41 Leeson, D., N. Mac Dowell, N. Shah, C. Petit, and P.S. Fennell, 2017: A Techno-economic analysis and systematic
42 review of carbon capture and storage (CCS) applied to the iron and steel, cement, oil refining and pulp and
43 paper industries, as well as other high purity sources. *International Journal of Greenhouse Gas Control*, **61**,
44 71-84, doi:https://doi.org/10.1016/j.ijggc.2017.03.020.
- 45 Lefevre, C.E. et al., 2015: Heat protection behaviors and positive affect about heat during the 2013 heat wave in the
46 United Kingdom. *Social Science & Medicine*, **128**, 282-289, doi:10.1016/j.socscimed.2015.01.029.
- 47 Lefèvre, J., W. Wills, and J.-C. Hourcade, 2018: Combining low-carbon economic development and oil exploration in
48 Brazil? An energy-economy assessment. *Climate Policy*, 1-10, doi:10.1080/14693062.2018.1431198.
- 49 Leijten, F.R.M. et al., 2014: Factors that influence consumers' acceptance of future energy systems: the effects of
50 adjustment type, production level, and price. *Energy Efficiency*, **7(6)**, 973-985e, doi:10.1007/s12053-014-
51 9271-9.
- 52 Lemos, M.C., 2015: Usable climate knowledge for adaptive and co-managed water governance. *Current Opinion in*
53 *Environmental Sustainability*, **12**, 48-52, doi:10.1016/j.cosust.2014.09.005.
- 54 Lemos, M.C., Y.J. Lo, D.R. Nelson, H. Eakin, and A.M. Bedran-Martins, 2016: Linking development to climate
55 adaptation: Leveraging generic and specific capacities to reduce vulnerability to drought in NE Brazil. *Global*
56 *Environmental Change*, **39**, 170-179, doi:10.1016/j.gloenvcha.2016.05.001.
- 57 Lempert, R.J. and D. Prosnitz, 2011: *Governing geoengineering research: a political and technical vulnerability*
58 *analysis of potential near-term options*. RAND Corporation, Santa Monica, CA, 93 pp.
- 59 Lenferna, G.A., R.D. Russotto, A. Tan, S.M. Gardiner, and T.P. Ackerman, 2017: Relevant climate response tests for
60 stratospheric aerosol injection: A combined ethical and scientific analysis. *Earth's Future*, 577-591,

- 1 doi:10.1002/2016EF000504.
- 2 Lenton, T.M., 2010: The potential for land-based biological CO2 removal to lower future atmospheric CO2
3 concentration. *Carbon Management*, **1(1)**, 145-160, doi:10.4155/cmt.10.12.
- 4 Lenton, T.M., 2014: The Global Potential for Carbon Dioxide Removal. *Geoengineering of the Climate System*, 52-79,
5 doi:10.1039/9781782621225-00052.
- 6 Lesnikowski, A., J.D. Ford, R. Biesbroek, L. Berrang-Ford, and S.J. Heymann, 2016: National-level progress on
7 adaptation. *Nature Climate Change*, **6**, 261-266, doi:10.1038/nclimate2863.
- 8 Lesnikowski, A. et al., 2017: What does the Paris Agreement mean for adaptation? *Climate Policy*, **17(7)**, 825-831,
9 doi:10.1080/14693062.2016.1248889.
- 10 Lesnikowski, A.C., J.D. Ford, L. Berrang-Ford, M. Barrera, and J. Heymann, 2015: How are we adapting to climate
11 change? A global assessment. *Mitigation and Adaptation Strategies for Global Change*, **20(2)**, 277-293,
12 doi:10.1007/s11027-013-9491-x.
- 13 Levy, D.L. and D. Egan, 2003: A Neo-Gramscian Approach to Corporate Political Strategy: Conflict and
14 Accommodation in the Climate Change Negotiations. *Journal of Management Studies*, **40(4)**, 803-829.
- 15 Lewandowski, M., 2016: Designing the Business Models for Circular Economy-Towards the Conceptual Framework.
16 *Sustainability*, **8(1)**, 43, doi:10.3390/su8010043.
- 17 Li, F. et al., 2017: Urban ecological infrastructure: an integrated network for ecosystem services and sustainable urban
18 systems. *Journal of Cleaner Production*, **163(S1)**, S12-S18, doi:10.1016/j.jclepro.2016.02.079.
- 19 Li, H., J. He, Z.P. Bharucha, R. Lal, and J. Pretty, 2016: Improving China's food and environmental security with
20 conservation agriculture. *International Journal of Agricultural Sustainability*, **14(4)**, 377-391,
21 doi:10.1080/14735903.2016.1170330.
- 22 Li, J. and X. Wang, 2012: Energy and climate policy in China's twelfth five-year plan: A paradigm shift. *Energy Policy*,
23 **41**, 519-528, doi:http://dx.doi.org/10.1016/j.enpol.2011.11.012.
- 24 Li, L. and B.P.Y. Loo, 2017: Railway Development and Air Patronage in China, 1993-2012: Implications for Low-
25 Carbon Transport. *Journal of Regional Science*, **57(3)**, 507-522, doi:10.1111/jors.12276.
- 26 Li, N., D. Ma, and W. Chen, 2017: Quantifying the impacts of decarbonisation in China's cement sector: A perspective
27 from an integrated assessment approach. *Applied Energy*, **185**, 1840-1848,
28 doi:https://doi.org/10.1016/j.apenergy.2015.12.112.
- 29 Lilford, R.J. et al., 2017: Improving the health and welfare of people who live in slums.. *Lancet*, **389(10068)**, 559-570.
- 30 Lillemo, S., 2014: Measuring the effect of procrastination and environmental awareness on households' energy-saving
31 behaviours: An empirical approach. *Energy Policy*, **66**, 249-256,
32 doi:https://doi.org/10.1016/j.enpol.2013.10.077.
- 33 Lim-Camacho, L. et al., 2015: Facing the wave of change: stakeholder perspectives on climate adaptation for Australian
34 seafood supply chains. *Regional Environmental Change*, **15(4)**, 595-606, doi:10.1007/s10113-014-0670-4.
- 35 Lin, A.C., 2013: Does Geoengineering Present a Moral Hazard? *Ecology Law Quarterly*, **40**, 673-712,
36 doi:10.2307/24113611.
- 37 Lin, B.B. et al., 2017: How green is your garden?: Urban form and socio-demographic factors influence yard
38 vegetation, visitation, and ecosystem service benefits. *Landscape and Urban Planning*, **157**, 239-246,
39 doi:10.1016/j.landurbplan.2016.07.007.
- 40 Lin, C.S.K. et al., 2013: Food waste as a valuable resource for the production of chemicals, materials and fuels. Current
41 situation and global perspective. *Energy & Environmental Science*, doi:10.1039/c2ee23440h.
- 42 Lindenberg, S. and L. Steg, 2013: What makes organizations in market democracies adopt environmentally-friendly
43 policies? In: *Green Organizations: Driving Change with I-O Psychology* [Huffmann, A.H. and S.R. Klein
44 (eds.)]. Routledge, New York, pp. 93-114.
- 45 Linder, M. and M. Williander, 2017: Circular Business Model Innovation: Inherent Uncertainties. *Business Strategy
46 and the Environment*, **26(2)**, 182-196, doi:10.1002/bse.1906.
- 47 Lindoso, D.P. et al., 2014: Integrated assessment of smallholder farming's vulnerability to drought in the Brazilian
48 Semi-arid: a case study in Ceará. *Climatic Change*, **127(1)**, 93-105, doi:10.1007/s10584-014-1116-1.
- 49 Linnenluecke, M.K., A. Griffiths, and P.J. Mumby, 2015: Executives' engagement with climate science and perceived
50 need for business adaptation to climate change. *Climatic Change*, **131(2)**, 321-333, doi:10.1007/s10584-015-
51 1387-1.
- 52 Linnér, B.-O. and V. Wibeck, 2015: Dual high-stake emerging technologies: a review of the climate engineering
53 research literature. *Wiley Interdisciplinary Reviews: Climate Change*, **6(2)**, 255-268, doi:10.1002/wcc.333.
- 54 Linnerooth-Bayer, J. and S. Hochrainer-Stigler, 2015: Financial instruments for disaster risk management and climate
55 change adaptation. *Climatic Change*, **133(1)**, 85-100, doi:10.1007/s10584-013-1035-6.
- 56 Liu, W., W. Chen, and C. Peng, 2014: Assessing the effectiveness of green infrastructures on urban flooding reduction:
57 A community scale study. *Ecological Modelling*, **291(Supplement C)**, 6-14,
58 doi:https://doi.org/10.1016/j.ecolmodel.2014.07.012.
- 59 Liu, W., Z. Yu, X. Xie, K. von Gadow, and C. Peng, 2018: A critical analysis of the carbon neutrality assumption in life
60 cycle assessment of forest bioenergy systems. *Environmental Reviews*, **26(1)**, 93-101, doi:10.1139/er-2017-

- 1 0060.
- 2 Liu, X. et al., 2017: Microgrids for Enhancing the Power Grid Resilience in Extreme Conditions. *IEEE Transactions on*
- 3 *Smart Grid*, **8(2)**, 589-597, doi:10.1109/TSG.2016.2579999.
- 4 Lizarralde, G. et al., 2015: A systems approach to resilience in the built environment: the case of Cuba. *Disasters*,
- 5 **39(s1)**, s76-s95, doi:10.1111/disa.12109.
- 6 Lloyd, I.D. and M. Oppenheimer, 2014: On the Design of an International Governance Framework for Geoengineering.
- 7 *Global Environmental Politics*, **14(2)**, 45-63, doi:10.1162/GLEP_a_00228.
- 8 Loboda, T., 2014: Adaptation strategies to climate change in the Arctic: a global patchwork of reactive community-
- 9 scale initiatives. *Environmental Research Letters*, **9(11)**, 7-10, doi:10.1088/1748-9326/9/11/111006.
- 10 Locatelli, B., V. Evans, A. Wardell, A. Andrade, and R. Vignola, 2011: Forests and Climate Change in Latin America:
- 11 Linking Adaptation and Mitigation. *Forests*, **2(4)**, 431-450, doi:10.3390/f2010431.
- 12 Locatelli, B. et al., 2015: Tropical reforestation and climate change: beyond carbon. *Restoration Ecology*, **23(4)**, 337-
- 13 343, doi:10.1111/rec.12209.
- 14 Lockley, A., 2012: Comment on "Review of Methane Mitigation Technologies with Application to Rapid Release of
- 15 Methane from the Arctic". *Environmental Science & Technology*, **46(24)**, 13552-13553,
- 16 doi:10.1021/es303074j.
- 17 Lockley, A. and D.M. Coffman, 2016: Distinguishing morale hazard from moral hazard in geoengineering.
- 18 *Environmental Law Review*, **18(3)**, 194-204, doi:10.1177/1461452916659830.
- 19 Loftus, P., A. Cohen, J.C. Long, and J.D. Jenkins, 2014: A critical review of global decarbonization scenarios: what do
- 20 they tell us about feasibility? *Wiley Interdisciplinary Reviews: Climate Change*, **6(1)**, 93-112,
- 21 doi:10.1002/wcc.324.
- 22 Lohmann, U. and B. Gasparini, 2017: A cirrus cloud climate dial? *Science*, **357(6348)**, 248-249,
- 23 doi:10.1126/science.aan3325.
- 24 Lokhorst, A.M., C. Werner, H. Staats, E. van Dijk, and J.L. Gale, 2013: Commitment and Behavior Change: A Meta-
- 25 Analysis and Critical Review of Commitment-Making Strategies in Environmental Research. *Environment*
- 26 *and Behavior*, **45(1)**, 3-34, doi:10.1177/0013916511411477.
- 27 Loladze, I., 2014: Hidden shift of the ionome of plants exposed to elevated CO2 depletes minerals at the base of human
- 28 nutrition. *eLife*, **2014(3)**, 1-29, doi:10.7554/eLife.02245.
- 29 Lomax, G., M. Workman, T. Lenton, and N. Shah, 2015: Reframing the policy approach to greenhouse gas removal
- 30 technologies. *Energy Policy*, **78(Supplement C)**, 125-136, doi:https://doi.org/10.1016/j.enpol.2014.10.002.
- 31 Lombardi, M., P. Paziienza, and R. Rana, 2016: The EU environmental-energy policy for urban areas: The Covenant of
- 32 Mayors, the ELENA program and the role of ESCos. *Energy Policy*, **93(December)**, 33-40,
- 33 doi:10.1016/j.enpol.2016.02.040.
- 34 Long, J. and J. Shepherd, 2014: The Strategic Value of Geoengineering Research. In: *Global Environmental Change.*
- 35 *Handbook of Global Environmental Pollution* [Freedman, B. (ed.)]. Springer Netherlands, Dordrecht, The
- 36 Netherlands, pp. 757-770.
- 37 Loock, C., T. Staake, and F. Thiesse, 2013: Motivating energy-efficient behavior with green IS: An investigation of
- 38 goal setting and the role of defaults. *MIS Quarterly*, **37(4)**, 1313-1332.
- 39 Loring, P.A., S.C. Gerlach, and H.J. Penn, 2016: "Community work" in a climate of adaptation: Responding to change
- 40 in rural Alaska. *Human Ecology*, **44(1)**, 119-128, doi:10.1007/s10745-015-9800-y.
- 41 Lourenço, T.C., R. Swart, H. Goosen, and R. Street, 2016: The rise of demand-driven climate services. *Nature Climate*
- 42 *Change*, **6(1)**, 13-14, doi:10.1038/nclimate2836.
- 43 Lövbrand, E., M. Hjerpe, and B.-O. Linnér, 2017: Making climate governance global: how UN climate summitry
- 44 comes to matter in a complex climate regime. *Environmental Politics*, **26(4)**, 1-20,
- 45 doi:10.1080/09644016.2017.1319019.
- 46 Lovering, J.R., A. Yip, and T. Nordhaus, 2016: Historical construction costs of global nuclear power reactors. *Energy*
- 47 *Policy*, **91**, 371-382, doi:10.1016/j.enpol.2016.01.011.
- 48 Lovins, A.B., T. Palazzi, R. Laemel, and E. Goldfield, 2018: Relative deployment rates of renewable and nuclear
- 49 power: A cautionary tale of two metrics. *Energy Research & Social Science*, **38**, 188-192,
- 50 doi:10.1016/J.ERSS.2018.01.005.
- 51 LTA, 2013: *Land Transport Master Plan 2013*. 58 pp.
- 52 LTA, 2015: *Singapore Land Transport Statistics In Brief 2014*. 2 pp.
- 53 LTA, 2017: *Annual Vehicle Statistics 2016: Motor vehicle population by vehicle type*. 1 pp.
- 54 Luderer, G. et al., 2012: The economics of decarbonizing the energy system - results and insights from the RECIPE
- 55 model intercomparison. *Climatic Change*, **114(1)**, 9-37, doi:10.1007/s10584-011-0105-x.
- 56 Luderer, G. et al., 2016: *Deep decarbonisation towards 1.5 °C - 2 °C stabilisation. Policy findings from the ADVANCE*
- 57 *project (first edition)*. The ADVANCE Consortium, 42 pp.
- 58 Luderer, G. et al., 2018: Residual fossil CO2 determining carbon dioxide removal requirements in 1.5-2°C pathways.
- 59 *Nature Climate Change* (in press).
- 60 Lupíšek, A., M. Vaculíková, Manlík, J. Hodková, and J. Růžička, 2015: Design Strategies for Low Embodied Carbon

- 1 and Low Embodied Energy Buildings: Principles and Examples. *Energy Procedia*, **83**, 147-156,
2 doi:10.1016/j.egypro.2015.12.205.
- 3 Lusiana, B., M. van Noordwijk, and G. Cadisch, 2012: Land sparing or sharing? Exploring livestock fodder options in
4 combination with land use zoning and consequences for livelihoods and net carbon stocks using the FALLOW
5 model. *Agriculture, Ecosystems & Environment*, **159**, 145-160, doi:10.1016/j.agee.2012.07.006.
- 6 Lustick, I.S., D. Nettle, D.S. Wilson, H. Kokko, and B.A. Thayer, 2011: Institutional rigidity and evolutionary theory:
7 Trapped on a local maximum. *Cliodynamics: The Journal of Theoretical and Mathematical History*, **2(2)**.
- 8 Lutz, W. and R. Mutarak, 2017: Forecasting societies' adaptive capacities through a demographic metabolism model.
9 *Nature Climate Change*, **7(3)**, 177-184, doi:10.1038/nclimate3222.
- 10 Lwasa, S., 2010: Adapting urban areas in Africa to climate change: the case of Kampala. *Current Opinion in*
11 *Environmental Sustainability*, **2(3)**, 166-171, doi:10.1016/j.cosust.2010.06.009.
- 12 Lwasa, S., 2017: Options for reduction of greenhouse gas emissions in the low-emitting city and metropolitan region of
13 Kampala. *Carbon Management*, **8(3)**, 263-276, doi:10.1080/17583004.2017.1330592.
- 14 Lwasa, S. et al., 2014: Urban and peri-urban agriculture and forestry: Transcending poverty alleviation to climate
15 change mitigation and adaptation. *Urban Climate*, **7(Supplement C)**, 92-106,
16 doi:10.1016/j.uclim.2013.10.007.
- 17 Lwasa, S. et al., 2015: A meta-analysis of urban and peri-urban agriculture and forestry in mediating climate change.
18 *Current Opinion in Environmental Sustainability*, **13**, 68-73, doi:10.1016/j.cosust.2015.02.003.
- 19 Ma, D., A. Hasanbeigi, L. Price, and W. Chen, 2015: Assessment of energy-saving and emission reduction potentials in
20 China's ammonia industry. *Clean Technologies and Environmental Policy*, **17(6)**, 1633-1644,
21 doi:10.1007/s10098-014-0896-3.
- 22 Ma, Y., 2014: A Study on Carbon Financing Innovation of Financial Institutions in China. *International Journal of*
23 *Business Administration*, **5(103)**, 1923-4007, doi:10.5430/ijba.v5n4p103.
- 24 Mac Dowell, N., P.S. Fennell, N. Shah, and G.C. Maitland, 2017: The role of CO2 capture and utilization in mitigating
25 climate change. *Nature Climate Change*, **7(4)**, 243-249, doi:10.1038/nclimate3231.
- 26 MacDonald, A.E. et al., 2016: Future cost-competitive electricity systems and their impact on US CO2 emissions.
27 *Nature Climate Change*, **6(5)**, 526-531, doi:10.1038/nclimate2921.
- 28 MacDonald, J.P. et al., 2015: Protective factors for mental health and well-being in a changing climate: Perspectives
29 from Inuit youth in Nunatsiavut, Labrador. *Social Science & Medicine*, **141**, 133-141,
30 doi:10.1016/j.socscimed.2015.07.017.
- 31 Macedo, I.C., J.E.A. Seabra, and J.E.A.R. Silva, 2008: Green house gases emissions in the production and use of
32 ethanol from sugarcane in Brazil: The 2005/2006 averages and a prediction for 2020. *Biomass and Bioenergy*,
33 **32(7)**, 582-595, doi:10.1016/j.biombioe.2007.12.006.
- 34 MacKay, D.J.C., 2013: Could energy-intensive industries be powered by carbon-free electricity? *Philosophical*
35 *Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences*, **371(1986)**,
36 doi:10.1098/rsta.2011.0560.
- 37 Mackerron, G., 2014: Costs and economics of geoengineering. Climate Geoengineering Governance Working Paper
38 Series: 013, 28 pp.
- 39 Maclean, J., J. Tan, D. Tirpak, V. Sonntag-O'Brien, and E. Usher, 2008: *Public Finance Mechanisms to Mobilise*
40 *Investment in Climate Change Mitigation*. 40 pp.
- 41 MacMartin, D.G., K. Caldeira, and D.W. Keith, 2014: Solar geoengineering to limit the rate of temperature change.
42 *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*,
43 **372(2031)**, 20140134-20140134, doi:10.1098/rsta.2014.0134.
- 44 MacMartin, D.G., K.L. Ricke, and D.W. Keith, 2018: Solar geoengineering as part of an overall strategy for meeting
45 the 1.5°C Paris target. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and*
46 *Engineering Sciences*, **376(2119)**, 20160454, doi:10.1098/rsta.2016.0454.
- 47 Maggioni, V. et al., 2016: A Review of Merged High-Resolution Satellite Precipitation Product Accuracy during the
48 Tropical Rainfall Measuring Mission (TRMM) Era. *Journal of Hydrometeorology*, **17(4)**, 1101-1117,
49 doi:10.1175/JHM-D-15-0190.1.
- 50 Maghari, B.M. and A.M. Ardekani, 2011: Genetically modified foods and social concerns. *Avicenna journal of medical*
51 *biotechnology*, **3(3)**, 109-17.
- 52 Magnan, A., T. Ribera, and S. Treyer, 2015: National adaptation is also a global concern. Working Papers N°04/15, 16
53 pp.
- 54 Magnan, A.K. and T. Ribera, 2016: Global adaptation after Paris. *Science*, **352(6291)**, 1280-1282,
55 doi:10.1126/science.aaf5002.
- 56 Magnan, A.K. et al., 2016: Addressing the risk of maladaptation to climate change. *Wiley Interdisciplinary Reviews:*
57 *Climate Change*, **7(5)**, 646-665, doi:10.1002/wcc.409.
- 58 Magni, G., 2017: Indigenous knowledge and implications for the sustainable development agenda. *European Journal of*
59 *Education*, **52(4)**, 437-447, doi:10.1111/ejed.12238.
- 60 Mahlkow, N. and J. Donner, 2017: From Planning to Implementation? The Role of Climate Change Adaptation Plans to

- 1 Tackle Heat Stress: A Case Study of Berlin, Germany. *Journal of Planning Education and Research*, **37(4)**,
2 385-396, doi:10.1177/0739456X16664787.
- 3 Mahoo, H. et al., 2013: Seasonal weather forecasting: integration of indigenous and scientific knowledge. In:
4 *Innovation in smallholder farming in Africa: recent advances and recommendations. Proceedings of the*
5 *International Workshop on Agricultural Innovation Systems in Africa.*
- 6 Mahoo, H. et al., 2015: Integrating indigenous knowledge with scientific seasonal forecasts for climate risk
7 management in Lushoto district in Tanzania. CCAFS Working Paper no. 103, CGIAR Research Program on
8 Climate Change, Agriculture and Food Security (CAAFS), Copenhagen, Denmark, 32 pp.
- 9 Majzoobi, A. and A. Khodaei, 2017: Application of microgrids in providing ancillary services to the utility grid.
10 *Energy*, **123**, 555-563, doi:10.1016/j.energy.2017.01.113.
- 11 Maki, A., R.J. Burns, L. Ha, and A.J. Rothman, 2016: Paying people to protect the environment: A meta-analysis of
12 financial incentive interventions to promote proenvironmental behaviors. *Journal of Environmental*
13 *Psychology*, **47**, 242-255, doi:10.1016/j.jenvp.2016.07.006.
- 14 Malmodin, J., D. Lunden, A. Moberg, G. Andersson, and M. Nilsson, 2014: Life Cycle Assessment of ICT Carbon
15 Footprint and Operational Electricity Use from the Operator, National, and Subscriber Perspective in Sweden.
16 *JOURNAL OF INDUSTRIAL ECOLOGY*, **18(6)**, 829-845, doi:10.1111/jiec.12145.
- 17 Manning, D.A. and P. Renforth, 2013: Passive sequestration of atmospheric CO₂ through coupled plant-mineral
18 reactions in urban soils. *Environ Sci Technol*, **47(1)**, 135-141, doi:10.1021/es301250j.
- 19 Mannke, F., 2011: Key themes of local adaptation to climate change: results from mapping community-based initiatives
20 in Africa. In: *Experiences of Climate Change Adaptation in Africa* [Walter Leal Filho (ed.)]. pp. 17-32.
- 21 Manville, M., D.A. King, and M.J. Smart, 2017: The Driving Downturn: A Preliminary Assessment. *Journal of the*
22 *American Planning Association*, **83(1)**, 42-55, doi:10.1080/01944363.2016.1247653.
- 23 Maor, M., J. Tosun, and A. Jordan, 2017: Proportionate and disproportionate policy responses to climate change: core
24 concepts and empirical applications. *Journal of Environmental Policy & Planning*, 1-13,
25 doi:10.1080/1523908X.2017.1281730.
- 26 Mapfumo, P., F. Mtambanengwe, and R. Chikowo, 2016: Building on indigenous knowledge to strengthen the capacity
27 of smallholder farming communities to adapt to climate change and variability in southern Africa. *Climate and*
28 *Development*, **8(1)**, 72-82, doi:10.1080/17565529.2014.998604.
- 29 Maréchal, K., 2010: Not irrational but habitual: The importance of "behavioural lock-in" in energy consumption.
30 *Ecological Economics*, **69(5)**, 1104-1114, doi:10.1016/j.ecolecon.2009.12.004.
- 31 Marengo, J.A. and J.C. Espinoza, 2016: Extreme seasonal droughts and floods in Amazonia: causes, trends and
32 impacts. *International Journal of Climatology*, **36(3)**, 1033-1050, doi:10.1002/joc.4420.
- 33 Marengo, J.A. et al., 2013: Recent Extremes of Drought and Flooding in Amazonia: Vulnerabilities and Human
34 Adaptation. *American Journal of Climate Change*, **02(02)**, 87-96, doi:10.4236/ajcc.2013.22009.
- 35 Margerum, R.D. and C.J. Robinson, 2015: Collaborative partnerships and the challenges for sustainable water
36 management. *Current Opinion in Environmental Sustainability*, **12**, 53-58, doi:10.1016/j.cosust.2014.09.003.
- 37 Maru, Y.T., M. Stafford Smith, A. Sparrow, P.F. Pinho, and O.P. Dube, 2014: A linked vulnerability and resilience
38 framework for adaptation pathways in remote disadvantaged communities. *Global Environmental Change*, **28**,
39 337-350, doi:10.1016/j.gloenvcha.2013.12.007.
- 40 Massey, E. and D. Huitema, 2016: The emergence of climate change adaptation as a new field of public policy in
41 Europe. *Regional Environmental Change*, **16(2)**, 553-564, doi:10.1007/s10113-015-0771-8.
- 42 Massey, E., R. Biesbroek, D. Huitema, and A. Jordan, 2014: Climate policy innovation: The adoption and diffusion of
43 adaptation policies across Europe. *Global Environmental Change*, **29**, 434-443,
44 doi:10.1016/j.gloenvcha.2014.09.002.
- 45 Mathioudakis, V., P.W. Gerbens-Leenes, T.H. Van der Meer, and A.Y. Hoekstra, 2017: The water footprint of second-
46 generation bioenergy: A comparison of biomass feedstocks and conversion techniques. *Journal of Cleaner*
47 *Production*, **148**, 571-582, doi:10.1016/J.JCLEPRO.2017.02.032.
- 48 Mathy, S., P. Criqui, K. Knoop, M. Fishedick, and S. Samadi, 2016: Uncertainty management and the dynamic
49 adjustment of deep decarbonization pathways. *Climate Policy*, **16(sup1)**, S47-S62,
50 doi:10.1080/14693062.2016.1179618.
- 51 Mavhura, E., A. Collins, and P.P. Bongo, 2017: Flood vulnerability and relocation readiness in Zimbabwe. *Disaster*
52 *Prevention and Management: An International Journal*, **26(1)**, 41-54, doi:10.1108/DPM-05-2016-0101.
- 53 Mazzucato, M., 2013: *The entrepreneurial state*. Anthem Press, London, UK and New York, NY, USA, 237 pp.
- 54 Mazzucato, M., 2018: *Mission-Oriented Research & Innovation in the European Union: A problem-solving approach*
55 *to fuel innovation-led growth*. European Commission, Brussels, Belgium, 36 pp.
- 56 Mazzucato, M. and G. Semieniuk, 2017: Public financing of innovation: new questions. *Oxford Review of Economic*
57 *Policy*, **33(1)**, 24-48, doi:10.1093/oxrep/grw036.
- 58 Mbow, C., P. Smith, D. Skole, L. Duguma, and M. Bustamante, 2014: Achieving mitigation and adaptation to climate
59 change through sustainable agroforestry practices in Africa. *Current Opinion in Environmental Sustainability*,
60 **6(1)**, 8-14, doi:10.1016/j.cosust.2013.09.002.

- 1 McCarl, B.A., C. Peacocke, R. Chrisman, C.–C. Kung, and R.D. Sands, 2009: Economics of biochar production,
2 utilization and greenhouse gas offsets. In: *Biochar for environmental management: Science and technology*.
3 Earthscan: London, UK, pp. 341-358.
- 4 McClellan, J., D.W. Keith, and J. Apt, 2012: Cost analysis of stratospheric albedo modification delivery systems.
5 *Environmental Research Letters*, **7(3)**, 034019, doi:10.1088/1748-9326/7/3/034019.
- 6 McCormick, K. and T. Käberger, 2007: Key barriers for bioenergy in Europe: Economic conditions, know-how and
7 institutional capacity, and supply chain co-ordination. *Biomass and Bioenergy*, **31(7)**, 443-452,
8 doi:10.1016/j.biombioe.2007.01.008.
- 9 McCright, A.M. and R.E. Dunlap, 2011: Cool dudes: The denial of climate change among conservative white males in
10 the United States. *Global Environmental Change*, **21(4)**, 1163-1172, doi:10.1016/j.gloenvcha.2011.06.003.
- 11 McCright, A.M., R.E. Dunlap, and C. Xiao, 2013: Perceived scientific agreement and support for government action on
12 climate change in the USA. *Climatic Change*, **119**, 511-518, doi:10.1007/s10584-013-0704-9.
- 13 McCubbin, S.G., T. Pearce, J.D. Ford, and B. Smit, 2017: Social - ecological change and implications for food security
14 in Funafuti, Tuvalu. *Ecology and Society*, **22(1)**, 53-65, doi:10.5751/ES-09129-220153.
- 15 McCusker, K.E., K.C. Armour, C.M. Bitz, and D.S. Battisti, 2014: Rapid and extensive warming following cessation of
16 solar radiation management. *Environmental Research Letters*, **9(2)**, 024005, doi:10.1088/1748-
17 9326/9/2/024005.
- 18 McGlade, C. and P. Ekins, 2015: The geographical distribution of fossil fuels unused when limiting global warming to
19 2°C. *Nature*, **517(7533)**, 187-190.
- 20 McGlashan, N., N. Shah, B. Caldecott, and M. Workman, 2012: High-level techno-economic assessment of negative
21 emissions technologies. *Process Safety and Environmental Protection*, **90(6)**, 501-510,
22 doi:10.1016/j.psep.2012.10.004.
- 23 McGranahan, G., D. Schensul, and G. Singh, 2016: Inclusive urbanization: Can the 2030 Agenda be delivered without
24 it? *Environment and Urbanization*, **28(1)**, 13-34, doi:10.1177/0956247815627522.
- 25 McKay, B., S. Sauer, B. Richardson, and R. Herre, 2016: The political economy of sugarcane flexing: initial insights
26 from Brazil, Southern Africa and Cambodia. *The Journal of Peasant Studies*, **43(1)**, 195-223,
27 doi:10.1080/03066150.2014.992016.
- 28 McKinnon, C., 2018: Sleepwalking into lock-in? Avoiding wrongs to future people in the governance of solar radiation
29 management research. *Environmental Politics*, 1-19, doi:10.1080/09644016.2018.1450344.
- 30 McLaren, D., 2012: A comparative global assessment of potential negative emissions technologies. *Special Issue:*
31 *Negative emissions technology*, **90(6)**, 489-500, doi:10.1016/j.psep.2012.10.005.
- 32 McLaren, D., 2016: Mitigation deterrence and the "moral hazard" of solar radiation management. *Earth's Future*, **4(12)**,
33 596-602, doi:10.1002/2016EF000445.
- 34 McMillen, H.L. et al., 2014: Small islands, valuable insights: Systems of customary resource use and resilience to
35 climate change in the Pacific. *Ecology and Society*, **19(4)**, doi:10.5751/ES-06937-190444.
- 36 McNamara, K.E. and S.S. Prasad, 2014: Coping with extreme weather: Communities in Fiji and Vanuatu share their
37 experiences and knowledge. *Climatic Change*, **123(2)**, 121-132, doi:10.1007/s10584-013-1047-2.
- 38 McPhearson, T. et al., 2016: Scientists must have a say in the future of cities. *Nature*, **538(7624)**, 165-166,
39 doi:10.1038/538165a.
- 40 MDB, 2016: *Joint Report on Multilateral Development Banks' Climate Finance*. 45 pp.
- 41 Measham, T.G. et al., 2011: Adapting to climate change through local municipal planning: barriers and challenges.
42 *Mitigation and Adaptation Strategies for Global Change*, **16(8)**, 889-909, doi:10.1007/s11027-011-9301-2.
- 43 Medek, D.E., J. Schwartz, and S.S. Myers, 2017: Estimated Effects of Future Atmospheric CO2 Concentrations on
44 Protein Intake and the Risk of Protein Deficiency by Country and Region. *Environmental Health Perspectives*,
45 **125(8)**, 1-8, doi:10.1289/EHP41.
- 46 Mehta, L. et al., 2014: The politics of IWRM in Southern Africa. *International Journal of Water Resources*
47 *Development*, **30(3)**, 528-542, doi:10.1080/07900627.2014.916200.
- 48 Meijer, S.S., D. Catacutan, O.C. Ajayi, G.W. Sileshi, and M. Nieuwenhuis, 2015: The role of knowledge, attitudes and
49 perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-
50 Saharan Africa. *International Journal of Agricultural Sustainability*, **13(1)**, 40-54,
51 doi:10.1080/14735903.2014.912493.
- 52 Méjean, A., F. Lecocq, and Y. Mulugetta, 2015: Equity, burden sharing and development pathways: reframing
53 international climate negotiations. *International Environmental Agreements: Politics, Law and Economics*,
54 **15(4)**, 387-402, doi:10.1007/s10784-015-9302-9.
- 55 Melde, S., F. Laczko, and F. Gemenne, 2017: *Making mobility work for adaptation to environmental changes: Results*
56 *from the MECLIP global research*. International Organization for Migration.
- 57 Melica, G. et al., 2018: Multilevel governance of sustainable energy policies: The role of regions and provinces to
58 support the participation of small local authorities in the Covenant of Mayors. *Sustainable Cities and Society*,
59 **39**, 729-739, doi:10.1016/j.scs.2018.01.013.
- 60 Melvin, A.M. et al., 2017: Climate change damages to Alaska public infrastructure and the economics of proactive

- 1 adaptation. *Proceedings of the National Academy of Sciences*, **114(2)**, E122-E131,
2 doi:10.1073/pnas.1611056113.
- 3 Mercado, L.M. et al., 2009: Impact of changes in diffuse radiation on the global land carbon sink. *Nature*, **458(7241)**,
4 1014-1017, doi:10.1038/nature07949.
- 5 Mercer, D.E., 2004: Adoption of agroforestry innovations in the tropics: A review. *Agroforestry Systems*, **61-62(1-3)**,
6 311-328, doi:10.1023/B:AGFO.0000029007.85754.70.
- 7 Mercure, J.-F. et al., 2018: Environmental impact assessment for climate change policy with the simulation-based
8 integrated assessment model E3ME-FTT-GENIE. *Energy Strategy Reviews*, **20**, 195-208,
9 doi:10.1016/j.esr.2018.03.003.
- 10 Merk, C., G. Pönitzsch, and K. Rehdanz, 2016: Knowledge about aerosol injection does not reduce individual
11 mitigation efforts. *Environmental Research Letters*, **11(5)**, 054009, doi:10.1088/1748-9326/11/5/054009.
- 12 Merk, C., G. Pönitzsch, C. Kniebes, K. Rehdanz, and U. Schmidt, 2015: Exploring public perceptions of stratospheric
13 sulfate injection. *Climatic Change*, **130(2)**, 299-312, doi:10.1007/s10584-014-1317-7.
- 14 Merrey, D.J., 2009: African models for transnational river basin organisations in Africa: An unexplored dimension.
15 *Water Alternatives*, **2(2)**, 183-204.
- 16 Methmann, C. and A. Oels, 2015: From 'fearing' to 'empowering' climate refugees: Governing climate-induced
17 migration in the name of resilience. *Security Dialogue*, **46(1)**, 51-68, doi:10.1177/0967010614552548.
- 18 Meze-Hausken, E., 2004: Contrasting climate variability and meteorological drought with perceived drought and
19 climate change in northern Ethiopia. *Climate Research*, **27**, 19-31.
- 20 Mguni, P., L. Herslund, and M.B. Jensen, 2016: Sustainable urban drainage systems: examining the potential for green
21 infrastructure-based stormwater management for Sub-Saharan cities. *Natural Hazards*, **82(S2)**, 241-257,
22 doi:10.1007/s11069-016-2309-x.
- 23 Michaelowa, A., 2013: The politics of climate change in Germany: ambition versus lobby power. *Wiley*
24 *Interdisciplinary Reviews: Climate Change*, **4(4)**, 315-320, doi:10.1002/wcc.224.
- 25 Michaelowa, A., M. Allen, and F. Sha, 2018: Policy instruments for limiting global temperature rise to 1.5°C - can
26 humanity rise to the challenge? *Climate Policy*, **18(3)**, 275-286, doi:10.1080/14693062.2018.1426977.
- 27 Michaelowa, K. and A. Michaelowa, 2017: Transnational Climate Governance Initiatives: Designed for Effective
28 Climate Change Mitigation? *International Interactions*, **43(1)**, 129-155, doi:10.1080/03050629.2017.1256110.
- 29 Midden, C. and J. Ham, 2012: Persuasive technology to promote pro-environmental behaviour. In: *Environmental*
30 *psychology: An introduction* [Steg, L., A.E. Berg, and J.I.M.E. de Groot (eds.)]. John Wiley & Sons, Oxford,
31 UK, pp. 243-254.
- 32 Middlemiss, L., 2011: The effects of community-based action for sustainability on participants' lifestyles. *Local*
33 *Environment*, **16(3)**, 265-280, doi:10.1080/13549839.2011.566850.
- 34 Mikunda, T. et al., 2014: Designing policy for deployment of CCS in industry. *Climate Policy*, **14(5)**, 665-676,
35 doi:10.1080/14693062.2014.905441.
- 36 Miles, D., 1993: Testing for Short Termism in the UK Stock Market. *The Economic Journal*, **103(421)**, 1379-1396,
37 doi:10.2307/2234472.
- 38 Milinski, M., D. Semmann, H.-J. Krambeck, and J. Marotzke, 2006: Stabilizing the Earth 's climate is not a losing
39 game :. *Proceeding of the National Academy of Sciences of the United States of America (PNAS)*, **103(11)**,
40 3994-3998.
- 41 Millard-Ball, A. and L. Schipper, 2011: Are We Reaching Peak Travel? Trends in Passenger Transport in Eight
42 Industrialized Countries. *Transport Reviews*, **31(3)**, 357-378, doi:10.1080/01441647.2010.518291.
- 43 Mills, M.P., 2015: Shale 2.0: Technology and the Coming Big-Data Revolution in America's Shale Oil Fields. *Trends*
44 *Magazine*, 21-26.
- 45 Milner, A.M. et al., 2017: Glacier shrinkage driving global changes in downstream systems. *Proceedings of the*
46 *National Academy of Sciences*, **114(37)**, 9770-9778, doi:10.1073/pnas.1619807114.
- 47 Mimura, N. et al., 2014: Adaptation Planning and Implementation. In: *Climate Change 2014: Impacts, Adaptation, and*
48 *Vulnerability. Part A: Global and Sectoral Aspects* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, and
49 M.D. Mastrandrea (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY,
50 USA, pp. 869-898.
- 51 Minville, M., F. Brissette, S. Krau, and R. Leconte, 2009: Adaptation to climate change in the management of a
52 Canadian water-resources system exploited for hydropower. *Water Resources Management*, **23(14)**, 2965-
53 2986, doi:10.1007/s11269-009-9418-1.
- 54 Minx, J., W.F. Lamb, M.W. Callaghan, L. Bornmann, and S. Fuss, 2017: Fast growing research on negative emissions.
55 *Environmental Research Letters*, **12(3)**.
- 56 Minx, J.C. et al., 2018: Negative emissions: Part 1 - research landscape and synthesis. *Environmental Research Letters*
57 (in press), doi:10.1088/1748-9326/aabf9b.
- 58 Mir-Artigues, P. and P. del Río, 2014: Combining tariffs, investment subsidies and soft loans in a renewable electricity
59 deployment policy. *Energy Policy*, **69**, 430-442, doi:10.1016/j.enpol.2014.01.040.
- 60 Mistry, J. and A. Berardi, 2016: Bridging indigenous and scientific knowledge. *Science*, **352(6291)**, 1274-1275,

- 1 doi:10.1126/science.aaf1160.
- 2 Mitchell, D. et al., 2017: Half a degree additional warming, prognosis and projected impacts (HAPPI): background and
3 experimental design. *Geoscientific Model Development*, **10(2)**, 571-583, doi:10.5194/gmd-10-571-2017.
- 4 Mitchell, R., 2013: *Agreement on the Establishment of the Limpopo Watercourse Commission*. South African
5 Department of Foreign Affairs, Office of the Chief State Law Adviser (IL), Treaty and Information
6 Management Section.
- 7 Mitlin, D., 2005: Understanding chronic poverty in urban areas. *International Planning Studies*, **10(1)**, 3-19,
8 doi:10.1080/13563470500159220.
- 9 Mitlin, D. and D. Satterthwaite, 2013: *Urban poverty in the global South: scale and nature*. Routledge, Abingdon, UK
10 and New York, NY, USA.
- 11 Mittal, S., H. Dai, and P.R. Shukla, 2016: Low carbon urban transport scenarios for China and India: A comparative
12 assessment. *Transportation Research Part D: Transport and Environment*, **44**, 266-276,
13 doi:10.1016/j.trd.2015.04.002.
- 14 Moffatt, S., 2014: Resilience and competing temporalities in cities. *Building Research & Information*, **42(2)**, 202-220,
15 doi:10.1080/09613218.2014.869894.
- 16 Möllersten, K., J. Yan, and J. R. Moreira, 2003: Potential market niches for biomass energy with CO₂ capture and
17 storage-Opportunities for energy supply with negative CO₂ emissions. *Biomass and Bioenergy*, **25(3)**, 273-
18 285, doi:https://doi.org/10.1016/S0961-9534(03)00013-8.
- 19 Monstadt, J. and A. Wolff, 2015: Energy transition or incremental change? Green policy agendas and the adaptability
20 of the urban energy regime in Los Angeles. *Energy Policy*, **78**, 213-224, doi:10.1016/j.enpol.2014.10.022.
- 21 Montserrat, F. et al., 2017: Olivine Dissolution in Seawater: Implications for CO₂ Sequestration through Enhanced
22 Weathering in Coastal Environments. *Environ Sci Technol*, **51(7)**, 3960-3972, doi:10.1021/acs.est.6b05942.
- 23 Montzka, S.A., E.J. Dlugokencky, and J.H. Butler, 2011: Non-CO₂ Greenhouse Gases and Climate Change. *Nature*,
24 **476**, 43-50, doi:10.1038/nature10322.
- 25 Mooij, R.A., 2000: *Environmental Taxation and the Double Dividend*. Emerald Group Publishing Ltd, Bingley, UK,
26 292 pp.
- 27 Moore, J.C., S. Jevrejeva, and A. Grinsted, 2010: Efficacy of geoengineering to limit 21st century sea-level rise.
28 *Proceedings of the National Academy of Sciences*, **107(36)**, 15699-15703, doi:10.1073/pnas.1008153107.
- 29 Moreno-Cruz, J.B. and D.W. Keith, 2013: Climate policy under uncertainty: a case for solar geoengineering. *Climatic
30 Change*, **121(3)**, 431-444, doi:10.1007/s10584-012-0487-4.
- 31 Morita, K. and K. Matsumoto, 2015: Financing Adaptation to Climate Change in Developing Countries. *Handbook of
32 Climate Change Adaptation*, 983-1005, doi:10.1007/978-3-642-38670-1_22.
- 33 Moriyama, R. et al., 2016: The cost of stratospheric climate engineering revisited. *Mitigation and Adaptation Strategies
34 for Global Change*, 1-22, doi:10.1007/s11027-016-9723-y.
- 35 Morrow, D.R., 2014: Starting a flood to stop a fire? Some moral constraints on solar radiation management. *Ethics,
36 Policy & Environment*, **17(2)**, 123-138, doi:10.1080/21550085.2014.926056.
- 37 Mortreux, C. and J. Barnett, 2009: Climate change, migration and adaptation in Funafuti, Tuvalu. *Global
38 Environmental Change*, **19(1)**, 105-112, doi:10.1016/j.gloenvcha.2008.09.006.
- 39 Moser, S.C., 2014: Communicating adaptation to climate change: The art and science of public engagement when
40 climate change comes home. *Wiley Interdisciplinary Reviews: Climate Change*, **5(3)**, 337-358,
41 doi:10.1002/wcc.276.
- 42 Moss, R.H. et al., 2013: Hell and High Water: Practice-Relevant Adaptation Science. *Science*, **342(6159)**, 696-698,
43 doi:10.1126/science.1239569.
- 44 Mota-Babiloni, A., P. Makhnatch, and R. Khodabandeh, 2017: Recent investigations in HFCs substitution with lower
45 GWP synthetic alternatives: Focus on energetic performance and environmental impact. *International Journal
46 of Refrigeration*, **82**, 288-301, doi:10.1016/j.ijrefrig.2017.06.026.
- 47 Mouratiadou, I. et al., 2016: The impact of climate change mitigation on water demand for energy and food: An
48 integrated analysis based on the Shared Socioeconomic Pathways. *Environmental Science & Policy*, **64**, 48-58,
49 doi:10.1016/J.ENVSCI.2016.06.007.
- 50 Mousavi, B. and M. Blesl, 2018: Analysis of the Relative Roles of Supply-Side and Demand-Side Measures in
51 Tackling the Global 1.5 °C Target. In: *Limiting Global Warming to Well Below 2 °C: Energy System
52 Modelling and Policy Development* [Giannakidis, G., K. Karlsson, M. Labriet, and B. Gallachóir (eds.)].
53 Springer International Publishing, Cham, Switzerland, pp. 67-83.
- 54 Muench, S., S. Thuss, and E. Guenther, 2014: What hampers energy system transformations? The case of smart grids.
55 *Energy Policy*, **73**, 80-92, doi:10.1016/J.ENPOL.2014.05.051.
- 56 Mullaney, J., T. Lucke, and S.J. Trueman, 2015: A review of benefits and challenges in growing street trees in paved
57 urban environments. *Landscape and Urban Planning*, **134**, 157-166, doi:10.1016/j.landurbplan.2014.10.013.
- 58 Mulville, M., K. Jones, G. Huebner, and J. Powell-Greig, 2017: Energy-saving occupant behaviours in offices: change
59 strategies. *Building Research & Information*, **45(8)**, 861-874, doi:10.1080/09613218.2016.1212299.
- 60 Munck, J., J.G. Rozema, and L.A. Frye-levine, 2014: Institutional inertia and climate change: a review of the new

- 1 institutionalist literature. *WIREs Clim Change*, **5(October)**, 639-648, doi:10.1002/wcc.292.
- 2 Mundaca, L., 2007: Transaction costs of Tradable White Certificate schemes : The Energy Efficiency Commitment as
3 case study. *Energy Policy*, **35**, 4340-4354, doi:10.1016/j.enpol.2007.02.029.
- 4 Mundaca, L. and A. Markandya, 2016: Assessing regional progress towards a 'Green Energy Economy'. *Applied*
5 *Energy*, **179**, 1372-1394, doi:10.1016/j.apenergy.2015.10.098.
- 6 Murphy, A.G., J. Hartell, V. Cárdenas, and J.R. Skees, 2012: *Risk Management Instruments for Food Price Volatility*
7 *and Weather Risk in Latin America and the Caribbean: The Use of Risk Management Instruments*. Discussion
8 Paper, Inter-American Development Bank, 110 pp.
- 9 Murrant, D., A. Quinn, and L. Chapman, 2015: The water-energy nexus: Future water resource availability and its
10 implications on UK thermal power generation. *Water and Environment Journal*, **29(3)**, 307-319,
11 doi:10.1111/wej.12126.
- 12 Musall, F.D. and O. Kuik, 2011: Local acceptance of renewable energy-A case study from southeast Germany. *Energy*
13 *Policy*, **39(6)**, 3252-3260, doi:10.1016/j.enpol.2011.03.017.
- 14 Mushtaq, S., 2016: Economic and policy implications of relocation of agricultural production systems under changing
15 climate: Example of Australian rice industry. *Land Use Policy*, **52**, 277-286,
16 doi:10.1016/J.LANDUSEPOL.2015.12.029.
- 17 Mushtaq, S., 2018: Managing climate risks through transformational adaptation: Economic and policy implications for
18 key production regions in Australia. *Climate Risk Management*, **19**, 48-60, doi:10.1016/J.CRM.2017.12.001.
- 19 Mycoo, M., 2017: *A Blue Urban Agenda: Adapting to Climate Change in the Coastal Cities of Caribbean and Pacific*
20 *Small Island Developing States*.
- 21 Myers, C.D., T. Ritter, and A. Rockway, 2017: Community Deliberation to Build Local Capacity for Climate Change
22 Adaptation: The Rural Climate Dialogues Program. In: *Climate Change Adaptation in North America:*
23 *Fostering Resilience and the Regional Capacity to Adapt* [Leal Filho, W. and J.M. Keenan (eds.)]. Springer
24 International Publishing, Cham, pp. 9-26.
- 25 Myers, T.A., E.W. Maibach, C. Roser-Renouf, K. Akerlof, and A.A. Leiserowitz, 2012: The relationship between
26 personal experience and belief in the reality of global warming. *Nature Climate Change*, **3**, 343-347,
27 doi:10.1038/nclimate1754.
- 28 Myhre, G. et al., 2013: Anthropogenic and Natural Radiative Forcing. In: *Climate Change 2013: The Physical Science*
29 *Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on*
30 *Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y.
31 Xia, V. Bex, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New
32 York, NY, USA, pp. 659-740.
- 33 Nabernegg, S. et al., 2017: The Deployment of Low Carbon Technologies in Energy Intensive Industries: A
34 Macroeconomic Analysis for Europe, China and India. *Energies*, **10(3)**, 360, doi:10.3390/en10030360.
- 35 Nadaï, A. and O. Labussière, 2017: Landscape commons, following wind power fault lines. The case of Seine-et-Marne
36 (France). *Energy Policy*, **109**, 807-816, doi:10.1016/j.enpol.2017.06.049.
- 37 Nägele, F., T. Kasper, and B. Girod, 2017: Turning up the heat on obsolete thermostats: A simulation-based comparison
38 of intelligent control approaches for residential heating systems. *Renewable and Sustainable Energy Reviews*,
39 **75(January)**, 1254-1268, doi:10.1016/j.rser.2016.11.112.
- 40 Nair, S., B. George, H.M. Malano, M. Arora, and B. Nawarathna, 2014: Water-energy-greenhouse gas nexus of urban
41 water systems: Review of concepts, state-of-art and methods. *Resources, Conservation and Recycling*, **89**, 1-
42 10, doi:10.1016/j.resconrec.2014.05.007.
- 43 Nakashima, D.J., K. Galloway McLean, H.D. Thulstrup, A. Ramos Castillo, and J.T. Rubis, 2012: *Weathering*
44 *Uncertainty: Traditional Knowledge for Climate Change Assessment and Adaptation*. UNESCO, and Darwin,
45 UNU, Paris, 120 pp.
- 46 Nakhoda, S. and C. Watson, 2016: Adaptation finance and the infrastructure agenda. Overseas Development Institute,
47 London, UK, 40 pp.
- 48 Nalau, J., B.L. Preston, and M.C. Maloney, 2015: Is adaptation a local responsibility? *Environmental Science & Policy*,
49 **48**, 89-98.
- 50 Napp, T. et al., 2017: Exploring the Feasibility of Low-Carbon Scenarios Using Historical Energy Transitions Analysis.
51 *Energies*, **10(1)**.
- 52 Napp, T.A., A. Gambhir, T.P. Hills, N. Florin, and P.S. Fennell, 2014: A review of the technologies, economics and
53 policy instruments for decarbonising energy-intensive manufacturing industries. *Renewable and Sustainable*
54 *Energy Reviews*, **30(Supplement C)**, 616-640, doi:https://doi.org/10.1016/j.rser.2013.10.036.
- 55 Natcher, D.C. et al., 2007: Notions of time and sentience: Methodological considerations for Arctic climate change
56 research. *Arctic Anthropology*, **44(2)**, 113-126, doi:10.1353/arc.2011.0099.
- 57 NCE, 2016: *The Sustainable Infrastructure Imperative: Financing for Better Grown and Development*. The New
58 Climate Economy (NCE), 1-12 pp.
- 59 NEC, 2011: *Second National Communication to the UNFCCC*. National Environment Commission, Royal Government
60 of Bhutan, Thimphu, Bhutan, 160 pp.

- 1 NEC, 2015: *Communication of INDC of the Kingdom of Bhutan*. 8 pp.
- 2 Nemet, G., 2014: Solar Photovoltaics: Multiple Drivers of Technological Improvement. In: *Energy Technology*
3 *Innovation* [Grubler, A. and C. Wilson (eds.)]. Cambridge University Press, Cambridge, UK, pp. 400.
- 4 Nemet, G.F., M. Jakob, J.C. Steckel, and O. Edenhofer, 2017: Addressing policy credibility problems for low-carbon
5 investment. *Global Environmental Change*, **42**, 47-57, doi:10.1016/j.gloenvcha.2016.12.004.
- 6 Nemet, G.F. et al., 2018: Negative emissions - Part 3: Innovation and upscaling. *Environmental Research Letters* (in
7 press), doi:10.1088/1748-9326/aabff4.
- 8 Newell, P. and M. Paterson, 1998: A Climate For Business: Global Warming, the State and Capital. *Review of*
9 *International Political Economy*, **5**, 679-703.
- 10 Newell, R.G. and W.A. Pizer, 2003: Regulating stock externalities under uncertainty. *Journal of Environmental*
11 *Economics and Management*, **45(2)**, 416-432, doi:10.1016/S0095-0696(02)00016-5.
- 12 Newham, M. and B. Conradie, 2013: A Critical Review of South Africa's Carbon Tax Policy Paper: Recommendations
13 for the Implementation of an Offset Mechanism. CSSR Working Paper.
- 14 Newman, P., 2017: Decoupling Economic Growth from Fossil Fuels. *Modern Economy*, **08(06)**, 791-805.
- 15 Newman, P. and J. Kenworthy, 2011: Peak Car Use: Understanding the Demise of Automobile Dependence. *Journal of*
16 *World Transport Policy and Practice*, **17(2)**, 31-42.
- 17 Newman, P. and J. Kenworthy, 2015: The End of Automobile Dependence: How Cities are Moving Beyond Car-based
18 Planning. In: *The End of Automobile Dependence*. Island Press/Center for Resource Economics, Washington,
19 DC, pp. 201-226.
- 20 Newman, P., L. Kosonen, and J. Kenworthy, 2016: Theory of urban fabrics: planning the walking, transit/public
21 transport and automobile/motor car cities for reduced car dependency. *Town Planning Review*, **87(4)**, 429-458,
22 doi:10.3828/tp.2016.28.
- 23 Newman, P., T. Beatley, and H. Boyer, 2017: *Resilient Cities: Overcoming Fossil Fuel Dependence*. Island Press,
24 Washington DC, USA, 264 pp.
- 25 Ngendakumana, S. et al., 2017: Implementing REDD+ : learning from forest conservation policy and social safeguards
26 frameworks in Cameroon. *International Forestry Review*, **19(2)**, 209-223, doi:10.1505/146554817821255187.
- 27 Nguyen, T.T.T., P.J. Bowman, M. Haile-Mariam, J.E. Pryce, and B.J. Hayes, 2016: Genomic selection for tolerance to
28 heat stress in Australian dairy cattle. *Journal of Dairy Science*, **99(4)**, 2849-2862, doi:10.3168/jds.2015-9685.
- 29 Nicholson, S., 2013: The Promises and Perils of Geoengineering. In: *State of the World 2013: Is Sustainability Still*
30 *Possible?* [Worldwatch Institute (ed.)]. Island Press/Center for Resource Economics, Washington DC, USA,
31 pp. 317-331.
- 32 Nicholson, S., S. Jinnah, and A. Gillespie, 2018: Solar radiation management: a proposal for immediate polycentric
33 governance. *Climate Policy*, **18(3)**, 322-334, doi:10.1080/14693062.2017.1400944.
- 34 Nicolson, M., G. Huebner, and D. Shipworth, 2017: Are consumers willing to switch to smart time of use electricity
35 tariffs? The importance of loss-aversion and electric vehicle ownership. *Energy Research and Social Science*,
36 **23**, 82-96, doi:10.1016/j.erss.2016.12.001.
- 37 Niemeier, U. and C. Timmreck, 2015: What is the limit of climate engineering by stratospheric injection of SO₂?
38 *Atmospheric Chemistry and Physics*, **15(16)**, 9129-9141, doi:10.5194/acp-15-9129-2015.
- 39 Nierop, S.C.A., 2014: Envisioning resilient electrical infrastructure: A policy framework for incorporating future
40 climate change into electricity sector planning. *Environmental Science and Policy*, **40**,
41 doi:10.1016/j.envsci.2014.04.011.
- 42 Nieto, J., Carpintero, and L.J. Miguel, 2018: Less than 2 °C? An Economic-Environmental Evaluation of the Paris
43 Agreement. *Ecological Economics*, **146**, 69-84, doi:10.1016/j.ecolecon.2017.10.007.
- 44 Nightingale, A.J., 2017: Power and politics in climate change adaptation efforts: Struggles over authority and
45 recognition in the context of political instability. *Geoforum*, **84**, 11-20, doi:10.1016/j.geoforum.2017.05.011.
- 46 Nijland, H. and J. Meerkerk, 2017: Environmental Innovation and Societal Transitions Mobility and environmental
47 impacts of car sharing in the Netherlands. *Environmental Innovation and Societal Transitions*, **23**, 84-91,
48 doi:10.1016/j.eist.2017.02.001.
- 49 Nikiforos, M. and G. Zezza, 2017: Stock-flow Consistent Macroeconomic Models: A Survey. LEI Working Paper No.
50 891, 71 pp.
- 51 Nissinen, A. et al., 2015: Combinations of policy instruments to decrease the climate impacts of housing, passenger
52 transport and food in Finland. *Journal of Cleaner Production*, **107**, 455-466,
53 doi:10.1016/j.jclepro.2014.08.095.
- 54 NITI Aayog and RMI, 2017: *India Leaps Ahead: Transformative Mobility Solutions for All*. NITI Aayog and Rocky
55 Mountain Institute (RMI), New Delhi and Colorado, 134 pp.
- 56 Nitschke, M., A. Krackowizer, L.A. Hansen, P. Bi, and R.G. Tucker, 2017: Heat Health Messages: A Randomized
57 Controlled Trial of a Preventative Messages Tool in the Older Population of South Australia. *International*
58 *Journal of Environmental Research and Public Health*, **14(9)**, doi:10.3390/ijerph14090992.
- 59 Nitschke, M. et al., 2016: Evaluation of a heat warning system in Adelaide, South Australia, using case-series analysis.
60 *BMJ open*, **6(7)**, e012125, doi:10.1136/bmjopen-2016-012125.

- 1 Noble, I. et al., 2014: Adaptation needs and options. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability.*
2 *Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the*
3 *Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D.
4 Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N.
5 Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge,
6 United Kingdom and New York, NY, USA, pp. 659-708.
- 7 Nolan, J.M., P.W. Schultz, R.B. Cialdini, N.J. Goldstein, and V. Griskevicius, 2008: Normative Social Influence is
8 Underdetected. *Personality and Social Psychology Bulletin*, **34(7)**, 913-923, doi:10.1177/0146167208316691.
- 9 Noppers, E.H., K. Keizer, J.W. Bolderdijk, and L. Steg, 2014: The adoption of sustainable innovations : Driven by
10 symbolic and environmental motives. *Global Environmental Change*, **25**, 52-62.
- 11 Nordhaus, W., 2015: Climate clubs: Overcoming free-riding in international climate policy. *American Economic*
12 *Review*, **105(4)**, 1339-1370, doi:10.1257/aer.15000001.
- 13 North, D.C., 1990: *Institutions, institutional change and economic performance*. Cambridge University Press,
14 Cambridge, UK, 152 pp.
- 15 Nowak, D.J., D.E. Crane, and J.C. Stevens, 2006: Air pollution removal by urban trees and shrubs in the United States.
16 *Urban Forestry & Urban Greening*, **4(3-4)**, 115-123, doi:10.1016/j.ufug.2006.01.007.
- 17 NPCC, 2015: *A Knowledge Base for Climate Resilience in New York City: Post-Hurricane Sandy Science and*
18 *Assessment*.
- 19 NRC, 2015a: *Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration*. National Academies Press,
20 Washington DC, USA, 154 pp.
- 21 NRC, 2015b: *Climate Intervention: Reflecting Sunlight to Cool Earth*. National Research Council (NRC). The National
22 Academies Press, Washington DC, USA, 260 pp.
- 23 NRC, 2015c: Governance of Research and Other Sociopolitical Considerations. In: *Climate Intervention: Reflecting*
24 *Sunlight to Cool Earth*. The National Academies Press, Washington DC, USA, pp. 149-175.
- 25 Nunn, P.D., J. Runman, M. Falanruw, and R. Kumar, 2017: Culturally grounded responses to coastal change on islands
26 in the Federated States of Micronesia, northwest Pacific Ocean. *Regional Environmental Change*, **17(4)**, 959-
27 971, doi:10.1007/s10113-016-0950-2.
- 28 Nurse, L.A. et al., 2014: Small islands. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B:*
29 *Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental*
30 *Panel of Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M.
31 Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R.
32 Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New
33 York, NY, USA, pp. 1613-1654.
- 34 Nyagwambo, N.L., E. Chonguica, D. Cox, and F. Monggae, 2008: *Local Governments and IWRM in the SADC Region*.
35 Institute of Water and Sanitation Development (IWSD), Harare, Zimbabwe, 58 pp.
- 36 Nyantakyi-Frimpong, H. and R. Bezner-Kerr, 2015: The relative importance of climate change in the context of
37 multiple stressors in semi-arid Ghana. *Global Environmental Change*, **32**, 40-56,
38 doi:10.1016/j.gloenvcha.2015.03.003.
- 39 NYC Parks, 2010: *Designing the Edge: Creating a Living Urban Shore at Harlem River Park*. NYC Department of
40 Parks & Recreation, Metropolitan Waterfront Alliance, Harlem River Park Task Force, NY Department of
41 State Division of Coastal Resources, New York, NY, USA, 52 pp.
- 42 Nyholm, E., M. Odenberger, and F. Johnsson, 2017: An economic assessment of distributed solar PV generation in
43 Sweden from a consumer perspective - The impact of demand response. *Renewable Energy*, **108(Supplement**
44 **C)**, 169-178, doi:https://doi.org/10.1016/j.renene.2017.02.050.
- 45 Nykvist, B. and M. Nilsson, 2015: Rapidly falling costs of battery packs for electric vehicles. *Nature Climate Change*,
46 **5(4)**, 329-332.
- 47 Nyong, A., F. Adesina, and B. Osman Elasha, 2007: The value of indigenous knowledge in climate change mitigation
48 and adaptation strategies in the African Sahel. *Mitigation and Adaptation Strategies for Global Change*, **12(5)**,
49 787-797, doi:10.1007/s11027-007-9099-0.
- 50 Obergassel, W. et al., 2016: *Phoenix from the Ashes - An Analysis of the Paris Agreement to the United Nations*
51 *Framework Convention on Climate Change - Part II*. Wuppertal Institute for Climate, Environment and
52 Energy, Wuppertal, 10 pp.
- 53 Ockwell, D. and R. Byrne, 2016: Improving technology transfer through national systems of innovation: climate
54 relevant innovation-system builders (CRIBs). *Climate Policy*, **16(7)**, 836-854,
55 doi:10.1080/14693062.2015.1052958.
- 56 Ockwell, D., A. Sagar, and H. de Coninck, 2015: Collaborative research and development (R&D) for climate
57 technology transfer and uptake in developing countries: towards a needs driven approach. *Climatic Change*,
58 **131(3)**, 401-415, doi:10.1007/s10584-014-1123-2.
- 59 OECD, 2015: *Climate Finance in 2013-14 and the USD 100 billion goal: A Report by the OECD in Collaboration with*
60 *Climate Policy Initiative*. OECD Publishing, Paris, France.

- 1 OECD, 2016a: *2020 Projections of Climate Finance Towards the USD 100 Billion Goal: Technical Note*. OECD
2 Publishing, Paris, France.
- 3 OECD, 2016b: *African Economic Outlook 2016*. OECD Publishing, 400 pp.
- 4 OECD, 2017a: Investing in Climate, Investing in Growth. , 314, doi:10.1787/9789264273528-1-en.
- 5 OECD, 2017b: *Mobilising Bond Markets for a Low-Carbon Transition*. OECD Publishing, Paris, 132 pp.
- 6 OECD, 2017c: *The Next Production Revolution : Implications for Governments and Business (Summary)*. OECD
7 Publishing, Paris.
- 8 OECD/FAO, 2017: *OECD-FAO Agricultural Outlook 2017-2026*.
- 9 OECD/IEA/NEA/ITF, 2015: *Aligning Policies for a Low-carbon Economy*. OECD Publishing, Paris.
- 10 Ogunbode, C.A., Y. Liu, and N. Tausch, 2017: The moderating role of political affiliation in the link between flooding
11 experience and preparedness to reduce energy use. *Climatic Change*, doi:10.1007/s10584-017-2089-7.
- 12 O'Hare, P., I. White, and A. Connelly, 2016: Insurance as maladaptation: Resilience and the 'business as usual' paradox.
13 *Environment and Planning C: Government and Policy*, **34(6)**, 1175-1193, doi:10.1177/0263774X15602022.
- 14 Ohndorf, M., J. Blasch, and R. Schubert, 2015: Emission budget approaches for burden sharing: some thoughts from an
15 environmental economics point of view. *Climatic Change*, **133(3)**, 385-395, doi:10.1007/s10584-015-1442-y.
- 16 Ölander, F. and J. Thøgersen, 2014: Informing Versus Nudging in Environmental Policy. *Journal of Consumer Policy*,
17 **37(3)**, 341-356, doi:10.1007/s10603-014-9256-2.
- 18 Oldenbroek, V., L.A. Verhoef, and A.J.M. van Wijk, 2017: Fuel cell electric vehicle as a power plant: Fully renewable
19 integrated transport and energy system design and analysis for smart city areas. *International Journal of*
20 *Hydrogen Energy*, **42(12)**, 8166-8196, doi:10.1016/j.ijhydene.2017.01.155.
- 21 O'Leary, J.K. et al., 2017: The Resilience of Marine Ecosystems to Climatic Disturbances. *BioScience*, **67(3)**, 208-220,
22 doi:10.1093/biosci/biw161.
- 23 Oliver, T.H. and M.D. Morecroft, 2014: Interactions between climate change and land use change on biodiversity:
24 attribution problems, risks, and opportunities. *Wiley Interdisciplinary Reviews: Climate Change*, **5(3)**, 317-
25 335, doi:10.1002/wcc.271.
- 26 O'Neill, B.C. et al., 2015: The roads ahead: Narratives for shared socioeconomic pathways describing world futures in
27 the 21st century. *Global Environmental Change*, **42(January)**, 169-180, doi:10.1016/j.gloenvcha.2015.01.004.
- 28 O'Neill, B.C. et al., 2017: IPCC reasons for concern regarding climate change risks. *Nature Climate Change*, **7(1)**,
29 doi:10.1038/nclimate3179.
- 30 O'Neill, S. and S. Nicholson-Cole, 2009: "Fear Won't Do It" Visual and Iconic Representations. *Science*
31 *Communication*, **30(3)**, 355-379.
- 32 O'Neill, S.J., M. Boykoff, S. Niemeyer, and S.A. Day, 2013: On the use of imagery for climate change engagement.
33 *Global Environmental Change*, **23**, 413-421.
- 34 OneNYC Team, 2015: *One New York: The Plan for a Strong and Just City*. Office of the Mayor of New York City,
35 New York, NY, USA, 354 pp.
- 36 Opio, C. et al., 2013: Greenhouse gas emissions from ruminant supply chains-A global life cycle assessment. *Food and*
37 *agriculture organization of the United Nations (FAO), Rome*, 1-214.
- 38 Osbaldiston, R. and J.P. Schott, 2012: Environmental Sustainability and Behavioral Science: Meta-Analysis of
39 Proenvironmental Behavior Experiments. *Environment and Behavior*, **44(2)**, 257-299,
40 doi:10.1177/0013916511402673.
- 41 Osei, P.D., 2007: Policy responses, institutional networks management and post-Hurricane Ivan reconstruction in
42 Jamaica. *Disaster Prevention and Management: An International Journal*, **16(2)**, 217-234.
- 43 Ostrom, E., 2009: A general framework for analyzing sustainability of social-ecological systems. *Science*, **325(5939)**,
44 419-422, doi:10.1126/science.1172133.
- 45 Ostrom, E. and J. Walker (eds.), 2005: *Trust and Reciprocity: Interdisciplinary Lessons for Experimental Research*.
46 Russell Sage Foundation, New York, NY, USA, 424 pp.
- 47 Ostrom, E., J. Burger, C.B. Field, R.B. Norgaard, and D. Policansky, 1999: Revisiting the Commons: Local Lessons,
48 Global Challenges. *Science*, **284(5412)**, 278-282, doi:10.1126/science.284.5412.278.
- 49 Oteros-Rozas, E. et al., 2015: Participatory scenario planning in place-based social-ecological research: insights and
50 experiences from 23 case studies. *Ecology and Society*, **20(4)**, doi:10.5751/es-07985-200432.
- 51 Ouyang, M. and L. Dueñas-Osorio, 2014: Multi-dimensional hurricane resilience assessment of electric power systems.
52 *Structural Safety*, **48(Supplement C)**, 15-24, doi:10.1016/j.strusafe.2014.01.001.
- 53 Overmars, K.P. et al., 2014: Estimating the opportunity costs of reducing carbon dioxide emissions via avoided
54 deforestation, using integrated assessment modelling. *Land Use Policy*, **41(Supplement C)**, 45-60,
55 doi:https://doi.org/10.1016/j.landusepol.2014.04.015.
- 56 Owen, R., 2014: *Solar radiation management: the governance of research*. 212-248 pp.
- 57 Pablo-Romero, M.P., A. Sánchez-Braza, J. Salvador-Ponce, and N. Sánchez-Labrador, 2017: An overview of feed-in
58 tariffs, premiums and tenders to promote electricity from biogas in the EU-28. *Renewable and Sustainable*
59 *Energy Reviews*, **73**, 1366-1379, doi:10.1016/j.rser.2017.01.132.
- 60 Pahl, S., J. Goodhew, C. Boomsma, and S.R.J. Sheppard, 2016: The Role of Energy Visualization in Addressing

- 1 Energy Use : Insights from the eViz Project. *Frontiers in Psychology*, **7**(February), 92,
2 doi:10.3389/fpsyg.2016.00092.
- 3 PAHO/WHO, 2016: *Strategy for Technical Cooperation with the United Kingdom Overseas Territories (UKOTs) in the*
4 *Caribbean 2016-2022*. World Health Organization Regional Office for the Americas, Washington DC, USA,
5 57 pp.
- 6 Pan, X., M. Elzen, N. Höhne, F. Teng, and L. Wang, 2017: Exploring fair and ambitious mitigation contributions under
7 the Paris Agreement goals. *Environmental Science & Policy*, **74**, 49-56, doi:10.1016/j.envsci.2017.04.020.
- 8 Panagopoulos, T., J.A. González Duque, and M. Bostenaru Dan, 2016: Urban planning with respect to environmental
9 quality and human well-being. *Environmental Pollution*, **208**, 137-144, doi:10.1016/j.envpol.2015.07.038.
- 10 Pant, L.P., B. Adhikari, and K.K. Bhattarai, 2015: Adaptive transition for transformations to sustainability in
11 developing countries. *Current Opinion in Environmental Sustainability*, **14**, 206-212,
12 doi:10.1016/j.cosust.2015.07.006.
- 13 Panteli, M. and P. Mancarella, 2015: Influence of extreme weather and climate change on the resilience of power
14 systems: Impacts and possible mitigation strategies. *Electric Power Systems Research*, **127**, 259-270,
15 doi:10.1016/j.eprsr.2015.06.012.
- 16 Panteli, M., D.N. Trakas, P. Mancarella, and N.D. Hatzigiorgiou, 2016: Boosting the Power Grid Resilience to Extreme
17 Weather Events Using Defensive Islanding. *IEEE Transactions on Smart Grid*, **7**(6), 2913-2922,
18 doi:10.1109/TSG.2016.2535228.
- 19 Papargyropoulou, E., R. Lozano, J. K. Steinberger, N. Wright, and Z. Ujang, 2014: The food waste hierarchy as a
20 framework for the management of food surplus and food waste. *Journal of Cleaner Production*, **76**, 106-115,
21 doi:10.1016/j.jclepro.2014.04.020.
- 22 Parag, Y. and B.K. Sovacool, 2016: Electricity market design for the prosumer era. *Nature Energy*, **1**(4), 16032,
23 doi:10.1038/nenergy.2016.32.
- 24 Paraiso, M.L.S. and N. Gouveia, 2015: Health risks due to pre-harvesting sugarcane burning in São Paulo State, Brazil.
25 *Revista Brasileira de Epidemiologia*, **18**(3), 691-701, doi:10.1590/1980-5497201500030014.
- 26 Pardo, P. et al., 2014: A review on high temperature thermochemical heat energy storage. *Renewable and Sustainable*
27 *Energy Reviews*, **32**, 591-610, doi:10.1016/j.rser.2013.12.014.
- 28 Parikh, K.S. and J.K. Parikh, 2016: Realizing potential savings of energy and emissions from efficient household
29 appliances in India. *Energy Policy*, **97**, 102-111, doi:10.1016/j.enpol.2016.07.005.
- 30 Parker, A., 2014: Governing solar geoengineering research as it leaves the laboratory. *Philosophical Transactions of the*
31 *Royal Society A: Mathematical, Physical and Engineering Sciences*, **372**(2031), 20140173-20140173,
32 doi:10.1098/rsta.2014.0173.
- 33 Parkes, B., A. Challinor, and K. Nicklin, 2015: Crop failure rates in a geoengineered climate: impact of climate change
34 and marine cloud brightening. *Environmental Research Letters*, **10**(8), 084003, doi:10.1088/1748-
35 9326/10/8/084003.
- 36 Parkhill, K., N. Pidgeon, A. Corner, and N. Vaughan, 2013: Deliberation and Responsible Innovation: A
37 Geoengineering Case Study. In: *Responsible Innovation* [Owen, R., J. Bessant, and M. Heintz (eds.)]. John
38 Wiley & Sons Ltd, Chichester, UK, pp. 219-239.
- 39 Parkinson, S.C. and N. Djilali, 2015: Robust response to hydro-climatic change in electricity generation planning.
40 *Climatic Change*, **130**(4), 475-489, doi:10.1007/s10584-015-1359-5.
- 41 Parnell, S., 2015: Fostering Transformative Climate Adaptation and Mitigation in the African City: Opportunities and
42 Constraints of Urban Planning. In: *Urban Vulnerability and Climate Change in Africa: A Multidisciplinary*
43 *Approach*. Springer, Cham, Switzerland, pp. 349-367.
- 44 Parry, I.W.H., D. Evans, and W.E. Oates, 2014: Are energy efficiency standards justified? *Journal of Environmental*
45 *Economics and Management*, **67**(2), 104-125, doi:10.1016/j.jeem.2013.11.003.
- 46 Parson, E.A., 2017: Starting the Dialogue on Climate Engineering Governance: A World Commission. Fixing Climate
47 Governance Series Policy Brief No. 8, Centre for International Governance Innovation, Waterloo.
- 48 Pasimeni, M.R. et al., 2014: Scales, strategies and actions for effective energy planning: A review. *Energy Policy*, **65**,
49 165-174, doi:10.1016/j.enpol.2013.10.027.
- 50 Pasquini, L., G. Ziervogel, R.M. Cowling, and C. Shearing, 2015: What enables local governments to mainstream
51 climate change adaptation? Lessons learned from two municipal case studies in the Western Cape, South
52 Africa. *Climate and Development*, **7**(1), 60-70, doi:10.1080/17565529.2014.886994.
- 53 Patel, R., G. Walker, M. Bhatt, and V. Pathak, 2017: The Demand for Disaster Microinsurance for Small Businesses in
54 Urban Slums: The Results of Surveys in Three Indian Cities. *PLOS Currents Disasters*, **9**,
55 doi:10.1371/currents.dis.83315629ac7cae7e2c4f78c589a3ce1c.
- 56 Patt, A., 2017: Beyond the tragedy of the commons: Reframing effective climate change governance. *Energy Research*
57 *& Social Science*, **34**, 1-3, doi:10.1016/j.erss.2017.05.023.
- 58 Patt, A.G. and D. Schröter, 2008: Perceptions of climate risk in Mozambique: Implications for the success of adaptation
59 strategies. *Global Environmental Change*, **18**(3), 458-467, doi:10.1016/j.gloenvcha.2008.04.002.
- 60 Pattanayak, S.K., D.E. Mercer, E. Sills, and J.C. Yang, 2003: Taking stock of agroforestry adoption studies.

- 1 *Agroforestry Systems*, **57(3)**, 173-186, doi:10.1023/A:1024809108210.
- 2 Patterson, J.J. et al., 2018: Political feasibility of 1.5 C societal transformations: the role of social justice. *Current*
- 3 *Opinion in Environmental Sustainability*, **31**, 1-9, doi:10.1016/j.cosust.2017.11.002.
- 4 Paul, K.I. et al., 2016: Managing reforestation to sequester carbon, increase biodiversity potential and minimize loss of
- 5 agricultural land. *Land Use Policy*, **51**, 135-149, doi:https://doi.org/10.1016/j.landusepol.2015.10.027.
- 6 Pauw, W.P., R.J.T. Klein, P. Vellinga, and F. Biermann, 2016a: Private finance for adaptation: do private realities meet
- 7 public ambitions? *Climatic Change*, **134(4)**, 489-503, doi:10.1007/s10584-015-1539-3.
- 8 Pauw, W.P. et al., 2016b: NDC Explorer. <https://klimalog.die-gdi.de/ndc> (Accessed: 14 December 2017).
- 9 Pauw, W.P. et al., 2018: Beyond headline mitigation numbers: we need more transparent and comparable NDCs to
- 10 achieve the Paris Agreement on climate change. *Climatic Change*, **147(1-2)**, 23-29, doi:10.1007/s10584-017-
- 11 2122-x.
- 12 Peake, S. and P. Ekins, 2017: Exploring the financial and investment implications of the Paris Agreement. *Climate*
- 13 *Policy*, **17(7)**, 832-852, doi:10.1080/14693062.2016.1258633.
- 14 Pearce, T., J. Ford, A.C. Willox, and B. Smit, 2015: Inuit Traditional Ecological Knowledge (TEK), Subsistence
- 15 Hunting and Adaptation to Climate Change in the Canadian Arctic. *Arctic*, **68(2)**, 233-245.
- 16 Pearce, T., R. Currenti, A. Mateiwai, and B. Doran, 2017: Adaptation to climate change and freshwater resources in
- 17 Vusama village, Viti Levu, Fiji. *Regional Environmental Change*, 1-10, doi:10.1007/s10113-017-1222-5.
- 18 Pearce, T.C.L., 2018: Incorporating Indigenous Knowledge in Research. In: *Routledge Handbook of Environmental*
- 19 *Migration and Displacement* [McLeman, R. and F. Gemenne (eds.)]. Taylor & Francis Group, New York and
- 20 London, pp. 125-134.
- 21 Pellegrino, M., M. Simonetti, and G. Chiesa, 2016: Reducing thermal discomfort and energy consumption of Indian
- 22 residential buildings: Model validation by in-field measurements and simulation of low-cost interventions.
- 23 *Energy and Buildings*, **113**, 145-158, doi:10.1016/j.enbuild.2015.12.015.
- 24 Pelletier, L.G., K.M. Tuson, I. Green-Demers, K. Noels, and A.M. Beaton, 1998: Why Are You Doing Things for the
- 25 Environment? The Motivation Toward the Environment Scale (MTES). *Journal of Applied Social Psychology*,
- 26 **28(5)**, 437-468, doi:10.1111/j.1559-1816.1998.tb01714.x.
- 27 Pelling, M., K. O'Brien, and D. Matyas, 2015: Adaptation and transformation. *Climatic Change*, **133(1)**, 113-127,
- 28 doi:10.1007/s10584-014-1303-0.
- 29 Pelling, M. et al., 2018: Africa's urban adaptation transition under a 1.5° climate. *Current Opinion in Environmental*
- 30 *Sustainability*, **31**, 10-15, doi:10.1016/j.cosust.2017.11.005.
- 31 Peng, J. et al., 2016: Markedly enhanced absorption and direct radiative forcing of black carbon under polluted urban
- 32 environments. *Proceedings of the National Academy of Sciences of the United States of America*, 1602310113-
- 33 , doi:10.1073/pnas.1602310113.
- 34 Perlaviciute, G. and L. Steg, 2014: Contextual and psychological factors shaping evaluations and acceptability of
- 35 energy alternatives: Integrated review and research agenda. *Renewable and Sustainable Energy Reviews*, **35**,
- 36 361-381, doi:10.1016/j.rser.2014.04.003.
- 37 Perrels, A., T. Frei, F. Espejo, L. Jamin, and A. Thomalla, 2013: Socio-economic benefits of weather and climate
- 38 services in Europe. *Advances in Science & Research*, doi:10.5194/asr-1-1-2013.
- 39 Perrier, Q., 2016: A robust nuclear strategy for France.
- 40 Persson, U.M., 2015: The impact of biofuel demand on agricultural commodity prices: a systematic review. *Wiley*
- 41 *Interdisciplinary Reviews: Energy and Environment*, **4(5)**, 410-428, doi:10.1002/wene.155.
- 42 Perugini, L. et al., 2017: Biophysical effects on temperature and precipitation due to land cover change. *Environmental*
- 43 *Research Letters*, **12(5)**, doi:10.1088/1748-9326/aa6b3f.
- 44 Peters, A.M., E. van der Werff, and L. Steg, 2018: Beyond purchasing: Electric vehicle adoption motivation and
- 45 consistent sustainable energy behaviour in the Netherlands. *Energy Research & Social Science*, **39**, 234-247.
- 46 Peters, G.P. and O. Geden, 2017: Catalysing a political shift from low to negative carbon. *Nature Clim. Change*, **7(9)**,
- 47 619-621, doi:10.1038/nclimate3369.
- 48 Peters, G.P. et al., 2017: Key indicators to track current progress and future ambition of the Paris Agreement. *Nature*
- 49 *Climate Change*, **7(2)**, 118-122, doi:10.1038/nclimate3202.
- 50 Pfeiffer, A., R. Millar, C. Hepburn, and E. Beinhocker, 2016: The '2°C capital stock' for electricity generation:
- 51 Committed cumulative carbon emissions from the electricity generation sector and the transition to a green
- 52 economy. *Applied Energy*, **179**, 1395-1408, doi:10.1016/j.apenergy.2016.02.093.
- 53 Pfeiffer, L. and C.-Y.C. Lin, 2014: Does efficient irrigation technology lead to reduced groundwater extraction?
- 54 Empirical evidence. *Journal of Environmental Economics and Management*, **67(2)**, 189-208,
- 55 doi:10.1016/j.jeem.2013.12.002.
- 56 Philibert, C., 2017: *Renewable Energy for Industry. From green energy to green materials and fuels*. IEA, Paris,
- 57 France, 72 pp.
- 58 Pichert, D. and K. Katsikopoulos, 2008: Green defaults: Information presentation and pro-environmental behaviour.
- 59 *Journal of Environmental Psychology*, **28(1)**, 63-73, doi:10.1016/j.jenvp.2007.09.004.
- 60 Pichler, A. and E. Striessnig, 2013: Differential vulnerability to hurricanes in Cuba, Haiti, and the Dominican Republic:

- 1 the contribution of education. *Ecology and society*, **18(3)**.
- 2 Pichler, M., A. Schaffartzik, H. Haberl, and C. Görg, 2017: Drivers of society-nature relations in the Anthropocene and
3 their implications for sustainability transformations. *Current Opinion in Environmental Sustainability*, **26-27**,
4 32-36, doi:10.1016/j.cosust.2017.01.017.
- 5 Pickering, N.K. et al., 2015: Animal board invited review: genetic possibilities to reduce enteric methane emissions
6 from ruminants. *animal*, **9(09)**, 1431-1440, doi:10.1017/S1751731115000968.
- 7 Pielke, R.A., 2009: An idealized assessment of the economics of air capture of carbon dioxide in mitigation policy.
8 *environmental science & policy*, **12(3)**, 216-225.
- 9 Pierpaoli, E., G. Carli, E. Pignatti, and M. Canavari, 2013: Drivers of Precision Agriculture Technologies Adoption: A
10 Literature Review. *Procedia Technology*, **8(Haicta)**, 61-69, doi:10.1016/j.protcy.2013.11.010.
- 11 Pierrehumbert, R.T., 2014: Short-Lived Climate Pollution. *Annual Review of Earth and Planetary Sciences*, **42**, 341-79,
12 doi:10.1146/annurev-earth-060313-054843.
- 13 Piketty, T., 2014: *Capital in the Twenty-first Century*. The Belknap Press of Harvard University Press, Cambridge, MA,
14 USA, 696 pp.
- 15 Pindyck, 2017: The Use and Misuse of Models for Climate Policy. *Review of Environmental Economics and Policy*,
16 **11(1)**, 100-114.
- 17 Pinho, P.F., J.A. Marengo, and M.S. Smith, 2015: Complex socio-ecological dynamics driven by extreme events in the
18 Amazon. *Regional Environmental Change*, **15(4)**, doi:10.1007/s10113-014-0659-z.
- 19 Pinho, P.F. et al., 2014: Ecosystem protection and poverty alleviation in the tropics: Perspective from a historical
20 evolution of policy-making in the Brazilian Amazon. *Ecosystem Services*, **8**, 97-109,
21 doi:10.1016/j.ecoser.2014.03.002.
- 22 Pisano, I. and M. Lubell, 2017: Environmental Behavior in Cross-National Perspective : A Multilevel Analysis of 30
23 Countries. *Environment & Behavior*, **49(1)**, 31-58, doi:10.1177/0013916515600494.
- 24 Pitari, G. et al., 2014: Stratospheric ozone response to sulfate geoengineering: Results from the Geoengineering Model
25 Intercomparison Project (GeoMIP). *Journal of Geophysical Research: Atmospheres*, **119(5)**, 2629-2653,
26 doi:10.1002/2013JD020566.
- 27 Pittelkow, C.M. et al., 2014: Productivity limits and potentials of the principles of conservation agriculture. *Nature*,
28 **517(7534)**, 365-368, doi:10.1038/nature13809.
- 29 Pittock, J., H. Bjornlund, R. Stirzaker, and A. van Rooyen, 2017: Communal irrigation systems in South-Eastern
30 Africa: findings on productivity and profitability. *International Journal of Water Resources Development*,
31 **33(5)**, 839-847, doi:10.1080/07900627.2017.1324768.
- 32 Pizer, W.A., 2002: Combining price and quantity controls to mitigate global climate change. *Journal of Public*
33 *Economics*, **85(3)**, 409-434, doi:10.1016/S0047-2727(01)00118-9.
- 34 Place, F. et al., 2012: Improved Policies for Facilitating the Adoption of Agroforestry. *Agroforestry for Biodiversity and*
35 *Ecosystem Services - Science and Practice*, doi:10.5772/34524.
- 36 Platanga, A. and B. Scholtens, 2016: *The Financial Impact of Divestment from Fossil Fuels*. 47 pp.
- 37 Plazzotta, M., R. Séférian, H. Douville, B. Kravitz, and J. Tjiputra, 2018: Land surface cooling induced by sulfate
38 geoengineering constrained by major volcanic eruptions. *Geophysical Research Letters*,
39 doi:10.1029/2018GL077583.
- 40 Plevin, R.J., M. O'Hare, A.D. Jones, M.S. Torn, and H.K. Gibbs, 2010: Greenhouse Gas Emissions from Biofuels'
41 Indirect Land Use Change Are Uncertain but May Be Much Greater than Previously Estimated. *Environmental*
42 *Science & Technology*, **44(21)**, 8015-8021, doi:10.1021/es101946t.
- 43 Poeplau, C. and A. Don, 2015: Carbon sequestration in agricultural soils via cultivation of cover crops - A meta-
44 analysis. *Agriculture, Ecosystems & Environment*, **200**, 33-41, doi:https://doi.org/10.1016/j.agee.2014.10.024.
- 45 Poff, N.L.R. et al., 2016: Sustainable water management under future uncertainty with eco-engineering decision
46 scaling. *Nature Climate Change*, **6(1)**, 25-34, doi:10.1038/nclimate2765.
- 47 Pollak, M., B. Meyer, and E. Wilson, 2011: Reducing greenhouse gas emissions: Lessons from state climate action
48 plans. *Energy Policy*, **39(9)**, 5429-5439, doi:10.1016/j.enpol.2011.05.020.
- 49 Pollitt, H., 2018: Policies for limiting climate change to well below 2°C. (in press).
- 50 Pollitt, H. and J.-F. Mercure, 2017: The role of money and the financial sector in energy-economy models used for
51 assessing climate and energy policy. *Climate Policy*, 1-14, doi:10.1080/14693062.2016.1277685.
- 52 Poortinga, W., L. Steg, and C. Vlek, 2002: Environmental Risk Concern and Preferences for Energy-Saving Measures.
53 *Environment & Behavior*, **34(4)**, 455-478.
- 54 Poortinga, W., L. Steg, C. Vlek, and G. Wiersma, 2003: Household preferences for energy-saving measures: A conjoint
55 analysis. *Journal of Economic Psychology*, **24(1)**, 49-64.
- 56 Popp, A. et al., 2014a: Land-use protection for climate change mitigation. *Nature Climate Change*, **4(12)**, 1095-1098,
57 doi:10.1038/nclimate2444.
- 58 Popp, A. et al., 2014b: Land-use transition for bioenergy and climate stabilization: model comparison of drivers,
59 impacts and interactions with other land use based mitigation options. *Climatic Change*, **123(3-4)**, 495-509,
60 doi:10.1007/s10584-013-0926-x.

- 1 Pradhan, A., C. Chan, P.K. Roul, J. Halbrecht, and B. Sipes, 2018: Potential of conservation agriculture (CA) for
2 climate change adaptation and food security under rainfed uplands of India: A transdisciplinary approach.
3 *Agricultural Systems*, **163**, 27-35, doi:10.1016/j.agsy.2017.01.002.
- 4 Preston, B.L., J. Mustelin, and M.C. Maloney, 2013: Climate adaptation heuristics and the science/policy divide.
5 *Mitigation and Adaptation Strategies for Global Change*, **20(3)**, 467-497, doi:10.1007/s11027-013-9503-x.
- 6 Preston, B.L., L. Rickards, H. Fünfgeld, and R.J. Keenan, 2015: Toward reflexive climate adaptation research. *Current*
7 *Opinion in Environmental Sustainability*, **14**, 127-135, doi:10.1016/j.cosust.2015.05.002.
- 8 Preston, C.J., 2013: Ethics and geoengineering: reviewing the moral issues raised by solar radiation management and
9 carbon dioxide removal. *Wiley Interdisciplinary Reviews: Climate Change*, **4(1)**, 23-37, doi:10.1002/wcc.198.
- 10 Preston, C.J. (ed.), 2016: *Climate Justice and Geoengineering: Ethics and Policy in the Atmospheric Anthropocene*.
11 Rowman & Littlefield International, London, UK, 234 pp.
- 12 Pretty, J. and Z.P. Bharucha, 2014: Sustainable intensification in agricultural systems. *Annals of Botany*, **114(8)**, 1571-
13 1596, doi:10.1093/aob/mcu205.
- 14 Pretzsch, H. et al., 2017: Climate change accelerates growth of urban trees in metropolises worldwide. *Scientific*
15 *Reports*, **7(1)**, 15403, doi:10.1038/s41598-017-14831-w.
- 16 Pritchard, C., A. Yang, P. Holmes, and M. Wilkinson, 2015: Thermodynamics, economics and systems thinking: What
17 role for air capture of CO₂? *Process Safety and Environmental Protection*, **94**, 188-195,
18 doi:10.1016/j.psep.2014.06.011.
- 19 Pritoni, M., A.K. Meier, C. Aragon, D. Perry, and T. Pepper, 2015: Energy efficiency and the misuse of programmable
20 thermostats: The effectiveness of crowdsourcing for understanding household behavior. *Energy Research &*
21 *Social Science*, **8**, 190-197, doi:10.1016/j.erss.2015.06.002.
- 22 Proost, S. and D. Van Regemorter, 1995: The double dividend and the role of inequality aversion and macroeconomic
23 regimes. *International Tax and Public Finance*, **2(2)**, 207-219, doi:10.1007/BF00877497.
- 24 Pueyo, A. and R. Hanna, 2015: *What level of electricity access is required to enable and sustain poverty reduction?*
25 *Annex I Literature review*. Practical Action Consulting, Bourton-on-Dunsmore, UK, 65 pp.
- 26 Puppim de Oliveira, J.A. et al., 2013: Promoting win-win situations in climate change mitigation, local environmental
27 quality and development in Asian cities through co-benefits. *Journal of Cleaner Production*, **58**, 1-6,
28 doi:10.1016/j.jclepro.2013.08.011.
- 29 Pyörälä, P. et al., 2014: Effects of Management on Economic Profitability of Forest Biomass Production and Carbon
30 Neutrality of Bioenergy Use in Norway Spruce Stands Under the Changing Climate. *Bioenergy Research*,
31 **7(1)**, 279-294, doi:10.1007/s12155-013-9372-x.
- 32 Qazi, S. and W. Young Jr., 2014: Disaster relief management and resilience using photovoltaic energy.
- 33 Qin, Z., J.B. Dunn, H. Kwon, S. Mueller, and M.M. Wander, 2016: Soil carbon sequestration and land use change
34 associated with biofuel production: empirical evidence. *GCB Bioenergy*, **8(1)**, 66-80, doi:10.1111/gcbb.12237.
- 35 Quaas, M.F., J. Quaas, W. Rickels, and O. Boucher, 2017: Are there reasons against open-ended research into solar
36 radiation management? A model of intergenerational decision-making under uncertainty. *Journal of*
37 *Environmental Economics and Management*, **84**, 1-17, doi:10.1016/j.jeem.2017.02.002.
- 38 Quandt, A., H. Neufeldt, and J.T. McCabe, 2017: The role of agroforestry in building livelihood resilience to floods and
39 drought in semiarid Kenya. *Ecology and Society*, **22(3)**, doi:10.5751/ES-09461-220310.
- 40 Quitzow, R., 2015: Assessing policy strategies for the promotion of environmental technologies: A review of India's
41 National Solar Mission. *Research Policy*, **44(1)**, 233-243, doi:https://doi.org/10.1016/j.respol.2014.09.003.
- 42 Rabitz, F., 2016: Going rogue? Scenarios for unilateral geoengineering. *Futures*, **84**, 98-107,
43 doi:10.1016/j.futures.2016.11.001.
- 44 Radhakrishnan, M., A. Pathirana, R.M. Ashley, B. Gersonius, and C. Zevenbergen, 2018: Flexible adaptation planning
45 for water sensitive cities. *Cities*, doi:10.1016/J.CITIES.2018.01.022.
- 46 Rai, V., D.C. Reeves, and R. Margolis, 2016: Overcoming barriers and uncertainties in the adoption of residential solar
47 PV. *Renewable Energy*, **89**, 498-505, doi:10.1016/j.renene.2015.11.080.
- 48 Rajamani, L., 2016: Ambition and Differentiation in the 2015 Paris Agreement: Interpretative Possibilities and
49 Underlying Politics. *International and Comparative Law Quarterly*, **65(02)**, 493-514,
50 doi:10.1017/S0020589316000130.
- 51 Rajan, R.G., 2011: *Fault Lines: How Hidden Fractures Still Threaten the World Economy*. Princeton University Press,
52 Princeton, NJ, USA and Woodstock, UK, 280 pp.
- 53 Rakatama, A., R. Pandit, C. Ma, and S. Iftekhar, 2017: The costs and benefits of REDD+: A review of the literature.
54 *Forest Policy and Economics*, **75(Supplement C)**, 103-111, doi:https://doi.org/10.1016/j.forpol.2016.08.006.
- 55 Ramachandran, S., V. Ramaswamy, G.L. Stenchikov, and A. Robock, 2000: Radiative impact of the Mount Pinatubo
56 volcanic eruption: Lower stratospheric response. *Journal of Geophysical Research*, **105(D19)**, 24409,
57 doi:10.1029/2000JD900355.
- 58 Ramage, M.H. et al., 2017: The wood from the trees: The use of timber in construction. *Renewable and Sustainable*
59 *Energy Reviews*, **68**, 333-359, doi:10.1016/j.rser.2016.09.107.
- 60 Ramankutty, N. et al., 2018: Trends in Global Agricultural Land Use: Implications for Environmental Health and Food

- 1 Security. *Annual Review of Plant Biology*, **69(1)**, annurev-arplant-042817-040256, doi:10.1146/annurev-arplant-042817-040256.
- 2
- 3 Ran, F.A. et al., 2013: Genome engineering using the CRISPR-Cas9 system. *Nature Protocols*, **8(11)**, 2281-2308, doi:10.1038/nprot.2013.143.
- 4
- 5 Rand, J. and B. Hoen, 2017: Thirty years of North American wind energy acceptance research: What have we learned? *Energy Research & Social Science*, **29(Supplement C)**, 135-148, doi:https://doi.org/10.1016/j.erss.2017.05.019.
- 6
- 7 Ranganathan, J. et al., 2016: Shifting Diets for a Sustainable Food Future. Installment 11 of Creating a Sustainable Food Future, 90 pp.
- 8
- 9 Ranjan, M. and H.J. Herzog, 2011: Feasibility of air capture. *Energy Procedia*, **4**, 2869-2876.
- 10
- 11 Rasul, G. and B. Sharma, 2016: The nexus approach to water-energy-food security: an option for adaptation to climate change. *Climate Policy*, **16(6)**, 682-702, doi:10.1080/14693062.2015.1029865.
- 12
- 13 Rathore, D., A.-S. Nizami, A. Singh, and D. Pant, 2016: Key issues in estimating energy and greenhouse gas savings of biofuels: challenges and perspectives. *Biofuel Research Journal*, **3(2)**, 380-393, doi:10.18331/BRJ2016.3.2.3.
- 14
- 15 Rau, G.H. et al., 2013: Direct electrolytic dissolution of silicate minerals for air CO₂ mitigation and carbon-negative H₂ production.. *Proceedings of the National Academy of Sciences of the United States of America*, **110(25)**, 10095-100, doi:10.1073/pnas.1222358110.
- 16
- 17 Ray, A., L. Hughes, D.M. Konisky, and C. Kaylor, 2017: Extreme weather exposure and support for climate change adaptation. *Global Environmental Change*, **46(June)**, 104-113, doi:10.1016/j.gloenvcha.2017.07.002.
- 18
- 19 RCI, 2008: *Rotterdam Climate Proof: The Rotterdam Challenge on Water and Climate Adaptation*. Rotterdam Climate Initiative (RCI), Rotterdam, Amsterdam, 11 pp.
- 20
- 21 RCI, 2013: *Rotterdam Climate Change Adaptation Strategy*. Rotterdam Climate Initiative (RCI), Rotterdam, 70 pp.
- 22
- 23 RCI, 2017: Rotterdam Climate Initiative. <http://www.rotterdamclimateinitiative.nl> (Accessed: 23 November 2017).
- 24
- 25 Reckien, D., J. Flacke, M. Olazabal, and O. Heidrich, 2015: The Influence of drivers and barriers on urban adaptation and mitigation plans - An empirical analysis of european cities. *PLOS ONE*, **10(8)**, e0135597.
- 26
- 27 Reckien, D. et al., 2014: Climate change response in Europe: what's the reality? Analysis of adaptation and mitigation plans from 200 urban areas in 11 countries. *Climatic Change*, **122(1)**, 331-340, doi:10.1007/s10584-013-0989-8.
- 28
- 29 Reckien, D. et al., 2017: Climate change, equity and the Sustainable Development Goals: an urban perspective. *Environment & Urbanization*, **29(1)**, 159-182, doi:10.1177/0956247816677778.
- 30
- 31 Refsgaard, K. and K. Magnussen, 2009: Household behaviour and attitudes with respect to recycling food waste - experiences from focus groups. *Journal of Environmental Management*, doi:10.1016/j.jenvman.2008.01.018.
- 32
- 33 Rehmatulla, N. and T. Smith, 2015: Barriers to energy efficiency in shipping: A triangulated approach to investigate the principal agent problem. *Energy Policy*, **84(Supplement C)**, 44-57, doi:10.1016/j.enpol.2015.04.019.
- 34
- 35 Reid, H., 2016: Ecosystem- and community-based adaptation: learning from community-based natural resource management. *Climate and Development*, **8(1)**, 4-9, doi:10.1080/17565529.2015.1034233.
- 36
- 37 Reid, H. et al., 2009: Community-based adaptation to climate change: An overview. *Participatory Learning and Action*, **60**, 11-38.
- 38
- 39 REN21, 2012: *Renwables 2017: Global Status Report*. 302 pp.
- 40
- 41 Renforth, P., 2012: The potential of enhanced weathering in the UK. *International Journal of Greenhouse Gas Control*, **10**, 229-243, doi:10.1016/j.ijggc.2012.06.011.
- 42
- 43 Renforth, P. and G. Henderson, 2017: Assessing ocean alkalinity for carbon sequestration. *Reviews of Geophysics*, n/a-n/a, doi:10.1002/2016RG000533.
- 44
- 45 Repo, A., J.-P. Tuovinen, and J. Liski, 2015: Can we produce carbon and climate neutral forest bioenergy? *GCB Bioenergy*, **7(2)**, 253-262, doi:10.1111/gcbb.12134.
- 46
- 47 Revi, A., 2016: Afterwards: Habitat III and the Sustainable Development Goals. *Urbanisation*, **1(2)**, x-xiv, doi:10.1177/2455747116682899.
- 48
- 49 Revi, A., 2017: Re-imagining the United Nations ' Response to a Twenty-first-century Urban World. *Urbanisation*, **2(2)**, 1-7, doi:10.1177/2455747117740438.
- 50
- 51 Revi, A. and C. Rosenzweig, 2013: *The urban opportunity: Enabling transformative and sustainable development*.
- 52
- 53 Revi, A. et al., 2014a: Towards transformative adaptation in cities: the IPCC's Fifth Assessment. *Environment and Urbanization*, **26(1)**, 11-28.
- 54
- 55 Revi, A. et al., 2014b: Urban Areas. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 535-612.
- 56
- 57 Rey Benayas, J.M. et al., 2009: Enhancement of biodiversity and ecosystem services by ecological restoration: a meta-analysis. *Science*, **325(5944)**, 1121-4, doi:10.1126/science.1172460.
- 58
- 59
- 60

- 1 Reynolds, J.L., 2015: An Economic Analysis of Liability and Compensation for Harm from Large-Scale Field Research
2 in Solar Climate Engineering. *Climate Law*, **5(2-4)**, 182-209, doi:10.1163/18786561-00504004.
- 3 Reynolds, J.L., J.L. Contreras, and J.D. Sarnoff, 2018: Intellectual property policies for solar geoengineering. *Wiley*
4 *Interdisciplinary Reviews: Climate Change*, **9(2)**, 1-7, doi:10.1002/wcc.512.
- 5 Reynolds, T.W., A. Bostrom, D. Read, and M.G. Morgan, 2010: Now What Do People Know About Global Climate
6 Change? Survey Studies of Educated Laypeople. *Risk Analysis*, **30(10)**, 1520-1538, doi:10.1111/j.1539-
7 6924.2010.01448.x.
- 8 RGoB, 2012: The Report of the High-Level Meeting on Wellbeing and Happiness: Defining a New Economic
9 Paradigm. , 166.
- 10 RGoB, 2013: Eleventh Five Year Plan Volume I : Main Document. .
- 11 RGoB, 2016: Economic Development Policy. , 49.
- 12 Riahi, K. et al., 2015: Locked into Copenhagen pledges - Implications of short-term emission targets for the cost and
13 feasibility of long-term climate goals. *Technological Forecasting and Social Change*, **90(PA)**, 8-23,
14 doi:10.1016/j.techfore.2013.09.016.
- 15 Riahi, K. et al., 2017: The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions
16 implications: An overview. *Global Environmental Change*, **42**, 153-168,
17 doi:10.1016/j.gloenvcha.2016.05.009.
- 18 Ribeiro, H., 2008: Sugar cane burning in Brazil: respiratory health effects. *Revista de Saúde Pública*, **42(2)**, 1-6.
- 19 Rickards, L. and S.M. Howden, 2012: Transformational adaptation: agriculture and climate change. *Crop and Pasture*
20 *Science*, **63(3)**, 240, doi:10.1071/CP11172.
- 21 Ricke, K.L., J.B. Moreno-Cruz, and K. Caldeira, 2013: Strategic incentives for climate geoengineering coalitions to
22 exclude broad participation. *Environmental Research Letters*, **8(1)**, 014021, doi:10.1088/1748-
23 9326/8/1/014021.
- 24 Ricke, K.L., J.B. Moreno-Cruz, J. Schewe, A. Levermann, and K. Caldeira, 2015: Policy thresholds in mitigation.
25 *Nature Geoscience*, **9(1)**, 5-6, doi:10.1038/ngeo2607.
- 26 Ringel, M., 2017: Energy efficiency policy governance in a multi-level administration structure - evidence from
27 Germany. *Energy Efficiency*, **10(3)**, 753-776, doi:10.1007/s12053-016-9484-1.
- 28 Rinkevich, B., 2014: Rebuilding coral reefs: does active reef restoration lead to sustainable reefs? *Current Opinion in*
29 *Environmental Sustainability*, **7**, 28-36, doi:10.1016/j.cosust.2013.11.018.
- 30 Rippke, U. et al., 2016: Timescales of transformational climate change adaptation in sub-Saharan African agriculture.
31 *Nature Climate Change*, **6(6)**, 605-609, doi:10.1038/nclimate2947.
- 32 Ritzenhofen, I. and S. Spinler, 2016: Optimal design of feed-in-tariffs to stimulate renewable energy investments under
33 regulatory uncertainty - A real options analysis. *Energy Economics*, **53**, 76-89,
34 doi:10.1016/j.eneco.2014.12.008.
- 35 Rivas, S. et al., 2015: *The Covenant of Mayors: In-depth Analysis of Sustainable Energy Action Plans*. EUR 27526 EN,
36 170 pp.
- 37 Robert, A. et al., 2014: Cities and the New Climate Economy: the transformative role of global urban growth. *The New*
38 *Climate Economy (NCE)*, 1-70 pp.
- 39 Roberts, D., 2016: The New Climate Calculus: 1.5°C = Paris Agreement, Cities, Local Government, Science and
40 Champions (PLSC²). *Urbanisation*, **1(2)**, 71-78, doi:10.1177/2455747116672474.
- 41 Roberts, J.T. and B. Parks, 2006: *A climate of injustice: Global inequality, north-south politics, and climate policy*.
42 MIT press.
- 43 Roberts, J.T. and R. Weikmans, 2017: Postface: fragmentation, failing trust and enduring tensions over what counts as
44 climate finance. *International Environmental Agreements: Politics, Law and Economics*, **17(1)**, 129-137.
- 45 Roberts, J.T. et al., 2017: How Will We Pay for Loss and Damage? *Ethics, Policy & Environment*, **20(2)**, 208-226.
- 46 Robertson, J.L. and J.E. Barling, 2015: The psychology of green organizations. .
- 47 Robinson, S., 2017: Climate change adaptation trends in small island developing states. *Mitigation and Adaptation*
48 *Strategies for Global Change*, **22(4)**, 669-691.
- 49 Robinson, S.- and M. Dornan, 2017: International financing for climate change adaptation in small island developing
50 states. *Regional Environmental Change*, **17(4)**, 1103-1115, doi:10.1007/s10113-016-1085-1.
- 51 Robiou du Pont, Y. et al., 2017: Equitable mitigation to achieve the Paris Agreement goals. *Nature Climate Change*,
52 **7(1)**, 38-43, doi:10.1038/nclimate3186.
- 53 Robledo-Abad, C. et al., 2017: Bioenergy production and sustainable development: science base for policymaking
54 remains limited. *GCB Bioenergy*, **9(3)**, 541-556, doi:10.1111/gcbb.12338.
- 55 Robock, A., 2012: Is Geoengineering Research Ethical? *Peace and Security*, 1-11.
- 56 Robock, A., 2016: Albedo enhancement by stratospheric sulfur injections: More research needed. *Earth's Future*, **4(12)**,
57 644-648, doi:10.1002/2016EF000407.
- 58 Robock, A., L. Oman, and G.L. Stenchikov, 2008: Regional climate responses to geoengineering with tropical and
59 Arctic SO₂ injections. *Journal of Geophysical Research: Atmospheres*, **113(D16)**, D16101,
60 doi:10.1029/2008JD010050.

- 1 Robock, A., A. Marquardt, B. Kravitz, and G. Stenchikov, 2009: Benefits, risks, and costs of stratospheric
2 geoengineering. *Geophysical Research Letters*, **36(19)**.
- 3 Rochedo, P.R.R. et al., 2016: Carbon capture potential and costs in Brazil. *Journal of Cleaner Production*, **131**, 280-
4 295, doi:10.1016/j.jclepro.2016.05.033.
- 5 Rockström, J. et al., 2017: A roadmap for rapid decarbonization. *Science*, **355(6331)**, 1269-1271,
6 doi:10.1126/science.aah3443.
- 7 Rode, P. et al., 2014: Accessibility in Cities: Transport and Urban Form. *The New Climate Economy*, 1-61 pp.
- 8 Rodríguez, H., 2015: Risk and Trust in Institutions That Regulate Strategic Technological Innovations: Challenges for a
9 Socially Legitimate Risk Analysis. In: *New Perspectives on Technology, Values, and Ethics* [Gonzalez, W.
10 (ed.)]. Springer, Cham, pp. 147-166.
- 11 Roe, M.J., 2001: *Strong Managers, Weak Owners: The Political Roots of American Corporate Finance*. Princeton
12 University Press, Princeton, NJ, USA, 342 pp.
- 13 Roelfsema, M., M. Harmsen, J.J.G. Olivier, A.F. Hof, and D.P. van Vuuren, 2018: Integrated assessment of
14 international climate mitigation commitments outside the UNFCCC. *Global Environmental Change*, **48**, 67-
15 75, doi:10.1016/j.gloenvcha.2017.11.001.
- 16 Rogelj, J. et al., 2014: Disentangling the effects of CO₂ and short-lived climate forcer mitigation. *Proceedings of the
17 National Academy of Sciences*, **111(46)**, 16325-16330, doi:10.1073/pnas.1415631111.
- 18 Rogelj, J. et al., 2016: Perspective : Paris Agreement climate proposals need boost to keep warming well below 2 ° C.
19 *Nature*, **534(June)**, 631-639, doi:10.1038/nature18307.
- 20 Rogelj, J. et al., 2017: Understanding the origin of Paris Agreement emission uncertainties. *Nature Communications*, **8**,
21 15748, doi:10.1038/ncomms15748.
- 22 Rogers, D. and V. Tsirkunov, 2010: *Costs and Benefits of Early Warning Systems*.
- 23 Rogge, K.S., F. Kern, and M. Howlett, 2017: Conceptual and empirical advances in analysing policy mixes for energy
24 transitions. *Energy Research & Social Science*, **33**, 1-10, doi:10.1016/j.erss.2017.09.025.
- 25 Roh, S., 2017: Big Data Analysis of Public Acceptance of Nuclear Power in Korea. *Nuclear Engineering and
26 Technology*, **49(4)**, 850-854, doi:https://doi.org/10.1016/j.net.2016.12.015.
- 27 Romero-Lankao, P., S. Hughes, A. Rosas-Huerta, R. Borquez, and D.M. Gnatz, 2013: Institutional capacity for climate
28 change responses: An examination of construction and pathways in Mexico City and Santiago. *Environment
29 and Planning C: Government and Policy*, **31(5)**, 785-805, doi:10.1068/c12173.
- 30 Romero-Lankao, P. et al., 2018: Governance and policy. In: *Climate Change and Cities: Second Assessment Report of
31 the Urban Climate Change Research Network* [Rosenzweig, C., W. Solecki, P. Romero-Lankao, S. Mehrotra,
32 S. Dhakal, and S. Ali Ibrahim (eds.)]. Cambridge University Press.
- 33 Rööös, E. et al., 2017: Protein futures for Western Europe: potential land use and climate impacts in 2050. *Regional
34 Environmental Change*, **17(2)**, 367-377, doi:10.1007/s10113-016-1013-4.
- 35 Roques, F.A., D.M. Newbery, and W.J. Nuttall, 2008: Fuel mix diversification incentives in liberalized electricity
36 markets: A Mean--Variance Portfolio theory approach. *Energy Economics*, **30(4)**, 1831-1849,
37 doi:10.1016/j.eneco.2007.11.008.
- 38 Rosa, E.A. and T. Dietz, 2012: Human drivers of national greenhouse-gas emissions. *Nature Climate Change*, **2**, 581-
39 586, doi:10.1038/nclimate1506.
- 40 Rose, A., 2016: Capturing the co-benefits of disaster risk management on the private sector side. 33 pp.
- 41 Rose, S.K., R. Richels, G. Blanford, and T. Rutherford, 2017: The Paris Agreement and next steps in limiting global
42 warming. *Climatic Change*, **142(1-2)**, 255-270, doi:10.1007/s10584-017-1935-y.
- 43 Rosenbloom, D., 2017: Pathways: An emerging concept for the theory and governance of low-carbon transitions.
44 *Global Environmental Change*, **43**, 37-50, doi:10.1016/j.gloenvcha.2016.12.011.
- 45 Rosenow, J., F. Kern, and K. Rogge, 2017: The need for comprehensive and well targeted instrument mixes to
46 stimulate energy transitions: The case of energy efficiency policy. *Energy Research & Social Science*, **33**, 95-
47 104, doi:https://doi.org/10.1016/j.erss.2017.09.013.
- 48 Rosenzweig, C. and W. Solecki, 2014: Hurricane Sandy and adaptation pathways in New York: Lessons from a first-
49 responder city. *Global Environmental Change*, **28**, 395-408, doi:10.1016/J.GLOENVCHA.2014.05.003.
- 50 Rosenzweig, C. et al., 2015: *ARC3.2 Summary for city leaders*. Urban Climate Change Research Network. Columbia
51 University, New York, NY, USA, 28 pp.
- 52 Roser, D., C. Huggel, M. Ohndorf, and I. Wallimann-Helmer, 2015: Advancing the interdisciplinary dialogue on
53 climate justice. *Climatic Change*, **133(3)**, 349-359, doi:10.1007/s10584-015-1556-2.
- 54 Ross, M.L., 2015: What Have We Learned about the Resource Curse? *Annual Review of Political Science*, **18(1)**, 239-
55 259, doi:10.1146/annurev-polisci-052213-040359.
- 56 Rothman, D.S., P. Romero-Lankao, V.J. Schweizer, and B.A. Bee, 2014: Challenges to adaptation: a fundamental
57 concept for the shared socio-economic pathways and beyond. *Climatic Change*, **122(3)**, 495-507,
58 doi:10.1007/s10584-013-0907-0.
- 59 Roudier, P., A. Alhassane, C. Baron, S. Louvet, and B. Sultan, 2016: Assessing the benefits of weather and seasonal
60 forecasts to millet growers in Niger. *Agricultural and Forest Meteorology*, **223**, 168-180,

- 1 doi:10.1016/j.agrformet.2016.04.010.
- 2 Rozenberg, J., S. Hallegatte, B. Perrissin-Fabert, and J.-C. Hourcade, 2013: Funding low-carbon investments in the
3 absence of a carbon tax. *Climate Policy*, **13**(1), 134-141, doi:10.1080/14693062.2012.691222.
- 4 Rubin, E.S., J.E. Davison, and H.J. Herzog, 2015: The cost of CO₂ capture and storage. *International Journal of*
5 *Greenhouse Gas Control*, **40**, 378-400, doi:10.1016/j.ijggc.2015.05.018.
- 6 Ruepert, A. et al., 2016: Environmental considerations in the organizational context: A pathway to pro-environmental
7 behaviour at work. *Energy Research and Social Science*, **17**, doi:10.1016/j.erss.2016.04.004.
- 8 Ruparathna, R., K. Hewage, and R. Sadiq, 2016: Improving the energy efficiency of the existing building stock: A
9 critical review of commercial and institutional buildings. *Renewable and Sustainable Energy Reviews*, **53**,
10 1032-1045.
- 11 Ryaboshapko, A.G. and A.P. Revokatova, 2015: Technical Capabilities for Creating an Aerosol Layer In the
12 Stratosphere for Climate Stabilization Purpose. *Problems of environmental monitoring and ecosystem*
13 *modeling*, **T 26**(2), 115-127.
- 14 Sælen, H. and S. Kallbekken, 2011: A choice experiment on fuel taxation and earmarking in Norway. *Ecological*
15 *Economics*, **70**(11), 2181-2190, doi:10.1016/j.econ.2011.06.024.
- 16 Safarzyńska, K. and J.C.J.M. van den Bergh, 2017: Financial stability at risk due to investing rapidly in renewable
17 energy. *Energy Policy*, **108**(October 2016), 12-20, doi:10.1016/j.enpol.2017.05.042.
- 18 Salon, D., M.G. Boarnet, S. Handy, S. Spears, and G. Tal, 2012: How do local actions affect VMT? A critical review of
19 the empirical evidence. *Transportation Research Part D: Transport and Environment*, **17**(7), 495-508,
20 doi:10.1016/j.trd.2012.05.006.
- 21 Salter, S., G. Sortino, and J. Latham, 2008: Sea-going hardware for the cloud albedo method of reversing global
22 warming. *Philosophical transactions. Series A, Mathematical, physical, and engineering sciences*, **366**(1882),
23 3989-4006, doi:10.1098/rsta.2008.0136.
- 24 Salvo, A., J. Brito, P. Artaxo, and F.M. Geiger, 2017: Reduced ultrafine particle levels in São Paulo's atmosphere
25 during shifts from gasoline to ethanol use. *Nature Communications*, **8**(77), 1-14.
- 26 Samset, B.H. et al., 2018: Climate Impacts From a Removal of Anthropogenic Aerosol Emissions. *Geophysical*
27 *Research Letters*, **45**(2), 1020-1029, doi:10.1002/2017GL076079.
- 28 Sanchez, D.L. and V. Sivaram, 2017: Saving innovative climate and energy research: Four recommendations for
29 Mission Innovation. *Energy Research and Social Science*, **29**(May), 123-126, doi:10.1016/j.erss.2017.05.022.
- 30 Sand, M. et al., 2015: Response of Arctic temperature to changes in emissions of short-lived climate forcers. *Nature*
31 *Climate Change*, **6**(3), 286-289, doi:10.1038/nclimate2880.
- 32 Sanderson, B.M., B.C. O'Neill, and C. Tebaldi, 2016: What would it take to achieve the Paris temperature targets?
33 *Geophysical Research Letters*, **43**(13), 7133-7142, doi:10.1002/2016GL069563.
- 34 Sandler, T., 2017: Collective action and geoengineering. *The Review of International Organizations*, 1-21,
35 doi:10.1007/s11558-017-9282-3.
- 36 Sands, R., 2018: U.S. Carbon Tax Scenarios and Bioenergy. *Climate Change Economics (CCE)*, **9**(1), 1-12,
37 doi:10.1142/S2010007818400109.
- 38 Sanesi, G., G. Colangelo, R. Laforteza, E. Calvo, and C. Davies, 2017: Urban green infrastructure and urban forests: a
39 case study of the Metropolitan Area of Milan. *Landscape Research*, **42**(2), 164-175,
40 doi:10.1080/01426397.2016.1173658.
- 41 Sanna, A., M. Dri, M.R. Hall, and M. Maroto-Valer, 2012: Waste materials for carbon capture and storage by
42 mineralisation (CCSM) - A UK perspective. *Applied Energy*, **99**, 545-554,
43 doi:10.1016/J.APENERGY.2012.06.049.
- 44 Santangeli, A. et al., 2016: Global change synergies and trade-offs between renewable energy and biodiversity. *GCB*
45 *Bioenergy*, **8**(5), 941-951, doi:10.1111/gcbb.12299.
- 46 Santos, G., 2008: The London experience. In: *Pricing in Road Transport: A Multi-Disciplinary Perspective* [Verhoef,
47 E., M. Bliemer, L. Steg, and B. van Wee (eds.)]. Edward Elgar Publishing, Cheltenham, UK, pp. 273-292.
- 48 Sanz-Pérez, E.S., C.R. Murdock, S.A. Didas, and C.W. Jones, 2016: Direct Capture of CO₂ from Ambient Air.
49 *Chemical Reviews*, **116**(19), 11840-11876, doi:10.1021/acs.chemrev.6b00173.
- 50 Sarmiento, H. and C. Tilly, 2018: Governance Lessons from Urban Informality. *Politics and Governance*, **6**(1), 199,
51 doi:10.17645/pag.v6i1.1169.
- 52 Sarmiento, J.L. and J.C. Orr, 1991: Three-dimensional simulations of the impact of Southern Ocean nutrient depletion
53 on atmospheric CO₂ and ocean chemistry. *Limnology and Oceanography*, **36**(8), 1928-1950.
- 54 Sartor, O., 2013: Carbon Leakage in the Primary Aluminium Sector: What Evidence after 6.5 Years of the EU ETS?
55 USAEE Working Paper No. 13-106, Social Science Research Network, Rochester, NY, USA, 20 pp.
- 56 Satterthwaite, D. and S. Bartlett, 2017: Editorial: The full spectrum of risk in urban centres: changing perceptions,
57 changing priorities. *Environment and Urbanization*, **29**(1), 3-14, doi:10.1177/0956247817691921.
- 58 Satterthwaite, D., D. Archer, S. Colenbrander, D. Dodman, and J. Hardoy, 2018: Responding to climate change in cities
59 and in their informal settlements and economies. 1-61 pp.
- 60 Saunders, M.I. et al., 2014: Interdependency of tropical marine ecosystems in response to climate change. *Nature*

- 1 *Climate Change*, **4(8)**, 724-729, doi:10.1038/NCLIMATE2274.
- 2 Savo, V. et al., 2016: Observations of climate change among subsistence-oriented communities around the world.
- 3 *Nature Climate Change*, **6(5)**, 462-473, doi:10.1038/nclimate2958.
- 4 Schaeffer, R. et al., 2012: Energy sector vulnerability to climate change: A review. *Energy*, **38(1)**, 1-12,
- 5 doi:10.1016/j.energy.2011.11.056.
- 6 Schaeffer, S.M. and P.A. Nakata, 2015: Plant Science Review article CRISPR / Cas9-mediated genome editing and
- 7 gene replacement in plants : Transitioning from lab to field. *Plant Science*, **240**, 130-142,
- 8 doi:10.1016/j.plantsci.2015.09.011.
- 9 Schäfer, S. et al., 2013: Field tests of solar climate engineering. *Nature Climate Change*, **3**, 766.
- 10 Scheben, A., Y. Yuan, and D. Edwards, 2016: Advances in genomics for adapting crops to climate change. *Current*
- 11 *Plant Biology*, **6**, 2-10, doi:10.1016/j.cpb.2016.09.001.
- 12 Scheer, D. and O. Renn, 2014: Public Perception of geoengineering and its consequences for public debate. *Climatic*
- 13 *Change*, **125(3-4)**, 305-318, doi:10.1007/s10584-014-1177-1.
- 14 Schelling, T.C., 1991: Cooperative Approaches to Global Warming. In: *Global Warming, Economic Policy Responses*
- 15 [Dornbusch, R. and J.M. Poterba (eds.)]. MIT Press.
- 16 Schimmelpfennig, D. and R. Ebel, 2016: Sequential adoption and cost savings from precision agriculture. *Journal of*
- 17 *Agricultural and Resource Economics*, **41(1)**, 97-115.
- 18 Schlenker, W. and M.J. Roberts, 2009: Nonlinear temperature effects indicate severe damages to US crop yields under
- 19 climate change. *Proceedings of the National Academy of Sciences*, **106(37)**, 15594.
- 20 Schleussner, C.-F. et al., 2016: Differential climate impacts for policy-relevant limits to global warming: the case of 1.5
- 21 °C and 2 °C. *Earth System Dynamics*, **7(2)**, 327-351, doi:10.5194/esd-7-327-2016.
- 22 Schmale, J., D. Shindell, E. von Schneidmeyer, I. Chabay, and M. Lawrence, 2014: Clean up our skies. *Nature*, **515**,
- 23 335-337, doi:10.1038/515335a.
- 24 Schmeier, S., 2014: International River Basin Organizations Lost in Translation? Transboundary River Basin
- 25 Governance Between Science and Policy. In: *The Global Water System in the Anthropocene*. Springer
- 26 International Publishing, Cham, pp. 369-383.
- 27 Schmitt, M.T., L.B. Akin, J. Axsen, and R.L. Shwom, 2018: Unpacking the Relationships Between Pro-environmental
- 28 Behavior, Life Satisfaction, and Perceived Ecological Threat. *Ecological Economics*, **143**, 130-140,
- 29 doi:10.1016/j.ecolecon.2017.07.007.
- 30 Schneider, M. et al., 2017: *The World Nuclear Industry Status Report 2017*. Mycle Schneider Consulting, Paris, France,
- 31 267 pp.
- 32 Schoenefeld, J.J., M. Hildén, and A.J. Jordan, 2016: The challenges of monitoring national climate policy: learning
- 33 lessons from the EU. *Climate Policy*, 1-11, doi:10.1080/14693062.2016.1248887.
- 34 Schoemaker, D. and R. van Tilburg, 2016: Financial risks and opportunities in the time of climate change. Bruegel
- 35 Policy Brief 2016/02, 8 pp.
- 36 Schroeder, R. and K. Schroeder, 2014: Happy Environments: Bhutan, Interdependence and the West. *Sustainability*,
- 37 **6(6)**, doi:10.3390/su6063521.
- 38 Schubert, J.E., M. Burns, B.F. Sanders, and T. Fletcher, 2016: To what extent can green infrastructure mitigate
- 39 downstream flooding in a peri-urban catchment?.
- 40 Schuiling, R.D. and P. Krijgsman, 2006: Enhanced Weathering: An Effective and Cheap Tool to Sequester Co2.
- 41 *Climatic Change*, **74(1)**, 349-354, doi:10.1007/s10584-005-3485-y.
- 42 Schuiling, R.D. and P.L. de Boer, 2010: Coastal spreading of olivine to control atmospheric CO2 concentrations: A
- 43 critical analysis of viability. Comment: Nature and laboratory models are different. *International Journal of*
- 44 *Greenhouse Gas Control*, **4(5)**, 855-856, doi:10.1016/j.ijggc.2010.04.012.
- 45 Schuitema, G. and L. Steg, 2008: The role of revenue use in the acceptability of transport pricing policies.
- 46 *Transportation Research Part F: Traffic Psychology and Behaviour*, **11(3)**, doi:10.1016/j.trf.2007.11.003.
- 47 Schuitema, G., L. Steg, and S. Forward, 2010a: Explaining differences in acceptability before and acceptance after the
- 48 implementation of a congestion charge in Stockholm. *Transportation Research Part A: Policy and Practice*,
- 49 **44(2)**, 99-109, doi:10.1016/j.tra.2009.11.005.
- 50 Schuitema, G., L. Steg, and J.A. Rothengatter, 2010b: The acceptability , personal outcome expectations , and expected
- 51 effects of transport pricing policies. *Journal of Environmental Psychology*, **30**, 587-593,
- 52 doi:10.1016/j.jenvp.2010.05.002.
- 53 Schuitema, G., L. Steg, and M. van Kruining, 2011: When Are Transport Pricing Policies Fair and Acceptable? *Social*
- 54 *Justice Research*, **24(1)**, 66-84, doi:10.1007/s11211-011-0124-9.
- 55 Schuler, M.L., O. Mantegazza, and A.P.M. Weber, 2016: Engineering C4 photosynthesis into C3 chassis in the
- 56 synthetic biology age. *The Plant journal: for cell and molecular biology*, **87(1)**, 51-65, doi:10.1111/tpj.13155.
- 57 Schulze, E.-D., C. Körner, B.E. Law, H. Haberl, and S. Luyssaert, 2012: Large-scale bioenergy from additional harvest
- 58 of forest biomass is neither sustainable nor greenhouse gas neutral. *GCB Bioenergy*, **4(6)**, 611-616,
- 59 doi:10.1111/j.1757-1707.2012.01169.x.
- 60 Schwan, S. and X. Yu, 2017: Social protection as a strategy to address climate-induced migration. *International*

- 1 *Journal of Climate Change Strategies and Management*, IJCCSM-01-2017-0019, doi:10.1108/IJCCSM-01-
2 2017-0019.
- 3 Schwartz, D., W. Bruine de Bruin, B. Fischhoff, and L. Lave, 2015: Advertising energy saving programs: The potential
4 environmental cost of emphasizing monetary savings.. *Journal of Experimental Psychology: Applied*, **21(2)**,
5 158-166, doi:10.1037/xap0000042.
- 6 Scott, C.A., M. Kurian, and J.L. Wescoat, 2015: The Water-Energy-Food Nexus: Enhancing Adaptive Capacity to
7 Complex Global Challenges. *Governing the Nexus*, 15-38, doi:10.1007/978-3-319-05747-7_2.
- 8 Scott, M.J. et al., 2015: Calculating impacts of energy standards on energy demand in U.S. buildings with uncertainty in
9 an integrated assessment model. *Energy*, **90**, 1682-1694, doi:10.1016/j.energy.2015.06.127.
- 10 Scott, V. and O. Geden, 2018: The challenge of carbon dioxide removal for EU policy-making. *Nature Energy*, 1-3,
11 doi:10.1038/s41560-018-0124-1.
- 12 Scott, V., R.S. Haszeldine, S.F.B. Tett, and A. Oschlies, 2015: Fossil fuels in a trillion tonne world. *Nature Climate
13 Change*, **5(5)**, 419-423.
- 14 Scovronick, N., C. Dora, E. Fletcher, A. Haines, and D. Shindell, 2015: Reduce short-lived climate pollutants for
15 multiple benefits. *The Lancet*, **386(10006)**, e28-e31, doi:10.1016/S0140-6736(15)61043-1.
- 16 Searchinger, T. et al., 2008: Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from
17 Land-Use Change. *Science*, **319(5867)**, 1238-1240, doi:10.1126/science.1151861.
- 18 Searchinger, T.D., T. Beringer, and A. Strong, 2017: Does the world have low-carbon bioenergy potential from the
19 dedicated use of land? *Energy Policy*, **110**, 434-446, doi:10.1016/J.ENPOL.2017.08.016.
- 20 Seba, T., 2014: *Clean Disruption of Energy and Transportation: How Silicon Valley Will Make Oil, Nuclear, Natural
21 Gas, Coal, Electric Utilities and Conventional Cars Obsolete by 2030*. Clean Planet Ventures, Silicon Valley,
22 CA, USA, 290 pp.
- 23 Seidl, R. et al., 2017: Forest disturbances under climate change. *Nature Climate Change*, **7**, 395.
- 24 Seigo, S.L.O., S. Dohle, and M. Siegrist, 2014: Public perception of carbon capture and storage (CCS): A review.
25 *Renewable and Sustainable Energy Reviews*, **38**, 848-863, doi:10.1016/j.rser.2014.07.017.
- 26 Sejersen, F., 2015: *Rethinking Greenland and the arctic in the era of climate change: New northern horizons*. 235 pp.
- 27 Semprini, G., R. Gulli, and A. Ferrante, 2017: Deep regeneration vs shallow renovation to achieve nearly Zero Energy
28 in existing buildings. *Energy and Buildings*, **156**, 327-342, doi:10.1016/j.enbuild.2017.09.044.
- 29 Sen, B., M. Noori, and O. Tatari, 2017: Will Corporate Average Fuel Economy (CAFE) Standard help? Modeling
30 CAFE's impact on market share of electric vehicles. *Energy Policy*, **109**, 279-287,
31 doi:10.1016/j.enpol.2017.07.008.
- 32 Sendzimir, J., C.P. Reija, and P. Magnuszewski, 2011: Rebuilding Resilience in the Sahel. *Ecology and society*, **16(3)**,
33 1-29, doi:10.5751/ES-04198-160301.
- 34 Seneviratne, S.I. et al., 2018: Land radiative management as contributor to regional-scale climate adaptation and
35 mitigation. *Nature Geoscience*, **11(2)**, 88-96, doi:10.1038/s41561-017-0057-5.
- 36 Serrao-Neumann, S., F. Crick, B. Harman, G. Schuch, and D.L. Choy, 2015: Maximising synergies between disaster
37 risk reduction and climate change adaptation: Potential enablers for improved planning outcomes.
38 *Environmental Science and Policy*, **50**, 46-61, doi:10.1016/j.envsci.2015.01.017.
- 39 Sewando, P.T., K.D. Mutabazi, and N.Y.S. Mdoe, 2016: Vulnerability of agro-pastoral farmers to climate risks in
40 northern and central Tanzania. *Development Studies Research*, **3(1)**, 11-24,
41 doi:10.1080/21665095.2016.1238311.
- 42 Seyfang, G. and A. Haxeltine, 2012: Growing grassroots innovations: Exploring the role of community-based initiatives
43 in governing sustainable energy transitions. *Environment and Planning C: Politics and Space*, **30(3)**, 381-400,
44 doi:https://doi.org/10.1068/c10222.
- 45 Shaffer, L.J., 2014: Making Sense of Local Climate Change in Rural Tanzania Through Knowledge Co-Production.
46 *Journal of Ethnobiology*, **34(3)**, 315-334, doi:10.2993/0278-0771-34.3.315.
- 47 Shah, N., M. Wei, V. Letschert, A. Phadke, and E.O. Lawrence, 2015: *Benefits of Leapfrogging to Super-efficiency and
48 Low Global Warming Potential Refrigerants in Room Air Conditioning*. Lawrence Berkeley National
49 Laboratory, Berkeley.
- 50 Shang, Y. et al., 2018: China's energy-water nexus: Assessing water conservation synergies of the total coal
51 consumption cap strategy until 2050. *Applied Energy*, **210**, 643-660, doi:10.1016/j.apenergy.2016.11.008.
- 52 Shapiro, S., 2016: The realpolitik of building codes: overcoming practical limitations to climate resilience. *Building
53 Research & Information*, **44(5-6)**, 490-506, doi:10.1080/09613218.2016.1156957.
- 54 Sharadin, N., 2018: Rational Coherence in Environmental Policy: Paris, Montreal, and Kigali. *Ethics, Policy &
55 Environment*, **21(1)**, 4-8, doi:10.1080/21550085.2018.1447885.
- 56 Sharma, R., 2018: Financing Indian Urban Rail through Land Development: Case Studies and Implications for the
57 Accelerated Reduction in Oil Associated with 1.5 °C. *Urban Planning*, **3(2)**, 21-34,
58 doi:10.17645/up.v3i2.1158.
- 59 Shaw, C., S. Hales, P. Howden-Chapman, and R. Edwards, 2014: Health co-benefits of climate change mitigation
60 policies in the transport sector. *Nature Climate Change*, **4(6)**, 427-433, doi:10.1038/nclimate2247.

- 1 Shayegh, S., D.L. Sanchez, and K. Caldeira, 2017: Evaluating relative benefits of different types of R&D for clean
2 energy technologies. *Energy Policy*, doi:10.1016/j.enpol.2017.05.029.
- 3 Sheeran, K., 2006: Who Should Abate Carbon Emissions? A Note. *Environmental and Resource Economics*, **35(2)**, 89-
4 98.
- 5 Sherman, M., J. Ford, A. Llanos-Cuentas, and M.J. Valdivia, 2016: Food system vulnerability amidst the extreme 2010-
6 -2011 flooding in the Peruvian Amazon: a case study from the Ucayali region. *Food Security*, **8(3)**, 551-570,
7 doi:10.1007/s12571-016-0583-9.
- 8 Shi, L. et al., 2016: Roadmap towards justice in urban climate adaptation research. *Nature Climate Change*, **6(2)**, 131-
9 137, doi:10.1038/nclimate2841.
- 10 Shindell, D., J.S. Fuglestedt, and W.J. Collins, 2017a: The Social Cost of Methane: Theory and Applications. *Faraday*
11 *Discuss.*, doi:10.1039/C7FD00009J.
- 12 Shindell, D. et al., 2012: Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and
13 Food Security. *Science*, **335(6065)**.
- 14 Shindell, D. et al., 2017b: A climate policy pathway for near- and long-term benefits. *Science*, **356(6337)**, 493 LP - 494.
- 15 Shine, T. and G. Campillo, 2016: The Role of Development Finance in Climate Action Post-2015. .
- 16 Shleifer, A. and R.W. Vishny, 1990: Equilibrium Short Horizons of Investors and Firms. *The American Economic*
17 *Review*, **80(2)**, 148-153.
- 18 Shrivastava, P. and S. Persson, 2018: Silent transformation to 1.5°C-with China's encumbered leading. *Current Opinion*
19 *in Environmental Sustainability*, **31**, 130-136, doi:https://doi.org/10.1016/j.cosust.2018.02.014.
- 20 Shue, H., 2018: Mitigation gambles: uncertainty, urgency and the last gamble possible. *Philosophical transactions.*
21 *Series A, Mathematical, physical, and engineering sciences*, **376(2119)**, 20170105,
22 doi:10.1098/rsta.2017.0105.
- 23 Shukla, P.R., 2005: Aligning justice and efficiency in the global climate change regime: A developing country
24 perspective. *Advances in the Economics of Environmental Resources*, **5**, 121-144.
- 25 Shukla, P.R., J.-C. Hourcade, E. La Rovere, E. Espagne, and B. Perrissin-Fabert, 2017: Revisiting the Carbon Pricing
26 Challenge after COP21 and COP22. CIRED Working Paper No. 2017-59, 8 pp.
- 27 Sida, T.S., F. Baudron, H. Kim, and K.E. Giller, 2018: Climate-smart agroforestry: *Faidherbia albida* trees buffer wheat
28 against climatic extremes in the Central Rift Valley of Ethiopia. *Agricultural and Forest Meteorology*, **248**,
29 339-347, doi:10.1016/j.agrformet.2017.10.013.
- 30 Siders, A.R., 2017: A role for strategies in urban climate change adaptation planning: Lessons from London. *Regional*
31 *Environmental Change*, **17(6)**, 1801-1810, doi:10.1007/s10113-017-1153-1.
- 32 Siegmeier, J. et al., 2018: The fiscal benefits of stringent climate change mitigation: an overview. *Climate Policy*, **18(3)**,
33 352-367, doi:10.1080/14693062.2017.1400943.
- 34 SIFMA, 2017: *2017 Fact book*. 96 pp.
- 35 Sikka, A.K., A. Islam, and K.V. Rao, 2018: Climate-Smart Land and Water Management for Sustainable Agriculture.
36 *Irrigation and Drainage*, **67(1)**, 72-81, doi:10.1002/ird.2162.
- 37 Simon, A.J., N.B. Kaahaaina, S. Julio Friedmann, and R.D. Aines, 2011: Systems analysis and cost estimates for large
38 scale capture of carbon dioxide from air. *Energy Procedia*, **4**, 2893-2900,
39 doi:10.1016/J.EGYPRO.2011.02.196.
- 40 Simon, D. and H. Leck, 2015: Understanding climate adaptation and transformation challenges in African cities.
41 *Current Opinion in Environmental Sustainability*, **13**, 109-116, doi:10.1016/j.cosust.2015.03.003.
- 42 Simone, A.M. and E.A. Pieterse, 2017: *New urban worlds: inhabiting dissonant times*. 192 pp.
- 43 Sims, R. et al., 2014: Transport. In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working*
44 *Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* []. Cambridge
45 University Press, Cambridge, United Kingdom and New York, NY, USA. pp. 599-670.
- 46 Singh, C., P. Dorward, and H. Osbahr, 2016a: Developing a holistic approach to the analysis of farmer decision-
47 making: Implications for adaptation policy and practice in developing countries. *Land Use Policy*, **59**, 329-
48 343, doi:10.1016/j.landusepol.2016.06.041.
- 49 Singh, C., P. Urquhart, and E. Kituyi, 2016b: From pilots to systems: Barriers and enablers to scaling up the use of
50 climate information services in smallholder farming communities. CARIAA Working Paper no. 3, 56 pp.
- 51 Singh, C. et al., 2017: The utility of weather and climate information for adaptation decision-making: current uses and
52 future prospects in Africa and India. *Climate and Development*, 1-17, doi:10.1080/17565529.2017.1318744.
- 53 Sinha, A., L.A. Darunte, C.W. Jones, M.J. Realff, and Y. Kawajiri, 2017: Systems Design and Economic Analysis of
54 Direct Air Capture of CO₂ through Temperature Vacuum Swing Adsorption Using MIL-101(Cr)-PEI-800 and
55 mmen-Mg₂ (dobpdc) MOF Adsorbents. *Industrial & Engineering Chemistry Research*, **56(3)**, 750-764,
56 doi:10.1021/acs.iecr.6b03887.
- 57 Sirkis, A. et al., 2015: *Moving the trillions: a debate on positive pricing of mitigation actions*. Centro Brasil No Clima,
58 Rio de Janeiro, Brazil, 157 pp.
- 59 Sivakumar, M.V.K., C. Collins, A. Jay, and J. Hansen, 2014: Regional priorities for strengthening climate services for
60 farmers in Africa and South Asia. CCAFS Working Paper, 36 pp.

- 1 Sjöberg, L. and B.-M. Drottz-Sjöberg, 2001: Fairness, risk and risk tolerance in the siting of a nuclear waste repository.
2 *Journal of Risk Research*, **4(1)**, 75-101, doi:10.1080/136698701456040.
- 3 Skougaard Kaspersen, P., N. Høegh Ravn, K. Arnbjerg-Nielsen, H. Madsen, and M. Drews, 2015: Influence of urban
4 land cover changes and climate change for the exposure of European cities to flooding during high-intensity
5 precipitation. *Proceedings of the International Association of Hydrological Sciences*, **370**, 21-27,
6 doi:10.5194/piahs-370-21-2015.
- 7 Skuce, P.J., E.R. Morgan, J. van Dijk, and M. Mitchell, 2013: Animal health aspects of adaptation to climate change:
8 beating the heat and parasites in a warming Europe. *animal*, **7(s2)**, 333-345.
- 9 Slade, R., A. Bauen, and R. Gross, 2014: Global bioenergy resources. *Nature Climate Change*, **4(2)**, 99-105.
- 10 Slee, B., 2015: Is there a case for community-based equity participation in Scottish on-shore wind energy production?
11 Gaps in evidence and research needs. *Renewable and Sustainable Energy Reviews*, **41**, 540-549,
12 doi:10.1016/j.rser.2014.08.064.
- 13 Sleenhoff, S., E. Cuppen, and P. Osseweijer, 2015: Unravelling emotional viewpoints on a bio-based economy using Q
14 methodology. *Public Understanding of Science*, **24(7)**, 858-877, doi:10.1177/0963662513517071.
- 15 Smith, C.J. et al., 2017: Impacts of stratospheric sulfate geoengineering on global solar photovoltaic and concentrating
16 solar power resource. *Journal of Applied Meteorology and Climatology*, JAMC-D-16-0298.1,
17 doi:10.1175/JAMC-D-16-0298.1.
- 18 Smith, H. and P. Jenkins, 2015: Trans-disciplinary research and strategic urban expansion planning in a context of weak
19 institutional capacity: Case study of Huambo, Angola. *Habitat International*, **46**, 244-251,
20 doi:10.1016/j.habitatint.2014.10.006.
- 21 Smith, H., E. Kruger, J. Knot, and J. Blignaut, 2017: Conservation Agriculture in South Africa: Lessons from Case
22 Studies. In: *Building Resilient Farming Systems in a Changing Climate* [Kassam, A.H. (ed.)].
- 23 Smith, H.A. and K. Sharp, 2012: Indigenous climate knowledges. *Wiley Interdisciplinary Reviews-Climate Change*,
24 **3(5)**, doi:10.1002/wcc.185.
- 25 Smith, J.B., J.M. Vogel, and J.E. Cromwell III, 2009: An architecture for government action on adaptation to climate
26 change. An editorial comment. *Climatic Change*, **95(1-2)**, 53-61, doi:10.1007/s10584-009-9623-1.
- 27 Smith, K.R. et al., 2014: Human health: Impacts, adaptation, and co-benefits. In: *Climate Change 2014 Impacts,*
28 *Adaptation, and Vulnerability* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, and T.E.
29 Bilir (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 709-
30 754.
- 31 Smith, L.J. and M.S. Torn, 2013: Ecological limits to terrestrial biological carbon dioxide removal. *Climatic Change*,
32 **118(1)**, 89-103, doi:10.1007/s10584-012-0682-3.
- 33 Smith, P., 2016: Soil carbon sequestration and biochar as negative emission technologies. *Global Change Biology*,
34 **22(3)**, 1315-1324, doi:10.1111/gcb.13178.
- 35 Smith, P., R.S. Haszeldine, and S.M. Smith, 2016a: Preliminary assessment of the potential for, and limitations to,
36 terrestrial negative emission technologies in the UK. *Environ. Sci.: Processes Impacts*, **18(11)**, 1400-1405,
37 doi:10.1039/C6EM00386A.
- 38 Smith, P. et al., 2014: Agriculture, Forestry and Other Land Use (AFOLU). In: *Climate Change 2014: Mitigation of*
39 *Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental*
40 *Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth,
41 A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T.
42 Zwickel, and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York,
43 NY, USA, Cambridge, United Kingdom and New York, NY, USA, pp. 811-922.
- 44 Smith, P. et al., 2016b: Biophysical and economic limits to negative CO₂ emissions. *Nature Climate Change*, **6(1)**, 42-
45 50, doi:10.1038/nclimate2870.
- 46 Smith, S.J. and A. Mizrahi, 2013: Near-term climate mitigation by short-lived forcers. *Proceedings of the National*
47 *Academy of Sciences*, **110(35)**, 14202-14206, doi:10.1073/pnas.1308470110.
- 48 Smith, S.J. and P.J. Rasch, 2013: The long-term policy context for solar radiation management. *Climatic Change*,
49 **121(3)**, 487-497, doi:10.1007/s10584-012-0577-3.
- 50 Smithers, R., E. Holdaway, N. Rass, and N. Sanchez Ibrahim, 2017: Linking National Adaptation Plan Processes and
51 Nationally Determined Contributions. Climate Change Policy Brief, 8 pp.
- 52 Smucker, T.A. et al., 2015: Differentiated livelihoods, local institutions, and the adaptation imperative: Assessing
53 climate change adaptation policy in Tanzania. *Geoforum*, **59**, 39-50, doi:10.1016/J.GEOFORUM.2014.11.018.
- 54 Snow, J.T. et al., 2016: *A New Vision for Weather and Climate Services in Africa*.
- 55 Soares-Filho, B. et al., 2010: Role of Brazilian Amazon protected areas in climate change mitigation. *Proceedings of*
56 *the National Academy of Sciences*, **107(24)**, 10821-10826, doi:10.1073/pnas.0913048107.
- 57 Soccol, C.R. et al., 2010: Bioethanol from lignocelluloses: Status and perspectives in Brazil. *Bioresource Technology*,
58 **101(13)**, 4820-4825, doi:10.1016/J.BIORTECH.2009.11.067.
- 59 Socolow, R. et al., 2011: *Direct air capture of CO₂ with chemicals: A technology assessment for the APS Panel on*
60 *Public Affairs*. 100 pp.

- 1 Soderlund, J. and P. Newman, 2015: Biophilic architecture: a review of the rationale and outcomes. *AIMS*
2 *Environmental Science*, **2(4)**, 950-969, doi:10.3934/environsci.2015.4.950.
- 3 Sohlberg, J., 2017: The effect of elite polarization: A comparative perspective on how party elites influence attitudes
4 and behavior on climate change in the European union. *Sustainability*, **9(1)**, 1-13, doi:10.3390/su9010039.
- 5 Solecki, W., K.C. Seto, and P.J. Marcotullio, 2013: It's Time for an Urbanization Science. *Environment: Science and*
6 *Policy for Sustainable Development*, **55(1)**, 12-17, doi:10.1080/00139157.2013.748387.
- 7 Solecki, W., M. Pelling, and M. Garschagen, 2017: Transitions between risk management regimes in cities. *Ecology*
8 *And Society*, **22(2)**, doi:10.5751/ES-09102-220238.
- 9 Solecki, W. et al., 2018: City transformations in a 1.5 °C warmer world. *Nature Climate Change*, **8(3)**, 177-181,
10 doi:10.1038/s41558-018-0101-5.
- 11 Somanathan, E. et al., 2014: National and Sub-national Policies and Institutions. In: *Climate Change 2014: Mitigation*
12 *of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the*
13 *Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S.
14 Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer,
15 C. von Stechow, T. Zwickel, and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom
16 and New York, NY, USA.
- 17 Sorrell, S., J. Dimitropoulos, and M. Sommerville, 2009: Empirical estimates of the direct rebound effect: A review.
18 *Energy Policy*, **37(4)**, 1356-1371, doi:10.1016/j.enpol.2008.11.026.
- 19 Sovacool, B.K., 2016: How long will it take? Conceptualizing the temporal dynamics of energy transitions. *Energy*
20 *Research and Social Science*, **13**, 202-215, doi:10.1016/j.erss.2015.12.020.
- 21 Sovacool, B.K., B.-O. Linnér, and M.E. Goodsite, 2015: The political economy of climate adaptation. *Nature Clim.*
22 *Change*, **5(7)**, 616-618, doi:10.1038/nclimate2665.
- 23 Sovacool, B.K., B.O. Linner, and R.J.T. Klein, 2017: Climate change adaptation and the Least Developed Countries
24 Fund (LDCF): Qualitative insights from policy implementation in the Asia-Pacific. *Climatic Change*, **140(2)**,
25 209-226, doi:10.1007/s10584-016-1839-2.
- 26 Spence, A., W. Poortinga, C. Butler, and N.F. Pidgeon, 2011: Perceptions of climate change and willingness to save
27 energy related to flood experience. *Nature Climate Change*, **1(1)**, 46-49, doi:10.1038/nclimate1059.
- 28 Spencer, B. et al., 2017: Case studies in co-benefits approaches to climate change mitigation and adaptation. *Journal of*
29 *Environmental Planning and Management*, **60(4)**, 647-667, doi:10.1080/09640568.2016.1168287.
- 30 Spencer, T., R. Pierfederici, and others, 2015: *Beyond the numbers: understanding the transformation induced by*
31 *INDCs*. N°05/15, 80 pp.
- 32 Springmann, M., H.C.J. Godfray, M. Rayner, and P. Scarborough, 2016: Analysis and valuation of the health and
33 climate change cobenefits of dietary change. *Proceedings of the National Academy of Sciences*, **113(15)**, 4146-
34 4151, doi:10.1073/pnas.1523119113.
- 35 Stadelmann, M., 2017: Energy Research & Social Science Mind the gap ? Critically reviewing the energy efficiency
36 gap with empirical evidence. *Energy Research & Social Science*, **27**, 117-128, doi:10.1016/j.erss.2017.03.006.
- 37 Stavins, R.N., 1988: *Project 88 - Harnessing Market Forces to Protect Our Environment: Initiatives for the New*
38 *President. A Public Policy Study sponsored by Senator Timothy E. Wirth, Colorado, and Senator John Heinz,*
39 *Pennsylvania*.
- 40 Stavins, R.N. et al., 2014: International Cooperation: Agreements & Instruments. In: *Climate Change 2014: Mitigation*
41 *of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the*
42 *Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S.
43 Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer,
44 C. von Stechow, T. Zwickel, and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom
45 and New York, NY, USA, pp. 1001 - 1081.
- 46 Steenhof, P. and E. Sparling, 2011: The role of codes, standards, and related instruments in facilitating adaptation to
47 climate change. In: *Climate Change Adaptation in Developed Nations: From Theory to Practice* [Ford, J.D.
48 and L. Berrang-Ford (eds.)]. Advances in Global Change Research, Springer, Dordrecht, Netherlands, pp. 243-
49 254.
- 50 Steg, L., 2016: Values, Norms, and Intrinsic Motivation to Act Proenvironmentally. *Annual Review of Environment and*
51 *Resources*, **41(1)**, 277-292, doi:10.1146/annurev-environ-110615-085947.
- 52 Steg, L. and C. Vlek, 2009: Encouraging pro-environmental behaviour: An integrative review and research agenda.
53 *Journal of Environmental Psychology*, **29(3)**, doi:10.1016/j.jenvp.2008.10.004.
- 54 Steg, L. and J. de Groot, 2010: Explaining prosocial intentions: Testing causal relationships in the norm activation
55 model. *British Journal of Social Psychology*, **49(4)**, doi:10.1348/014466609X477745.
- 56 Steg, L., L. Dreijerink, and W. Abrahamse, 2005: Factors influencing the acceptability of energy policies: A test of
57 VBN theory. *Journal of Environmental Psychology*, **25(4)**, 415-425, doi:10.1016/j.jenvp.2005.08.003.
- 58 Steg, L., L. Dreijerink, and W. Abrahamse, 2006: Why are Energy Policies Acceptable and Effective? *Environment and*
59 *Behavior*, **38(1)**, 92-111, doi:10.1177/0013916505278519.
- 60 Steg, L., G. Perlaviciute, and E. van der Werff, 2015: Understanding the human dimensions of a sustainable energy

- 1 transition. *Frontiers in Psychology*, **6**, 1-17, doi:10.3389/fpsyg.2015.00805.
- 2 Steg, L., R. Shwom, and T. Dietz, 2017: What drives energy consumers? *IEEE Power & Energy*.
- 3 Steinhoff, D.F., A.J. Monaghan, and M.P. Clark, 2014: Projected impact of twenty-first century ENSO changes on
4 rainfall over Central America and northwest South America from CMIP5 AOGCMs. *Climate Dynamics*, **44(5-6)**, 1329-1349, doi:10.1007/s00382-014-2196-3.
- 5
- 6 Sterling, E.J. et al., 2017: Biocultural approaches to well-being and sustainability indicators across scales. *Nature
7 Ecology & Evolution*, **1(12)**, 1798-1806, doi:10.1038/s41559-017-0349-6.
- 8 Sterman, J.D., L. Siegel, and J.N. Rooney-Varga, 2018: Does replacing coal with wood lower CO 2 emissions?
9 Dynamic lifecycle analysis of wood bioenergy. *Environmental Research Letters*, **13(1)**, 015007,
10 doi:10.1088/1748-9326/aaa512.
- 11 Stern, N., 2013: The Structure of Economic Modeling of the Potential Impacts of Climate Change: Grafting Gross
12 Underestimation of Risk onto Already Narrow Science Models. *Journal of Economic Literature*, **51(3)**, 838-
13 859, doi:10.1257/jel.51.3.838.
- 14 Stern, N., 2015: Economic development, climate and values: making policy. *Proceedings of the Royal Society of
15 London B: Biological Sciences*, **282(1812)**, n/a-n/a, doi:10.1098/rspb.2015.0820.
- 16 Stern, P.C., 2011: Design principles for global commons: natural resources and emerging technologies. *International
17 Journal of the Commons*, **5(2)**, 213-232.
- 18 Stern, P.C., 2014: Individual and household interactions with energy systems: Toward integrated understanding. *Energy
19 Research & Social Science*, **1**, 41-48, doi:10.1016/j.erss.2014.03.003.
- 20 Stern, P.C. and G.T. Gardner, 1981: Psychological research and energy policy. *American Psychologist*, **36(4)**, 329-342,
21 doi:10.1037/0003-066X.36.4.329.
- 22 Stern, P.C. et al., 2016a: consumption by households and organizations. *Nature Energy*, **1(May)**, 16043,
23 doi:10.1038/NENERGY.2016.43.
- 24 Stern, P.C. et al., 2016b: Opportunities and insights for reducing fossil fuel consumption by households and
25 organizations. *Nature Energy*, **1(May)**, 16043, doi:10.1038/NENERGY.2016.43.
- 26 Stevanović, M. et al., 2017: Mitigation Strategies for Greenhouse Gas Emissions from Agriculture and Land-Use
27 Change: Consequences for Food Prices. *Environmental Science & Technology*, **51(1)**, 365-374,
28 doi:10.1021/acs.est.6b04291.
- 29 Stevenson, H. and J.S. Dryzek, 2014: *Democratizing Global Climate Governance*. Cambridge University Press,
30 Cambridge, UK and New York, NY, USA, 256 pp.
- 31 Stevenson, M. et al., 2016: Land use, transport, and population health: estimating the health benefits of compact cities.
32 *The Lancet*, **388(10062)**, 2925-2935, doi:10.1016/S0140-6736(16)30067-8.
- 33 Stiglitz, J.E., 2002: *Globalization and its Discontents*. W. W. Norton & Company, New York, NY, USA, 304 pp.
- 34 Stiglitz, J.E. et al., 2017: *Report of the High-Level Commission on Carbon Prices*. Carbon Pricing Leadership
35 Coalition, 68 pp.
- 36 Stjern, C.W. et al., 2017: Rapid Adjustments Cause Weak Surface Temperature Response to Increased Black Carbon
37 Concentrations. *Journal of Geophysical Research: Atmospheres*, **122(21)**, 11,411-462,481,
38 doi:10.1002/2017JD027326.
- 39 Stohl, A. et al., 2015: Evaluating the climate and air quality impacts of short-lived pollutants. *Atmospheric Chemistry
40 and Physics*, **15(18)**, 10529-10566, doi:10.5194/acp-15-10529-2015.
- 41 Stolaroff, J.K. et al., 2012: Review of methane mitigation technologies with application to rapid release of methane
42 from the Arctic. *Environmental Science & Technology*, **46**, 6455-6469, doi:10.1021/es204686w.
- 43 Storelvmo, T., W.R. Boos, and N. Herger, 2014: Cirrus cloud seeding: a climate engineering mechanism with reduced
44 side effects? *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering
45 Sciences*, **372(2031)**, 20140116-20140116, doi:10.1098/rsta.2014.0116.
- 46 Strassburg, B.B.N. et al., 2014: Biophysical suitability, economic pressure and land-cover change: a global probabilistic
47 approach and insights for REDD+. *Sustainability Science*, **9(2)**, 129-141, doi:10.1007/s11625-013-0209-5.
- 48 Strefler, J., T. Amann, N. Bauer, E. Krieglger, and J. Hartmann, 2018: Potential and costs of carbon dioxide removal by
49 Enhanced Weathering of rocks. *Environmental Research Letters*, **13(3)**, 034010, doi:10.1088/1748-
50 9326/aaa9c4.
- 51 Stua, M., 2017: *From the Paris Agreement to a Low-Carbon Bretton Woods: Rationale for the Establishment of a
52 Mitigation*. Springer.
- 53 Studart, R. and K. Gallagher, 2015: Guaranteeing Finance for Sustainable Infrastructure: A Proposal. In: *Moving the
54 Trillions - a debate on positive pricing of mitigation actions*. pp. 92-113.
- 55 Stults, M. and S.C. Woodruff, 2017: Looking under the hood of local adaptation plans: shedding light on the actions
56 prioritized to build local resilience to climate change. *Mitigation and Adaptation Strategies for Global
57 Change*, **22(8)**, 1249-1279, doi:10.1007/s11027-016-9725-9.
- 58 Su, Y., P. Zhang, and Y. Su, 2015: An overview of biofuels policies and industrialization in the major biofuel
59 producing countries. *Renewable and Sustainable Energy Reviews*, **50**, 991-1003,
60 doi:https://doi.org/10.1016/j.rser.2015.04.032.

- 1 Suarez, P. and M. van Aalst, 2017: Geoengineering: a humanitarian concern. *Earth's Future*, **5**, 183-195,
2 doi:10.1002/ef2.181.
- 3 Sugiyama, M., Y. Arino, T. Kosugi, A. Kurosawa, and S. Watanabe, 2017a: Next steps in geoengineering scenario
4 research: limited deployment scenarios and beyond. *Climate Policy*, 1-9,
5 doi:10.1080/14693062.2017.1323721.
- 6 Sugiyama, M. et al., 2017b: Transdisciplinary co-design of scientific research agendas: 40 research questions for
7 socially relevant climate engineering research. *Sustainability Science*, **12(1)**, 31-44, doi:10.1007/s11625-016-
8 0376-2.
- 9 Sullivan-Wiley, K.A. and A.G. Short Gianotti, 2017: Risk Perception in a Multi-Hazard Environment. *World*
10 *Development*, **97**, 138-152, doi:10.1016/j.worlddev.2017.04.002.
- 11 Summers, L.H., 2016: The Age of Secular Stagnation: What It Is and What to Do About It. *Foreign Affairs*, **95**, 2.
- 12 Sun, Y., G. Huang, X. Xu, and A.C.-K. Lai, 2018: Building-group-level performance evaluations of net zero energy
13 buildings with non-collaborative controls. *Applied Energy*, **212**, 565-576, doi:10.1016/j.apenergy.2017.11.076.
- 14 Sunderlin, W.D. et al., 2014: How are REDD+ Proponents Addressing Tenure Problems? Evidence from Brazil,
15 Cameroon, Tanzania, Indonesia, and Vietnam. *World Development*, **55**, 37-52,
16 doi:10.1016/j.worlddev.2013.01.013.
- 17 Sundqvist, E., P. Crill, M. Mölder, P. Vestin, and A. Lindroth, 2012: Atmospheric methane removal by boreal plants.
18 *Geophysical Research Letters*, **39(21)**, n/a-n/a, doi:10.1029/2012GL053592.
- 19 Sunikka-Blank, M. and Y. Iwafune, 2011: Sustainable Building in Japan - Observations on a Market Transformation
20 Policy. *Environmental Policy and Governance*, **21(5)**, 351-363, doi:10.1002/eet.580.
- 21 Surminski, S., 2013: Private-sector adaptation to climate risk. *Nature Clim. Change*, **3(11)**, 943-945,
22 doi:10.1038/nclimate2040.
- 23 Sutherland, R.J., 1991: Market barriers to energy-efficiency investments. *Energy Journal*, **12(3)**, 15-34.
- 24 Svoboda, T., 2017: *The Ethics of Climate Engineering: Solar Radiation Management and Non-Ideal Justice*.
25 Routledge, Abingdon, UK and New York, NY, USA, 232 pp.
- 26 Swatuk, L.A., 2015: Water conflict and cooperation in Southern Africa. *Wiley Interdisciplinary Reviews: Water*, **2(3)**,
27 215-230, doi:10.1002/wat2.1070.
- 28 Szabó, S., M. Moner-Girona, I. Kougias, R. Bailis, and K. Bódis, 2016: Identification of advantageous electricity
29 generation options in sub-Saharan Africa integrating existing resources. *Nature Energy*, **1**, 16140,
30 doi:10.1038/nenergy.2016.140.
- 31 Szerszynski, B., M. Kearnes, P. Macnaghten, R. Owen, and J. Stilgoe, 2013: Why solar radiation management
32 geoengineering and democracy won't mix. *Environment and Planning A*, **45(12)**, 2809-2816,
33 doi:10.1068/a45649.
- 34 Tacoli, C., B. Bukhari, and S. Fisher, 2013: *Urban poverty, food security and climate change*. IIED, Human
35 Settlements Group.
- 36 Tait, L. and M. Euston-Brown, 2017: What role can African cities play in low-carbon development? A multilevel
37 governance perspective of Ghana, Uganda and South Africa. *Journal of Energy in Southern Africa*, **28(3)**, 43,
38 doi:10.17159/2413-3051/2017/v28i3a1959.
- 39 Takahashi, B., M. Burnham, C. Terracina-Hartman, A.R. Sopchak, and T. Selfa, 2016: Climate Change Perceptions of
40 NY State Farmers : The Role of Risk Perceptions and Adaptive Capacity. *Environmental Management*, **58(6)**,
41 946-957, doi:10.1007/s00267-016-0742-y.
- 42 Takahashi, N. et al., 2015: Community Trial on Heat Related-Illness Prevention Behaviors and Knowledge for the
43 Elderly. *International Journal of Environmental Research and Public Health*, **12(3)**,
44 doi:10.3390/ijerph120303188.
- 45 Talberg, A., P. Christoff, S. Thomas, and D. Karoly, 2018: Geoengineering governance-by-default: an earth system
46 governance perspective. *International Environmental Agreements: Politics, Law and Economics*, **18(2)**, 229-
47 253, doi:10.1007/s10784-017-9374-9.
- 48 Tall, A. et al., 2014: Scaling up climate services for farmers: Mission possible. Learning from good practice in Africa
49 and South Asia. CCAFS Report No. 13, 44 pp.
- 50 Tallis, M., G. Taylor, D. Sinnett, and P. Freer-Smith, 2011: Estimating the removal of atmospheric particulate pollution
51 by the urban tree canopy of London, under current and future environments. *Landscape and Urban Planning*,
52 **103(2)**, 129-138, doi:10.1016/j.landurbplan.2011.07.003.
- 53 Tasse, G., 2014: Competing in Advanced Manufacturing: The Need for Improved Growth Models and Policies.
54 *Journal of Economic Perspectives*, **28(1)**, 27-48, doi:10.1257/jep.28.1.27.
- 55 Taub, D.R., B. Miller, and H. Allen, 2008: Effects of elevated CO₂ on the protein concentration of food crops: a meta-
56 analysis. *Global Change Biology*, **14(3)**, 565-575, doi:10.1111/j.1365-2486.2007.01511.x.
- 57 Taufik, D., J.W. Bolderdijk, and L. Steg, 2015: Acting green elicits a literal warm glow. *Nature Climate Change*, **5(1)**,
58 37-40, doi:10.1038/nclimate2449.
- 59 Taufik, D., J.W. Bolderdijk, and L. Steg, 2016: Going green? The relative importance of feelings over calculation in
60 driving environmental intent in the Netherlands and the United States. *Energy Research & Social Science*, **22**,

- 1 52-62, doi:10.1016/j.erss.2016.08.012.
- 2 Taylor, A.L., S. Dessai, and W. Bruine de Bruin, 2014: Public perception of climate risk and adaptation in the UK: A
3 review of the literature. *Climate Risk Management*, **4-5**, 1-16, doi:10.1016/j.crm.2014.09.001.
- 4 Taylor, L.L. et al., 2016: Enhanced weathering strategies for stabilizing climate and averting ocean acidification.
5 *Nature Clim. Change*, **6(4)**, 402-406.
- 6 TEC, 2016: *Updated guidance on technology action plans*. UNFCCC, Bonn, Germany, 21 pp.
- 7 Teferi, Z. and P. Newman, 2017: Slum Regeneration and Sustainability: Applying the Extended Metabolism Model and
8 the SDGs. *Sustainability*, **9(12)**, 2273, doi:10.3390/su9122273.
- 9 Teferi, Z.A. and P. Newman, 2018: Slum Upgrading: Can the 1.5 °C Carbon Reduction Work with SDGs in these
10 Settlements? *Urban Planning*, **3(2)**, 52, doi:10.17645/up.v3i2.1239.
- 11 Tehranian, H. and J.F. Waegelin, 1985: Market reaction to short-term executive compensation plan adoption. *Journal*
12 *of Accounting and Economics*, **7(1-3)**, 131-144, doi:10.1016/0165-4101(85)90032-1.
- 13 ten Berge, H.F.M. et al., 2012: Olivine weathering in soil, and its effects on growth and nutrient uptake in Ryegrass
14 (*Lolium perenne* L.): a pot experiment. *PLoS One*, **7(8)**, e42098, doi:10.1371/journal.pone.0042098.
- 15 Termeer, C.J.A.M., A. Dewulf, and G.R. Biesbroek, 2017: Transformational change: governance interventions for
16 climate change adaptation from a continuous change perspective. *Journal of Environmental Planning and*
17 *Management*, **60(4)**, 558-576, doi:10.1080/09640568.2016.1168288.
- 18 Tessler, Z.D. et al., 2015: Profiling risk and sustainability in coastal deltas of the world. *Science*, **349(6248)**, 638-643,
19 doi:10.1126/science.aab3574.
- 20 Teulings, C. and R. Baldwin (eds.), 2014: *Secular stagnation: Facts, causes, and cures*. Centre for Economic Policy
21 Research Press, London, UK, 154 pp.
- 22 The City of New York, 2013: *A Stronger, More Resilient New York*.
- 23 The City of New York, 2017: *Preliminary Climate Resiliency Design Guidelines*. NYC Mayor's Office of Recovery &
24 Resiliency.
- 25 The World Bank Data, 2018: Market capitalization of listed domestic companies (current US\$).
26 <https://data.worldbank.org/indicator/CM.MKT.LCAP.CD> (Accessed: 15 May 2018).
- 27 Thi Hong Phuong, L., G.R. Biesbroek, and A.E.J. Wals, 2017: The interplay between social learning and adaptive
28 capacity in climate change adaptation: A systematic review. *NJAS - Wageningen Journal of Life Sciences*, **82**,
29 1-9, doi:10.1016/j.njas.2017.05.001.
- 30 Thieme, T.A., 2017: The hustle economy. *Progress in Human Geography*, 030913251769003,
31 doi:10.1177/0309132517690039.
- 32 Thøgersen, J., Ölander, F., 2003: Spillover of environment-friendly consumer behaviour. *Journal of Environmental*
33 *Psychology*, **23**, 225-236, doi:10.1016/S0272-4944(03)00018-5.
- 34 Thomas, S., L.-A. Brischke, J. Thema, L. Leuser, and M. Kopatz, 2017: Energy sufficiency policy: how to limit energy
35 consumption and per capita dwelling size in a decent way. In: *Proceedings of the ECEEE Summer Study*.
- 36 Thomas, S.D., 1988: The realities of nuclear power : international economic and regulatory experience.. , 289.
- 37 Thomson, G. and P. Newman, 2016: Geoengineering in the Anthropocene through Regenerative Urbanism.
38 *Geosciences*, **6(4)**, 46, doi:10.3390/geosciences6040046.
- 39 Thornton, P.K. and M. Herrero, 2014: Climate change adaptation in mixed crop-livestock systems in developing
40 countries. *Global Food Security*, **3(2)**, 99-107, doi:10.1016/j.gfs.2014.02.002.
- 41 Thornton, P.K. and M. Herrero, 2015: Adapting to climate change in the mixed crop and livestock farming systems in
42 sub-Saharan Africa. *Nature Climate Change*, **5(9)**, 830-836.
- 43 Thornton, P.K. et al., 2018: A Qualitative Evaluation of CSA Options in Mixed Crop-Livestock Systems in Developing
44 Countries. In: *Climate Smart Agriculture : Building Resilience to Climate Change* [Lipper, L., N. McCarthy,
45 D. Zilberman, S. Asfaw, and G. Branca (eds.)]. Springer International Publishing, Cham, pp. 385-423.
- 46 Thornton, T.F. and N. Manasfi, 2010: Adaptation-Genuine and Spurious: Demystifying Adaptation Processes in
47 Relation to Climate Change. *Environment and Society*, **1(1)**, doi:10.3167/ares.2010.010107.
- 48 Thornton, T.F. and C. Comberti, 2017: Synergies and trade-offs between adaptation, mitigation and development.
49 *Climatic Change*, **140(1)**, 5-18, doi:10.1007/s10584-013-0884-3.
- 50 Tiefenbeck, V. et al., 2016: Overcoming Salience Bias: How Real-Time Feedback Fosters Resource Conservation.
51 *Management Science*, mns.2016.2646, doi:10.1287/mns.2016.2646.
- 52 Tilleard, S. and J. Ford, 2016: Adaptation readiness and adaptive capacity of transboundary river basins. *Climatic*
53 *Change*, **137(3-4)**, 575-591, doi:10.1007/s10584-016-1699-9.
- 54 Tilman, D. and M. Clark, 2014: Global diets link environmental sustainability and human health. *Nature*, **515(7528)**,
55 518-522, doi:10.1038/nature13959.
- 56 Tilmes, S., B.M.M. Sanderson, and B.C. O'Neill, 2016: Climate impacts of geoengineering in a delayed mitigation
57 scenario. *Geophysical Research Letters*, **43(15)**, 8222-8229, doi:10.1002/2016GL070122.
- 58 Tilmes, S. et al., 2012: Impact of very short-lived halogens on stratospheric ozone abundance and UV radiation in a
59 geo-engineered atmosphere. *Atmospheric Chemistry and Physics*, **12(22)**, 10945-10955, doi:10.5194/acp-12-
60 10945-2012.

- 1 Tjiputra, J.F., A. Grini, and H. Lee, 2016: Impact of idealized future stratospheric aerosol injection on the large-scale
2 ocean and land carbon cycles. *Journal of Geophysical Research: Biogeosciences*, **121(1)**, 2-27,
3 doi:10.1002/2015JG003045.
- 4 Tobler, C., V.H.M. Visschers, and M. Siegrist, 2011: Organic Tomatoes Versus Canned Beans: How Do Consumers
5 Assess the Environmental Friendliness of Vegetables? *Environment and Behavior*, **43(5)**, 591-611,
6 doi:10.1177/0013916510372865.
- 7 Tobler, C., V.H.M. Visschers, and M. Siegrist, 2012: Consumers' knowledge about climate change. *Climatic Change*,
8 **114(2)**, 189-209, doi:10.1007/s10584-011-0393-1.
- 9 Tokarska, K.B. and K. Zickfeld, 2015: The effectiveness of net negative carbon dioxide emissions in reversing
10 anthropogenic climate change. *Environmental Research Letters*, **10(9)**, 094013, doi:10.1088/1748-
11 9326/10/9/094013.
- 12 Toleikyte, A., L. Kranzl, and A. Müller, 2018: Cost curves of energy efficiency investments in buildings -
13 Methodologies and a case study of Lithuania. *Energy Policy*, **115**, 148-157, doi:10.1016/j.enpol.2017.12.043.
- 14 Tollefson, J., 2017: World's carbon emissions set to spike by 2% in 2017. *Nature*, **551(7680)**, 283-283,
15 doi:10.1038/nature.2017.22995.
- 16 Torssonen, P. et al., 2016: Effects of climate change and management on net climate impacts of production and
17 utilization of energy biomass in Norway spruce with stable age-class distribution. *GCB Bioenergy*, **8(2)**, 419-
18 427, doi:10.1111/gcbb.12258.
- 19 Trabacchi, C. and B.K. Buchner, 2017: Adaptation Finance: Setting the Ground for Post-Paris Action. *Climate Finance*,
20 **Volume 2**, 35-54, doi:doi:10.1142/9789814641814_0003.
- 21 Trenberth, K.E., M. Marquis, and S. Zebiak, 2016: The vital need for a climate information system. *Nature Climate*
22 *Change*, **6(12)**, 1057-1059, doi:10.1038/nclimate3170.
- 23 Trisos, C.H. et al., 2018: Potentially dangerous consequences for biodiversity of solar geoengineering implementation
24 and termination. *Nature Ecology & Evolution*, **2(3)**, 475-482, doi:10.1038/s41559-017-0431-0.
- 25 Truelove, H., A.R. Carrico, and L. Thabrew, 2015: A socio-psychological model for analyzing climate change
26 adaptation: A case study of Sri Lankan paddy farmers. *Global Environmental Change*, **31**, 85-97,
27 doi:10.1016/j.gloenvcha.2014.12.010.
- 28 Truelove, H.B., A.R. Carrico, E.U. Weber, K.T. Raimi, and M.P. Vandenberg, 2014: Positive and negative spillover of
29 pro-environmental behavior: An integrative review and theoretical framework. *Global Environmental Change*,
30 **29**, 127-138, doi:10.1016/j.gloenvcha.2014.09.004.
- 31 Tschakert, P. et al., 2017: Climate change and loss, as if people mattered: values, places, and experiences. *Wiley*
32 *Interdisciplinary Reviews: Climate Change*, **8(5)**, doi:10.1002/wcc.476.
- 33 Tukker, A. et al., 2011: Environmental impacts of changes to healthier diets in Europe. *Ecological Economics*, **70(10)**,
34 1776-1788, doi:10.1016/J.ECOLECON.2011.05.001.
- 35 Tuomisto, H.L. and M.J. Teixeira de Mattos, 2011: Environmental Impacts of Cultured Meat Production.
36 *Environmental Science & Technology*, **45(14)**, 6117-6123, doi:10.1021/es200130u.
- 37 Turner, P.A. et al., 2018: The global overlap of bioenergy and carbon sequestration potential. *Climatic Change*, **148(1-**
38 **2)**, 1-10, doi:10.1007/s10584-018-2189-z.
- 39 Turnhout, E. et al., 2017: Envisioning REDD+ in a post-Paris era: between evolving expectations and current practice.
40 *Wiley Interdisciplinary Reviews: Climate Change*, **8(1)**, e425, doi:10.1002/wcc.425.
- 41 UN, 2014: *World urbanisation prospects, 2014 revisions*. Department of Economic and Social Affairs, New York, NY,
42 USA.
- 43 UN, 2016: *Transforming our World: The 2030 Agenda for Sustainable Development*. A/RES/70/1, United Nations
44 (UN), New York, NY, USA, 41 pp.
- 45 UN, 2017: *World Population Prospects - 2017 Revision*. Department of Economic and Social Affairs, Population
46 Division, United Nations, Paris, France.
- 47 Ünal, A.B., L. Steg, and M. Gorsira, 2017: Values Versus Environmental Knowledge as Triggers of a Process of
48 Activation of Personal Norms for Eco-Driving. *Environment and Behavior*, 001391651772899,
49 doi:10.1177/0013916517728991.
- 50 UNCBD, 2010: *Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity at its*
51 *Tenth Meeting*. 1-9 pp.
- 52 Underwood, B.S., Z. Guido, P. Gudipudi, and Y. Feinberg, 2017: Increased costs to US pavement infrastructure from
53 future temperature rise. *Nature Climate Change*, **7(10)**, 704-707, doi:10.1038/nclimate3390.
- 54 UNEP, 2005: *Enhancing Capacity Building for Integrated Policy Design and Implementation for Sustainable*
55 *Development*. Economics and Trade Branch, Division of Technology, Industry and Economics, United Nations
56 Environment Programme, Geneva, Switzerland, 65 pp.
- 57 UNEP, 2011: *Near-term Climate Protection and Clean Air Benefits: Actions for Controlling Short-Lived Climate*
58 *Forcers*. United Nations Environment Programme (UNEP), Nairobi, Kenya, 78 pp.
- 59 UNEP, 2014: *Decoupling 2: Technologies, Opportunities and Policy Options*. United Nations Environment
60 Programme, Nairobi, Kenya, 174 pp.

- 1 UNEP, 2015: *The financial system we need; aligning the financial system with sustainable development*. United
2 Nations Environment Programme, 112 pp.
- 3 UNEP, 2016: *The Adaptation Finance Gap Report 2016*. United Nations Environment Programme (UNEP).
- 4 UNEP, 2017a: *The Adaptation Gap Report 2017*. United Nations Environment Programme (UNEP), Nairobi, Kenya.
- 5 UNEP, 2017b: *The Emissions Gap Report 2017*.
- 6 UNESCO, 2017: What is Local and Indigenous Knowledge? [http://www.unesco.org/new/en/natural-sciences/priority-](http://www.unesco.org/new/en/natural-sciences/priority-areas/links/related-information/what-is-local-and-indigenous-knowledge)
7 [areas/links/related-information/what-is-local-and-indigenous-knowledge](http://www.unesco.org/new/en/natural-sciences/priority-areas/links/related-information/what-is-local-and-indigenous-knowledge) (Accessed: 12 May 2018).
- 8 UNFCCC, 1992: *United Nations Framework Convention on Climate Change*. UNFCCC, Bonn, Germany.
- 9 UNFCCC, 2015: Adoption of the Paris Agreement. In: *Report of the Conference of the Parties on its twenty-first*
10 *session, held in Paris from 30 November to 13 December 2015*. FCCC/CP/2015/10/Add.1, United Nations
11 Framework Convention on Climate Change (UNFCCC), pp. 32.
- 12 UN-Habitat, 2011: *Cities and Climate Change: Global Report on Human Settlements 2011*. 300 pp.
- 13 UN-Habitat, 2017: Sustainable Urbanisation in the Paris Agreement. .
- 14 UNISDR, 2009: *Global Assessment Report on Disaster Risk Reduction 2009 - Risk and Poverty in a Changing Climate:*
15 *Invest Today for a Safer Tomorrow*. United Nations International Strategy for Disaster Reduction, Geneva,
16 Switzerland, 14 pp.
- 17 Upadhyay, A.P. and A. Bijalwan, 2015: Climate Change Adaptation: Services and Role of Information Communication
18 Technology (ICT) in India. *American Journal of Environmental Protection*, **4(1)**, 70-74,
19 doi:10.11648/j.ajep.20150401.20.
- 20 Upton, G.B. and B.F. Snyder, 2017: Funding Renewable Energy: An Analysis of Renewable Portfolio Standards.
21 *Energy Economics*, **66(0)**, 205-216, doi:10.1016/j.eneco.2017.06.003.
- 22 Ura, K., 2015: The Experience of Gross National Happiness as Development Framework. , 38.
- 23 Ürge-Vorsatz, D., S.T. Herrero, N.K. Dubash, and F. Lecocq, 2014: Measuring the Co-Benefits of Climate Change
24 Mitigation. *Annual Review of Environment and Resources*, **39(1)**, 549-582, doi:10.1146/annurev-environ-
25 031312-125456.
- 26 Valdivia, C., C. Barbieri, and M.A. Gold, 2012: Between Forestry and Farming: Policy and Environmental Implications
27 of the Barriers to Agroforestry Adoption. *Canadian Journal of Agricultural Economics*, **60(2)**, 155-175,
28 doi:10.1111/j.1744-7976.2012.01248.x.
- 29 van Asselt, H., P. Pauw, and H. Sælen, 2015: Assessment and Review under a 2015 Climate Change Agreement. .
- 30 van der Brugge, R. and R. Roosjen, 2015: An institutional and sociocultural perspective on the adaptation pathways
31 approach. *Journal of Water and Climate Change*, **6(4)**, 743-758, doi:10.2166/wcc.2015.001.
- 32 van der Giesen, C. et al., 2017: A Life Cycle Assessment Case Study of Coal-Fired Electricity Generation with
33 Humidity Swing Direct Air Capture of CO₂ versus MEA-Based Postcombustion Capture. *Environmental*
34 *Science & Technology*, **51(2)**, 1024-1034, doi:10.1021/acs.est.6b05028.
- 35 van der Keur, P. et al., 2016: Identification and analysis of uncertainty in disaster risk reduction and climate change
36 adaptation in South and Southeast Asia. *International Journal of Disaster Risk Reduction*, **16**, 208-214,
37 doi:10.1016/j.ijdr.2016.03.002.
- 38 van Der Werff, E. and L. Steg, 2015: One model to predict them all: Predicting energy behaviours with the norm
39 activation model. *Energy Research and Social Science*, **6(July)**, 8-14, doi:10.1016/j.erss.2014.11.002.
- 40 van der Werff, E., L. Steg, and K. Keizer, 2013a: It is a moral issue: The relationship between environmental self-
41 identity, obligation-based intrinsic motivation and pro-environmental behaviour. *Global Environmental*
42 *Change*, **23(5)**, 1258-1265, doi:10.1016/j.gloenvcha.2013.07.018.
- 43 van der Werff, E., L. Steg, and K. Keizer, 2013b: The value of environmental self-identity: The relationship between
44 biospheric values, environmental self-identity and environmental preferences, intentions and behaviour.
45 *Journal of Environmental Psychology*, **34**, 55-63, doi:10.1016/j.jenvp.2012.12.006.
- 46 van der Werff, E., L. Steg, and K. Keizer, 2014a: Follow the signal: When past pro-environmental actions signal who
47 you are. *Journal of Environmental Psychology*, **40**, 273-282, doi:10.1016/j.jenvp.2014.07.004.
- 48 van der Werff, E., L. Steg, and K. Keizer, 2014b: I Am What I Am, by Looking Past the Present: The Influence of
49 Biospheric Values and Past Behavior on Environmental. *Environment and Behavior*, **46(5)**, 626-657,
50 doi:10.1177/0013916512475209.
- 51 van Dooren, C., M. Marinussen, H. Blonk, H. Aiking, and P. Vellinga, 2014: Exploring dietary guidelines based on
52 ecological and nutritional values: A comparison of six dietary patterns. *Food Policy*, **44**, 36-46,
53 doi:10.1016/j.foodpol.2013.11.002.
- 54 van Kasteren, Y., 2014: How are householders talking about climate change adaptation? *Journal of Environmental*
55 *Psychology*, **40**, 339-350, doi:10.1016/J.JENVP.2014.09.001.
- 56 van Oppen, M.J.H., J.K. Oliver, H.M. Putnam, and R.D. Gates, 2015: Building coral reef resilience through assisted
57 evolution. *Proceedings of the National Academy of Sciences*, **112(8)**, 2307-2313,
58 doi:10.1073/pnas.1422301112.
- 59 van Sluisveld, M.A.E. et al., 2015: Comparing future patterns of energy system change in 2 °C scenarios with
60 historically observed rates of change. *Global Environmental Change*, **35**, 436-449,

- 1 doi:10.1016/j.gloenvcha.2015.09.019.
- 2 van Soest, D.P. and E.H. Bulte, 2001: Does the Energy-Efficiency Paradox Exist? Technological Progress and
3 Uncertainty. *Environmental and Resource Economics*, **18(1)**, 101-112, doi:10.1023/A:101112406964.
- 4 van Soest, H.L. et al., 2017: Early action on Paris Agreement allows for more time to change energy systems. *Climatic
5 Change*, **144(2)**, 165-179, doi:10.1007/s10584-017-2027-8.
- 6 van Vliet, M.T.H., D. Wiberg, S. Leduc, and K. Riahi, 2016: Power-generation system vulnerability and adaptation to
7 changes in climate and water resources. *Nature Climate Change*, **6(4)**, 375-380, doi:10.1038/nclimate2903.
- 8 van Vuuren, D.P., O.Y. Edelenbosch, D.L. McCollum, and K. Riahi, 2017: A special issue on model-based long-term
9 transport scenarios: Model comparison and new methodological developments to improve energy and climate
10 policy analysis. *Transportation Research Part D: Transport and Environment*, **55**, 277-280,
11 doi:10.1016/j.trd.2017.05.003.
- 12 van Vuuren, D.P. et al., 2018: Alternative pathways to the 1.5 °C target reduce the need for negative emission
13 technologies. *Nature Climate Change*, **8(5)**, 391-397, doi:10.1038/s41558-018-0119-8.
- 14 Vandentorren, S. et al., 2006: Heat-related mortality August 2003 Heat Wave in France : Risk Factors for Death of
15 Elderly People Living at Home. *European Journal of Public Health*, **16(6)**, 583-591,
16 doi:10.1093/eurpub/ckl063.
- 17 Vandyck, T., K. Keramidis, B. Saveyn, A. Kitous, and Z. Vrontisi, 2016: A global stocktake of the Paris pledges:
18 Implications for energy systems and economy. *Global Environmental Change*, **41**, 46-63,
19 doi:10.1016/j.gloenvcha.2016.08.006.
- 20 Varela-Ortega, C. et al., 2016: How can irrigated agriculture adapt to climate change? Insights from the Guadiana Basin
21 in Spain. *Regional Environmental Change*, **16(1)**, 59.
- 22 Vaughan, C. and S. Dessai, 2014: Climate services for society: Origins, institutional arrangements, and design elements
23 for an evaluation framework. *WIREs Climate Change*, **5(5)**, 587-603, doi:10.1002/wcc.290.
- 24 Vaughan, C. et al., 2018: Surveying climate services: What can we learn from a bird's eye view? *Weather, Climate, and
25 Society*, WCAS-D-17-0030.1, doi:10.1175/WCAS-D-17-0030.1.
- 26 Vaughan, N.E. and C. Gough, 2016: Expert assessment concludes negative emissions scenarios may not deliver.
27 *Environmental Research Letters*, **11(9)**, 095003, doi:10.1088/1748-9326/11/9/095003.
- 28 Velásquez Barrero, L.S., 1998: Agenda 21: a form of joint environmental management in Manizales, Colombia.
29 *Environment and Urbanization*, **10(2)**, 9-36.
- 30 Velders, G.J.M., D.W. Fahey, J.S. Daniel, S.O. Andersen, and M. McFarland, 2015: Future atmospheric abundances
31 and climate forcings from scenarios of global and regional hydrofluorocarbon (HFC) emissions. *Atmospheric
32 Environment*, **123**, 200-209, doi:10.1016/j.atmosenv.2015.10.071.
- 33 Veldman, J.W. et al., 2015: Where Tree Planting and Forest Expansion are Bad for Biodiversity and Ecosystem
34 Services. *BioScience*, **65(10)**, 1011-1018, doi:10.1093/biosci/biv118.
- 35 Venables, A.J., 2016: Using Natural Resources for Development: Why Has It Proven So Difficult? *Journal of
36 Economic Perspectives*, **30(1)**, 161-184, doi:10.1257/jep.30.1.161.
- 37 Venhoeven, L.A., J.W. Bolderdijk, and L. Steg, 2013: Explaining the paradox: How pro-environmental behaviour can
38 both thwart and foster well-being. *Sustainability (Switzerland)*, **5(4)**, 1372-1386, doi:10.3390/su5041372.
- 39 Venhoeven, L.A., J.W. Bolderdijk, and L. Steg, 2016: Why acting environmentally-friendly feels good: Exploring the
40 role of self-image. *Frontiers in Psychology*, **7(NOV)**, 1990-1991, doi:10.3389/fpsyg.2016.01846.
- 41 Venkataraman, C., S. Ghosh, and M. Kandlikar, 2016: Breaking out of the Box: India and Climate Action on Short-
42 Lived Climate Pollutants. *Environmental Science & Technology*, **50(23)**, 12527-12529,
43 doi:10.1021/acs.est.6b05246.
- 44 Vergara, W., A.R. Rios, L.M. Galindo, and J. Samaniego, 2015: Physical Damages Associated with Climate Change
45 Impacts and the Need for Adaptation Actions in Latin America and the Caribbean. In: *Handbook of Climate
46 Change Adaptation* [Leal Filho, W. (ed.)]. Springer-Verlag GmbH Berlin Heidelberg, Berlin and Heidelberg
47 Germany, pp. 479-491.
- 48 Verhoef, L.A., B.W. Budde, C. Chockalingam, B. García Nodar, and A.J.M. van Wijk, 2018: The effect of additive
49 manufacturing on global energy demand: An assessment using a bottom-up approach. *Energy Policy*, **112**,
50 349-360, doi:10.1016/j.enpol.2017.10.034.
- 51 Verplanken, B. and D. Roy, 2013: "My Worries Are Rational, Climate Change Is Not": Habitual Ecological Worrying
52 Is an Adaptive Response. *PLoS ONE*, **8(9)**, e74708, doi:10.1371/journal.pone.0074708.
- 53 Verplanken, B. and D. Roy, 2016: Empowering interventions to promote sustainable lifestyles: Testing the habit
54 discontinuity hypothesis in a field experiment. *Journal of Environmental Psychology*, **45**, 127-134,
55 doi:10.1016/j.jenvp.2015.11.008.
- 56 Verplanken, B., H. Aarts, and A. Van Knippenberg, 1997: Habit, information acquisition, and the process of making
57 travel mode choices. *European Journal of Social Psychology*, **27(5)**, 539-560, doi:10.1002/(SICI)1099-
58 0992(199709/10)27:5<539::AID-EJSP831>3.0.CO;2-A.
- 59 Verstegen, J. et al., 2015: What can and can't we say about indirect land-use change in Brazil using an integrated
60 economic - land-use change model? *GCB Bioenergy*, **8(3)**, 561-578, doi:10.1111/gcbb.12270.

- 1 Veugelers, R., 2012: Which policy instruments to induce clean innovating? *Research Policy*, **41(10)**, 1770-1778,
2 doi:https://doi.org/10.1016/j.respol.2012.06.012.
- 3 Vicente-Vicente, J.L., R. García-Ruiz, R. Francaviglia, E. Aguilera, and P. Smith, 2016: Soil carbon sequestration rates
4 under Mediterranean woody crops using recommended management practices: A meta-analysis. *Agriculture,*
5 *Ecosystems & Environment*, **235**, 204-214, doi:https://doi.org/10.1016/j.agee.2016.10.024.
- 6 Viegas, J., L. Martinez, P. Crist, and S. Masterson, 2016: Shared Mobility: Innovation for Liveable Cities. *International*
7 *Transport Forum's Corporate Partnership Board*, 1-56, doi:10.1787/5jlwvz8bd4mx-en.
- 8 Villarroel Walker, R., M.B. Beck, J.W. Hall, R.J. Dawson, and O. Heidrich, 2014: The energy-water-food nexus:
9 Strategic analysis of technologies for transforming the urban metabolism. *Journal of Environmental*
10 *Management*, **141**, 104-115, doi:10.1016/j.jenvman.2014.01.054.
- 11 Vinke-de Kruijf, J. and C. Pahl-Wostl, 2016: A multi-level perspective on learning about climate change adaptation
12 through international cooperation. *Environmental Science & Policy*, **66**, 242-249,
13 doi:10.1016/j.envsci.2016.07.004.
- 14 Vision 2020 Project Team, 2011: *Vision 2020: New York City Comprehensive Waterfront Plan*. 192 pp.
- 15 Visoni, D., G. Pitari, and V. Aquila, 2017a: Sulfate geoengineering: a review of the factors controlling the needed
16 injection of sulfur dioxide. *Atmospheric Chemistry and Physics*, **17(6)**, 3879-3889, doi:10.5194/acp-2016-985,
17 2016.
- 18 Visoni, D. et al., 2017b: Sulfate Geoengineering Impact on Methane Transport and Lifetime : Results from the
19 Geoengineering Model Intercomparison Project (GeoMIP). *Atmos. Chem. Phys.*, **15(July)**, 1-35,
20 doi:10.5194/acp-17-11209-2017.
- 21 Visschers, V.H.M., J. Shi, M. Siegrist, and J. Arvai, 2017: Beliefs and values explain international differences in
22 perception of solar radiation management: insights from a cross-country survey. *Climatic Change*, **142(3-4)**,
23 531-544, doi:10.1007/s10584-017-1970-8.
- 24 Vlek, C.A.J. and L. Steg, 2007: Human behavior and environmental sustainability: Problems, driving forces, and
25 research topics. *Journal of Social Issues*, **63(1)**, 1-19, doi:10.1111/j.1540-4560.2007.00493.x.
- 26 Vogel, C., S.C. Moser, R.E. Kasperson, and G.D. Dabelko, 2007: Linking vulnerability, adaptation, and resilience
27 science to practice: Pathways, players, and partnerships. *Global Environmental Change*, **17(3-4)**, 349-364,
28 doi:doi: 10.1016/j.gloenvcha.2007.05.002.
- 29 von der Assen, N., J. Jung, and A. Bardow, 2013: Life-cycle assessment of carbon dioxide capture and utilization:
30 avoiding the pitfalls. *Energy & Environmental Science*, **6(9)**, 2721-2734, doi:10.1039/C3EE41151F.
- 31 Voskamp, I.M. and F.H.M. Van de Ven, 2015: Planning support system for climate adaptation: Composing effective
32 sets of blue-green measures to reduce urban vulnerability to extreme weather events. *Building and*
33 *Environment*, **83**, 159-167, doi:10.1016/j.buildenv.2014.07.018.
- 34 Vrontisi, Z. et al., 2018: Enhancing global climate policy ambition towards a 1.5 °C stabilization: a short-term multi-
35 model assessment. *Environmental Research Letters*, **13(4)**, 044039, doi:10.1088/1748-9326/aab53e.
- 36 Wachsmuth, D., D.A. Cohen, and H. Angelo, 2016: Expand the frontiers of urban sustainability. *Nature*, **536(7617)**,
37 391-393, doi:10.1038/536391a.
- 38 Wadud, Z., D. MacKenzie, and P. Leiby, 2016: Help or hindrance? The travel, energy and carbon impacts of highly
39 automated vehicles. *Transportation Research Part A: Policy and Practice*, **86**, 1-18,
40 doi:10.1016/j.tra.2015.12.001.
- 41 Waisman, H., J. Rozenberg, and J.C. Hourcade, 2013: Monetary compensations in climate policy through the lens of a
42 general equilibrium assessment: The case of oil-exporting countries. *Energy Policy*, **63**, 951-961.
- 43 Waisman, H., C. Guivarch, F. Grazi, and J.C. Hourcade, 2012: The Imaclim-R model: infrastructures, technical inertia
44 and the costs of low carbon futures under imperfect foresight. *Climatic Change*, **114(1)**, 101-120,
45 doi:10.1007/s10584-011-0387-z.
- 46 Walker, W. and M. Lönnroth, 1983: Nuclear power struggles : industrial competition and proliferation control. , 204.
- 47 Wallace, B., 2017: A framework for adapting to climate change risk in coastal cities. *Environmental Hazards*, **16(2)**,
48 149-164, doi:10.1080/17477891.2017.1298511.
- 49 Walsh, J.E., 2014: Intensified warming of the Arctic: Causes and impacts on middle latitudes. *Global and Planetary*
50 *Change*, **117(Supplement C)**, 52-63, doi:10.1016/j.gloplacha.2014.03.003.
- 51 Wamsler, C., 2007: Bridging the gaps : stakeholder-based strategies for risk reduction and financing for the urban poor.
52 *Environment & Urbanization*, **19(1)**, 115-152, doi:10.1177/0956247807077029.
- 53 Wamsler, C., 2017: Stakeholder involvement in strategic adaptation planning: Transdisciplinarity and co-production at
54 stake? *Environmental Science & Policy*, **75(March)**, 148-157, doi:10.1016/j.envsci.2017.03.016.
- 55 Wamsler, C. and E. Brink, 2014a: Interfacing citizens' and institutions' practice and responsibilities for climate change
56 adaptation. *Urban Climate*, **7**, 64-91, doi:10.1016/j.uclim.2013.10.009.
- 57 Wamsler, C. and E. Brink, 2014b: Moving beyond short-term coping and adaptation. *Environment & Urbanization*,
58 **26(6)**, 86-111, doi:10.1177/0956247813516061.
- 59 Wang, G. et al., 2017: Continued increase of extreme El Nino frequency long after 1.5°C warming stabilization. *Nature*
60 *Clim. Change*, **7(8)**, 568-572, doi:10.1038/nclimate3351.

- 1 Wang, Q., F. Xiao, F. Zhang, and S. Wang, 2013: Labile soil organic carbon and microbial activity in three subtropical
2 plantations. *Forestry*, **86(5)**, 569-574, doi:10.1093/forestry/cpt024.
- 3 Wang, Q., X. Chen, A.N. Jha, and H. Rogers, 2014: Natural gas from shale formation - The evolution, evidences and
4 challenges of shale gas revolution in United States. *Renewable and Sustainable Energy Reviews*, **30**, 1-28,
5 doi:https://doi.org/10.1016/j.rser.2013.08.065.
- 6 Wang, Q. et al., 2015: Structural Evolution of Household Energy Consumption: A China Study. *Sustainability*, **7**, 3919-
7 3932, doi:10.3390/su7043919.
- 8 Wang, X. et al., 2016: Taking account of governance: Implications for land-use dynamics, food prices, and trade
9 patterns. *Ecological Economics*, **122(Supplement C)**, 12-24,
10 doi:https://doi.org/10.1016/j.ecolecon.2015.11.018.
- 11 Wangui, E.E. and T.A. Smucker, 2017: Gendered opportunities and constraints to scaling up: a case study of
12 spontaneous adaptation in a pastoralist community in Mwangi District, Tanzania. *Climate and Development*,
13 1-8, doi:10.1080/17565529.2017.1301867.
- 14 Ward, J., S. Fankhauser, C. Hepburn, H. Jackson, and R. Rajan, 2009: *Catalysing low-carbon growth in developing
15 economies: Public Finance Mechanisms to scale up private sector investment in climate solution*. 28 pp.
- 16 Ward, P.J., W.P. Pauw, M.W. van Buuren, and M.A. Marfai, 2013: Governance of flood risk management in a time of
17 climate change: the cases of Jakarta and Rotterdam. *Environmental Politics*, **22(3)**, 518-536,
18 doi:10.1080/09644016.2012.683155.
- 19 Warren, C.R. et al., 2005: Green On Green': Public perceptions of wind power in Scotland and Ireland. *Journal of
20 Environmental Planning and Management*, **48(6)**, 853-875, doi:10.1080/09640560500294376.
- 21 Waters, J. and W.N. Adger, 2017: Spatial, network and temporal dimensions of the determinants of adaptive capacity in
22 poor urban areas. *Global Environmental Change*, **46**, 42-49, doi:10.1016/j.gloenvcha.2017.06.011.
- 23 Watkins, K., 2015: Power, people, planet: seizing Africa's energy and climate opportunities. .
- 24 Weber, E.U., 2015: Climate change demands behavioral change: What are the challenges. *Social Research: An
25 International Quarterly*, **82(3)**.
- 26 Wee, B., 2015: Peak car: The first signs of a shift towards ICT-based activities replacing travel? A discussion paper.
27 *Transport Policy*, **42**, 1-3, doi:10.1016/j.tranpol.2015.04.002.
- 28 Weenig, M.W.H. and C.J.H. Midden, 1991: Communication Network Influences on Information Diffusion and
29 Persuasion. *Journal of Per*, **61(5)**, 734-742.
- 30 Wehkamp, J., N. Koch, S. Lübbens, and S. Fuss, 2018a: Governance and deforestation - a meta-analysis in economics.
31 *Ecological Economics*, **144**, 214-227, doi:10.1016/j.ecolecon.2017.07.030.
- 32 Wehkamp, J. et al., 2018b: Accounting for institutional capacity in global forest modeling. *Environmental Modelling &
33 Software* (in press), doi:10.1016/j.envsoft.2018.01.020.
- 34 Wehner, M.F., K.A. Reed, B. Loring, D. Stone, and H. Krishnan, 2018: Changes in tropical cyclones under stabilized
35 1.5 and 2.0°C global warming scenarios as simulated by the Community Atmospheric Model under the HAPPI
36 protocols. *Earth System Dynamics*, **9(1)**, 187-195, doi:10.5194/esd-9-187-2018.
- 37 Wei, M., S.J. Smith, and M.D. Sohn, 2017: Experience curve development and cost reduction disaggregation for fuel
38 cell markets in Japan and the US. *Applied Energy*, **191**, 346-357,
39 doi:https://doi.org/10.1016/j.apenergy.2017.01.056.
- 40 Wei, Y., D. Tang, Y. Ding, and G. Agoramoorthy, 2016: Incorporating water consumption into crop water footprint: A
41 case study of China's South-North Water Diversion Project. *Science of The Total Environment*, **545-546**, 601-
42 608, doi:10.1016/J.SCITOTENV.2015.12.062.
- 43 Weindl, I. et al., 2015: Livestock in a changing climate: production system transitions as an adaptation strategy for
44 agriculture. *Environmental Research Letters*, **10(9)**, 94021.
- 45 Weitzman, M.L., 2015: A Voting Architecture for the Governance of Free-Driver Externalities, with Application to
46 Geoengineering. *Scandinavian Journal of Economics*, **117(4)**, 1049-1068, doi:10.1111/sjoe.12120.
- 47 Wejs, A., K. Harvold, S.V. Larsen, and I.-L. Saglie, 2014: Legitimacy building in weak institutional settings: climate
48 change adaptation at local level in Denmark and Norway. *Environmental Politics*, **23(3)**, 490-508,
49 doi:10.1080/09644016.2013.854967.
- 50 Weldegebriel, Z.B. and M. Prowse, 2013: Climate-Change Adaptation in Ethiopia: To What Extent Does Social
51 Protection Influence Livelihood Diversification? *Development Policy Review*, **31**, o35-o56,
52 doi:10.1111/dpr.12038.
- 53 Well, M. and A. Carrapatoso, 2017: REDD+ finance: policy making in the context of fragmented institutions. *Climate
54 Policy*, **17(6)**, 687-707, doi:10.1080/14693062.2016.1202096.
- 55 Wells, L., B. Rismanchi, and L. Aye, 2018: A review of Net Zero Energy Buildings with reflections on the Australian
56 context. *Energy and Buildings*, **158**, 616-628, doi:10.1016/j.enbuild.2017.10.055.
- 57 Wenzel, G.W., 2009: Canadian Inuit subsistence and ecological instability - If the climate changes, must the Inuit?
58 *Polar Research*, **28(1)**, 89-99, doi:10.1111/j.1751-8369.2009.00098.x.
- 59 Wesseling, J.H. et al., 2017: The transition of energy intensive processing industries towards deep decarbonization:
60 Characteristics and implications for future research. *Renewable and Sustainable Energy Reviews*,

- 1 **79(Supplement C)**, 1303-1313, doi:10.1016/j.rser.2017.05.156.
- 2 West, S.E. and R.C. Williams, 2004: Estimates from a consumer demand system: implications for the incidence of
3 environmental taxes. *Journal of Environmental Economics and Management*, **47(3)**, 535-558,
4 doi:10.1016/j.jeem.2003.11.004.
- 5 Westphal, M.I., S. Martin, L. Zhou, and D. Satterthwaite, 2017: Powering Cities in the Global South: How Energy
6 Access for All Benefits the Economy and the Environment. , 55.
- 7 White, C.J. et al., 2017: Potential applications of subseasonal-to-seasonal (S2S) predictions. *Meteorological*
8 *Applications*, doi:10.1002/met.1654.
- 9 White, R., J. Turpie, and G. Letley, 2017: *Greening Africa's Cities: Enhancing the Relationship between Urbanization,*
10 *Environmental Assets, and Ecosystem Services*. 56 pp.
- 11 Whitmarsh, L., G. Seyfang, and S.O.N. Workspace., 2011: Public engagement with carbon and climate change: To
12 what extent is the public 'carbon capable'? *Global Environmental Change*, **21(1)**, 56-65,
13 doi:10.1016/j.gloenvcha.2010.07.011.
- 14 WHO, 2015: Lessons learned on health adaptation to climate variability and change: experiences across low- and
15 middle-income countries. *WHO*.
- 16 Whyte, K.P., 2012: Now This! Indigenous Sovereignty, Political Obliviousness and Governance Models for SRM
17 Research. *Ethics, Policy & Environment*, **15(2)**, 172-187, doi:10.1080/21550085.2012.685570.
- 18 Wibeck, V. et al., 2017: Making sense of climate engineering: a focus group study of lay publics in four countries.
19 *Climatic Change*, **145(1-2)**, 1-14, doi:10.1007/s10584-017-2067-0.
- 20 Wigand, C. et al., 2017: A Climate Change Adaptation Strategy for Management of Coastal Marsh Systems. *Estuaries*
21 *and Coasts*, **40(3)**, 682-693, doi:10.1007/s12237-015-0003-y.
- 22 Wilcox, J., P.C. Psarras, and S. Liguori, 2017: Assessment of reasonable opportunities for direct air capture.
23 *Environmental Research Letters*, **12(6)**, 65001.
- 24 Williams, M. et al., 2011: Options for policy responses and their impacts. In: *Integrated Assessment of Black Carbon*
25 *and Tropospheric Ozone*. United Nations Environment Programme (UNEP), Nairobi, Kenya, pp. 171-250.
- 26 Williams, P. et al., 2017: Community-based observing networks and systems in the Arctic: Human perceptions of
27 environmental change and instrument-derived data. *Regional Environmental Change*, doi:10.1007/s10113-
28 017-1220-7.
- 29 Williams, P.M. and E.R.M. Druffel, 1987: Radiocarbon in dissolved organic matter in the central North Pacific Ocean.
30 *Nature*, **330(6145)**, 246-248, doi:10.1038/330246a0.
- 31 Williamson, P. and R. Bodle, 2016: Update on Climate Geoengineering in Relation to the Convention on Biological
32 Diversity: Potential Impacts and Regulatory Framework. , 158.
- 33 Williamson, P. et al., 2012: Ocean fertilization for geoengineering: A review of effectiveness, environmental impacts
34 and emerging governance. *Process Safety and Environmental Protection*, **90(6)**, 475-488,
35 doi:10.1016/J.PSEP.2012.10.007.
- 36 Willis, R., 2017: How Members of Parliament understand and respond to climate change. *The Sociological Review*, 1-
37 17, doi:10.1177/0038026117731658.
- 38 Wilson, C., 2012: Up-scaling, formative phases, and learning in the historical diffusion of energy technologies. *Energy*
39 *Policy*, **50**, 81-94, doi:10.1016/j.enpol.2012.04.077.
- 40 Wilson, C. and H. Dowlatabadi, 2007: Models of Decision Making and Residential Energy Use. *Annual Review of*
41 *Environment and Resources*, **32(1)**, 169-203, doi:10.1146/annurev.energy.32.053006.141137.
- 42 Wilson, C., A. Grubler, N. Bauer, V. Krey, and K. Riahi, 2013: Future capacity growth of energy technologies: Are
43 scenarios consistent with historical evidence? *Climatic Change*, **118(2)**, 381-395, doi:10.1007/s10584-012-
44 0618-y.
- 45 Wilson, S.A. et al., 2009: Carbon Dioxide Fixation within Mine Wastes of Ultramafic-Hosted Ore Deposits: Examples
46 from the Clinton Creek and Cassiar Chrysotile Deposits, Canada. *Economic Geology*, **104(1)**, 95-112.
- 47 Windeatt, J.H. et al., 2014: Characteristics of biochars from crop residues: Potential for carbon sequestration and soil
48 amendment. *Journal of Environmental Management*, **146**, 189-197,
49 doi:https://doi.org/10.1016/j.jenvman.2014.08.003.
- 50 Winkler, H., 2017: Reducing energy poverty through carbon tax revenues in South Africa. *Journal of Energy in*
51 *Southern Africa*, **28(3)**, 12, doi:10.17159/2413-3051/2017/v28i3a2332.
- 52 Winkler, H. and N.K. Dubash, 2015: Who determines transformational change in development and climate finance?
53 *Climate Policy*, 783-791, doi:DOI: 10.1080/14693062.2015.1033674.
- 54 Winkler, H., T. Letete, and A. Marquard, 2013: Equitable access to sustainable development: operationalizing key
55 criteria. *Climate Policy*, **13(4)**, 411-432, doi:10.1080/14693062.2013.777610.
- 56 Winkler, H. et al., 2011: Equitable access to sustainable development: Contribution to the body of scientific knowledge.
57 *Beijing, Brasilia, Cape Town, and Mumbai: BASIC Experts*.
- 58 Winkler, H. et al., 2017: Countries start to explain how their climate contributions are fair: more rigour needed.
59 *International Environmental Agreements: Politics, Law and Economics*, doi:10.1007/s10784-017-9381-x.
- 60 Wise, M., M. Muratori, and P. Kyle, 2017: Biojet fuels and emissions mitigation in aviation: An integrated assessment

- 1 modeling analysis. *Transportation Research Part D: Transport and Environment*, **52**, 244-253,
2 doi:10.1016/j.trd.2017.03.006.
- 3 WMO, 2015: Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services. ,
4 308.
- 5 Wolak, F.A., 2011: Do residential customers respond to hourly prices? Evidence from a dynamic pricing experiment.
6 *American Economic Review*, **101(3)**, 83-87, doi:10.1257/aer.101.3.83.
- 7 Wolfrom, L. and M. Yokoi-Arai, 2015: Financial instruments for managing disaster risks related to climate change.
8 *OECD Journal: Financial Market Trends*, **2015(1)**, 25-47.
- 9 Wollenberg, E. et al., 2016: Reducing emissions from agriculture to meet the 2C target. *Global Change Biology*,
10 **22(12)**, 3859-3864, doi:10.1111/gcb.13340.
- 11 Wolske, K.S., P.C. Stern, and T. Dietz, 2017: Explaining interest in adopting residential solar photovoltaic systems in
12 the United States: Toward an integration of behavioral theories. *Energy Research & Social Science*, **25**, 134-
13 151, doi:10.1016/j.erss.2016.12.023.
- 14 Wong, P.-H., 2014: Maintenance Required: The Ethics of Geoengineering and Post-Implementation Scenarios. *Ethics*,
15 *Policy & Environment*, **17(2)**, 186-191, doi:10.1080/21550085.2014.926090.
- 16 Wong, S., 2012: Overcoming obstacles against effective solar lighting interventions in South Asia. *Energy Policy*, **40**,
17 110-120, doi:https://doi.org/10.1016/j.enpol.2010.09.030.
- 18 Wood, B.T., C.H. Quinn, L.C. Stringer, and A.J. Dougill, 2017: Investigating Climate Compatible Development
19 Outcomes and their Implications for Distributive Justice: Evidence from Malawi. *Environmental Management*,
20 **1**, 1-18, doi:10.1007/s00267-017-0890-8.
- 21 Wood, P. and F. Jotzo, 2011: Price floors for emissions trading. *Energy Policy*, **39(3)**, 1746-1753.
- 22 Wood, S.A., A.S. Jina, M. Jain, P. Kristjanson, and R.S. DeFries, 2014: Smallholder farmer cropping decisions related
23 to climate variability across multiple regions. *Global Environmental Change*, **25**, 163-172,
24 doi:10.1016/j.gloenvcha.2013.12.011.
- 25 Woodcock, J. et al., 2009: Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport.
26 *The Lancet*, **374(9705)**, 1930-1943, doi:10.1016/S0140-6736(09)61714-1.
- 27 Woodruff, S.C. and M. Stults, 2016: Numerous strategies but limited implementation guidance in US local adaptation
28 plans. *Nature Climate Change*, **6(8)**, 796-802, doi:10.1038/nclimate3012.
- 29 Woods, B.A., H. Nielsen, A.B. Pedersen, and D. Kristofersson, 2017: Farmers' perceptions of climate change and their
30 likely responses in Danish agriculture. *Land Use Policy*, **65(May 2015)**, 109-120,
31 doi:10.1016/j.landusepol.2017.04.007.
- 32 Woolf, D., J.E. Amonette, A. Street-Perrott, J. Lehmann, and S. Joseph, 2010: Sustainable bio-char to mitigate global
33 climate change. *Nature Communications*, **1(56)**, doi:doi:10.1038/ncomms1053.
- 34 World Bank, 2016: *World Bank Group Climate Action Plan*. World Bank, Washington DC, USA, 59 pp.
- 35 World Bank, 2017a: Pacific Possible: Long-term Economic Opportunities and Challenges for Pacific Island Countries. .
- 36 World Bank, 2017b: Understanding Poverty: Safety Nets. <http://www.worldbank.org/en/topic/safetynets> (Accessed: 4
37 December 2017).
- 38 World Bank, 2018a: Global Financial Development Report - Bankers without borders. , 01 - 137, doi:10.1596/978-1-
39 4648-1148-7.
- 40 World Bank, 2018b: Groundswell: Preparing for Internal Climate Migration. .
- 41 World Economic Forum, 2013: *The Green Investment Report: ways and means to unlock private finance for green
42 growth*. 40 pp.
- 43 World Economic Forum, 2015: Industrial Internet of Things. .
- 44 Wright, H. et al., 2014: Farmers, food and climate change: ensuring community-based adaptation is mainstreamed into
45 agricultural programmes. *Climate and Development*, **6(4)**, 318-328, doi:10.1080/17565529.2014.965654.
- 46 Wu, P., J. Ridley, A. Pardaens, R. Levine, and J. Lowe, 2015: The reversibility of CO2 induced climate change.
47 *Climate Dynamics*, **45(3)**, 745-754, doi:10.1007/s00382-014-2302-6.
- 48 Xia, L., A. Robock, S. Tilmes, and R.R. Neely, 2016: Stratospheric sulfate geoengineering could enhance the terrestrial
49 photosynthesis rate. *Atmospheric Chemistry and Physics*, **16(3)**, 1479-1489, doi:10.5194/acp-16-1479-2016.
- 50 Xiao, J.J., H. Li, J. Jian, and X. Haifeng, 2011: Sustainable Consumption and Life Satisfaction. *Social Indicators
51 Research*, **104(2)**, 323-329, doi:10.1007/s11205-010-9746-9.
- 52 Xie, J. et al., 2017: An integrated assessment of urban flooding mitigation strategies for robust decision making.
53 *Environmental Modelling & Software*, **95(Supplement C)**, 143-155, doi:10.1016/j.envsoft.2017.06.027.
- 54 Xu, Y. and V. Ramanathan, 2017: Well below 2°C: Mitigation strategies for avoiding dangerous to catastrophic climate
55 changes. *Proceedings of the National Academy of Sciences*, **114(39)**, 10315-10323,
56 doi:10.1073/pnas.1618481114.
- 57 Xue, X. et al., 2015: Critical insights for a sustainability framework to address integrated community water services:
58 Technical metrics and approaches. *Water Research*, **77**, 155-169, doi:10.1016/j.watres.2015.03.017.
- 59 Yamamoto, L., D.A. Serraglio, and F.S. Cavedon-Capdeville, 2017: Human mobility in the context of climate change
60 and disasters: a South American approach. *International Journal of Climate Change Strategies and*

- 1 *Management*, IJCCSM-03-2017-0069, doi:10.1108/IJCCSM-03-2017-0069.
- 2 Yang, Y.C.E., S. Wi, P.A. Ray, C.M. Brown, and A.F. Khalil, 2016: The future nexus of the Brahmaputra River Basin:
3 Climate, water, energy and food trajectories. *Global Environmental Change*, **37**, 16-30,
4 doi:10.1016/j.gloenvcha.2016.01.002.
- 5 Yangka, D. and M. Diesendorf, 2016: Modeling the benefits of electric cooking in Bhutan: A long term perspective.
6 *Renewable and Sustainable Energy Reviews*, **59**, 494-503, doi:10.1016/j.rser.2015.12.265.
- 7 Yangka, D. and P. Newman, 2018: Bhutan: Can the 1.5 °C Agenda Be Integrated with Growth in Wealth and
8 Happiness? *Urban Planning*, **3(2)**, 94, doi:10.17645/up.v3i2.1250.
- 9 Yax L., P. and S. Álvarez, 2016: Bioindicadores y conocimiento ancestral/tradicional para el pronóstico meteorológico
10 en comunicados indígenas Maya - K'iche' de Nahualá, Sololá. Poster Presentation pp.
- 11 Yenneti, K. and R. Day, 2016: Distributional justice in solar energy implementation in India: The case of Charanka
12 solar park. *Journal of Rural Studies*, **46**, 35-46, doi:10.1016/j.jrurstud.2016.05.009.
- 13 Young, O.R., 2016: *Governing Complex Systems: Social Capital for the Anthropocene*. The MIT Press, Cambridge,
14 MA, USA and London, UK, 296 pp.
- 15 Young, W. et al., 2015: Changing Behaviour: Successful Environmental Programmes in the Workplace. *Business
16 Strategy and the Environment*, **24(8)**, 689-703, doi:10.1002/bse.1836.
- 17 Yuan, X., J. Zuo, R. Ma, and Y. Wang, 2017: How would social acceptance affect nuclear power development? A study
18 from China. *Journal of Cleaner Production*, **163(Supplement C)**, 179-186,
19 doi:https://doi.org/10.1016/j.jclepro.2015.04.049.
- 20 Zahariev, K., J.R. Christian, and K.L. Denman, 2008: Preindustrial, historical, and fertilization simulations using a
21 global ocean carbon model with new parameterizations of iron limitation, calcification, and N₂ fixation.
22 *Progress in Oceanography*, **77(1)**, 56-82, doi:10.1016/j.pocean.2008.01.007.
- 23 Zanchi, G., N. Pena, and N. Bird, 2012: Is woody bioenergy carbon neutral? A comparative assessment of emissions
24 from consumption of woody bioenergy and fossil fuel. *GCB Bioenergy*, **4(6)**, 761-772, doi:10.1111/j.1757-
25 1707.2011.01149.x.
- 26 Zangheri, P., R. Armani, M. Pietrobon, and L. Pagliano, 2018: Identification of cost-optimal and NZEB refurbishment
27 levels for representative climates and building typologies across Europe. *Energy Efficiency*, **11(2)**, 337-369,
28 doi:10.1007/s12053-017-9566-8.
- 29 Zaval, L., E.M. Markowitz, and E.U. Weber, 2015: How Will I Be Remembered? Conserving the Environment for the
30 Sake of One's Legacy. *Psychological Science*, **26(2)**, 231-236, doi:10.1177/0956797614561266.
- 31 Zeebe, R.E., 2005: Feasibility of ocean fertilization and its impact on future atmospheric CO₂ levels. *Geophysical
32 Research Letters*, **32(9)**, doi:10.1029/2005gl022449.
- 33 Zelli, F., 2011: The fragmentation of the global climate governance architecture. *Wiley Interdisciplinary Reviews:
34 Climate Change*, **2(1)**, 255-270.
- 35 Zeman, F., 2014: Reducing the Cost of Ca-Based Direct Air Capture of CO₂. *Environmental Science & Technology*,
36 **48(19)**, 11730-11735, doi:10.1021/es502887y.
- 37 Zeng, S. and Z. Chen, 2016: Impact of fossil fuel subsidy reform in China: Estimations of household welfare effects
38 based on 2007-2012 data. *Economic and Political Studies*, **4(3)**, 299-318,
39 doi:10.1080/20954816.2016.1218669.
- 40 Zhang, H., 2016: Towards global green shipping: the development of international regulations on reduction of GHG
41 emissions from ships. *International Environmental Agreements: Politics, Law and Economics*, **16(4)**, 561-577,
42 doi:10.1007/s10784-014-9270-5.
- 43 Zhang, H., W. Chen, and W. Huang, 2016: TIMES modelling of transport sector in China and USA: Comparisons from
44 a decarbonization perspective. *Applied Energy*, **162**, 1505-1514, doi:10.1016/j.apenergy.2015.08.124.
- 45 Zhang, W. et al., 2017: Perception, knowledge and behaviors related to typhoon: A cross sectional study among rural
46 residents in Zhejiang, China. *International Journal of Environmental Research and Public Health*, **14(5)**, 1-12,
47 doi:10.3390/ijerph14050492.
- 48 Ziervogel, G., A. Cowen, and J. Ziniades, 2016a: Moving from Adaptive to Transformative Capacity: Building
49 Foundations for Inclusive, Thriving, and Regenerative Urban Settlements. *Sustainability*, **8(9)**, 955,
50 doi:10.3390/su8090955.
- 51 Ziervogel, G., J. Waddell, W. Smit, and A. Taylor, 2016b: Flooding in Cape Town's informal settlements: barriers to
52 collaborative urban risk governance. *South African Geographical Journal*, **98(1)**, 1-20,
53 doi:10.1080/03736245.2014.924867.
- 54 Ziervogel, G. et al., 2017: Inserting rights and justice into urban resilience: a focus on everyday risk. *Environment and
55 Urbanization*, **29(1)**, 123-138, doi:10.1177/0956247816686905.
- 56 Zomer, R.J. et al., 2016: Global Tree Cover and Biomass Carbon on Agricultural Land: The contribution of
57 agroforestry to global and national carbon budgets. *Scientific Reports*, **6(April)**, 29987,
58 doi:10.1038/srep29987.
- 59 Zusman, E., A. Miyatsuka, J. Romero, and M. Arif, 2015: Aligning Interests around Mitigating Short Lived Climate
60 Pollutants (SLCP) in Asia: A Stepwise Approach. , 14.