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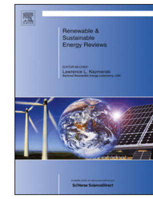

Renewable technologies and risk mitigation in small island developing states: Fiji's electricity sector

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ABSTRACT

Renewable technologies have been advocated in Small Island Developing States (SIDS) as a risk mitigation measure against oil price volatility. This paper applies empirical data in a custom-built stochastic simulation model in order to assess the economic impacts of renewable technology investments in Fiji's electricity grid. The model extends previous applications of portfolio theory to the electricity sector by incorporating variability of output from different technologies. The results demonstrate that investments in low-cost, low-risk renewable technologies, such as geothermal, energy efficiency, biomass and bagasse technologies, can be expected to lower both generation costs and financial risk for the electricity grid in Fiji. These results are driven by the reduction in oil-fired generation that these investments entail. The benefits of hydropower and several other "intermittent" renewable technologies are more limited in the model, given that they require costly investment in back-up oil based generating capacity.

Contents

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1. Introduction

Investments in renewable technologies are widely advocated in Small Island Developing States (SIDS) as a response to high oil prices. This follows a decade of oil price volatility in which prices reached record levels. High oil prices have had adverse macroeconomic implications for SIDS, with their impact being particularly detrimental in the electricity sector given widespread reliance on generators that operate on diesel and heavy fuel oil [1,2]. Among SIDS in the Pacific (commonly termed Pacific island countries), high oil prices have increased electricity prices, compromising the energy security of poorer households[3]. In countries where cost increases have been absorbed by state-owned utilities, high oil prices have had adverse fiscal consequences, with electricity consequently rationed in several cases [5–8]. The Asian Development Bank in 2009 estimated that Pacific island economies were among the most vulnerable in the Asia-Pacific to oil price volatility (of the 10 most vulnerable economies in the Asia-Pacific, seven were Pacific island countries) [9].

Renewable-based electricity production has the potential to reduce vulnerability to oil price volatility by replacing oil-based generation. Investment in renewable technologies in SIDS is widely supported by governments and development partners. The Pacific Islands Forum *Leaders Communiqué* in 2008: "highlighted the critical importance of efforts to reduce dependence on oil through measures to improve energy efficiency and move towards greater use of renewable energy" [10]: 2. However, there have been no rigorous attempts to date to measure the impact of renewable technologies on financial risk in these countries.

The paper applies portfolio theory to scenarios of future electricity generation in Fiji, with the aim of assessing the impact of different renewable technologies on both expected portfolio generation cost and financial risk. In doing so, the paper extends existing applications of portfolio analysis to the electricity sector by incorporating the variability in power output of different technologies into a custom-built stochastic simulation model of electricity generation in Fiji. The study is unique in its application of portfolio analysis in a context where the electricity grid is isolated, and where fossil fuel-based power generation technologies are more costly than many renewable technologies.

The paper begins by providing an overview of portfolio theory and its application to the electricity sector. It subsequently introduces the case study, discussing the impact of high oil prices on Fiji's electricity sector and renewable energy options that are available. The sections that follow describe the model, results, and implications for future research and public policy.

2. Renewable energy and risk

2.1. Application of portfolio theory to the electricity sector

Renewable energy features prominently in initiatives to improve energy security. Renewable energy technologies are said to have the potential to contribute to "adequate, affordable and reliable supplies of energy" by "contributing to fuel mix diversification" through reduced reliance on fossil fuels such as oil and gas. In the electricity sector, it is similarly argued that renewable technology investments can "reduce the variability of generation costs" through diversification [11].

One method that has been used to assess the impact of renewable technologies on financial risk in the electricity sector involves an application of portfolio theory.

Mean-variance portfolio theory (referred to below simply as portfolio theory) was developed by Harry Markowitz as a method of valuing financial market securities based on the return and risk implications of each security for a portfolio of financial securities [12]. According to portfolio theory, the value of any security or investment has two components: its expected (mean) return and the risk associated with that return (being the risk that the actual return from the security will differ to its expected return). The risk of a security is defined as the standard deviation of past returns [13].

Portfolio theory considers the return and risk implications of a security in terms of its impact on the return and risk of an investor's *portfolio* of securities. This means that when the returns of the security in question are highly correlated with those of the portfolio, it will increase the risk of the portfolio. On the other hand, if the returns of the security in question are negatively correlated with the returns of the portfolio, its inclusion in the portfolio will reduce the total risk associated with the portfolio.

Portfolio theory can be applied to the electricity sector in much the same way as it is to financial securities, in order to assess the impact of investment in a technology on the expected average generation cost and financial risk of a portfolio of generation technologies. The type of risk that is incorporated in this type of analysis is financial risk, meaning the risk that actual generation costs will differ from expected generation costs in the future.

Portfolio theory was first applied to the electricity sector by Bar-Lev and Katz [14], who used it to measure the benefits for utilities of diversifying their fuel suppliers. More recently, it has been used to examine investments in electricity generation technologies in Europe, the United States, Switzerland, the United Kingdom, Scotland, the Netherlands, Ireland, Turkey, and Australia [15–26]. Portfolio analysis has also been applied to liberalised electricity markets where electricity suppliers do not share the same return and risk concerns as the grid [22,27,28]. A number of authors have incorporated load factors to better represent the real world, decomposing the load into peak and base load supply, and assigning specific technologies/contracts to meet different load types [29,30].

The majority of applications of portfolio theory to the electricity sector have focused on the risk mitigation benefits of renewable technologies. Such studies have consistently found that renewable technologies reduce the financial risk of existing technology portfolios, given that the cost streams of renewable technologies are not correlated with those of technologies currently used for electricity generation.

The basis for these findings can be illustrated using the simple equations below (the same procedure can be performed for portfolios with more than two technologies, although the mathematics becomes more complicated) [13]. Consider an electricity grid with a high-risk but low-cost technology 1 (the equivalent of gas-fired power generation in Europe), and a low-risk but high-cost technology 2 (the equivalent of solar-power in Europe).

[3] There are many definitions of energy security, as highlighted by Martchamadol and Kumar [3]. The International Energy Agency defines energy security as: "adequate, affordable and reliable supplies of energy" [4].