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Climate proofing island energy infrastructure systems: Framing resilience based policy interventions

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ABSTRACT

One of the most discernible impacts of climate change is the increasing severity and unpredictability of extreme weather conditions. Small island developing states are particularly vulnerable to these conditions, with one of the impacts being on energy supplies due to damaging energy infrastructure, resulting in power outages and economic losses. Drawing on resilience theory to frame the discourse, we present an updated overview of how island energy infrastructures have been and continue to be negatively impacted. This same framework also provides a lens through which we identify the challenges involved in recovery, rebuilding and returning energy security in these contexts.

1. Introduction

Small Island Developing States (SIDS) are a group of developing countries facing specific but also similar environmental and economic challenges. SIDS are small, remote and isolated states disconnected to the main continent with limited resources which make them more vulnerable (Wolf et al., 2016). SIDS are geographically located in three distinct regions namely in the AIMS (Africa, Indian Ocean, Mediterranean and South China Sea), Caribbean and Pacific, with a significant number of them located in the Caribbean and South Pacific regions (Surroop et al., 2018). There are 37 SIDS that are UN members in the three regions. The land-to-sea ratios for the SIDS are huge such that in many cases, the Exclusive Economic Zones (EEZs) are larger than the land area. The EEZ for Samoa, for example, is eight times the land surface area.

Most of the SIDS depend heavily on fossil fuels which is used for power generation and transportation. Some SIDS like Trinidad and Tobago and Papua New Guinea (PNG) produce and export fossil fuels. Though renewable energy is present in the form of biomass (bagasse), hydropower, solar, wind; they are only a limited percentage of their energy mix except in countries like Fiji where there is significant amount of hydropower. However, solar water heater is very popular in SIDS since they are blessed by a good solar regime.

All countries are facing the climate change effect, however given that SIDS are surrounded by the ocean make them more vulnerable to the effect of climate change although they are the ones contributing less in terms of greenhouse gases emissions. Irrespective of the geographical location of the SIDS, they are all vulnerable to extreme weather conditions like tropical storms, cyclones and hurricanes, severe droughts, flooding, flash flood, rising sea levels and other weather-related phenomena. The extreme weather conditions which are becoming more frequent are affecting the SIDS negatively. In many cases, the energy infrastructure has been badly affected where a major portion of the islanders are deprived from the supply of electricity (Shah et al., 2016).

When viewed through the lens of resilience theory, the question becomes one of investigating nature of how the human, natural and physical infrastructure elements that interact in such intimate and limited conditions of small island developing states, can be handled when opposed to climate induced disturbances and uncertainty. Furthermore, while it can be well acknowledged that resilient infrastructure, energy and otherwise, is a preoccupation of the engineering sciences (Kennedy and Corfee-Morlot, 2013; O'Rourke, 2007), here we attempt to pull this into the realm of possible policy level prescriptions that would meaningfully support efforts in SIDS. Data were collected on various SIDS on their demographic, energy consumption, impact on the energy infrastructure. The data were assessed to come up with climate resilience-based policy for energy infrastructure.

Section 2 of this article provides an overview on the energy profile and the demographic situation of SIDS. Section 3 presents views on resilience theory and in section 4, the theoretical lens is applied to highlight the impacts of different extreme weather conditions in the different geographically located SIDS. Section 5 then provides a

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Table 1
Population, land area and GDP of SIDS.
Source: World Bank, 2017a

SIDS	Population	Land Area (km^2)	GDP (USD million)
Antigua and Barbuda	92000	440	1300
Bahamas	388000	10000	8900
Barbados	284000	430	4400
Belize	359000	23000	1800
Cape Verde	521000	4000	1600
Comoros	788000	1900	565
Cuba	11400000	104000	87100
Dominica	73000	750	517
Dominican Republic	10500000	48000	68100
Federated States of Micronesia	104000	700	315
Fiji	892000	18000	4400
Grenada	107000	340	984
Guinea-Bissau	1800000	28000	1100
Guyana	767000	197000	3200
Haiti	10700000	28000	8800
Jamaica	2800000	11000	14300
Kiribati	112000	810	160
Maldives	409000	300	3400
Marshall Islands	53000	180	179
Mauritius	1300000	2000	11700
Nauru	12000	20	100.5
Palau	21000	460	287
PNG	7600000	453000	16900
Samoa	193000	2800	761
São T & P	190000	960	317.7
Seychelles	93000	460	1400
Singapore	5500000	709	292700
Solomon Islands	584000	28000	1100
St Kitts and Nevis	56000	260	876
St Lucia	185000	610	1400
St Vincent & Grenadines	109000	390	737
Suriname	543000	156000	5200
Timor-Leste	1200000	1000	1400
Tonga	106000	720	435
Trinidad and Tobago	1400000	5100	23600
Tuvalu	10000	30	32.7
Vanuatu	265000	12000	742

discussion of the current situation in SIDS, highlighting some of the actions taken towards increasing the resilience of the energy infrastructure in these small islands. Section 6 draws from that discussion to provide a resiliency-based framework of policy level approaches to consider. Lastly, section 7 suggests how this study contributes to advancing policy action that supports practical implementation.

2. Energy profile

2.1. Demographics

SIDS are generally small expect for few of them, however, they are diverse from each other in terms of population size and Gross Domestic Product (GDP). The land surface area varies considerably from Nauru, the smallest island with a surface area of 20 km^2 and a total population of 12000 to PNG with a surface area of 453000 km^2 and a population of 7.6 million as shown in Table 1. Since Singapore is very developed, it has the highest GDP of 292700 million USD and Tuvalu has the lowest GDP of 32.7 million USD.

The variation in population and size of the islands lead to very different population densities. Singapore, for example, has a total population of 5.5 million over a surface area of 709 km^2 which makes it the most densely populated SIDS. It has a population density of 7757 people per km^2 followed by Maldives and Timor-Leste. Surinam and Guyana are the least densely populated with a population density of 3 and 4 people/km^2 respectively as shown in Fig. 1.

2.2. Energy consumption

Energy access and security is one of the big challenges in SIDS. SIDS are mostly heavily dependent on fossil fuels. The purchase cost of fossil fuels is very high due to the remoteness and old infrastructure of the islands. In fact, many SIDS spend a significant share of their national budgets on importing fossil fuels and in some cases the same amount, if not more, is spent in addressing the negative impact of climate change in their respective jurisdiction (Shah and Niles, 2016).

The energy consumption varies between SIDS and this is mainly due to the affordability of energy. Many SIDS cannot afford to provide energy access to all the population due to the high cost of energy. Moreover, some SIDS cannot afford or are very slow in terms of economic development and in the absence of economic development the wealth of the country cannot improve. As such, the energy consumption per capita is very low. As observed in Fig. 2, Timor-Leste has the lowest energy use per capita with a consumption of 60 kg oil equivalent followed by Guinea-Bissau and Comoros with an energy consumption of 64 and 65 kg oil equivalent respectively. Trinidad and Tobago has the highest energy consumption per capita which corresponds to 14447 kg oil equivalent followed by Singapore with 5122 kg oil equivalent.

Timilsina and Shah (2016) stated that the energy consumption per capita is above 4877 kg oil equivalent for high income countries, below 4877 and above 1283 kg oil equivalent for middle income countries and above 359 kg oil equivalent for low income countries. If these criteria are used, Timor-Leste, Guinea-Bissau, Comoros, Kiribati, Solomon Islands, Vanuatu, Cape Verde, São Tome & Principe and Samoa are below low income countries, Haiti, Tonga, Dominica, Marshall Islands, Belize, Fiji, St Vincent & Grenadines, Guyana, Dominican Republic, St Lucia, Grenada, Maldives, Jamaica, Cuba, Mauritius and Suriname are below middle income countries, Barbados, St Kitts and Nevis, Antigua and Barbuda, Bahamas and Seychelles are middle income countries and Singapore and Trinidad and Tobago are high income countries only from an energy consumption perspectives.

2.3. Installed capacity

Electricity is produced from different sources namely, oil, coal, biomass, hydro, solar, wind among others. However, fossil fuels remain the dominating one in most SIDS. Electricity is produced either by the state-owned power plants or independent power producers. The power transmission and distribution is done by the utility companies which are mostly owned by the Government, however, in some cases, it is public and private partnership. The total installed capacity is depended on the affordability and the level of development of the country. Countries that are developed have a better installed capacity and transmission and distribution with a high percentage of access to energy. The highest installed capacity is in Singapore which has a GDP of 292700 million USD with a total installed capacity of 10.7 GW and is the most developed SIDS while there are five other countries that have installation capacities of more than 1 GW namely Jamaica – 1.2 GW, Trinidad and Tobago – 1.43 GW, Dominican Republic – 3 GW, Cuba – 5.5 GW, and Singapore - 10.7 GW. Tuvalu has the lowest installed capacity – 3.9 MW followed by Nauru – 4.9 MW and Kiribati – 5.8 MW as observed in Fig. 3.

3. Theoretical foundation: resilience theory

While the original conceptualization of resiliency of systems is not new and has been a fundamental focus of study and application across fields grounded in the discipline of physics for near a century, it is only more recently that scholars in the natural and social sciences have come to consider how resilient systems resemble (or not) ecological and sociological dynamics. By the mid-2000's with the increasingly urgent scientific reportings of world bodies such as the IPCC, on the status of global warming and how this phenomena is both impacted by and