Future Costs, Benefits, and Impacts of Renewables Used to Meet U.S. Renewable Portfolio Standards

In 2015 and 2016, seven states raised and extended their final renewable portfolio standard (RPS) targets, while another state enacted a new RPS policy. Interest in expanding and strengthening state RPS programs may continue, while efforts like recent proposals in many states to repeal or freeze existing RPS policies may also persist. In either context, questions about the potential costs, benefits, and other impacts of RPS programs are usually central to the decision-making process.

Previous studies have analyzed the historical costs, benefits, and impacts of renewables use to meet RPS policies (Wiser et al. 2016; Barbose et al. 2015; Heeter et al. 2014). Building on that work, the National Renewable Energy Laboratory (NREL) and Lawrence Berkeley National Laboratory (LBNL) have undertaken a new study (Mai et al. 2016) to answer additional questions:

1. What are the potential *future* costs, benefits, and impacts of renewables used to meet state RPSs as currently structured?
2. How would these potential costs, benefits, and impacts change with greater levels of renewable deployment?

This analysis of prospective costs, benefits, and impacts is structured around two scenarios evaluated using NREL's Regional Energy Deployment System (ReEDS) model: an Existing RPS scenario, which assumes that RPS requirements continue to grow based on existing state RPS policies as of July 2016; and a High Renewable Electricity (RE) scenario, which assumes that nearly all states adopt an RPS with relatively aggressive targets. The results of these scenarios are compared to a No RPS baseline scenario that assumes no further growth in RPS requirements beyond 2015 but includes limited economic growth in renewables.

By 2050, renewables (including hydropower) reach 40% of U.S. electricity generation under the Existing RPS scenario and 49% under the High RE scenario, compared to 34% in the baseline No RPS scenario (see Figure 1). These estimates are up from about 14% renewable penetration in 2015. The Existing RPS scenario results in 122 gigawatts (GW) (296 terawatt-hours [TWh]) of renewables above the No RPS scenario by 2050, while the High RE scenario results in 331 GW (765 TWh) of incremental renewable generation by 2050. These increases are estimated to avoid primarily fossil—both coal and gas—generation. These values reflect the amount of incremental RE needed to satisfy RPS requirements beyond 2014 and serve as the basis for which we evaluate the costs, benefits, and impacts.

The Regional Energy Deployment System (ReEDS) is a long-term capacity-expansion model for the deployment of electric power generation technologies and transmission infrastructure throughout the contiguous United States.

ReEDS provides a detailed representation of electricity generation and transmission systems and specifically addresses a variety of issues related to renewable energy technologies, including accessibility and cost of transmission, regional quality of renewable resources, seasonal and diurnal load and generation profiles, variability and uncertainty of wind and solar power, and the influence of variability on the reliability of electric power provision. ReEDS addresses these issues through a highly discretized regional structure, explicit statistical treatment of the variability in wind and solar output over time, and consideration of ancillary service requirements and costs.

In this analysis, costs, benefits, and other impacts are measured relative to the No RPS scenario and are thus based on all RE growth beyond 2015 used to meet future RPS compliance. The study examines benefits and impacts with respect to air pollution and avoided human health damages, greenhouse gas (GHG) emissions, water consumption and withdrawals, RE workforce and economic development, and consumer natural gas bills. The key findings of the analysis are summarized in Figures 2 and 3.

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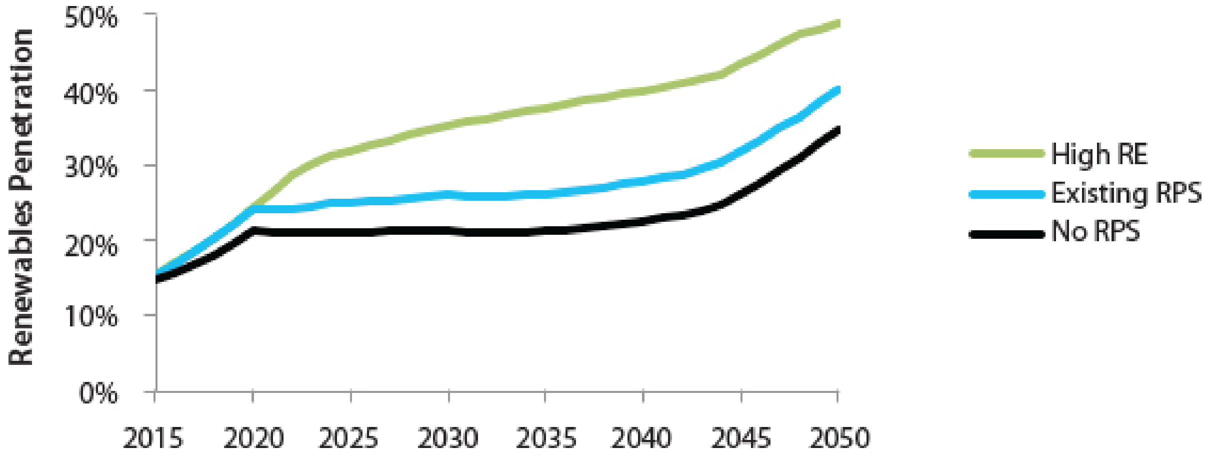

Figure 1. U.S. renewables penetration under three modeled scenarios

The Existing RPS scenario yields cumulative air pollutant emissions savings from 2015 to 2050 equal to 2.1 million metric tons of sulphur dioxide (SO_2) (5.5% as a percentage of total electricity sector emissions), 2.5 million metric tons of nitrogen oxide (NO_x) (5.7%), and 0.3 million metric tons of particulate matter 2.5 ($PM_{2.5}$) (4.5%). Based on these reductions, total health and environmental benefits are estimated to be $97 billion (central estimate), or 2.4¢ per kilowatt-hour of renewable energy (kWh-RE). In addition, the Existing RPS scenario yields cumulative GHG savings from 2015 to 2050 equal to 4.7 billion metric tons of carbon dioxide equivalent (CO_2e), or 6% of total life-cycle emissions from the electricity sector. Under the central estimate, global climate damage reductions equal $161 billion on a discounted, present value basis, or 3.9¢/kWh-RE.

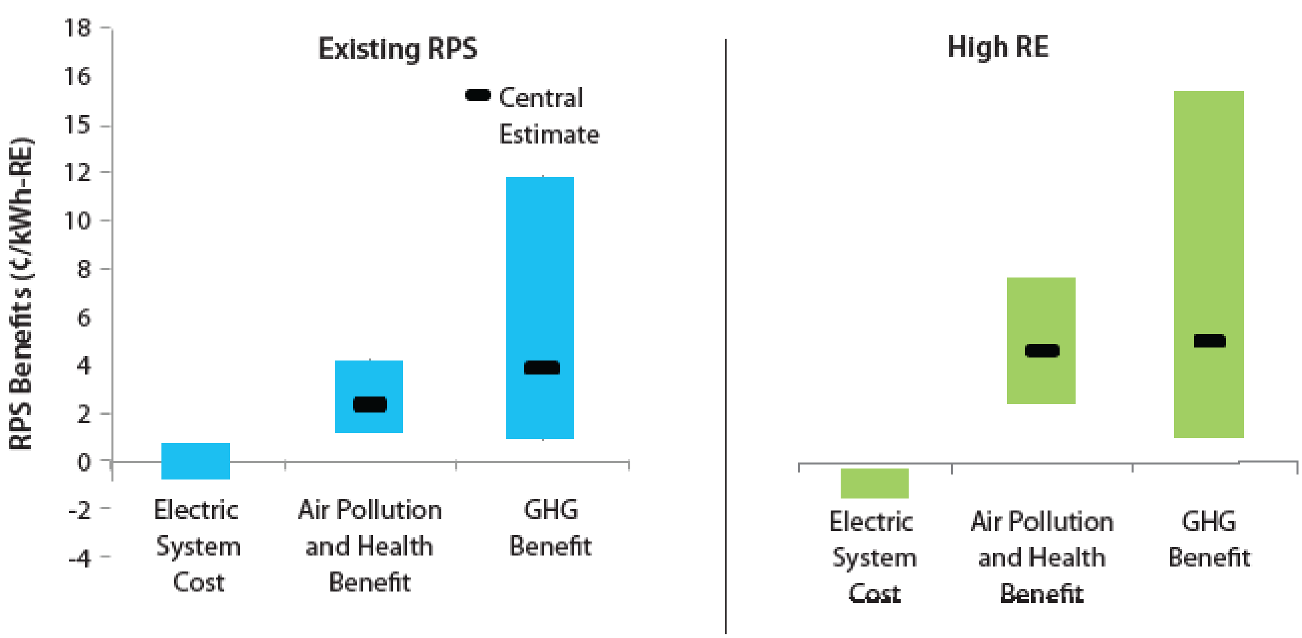

Figure 2. Comparison of costs, benefits, and impacts under the Existing RPS and High RE scenarios

Note: Water benefits and gross jobs and economic impacts are not shown here

		EXISTING RPS		HIGH RE	
RENEWABLE ENERGY IN 2050		increased by ↑ 122 GW | 296 TWh		increased by ↑ 331 GW | 765 TWh	
COSTS	ELECTRIC SYSTEM COSTS	range from -0.7% to 0.8%	equivalent to +/– $31 billion *estimates span +/- 0.75¢/kWh-RE*	range from 0.6% to 4.5%	equivalent to $23 billion– $194 billion *estimates span 0.26-1.5¢/kWh-RE*
COSTS	ELECTRICITY PRICES	range from -2.4 cents/kWh to 1 cent/kWH		range from -1.9 cents/kWh to 4.2 cents/kWH	
BENEFITS	SULFUR DIOXIDE	reduced by ↓ 6% | 2.1 million metric tons SO_2	equivalent to $97 billion (2.4¢/kWh-RE) *estimates span $48 billion-$175 billion (1.2-4.2¢/kWh-RE)*	reduced by ↓ 29% | 11.1 million metric tons SO_2	equivalent to $558 billion (5.0¢/kWh-RE) *estimates span $303 billion-$917 billion; 2.7-8.2¢/kWh-RE*
BENEFITS	NITROGEN OXIDES	reduced by ↓ 6% | 2.5 million metric tons NO_x		reduced by ↓ 29% | 12.8 million metric tons NO_x	
BENEFITS	PARTICULATE MATTER 2.5	reduced by ↓ 5% | 0.3 million metric tons $PM_{2.5}$		reduced by ↓ 29% | 1.8 million metric tons $PM_{2.5}$	
BENEFITS	GREENHOUSE GAS EMISSIONS	reduced by ↓ 6% | 4.7 billion metric tons CO_2e	equivalent to $161 billion (3.9¢/kWh-RE) *estimates span $37 billion-$487 billion (0.9-11.8¢/kWh-RE)*	reduced by ↓ 23% | 18.1 billion metric tons CO_2e	equivalent to $599 billion (5.4¢/kWh-RE) *estimates span $132 billion-$1,821 billion (1.2-16.3¢/kWh-RE)*
BENEFITS	WATER USE	reduced by ↓ 4% consumption | 3% withdrawal		reduced by ↓ 18% consumption | 18% withdrawal	
IMPACTS	NATURAL GAS	reduced by ↓ 35 quads (3.3%)	equivalent to $78 billion impact 1.9¢/kWh-RE	reduced by ↓ 46 quads (4.3%)	equivalent to $99 billion impact 0.9¢/kWh-RE
IMPACTS	RE JOB NEEDS	increase in ↑ 19% RE-employment	equivalent to 4.7 million RE job-years	increase in ↑ 47% RE-employment	equivalent to 11.5 million RE job-years

Figure 3. Cost, benefits, and impacts of the Existing RPS and High RE scenario relative to the No RPS Scenario, 2015-2050

The High RE scenario leads to cumulative air emission savings from 2015 to 2050 of 11.1 (29%), 12.8 (29%), and 1.8 (29%) million metric tons of SO_2, NO_x, and $PM_{2.5}$, respectively. The health benefits of these reduced emissions are estimated to be $558 billion on a present-value basis (central estimate), or 5.0¢/kWh-RE. In addition, GHG savings equal 18.1 billion metric tons, equivalent to 23% of total life-cycle emission in the electricity sector from 2015 to 2050. Using "central" estimates, the present-value global climate damage reductions from the High RE scenario equal $599 billion, equivalent to a levelized benefit of 5.4¢/kWh-RE.

In addition to the reduced air pollution and avoided human health damages and GHG benefits, the Existing RPS and High RE scenarios also yield benefits and impacts in the form of: reduced water consumption and withdrawals; an increase in gross renewable industry-related workforce; and lower consumer natural gas bills that result from the overall reduced natural gas demand.

When comparing the costs and monetized benefits, we find that the benefits exceed the costs, even when considering the highest cost and lowest benefit outcomes (Figure 2). Under the Existing RPS scenario, the high end costs are 0.75¢/kWh-RE, while air pollution and health benefits total at least 1.2¢/kWh-RE and GHG benefits total at least 0.9¢/kWh-RE. Under the High RE scenario, the high end costs are 1.5¢/kWh-RE while air pollution and health benefits total at least 2.7¢/kWh-RE and GHG benefits total at least 1.2¢/kWh-RE. The figures here are presented on a national basis and reflect levelized 2015-2050 values. These cost ranges in Figure 2 reflect varying assumptions about future natural gas prices and renewable technology costs.

The analysis considers an important subset—but not all—potential benefits and impacts; for example, we do not quantify land use and wildlife impacts. In addition, while the analysis examines the costs, benefits, and impacts of RE needed to meet RPS requirements going forward, it does not seek to attribute those effects solely to RPS policies, as a variety of other policy and market forces may also contribute to renewables growth over the study horizon. Moreover, although this analysis shows that the estimated benefits of RPS policies are greater than their costs, this does not imply that these policies are necessarily the most cost-effective way to achieve the benefits and impacts discussed in this paper. Finally, our work distinguishes between the potential benefits and impacts of RPS programs. Impacts are best considered resource transfers, benefiting some stakeholders at the expense of others, although such impacts might still be relevant to evaluating state RPS programs. Despite these limitations, this analysis can inform decision makers about the prospective costs, merits, and value of state RPS programs as they consider revisions to existing policies and development of new policies.

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