Chapter 11
Innovation for the Better: How Renewable Energy Technologies Improve Living Standards

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Abstract Energy has always been of paramount importance for human societies. It played an instrumental role in the progress of nations. Throughout history, communities have sought to control and manage energy resources through technology. This chapter presents examples of innovation in energy technologies and services that aimed to improve living standards in local communities. The study exemplifies communities in the districts of Pikine and Guédiawaye, with solar photovoltaic systems to improve access in high schools. Our ambition is to learn from motivations, experience and people's testimonials, the determinants of a successful energy transition in local communities.

Keyword Solar photovoltaic · Sizing · Energy Cost · Education

1 Introduction

Energy and human progress feature both shades of a metaphysical and physical question. Human behaviour is affected by the characteristics of accessible energy sources. These behaviours range from the exploitation of fossil fuels that helped nations prosper and cause global changes to the use of locally available renewable energy resources that open a new era of technological innovation. In between lies the conflicting forces of routine with supply from conventional energy resources that the recent COVID-19 pandemic has made exceptionally cheap and the aspirations of citizens for new standards of living that preserve the common goods such as climate and biodiversity.

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Energy sustainability is at the confluence of environment friendliness, economic accessibility and social acceptance. For a long time, the analysis of energy-related issues focused on one or the other of these dimensions without exploring their nexus regions. An example is an approach in modelling energy systems, whether computational equilibrium or scenario simulation, which determines the cost of the future sustainable energy system but overlooks its environment and social impact.

In this chapter, we document the case of the energy-education nexus and learn from examples the drivers of success in innovative energy solutions to improve the living standards of communities in sub-Saharan Africa.

2 Methodological Approach

The study methodology consists in case studies, along with data collection and analysis. Data of the case studies exemplified are from the inter-municipal cooperation project jointly implemented by the municipalities of Pikine and Guediawaye in Senegal. The project targets high schools with solar power systems to improve education facilities.

Within the project implementation, two pilot systems have been installed in Limamoulaye (45 kW) and Thiaroye (30 kW) high schools to connect new educational materials such as desktops while reducing the electricity bill of the municipalities. A photovoltaic monitoring system via inverters was also installed in order to centralize the monitoring data and possibly access it via software. The monitoring system collects information on the following indicators:

- Electricity production per period
- Electricity consumption per period
- Indicators of operations in the remote maintenance of the systems
- Detection of deficiencies in the solar photovoltaic systems

The data collection covered a period of 12 months from January to December 2019 and was carried out by retrieving detailed inverter parameters, alarm production data and historical data messages recorded in real time. The data can be viewed remotely since the recorders have an integrated server that enables monitoring of the system, which contributes to limit production losses and improve the performance of solar systems (Bressan, 2014).

3 Results of the Analysis

3.1 Electricity Supply from the Solar Photovoltaic Systems

Figures 11.1 and 11.2 display the production curve of the solar systems and the energy consumption curve of each of the two high schools.

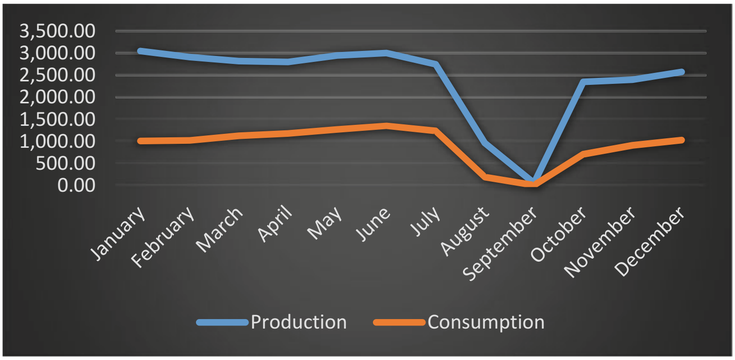

Fig. 11.1 Solar production versus Energy consumption for Limamoulaye High School

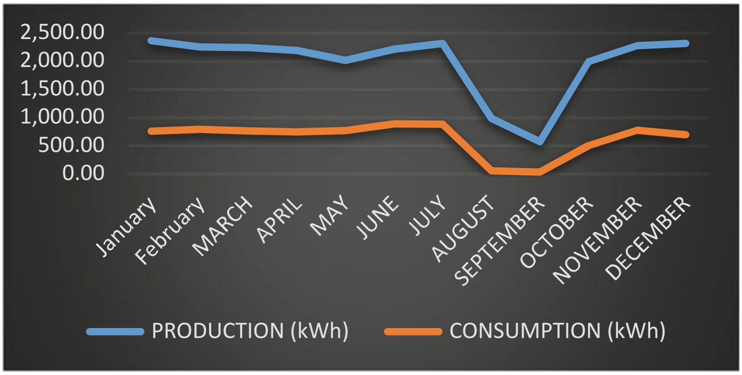

Fig. 11.2 Solar production versus Energy consumption for Thiaroye High School

The analysis of the Figure shows a regular energy production by solar systems between January and July, with an average of 2386 kWh per month. We can see a decline of both curves between the end of July and September due to the reduction of school activities; the academic year finishing at the end of July. This period also coincides with the rainy season, when clouds affect solar irradiation. This demonstrates the adequacy of solar photovoltaic systems with schools' activities in Senegal. From October, the solar system progressively increases production due to an increase in solar irradiation. October also coincides with the start of a new academic year.

Consumption over the period followed the same path, with demand being constantly below the production capacity of the system at an average of 919 kWh per month. This demonstrates an oversizing of the solar system.

The analysis of Fig. 11.2 shows patterns similar to Fig. 11.1. The average electricity production of the solar system during the period January-July is 1965 kWh, and the average consumption of school activities during the same period is 796 kWh.

3.2 *Electricity Supply from the Interconnected Grid*

Table 11.1 displays the quantities and costs of electricity supplied by the interconnected grid to Limamoulaye High School during the period from January to December 2018, 1 year before the installation of the solar photovoltaic system.

Table 11.2 displays the quantities and costs of electricity supplied by the interconnected grid to Thiaroye High School during the period from January to December 2018, 1 year before the installation of the solar photovoltaic system.

The economic value of the solar photovoltaic system is measured by comparing the investment cost, and savings on periodic energy bills received the year before the system installation from the national utility, which is also the manager of the grid.

Table 11.1 Electricity supply from the grid (Limamoulaye High School)

Month	Cons.	Cost (FCFA 110 per kWh)	Cost (EUR 0.17 per kWh)
January	1769	194,590	296.6
February	1995	219,450	334.5
March	1772	194,920	297.1
April	1829	201,190	306.7
May	1790	196,900	300.2
June	1772	194,920	297.1
July	1521	167,310	255.1
August	575	63,250	96.4
September	750	82,500	125.8
October	1189	130,790	199.4
November	911	100,210	152.8
December	1482	163,020	248.5
Total		1,909,050	2910

Table 11.2 Electricity supply from the grid (Thiaroye High School)

Month	Cons.	Cost (FCFA 110 per kWh)	Cost (EUR 0.17 per kWh)
January	1269	164,970	251.5
February	1195	155,350	236.8
March	1372	178,360	271.9
April	1229	159,770	243.6
May	1190	154,700	235.8
June	1372	178,360	271.9
July	1421	184,730	281.6
August	375	48,750	74.3
September	450	58,500	89.2
October	1100	143,000	218
November	850	110,500	168.4
December	1350	175,500	267.5
Total		1,712,490	2610.7

With an average cost of EUR 3 per Watt installed at Limamoulaye high school, the system returns a cost-saving of EUR 2910 per annum. This corresponds to a payback period of forty-six (46) years and a net present value of EUR -111,674.35. With an average cost of EUR 3 per Watt installed in Thiaroye high school, the system returns a cost-saving of EUR 2610.7 per annum. This corresponds to a payback period of thirty-four (34) years and a net present value of EUR – 69,073.4.

4 Discussion of Results

Findings in the previous section actually reveal a number of issues related to the demonstration of renewable energy technologies in the local communities of developing countries, besides their impact on living standards.

The problem relates to the solar photovoltaic system sizing. In both schools, it appears that the capacity of production installed is higher than the demand. The problem derives from a combination of three factors: (1) models of acquisition of the renewable energy technology, (2) focus on the restrictive dimensions of energy sustainability, and (3) lack of capacity of local installers.

The first dimension of the problem relates to the donor-led initiatives structure. Usually, pilot projects to estimate the relevance of renewable energy technologies in local communities of sub-Saharan Africa are financed with donations from non-governmental organizations or multilateral international cooperation agencies. The absence of profitability criteria in the transaction creates a perception of gratuity, which overlooks the economic dimension of the sustainability agenda and compromises replicability. The municipality accounts for savings from bills without realizing that the amounts saved are at an initial cost that is much higher. It clearly appears that financial figures computed for both installations, meaning payback period and net present value, are unfavourable, and the model could not be replicated with technologies that are acquired from private suppliers.

In addition to energy bills, the system definitely reduces CO2 emissions. Electricity generation from the Senegal utility emits an average 0.56 tonnes CO2-eq per MWh (UNFCCC, 2017). Therefore, a replacement by solar photovoltaic generation avoids an equivalent amount of emissions. The solar photovoltaic systems also feature a positive social impact; the interconnected grid supply is erratic, and power cuts are frequent. Therefore, self-production with rooftop solar photovoltaic systems ensures control over the electricity supply of the school and consequently powers some academic activities such as learning with computers.

The lack of qualified technical resources in local communities, especially in remote rural areas of sub-Saharan Africa, is another drawback in the energy transition agenda. Sizing is a necessary step in the installation of decentralized energy technologies. However, when capacities are not available, the installation of renewable energy technologies only consists of connecting wires and devices. Figures 11.1 and 11.2 with production versus consumption curves show that the solar photovoltaic systems available in these municipalities could power, at least, two additional buildings with similar consumption patterns. This would correspond to division by a factor of 2 of the payback period and a multiplication of the net present value by a factor of 1.4.

5 Conclusion

It is indisputable that a transition towards the sustainability of energy systems features positive values in sub-Saharan Africa. Firstly, the renewable energy resources, including solar irradiation and insulation hours, is readily available. Secondly, the business-as-usual energy production processes use fossil fuels that emit greenhouse gases such as carbon dioxide (CO2), methane (CH4), and nitrous oxides (NOx). Therefore, a replacement with renewable energy technologies such as solar photovoltaic systems avoids these emissions. Thirdly, the obsolescence of the grid infrastructure in many sub-Saharan Africa countries or sometimes the prohibitive costs of grid extension to rural communities make supply with decentralized systems more secure. However, the business model of acquisition, planning and installation makes renewable energy technologies unsustainable. This contributes to the still common perception of the energy transition agenda as expensive compared to the routine of supply with the interconnected grid.

From the two examples presented in this chapter, it appears that some factors should be investigated in priority, which includes the technology acquisition model (sale versus donation) and the technical capacity of human resources available in local communities for the installation of technologies. Both require prior attention before the definition of the sustainable energy agenda. Otherwise, the process of transition to energy sustainability will continue to stagnate from pilot installations of different renewable energy technologies without viable replication models.

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