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Dimensions of Energy Security in Small Island Developing States

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ABSTRACT

For any Small Island Developing States (SIDS) that imports oil, energy security is very important and is dealt with seriousness. This paper attempts to look at the gap in the literature and to identify the dimensions on which a secure and sustainable supply of energy depend in SIDS. Seven dimensions were identified which offer a framework for conceptualising and/or assessing key energy security dimensions in small island nations which are import dependent; energy prices; climate change and resilience; governance; infrastructure; equity; and energy efficiency. This article provides recommendations of selected strategies and actions to improve energy security in SIDS.

Keywords Small Islands developing States (SIDS); Energy security; Strategies

1. Introduction

Energy security has been broadly and incomprehensively defined within scientific literature (Ebinger, 2011). While some authors conceptualised energy security as relative to economic development, others studied energy security in terms of energy availability, resource affordability, environmental sustainability, energy efficiency and technology (APERC, 2007; Lefèvre, 2010; Sovacool and Mukherjee; 2011; Cao and Bluth, 2012; Hughes, 2012; Chuang and Ma, 2013; Selvakkumaran and Limmeechokchai, 2013; Martchamadol and Kumar, 2013; Misila et al., 2015; Phdungslip, 2015). Kucharski and Unesaki (2015) supported Winzer (2012) and Leal Filho and Voudouris (2013), who stated that energy security is concerned about risks and vulnerabilities whether geopolitical risks or natural disastrous events. Cherp and Jewell (2011) discussed robustness, sovereignty and resilience as three perspectives of energy security. Chester (2010) discussed the polysemous nature of energy security while referring to other authors' claims on the vague, elusive, inherently difficult, abstracted and blurred concepts of energy security. Rosen (2009) looked at the key energy-related steps in addressing climate change.

While it is widely agreed that 'energy' refers to both primary (oil, coal, natural gas and renewable energy) and secondary sources (electricity), a wide range of literature predominantly focuses on the reliability of oil supply when the topic of energy security is discussed (Vivoda, 2010; Stringer, 2008). Most probably, this is because oil is the most consumed primary energy resource in the world accounting nearly 33% of the global energy market (BP, 2016; Vivoda, 2010) and because oil prices are often fluctuating as a result of political instability and conflicts in major oil producing countries (Asif and Muneer, 2007). Volatile oil prices have negative repercussions on both oil exporters – as they are faced with varying revenues – and oil importers as they perceive significant uncertainty on imports costs and fuel subsidy level, and in this context, numerous studies were conducted to better understand, define and characterise the whole concept of energy security (Rentschler, 2013; Narula and Reddy, 2016). Policymakers often measure energy security through a number of energy indicators and indices derived from suitable dimensions or assessment instruments, which are factors that influence a stable energy supply in a country (Narula and Reddy, 2015). Hence, Vivoda (2010) proposed 11 dimensions and several attributes to gauge energy performance, Sovacool (2011) presented 20 dimensions and Von Hippel et al. (2011) provided six dimensions and numerous attributes and strategies to characterise energy security performance. Based on these dimensions, a number of authors have developed indices, for example, Lefèvre (2010) developed the Energy Security Price Index (ESPI), Gupta (2009) came up with the Oil Vulnerability Index (OVI), ex-ante and ex-post indicators by Löschel et al. (2010) and the Aggregated Energy Security Performance Indicator (AESPI) by Marchamadol and Kumar, 2013 among other researchers. Research on energy security in Small Island Developing States (SIDS) member states (see Table 1 for list) is of high relevance as they are net energy importers and are intricated by unique geographic, demographic, economic and environmental challenges (Blancard and Hoarau, 2013; UNEP, 2014). SIDS are geographically located in the Atlantic, Indian Ocean, Mediterranean and South China Sea (AIMS), Caribbean and Pacific regions. The total population in the SIDS in this study is around 61,516,000 with the largest share in the Caribbean which represents 65% followed by Pacific with 18% and AIMS 17% (World Bank, 2017). However, research on energy security in SIDS is in its infancy and this study is the first of its kind to come up with relevant indicators of energy security applicable to island states. There appears to be little progress on indicator development because, so far little has been done to identify meaningful dimensions on which a stable energy supply in islands depends. The World Energy Council (2017) developed the world energy trilemma index and reported that there are only five SIDS in the list of 125 countries assessed. The energy trilemma ranking is based on energy security, energy equity and environmental sustainability, morerecently taking CO2 emissions into account (Leal Filho 2015). Denmark is ranked first in the list of 125 countries and the five SIDS are Singapore - 22^{nd}, Mauritius – 47^{th}, Dominican Republic – 79^{th}, Jamaica – 85^{th} and Trinidad & Tobago – 88^{th} (WEC, 2017) The uniqueness of this paper is that, firstly, it develops a conceptual framing of relevant energy security dimensions of SIDS and secondly, it draws from a review of some potential initiatives, some recommendations of selected strategies and measures to improve energy security in SIDS context. The article thus contributes to filling a literature gap on energy security and seeks to refocus attention to initiate further research for energy sector development in SIDS.

Table 1. List of Small Island Developing States (SIDS)[1] (Source: UNEP, 2014)

SIDS region	SIDS countries

[1] While brief references are made to Papua New Guinea (PNG) and Trinidad & Tobago, the hypothesis elaborated made in this article are less applicable to PNG. PNG and Trinidad & Tobago are energy exporter and energy importers and exporters have different dimensions on which their supply of oil to their population depends. Energy security aspects of oil exporters have to be dealt separately and is beyond the scope of this paper.

AIMS	Cape Verde, Comoros, Guinea–Bissau, Maldives, Mauritius, Sao Tome and Principe, Seychelles, [2]Singapore
Caribbean	Antigua and Barbuda, Bahamas, Barbados, Belize, Cuba, Dominica, Dominican Republic, Grenada, Guyana, Haiti, Jamaica, St Kitts and Nevis, St Lucia, St Vincent and Grenadines, Suriname, Trinidad and Tobago
Pacific	Fiji, Kiribati, Marshall Islands, Federated States of Micronesia, Nauru, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tonga, Tuvalu, Vanuatu

2. Methods for data collection

Two methodological approaches were simultaneously used to characterise key dimensions of energy security that are relevant to SIDS. Firstly, a review of present literature based on energy development in SIDS and energy security was conducted. Literature on islands' energy sector was obtained mostly from intergovernmental and think–tank reports. The aim of literature search was to identify major energy security dimensions and their applicability in small islands. To support some arguments, statistical data from various international databases were collected such as the World Development Indicators of the World Bank, the International Disaster Database from the Centre for Research on the Epidemiology of Disasters (CRED) and the Electricity Database from the International Energy Agency (IEA). Where data was unavailable from these sources, information was retrieved from governmental statistical publications, reports from development banks, regional agencies and national organisations along with a wide range of peer–reviewed papers. Efforts have been made to gather, as far as possible, the most up–to–date data. Accuracy and authenticity of the data collected was maintained by cross–checking with other statistical reports.

Secondly, to consolidate the findings of the literature review, a qualitative survey was carried out among energy practitioners in Mauritius, Fiji, Samoa, Vanuatu, Tonga, Tuvalu and Federated States of Micronesia. The survey was carried out in 2014 as part of the L^3EAP Project (www.project-l3eap.eu) which aims to develop and provide lifelong learning approaches and

[2] Singapore is not a developing state but a developed country, but is part of the SIDS group. The findings in this study can equally by applicable to Singapore as the country share similar environmental and economic challenges as other SIDS members

strengthen local capacities on energy access, security and efficiency in SIDS. Respondents were chosen purposively and constituted of energy professionals working for non–governmental organisations (NGOs), the private and public sectors, utility companies and renewable energy agencies. The survey received 32 respondents from Mauritius and 29 from the Pacific Island Countries (PICs) – 61 in total. From PICs, 4 participants were energy analysts from the Department of Energy, 12 participants were from NGOs, 7 participants from utility companies and 6 from private companies working in the energy domain. In Mauritius, 28 participants were from the power producing companies, 3 from utility companies and 1 from a research institution. Most respondents search for securing energy resources as part of their professional responsibility. Respondents with practical knowledge of energy security was sought rather than experts with predominantly theoretical knowledge. Survey in the Caribbean islands could not be conducted but views from participants can presumably be extended to reflect the energy security issues and dimensions in the Caribbean islands. Respondents were asked basic bio–data information and to give their views on 'energy security' in open–ended questions.

3 Data analysis and discussion

Responses obtained were processed as per Miles and Huberman (1994) and Patton (2002) and as previously applied in Blumer et al. (2015). Recurrent themes from the wide range of views from the survey were used to develop a set of codes which were labelled as (i) import dependency, (ii) energy prices, (iii) climate change and resilience, (iv) governance, (v) energy infrastructure, (vi) equity and (vii) energy efficiency. Some responses, such as one energy expert said: "Energy security has two key dimensions – reliability and resilience is attributed to two codes; "reliability" attributed to code (i) and "resilience" to code (iii).

Results has been simplified as in Table 2 which gives the proposed dimensions for a secure energy system in SIDS and the percentage recurrence in the responses of the survey sample. The percentage recurrence is the number of parameters applicable to a particular code divided by the total number of codes recorded. Most experts claimed *import dependency* and affordable *energy prices* as mandatory parameters for a secure energy system in islands. This is not surprising as these two dimensions figure in a wide range of literature. In most scientific literature, these two terms are known as 'availability' and 'affordability' of energy.

The survey results showed *climate change and resilience* among the top three priorities for a secure energy system in islands. It is important to highlight a piece of observation: contrasting these results with a study by Ang et al. (2015) who ranked *environment* fifth from a wide range of studies on energy security from developed countries namely China and Japan, the problem of climate change is more pronounced in SIDS. Other important dimensions identified by experts are governance, energy infrastructure, equal energy distribution and energy efficiency which are further commented in the next section.

Table 2. Survey results from open–ended question and percentage recurrence in responses

Some Keywords/phrases	Dimensions	Percentage
Availability; adequate; reliability; Consistent	Import dependency	46%
Reasonable and affordable prices; economic performance	Energy prices	15%
Clean energy; sustainability; resilience; shocks; withstanding threats; external forces	Climate change and resilience	14%
Management of energy supplies; requirements of a nation	Governance	8%
Generation and distribution system; fuel storage facilities	Energy Infrastructure	6%
Equal distribution; the right; not discriminated against	Equity	6%
Efficient; intelligent use	Energy efficiency	3%

4 Dimensions of energy security in SIDS

4.1 Import dependency

Based on the survey, it was noted that the first and most important dimension which characterise energy security in SIDS is import dependency. In general, SIDS are net oil importers. Most energy practitioners agreed that oil import to SIDS countries encompasses all other energy security dimensions which is spearheaded by their high consumption. Fig. 1 show the electricity mix in

Africa, Caribbean and Pacific SIDS and as observed over 70% of energy demand for electricity is satisfied by fossil fuels which are imported. They explained that high dependency on oil exposes SIDS to the direct risks of supply disruptions and possible effective solutions (such as source diversification) are not economically feasible in SIDS context. Country-wise, Suriname, Dominica, Fiji, Belize, Cape Verde and Sao Tomes and Principe have diversified energy mix by deploying sustainable energy sources like wind and hydro to enhance energy security, but renewable energy development in SIDS is still constrained by a number of barriers as Timilsina and Shah (2016) discussed in their paper. Raghoo et al. (2017) studied the feasibility of diversifying the energy mix by importing natural gas from neighbouring countries but the possibility of supply disruption remains. Alternatively, source modification can be sought to improve energy security (APERC, 2007). Instead of importing oil from only one country, oil importers can purchase oil from different countries and thus mitigate the risks of supply disruptions (Ang et al., 2015). However, source diversification has its limitations over geographical distance, political relationships with exporting countries, energy policies and the resources required to implement those policies (Vivoda, 2009). Source diversification seems more an ‘elusive’ concept as SIDS import relatively small amount of oil over long distance. In Mauritius, petroleum products are imported from Mangalore Refineries and Petrochemicals Ltd on a 22–day shuttle over 4600 km. Importing oil from different suppliers can increase energy expenses directly impacting the domestic sale of oil.

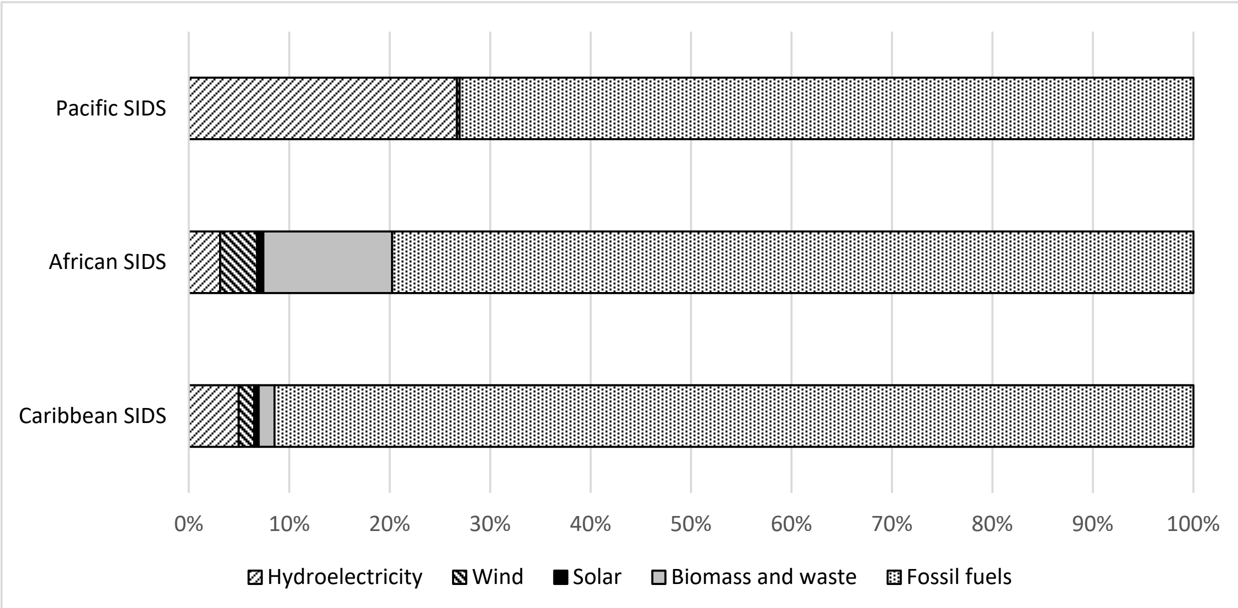

Fig. 1. Electricity generation mix in Pacific, African and Caribbean SIDS, 2015 (Source: authors' illustration from data from EIA, 2015)

4.2 Energy Prices

The second factor that the survey revealed influencing energy security in SIDS is energy prices. Energy practitioners discussed how energy prices as an economic dimension, influence energy security. Being small and having a negligible oil demand on the international market, SIDS have less control on the price of goods they import and export and are therefore, 'price–takers' rather than 'price–setters' (Briguglio, 1995). Since SIDS are sea–locked, they rely extensively on air or maritime transport for imports and exports. Freight costs are unusually high because SIDS lie outside the conventional zone where most ships circumnavigate. This increases oil expenditures in SIDS where often oil imports is a fraction of country's overall GDP. Fig. 2 provides GDP share dedicated to oil imports in selected SIDS for which data is available, where this fraction is as high as 28% in Palau. Being highly reliant on oil makes SIDS susceptible to oil price shocks. In a study, Bacon and Kojima (2008) showed that the changes in economic susceptibility, that is, the variations in the share of GDP accounted by the importation of oil from 1996 to 2006, in Guyana was 20.2%, Seychelles, 14.8%, Maldives, 10.1% and Belize, 6.9% as compared to Switzerland, 1.0%, Mali, 0.8% and Uganda, 2.0%. Oil price hikes give rise to inflation, trade deficits and high import bills. To counteract the impact of rising oil prices, SIDS have to seek aid through foreign direct investments, grants or by borrowing from other countries. On a household level, a rise in energy price causes inflation which can surcharge family budget and disproportionately affect those who show little resilience to cope with price fluctuations. Businesses might be less competitive as they have to raise input costs and unlikely to increase final prices. Therefore, export decreases which can dis–equilibrate balance of payments. Declining economic growth can pressurise government to inject funds for fuel subsidisation. For example, in 2008, Marshall Islands government has injected $8 million to the state-owned utility company for continuous oil procurement (Davies and Sugden, 2010).

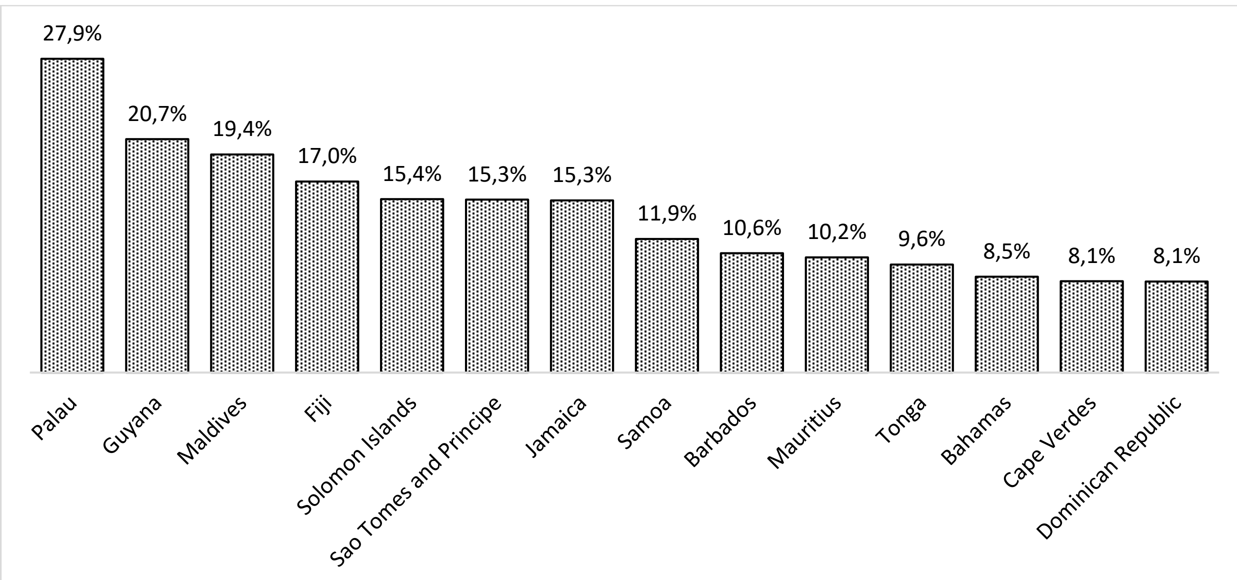

Fig. 2. Percentage share of GDP on oil imports for selected SIDS, 2013 (Source: World Development Indicators, World Bank; authors' calculations)

4.3 Climate change and resilience

Resilience is the ability to make extra preparations and to adapt to changing environment so as to resist and address disruptions at the earliest (President Policy Directive 21, 2013) and our experts aim address the disastrous effects of climate change on island nations and their inability to mitigate and adapt to them. An energy system cannot be sustainable if it causes environmental externalities such as overexploitation of natural resources, air pollution and contribute to the negative consequences of climate change. Climate change is known to destabilise naturally–occurring cycles and to be an initiator of more frequent and severe natural calamities such as droughts, floods, tropical cyclones and tsunamis. Cyclones are formed by the interaction of the atmosphere and sea and are quite impactful for islands causing massive destruction of infrastructure, communication services and settlements. (UNEP, 2014). The damage caused by natural disasters can even surpass a country's GDP resulting in major economic set–back (Fig. 3). In Haiti, for example, total costs of damage from natural disasters from 2000–2014 were 118.0% of its GDP (high because of January 2010 earthquake), in Samoa total costs amounted to 41.8% of its GDP as shown in Fig 3. and in Dominican Republic (DR) total damage was about 0.5% of its GDP. In SIDS, experts take climate change as a subset of energy security. Past authors have synergised climate change, energy access, renewable energy and air pollution with energy security policies for many countries (Bazilian et al., 2011; Bang, 2010; Bollen et al., 2010; King and Gulledge, 2016; Rogers–Hayden et al., 2011; Shadman et al., 2016; van Vliet et al., 2012) which highlight the need to implement climate change mitigations measures to build resilience and maintain energy security.

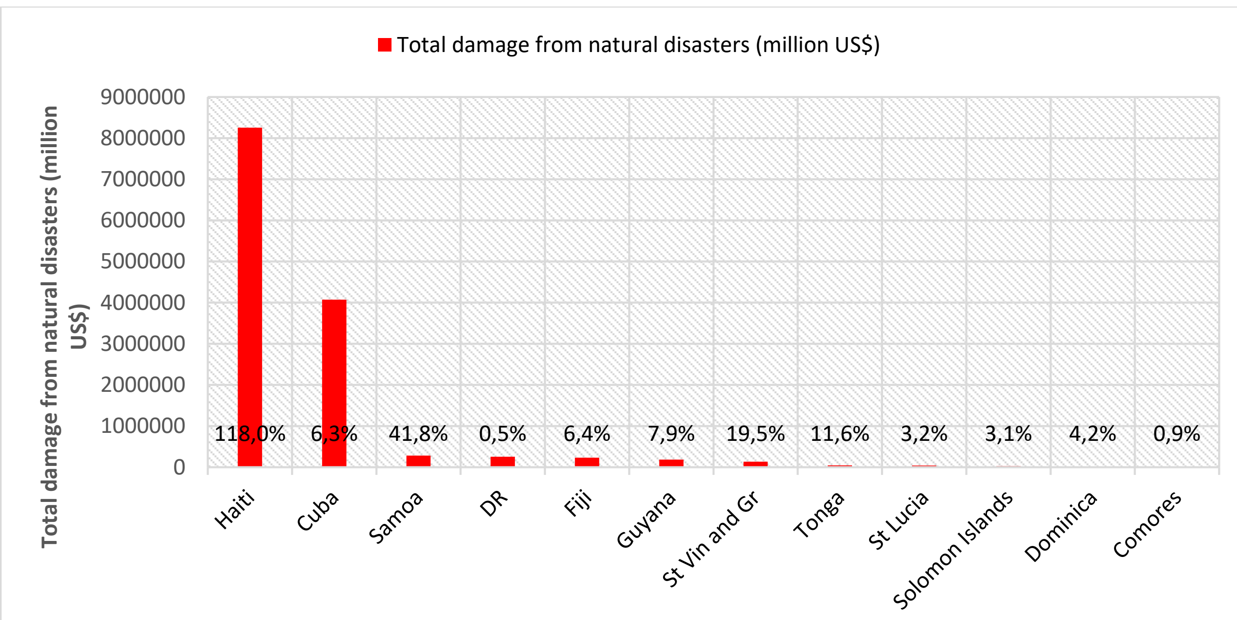

Fig. 3. Cumulative total cost of damages from natural disasters for the period 2000–2014 in some selected SIDS and the percentage share of GDP it accounts for (Sources: World Development Indicators, World Bank; International Disaster Database; authors' calculations)

For SIDS, being resilient to disruptions does not only mean disruptions from changing environmental conditions. It is a risk management approach (Roege et al., 2014) that does not only include withstanding climatic conditions, but other shocks like terrorism, accidents, sabotage, theft and import supply risks, too (Yeeles and Akporiaye, 2016). As put forward in Goldthau and Sovacool (2012), energy systems fall short of resilience that can be detrimental to external shocks and this is an issue in SIDS as potential approaches to enforce resilience are still unimplemented. A typical example is the threat of attacks from Somalian pirates to oil tankers destined to countries in the Indian Ocean where there is still room for improvement though some measures have been taken.

4.4 Governance

The role of governmental authorities of oil importing countries is critical to devise and coordinate policies around energy and sustainability issues (Fudge et al., 2016). Sound and forward–looking government can establish energy policies to mitigate short–term oil disruptions and build tough and robust infrastructure to maintain long–term energy supply (Ang et al., 2015). Most of the government in SIDS provide subsidy to dampen oil prices and thus, make energy costs affordable to islanders. The example of the Marshall Islands given above, where the government injected $8 million, best illustrates such effort from their government. Other examples include Samoa where the government has reduced tax rates on petroleum products to lessen the burden on consumers (Davies and Sugden, 2010). Indeed, fuel subsidisation can increase government expenditures on the national budget, and this is why good governance is required to efficiently balance revenues and expenditures in the national budget. For oil importers, government authorities have to plan and intervene promptly to reduce impacts of energy security.

4.5 Energy Infrastructure

It was found that the fifth aspect of energy security was energy infrastructure. Energy infrastructure refers to all components of the energy supply chain, which in the case of SIDS refers to transport by sea, disembarkment of oil, conversion to secondary sources (electricity) and its transmission and distribution or supply of primary energy sources. Hence, energy infrastructure for oil importing countries include high efficiency refineries, proper oil tankers, adequate berthing and ports and oil tanks for oil storage. In this respect, ports need to be equipped with proper berthing lengths, quay apron areas and road access. Regular maintenance has to be done to ensure that port infrastructure provide the intended function. In addition, maritime accidents occurring from either sinking ships, collisions of ships or collision with port infrastructure can narrow approach channels and obstruct anchorages and port areas in some SIDS (UNCTAD, 2014). Since most SIDS have only one berth, damage to it can hinder imports and exports of goods. This is a direct threat to a country's energy security as infrastructure is the key component of the oil supply chain. Poor maintenance and inadequate financial and technical resources can cause accidents like oil spills. The Asian Development Bank (2007) provides some serious issues with port infrastructure in the Pacific countries and among, highlights that Palau port, which dates back to World War II need to be overhauled for continuous operation. Oil storage tanks have to be robust enough to resist natural disasters.

Efficient infrastructure is also vital to maintain security of electricity supply. Less efficient cables and transformers and other equipment for electricity transmission and distribution is mandatory for adequate electricity distribution. In Haiti for instance, 60% of electricity supplied on the grid is lost in terms of transmission and distribution losses (World Bank, 2014) which entail high economic consequences for the country. Though these losses cannot be completely eliminated, they can be minimized by regular maintenance, improvement in power factor among other measures. Besides, the March 2011 nuclear catastrophe in Japan and the subsequent huge trade deficits the disaster created for the country (Vivoda, 2012) directly indicate the need for proper planning of electricity generating infrastructure to withstand disasters of any magnitude.

4.6 Equity

An energy system cannot be regarded as secure if there exist within the system an unequal distribution of energy where some areas have access to energy while others do not. The relation between equity and energy security can be discussed in two ways – firstly, in terms of oil supply and with respect to the supply secondary energy sources (electricity). The first way lies in the unequal distribution of oil among energy importers and exporters. Thus, Asian–Pacific, European and North–American countries consume 80% of the world oil but control 10% of the world's oil reserves. Former Soviet Union, Africa, Latin America and countries making the Middle East control 90% of the global oil reserves but consume 20% of the global oil (BP, 2008 cited in Vivoda, 2009). The global energy market is therefore, quite unbalanced. On the other side, the sheer size and pace of growth of China and India is changing the global energy market with an ever-increasing appetite for oil (Vivoda, 2010). Under these circumstances, for holding more of this finite volume of oil, China has planned energy strategies such as import diversification (Wu, 2014) which can efficiently hog more oil resulting in greater competition for oil on the market. Experts discussed that even though equity is difficult to quantify, within such fierce competition, SIDS fall far behind and are often ignored due to their relatively small oil consumption and inability to offer competitive prices. In simple terms, SIDS are neither competitive nor powerful enough to compete with superpowers for oil to which SIDS are highly dependent on.

Secondly, domestic supply of energy in terms of electricity is rarely viewed as equitable as some regions have a reliable supply of electricity while in other regions, especially in villages and rural areas access to electricity is basically low. In the PICs for instance, electrification rate (amount of population having access to electricity) varies from 14% in Solomon Islands and 17% in Vanuatu as compared to 89% in Fiji to 99% in Samoa (Dornan, 2014). The inability to supply equitable access to energy results in poverty aggravation and the deepening of the rich–poor gap in developing countries.

4.7 Energy efficiency

Energy security and efficiency is closely linked as reported by the World Bank (2005) and ESCAP (2008). By opting for more efficient energy technologies, the overall energy demand (whether in terms of oil or electricity) of a particular region can be reduced, thus alleviating the pressure on governmental authorities to supply more energy. Government will therefore have more funds to inject in other priority areas for better development of the country. Energy efficiency is an effective tool to mitigate global emissions and to tackle oil security problems in cases of oil price hikes. It is a cost–effective strategy to mitigate risks of energy security in islands (Raghoo et al., 2017).

5 Potential strategies for improving energy security in SIDS

An account of different practical initiatives that can be adopted to enhance security of energy supply in oil importing SIDS is given here. Before any initiative or policy is passed, a comprehensive feasibility study must be conducted to identify flaws and benefits in the proposed strategy. The applicability of each strategy in the context of SIDS is beyond the scope of this paper. It only presents some potential ways for energy security improvement in islands.

5.1 Demand Side Management (DSM) and Energy Efficiency

Previously pointed out by Narula and Reddy (2016), the intensive focus on 'security of energy supply' leads to confusion of the role of demand side management and energy efficiency in enhancing energy security. DSM consists of a set of activities that monitors and alters end–users' energy demand. It is achieved by efficiency improvements on the customer's side and ultimately results in an overall reduction of fossil fuels consumption. Benefits of DSM practices and relevant management techniques are thoroughly discussed in Strbac (2008). For SIDS, DSM is the least costly option to reduce dependency on oil imports.

Energy efficient measures can be adopted in industries, transport and buildings. For industries that rely on oil to power equipment, proper housekeeping, regular maintenance, industrial energy audits and using more efficient machinery in the plant can decrease fuel input. Energy efficiency in buildings can be achieved by applying efficient techniques (such as passive solar technologies) in the construction phase of buildings. Simple household measures such as proper tuning of air conditioners, switching off electrical appliances when not in use or using more efficient lamps for lighting can enormously help in cutting–off electricity bill and in the foremost, oil consumption in a region and eventually releases of greenhouse gases. In the transportation sector, which is the most oil consuming sector, proper road planning such as street layouts, pavements improvements and other infrastructural measures can help to reduce oil intake in vehicles. Using hybrid cars, prioritising walking and cycling for short distances, reducing travel speed for vehicles and mass transport are also good initiatives to curb oil intake (Sathaye et al., 2007). As simple as it may seem, some energy efficient practices require little or no cost at all. It is the coalition of these million individual small actions by islanders that can reduce dependency on imported fossil fuels.

As an example of energy efficiency initiative, the proposed Sea Water Air Conditioning Project (SWAC) in Mauritius to use seawater pumped from the ocean to replace air conditioning in buildings in the capital city is a major project expected to replace the equivalent of 30 MW electrical power by an ocean derived cooling system (REN21, 2015). With regards to the different energy efficiency measures and policies available (see IEA, 2015), it is essential to implement an action plan based on funds available, environment, demography and other territorial data to assess which measure or policy is best–suited for which region (Sanseverino et al., 2014).

5.2 Strategic Petroleum Reserves (SPR)

SPR or stockpiling is the storage of petroleum to be used during short–term oil supply disruptions or in emergency situations such as in the occurrence of natural catastrophes. SPR is not a recent approach to tackle oil security problems (for e.g., see Balas, 1979) but since most academic literature is focussed on the United States, China or in IEA member countries, SPR probable application within SIDS has remained understudied. While setting up of an SPR in small islands can be subjected to many debates due to numerous factors to be considered, such as optimal size of the reserve, financial and institutional issues, drawdown decision; it nevertheless represents a good mean to plan for anticipated oil scarcity. Benefits of having SPR are purely economic. First, there are opportunities that exist where government can buy oil at a lower price and sell it to customers at a higher price. Secondly, SPR can dampen oil price hikes during disruptions thereby limiting economic setback and panic buying. This gives economies enough time to find alternative solutions to alleviate oil supply shortages (Paik et al., 1999) and also provide with a short–term solution to tackle oil price spikes issues. In the exceptional case of SIDS, frequent natural catastrophes can paralyse port activities or make it difficult for ships to deliver oil. In these cases, reserves from the SPR can be drawn to satisfy energy needs rather than attempting to disembark oil from ships under poor meteorological conditions. Finally, it can alleviate politically or economically motivated oil disruptions (Taylor and van Doren, 2005). Paik et al. (1999) discussed the available technologies for oil storage and their cost implications. Other authors (Meng et al., 2016; Zhou et al., 2016; Zhu et al., 2012) have focussed on optimal sizing of oil reserves by stochastic modelling.

Leiby et al. (2002) argued that the cost that small economies have to bear to set up oil stockpiles do not justify the relevant benefits accrued. However, benefits derived from stockpiling are additive and thus, a reserve can be jointly shared by a collection of nearby islands especially, in the Caribbean and Pacific regions. In addition, stockpiling oil can thus be used as a tool for diplomacy.

5.3 Energy mix diversification

SIDS are blessed with a huge renewable energy potential whose exploitation and development are highly encouraged to diversify energy mix and to reduce dependency on oil imports. Much efforts have already been done to expand sustainable sources of energy in SIDS. Most of the SIDS have established RE goals by a certain time period (except Papua New Guinea) (Dornan, 2014).

Mauritius for instance, has come up with a long–term energy strategic plan and is expected to generate 8% electricity by wind, 6% by hydro, 2% by solar PV and 2% by geothermal energy by 2025 from existing 3% hydro and 0.2% solar with limited work geothermal energy so far (CSO, 2015; MEPU, 2009; Surroop and Raghoo, 2017; Wolf et al., 2017). A wind farm has recently started but there is still a long way to go to achieve targets. Table 3 demonstrates the RE potential for some Caribbean SIDS, as an example.

Table 3. Renewable energy potential in Caribbean SIDS (Source: Nextant, 2010)

Caribbean islands	Wind (MW)	Geothermal (MW)	Hydro (MW)	Solar PV (MW)
Antigua and Barbuda	400	-	-	27
Barbados	10	-	-	26
Dominica	-	100	8	45
Dominican Republic	3200	-	210	2899
Grenada	11	499	-	21
Haiti	10	-	50	1654
Jamaica	70	-	22	650
St Kitts and Nevis	5	300	-	16

There is no debate on the fact that SIDS are blessed with abundant RE sources (Shirley and Kammen, 2013; Timilsina and Shah, 2016; Prasad et al., 2017). Arguably, solar, wind, biomass and hydroelectricity seem the most preferred RE sources notably because of the current mature status of their technologies and the cost–competitiveness with fossil fuel technologies. However, there are some financial and institutional barriers that small islands face to achieve RE targets. Although SIDS receive some financial aid (known as Official Development Assistance, ODA) (Niles and Lloyd, 2013), governments are unable to invest in the energy sector as they have to improve other sectors such as education, water, food security and poverty alleviation. Timilsina and Shah (2016) comprehensively described the barriers and ‘policy enablers’ for more renewable energy development in SIDS. It is also very difficult to access finance from foreign investment due to significant development challenges (Dornan, 2015) such as lack of incentives for private sector participation, diseconomies of scale and a thin financial base. However, as demonstrated by Dornan and Jotzo (2015), who applied the portfolio theory in SIDS, found that energy efficiency measures combined with renewable technologies help in reducing the cost of production which in turn reduces the financial risk. This is in contrary with other countries where there exists a cost–risk trade–off for RE integration. Ultimately, to drive more RE within SIDS, it is important to establish incentives to allow elements of an economy (private sector, for instance) to participate and invest in more sustainable sources. An example is the Turtle Beach Resort in Barbados where French Polynesian government gave a 35% tax credit to substitute electric water heating powered by diesel generators by solar water heating hence yielding $1.48 million in energy savings and 655 tons of carbon emissions avoided from 1997 to 2013 (IRENA, 2014). Another policy instrument is feed–in tariff (FIT) which guarantees investors a fixed price for electricity generated from green sources for them to attain a reasonable return on investment (Jacobs et al., 2013). Gaps in technical and educational skills of islanders to handle renewable energy technologies can be addressed by training and capacity building.

6 Conclusion

Energy security is fundamental for the sustainable socio-economic development of SIDS. Since SIDS are not energy self–sufficiency and rely mostly on fossil fuels for meeting their energy needs, the security of energy supplies is of utmost importance. In this article, an attempt has been made to identify potential determinants of energy security for Small Island Developing States. The seven dimensions identified are regarded key to ensuring a more secure energy supply in SIDS. Hence, it is suggested that, based on the conceptual framework presented in this paper, more research work is needed to develop energy security indicators and indices in SIDS. Dimensions proposed coupled with the special vulnerabilities faced by islands, can be considered to gauge energy security performance and, thus, improve planning for future energy policies. It can also be observed that most strategies to enhance energy security are either underexploited or understudied, indicating further research opportunities. Energy efficiency, being a key to improve energy security is either misunderstood or ignored by policymakers so more awareness raising and communicating the advantages of efficient use and production of energy is needed for small island nations.

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