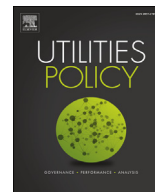




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Exploring options for a 100% renewable energy system in Mauritius by 2050

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ABSTRACT

This paper aims at critically analyzing the present and the proposed energy resource mix in Mauritius in order to make recommendations for a 100% renewable energy system for the island by 2050. While the Long Term Energy Strategy for the period 2009–2025 devised by the Government of Mauritius sets pathways for the future in a sustainable manner, it does not evaluate the feasibility of the options that will help in supporting this transition. Its scope is limited as the proposed framework aims at achieving only 35% self-sufficiency in terms of electricity supply by 2025 against 20% currently. This paper explores the main building blocks of a new energy paradigm by extending the analysis to 2050 in view of identifying systemic and holistic policies and strategies that will pave the way to a clean and efficient energy supply. Most notably, we look beyond electricity only to assess the energy system comprehensively in terms alternative resources for primary uses, including energy-intensive transportation and cooling. Ultimately, it also enhances the near-term energy framework by setting more ambitious green energy targets as a stepping-stone towards 100% energy self-sufficiency by 2050.

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1. Introduction

Energy is widely acknowledged as being one of the most critical and pervasive issues that will challenge decision-makers globally during this century. On the one hand, the importance of energy in fueling sustained economic growth and development has prompted governments to ensure that their relentlessly rising energy demands are met adequately at all times. On the other hand, the 82% share of fossil fuels in the global energy mix raises concerns about detrimental environmental impacts and energy security (IEA, 2013). New power systems and integration of several energy resources are becoming more and more common throughout the world (Clark and Cooke, 2011). Harnessing renewable energy (RE) sources can contribute to decarbonizing the energy system and upholding long-term energy security worldwide. Since the turn of the century, the share of RE in the energy mix of many developed countries has increased substantially and this trend is expected to continue in the future. Nevertheless, the various technical and economic challenges posed by a high level of RE integration have

led many experts to dismiss the development of a 100% RE mix as a utopian ideal. However, recent studies point out that the design of carbon-neutral energy systems is technologically achievable (Jacobson et al., 2014; Elliston et al., 2013). The prospects for a completely “green” system improve each year as favorable market economics and continuing technological innovation contribute to make RE technologies less expensive, more efficient, and reliable. A host of developed countries, including Denmark (Lund and Mathiesen, 2009), Portugal (Krajačić et al., 2011), Ireland (Connolly et al., 2011) and New Zealand (Mason et al., 2010), have already developed elaborate roadmaps that detail the optimized combinations of RE resources and ancillary capabilities to meet their energy demands exclusively through clean energy sources in the long term.

Developing countries have a key role to play in the concerted effort towards the global transition to greater reliance on renewable energy resources. Rising energy demand is characteristic of most developing nations as their expenditures on energy-consuming services that provide enhanced productivity, leisure, and comfort escalate. The International Energy Outlook 2013 report projects that growth in world energy consumption will predominantly emanate from non-OECD (Organisation for Economic Co-

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operation and Development) countries in the future (IEO, 2013). Thus, energy use in non-OECD countries is expected to grow by 2.2% annually and their share of global energy consumption is projected to rise from 54% in 2010 to 65% in 2040 (IEO, 2013). With this in mind, developing nations also account for 95 out of the 138 countries with RE support policies in 2014, up from 15 in 2005 (REN21, 2014). In addition, five developing countries (Uruguay, Mauritius, Costa Rica, South Africa, and Nicaragua) led the investments per gross domestic product (GDP) on RE technologies IEA, 2013, spending between 0.8% and 1.6% of their GDP in this area (REN21, 2014). These initiatives underscore the fact that developing and emerging countries appear to be poised to make the switch to 100% RE given the necessary financial, political, and technological support. Owing to their unique characteristics and vulnerabilities, small island developing states (SIDS) denote a distinctive case for sustainable development among developing economies. The absence of exploitable natural resources in SIDS implies a massive reliance on imported fossil fuels for their energy requirements causing their small economies to be extremely vulnerable to fuel-price fluctuations. This vulnerability is mainly due to their remote geographic location and economic structure (Levantis, 2008). Energy prices in SIDS are much higher than in continental countries because of high fuel transportation costs and constraints on exploiting scale economies through bulk purchasing. The economies of SIDS also rely on fuel-intensive activities such as tourism. As a result, a significant share of the national budget is devoted to oil imports. In general, fuel imports represent up to 20% of the annual import costs of SIDS, and between 5 and 20% of their GDP (Walker-Leigh, 2012). The vulnerability of SIDS economies to fossil fuel price increases was clearly illustrated in Mauritius when the 2008 oil crisis increased these costs by 28% to reach USD 921.2 million as compared to USD 721.3 million in the previous year (MOENDU, 2010). The electricity utilities in SIDS are typically state-owned and have overall control over the distribution and transmission of electrical power. In addition, SIDS have high exposure to multiple and extreme vagaries of climate change, adding to the imperative of moving towards a sustainable future. These factors indicate that small islands constitute excellent test beds for a decarbonization of the energy system. A related contemporary issue confronting power system planners worldwide is the merging of the central grid with on-site or distributed power. This new approach to energy generation can help provide power while reducing greenhouse gas (GHG) emissions and protecting the environment. Today's more "agile" systems (Clark and Bradshaw, 2004) interconnect power systems with renewable on-site power generation that may not be controlled by the public utility, as in the case of Mauritius and elsewhere. Agile systems can underpin the new energy paradigm for SIDS.

We assess the energy situation in Mauritius, a small island state, and present the main building blocks of a new energy paradigm aiming at achieving a 100% RE target by the year 2050. It critically analyzes the present energy mix in order to make recommendations for a 100% RE system on the island by 2050. While the Long-Term Energy Strategy (LTES) for the period 2009–2025 devised by the Government of Mauritius sets pathways for a sustainable future, it does not evaluate scenarios that would achieve the objectives set. In addition, it limits the scope of the RE targets to 35% and the planning horizon to 2025, and considers electrical power only. This paper proposes to extend the analysis to 2050 by looking beyond electricity only to assess the energy system comprehensively in terms of alternative resources for primary uses, including energy-intensive transportation and cooling. A longer planning horizon is considered here because the new energy paradigm requires new energy infrastructure investments with lengthy lead times. Moreover, novel energy technologies can be slow to mature

and fully penetrate the market. For these reasons, most international efforts to curb greenhouse gas emissions and to reach ambitious RE integration goals, such as the 21st Conference of Parties (COP21) agreement and the EU decarbonization roadmap, use the year 2050 as their target. Furthermore, as mentioned in Section 1, many studies have been performed in different countries that are pledging their efforts towards 100% RE. Most of these studies have specified 2050 as a target based on an understanding that a full turnover of the electricity sector by 2050 is needed to avoid an increase in the global average temperature beyond 2 °C (Verbruggen and Lauber, 2009).

The rest of the paper is structured as follows. Section 2 provides an account of the present energy mix of Mauritius and mentions the main challenges faced by the energy sector. Section 3 critically analyzes the energy portfolio proposed by the Government through 2025. Section 4 elaborates on realistic options that Mauritius could exploit in order to achieve the 100% RE target by 2050. Section 5 concludes by highlighting the pre-requirements for the successful implementation of this ambitious energy transition.

2. Current energy status of Mauritius

2.1. Primary energy requirements

Mauritius is located in the South West of the Indian Ocean, off the eastern coast of Madagascar. With a population of 1.2 million for a total surface area of 1865 km², Mauritius has one of the highest population densities in the world (SM, 2011). The country is highly dependent on imported fossil fuels for its primary energy requirements, with a share of 84% consisting mostly of coal and petroleum products, as shown in Fig. 1 (SM, 2016a). Primary energy requirements have grown steadily during the last decade, at a yearly rate of around 5%. Per-capita energy requirements for Mauritius are high relative to most developing nations in Africa but still low as compared to developed countries (World Bank, 2016).

In developing countries like Mauritius, the growth in energy consumption is largely due to the pace of economic development, resulting in associated financial burden together with the adverse environmental implications of consuming fossil fuels. Energy statistics reveal that the transportation sector is by far the highest final energy consumer, accounting for 50.7% of the total final energy consumption of the country, followed by manufacturing, households, commercial/distributive trade and agriculture which represented 23.7%, 14.2%, 10.5%, and 0.5% of the energy consumed respectively (SM, 2016a). The higher standards of living ushered by economic growth of the country have brought a considerable increase in the number of vehicles. While the number of registered vehicles has increased significantly by 52% to reach 486,124 during the period 2006–2015 as illustrated in Fig. 2 (SM, 2015a,b, 2016a,b), the corresponding growth in petroleum imports for transportation was only 20%. The importation of more efficient vehicles and the availability of better quality fuels since 2006 have contributed greatly in mitigating the surge in transport-related fuel imports. Between 15,000 and 20,000 vehicles are added annually on the roads, thereby worsening traffic problems despite the construction of new motorways. One study estimated that traffic congestion cost the Mauritian economy about USD 33 million worth of surplus petroleum products annually (MEF, 2007). Nevertheless, being the biggest end-user of energy, the oil-dominated transport sector has considerable energy security and GHG emission implications. Several projects are presently under development to curtail the energy use by transportation. These include enlargement of motorways to cater for a special bus lane and introduction of Light Rail Transport (LRT) to provide an efficient and quality mass public transport system from the capital city to the main cities (MPILT,

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