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An economic analysis for the design of ipp contracts for grid-connected renewable energy projects

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A B S T R A C T

In this paper, we undertake an integrated financial, economic, stakeholder analysis of a grid-connected onshore wind project that is owned and operated by an independent power producer (IPP) in Santiago Island, Cape Verde. This IPP project has received considerable positive publicity and has won many awards. Cape Verde has a very good wind resource, but it suffers from high transportation costs for petroleum fuels due to its location. Hence, it would appear to be an ideal site for an IPP investment in a wind farm. This analysis is conducted from the perspectives of the electric utility, the country's economy, the government, and the private sector investor. The key question is whether the design of the power purchase agreement (PPA) can simultaneously yield a high enough cash flow for the project to be bankable while at the same time yielding a positive net financial and economic present value to the electric utility and the country respectively. The analysis shows that a negotiated PPA results in a negative outcome for the economy of Cape Verde in almost all circumstances. In contrast, the owners of the IPP are guaranteed, under all circumstances, a very substantial return on their investment.

1. Introduction

During the last two decades, the role of the private sector in undertaking renewable energy projects has increased worldwide. Initially this growth occurred primarily in the industrialised countries of Europe and North America. In recent years, the expansion of this type of arrangement has also increased in developing countries [1–5]. It is common practice in some developing countries for state-owned electric utilities to sign long-term power purchase agreements (PPAs) with private electricity generators [5–9]. The objective of these arrangements is to make these projects financially feasible [8–11]. From the perspective of the international financial institutions, these public-private partnership (PPP) projects need to be bankable [8,9]. It is less certain, however, that such arrangements for procuring renewable energy projects have been designed to deliver a long-term net positive impact on the economies of these countries.

Previous studies evaluated the economic viability of wind farm projects under the assumption that such investments were made by a public electric utility [12–15]. The focus of this paper is on the economics of grid-connected wind energy investments under the assumption that such investments are made by a private investor (IPP). Therefore, the design of appropriate PPAs for such investments is critical to the determination of the final outcome of the investment.

This paper departs from previous studies in two fundamental ways. First, an integrated investment appraisal framework is introduced for the evaluation of the impacts of the PPA. This framework allows one to determine the conditions under which it is possible to have a financially sound PPA that also yields a positive net benefit to the electric utility and the country. Furthermore, it allows one to assess if the designers of the project had the right balance between securing a satisfactory degree of certainty on the financial feasibility of the IPP project and securing a similar degree of certainty on yielding a positive net economic outcome to the country. The results of such an integrated investment appraisal provide the information needed by the government and its private partners to design arrangements that yield a sustainable outcome.

This research contributes to the growing literature on the discussion of the economic viability of renewable energy generation projects. It is unique in that it enables one to estimate simultaneously the returns on such PPP investments from the perspectives of the electric utility, its private sector partner, and the country. Thus, it contributes to the existing literature by providing a framework for the analysis of policy changes that consistently consider the welfare of each party to the arrangement. This framework can be applied for any power system that uses similar contractual arrangements for renewable investments.

This integrated appraisal framework is applied to a wind farm project in Santiago Island of Cape Verde. This project was implemented

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due to the highly favorable wind conditions and the high cost of conventional electricity generation in Cape Verde [16,17]. The foreign-owned independent power producer (IPP; Cabeólica) built the wind farm project and signed a long-term PPA contract with the public electric utility in Cape Verde [17]. After its implementation, it won several awards as a successful IPP renewable energy project. In 2011, Cabeólica won the Best Renewable Project in Africa Award at the African Energy Awards ceremony in Johannesburg, South Africa. The project was chosen for being the first commercial-scale public-private partnership for the construction and management of wind farms in Sub-Saharan Africa [18]. In 2013, it won the Ashden Award for leading the way in wind-powered energy security [18]. In 2014, the project was cited by the International Finance Corporation and by the Infrastructure Journal as one of the top public-private partnerships in emerging markets [19].

1.1. An overview of Cape-Verde's energy sector

Cape Verde is a lower-middle-income archipelago in the Atlantic Ocean off the west coast of Africa, with a total population of 520,500 spread over ten islands [20]. As of 2015, the nominal gross domestic product (GDP) per capita in Cape Verde reached US$3075 [20]. Santiago island of Cape-Verde is the largest, with about 60% of the total population of the country living there [21]. The power system in Santiago Island of Cape-Verde is typical of island economies and the smaller countries of Africa, Asia and Latin America [22,23]. The electricity coverage is almost 100% in urban areas, but it is 84% in rural areas where 35% of the total population lives [24]. The Cape Verde electricity network is composed of isolated electricity grids on each island without any interconnection between them. The public electric utility company, ELECTRA, is responsible for generation, transmission and distribution of electricity.

The high cost of electricity generation, frequent blackouts and high energy losses have created a barrier to achieving higher economic growth in Cape Verde [21,25–30]. In response to both the deterioration of ELECTRA's capital assets and the need to meet the ensuing increased demand for power, the government of Cape Verde has initiated a long-term investment plan for the generation, transmission and distribution of electricity. As a first step, the national government implemented a series of rehabilitation projects with financial support from international organizations (e.g. World Bank) and regional banks (e.g. African Development Bank and the European Investment Bank) [30].

Alongside investments in grid infrastructure, ELECTRA also undertook to switch fuels from the more expensive heavy fuel oil (HFO) 180 to a less expensive HFO 380 [29]. Another purpose of extending the transmission lines to isolated loads was to increase the potential for fuel switching, as these isolated loads were being supplied by small, expensive and polluting diesel generators [29]. These new and rehabilitation investments in generation, transmission and distribution will eventually allow ELECTRA to take advantage of economies of scale in generation by operating a small number of centralized power stations.

Owing to the strength and stability of the wind speed across the islands and the high delivered costs of petroleum products, Cape Verde is potentially a very favorable location for electricity generation investments powered by wind [15–17,31,32]. Therefore, investments in grid-connected onshore wind farms have been perceived as way to reduce the high costs of thermal generation, to insulate electricity tariffs from the variability of oil prices and reduce emissions from electricity generation. The high solar irradiance level on the islands allows residential, hotel and industrial users to utilize it for water heating. Such solar applications contribute to the reduction of fuel use for electricity generation and potentially reduce the overall peak demand on the grid [33]. The stated objective of the government is to supply half of the total electricity demand solely through private sector investments in renewable electricity generation plants by 2020 [34].

1.2. A review of wind integration studies for Cape-Verde

Previous studies have argued that the integration of a major wind farm into the power supply on Santiago would be economically viable. For example, Cabral et al. [31] concluded that 5.1 MW grid-connected utility-scale wind integration constituted a good investment for Cape Verde based on the stated capital costs. A major problem with the Cabral et al. [31] study is that the wind investment capital costs are assumed to be only US$ 1.1 million per MW of wind capacity, which is much lower than the actual capital costs associated with such onshore wind investments in Cape Verde.

Duic et al. [15] studied the economic feasibility of grid-connected wind integration as compared to alternative conventional diesel and combined cycle generators. Duic et al. [15] investigated the potential influence of the Clean Development Mechanism (CDM) on the choice of technology for Santiago Island of Cape-Verde. Under the CDM scenario, the carbon emissions were priced at $25€/tCO_2$. At the stated capital costs of candidate technologies and projected peak demand growth, Duic et al. [15] concluded that the combined cycle technology would be the most cost-effective option if the CDM was not adopted. At the same capital costs and future peak demand projections, combined cycle with wind integration would produce the most cost-effective solution under the CDM.

Norgard and Fonseca [35] studied the technical utilization of grid-connected utility-scale wind integration in the energy systems of Cape Verde's islands as a function of wind capacity. Based on their technical study and the characteristics of the energy system for Santiago, the share of wind capacity up to 21% of the total generation can be produced and transmitted to the national grid without any losses. Norgard and Fonseca [35] further concluded that the avoided fuel savings from diesel plants alone justify the installation of wind farms in Cape Verde, including Santiago.

A World Bank study [29] for Cape Verde suggested that wind-based sources of electricity generation would not provide firm generation capacity on Santiago. The integration of wind capacity would not lead to any reduction in thermal capital expenditures by Cape Verde. As a consequence, wind sources of electricity generation are limited in their substitutability for conventional thermal generators and cannot meet the entire demand for energy due to their uncontrollable variability.

However, the studies by World Bank [29], Cabral et al. [31], and Norgard and Fonseca [35] do not take into account the actual electricity system supply and demand conditions of Cape Verde when evaluating the economic feasibility of wind farm investments. A major problem with the Duic et al [15] study is that the emission reductions are valued at a fixed price of $25€/tCO_2$ and are assumed to accrue to the electric utility as part of emission reduction benefits. However, the carbon prices are much lower than $25€/tCO_2$ and such benefits accrue to the private investor not to the electric utility. Finally, none of these studies carried out a financial or economic appraisal of the feasibility of electricity generation using a wind farm that was built and operated through an IPP. Therefore, the cost estimates of the wind investment were expressed as utility investments, which cannot be a proxy for the costs of such private investments. The reason is that IPP bears the upfront capital costs of the investments (€/MW) and sells wind energy to the electric utility (€/MWh).

2. Data

Before proceeding with the description of the data, it is worthwhile to state that wind power is examined in terms of how it is used as a substitute for power generated by conventional thermal plants. The installed wind capacity is introduced into the Santiago Island power grid with multiple sources of diesel generation capacity running on fuel oil and diesel.

Because the installed amount of wind power penetrates the system, an analysis of the optimal power mix "with" and "without" wind power