Food and Agriculture Organization of the United Nations

Costs and benefits of solar irrigation systems in Senegal

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Serge Noubondieu, Sapienza University of Rome
Alessandro Flammini, FAO
Stefania Bracco, FAO

with contributions from:
Maria Vittoria Peri (ENEA)
Andrea Micangeli, Sapienza University of Rome

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Acronyms and abbreviations

AICS	Italian Agency for Cooperation and Development
CPS	Comunità Promozione e Sviluppo (Community for Promotion of Development)
CBA	Cost Benefit Analysis
ENEA	Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (National Agency for New Technologies, Energy and Sustainable Economic Development)
FAO	Food and Agriculture Organization of the United Nations
GHG	Green House Gas
GIE	Groupement d'intérêt économique (Economic interest group)
INVESTA	Investing in Energy Sustainable Technology in Agrifood Sector
IPRES	National Institute for Retirement of Senegal
IRR	Internal Rate of Return
NGO	Non-governmental organization
NPV	Net Present Value
PBT	Pay-Back Time
PV	Photovoltaics
UEMOA	Union économique et monétaire de l'Afrique de L'Ouest (Economic and Monetary Union of Western Africa)
VAT	Value-added tax

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Background

The FAO project “Investing in Energy Sustainable Technologies in Agrifood Sector” (INVESTA) developed a methodology to analyze energy interventions in the agrifood sector[1]. The main purpose of the methodology is to assess costs and benefits associated with renewable energy and energy efficiency practices and to highlight hidden socio-economic and environmental costs and benefits of such interventions. This is important for decision-making for better targeting investments that will result in a net benefit to the society. The analytical approach has already been applied to specific energy interventions in the milk, vegetable, rice and tea value chains in Kenya, the Philippines, Tanzania and Tunisia.

In recent years, several experts (engineers, environmental supporters, government experts, agronomist technician, etc) are pushing for the installation of electric pumps fed by solar energy and modern irrigation systems in order to promote renewable energy and water use efficiency in agriculture particularly in rural areas of the developing world.

In this paper, the INVESTA methodology is applied to identify the real costs and benefits of solar irrigation systems in two international cooperation projects in Senegal.

[1] For more information on the project please visit www.fao.org/energy/agrifood-chains/investa/en/

1. Introduction to international cooperation projects

Nowadays, lawless immigration has become an emergency in many European Union countries, particularly those with the borders in the Mediterranean Sea. In 2015, the Italian Ministry of Internal Affairs decided to launch an international call proposal in other to support financially projects in rural areas aimed to improve living conditions and create jobs opportunities for young Africans, particularly in the countries where most of the people who are crossing Mediterranean are coming from (Senegal, Ethiopia, Ivory Coast, etc.). The main objective is to discourage the migrants who plan to cross the Mediterranean Sea leaving their own land by creating opportunities and development in their countries of origin. In 2016, the Italian Agency for Cooperation and Development (AICS) decided to finance projects in Senegal in other to promote the empowerment of women and young people through energy interventions in agriculture in rural areas. Design and installation of photovoltaic solar pumps and modern irrigation systems were among the main activities of the two projects. The non-governmental organization (NGO) CPS (www.cps-ong.it) promoted and coordinated the project “Professionals Without Borders” and the NGO Green Cross (www.greencrossitalia.org) managed the project “Energy to Stay”. A depth study has been carried out to highlight the real effects at local level of both interventions.

The analysis of costs, hidden benefits, socio economic and environmental impacts of the interventions have been made applying the methodology devised by the FAO INVESTA project (FAO-GIZ, 2018b). This methodology allows to check in depth the real costs and benefits of a renewable energy intervention in the agrifood sector. Its main steps are the financial cost-benefit analysis (CBA), the economic CBA (including value added along the value chains and transfer payments), and environmental and socio-economic impacts of the energy interventions over the lifetime of the investment. The selected indicators for the socio-economic and environmental impacts at intervention level are: soil quality; fertilizer use and efficiency; indoor air pollution; water use and efficiency; water quality; food loss; land requirement; greenhouse gas (GHG) emissions; access to energy; household income; time saving and employment (FAO-GIZ, 2018b).

2. Project “Professionals without borders”

The project "Professionals without borders: skills of diasporas for local economic development in Sub-Saharan Africa" is sponsored by the Italian Ministry of home affairs. The project, officially started in January 2017, stems from the awareness that diasporas can be a real asset for the development of countries of origin and it aims to identify and enhance the professional skills of migrants who live in Italy, and want to contribute to economic development in rural areas of Ivory Coast, Ethiopia and Senegal. The project also promotes the networking of immigrant associations and the Italian Cooperation with local institutions. Several migrants, in fact, acquire skills through education and training courses in Italian universities, and these skills could be exploited for social and economic development in their countries of origin. The project's overall objective is to contribute to promote transfer of knowledge, expertise and professional skills of the immigrants for the economic development of rural areas of the countries of origin.

2.1 Description of the energy intervention

Yene is a small municipality of 35 000 inhabitants overlooking the sea. It is located in the Rufisque department in the Dakar Region. There are no industries or equivalent employers able to provide local people with long-term job contracts. Fishing is the main activity that can provide long-term income to its young population. The alternative to fishing in the area is represented by emigration to Europe or the rural exodus to the large cities of Senegal (Dakar, Mbour, Thies, Rufisque, etc). The CPS NGO is promoting agriculture in two localities in Yene (Ndokoura, Toubab Dialaw) by offering technical assistance to GIE, a local cooperative of farmers. The shareholders of the cooperative are around 100 owners of land used for agriculture.

There are two seasons in Senegal: the rainy season (from July to September) and the dry season (from October to June). The biggest issue for the farmer is how to find enough water for the irrigation of the plants particularly during the nine month of the dry season.

Figure 1: Farms overview before building the photovoltaics plant

©FAO/Serge Noubondieu

Before the installation of the solar pumps in the farm in Ndokoura, water for irrigation was collected through a submersible pump installed inside a well. The electricity necessary to operate the pump was produced by a diesel generator (nominal power 3 kWA). The greatest challenge for the farmers was to insure the regular maintenance of the diesel generator, the submersible pumps and the purchase of right quantity of diesel particularly during the dry season. The local farmers' cooperative spent each year in average 403 USD for the purchase of diesel fuel. The situation was worse in the farm of Toubab Dialaw, where water for irrigation was collected manually from a well through a bucket connected to a rope.

The project "Professionals Without Borders" allowed to build three new water pumping solar plants to help farmers improve irrigation in both sites. The photovoltaic systems currently provide electricity to submersible pumps that allow the extraction of water from wells that have a maximum depth of 40 meters. Tanks of various sizes and PVC pipes have been designed and built for drip irrigation. The purpose is to promote water use efficiency in agriculture in the area. The main plants grown in the two sites are tomatoes, okra, chili, onion and salad. In Table 2.1 a summary of the interventions is provided.

Table 2.1: Summary of interventions (Professionals Without Borders project)

Site	Farm area [ha]	Volume of water tank [l]	Flow capacity of submersible pumps [m^3/day]	Power of the photovoltaic plant [W_p]	Irrigation system
Ndokoura	1.5	7 000	15	530	Drip irrigation with pvc pipes
Toubab Dialaw	2.1	15 000	85	1.530	Drip irrigation with pvc pipes

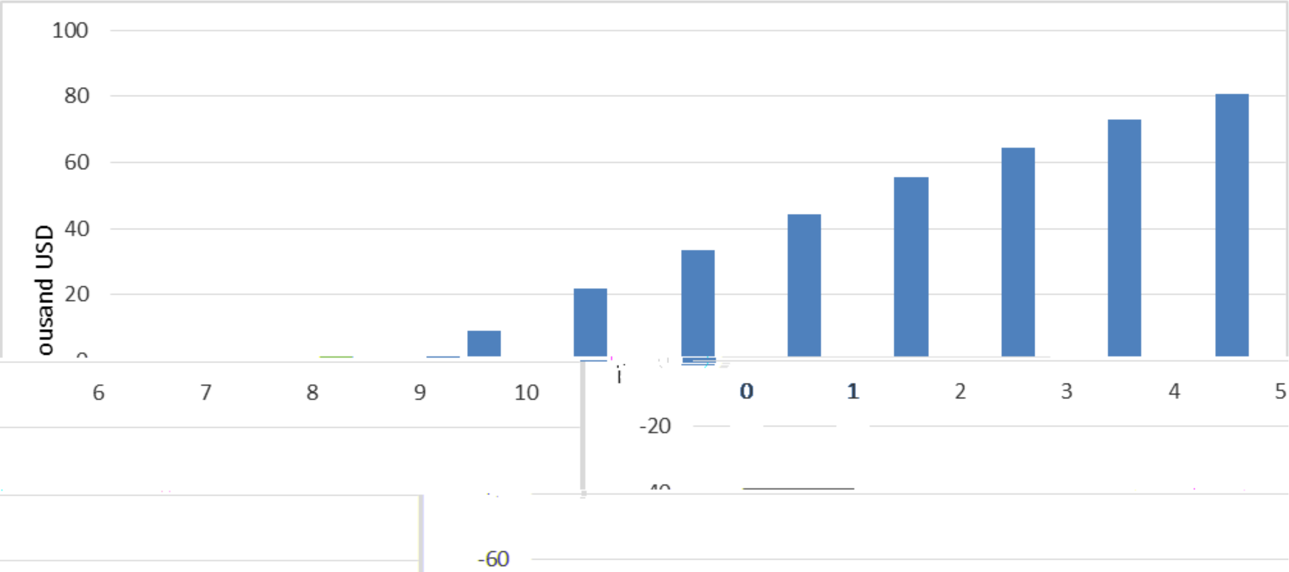
Figure 2: Pictures of interventions performed

2.2 Analysis of costs and benefits

2.2.1 Financial CBA

This section represents an analysis of costs and benefits of an intervention, including socio-economic and environmental impacts. The overall cost of purchase and installation of the solar irrigation plants listed in Table 2.1 is USD 38 297. The drill of the new wells was performed by a local company. The solar equipment (photovoltaic modules, inverters, controllers, submersible pumps, pipes, cables, etc.), manufactured in Europe, was purchased locally. The operation and maintenance activities necessary for the new plant are estimated in USD 299 per year. A social discount rate of 15% was assumed, which includes the cost of financing. The land used for agriculture belongs to the shareholders of farmer cooperative therefore there is no need to pay a rent. At the end of the season, 20% of the crops is consumed by the farmers to face their family needs and 80% is sold to the national market. The financial net present value (NPV) of the intervention after 10 years (assumed lifetime of submersible pumps) is USD 80 887. The internal rate of return (IRR) is 50%. The pay-back time (PBT) of the overall intervention is around 2 years.

Figure 3: Financial cumulative discounted net benefits of interventions over 10 years



2.2.2 Economic CBA

Subsidies and taxes

The introduction of solar pumps to collect water for irrigation implies the avoided use of the diesel genset. According to local taxation, the taxes incomes that the local government 'loses' from the avoided purchase of diesel by the farmers is USD 179 per year. The devices (PV modules, inverter, etc.) used to built the new plants are all imported from abroad, then customs duties has to be paid by their owners. Those duties represent new financial incomes for the government. In this case, the government of Senegal earned 294 USD through the port authority agency.

The solar pumps provide enough water for the correct irrigation of the crops. In the site of Toubab Dialaw, crops yield is around 60% of the theoretical reachable value. In the site of Ndokoura the yield remained under 50% of the maximum reachable value because the solar irrigation plant was not been properly designed. This because there was not enough money to build the suitable solar irrigation plant. The sale of more crops by the farmer's cooperative means more VAT (currently 18% in Senegal), an income for the local government. The first year, crop production reached 15.5 tons. The VAT collected by the government for the first year is estimated in USD 2 172. On this basis, the economic NPV at the end of the investment is USD 92 189 and the economic IRR is 57%.

Value added along the value chain

The crops must be cleaned before the transport to the local market. This is an important step necessary to facilitate and to accelerate the sale of the crops. The water currently used to clean the crops is collected by the solar water pumps of the new plants. Just by the lower energy costs to pump this water, farmers will save USD 910 per year.

Water use efficiency

The solar pump improves water availability for crop irrigation. The quantity of water currently used for irrigation purpose is, after the intervention, higher than the quantity that was collected using the genset generator and the submersible pump. The additional water used for irrigation in both the sites (Ndokoura and Toubab Dialaw) leads to a higher income of USD 1 008 for the farmers due to avoided irrigation water purchase (at USD 0.1 USD per m^3).

Employment

An electrician for photovoltaic plant and a plumber for the drip irrigation system are needed (part-time) to properly maintain the three new plants, as prescribed by the manufactures of the equipment. The overall cost of operations and maintenance (wages and cost of technicians, transport, spares parts, etc) for the first year is USD 299. The farmers' cooperative (GIE) will be responsible for managing the maintenance once the three new plants will start operating. The maintenance expenses are considered part of the operation costs of the farmers' cooperative.

Household income

The production of crops increased substantially since there is enough water available for the irrigation of the plants. The income of the cooperative of farmers has also increased. The shareholders of the cooperative are the same farmer families. Each family will earn at the end of the dry season USD 441. The household income has increased by 66 % comparing to the situation before the installation of solar pumps.

Time saving

The introduction of drip irrigation equipment in the farm allowed farmers to save time because irrigation operations are no longer done manually. The weekly travel of farmers to big cities (Mbour, Diaminodio, Rufisque, etc) to purchase diesel fuel for the genset are no longer necessary, leading to 940 hours per year saved for other activities. This represents a saving of USD 319.6 per year. The hourly wage in rural areas in Senegal is USD 0.43 according to the National Institute for Retirement of Senegal (IPRES).

Land requirement

During the design and construction of the solar irrigation system, we the space needed for the correct installation of the solar modules was taken into account, including the tanks for water accumulation and the technical room necessary for controllers and inverters. In our case, the land required is 41.4 m^2. This represents the 0.1 % of the overall space used for farming. The value of the space occupied by the plant is 754.4 USD (according to the local real estate market, the unit price of the land in the area was estimated in 18 USD/m^2).

GHG emissions

The solar pumps replaced electric pumps using a genset for water pumping to the tank. The diesel is no longer used for irrigation, thus GHG emissions avoided. In the current case, each year, 1 ton of CO_{2eq} will no longer be released. Following the figures released by the World Bank in 2017 (World Bank, 2017) concerning sanctions for countries that do not respect the restrictions on air pollution, the fine to be paid for such amount of emissions could be equaled to 37 USD per ton.

Table 2.2: Summary of environmental and socio-economic impacts of the intervention "Professionals Without Borders"

Name of the indicator	Impact	Impact indicator	Monetized indicator
Soil quality	no impact		
Fertilizer use and efficiency	no impact		
Indoor air pollution	no impact		
Water use and efficiency	negative	cm 10081	1 008 USD/year
Food loss	no impact		
Water quality	no impact		
Land requirement	negative	41.4 m^2	754.4 USD
GHG emissions	positive	1 tons of CO_{2eq}/year	37 USD /year
Access to energy	no impact		
Household income	positive		441 USD/year
Time saving	positive	940 hours	319.6 USD/year
Employment	positive	2 part-time skilled jobs created (1 electrician and 1 plumber)	179 USD/year

Added along the value chain	positive		910 USD/year
Added along the value chain	positive		910 USD/year

Color code: green: positive impact; white: no or negligible impact; red: negative impact.

2.2.3 Profitability

We have considered in our analysis that the interventions have been carried out through a loan from a local bank. The fixed interest rate is 10%. The social discount rate considered for evaluation of the NPV and the IRR (which considers financing but excludes inflation) is 10%. According to UEMOA[2], this is the basic interest rate applied by Banks in Senegal on investments. The inflation rate considered is 1.3%. On this basis, the financial NPV and the economic NPV after 10 years are positive. The pay-back time of intervention is 2 years (Figure 3). There are in fact important tax revenues (custom duties on imported technology, value added taxes linked to the sale of crops, etc) in favor of the local government (the society) due to the new intervention. There are also tax losses, particularly from the avoided purchase of diesel to run diesel generator. In addition, the maintenance of the new plants automatically means employment. There are two specialized jobs (electrician and plumber) created in Yene. The building of solar plants also means benefits for the local environment due to the reduction of GHG emissions. The land occupation impact is considered negligible because the portion of land occupied by the plant components is just 0.1% of the farm area.

Table 2.3: Financial and economic CBA of the interventions "Professionals Without Borders" (solar pumps and drip irrigation system)

Item	Unit	Value	Notes
Costs			
Capital cost	USD	38 296	Purchase and installation of the new plants at year 0
Maintenance cost	USD/year	299	
Additional labour cost	USD/year	0	
Other operating costs (fuel cost)	USD/year	0	
Missing tax revenue (fuel)	USD/year	179	Tax revenue lost by local

[2] Information available online at http://www.izf.net/content/taux-dint-r-t-place-1

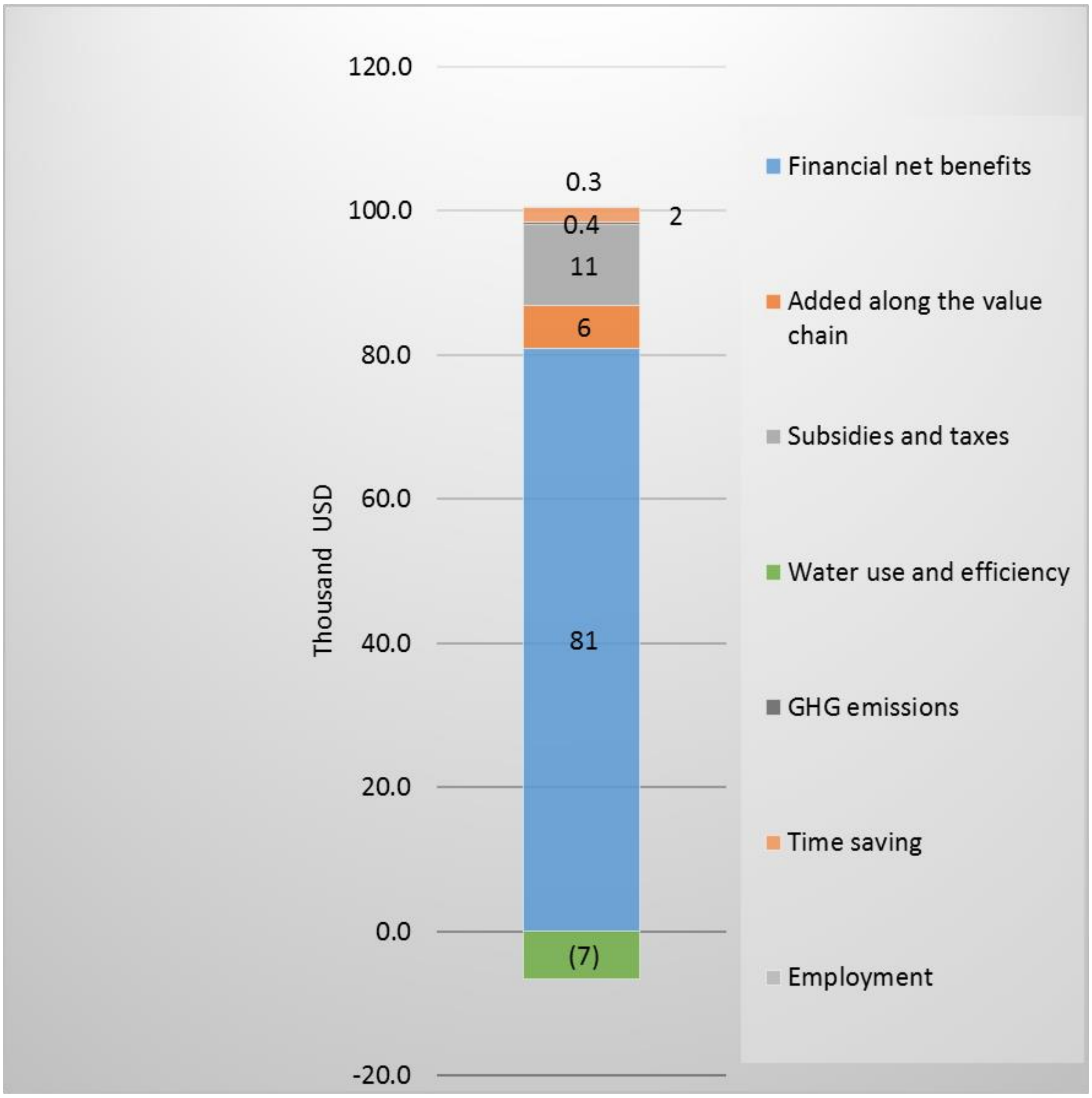
			government due to avoided diesel fuel purchase
Water use efficiency	USD/year	1 008	Cost of additional water used for irrigation
Benefits			
Value added along value chain	USD/year	910	Cleaning of the crops before selling
Net tax revenue (technology import)	USD	294	
GHG emissions	USD/year	62.899	Avoided emissions from the diesel generator
Employment	USD/year	179	
Household income	USD/year	441	Increase of families income of 66 %
Time saving	USD/year	319.6	
VAT revenue due to private spending	USD/year	2 172	Additional incomes in favor of local government linked to increase of the quantity of crops sold by farmers
Profitability indicators			
Financial IRR	**%**	**50**	
Financial NPV	**USD**	**80887**	
Economic IRR	**%**	**57**	
Economic NPV	**USD**	**92189**	

Note: Life expectancy of pumps used: 10 years. Discount rate 10 %. Inflation rate considered is 1.3%. Financial costs and benefits are on a yellow background; economic costs and benefits are on a green background.

2.2.4 Results

A forecast of the benefits of such intervention in the next 10 years is presented in Figure 4.

Figure 4: Cumulative economic costs and benefits of the intervention "Professionals Without Borders" after 10 years



3. Project "Energy to Stay"

In Senegal, migration is a harsh reality. Young people escape from drought, poverty and hunger, without any care of their own life in search of a better future abroad. "Energy to stay", in the *pulaar* language[3] "Hadii Yahde", is the new project that the NGO Green Cross has launched in Senegal in 2016 in order to improve living conditions of young people and women in rural areas in the Matam region (Figure 5). The purpose was to contribute to reduce irregular migration toward Europe. The project was funded by the Italian Agency for Development and Cooperation (AICS), and carried out in partnership with Enea. "Energy to stay" wants to create job opportunities in five rural villages in the north-eastern part of the country. In this area, the strong potential of development of agriculture is hampered by desertification, poor crop differentiation, the use of old and polluting machinery, and the high cost of fossil fuel (diesel, gasoline). Water pumping systems powered by photovoltaic panels were installed to avoid the consumption of more than 2 700 liters of diesel per year. Seeds will be provided for the farming of 37 hectares of land, new agricultural techniques based on crop rotation, and market strategies developed to strengthen the commercialization of products.

Figure 5: Map of Senegal – Region of Matam

Source: https://www.worldatlas.com/webimage/countrys/africa/sn.htm

Before the solar irrigation system, the greatest challenge for the farmers was to insure the regular maintenance of the diesel generator, the submersible pump and the purchase of fuel necessary for

[3] Pulaar is a language spoken primarily as a first language by the Fula and Toucouleur people in the Senegal River valley area, traditionally known as Futa Tooro, and further south and east. Pulaar speakers, known as *Haalpulaar'en* live in Senegal, Mauritania, the Gambia, and western Mali.

the diesel generator. Before the installation of the new system, the cooperative spent each year USD 1 824 to purchase the fuel.

The direct beneficiaries of the "Energy to stay" intervention are the shareholders of the local cooperative of farmers, called GIE, mostly made by women. Entire communities of five rural villages (22 500 people) will benefit indirectly from the strengthening of resilience and increased agricultural productivity. The real actors of this small revolution are women.

3.1 Description of the energy intervention

A photovoltaic system with a total power of 41 kW_p was built and several submersible water pumps were installed. A Californian irrigation system[4] was also realized to grow carrots, cabbages, peppers, lemons, mangoes, tomatoes, salad, and okra which are already grown in the area (even during the dry season) but with very low yields. The solar modules produce enough electricity to feed submersible pumps to collect water from the river Senegal and convey it to the fields to be irrigated. The intervention has allowed the replacement of both old diesel generators and old electric pumps. Table 3.1 presents a summary of the intervention achieved.

Table 3.1: Summary of the intervention "Energy to stay"

Site	Farm area [ha]	Volume of water tank [l]	Flow capacity of submersible pumps [m^3/day]	Power of the photovoltaic plant [W_p]	Irrigation system
Koundel	5.5	10	4 400	456	'Californian'
Woudourou	6	10	4 000	912	'Californian'
Sadel	13	11	4 800	912	'Californian'
Ballel Pathé	4.5	5	5 000	456	'Californian'
Sinthiou Diam Dior	8	5	n/a	456	'Californian'

[4] Irrigation method based on flooding. The method is widespread flooding in the state of California (USA), and therefore its name. It is very effective for growing rice.

Figure 6: Pictures of the "Energy to stay" solar irrigation system

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3.2 Analysis of costs, benefits, socio economic and environment impacts

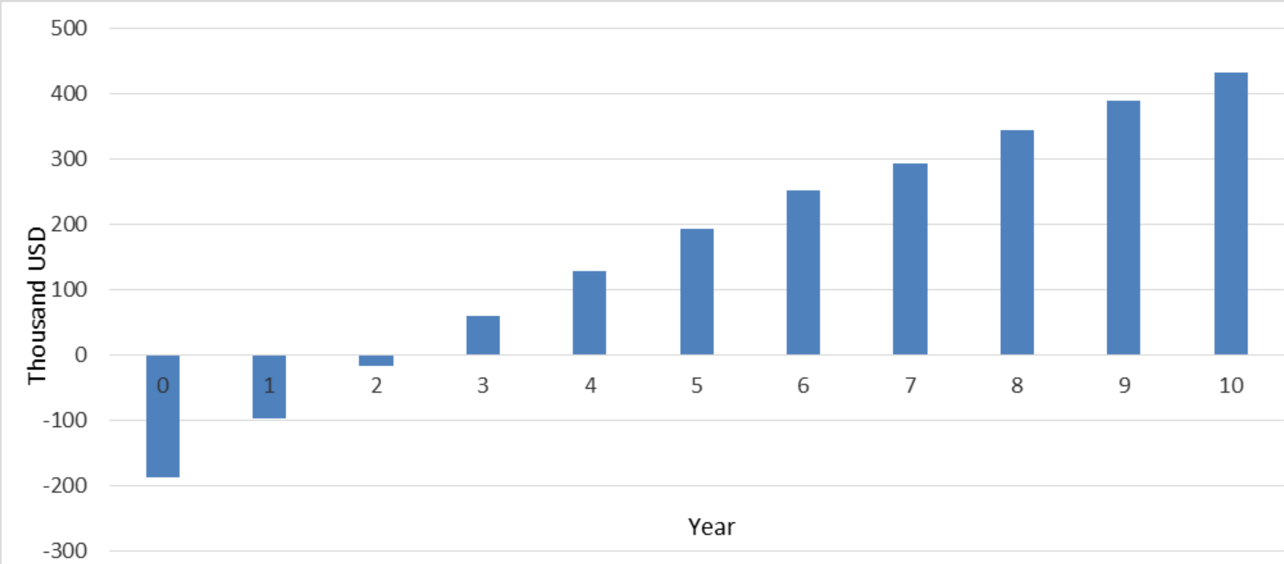
Again, the INVESTA methodology is applied in order to highlight the real socio-economic and environmental impacts of the intervention. In particular, the analysis focuses on the sites of Ballel Pathé and Woudourou.

3.2.1 Financial CBA

The overall cost of purchase and installation of the new plants is USD 163 682. There is no rent to pay because the land used for agriculture belongs to the farmer cooperative beneficiary of the investment. The financial NPV of intervention is 432 365 USD and the financial IRR is 57%. A social discount rate of 10% was used for evaluation of NPV and IRR, including the cost of financing. This is the basic interest rate in the country for the investments according to UEMOA[5].

[5] Information available online at http://www.izf.net/content/taux-dint-r-t-place-1

Figure 7: Financial cumulative discounted net benefits of the intervention "Energy to stay" over 10 years



3.2.2 Economic CBA

Subsidies and taxes

The photovoltaic solar modules replaced the old diesel genset, thus the related tax income in favor of the local government from the purchase of diesel by the farmer cooperative is no longer available. This is a loss for the local government of 729 USD every year. The equipment (PV modules, inverter, etc) used to build the new plants are all imported from abroad and the local government earned USD 8 261 of customs duty. The solar pump allows the provision of enough water to allow the correct irrigation of the crops (today at around 60 % of the maximum theoretical yield). The sale of more crops by the farmer cooperative means more VAT (18 % in Senegal), thus more income in favor of the local government. In the first year, the overall crop production reached 116 350 tons. The VAT collected by the government (in the first year) was 14 048 USD.

Value added along the chain value

The availability of water from the solar pump for irrigation purposes increased crop production. Most of the crops are collected and sold in the Rufisque, Mbour, or Dakar markets. The crops need to be washed properly before been brought to the market. The farmers save USD 3 558 per year only due to the increased water availability to clean the crops.

Water use efficiency

The solar pumps allowed a substantial increase of water availability for irrigation. Farmers actually have 1 368 cubic meters of water per day for irrigation purpose. Before the solar pumps, for the same land, the quantity of water available for irrigation was around 259.2 cubic meters per day. The water resources in the areas are therefore more exploited after the intervention. The additional cost of water used for irrigation is 4 447 USD per year. The unit price considered as reference for our evaluation is 0.1 USD/m^3 (indicative cost of irrigation water purchased locally, as a proxy for the social water cost).

Employment

The maintenance of the new system has to be done by qualified technicians. An electrician and a plumber are needed to perform properly all the operations necessary for maintenance of the new system. This is a part time job necessary to achieve all the maintenance operations prescribed by the manufacturers of the new equipment. The overall cost of maintenance operations (wages of technicians, spares pieces etc.) is 1 682 USD/year. This cost is borne by the farmer cooperative.

Household income

The crop yield has increased substantially since there is more water available for the irrigation, and the income of the cooperative has also increased. The shareholders of the cooperative are the families of farmers. Each family will earn at the end of the season additional USD 375. The household income has therefore increased by 100 % if compared to the situation before the installation of the solar system.

Time saving

Californian irrigation has allowed the farmers to save time. Manual irrigation and weekly travel to the nearest cities (Ourossougui, Matam, etc) to purchase the diesel fuel is no longer necessary. In this case 208 hours per year have been saved. According to IPRES, the national institute for retirement in Senegal, the average unit price of work in rural areas is 0.34 USD/hour. Therefore, it amounts to about around 70.72 USD/year (time available for other productive activities).

Land requirement

A solar system requires space. In the current case, the land needed for the solar panels, tanks and the technical room for the controller and inverter is 198 m^2. It represents 0.2% of the overall farm surface. The current value of such a space is about 3 564 USD according to local real estate market (18 USD/m^2).

GHG emissions

The replacement of the genset by a solar system means less GHG emission. In the current case, the quantity of CO_{2eq} avoided is 4.3 tons per year. According to the World Bank, 2017, estimate of sanctions for countries that do not respect the restrictions on GHG emission, this could equal 159.1 USD per year (the unit price reference[6] is 37 USD/ton CO_{2eq}).

[6] State and Trends of Carbon Pricing 2017 Washington DC November 2017 World bank group climate change

Table 3.2: Environmental and socio economic impact of the intervention "Energy to stay"

Name of the indicator	Impact	Impact indicator	Monetized indicator
Soil quality	no impact		
Fertilizer use and efficiency	no impact		
Indoor air pollution	no impact		
Water use and efficiency	negative	44 470 m^2	4 447 USD/year
Water quality	no impact		
Food loss	no impact		
Land requirement	negative	198 m^2	3 564 USD
GHG emissions	positive impact	4.3 tons of CO2eq/year	159.1/year
Access to energy	no impact	no impact	
Household income	positive	100 % of increase	375 USD/year
Time saving	positive	208 hours	70.72 USD/year
Employment	positive	2 part-time skilled jobs created (1 electrician and 1 plumber)	1 009 USD/year
Added along the value chain	positive		3 558 USD/year

Color code: green: positive impact; white: no or negligible impact; red: negative impact.

3.2.3 Profitability

The financial and economic NPV are positive. The economic NPV is 503 263 USD and the economic IRR is 64 %. The pay-back time of the intervention is 2 years (Figure 7). Custom duties on imported technology (solar modules, submersible pumps, inverter, etc.), value added tax on the sale of more crops and on maintenance operations represents a benefit for the local government. There are also tax losses, from the avoided purchase of diesel fuel for the genset. The overall balance is positive for the society. Following the exclusion of the genset there is a reduction of emission of CO_{2eq} of 4.3 tons per year. The land occupied can be considered negligible, and the benefits due to the availability of irrigation water are important.

Table 3.3: Financial and economic CBA of the interventions "Energy to stay" (solar pumps and Californian irrigation system)

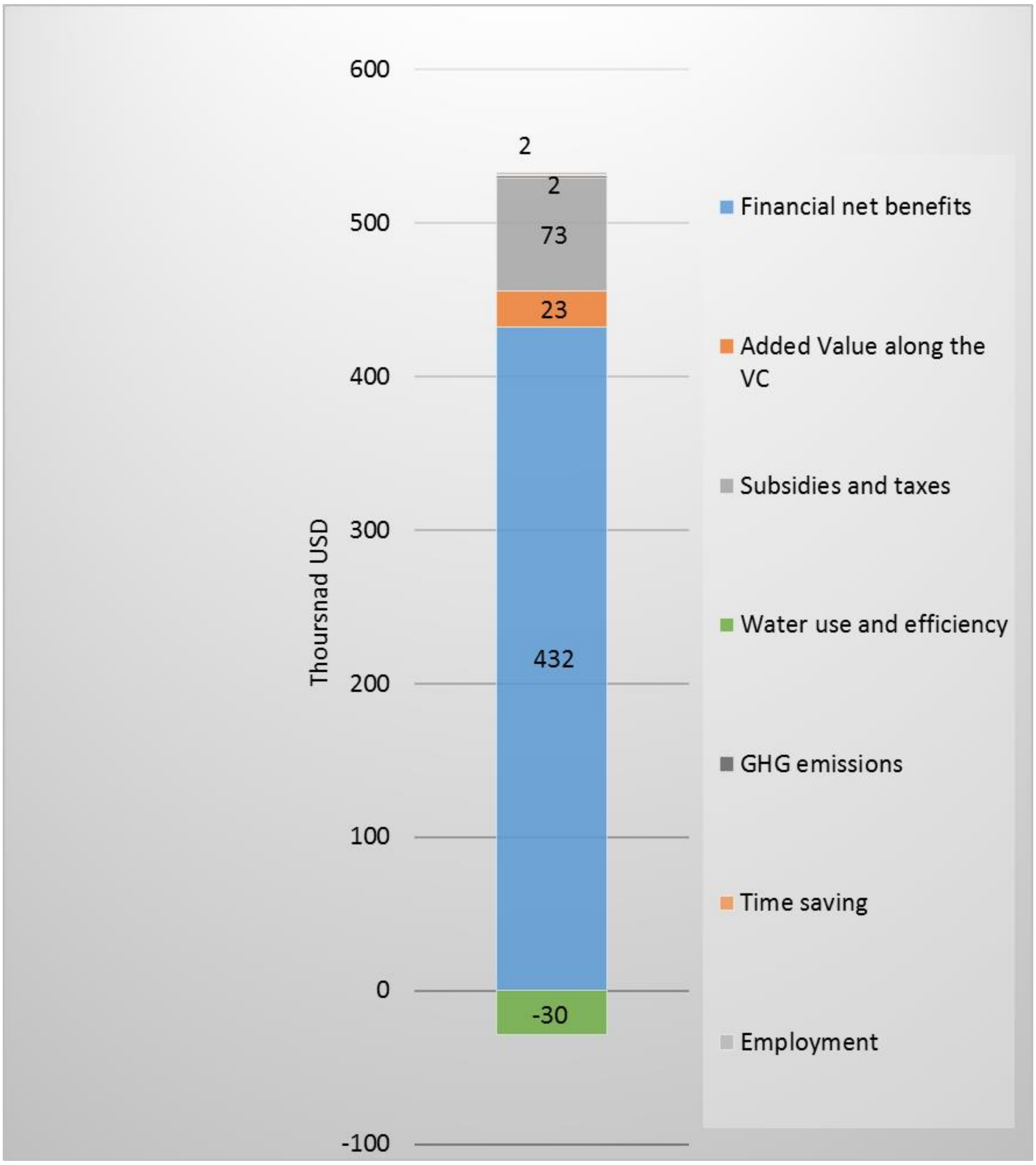
Item	Unit	Value	Notes
Costs			
Capital cost	USD	163 682	Purchase and installation made at year 0
Maintenance	USD/year	1 682	
Additional Labor costs	USD/year	0	
Other operating costs (fuel)	USD/year	0	
Missing tax revenue (fuel)	USD/year	811	
Water use efficiency	USD/year	4 447	Additional water used for irrigation
Benefits			
Value added along value chain	USD/year	3 558	Cleaning of the crops before sale
Net tax revenue-imported technologies	USD/year	8 261	Customs duties on imported technologies
VAT revenue private spending	USD/year	5 321	
GHG Emissions	USD/year	270.32	
Time saving	USD/year	70.72	
Employment	USD/year	1 009	Technicians for maintenance
Profitability indicators			
Financial NPV	USD	432 365	
Financial IRR	%	52	
Economic NPV	USD	503 263	
Economic IRR	%	64	

Note: Life expectancy of pumps used: 10 years. Discount rate 10 %. Financial costs and benefits are on a yellow background; economic costs and benefits are on a green background.

3.2.4 Results

A forecast of the benefits of the intervention at the end of the investment (10 years) is present in Figure 8.

Figure 8: Cumulative economic costs and benefits of the intervention "Energy to stay" after 10 years



4. Conclusions

Financial and economic comparison

Economic and financial NPV of both interventions are positive and in our case the economic benefits (or real benefits) are slightly higher than the financial benefits. The financial IRR in both cases are higher than the basic interest rate for financing of similar investments in the area (10%). The pay-back time of both investments is under 2 years. Similar studies carried out by FAO on similar types of interventions have brought to similar results (see FAO, 2018; FAO-GIZ, 2018a; FAO-GIZ, 2018b), in particularly on the expected pay-back time for investors. We could say that those interventions are highly profitable both from a financial and an economic point of view in such areas.

Environmental and socio-economic impact comparison

The replacement of fossil fuel powered electricity generators by solar systems for irrigation led in both case studies to a reduction of GHG emissions (the overall amount of carbon dioxide not released in the air following the intervention is equal to 5.3 tons per year) as well as other significant environmental, social and economic benefits. The increase in household income is considerable in both the cases and is higher than the minimum wage in rural areas (for the household). The introduction of new technological systems also requires two new part-time skilled professional figures in charge maintenance operations (employment creation).

References

FAO. 2018. *The benefits and risks of solar Power Irrigation – A global review.*

FAO. 2014. *Walking the Nexus Talk: Assessing the Water-Energy-Food Nexus in the Context of the Sustainable Energy for All Initiative*. By Alessandro Flammini, Manas Puri, Lucie Pluschke, Olivier Dubois.

FAO. 2011. *"Energy-Smart" Food for People and Climate*

FAO-GIZ. 2018a (under publication). Measuring Impacts and Enabling Investments in Energy-Smart Agrifood Chains - Findings From Four Country Studies.

FAO-GIZ. 2018b. *Costs and Benefits of Clean Energy Technologies in the Milk, Vegetable and Rice Value-Chains. Intervention Level*. By A. Flammini, S. Bracco, R. Sims, J. Cooke, A. Elia. Available online at www.fao.org/3/i8017en/I8017EN.pdf

Ministry of natural resources Canada. 2004. *Clean Energy Project Analysis – Photovoltaic Analysis Chapter* - Retscreen engineering and cases text books. Available at: https://www.nrcan.gc.ca/energy/software-tools/7465

RES4AFRICA-Enel Green Power-Ecsi. 2017. *Beyond the Energy Approach for Sustainable Development in Africa*. By Andrea Micangeli, Marco Aresti, Francesco Catucci, Elisa Farri https://www.res4africa.org/

World Bank Group. 2017. *State and Trends of Carbon Pricing 2017.* Available at: https://www.worldbank.org/

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