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Incentives for rural off grid electrification in Burkina Faso using LCOE

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ABSTRACT

Renewable energy can help developing countries meet their sustainable development goals through access to clean, secure, reliable and affordable energy. The scarcity and the depletion of conventional energy resources, with rising fuel prices and harmful emissions from fossil fuels, make electricity production from conventional energy sources highly unsustainable and economically unviable. Access to electricity for rural population is woefully low in Burkina Faso with only 15% electricity coverage for the all country. This paper uses the LCOE technique in a case study of Pissila a village of Burkina Faso to demonstrate that off grid hybrid solar PV/Diesel configuration is the optimum electricity production system that could help provide sustainable and affordable electricity to rural population. The results revealed that the hybrid configuration PV/Diesel leads to about 54% decrease of the LCOE when compared to conventional diesel generator stand alone configuration. Furthermore, it has been shown that the discount rate and fuel prices have a sharp impact on the LCOE. A decline of the interest rate from 9% to 0% results in 83% decrease of electricity cost while an increase of fuel cost from \$1.2/L to \$3/L results in a staggering 110% increase of the LCOE.

1. Introduction

The rapid industrialization that has been observed in the past three decades due to globalization, inventions in new technologies and increased household energy consumption has resulted in an unprecedented increase in the demand for electricity. This has led to a huge supply/demand gap in the power sector. Most African developing countries envision increased development in the near future. However, development requires an enormous level of energy consumption. Countries such as Burkina Faso that are not oil producers cannot afford to depend entirely on oil and gas for their electricity demands, especially today with fluctuating fossil fuel prices in the global market. Furthermore, the ongoing regular energy shortages that characterizes most African countries, imposes a rethink of integrated energy resource planning to increase access to electricity. It is projected that the supply/demand gap will continue to rise exponentially unless it is met by some other means of power generation. Inaccessibility of the grid power to the remote places and the lack of rural electrification have prompted for alternative sources of energy. Therefore, renewable energy could offer a viable alternative solution. However, the deployment and viability of potential projects are highly subjective to policy, regulation as well as availability of good investment schemes. It has been shown that technically it is feasible for renewable energy technologies (RETs) to replace the present fossil fuel electricity infrastructure [1–9]. However, financial barriers remain the main impediment to a renewable powered society.

Abundant literature has shown a close relationship between renewable energy and sustainable development and has concluded that renewable energy sources (RESs) meet all the basic requirements for both current and future sustainable energy supply scenarios [1,2]. As a result, during the last decades, the production of electricity from sunlight has been increasing rapidly as illustrated in Fig. 1. This is especially true in the case of photovoltaic (PV) solar energy, which has shown an annual growth rate of about 40% during the last decade. From 2000 to 2010, global solar PV deployment has increased from 0.26 GW to 16.1 GW, due to both technological innovations, that have considerably reduced manufacturing costs by up to 100 times, and various government incentives for consumers and producers [3–6]. Renewable energy technology (RET) deployment and investment continues to grow at an unprecedented rate with 44% of the total worldwide generation capacity added in 2011 coming from renewable sources (excl. large hydro) (UNEP, 2012) [7].

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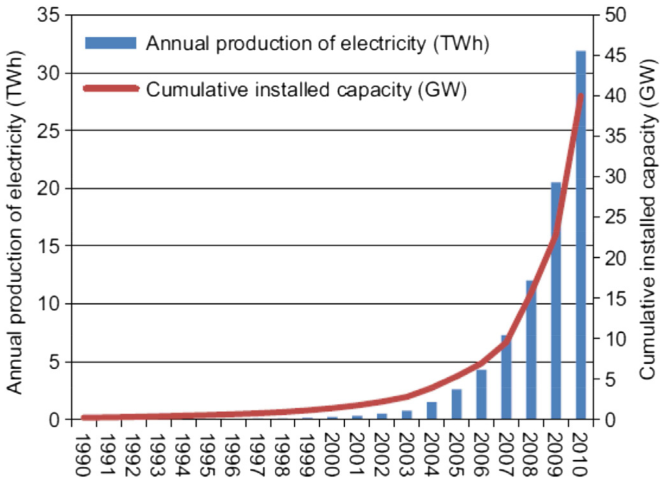

Fig. 1. PV potential in the world.

PV is considered as a clean, sustainable, renewable energy technology that can help meet the energy demands of the world's growing population, while reducing the adverse anthropogenic impacts of fossil fuel use [10,11].

Hybrid energy production configuration could be the answer to multiple photovoltaic penetration barriers and provide enough energy for the growing population in the developing world. A hybrid system combines more than one energy source. It usually combines renewable and conventional fossil energy sources. The increased reliability is one of the important benefits of these hybrid systems. Furthermore, it constitutes a great opportunity for rural electrification that could trigger social and economic development in these areas [12,13]. It can improve the quality of life of rural people by providing electricity for lighting of homes, shops, community centres and public places in villages. More than 5000 villages in Burkina Faso are still un-electrified and rely on kerosene and wood for lighting [14]. Thus, hybrid configurations could be the solution.

Many studies on solar based hybrid energy systems with respect to performance and optimization have been conducted. We can highlight Habib et al. (1999) paper on optimization method of a hybrid PV–wind energy system used to satisfy electricity requirements for a given load. The model aims to satisfy a constant load of 5 kW required for cathodic protection in offshore platforms. Furthermore, Lazou and Papatsoris (2000) performed the life cycle cost analysis of PV system for residential houses in different Mediterranean and European countries. Techno-economic analysis of a PV–diesel hybrid power generation system installed in a bungalow complex in Elounda, is presented by Bakos and Soursos (2002). Kamel and Dahl (2005) assessed the economics of hybrid power systems versus the present diesel generation technology in a desert agricultural area in Egypt by using optimization software. The objective is to determine the optimal size of the system at minimum cost [15–21].

In the above discussed literature, the optimum dimensions of the hybrid energy system are obtained by minimizing the system cost function. But, the types of investments and incentives that will minimize these systems have not been taken into account. Therefore, this paper focuses on costs for producers and how policy makers can implement schemes that will reduce the burden of the high initial cost of investment for photovoltaic and how they could attract more investor for PV electricity in Burkina Faso. To do so, this paper uses levelized cost of electricity (LCOE) and net present value (NPV) techniques to compare hybrid PV–diesel system, stand alone PV and stand alone diesel generator, based on the estimated electricity consumption profile for a village of 65,000 people in Burkina Faso. In this respect, the LCOE have been rigorously calculated taking into account the remarks underlined by several previous studies [22,23]. Finally, we would like to emphasize that one important aspect that directly emanates from our paper is that the LCOE calculation has been done based on data obtained from local banks that have been validated through existing projects. The novelty of this paper lies on the fact that its gives a broad range of ideas on how could policy makers implement incentives that will attract potential investors to invest in renewable energy for rural areas. Furthermore, this current case could be successfully replicated to other Sub Saharan African countries.

2. Status and growth of power sector in Burkina Faso

As illustrated in Fig. 2 Burkina Faso is a West African landlocked Sahelian country that is sharing borders with Benin, Ivory Coast, Ghana, Mali, Niger and Togo. It has around 274,000 square kilometres in size and a current population of about 16 millions. The country is blessed with high solar radiation levels. The daily global radiation is approximately between 4.5 and 6 kWh/m^2/day with sunshine ranging between 2300 and 3200 h per year in most parts of the country [24]. In 2008 Burkina Faso produced about 619.4 GWh, and imported more than 135.7 GWh of electricity. Electricity production is mainly based on fossil fuel which represents on average, about 70% of the total power generation capacity in the country.

Imported electricity (from Ghana and Ivory Coast) and hydroelectricity (from Kompienga Dam) represent respectively, 10 and 20% of the total electricity produced in the country. Electricity is currently produced through 28 fossil fuel based power stations and 4 hydropower stations. Despite the high level of government yearly subsidy around $33 million, Burkina still has one of the highest costs of electricity in the world, estimated at about $0.3/kWh. In comparison, the cost per kWh in UK and US is respectively about $0.17 and $0.14 [25,26]. As a result, due to the high cost of electricity, the country coverage rate is low. Electricity is mainly provided for urban areas and only 112 urban localities or districts out of 350 have access to electricity. Furthermore, electrification rate for the all country is about 15% while this rate is only about 3% for rural

Fig. 2. Burkina Faso map.