Utilities Policy 55 (2018) 69–78

Contents lists available at ScienceDirect

Utilities Policy

journal homepage: www.elsevier.com/locate/jup

Small island developing states and their suitability for electric vehicles and vehicle-to-grid services

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ARTICLE INFO

Keywords:
Islands
Electric vehicles
Vehicle-to-grid services

ABSTRACT

Small Island Developing States (SIDS), while at the forefront of international climate action, face a number of development challenges linked to their historic, geographic and socio-economic characteristics. Small populations and limited energy demand cap the penetration of renewable energy technologies. Electric vehicles (EVs) offer solutions for electricity storage, grid services, reduced fuel imports, and reduced pollution with associated health benefits. This paper provides a comprehensive review of literature on island applications of electric vehicles, making the case for SIDS as an area of opportunity for further exploration, and presenting the southern Caribbean island of Barbados as a case study.

1. Introduction

The international electric vehicle market is growing exponentially, with over 1 million fully electric vehicles in operation globally (IEA, 2017). Experts conservatively predict that by 2040, 35% of new car sales globally and 25% of the world's car fleet will be electric cars (BNEF, 2017). One of the major barriers to their widespread adoption is cost, but with lithium battery prices dropping rapidly, experts expect the standard electric car to have cost parity by 2021 in Europe and China (BNEF, 2017). Small islands are a prime market for electric vehicles with limited road networks, high fuel costs and the need for direct grid storage solutions. Conversion of local passenger and public transportation fleets could have major cost savings and dramatic regional environmental benefits whilst bringing typically marginalized communities to the forefront of global technological advancement.

This paper provides a comprehensive review of recent studies that explore the effect of electric vehicle integration on isolated island grids. All the studies to-date focus on islands that are overseas territories or constituents of developed/industrialized countries. Small Island Developing States do share similar technical challenges in the design of their energy systems and the management of their electricity grids. However, they differ in several areas; including weaker governance structures and lower research and development capacities, but mainly in attracting foreign direct investment and domestic private finance (World Bank, 2017). This paper discusses the application of electric vehicles and vehicle-to-grid services to SIDS, highlighting the impact of electric vehicles on greenhouse gas emissions. The Caribbean island of Barbados is making substantial private sector-led headway in the creation of an electric vehicle market and a case study of this island is presented to relate the principles of vehicle-to-grid services to an existing SIDS context.

2. Special considerations of small island developing states

2.1. Development challenges inherently connected to their energy systems

Small Island Developing States face many economic and technical challenges that differ to those of larger, more developed nations. These challenges primarily stem from their geography – specifically their limited areas, small populations and often-remote locations. Many also have limited natural resources, which hinder their ability to earn foreign exchange, resulting in economies that depend heavily upon imported goods and services (Weisser, 2004; IRENA, 2015). Their insularity and remoteness limit their market access for the trade of goods and services. The flight of human capital is also common with many professionals migrating to more developed countries in search of better prospects (Weisser, 2004). Fossil fuel imports, for electricity and transportation, comprise a large share of their GDP and limit their ability to develop. Fig. 1 and Table 1 present an overview of some of the key statistics for SIDS and compare them with selected US States and EU

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https://doi.org/10.1016/j.jup.2018.09.006
Received 28 February 2018; Received in revised form 11 September 2018; Accepted 12 September 2018

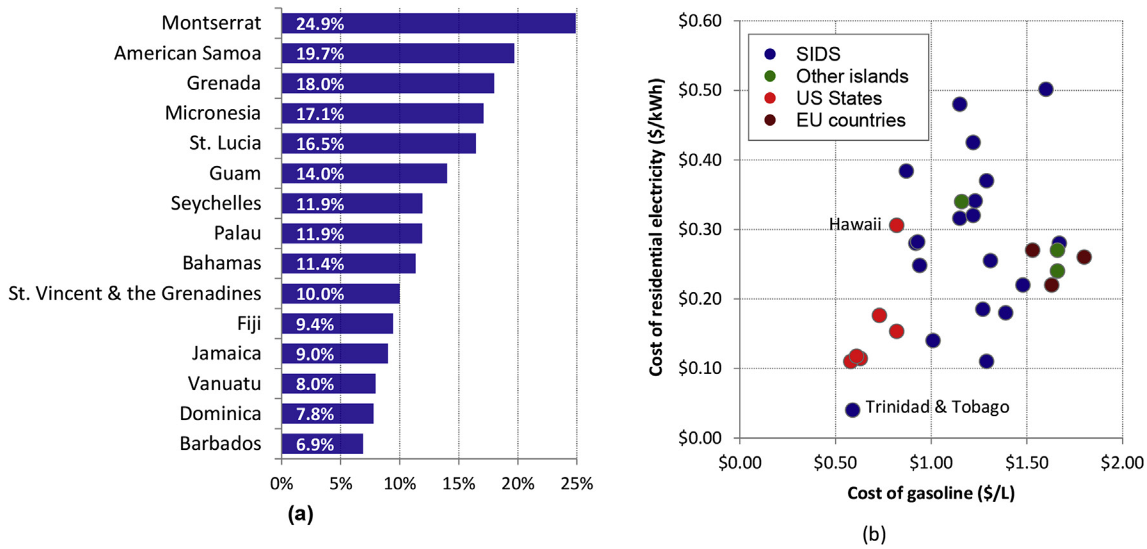

Fig. 1. (a) GDP spent on fuel imports for selected SIDS. (b) Cost of electricity and gasoline for selected countries/US states (from Table 1).

countries. In an effort to pay for increasing fuel import bills, governments often sacrifice investments on infrastructure upgrades, improving local technical capacity and other important areas required for economic development, which can lead to 'locked-in' scenarios in times of high oil prices (IRENA, 2015).

The fact that their fossil fuel derived energy systems create 'locked-in' scenarios is often paradoxical given that many of these islands have plentiful renewable energy resources (Weisser, 2004; Dornan and Shah, 2016). As most SIDS are located in the equatorial regions, they have an abundance of solar resources. Exposure to trade winds can provide them with enviable wind resources (Scheutzlich, 2011), with the deployment of utility-scale wind often emerging as the cheapest way to generate electricity (Hohmeyer, 2015). Waste management challenges and declining agricultural sectors lead to strong bioenergy potential. They also have marine energy potential, be it wave, tidal and/or ocean thermal energy conversion, and many volcanic islands have the potential for geothermal energy production (Hohmeyer, 2015; Wolf et al., 2016).

2.2. The transportation sector in small island developing states

Many of the development challenges that affect the energy sector in SIDS also impacts their transport sectors. As may be expected, challenges of remoteness and diseconomies-of-scale significantly impact island maritime and air transportation, and these are the subjects of several studies on island transport presented in UNCTAD (2014). These same development challenges also impact their road transport sectors. Worldwatch highlights a key observation in the Caribbean, in that road transport is often difficult to manage given a lack of available data on its status, which can subsequently lead to under-regulated and ill-designed transportation policies. This often results in negative impacts on local pollution levels, noise levels, congestion and subsequently human health. The World Bank's report on 'Climate and Disaster Resilient Transport in Small Island Developing States' (2017) makes similar observations for SIDS in other parts of the world.

3. Application of vehicle-to-grid services for small island developing states

Whilst the prospect of increased electricity demand from electrification of transport systems may be attractive to utility operators, e-mobility, as its often referred, will pose challenges to their grids. Weisser (2004) provides a useful background into the structure and operation of existing electricity grids for small island developing states. Here, we discuss the challenges of charging and charging strategies on these grids at the earlier stages of electric vehicle adoption, before discussing the potential benefits of more advanced charging capabilities to utility operators.

3.1. Charging and charging strategies

Given that the conventional energy demand of an electric vehicle is somewhere between 10 kWh and 100 kWh per charge, the cumulative charging of electric vehicles will have an impact on grid performance and stability. This is particularly so for relatively small, isolated grids whose installed capacities are below 200 MW.

Due to the high capital cost of electric vehicles, early adopters tend to be clustered in more affluent neighbourhoods, or businesses with large vehicle fleets (couriers, delivery firms, etc.), and due to an early lack of public charging infrastructure, charging typically takes place at home or places of business during the evening and nighttime. Therefore, in the early stages of electric vehicle adoption, isolated overloading of the grid may occur (Waldron and Kobylarek, 2011; Boulanger et al., 2011; Muratori et al., 2014). Distribution transformers and feeders can quickly become overloaded since an electric vehicle can increase the home or business's demand by 25% or more whilst charging (Boulanger et al., 2011). This can result in unscheduled maintenance, early equipment replacement, and loss of revenue from increased outages. It is therefore in the interest of the electric utilities to investigate the economics of different incentive schemes and the legal processes involved in their implementation.

Grid operators have several options to ensure that vehicle charging minimises any impact on their grids. Known collectively as charge management, these options involve the operators applying demand charges, time-of-use rates and dynamic pricing, which are in widespread use today given their application to larger, industrial clients (Amjad et al., 2018). Due to recent technological developments, additional options are emerging for charge management and are introduced throughout the remainder of this section.

If charge management is not employed, as the number of electric vehicles increases the additional loads posed by charging can lead to a change in an island's daily load profile and an increase the demand peak (see Fig. 2). Any change in the daily load profile can subsequently affect a utility's ability to manage generation, supply and distribution with respect to time and grid constraints, while increasing peak demand can put a strain on existing generating capacity (Dyke et al., 2010). The