SIDS-Appropriate Sustainable Energy Technology Assessment

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SIDS DOCK Secretariat

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Foreword

This *SIDS-appropriate Sustainable Energy Technology Assessment* is prepared by ing. Ruben Contreras-Lisperguer, MSc. and ing. Kevin de Cuba, MSc. of the Aruba Sustainable Development Foundation (ASDF), the authors would like to thank the SIDS DOCK Secretariat and the Caribbean Community Climate Change Center (CCCCC) for the entrusted task of preparing this report.

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Abbreviations

CC	Climate Change
EE	Energy Efficiency
GHG	Greenhouse Gas
GWh	Giga-watt-hour
kWh	Kilowatt hour
kW	Kilowatt
MW	Megawatt
PV	Photovoltaic
OTEC	Ocean thermal energy conversion
RE	Renewable Energy
RET	Renewable Energy Technology
RES	Renewable Energy Source
SET	Sustainable Energy Technology
SIDS	Small Island Developing States

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1. Introduction

1.1 Background

In December 2010, in Cancun, Mexico, during the Conference of Parties (COP-13)[1] meeting, the Small Island Developing States (SIDS) Sustainable Energy Initiative, called SIDS DOCK, was launched with four Partners: the Alliance of Small Island States (AOSIS), the United Nations Development Program (UNDP), the Energy Sector Management Assistance Program of the World Bank (ESMAP/WB), and the Government of Denmark. At this event a grant of US$ 14.5 million was announced as start-up contributions for the ***SIDS DOCK Support Program***. Please see Figure 1 for an impression of the geographical span of SIDS around the world.

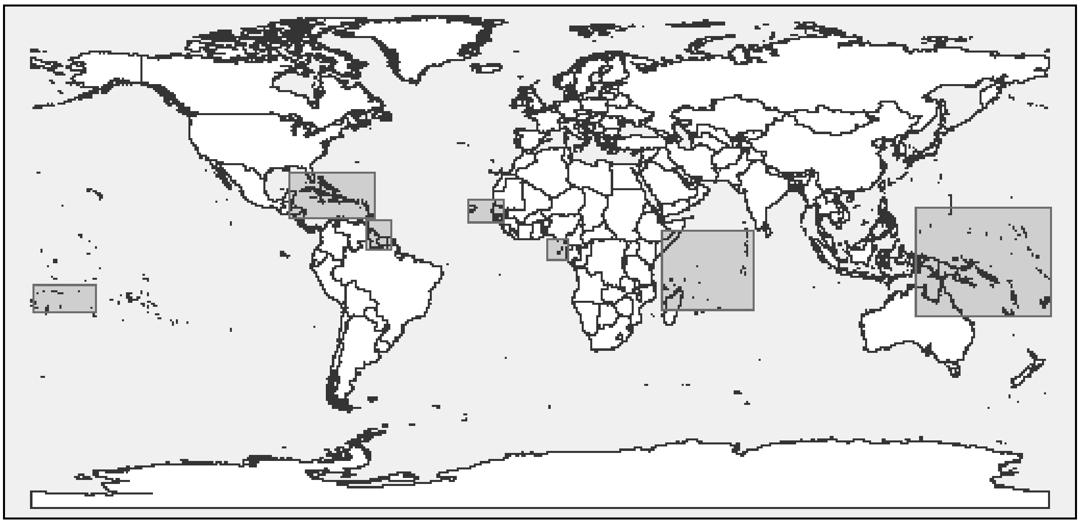

Figure 1 The geographical location (colored boxes) of SIDS around the world

The ***SIDS DOCK Support Program*** is designed to establish a necessary framework for the transformation of the energy sector in SIDS in the longer term. Within this scope, and in view of the funds available and time frame for delivery, two main outcomes are anticipated over 2011-12:

> Outcome 1: Creation of the enabling environment (e.g. legally, operationally, institutionally) to remove barriers and implement renewable energy (RE) and energy efficiency (EE) policy reforms based on international best practices, thus creating fiscal space for development and climate-resilient actions in the longer term; and
>
> Outcome 2: Implementation of projects that develop, deploy, and demonstrate RE and EE initiatives for potential scale-up through climate finance and other sources of funding.

Over the period of July to September 2011, the SIDS DOCK Implementation Modality was finalized in a series of meetings among the Partners. The ***SIDS DOCK Support Program*** is currently implemented under two existing agencies (UNDP and ESMAP/WB) in coordination with OASIS. The reason is that the Danish Government as principal donor requires a Project Management Group with existing financial and management capacity, including procurement, monitoring, and reporting procedures to manage the Danish funds for the implementation of the ***SIDS DOCK Support Program***.[2]

[1] The Conference of the Parties (COP) is the "supreme body" of the United Nations Framework Convention on Climate Change (UNFCCC), that is, its highest decision-making authority. It is an association of all the countries that are Parties to the Convention.

[2] Pacific Islands Forum Secretariat, Options Paper, *Improving Access to and Management of Climate Change Resources*, Main Report, September 2011

On December 08, 2011, the SIDS DOCK Steering Committee (composed of representatives of OASIS Member States, UNDP and ESMAP/WB) designated Belize as the Host Country for the SIDS DOCK Secretariat. On February 13, 2012, the SIDS DOCK Steering Committee held its first meeting for the year 2012 whereby during this meeting it approved a number of decisions relevant to the timely implementation of the ***SIDS DOCK Support Program***. Key decisions included the formal recording of Belize as Host Country of SIDS DOCK, and agreement for the registration of the SIDS DOCK as an international organization in keeping with Article VII of the SIDS DOCK Memorandum of Agreement (MoA), signed as of June 2012 by 30 SIDS Governments.[3]

In June 2012, the Interim SIDS DOCK Secretariat hosted at the Caribbean Community Climate Change Center (CCCCC) in Belize started its initial preparatory activities with funding from UNDP under the ***SIDS DOCK Support Program***. This funding is allocated to the development of the SIDS DOCK Platform under the ***SIDS DOCK Platform Support component***[4] and primarily focuses on the *Institutional Design and Strengthening of SIDS DOCK*.

Currently the SIDS DOCK Secretariat has four principal macro functions:

1. Assist SIDS transition to a sustainable energy sector, by increasing energy efficiency and development of renewable energy;
2. Providing a vehicle for mobilizing financial and technical resources to catalyze clean economic growth;
3. Provide SIDS with a mechanism for connecting with the global carbon market and taking advantage of the resource transfer possibilities that will be afforded; and
4. A mechanism to help SIDS generate the financial resources to invest in climate change adaptation.

As part of the Institutional Design and Strengthening of SIDS DOCK a specific need is identified to develop a *Strategic Plan to Identify, Assess and Transfer Energy Technologies that are SIDS-appropriate*. This is because SIDS DOCK is focused on developing deep expertise around specific types of low-carbon energy technologies that can be readily deployed across states, but at the same time allow close collaboration and relationship building with government officials and private sector participants in individual countries. SIDS DOCK also aims to forge alliances with major research institutions, non-profits, and private sector entities to facilitate SIDS-specific research and in-situ technology trials of specific energy technologies for future deployment.[5]

This *SIDS-appropriate Sustainable Energy Technology Assessment Report* focuses on the development of criteria for the identification, assessment, and categorization of energy technologies as SIDS-appropriate to be deployed in SIDS to achieve sustainable development. This categorization of energy technologies will allow the SIDS DOCK Secretariat and its Member States the initial prioritization and allocation of collective resources and efforts in the timely deployment or development of such technologies in SIDS considered suitable to address the energy needs.

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[3] The 30 AOSIS Member States that are Members of SIDS DOCK include, in the Pacific Ocean: Cook Islands, Federated States of Micronesia, Fiji, Independent State of Samoa, Kingdom of Tonga, Kiribati, Nauru, Republic of the Marshall Islands, Republic of Palau, Republic of Vanuatu, Solomon Islands, and Tuvalu; in the Caribbean: Antigua and Barbuda, Commonwealth of the Bahamas, Barbados, Belize, Commonwealth of Dominica, Dominican Republic, Grenada, Jamaica, Republic of Suriname, Republic of Trinidad and Tobago, St. Christopher (St. Kitts) and Nevis, St. Lucia, and St. Vincent and the Grenadines; in the Atlantic and Indian Oceans: Democratic Republic of São Tomé and Príncipe, Republic of Cape Verde, Republic of Maldives, Republic of Mauritius, and the Republic of the Seychelles.

[4] SIDS DOCK Support Program, A joint initiative of UNDP, ESMAP, and the World Bank, March 02, 2011, page 21.

[5] Terms of Reference: SIDS DOCK Support Program, Development of the SIDS DOCK Platform Component; *Development of a Strategic Plan to Identify, Assess, and Transfer Technologies that are SIDS-appropriate*, August 01, 2012.

1.2 What is SIDS DOCK?

SIDS DOCK is a SIDS-SIDS Institutional Mechanism (Specialized Fund) brought into life to facilitate the development of sustainable energy economy within small island developing states. It serves as a "docking station" through which SIDS can access global financial funds; in addition it functions as a SIDS-SIDS knowledge sharing and expertise hub on sustainable energy transition for the membership. The ultimate goal of SIDS DOCK is to assist its member states to:

1. Increase energy efficiency by 25 per cent (over a 2005 baseline);
2. Generate at least 50 per cent of their electric power from renewable resources; and
3. Decrease petroleum used for transportation by 25 per cent.

Please see Table 1 for a detailed list of SIDS DOCK members as of November 2012. All 30 SIDS DOCK member states are represented in the Alliance of Small Island Developing States (AOSIS), which is a coalition of Small Island and low-lying coastal countries that share similar development challenges and concerns about the environment, especially their vulnerability to the adverse effects of global climate change. It functions primarily as an ad hoc lobby and negotiating voice for Small Island Developing States (SIDS) within the United Nations. OASIS does not have a formal charter, regular budget or a secretariat but functions as a deliberative forum among ambassadors and UN delegations of representative countries in New York at the UN Headquarters.[6]

Table 1 Membership of SIDS DOCK (as per July 2012)

	Pacific Ocean		Caribbean
1	Cook Islands	**15**	Antigua and Barbuda
2	Fiji	**16**	Bahamas
3	Kiribati	**17**	Barbados
4	Federated States of Micronesia	**18**	Belize
5	Marshall Islands	**19**	Dominica
6	Nauru	**20**	Dominican Republic
7	Palau	**21**	Grenada
8	Samoa	**22**	Jamaica
9	Solomon Islands	**23**	St. Kitts and Nevis
10	Tonga	**24**	St. Lucia
11	Tuvalu	**25**	St. Vincent and the Grenadines
12	Vanuatu	**26**	Suriname
		27	Trinidad and Tobago
	Atlantic Ocean		**Indian Ocean**
13	Cape Verde	**28**	Maldives
14	Sao Tome and Principe	**29**	Mauritius
		30	Seychelles

Some countries have even higher ambitions, including the Republic of Maldives, which has a policy goal to become carbon neutral by 2020, and Tuvalu, with a policy goal of 100 percent electricity generated by renewables by 2020. An energy sector focused on promoting sustainable development rather than just providing energy to meet economic needs is essential to enable SIDS address critical long-term development challenges, particularly in the areas of global climate change, food security, waste management and guaranteeing availability of fresh water resources.

[6] Alliance of Small Island States (AOSIS), website: http://aosis.org/about-aosis/ (visited October 2012)

Increase of the global energy demand and environmental problems relating to fossil energy utilization are severely affecting energy security and environmental conditions on islands. An urgent demand for the use of alternative energy sources to replace the traditional fossil fuels is ahead. However, many challenges remain in place, such as the lack of proper mechanisms to identify, assess, and transfer renewable energy and energy efficiency technologies to SIDS and improve local technical capacity to operate and maintain such technology. Transition from fossil fuels to renewable energy use is a lengthy process, which requires a clear and concrete vision of this ultimate objective. By focusing specifically on defining which energy technologies are suitable to be deployed in SIDS, a narrower and concrete focus on how to prioritize energy technologies, set up development and deployment activities, and allocate the collective resources can be done more effectively to achieve the set SIDS DOCK objectives.

1.3 Scope of the Study

As mentioned above, this study focuses in particular on the development of criteria for the identification, assessment, and categorization of both supply and end-use energy technologies as SIDS-appropriate to be deployed in SIDS to achieve sustainable development. This required the creation of a new methodology to properly assess and categorize energy technologies as suitable to SIDS.[7]

The study focused primarily on assessing commercial and non-commercial renewable energy technologies (energy supply technologies) and secondly on energy efficiency appliances and devices (energy end-use technologies) and sustainable transport alternatives. The level of details was subject to the availability of publicly available information. Despite the comprehensive nature of this report, the findings presented in this report are not exhaustive or conclusive. The statistics gathered describing the conditions in each SIDS DOCK member state, were also subject to publicly available information and led to differentiated levels of statistical data quality presented.

The principal sources of information used in this report originate from websites from SIDS government ministries and agencies, local utilities, the ESMAP/World Bank, Caribbean Community Secretariat (CARICOM), the Organization of American States (OAS), the International Renewable Energy Agency (IRENA), the UN-Economic Commission for Latin America and the Caribbean (UN-ECLAC), United Nations Development Program (UNDP), the Alliance of Small Island States (AOSIS), the Asian Development Bank (ADB), the Pacific Islands Development Bank (PIDB), the Pacific Island Forum Secretariat (PIFS), the Secretariat of the Pacific Community (SPC), the Secretariat for the Pacific Regional Environmental Program (SPREP), the Caribbean Development Bank (CDB), the African Development Bank (AfDB), and other international and regional entities. The data was collected, through publications, and where possible by interviews or surveys. Additionally, all data used in tables and graphs are cited as footnote and also referenced and detailed in Annex II of this report.

1.4 Methodology

The methodology applied to execute this study is structured in eight phases and is as follows:

Phase 1 – First an explanation is provided regarding the rationale for the development of criteria and a methodology for the identification, assessment, and categorization of energy technologies as SIDS-appropriate (this is elaborated in Chapter 2).

[7] Terms of Reference: SIDS DOCK Support Program, Development of the SIDS DOCK Platform Component; *Development of a Strategic Plan to Identify, Assess, and Transfer Technologies that are SIDS-appropriate*, August 01, 2012.

Phase 2 – This is followed in Chapter 3 by a general description of the introduced "SIDS-appropriate ETA"-methodology, including the guiding principles for the creation of the methodology and explanation of all the criteria used to assess and categorize the renewable energy technologies reviewed.

Phase 3 - In order to have an initial picture of conditions in the SIDS DOCK member states, publically available data and information as the land availability, and present demographical, economical, legislative, energy sector (electricity), and renewable energy (RE) use conditions (if available), are gathered and processed in table format in Chapter 4 using the indicators described in Table 2 below. This format allows for the simple overview of the publically available data regarding SIDS and their respective energy sector information. Furthermore the gathered information allows for the identification of quantitative and qualitative differences, similarities, and conditions in each of the SIDS DOCK member states and by major SIDS regions.

Table 2 Indicators used to describe conditions in SIDS DOCK member states

Thematic area		Indicator	Description / Unit
I.	**Size**	Land availability	Total land surface area of a SIDS expressed in square kilometers
II.	**Demographics**	Population	# of inhabitants in a SIDS
		Population density	# of inhabitants per square kilometers
III.	**Economics**	GDP Nominal	This is a Gross Domestic Product that has not been adjusted for inflation
		Purchasing power parity (PPP)	This is a comparison of income among the SIDS
IV.	**Legislative**	Policy	Whether a national energy policy is in place or not in SIDS
		Regulations	Type and # of regulations in place relating to the electricity sector
		Ownership status of utility	Whether utility in SIDS is public, private or public-privately owned
		Power generation	Expressed whether self-generation is allowed or not in respective SIDS
V.	**Energy Sector**	Net energy generation and consumption	Expressed in GWhe (2009)
		Primary energy sources	Expressed qualitatively
		Average electricity tariff	Expressed in US$/kWh (by varying years)
		Energy sources in use for power generation	% of total power generation or any other unit available
		Electrification rate	% of households with access to electricity
VI.	**Renewable Energy**	Renewable energy potential	MW or any other unit available
		Primary renewable energy sources	MW or any other unit available
		Renewable energy technologies	# and type of RET used in each SIDS
		Renewable power generation	% of electricity from RETs

Furthermore a particular focus is set on assessing in more detail publically available reports and data regarding the renewable energy source (RES) potential in each respective SIDS. The RES analyzed and taken into account in this study, include main RES categories; solar, biomass, wind, hydro, geothermal and ocean energy resources and is in line with the definition of renewable energy sources in Article III of the Statutes of the International Renewable Energy Agency (presently the highest global authority regarding renewable energy development).[8]

Phase 4 – Once the main characteristics of SIDS are described and an overview of the RES potential based on publically available information is presented, this is followed by a process of literature review of the different

[8] International Renewable Energy Agency (IRENA), Statute of the International Renewable Energy Agency (IRENA), January 2009, see: http://www.irena.org/documents/uploadDocuments/Statute/IRENA_FC_Statute_signed_in_Bonn_26_01_2009_incl_declaration_on_further_authentic_versions.pdf (visited October, 2012)

renewable energy supply technologies currently commercially available and in pre-commercial stage (presented in Chapter 6). Recognizing the limitations in data availability, the energy technologies were qualitatively characterized in terms of:

a) Type of technology;

b) The economics;

c) Resource(s) conversion potential;

d) Environmental issues; and

e) Social impacts.

The characterization was limited to the availability of data and information relevant to these terms.

Phase 5 – Based on the state and RES potential in the SIDS countries (elaborated in Chapter 5) and the characterization of the energy technologies (described in Chapter 6), the renewable energy technologies (RETs) were assessed by gathering and reviewing the indicators used in the "SIDS-appropriate ETA"-method. The assessment of the RETs provides the outcomes of a qualitative judgment of the most suitable RETs (energy supply technologies) available for SIDS and the results are presented in the final section of Chapter 6.

Phase 6 – Energy Efficiency Technologies (EETs), serve as the category for all end-use energy technologies that includes among other energy efficient appliances, devices, machinery, including sustainable transport alternatives, as energy efficient or alternative transport vehicles. An analysis is performed regarding their potential costs in the context of SIDS. The results of this assessment are presented in Chapter 7.

Phase 7 – Finally, based on all the criteria, and quantitative and qualitative data presented and described through the report, the final phase entails the pre-selection of the most suitable, thus sustainable energy technologies (RETs and EETs) for each SIDS. The qualitative non-conclusive selection of the most suitable energy technologies for SIDS is presented in a table format in Chapter 8.

Phase 8 – General conclusions and recommendations are provided regarding the outcomes or findings of the report and related to the SIDS-appropriate Energy Technology Assessment method.

2. Why the focus on SIDS-appropriate Sustainable Energy Technologies

2.1 SIDS Sustainable Development Challenges

In recent decades SIDS are confronted with critical challenges impacting their ability to achieve sustainable development. With increasing frequency of financial, energy and food crises, the economic competitiveness and resilience of SIDS are weakened and it is increasingly becoming difficult for SIDS to remain relevant in the globalized economy. SIDS leaders recognize this reality and are therefore increasingly aiming to become less reliant on a single or limited economic sector by diversifying and assessing innovative and efficient practices, and reducing SIDS dependency on high foreign exchange expenditures as imported energy, to become more resilient to external shocks.

All SIDS around the globe have a clear commonality, which is an absolute limit in available space. This limitation of space determines the maximal carrying capacity of an island community to develop, prosper and sustain a good quality of life. In other words, the continuous population growth increases the pressure on the islands ecosystem to supply the island community with the resources and services necessary to satisfy the present and future needs of the community. These critical resources for sustaining such island communities are finite, as among other, (1) *land availability* – critical for housing, productive economic activities, infrastructure, nature conservation, recreation, and other competing land uses; (2) *availability of fresh water* – critical for drinking water supply and other productive uses; and (3) *availability of fresh or healthy food* – critical to the health and wellbeing of island communities.

Next to the finite resources in island nations, SIDS have other general characteristics distinguishing them from larger, continental and developed industrialized nations in the world. Please see Table 3 for a brief summary of such general characteristics.

Table 3 General characteristics of SIDS around the globe[9,10]

Category	Description
Small size	There are many disadvantages that derive from *small size*, including a narrow range of resources, which forces undue specialization; excessive dependence on international trade and hence vulnerability to global developments; high population density, which increases the pressure on already limited resources as high competition between land uses and intensity of land uses; high degree of interdependence between human and environmental systems, overuse of resources and premature depletion; relatively small watersheds and threatened supplies of fresh water; costly public administration and infrastructure, including transportation and communication; and limited institutional capacities and domestic markets and limited export volumes, spatial concentration of productive assets which are too small to achieve economies of scale.
Insularity and remoteness	High external transport costs, time delays and high costs in accessing external goods, delays and reduced quality in information flows, geopolitically weakened, economically disadvantaged, and reduced competitiveness.
Vulnerability to natural disasters	SIDS are located in among the most vulnerable regions in the world in relation to the intensity and frequency of natural and environmental disasters and their increasing impact, and face disproportionately high economic, social and environmental risks and consequences.
Fragile Ecosystems	Small exposed interiors, large stretches of low-lying coastal zones, and lack or limited natural resources, adverse effects of climate change and sea-level rise present significant risks to the sustainable development of SIDS, and the long-term effects of climate change may threaten the very existence and viability of some SIDS.

[9] De Comarmond, A., and Payet, R. *Small Island Developing States: Incubators of Innovative Adaptation and Sustainable Technologies?*, included in publication, *Coastal Zone and Climate Change*, edited by Michel, D., and Pandya, A.,The Henry L. Stimson Center, Washington, D.C., USA, 2010. See: http://www.stimson.org/images/uploads/research-pdfs/Alain.pdf (visited September, 2012)

[10] About SIDS, SIDS-A Special Case, SIDSnet website: http://www.sidsnet.org/about-sids (visited October, 2012)

Demographic factors	Limited human resource base, small population, rapid population changes and increases in population density, single urban centers, population concentrated on coastal zone, dis-economies of scale leading to high per capita costs for infrastructure and services.
Economic factors	Small economies, dependence on external finance, small internal market, high dependence on natural resources, highly specialized in a few major economic sectors (tourism, agriculture, and financial services), limited production or manufacturing capacity.

This non-exhausted list of characteristics accentuates the uniqueness of challenges facing small island developing countries in general and highlights the need to have a clear picture of the characteristics of each respective SIDS and the need to address the development needs of SIDS in a non-conventional manner.[11]

In addition Climate Change (CC) is considered among one of the most critical impediments to the long term well-being and in some cases even the survival of island communities since CC is increasingly impacting the environment and carrying capacity of SIDS. As SIDS population, agricultural land, and infrastructure tend to be concentrated in the coastal zone, any rise in sea level will have significant and profound effects on their economies and living conditions. Inundation of outlying islands and loss of land above the high-tide mark may result in loss of exclusive economic rights over extensive areas (e.g. for access to fishing areas and use of natural resources) and in the destruction of existing economic infrastructure as well as of existing human settlements. Furthermore, it may affect vegetation and saline intrusion that may adversely affect freshwater resources.

Certain physical and socioeconomic characteristics common to SIDS tend to intensify their vulnerability to climate change. As mentioned above, the high ratio of coast line to land area, high population density, and minimal elevation above sea level puts large parts of the population at risk from storms, flooding and erosion. Scarce freshwater supplies are at risk from even relatively small shifts in precipitation patterns or sea level. In addition, SIDS often depend on coastal ecosystems, including mangroves and coral reefs, for household income, revenue from tourism, and food. These ecosystems are threatened by rising sea surface temperatures, ocean acidification, and increased storm intensity as a result of climate change.

The challenge posed by climate change on development is well documented[12]. The disproportionate impact on SIDS, as the least contributors to the phenomenon emitting very low quantity of greenhouse gas (GHG), estimated at less than 0.05% compared with global emissions[13], is often contrasted with their comparatively limited capacity to respond to the climatic challenge.

Evidence from the Intergovernmental Panel on Climate Change (IPCC), points to higher average sea level rise (SLR) estimates than those previously reported[14]. Other threats identified include changes in precipitation and sea-surface temperatures, which coupled with the climatic characteristics of SIDS (e.g., El Niño, the monsoons, tropical cyclones and hurricanes) expose them to life-threatening circumstances. The impacts of these threats vary across regions. For instance, damage to coastal zones is a common denominator, with the consequent impact on the main economic infrastructure of SIDS (such as tourism) due to rising sea levels. The IPCC reports that global average sea-level has risen 1.3-2.3 mm per year over the period 1961 to 2003 and 2.4-3.8 mm/yr from 1993 to 2003. However, regional considerations are critical when it comes to SIDS.

[11] About SIDS, SIDS-A Special Case, SIDSnet website: http://www.sidsnet.org/about-sids (visited October, 2012)
[12] UNDP, Fighting Climate Change: Human Solidarity in a Divided World, Human Development Report 2007/2008, United Nations Development Programme, http://hdr.undp.org/en/reports/global/hdr2007-8/ (visited October, 2012)
[13] AOSIS, 'Frequently Asked Questions About Small Island Developing States Sustainable Energy Initiative – SIDS DOCK', Alliance of Small Island States, 2011. Retrieved from: http://aosis.info/sids-dock
[14] IPCC, Costal Zones and Small Islands – Working Group Number 2. Retrieved from: www.ipcc-wg2.gov/AR4/website/16.pdf (visited October, 2012)

For example, trends in the Maldives point to 4 mm/yr sea-level rises. Meanwhile, local variations can be found in the island of Trinidad –where indications in the north point to 1 mm/yr rise, in contrast to an estimated 4 mm/yr in the southern part of the island (UN-OHRLLS, 2009).[15] Overall, these impacts have significant social and economic implications.

Other climate change impacts include the destruction of infrastructure and development gains due to stronger tropical cyclones and hurricanes, such as those in 2004 (Grenada, Haiti and Niue), 2005 (the Cook Islands) and 2008 (Fiji and Haiti). For instance, Hurricane Ivan damaged 90% of the housing stock of the island of Grenada, with an estimated impact of US$527 million (or 38% of the country's GDP).

Finally, adverse impacts on drinking water and agricultural production are expected due to saline intrusion on coastal aquifers and the destruction of coral reefs and fishery habitats due to temperature rises and increased ocean acidification. Therefore, the diversity of impacts across SIDS needs to be considered at all times when developing a development assistance strategy for SIDS.

2.2 Energy for Sustainable Development

The energy demand in SIDS is mainly energy for power generation and mobility, these are presently generally satisfied through the import of fossil fuels from the international market that is converted into electricity and transmitted and/or distributed to the consumers of the electricity. Part of the imported fuel is centrally stored and then further distributed through retail gasoline stations to supply gasoline or diesel for vehicles used on the islands, while other fractions of this fuel is used for maritime transportation (including boats, ferries, cruise ships, etc.). Remaining energy uses include using imported gas for cooking, industrial uses and to a smaller extent for power generation and use in vehicles. See Figure 2 for a simplified and generalized overview of the energy lifecycle in SIDS.

[15] UN-OHRLLS, The Impact of Climate Change on the Development Prospects of the Least Developed Countries and Small Island Developing States, United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States, 2009. Retrieved from: http://www.unohrlls.org/UserFiles/File/LDC%20Documents/The%20impact%20of%20CC%20on%20LDCs%20and%20SIDS%20for%20web.pdf (visited October, 2012)

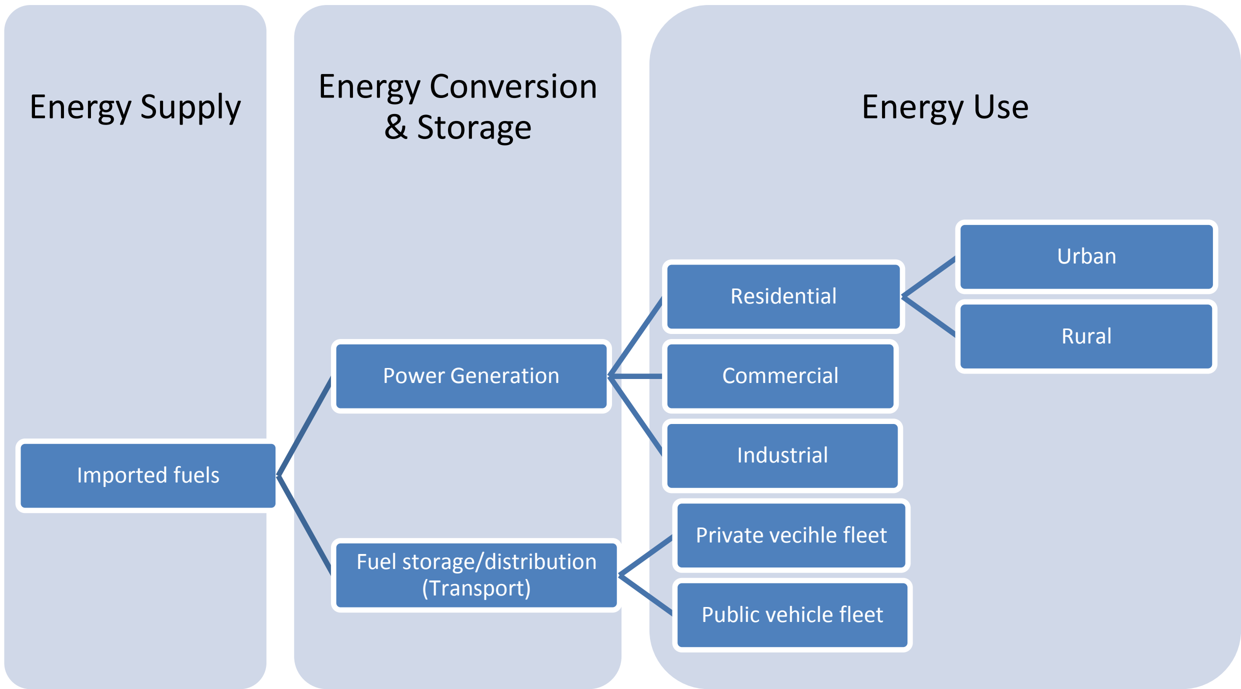

Figure 2 Simplified scheme of the energy life cycle in SIDS

The larger islands, archipelagos, and continental low-lying nations have an additional factor which is communities living further inland, in remote atolls, or at a critical distance from the urban centers that are not electrified and deal with very high cost of fuel import and power generation. In these cases alternative fuel supply options are used as transporting diesel in smaller quantities via boat or airplane to isolated areas and convert this into power using stand-alone diesel-fueled power generation and supplying users or a handful of public services buildings with electricity directly or via mini-grid infrastructure. Generally rural electrification with renewable energy technologies in these areas are to a lesser extent available or in place.

The critical problem of the current generalized energy sector outline in SIDS is that this energy life cycle is highly (>95%) dependent on imported fossil fuels that are increasingly becoming expensive and lead to (1) high cost of electricity rates, and (2) high gasoline and diesel prices for the consumers. This impacts the ability of households to afford basic energy services and challenge commercial users to remain competitive. Furthermore most of the conventional energy technologies lead to unintended environmental and socio-economic impacts as emitting GHGs contributing to climate change, generating public health issues or nuisance, or lead to unsustainable use of other natural resources (as fresh water, available space, and other resources) essential to the sustainable development of SIDS. The need to invest in storage infrastructure to store fuel (gasoline, diesel and jet fuel) to guarantee the continued supply of energy, because of the remoteness of many SIDS, represents an additional cost and land use competing challenge.

All the above, describe the different set of issues that come about with energy sector development and planning in SIDS. The initial understanding of the conditions, dynamics and performance of the energy sector in each respective SIDS DOCK member state using clear indicators is essential to determine the adequate interventions to facilitate the transition towards a low-carbon economic and sustainable development of SIDS.

Yet as of 2012 the majority of SIDS are still net energy importers, highly dependent on imported fossil fuels for power generation and transportation, and are dealing with steadily increasing electricity and fuel prices that challenge the economic development.

It is estimated that SIDS annually consume more than 250 million barrels of petroleum fuel to meet their energy needs. Over 90% of the commercial and industrial demand of SIDS is dependent on fossil-fuel imports. In many cases, electricity costs are reportedly as the highest in the world.[16] Therefore, there is greater realization amongst SIDS that a cleaner energy-supply mix, with increased renewable resource use, would result in significant savings on fuel imports and better standards of life in a less polluted environment. Recognizing energy is a key factor to achieve sustainable development is important to determine suitable instruments to assist SIDS in their endeavor to transition to low-carbon economies.

2.3 Technology as an instrument to drive sustainable energy development in SIDS

Technology innovation and in particular technology breakthroughs (e.g. the internet) have over time led to drastic restructuring of economies and are critical driving forces for development. Therefore to achieve sustainable development in SIDS, (1) the access to and use of renewable energy technologies (RETs) for the production of base load and peak electric power from sources other than imported fossil fuels and (2) the efficient use of power through energy efficient end-use technologies (EETs) in the production of goods and services, and (3) the introduction of alternative vehicles and new modalities of mobilization to achieve sustainable transportation, all are key to transition towards low carbon economies. Not all energy supply and end-use technologies are suitable to the conditions and needs in SIDS. Therefore the concept of SIDS-appropriate sustainable energy technologies is introduced, which enables SIDS to categorize energy technologies and prioritize energy technologies that are technically feasible, consistent with SIDS development objectives, and that are better tailored to the conditions and needs in island communities.

This definition is in line with the principles of sustainable development, where the aim is to promote the deployment of energy technologies that enable island communities to continuously find a proper balance between social and economic priorities while protecting the environment to satisfy the current and future energy needs of the community[17].

SIDS DOCK member states acknowledge the need and aim to use the available indigenous natural resources to develop a sustainable energy sector, but are confronted with multiple barriers to the *access to* and *deployment of* suitable sustainable energy technologies to address specific SIDS energy needs and secure reliable, affordable and clean energy. This assessment therefore focuses on developing criteria and a methodology for the *identification, assessment, and categorization of SIDS-appropriate energy technologies* to enable the SIDS DOCK Secretariat and its Member States to allocate efforts and resources to effectively facilitate the *transfer* of such energy technologies to make them increasingly available in SIDS to address the energy needs to transition towards low carbon economies and achieve sustainable development.

[16] Ibid. 26
[17] World Commission on Environment and Development (WCED). Our common future. Oxford: Oxford University Press, 1987 p. 43

3. Principles of a SIDS-appropriate technology assessment and categorization method

Energy technology assessment for sustainability and technology transfer is inherently a complex and dynamic process that requires a holistic and interdisciplinary approach. In the SIDS context, specifically, there is no formal and coherent approach to energy technology transfer from a sustainability perspective. Without a formal comprehensive or well integrated technology assessment approach to evaluate the suitability and sustainability of each technology, policy-makers, energy planners, and senior decision-makers are faced with difficulty in terms of making reasoned decisions about the appropriate technology options to transfer and deploy in SIDS.

Since, there is no existence of a formally peer-reviewed and internationally recognized and applied methodology regarding the selection of *SIDS-appropriate sustainable energy technologies*, a new methodology is introduced in this report. This Chapter is dedicated to the clarification of terms used, and the guiding principles on which this methodology is based.

3.1 Definition of SIDS-appropriate sustainable energy technologies

First of all, the concept of *SIDS-appropriate sustainable energy technologies* is introduced, which enables SIDS to categorize energy technologies and prioritize energy technologies that are (1) technically feasible, (2) consistent with sustainable development objectives, and (3) that are better tailored to the conditions and needs in island communities.

Guiding Principle #1:

(1) An energy technology is considered ***technically feasible***:

   a. Above all, when a primary *renewable energy resource* is positively identified in the *territory* of a particular SIDS and the technology's basic intentional design is to convert that particular primary energy source into an energy carrier or energy service; and

   b. The energy technology has passed the basic stages of its development, that includes the Research, Development, Demonstration, and Deployment stages to determine whether the technology is readily deployable.

This definition allows for the evaluator (SIDS DOCK Secretariat) to follow a rationale, whereby first of all clarity is required regarding the availability of a particular type of renewable energy resource (wind, solar, biomass, geothermal, etc.) that can be determined by performing RES assessments. Since SIDS have a clear delineation of the countries' sovereign territory and jurisdiction (where limits are determined by the Exclusive Economic Zone – EEZ), the RES has to be positively identified within the territory of the SIDS to guarantee the energy technology to be applied is subject to the prevailing legal and regulatory regime of the SIDS in question. Furthermore an understanding of the basic design, function or energy conversion process is needed to confirm that the identified primary renewable energy source can indeed be converted into an energy carrier or energy service with that particular technology.

In principle, technologies that are in the very early stages of commercialization, or that require very large, upfront capital investments or substantial outside expertise to operate—are likely to face additional deployment hurdles in SIDS. Therefore it is important to determine in what stage of technology development a particular energy technology is, to be able to assess the potential additional challenges and/or efforts needed to making the technology fully technically operational and deployable to be used (additional info regarding for instance clarity on operations and maintenance (O&M) standards and certifications, and a certain level of technology warranty by the technology provider could be requested).

Guiding Principle #2:

(2) An energy technology is consistent with the concept of ***sustainable development***:

a. When the technology enables island communities to continuously find a proper balance between social and economic priorities while protecting the environment to satisfy the current and future energy needs of the community; and

b. When the technology enables the transition towards a low-carbon economy to contribute to the mitigation of climate change which represents one of SIDS' greatest threats to their capacity to achieve sustainable development.

An energy technology cannot during its production and/or installation, and use (life cycle); lead to public health problems (as being a source of radio-active or hazardous waste), lead to increased risks and accidents on the job, or lead to the displacement of communities without proper mitigation efforts and/or compensation that impact the physical environment, and community both socially and economically. The energy technology needs to be as environmentally benign as possible, in other words as harmless to the environment as possible while enabling the creation of job opportunities, diversification of the economy, promote continuous innovation. And lastly, energy technologies may or may not emit a limited amount of Greenhouse Gases (GHGs) during their lifecycle (thus during their production and use), to contribute to the mitigation of climate change.

Guiding Principle #3:

(3) An energy technology is better tailored to SIDS ***conditions*** and ***needs***:

a. When the technology is applicable to conform to a SIDS *carrying capacity* (SIDS' physical limits and conditions), and is *socially and culturally accepted* by the island community; and

b. When the technology contributes to offsetting SIDS' dependency on imported fossil fuels to guarantee reliable and affordable power generation and transport.

The carrying capacity of SIDS is the maximum capacity (mainly determined by available space) of an island to support a community indefinitely by the island's ecosystem without destroying this same ecosystem. Especially in small island states (where space is very valuable), an energy technology should not demand significant or critical land or space that competes with more critical land uses for the community, nor lead to the destruction of sensitive ecosystems that provide essential ecosystem services to the community (as provision of food or fresh water). At the same time, there should be a general acceptance of an energy technology being introduced in the community. This is normally guaranteed by the early and proper involvement of key stakeholders in a SIDS community. Although at this stage it is not viable to gather SIDS DOCK member state's communities' input regarding their respective perspectives on energy technologies, via the literature and past project experiences one can gather general indications of the social or cultural acceptance of certain technologies (this social/cultural acceptance of energy technologies is generally driven by the access to information, the awareness level, and exercised religions in the community).

Furthermore island communities <u>need</u> reliable, affordable and clean energy services. Reliability is in this report determined by whether the technology is always dispatchable as base load, whether the technology and energy source are, even though intermittent, predictable as the daily solar irradiation cycle, and/or as a portfolio of energy technologies guarantee 100% availability of power in a year. Furthermore one of the most critical challenges to the sustainable development of SIDS is their dependency on imported fossil fuels for power generation and transportation. With average oil prices ranging in the US$90-100/barrel over the past 2-3 years, for most SIDS energy is one of/or the highest foreign exchange expenditure, impacting the national budgets and fiscal balance without any foreseeable significant decrease in oil prices. This means that energy technologies have to be able to offset the dependence on imported fossil fuels in a cost-effective manner which is mainly determined by the capital investment/turn-key investment cost of the technology, the energy conversion efficiency or yield, and the levelized cost of electricity. Cost-effective energy technologies will enable SIDS to reduce energy service costs as electricity rates or transportation fuel retail prices to make energy affordable to the SIDS community.

3.2 The importance of RE resource assessment for determining suitable RETs for SIDS

Among the most critical energy sector indicators to determine the applicability of SIDS-appropriate energy technologies is the RES potential in each respective SIDS DOCK member state. In the literature, there are various studies that assess the potential of the RES.[18,19,20] However, the data available is generally incomplete and merely focused on the regional potential. Furthermore there are critical issues with the type and discrepancies of energy resource assessments performed and publically available.

Some studies at the global or regional level show that for each of the energy source types, the potential availability is significant and exceeds the present electricity consumption and demand. Most resource assessment studies do not include the production cost, or the economic potential of converting and using renewable energy resources. Finally, the studies differ according to their regional aggregation and approach. Therefore no proper comparative analysis is possible between the categories of renewable energy source potentials at similar regional aggregation. Nevertheless in this study the intention is to highlight the renewable energy source availability (based on publically available data and information) for the SIDS DOCK membership.

In order to improve the assessment, collection, and presentation of this critical input for the future identification and assessment of SIDS-appropriate energy technologies, the SIDS DOCK Secretariat will need to start with the proper definition of the ***Renewable Energy Source (RES) Potential*** in SIDS. The main characteristic of RES is that they can be extracted in a 'renewable' manner. Wind, solar, ocean, and biomass energy sources are all derived from the irradiation from the sun which, when considered in timeframes of centuries, is a constant flow of energy to the earth. Additionally, geothermal energy sources originate from the exothermic process (release of heat) of radioactive decay of minerals in the inner segments of the earth that once transported to the surface (via a medium as water) and can be converted into power.

The presence and potential availability of wind, solar, geothermal, ocean and biomass energy sources over time and between regions is therefore relatively constant, but their extraction and use is essentially determined by geographical developments (e.g. land-use demands), by technical developments (e.g.

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[18] Johansson, T.B., et al., The Potential of Renewable Energy, Thematic Background Paper, Secretariat of the International Conference for Renewable Energies, January 2004, see: http://www.renewables2004.de/doc/DocCenter/TBP10-potentials.pdf (visited September, 2012)

[19] Garcia, A. and Meisen, P., Renewable Energy Potential of Small Island States, Global Energy Network Institute (GENI), August 2008, http://www.geni.org/globalenergy/library/technical-articles/generation/small-island-nations/renewable-energy-potential-of-small-island-states/Renewable%20Energy%20Potential%20of%20Small%20Island%20States1.pdf (visited September, 2012)

[20] Hoogwijk, M., and Graus, W., Global Potential of Renewable Energy Sources: A Literature Assessment, Background Report, REN21 – Renewable Energy Policy Network for the 21st century, Ecofys, see: http://www.ren21.net/Portals/97/documents/Publications/REN21_RE_Potentials_and_Cost_Background_document.pdf (Visited September, 2012)

introduction of innovative conversion technologies), economic developments (e.g. technology and labor cost variations), or implementation constraints (e.g. inadequate legislations). Thus when studying the potential of RES, aspects like demographic, geographical, technical, and economic developments need to be taken into consideration. Unfortunately past resource assessments have not been consistent in their scope and incorporation of such factors. As a result, over the past decades different types of energy resource potential assessments have been performed and methodologies developed. These assessments have been categorized by Slade R. (2010)[21] and adapted to all RESs[22] and are as follows:

- The **theoretical** potential is the theoretical limit of the primary energy resource. For solar driven energy sources, the theoretical potential is determined by the solar energy input that is converted into useful energy through the different sources available (e.g. being wind, ocean or biomass). For geothermal energy, the theoretical energy resource potential is determined by the geographical location and presence of tectonic breaks (e.g. in volcanic regions).
- The **geographical** potential is the theoretical potential reduced by the areas with conditions where energy sources are considered available and suitable for extraction and use.
- The **technical** potential is the geographical potential reduced by the losses of the conversion of the primary energy to secondary energy sources or carriers.
- The **economic** potential is the technical potential derived at cost levels that are competitive with alternative energy applications.
- The **implementation** potential is the total amount of the technical potential that is implemented in the energy system. Subsidies and other policy incentives can give an extra push to the implementation potential, but social barriers like environmental nuisance (e.g. noxious odor) can reduce the implementation potential. The implementation potential can be both higher and lower than the economic potential, but can never exceed the technical potential.

World Bank assessments[23,24] and European Commission funded projects as RECIPES[25] have attempted to indicate the potential for some RES in SIDS and developing countries. However, these studies do not elaborate on the used methodology, less on the definition of the type of potential estimated and assumed energy conversion performance dependent on technology used. These kind of assessments unfortunately instead of supporting the process of RETs transfer lead to the promotion of uncertainty and with limited or no clear clarification of uncertainty in data used and guidelines about how to determine the "real" renewable energy source potential for SIDS.

Assessing the RES potential in each respective SIDS DOCK member, in line with the categories described above, will bring about more insight regarding the wider renewable energy resource base availability among the SIDS DOCK membership and factors that influence the practical ability to extract and convert the

[21] Slade R. et al., The UK bio-energy resource base to 2050: estimates, assumptions, and uncertainties Working Paper, 2010. Retrieved from: www.ukerc.ac.uk/support/tiki-download_file.php?fileId=727 (Visited October, 2012)
[22] Adapted by the authors of this report
[23] Caribbean Regional Electricity Generation, Interconnection, and Fuels Supply Strategy, World Bank, 2010. Retrieved from: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2011/02/08/000112742_20110208142646/Rendered/PDF/594850Final0Report.pdf (Visited October, 2012)
[24] Caribbean Regional Electricity Supply Options, World Bank, 2011 Retrieved from: https://openknowledge.worldbank.org/bitstream/handle/10986/2738/594590ESW0WHIT1icity0Supply0Options.pdf?sequence=1.(Visited October, 2012)
[25] RECIPES, Renewable Potential, Country Report, 2005. Retrieved from: http://www.energyrecipes.org/reports/reports/061127%20Recipes%20-%20Pacific%20Islands%20RE%20potential%20report.pdf (Visited October, 2012)

renewable energy sources into productive uses or energy carriers. This enables the SIDS DOCK Secretariat and member states as a first critical step to identify energy technologies that are theoretically capable of converting the identified RES. In addition, the initial baseline RES assessments will enable the SIDS DOCK Secretariat and member states to determine the size of the potential renewable energy market and develop the reference conditions for assessing progress.

More importantly, the RES potential assessments will provide indications of the market size, the theoretical volume, capacity or density of energy yields; if or when and where suitable energy conversion technologies can be used. This opens the opportunity to establish short, medium and long term targets. SIDS DOCK will be able to determine on short term the use of suitable commercial energy technologies, while investing in research, development, and deployment (RD&D) of pre-commercial energy technologies for their timely introduction and use to further extract and convert the available RES potential.

Renewable energy resources are so various and disperse in the major SIDS regions that without an accurate, per country high resolution assessment of the RES potential based on all the categories described above, the *deployment and transfer* of RETs will continue to be a difficult challenge to overcome. In general and up to now the level of assessments performed regarding the RES potential in SIDS is poor.

But during the development of this report, as of November 2012, the International Renewable Energy Agency (IRENA) launched its Renewable Energy Potential Studies database.[26] This is the first global initiative of its kind with specific focus on gathering studies that assess the RES potential in countries, including SIDS. However, some of the studies gathered in this database tend not to be comprehensive assessments or cover all of the RES potential categories for SIDS. But this new initiative could function as a suitable platform for SIDS DOCK to build further on and exchange data with IRENA and making sure the data and methods used are consistent.

Finally, it is very difficult to promote *RE technologies transfer* that are based on unreliable and unsubstantiated data regarding RES potentials. Yet, since one of the goals of this report is to showcase the current energy sector conditions based on available information, a recollection of publically available RES potential data and results from previous studies is summarized and presented. Please note that the quality of the information is poor and inaccurate and therefore it is recommended to perform further and targeted RES assessments in SIDS complying with a commonly agreed methodology to properly access primary energy resource data, analyze and present the information. Furthermore, please note that the execution and/or detailed analysis of RES potential in SIDS DOCK member states is beyond the scope of this study.

[26] International Renewable Energy Agency (IRENA), Studies on Renewable Energy Potential, website: http://www.irena.org/potential_studies/index.aspx (visited November, 2012)

4. Criteria and method for the selection of SIDS-appropriate Energy Technologies

Since, there is no existence of a formally peer-reviewed and internationally recognized and applied methodology regarding the selection of SIDS-appropriate sustainable energy technologies, a new methodology is introduced in this Chapter.

The "SIDS-appropriate energy technology" assessment method (SIDS-appropriate ETA) is a modified, extended, and simplified version of the "5E" methodology.[27] Originally, the "5E" assessment approach was developed and used to assess the principal technologies for biomass-to-energy conversion based on the following criteria: technology evaluation (E1); energy efficiency (E2); environmental impacts (E3); economic viability (E4); and socio-political and human resource effectiveness (E5).[28] The 5E assessment is designed to assist in:

- Determining the suitability of biomass technologies for the conversion of biomass to electricity or fuel and other forms of energy;
- Comparing the range of available and prospective technology options for obtaining transportation fuels, electricity and other forms of energy and bi-products from the resources; and
- Estimating the potential for the technologies to enter and gain acceptance by stakeholders and the general public, and contribute to energy supplies.

4.1 Description of the "SIDS-appropriate ETA" Methodology

The SIDS-appropriate ETA method entails indicators to evaluate and categorize the RETs that are (1) technically feasible, (2) consistent with sustainable development objectives, and (3) that are better tailored to the conditions and needs in island communities. This objective is in line with the definition of *SIDS-appropriate sustainable energy technologies*.

Thus in this report we present a set of sustainability-related indicators important to categorize energy technologies as SIDS-appropriate sustainable energy technologies to enable the sustainable energy sector development in SIDS. These indicators were also developed or selected with the intention of describing the three pillars of sustainable development: the economic, environmental and social dimensions in the context of RETs for SIDS.

Due to the lack of availability of data (in particular quantitative data) and information, the indicators used for this SIDS-appropriate ETA methodology are defined in a simple and pragmatic way. The purpose of interpreting and using the indicators from a qualitative perspective in this report is to gather an initial idea of the suitability of this method to assess and categorize energy technologies as *SIDS-appropriate sustainable energy technologies*. It is anticipated that once more quantitative data becomes available; the same indicators in this SIDS-appropriate ETA methodology could be used. With a greater degree of validated and quantitative data more detailed and comprehensive information may be gathered to measure the indicators that contribute to the suitability and credibility of the SIDS-appropriate ETA methodology.

Despite the current qualitative nature of the SIDS-appropriate ETA methodology, the indicators are useful to determine the initial scope of technologies appropriate to SIDS which can help policy-makers and other key

[27] Schuetzle, D. and Greg Tamblyn, An Assessment of Biomass Conversion Technologies and Recommendations in Support of an Integrated Thermochemical Refinery Approach for the Production of Energy and Fuels from Rice Harvest Waste, DOE Report #DE-FC36-03G013071, Golden, CO.
[28] Ibid. 27

stakeholders in the preparation of an implementation plan to transfer, develop and deploy these technologies.

How indicators were developed and selected

To develop a holistic set of science-based and technically sound indicators, these were categorized in three sub-groups, namely (1) Environment, (2) Social, and (3) Economic. In this regard, for the development of the indicators the guiding principles regarding *SIDS-appropriate sustainable energy technologies* described in Chapter 3 were taken into account. Among these guiding principles reference is made to the need of the energy technologies to be consistent with the SIDS development objectives. Therefore use is made of existing guidance documents on sustainable development as discussed in the global community, especially taking into account the Millennium Development Goals (MDGs), the Commission on Sustainable Development (CSD), Agenda 21, and more recently the Sustainable Energy for All initiative launched by the UN. The latter has specific goals for energy access and energy security, while the MDGs provide concrete benchmarks in the context of sustainable development in its many dimensions, including issues as poverty. The objective is to make sure the selected or categorized energy technologies reviewed contribute to the international treaties and SIDS specific development objectives as promoting social development like poverty reduction, health or gender quality.

Finally, the selection of the indicators was based on their (a) relevance, (b) practicality, and (c) technical data quality. Additionally, the geographic scale of the SIDS had to be considered as to whether the full set of indicators was representative for all SIDS and sufficiently comprehensive while still allowing the process to be “practical”.

The criteria for selecting the indicators are set out below:

a. **Relevance**: An indicator must be relevant and allow the evaluator to describe as clear and detailed as possible the components and impacts of the technology assessed, also it must provide in a simple but effective manner some level of guidance to policy makers whether the technology is in line with the definition of *SIDS-appropriate sustainable energy technologies*. Relevance of the indicator is determined by how well-suited the indicator is to describe (quality) or measure (quantity) the impacts of the technology reviewed. The degree of relevance will always differ by region or location; this is why various indicators were selected in order to capture differences among the SIDS. Yet all indicators selected are applicable to all sources of RE that imply the wide range of RETs available today.

b. **Practicality**: The indicators used should allow the evaluator to gather information and assess the technology in a simple but effective manner. First a proper understanding of the goal of the methodology proposed in this report is required, which is to determine which technology can be categorized as *SIDS-appropriate sustainable energy technology*. Then the ability to evaluate the performance, quality and impacts related to a specific RET needs to be viable. In other words, the practicality depends on data availability and the ability to collect the primary data. But also whether the indicator is simple enough to make the process of data gathering less burdensome. In case of lack of available quantitative data, some indicators should not be used until new data is available. In the future, practicality of indicators will be mandated as the degree of access to reliable numerical data increases.

c. **Technical data quality**: A proper description and assessment of a technology and its characteristics are crucial to guarantee the transparency and validity of the assessment method. This validity or credibility is warranted by making sure the primary data or info used to measure the indicators originates from technical reports from reliable sources. This is a crucial element of this assessment method to prevent biased opinions or judgments that could negatively affect one technology over others and limit the ability of the evaluator to perform a proper comparative analysis. Peer reviewed reports and assessments, based on formally recognized scientific methodological approaches or industry standards, are crucial in this context since the evaluator will not be in a position to attest to the quality of the data gathered from public sources.

4.2 Indicators used in the "SIDS-appropriate ETA"-method

In this section each indicator is defined and its relationship to the goal of assessing and categorizing energy technologies as *SIDS-appropriate sustainable energy technologies* explained.

1. RES potential by technology

The identification and confirmation of RESs in the sovereign territory of SIDS is an important starting point. It allows for the establishment of a baseline to be able to perform an initial pre-selection of applicable RETs.

The rationale is that without the presence of a resource, as rivers for hydropower production or an estuary for tidal power production, some technologies can be discarded at once due to the physical characteristics of particular SIDS before further review and assessment. In addition even when a RES is positively identified in a SIDS territory, this RES potential may need to be further assessed and confirmed for each respective SIDS. Another important feature is whether there is sufficient sustained supply or consistency to guarantee the RES availability for future technology capacity expansion. An excellent situation is achieved when a RES potential is confirmed to be widely available and constant, and that its use potential is not limited by the availability of the RES.

Unfortunately because of the lack of availability of data, it is at this stage not possible to assess the RES quality to confirm the scope of RES availability and constancy in supply for further capacity expansion to address future energy needs of each respective SIDS. This will require more detailed demand and supply forecast studies per each respective SIDS, incorporating RES quality and supply capacity in the analysis. Nevertheless qualitative judgment is provided in this report regarding RES availability and consistency in supply for future use.

The evaluation of whether the RES potential has been properly assessed and confirmed falls also beyond the scope of this study since a RES potential within the territory of a SIDS requires on-site assessments and has to comply with the international scientific methodological approaches and industry standards. Nevertheless qualitative judgment is provided by making sure the data used in this evaluation originates from peer-reviewed reports and assessments.

Thus the information evaluated in this report is to positively confirm the presence of a renewable energy source (RES) and the available technological capability to convert this RES into an energy service or energy carrier. In addition qualitative judgment is provided in this report regarding RES availability and consistency in supply for future use. The categories used for evaluating the **RES potential** indicator are:

Table 4 Indicator 1: RES potential by technology

Category	Description
High	The RES is positively identified, and is considered widely available and constant
Medium	The RES is positively identified, and is considered available but with a pre-identified RES availability limit in the long term
Low	The RES is positively identified, and is considered sufficient but limited in availability
Not available	The RES is not sufficient and/or no further resource data is available

The **RES Potential** indicator allows in an early stage for the narrowing down of the scope of viable or applicable RETs in each respective SIDS DOCK member state territory determined by the physical conditions in each SIDS. It also complements the required information about an assessed energy technology regarding its compliance to Guiding Principle #1 stating that an energy technology needs to be *technically feasible* and Guiding Principle #3 regarding suitability of energy technologies to the *conditions* and *needs* of SIDS (see Section 3.1).

The results of the analysis regarding this indicator are presented separately in Chapter 5 as part of the general characteristics of SIDS DOCK members and provide an initial description in which SIDS certain RETs are discarded at an early stage.

2a. Technology Evaluation

This indicator is used to evaluate the state or progress of each technology by identifying its technological development. The validation of each stage as part of the technology development process is necessary to ensure the long-term success of deployment and application of the technology. The validation stages are:

Research – Laboratory studies have been successfully carried out using bench-scale experiments to validate key chemical and physical concepts, principles and processes. Computer models have been used to analyze and validate the technology. The research has been documented in patents and/or publications in peer-reviewed journals.

Development – All units and mechanical/chemical/physical processes of the RETs have been validated. Accurate energy balance measurements for each process unit have been made.

Demonstration – The objective of the demonstration plant is to fully establish and develop specifications as necessary for the construction and operation of a commercial full-scale plant.

Deployment – This final stage includes the engineering and design of a commercial system within the expected capital costs. The operating and maintenance costs are within due diligence estimates, as determined after the system has been running for at least 1 calendar year.

The information being evaluated under this indicator is to determine whether a technology and/or its components is/are in a start-up, pilot, demonstration, pre-commercial, commercial or mature stage. Commercially available and mature energy technologies can be deployed directly in SIDS if they qualify to other criteria to be classified as *SIDS-appropriate energy technologies*. Other technologies that have in theory great promise may not be commercially available yet, but justify the continued allocation of efforts and resources in R&D activities to develop these technologies for future introduction in SIDS. The categories used for evaluating the **Technology evaluation** indicator are:

Table 5 Indicator 2a: Technology evaluation

Category	Description
Excellent	The RET has been fully validated, tested in pilot projects and is commercially available
Good	The RET has been fully validated, tested in pilot projects and is in an early stage of commercial availability
Fair	The RET has been fully validated and currently is being tested in pilot projects and it is not commercially available
Not acceptable	The RET has been only fully validated in laboratories

Under the **Technology Evaluation** indicator, focus is set on the identification of commercial and pre-commercial energy technologies and to enable narrowing down the scope to commercially viable or applicable RETs in each respective SIDS DOCK member state. At the same time, information is gathered to have an initial impression regarding the learning curve and the timing when the technologies may become commercially available. This information is sub-divided in terms of the likeliness of a RET becoming categorized as a *SIDS-appropriate sustainable energy technology* and deployed in the short-, medium-, and long term in SIDS DOCK member states.

2b. Deployment potential

The likeliness of a RET becoming categorized as a *SIDS-appropriate sustainable energy technology* and deployed in the short-, medium-, and long term in SIDS is an additional set of information included in the analysis. Furthermore a qualitative judgment is provided regarding the RET capacity to bring about socio-economic benefits to the SIDS community. The categories used for evaluating the **Deployment Potential** indicator are:

Table 6 Indicator 2b: Deployment potential

Category	Description
Excellent	RET provides significant socio-economic benefits to SIDS community
Good	RET provides moderate socio-economic benefits to SIDS community
Fair	RET provides with modifications satisfactory socio-economic benefits to SIDS community
Not acceptable	RET does not provide satisfactory socio-economic benefits to SIDS community

The information provided complements the Guiding Principle #1 stating that an energy technology needs to be *technically feasible* (see Section 3.1). The results of the analysis regarding this indicator are presented in Table 24 where three different columns are provided including the qualitative judgment per technology and by the likely timing of deployment.

3. Energy Efficiency

This Energy Efficiency indicator is used to determine and compare the energy efficiencies for the energy production output versus input. Energy efficiency is also one of the key determinants of the relative greenhouse gas contribution of the technology cycle. Since offsetting the dependency on imported fossil fuels is one of the critical needs of SIDS, this indicator is used to gather information and data to compare the RET performance with the traditional fossil fueled power generation systems. The categories used for evaluating the **Energy Efficiency** indicator are:

Table 7 Indicator 3: Energy Efficiency

Category	Description
Excellent	The RET offers a superior EE compared with fossil fuel systems
Good	The RET offers a similar EE compared with fossil fuel systems
Fair	The RET offers a slight inferior EE compared with fossil fuel systems
Not acceptable	The RET offers an inferior EE compared with fossil fuel systems

The information provided complements all the three Guiding Principles, #1 stating that an energy technology needs to be *technically feasible*, Guiding Principle #2 consistency with the concept of *sustainable development,* and Guiding Principle #3 regarding suitability of energy technologies to the *conditions* and *needs* of SIDS (see Section 3.1). The results of the analysis regarding this indicator are presented in Table 24.

4. Environmental Impacts

This indicator is used to assess the potential impact of each system with respect to air, water and solid waste emissions and the consumption of natural resources in the production process. An acceptable technology is one that results in environmental benefits based on its total life cycle, preferably confirmed through life-cycle-assessments (LCA). The categories used for evaluating the **Environmental Impacts** indicator are:

Table 8 Indicator 4: Environmental Impacts

Category	Description
Excellent	Almost no environmental impact has been identified
Good	A minimum level of emission has been identified. The limits are imposed by current environmental limits and norms in SIDS
Fair	A moderate level of emission has been identified. The limits are imposed by current EPA environmental limits and norms in SIDS
Not acceptable	A significant level of emission has been identified. Emissions and environmental impacts are not acceptable by limits and norms established in SIDS

The information provided complements Guiding Principle #2 regarding the technologies consistency with the concept of *sustainable development,* and Guiding Principle #3 regarding suitability of energy technologies to the *conditions* and *needs* of SIDS (see Section 3.1). The results of the analysis regarding this indicator are presented in Table 24.

5. Economic Viability

Any newly introduced RET has to be cost-effective and be competitive to existing fossil fueled power generation systems. This means that energy technologies have to be able to offset the dependence on imported fossil fuels in a cost-effective manner which is mainly determined by the capital investment/turn-key investment cost of the technology, the energy conversion efficiency or yield, and the levelized cost of electricity. Taking into account the limited data available, a simplistic and practical way of measuring the economic viability of an energy technology is to gather the cost of production (US$/kWh). RET costs are estimated and compared with standard energy systems based on fossil fuel. The categories used for evaluating the **Economic Viability** indicator are:

Table 9 Indicator 5: Economic Viability

Category	Description
Excellent	RET has an inferior cost of production ($/kWh) compared with standard energy systems based on fossil fuel
Good	RET has a similar cost of production ($/kWh) compared with standard energy systems based on fossil fuel
Fair	RET has a slight superior cost of production ($/kWh) compared with standard energy systems based on fossil fuel
Not acceptable	RET has a superior cost of production ($/kWh) compared with standard energy systems based on fossil fuel

The information provided complements Guiding Principle #2 regarding the technologies consistency with the concept of *sustainable development,* and Guiding Principle #3 regarding suitability of energy technologies to the *conditions* and *needs* of SIDS (see Section 3.1). The results of the analysis regarding this indicator are presented in Table 24.

6. Socio-political acceptance

This indicator requires the gathering of information regarding the general acceptance of an energy technology being introduced in the community. This is normally guaranteed by the early and proper involvement of key stakeholders in a SIDS community. Although at this stage it is not viable to gather SIDS DOCK member state's communities' input regarding their respective perspectives on energy technologies, via the literature and past project experiences one can gather general indications of the social or cultural acceptance of certain technologies (this social/cultural acceptance of energy technologies is generally driven by the access to information, the awareness level, and exercised religions in the community). Issues such as societal benefits, environmental stewardship, and stakeholder needs and concerns are considered. This qualitative evaluation determines if the deployment of the technology will be acceptable to all interested parties. The categories used for evaluating the **Socio-political acceptance** indicator are:

Table 10 Indicator 6: Socio-political acceptance

Category	Description
Excellent	RET complies with all SIDS regulations and offers great social and environmental benefits
Good	RET complies with almost all SIDS regulations (minimal modifications are necessary for RETs to comply with all regulations in place) and offers great social and environmental benefits
Fair	RET complies with few SIDS regulations (major modifications are necessary for RETs to comply with all regulations in place) and offers great social and environmental benefits
Not acceptable	RET does not comply with any SIDS regulation

The information provided complements Guiding Principle #2 regarding the technologies consistency with the concept of *sustainable development,* and Guiding Principle #3 regarding suitability of energy technologies to the *conditions* and *needs* of SIDS (see Section 3.1). The results of the analysis regarding this indicator are presented in Table 24.

7. Land use

This indicator requires the gathering of information regarding the demand of land by each RET. The carrying capacity of SIDS is the maximum capacity (mainly determined by available space) of an island to support a community indefinitely by the island's ecosystem without destroying this same ecosystem. Especially in small island states (where space is very valuable), an energy technology should not demand significant or critical land or space that competes with more critical land uses for the community, nor lead to the destruction of sensitive ecosystems that provide essential ecosystem services to the community (as provision of food or fresh water). This indicator will help determine whether the deployment of the technology will be acceptable in terms of land use. The categories used for evaluating the **Land use** indicator are:

Table 11 Indicator 7: Land use

Category	Description
Excellent	Land demand for the technology is low compared with alternative land use
Good	Land demand for the technology is acceptable compared to alternative land use
Fair	Land demand for the technology is near or equal compared with alternative land use
Not acceptable	Land demand for the technology is higher than possibilities restricted by land use

The information provided complements Guiding Principle #3 regarding suitability of energy technologies to the *conditions* and *needs* of SIDS (see Section 3.1). The results of the analysis regarding this indicator are presented in Table 24.

8. Reliability

This indicator requires the gathering of information regarding the capability of the RET to use the renewable energy resource and generate power as base load. Island communities need reliable, affordable and clean energy services. Reliability is in this report determined by whether the technology is always dispatchable and whether the technology can guarantee (close to) 100% availability of power in a year. The potential advance of technology to use RES as a base load in the future is also taken into account (by for instance combining wind and solar technologies with energy storage technologies). The categories used for evaluating the **Reliability** indicator are:

Table 12 Indicator 8: Reliability

Category	Description
Excellent	RET uses the resource as a base load
Good	RET needs some advances to use the resource as a base load
Fair	RET is far from its potential to use the resource as a base load
Not acceptable	RET is or will not be able to use the resource as a base load

The information provided complements Guiding Principle #3 regarding suitability of energy technologies to the *conditions* and *needs* of SIDS (see Section 3.1). The results of the analysis regarding this indicator are presented in Table 24.

9. Adequacy of Energy Services

This indicator requires the gathering of information regarding whether RETs are successful in satisfying the provision of energy services and use. In certain SIDS there is a large segment of the population that lives in isolated regions or outer islands where only technologies that are small scale, modular in nature, and are easier to install and use, may be suitable. In this case the RET has to convert the RES into a needed energy service (heat for cooking, lighting, or other needs). The categories used for evaluating the **Adequacy of Energy Services** indicator are:

Table 13 Indicator 9: Adequacy of Energy Services

Category	Description
Excellent	The RET has a high capability to provide and satisfy energy services and use
Good	The RET has a medium capability to provide and satisfy energy services and use
Fair	The RET has a intermittent capability to provide and satisfy energy services and use
Not acceptable	The RET has a very low capability to provide and satisfy energy services and use

The information provided complements Guiding Principle #3 regarding suitability of energy technologies to the *conditions* and *needs* of SIDS (see Section 3.1). The results of the analysis regarding this indicator are presented in Table 24.

4.3 Scope and use of the SIDS-appropriate ETA methodology

This SIDS-appropriate Energy Technology Assessment method has been developed in order to identify, assess, categorize, and compile a list of energy technologies that are SIDS-appropriate (technically feasible, consistent with SIDS development objectives, cost-effective, environmentally sustainable, culturally compatible and socially acceptable). This initial list of SIDS-appropriate energy technologies is prepared to facilitate the process of developing a strategy and implementation plan for the transfer, development and deployment of these technologies in SIDS DOCK member states.

RET transfer requires more quantitative data regarding the potential viability of technological approaches for the production of energy from all the renewable energy sources (RES) in or near SIDS. The "SIDS-appropriate ETA" assessment approach should therefore be considered a 1st-order qualitative assessment and selection method applied to evaluate the potential viability and suitability of RETs for SIDS. Without the proper quantitative analyses for each indicator used in this methodology, in particular when taking into account specific conditions and needs in each respective SIDS, no conclusive judgment is possible regarding the energy technologies' compliance to the definition of *SIDS-appropriate sustainable energy technology*.

5. Available data and information per major SIDS region

In the following sections the data gathered through an extensive literature review is presented by the major SIDS regions, namely the Caribbean, Pacific, Atlantic, and Indian Ocean regions. This categorization is based on the current SIDS DOCK membership.

5.1 The Caribbean region

This section includes the thirteen countries from the Caribbean Region that are currently part of the SIDS DOCK membership. Please see Figure 3 and Table 14 for an overview of the SIDS characteristics and energy sector conditions as per 2012. Although these SIDS share several similarities belonging to the same region, they are also different in terms of size (e.g., range from 90 to 13,000 km²), population (e.g., range from 5,000 to 2.5 million), economic status (e.g., low, middle, and high income), geographical location (e.g., continental vs. islands), and constitutional setup (e.g., most formal British Overseas Territories).

Figure 3 – Map of the location of SIDS in the Caribbean Region[29]

The 13 SIDS DOCK member states are all independent island nations and with the exception of the Dominican Republic, are all members to the Caribbean Community (CARICOM). CARICOM established in 1973 as a regional multilateral organization has as its main purpose to promote economic integration and cooperation among its members, to ensure that the benefits of integration are equitably shared, and to coordinate foreign policy.[30]

[29] Source: The Heritage Foundation, see: http://www.heritage.org/research/reports/2012/10/caricom-us-should-push-back-against-chavez-in-the-caribbean (visited October, 2012)

[30] Ramjeet, Oscar (2009-04-16). "CARICOM countries will speak with one voice in meetings with US and Canadian leaders". Retrieved from: http://www.docstoc.com/docs/6434217/CARICOM (visited October, 2012)

The data presented in Table 14 is based on data gathered from past studies, research, and reports from a wide range of sources (please see Annex II to this report). Where data is not available, 3TIER[31] and Solar and Wind Energy Resource Assessment (SWERA)[32] were used in order to have some clue regarding the RES potential. Units are listed at the top of the table; except for those specified in the table.

[31] 3TIER is a web based solar and wind energy data provider. 3TIER uses weather science to provide data anywhere on earth and across all time horizons. For details please see: http://www.3tier.com (visited October, 2012)

[32] SWERA is an open web based solar and wind data provider. For details please see: http://maps.nrel.gov/SWERA (visited October, 2012)

Table 14 Characteristics of and Energy Sector conditions in Caribbean SIDS

Caribbean	Total area – Size (Km^2)	Population (2009)	GDP Nominal (N) and PPP (P) per capita (US$)	Energy Policy	Regulation	Elect Utility	Net Electricity Generation / Consumption (GWh) (2009)	Self-Generation Allowed (yes/no)	Average Electricity Tariff (US$/Kwh (2009)	Energy Resource in use for electricity	RE potential available by RE sources (MW) or any other data available	% of electricity from RETs	Primary RES utilized	RETs in use	% of Household with access to electricity
Antigua and Barbuda	440	81,799	$13,552 (N) $17,980 (P)	Yes- NEP 2011	Gov. – No independent	Pub-Act-Indefinite	120/110	NO	0.35	100% Thermal based on fossil fuel	Hydro: NO Wind:400 Geo: NO Solar PV:>>27 Biomass: Low Ocean: High	0%	-	Isolated and private small Solar PV systems -SWH	100
Bahamas	13,878	353,658	$23,175 (N) $30,958(P)	Yes- NEP 2011	Gov. – No independent	Pub/Privt. 1.BEC - Gov.-Perpetual 2.GBC-Joint venture of foreign utilities-Lic 2054	2,050/1,910	NO	0.31	100% Thermal based on fossil fuel	Hydro: NO Wind:15 Geo: NO Solar PV:58 Biomass: Low-Med Ocean: Med	0%	-	Isolated and private small Solar PV systems -SWH	99-100
Barbados	431	279,912	$16,148 (N) $23,416(P)	Yes- NEP 2007	Fair Trading Committee	Private-Lic 2028	1,010/910	NO		100% Thermal based on fossil fuel	Hydro: NO Wind:>10 Geo: NO Solar PV:>>26 Biomass: Low Ocean: Med	0%	-	Isolated and private small Solar PV systems -SWH	100
Belize	22,966	333,200	$4,349 (N) $8,263 (P)	NEP - Draft since 2010	PUC-Multi Sectorial	Private-Lic 2015	260/240	NO		66% Thermal 44% Hydro >>1% Biomass	Hydro: High Wind: High Geo: NO Solar PV: High Biomass: High Ocean: Med	44% from Hydro >>1% Biomass	Hydro Biomass	Hydro-Dam Cogeneration	89
Dominica	750	72,660	$6,909 (N) $13,815(P)	NEP - Draft since 2009	Independent -IRC	DOMLEC-Public/Private –Lic 2015	80/80	YES	0.43	75% Thermal 24% Hydro <1% Wind	Hydro:17 Wind:30 Geo:1,390 Solar PV:45 Biomass: Med-Low Ocean: Med	24% from Hydro <1% Wind <<1%Solar PV	Hydro Wind	Hydro-dam SWH	100
Dominican	48,442	9,378,818	$5,638 (N)	Yes-		Private and	11,560/9,88	YES		82.5% Thermal	Hydro:210	17.5% Hydro	Hydro		

Caribbean	Total area – Size (Km^2)	Population (2009)	GDP Nominal (N) and PPP (P) per capita (US$)	Energy Policy	Regulation	Elect Utility	Net Electricity Generation / Consumption (GWh) (2009)	Self-Generation Allowed (yes/no)	Average Electricity Tariff (US$/Kwh (2009)	Energy Resource in use for electricity	RE potential available by RE sources (MW) or any other data available	% of electricity from RETs	Primary RES utilized	RETs in use	% of Household with access to electricity
Republic			$9,286 (P)	National Energy Plan 2004-2015		Public-	0			17.5%Hydro	Wind:3,200 Geo: NO Solar PV:2,900 Biomass: Med-High Ocean: Med	<<1%Solar	Tiny fraction of Solar PV		
Grenada	344	110,000	$7,878 (N) $13,895 (P)	Yes - NEP adopted in 2011	Gov-No Independent	GRENLEC-Lic 2041	200/180	YES- <10kW net-metering with a cap of 1% peak demand-	0.37	100% Thermal-Fossil Fuel	Hydro:0.5 Wind:5 Geo: 1,100 Solar PV: >>8 Biomass: NO Ocean: Med	<1% Wind	Wind	Isolated and private small Solar PV systems -SWH	99
Jamaica	10,991	2,889,187	$5,402 (N) $9,029 (P)	Yes - NEP Adopted 2009	Off of Utility Regulation	Pub-Private and some IPP. Lic 2021	5,210/4,800		0.40	95% Thermal 5%Wind and Hydro	Hydro:>80 Wind:60 Geo: NO Solar PV: High Biomass:70 Ocean: Med	5% (3% Hydro—2%Wind)	Wind and Run–off Hydro	small Solar PV systems-SWH	95
St. Kitts and Nevis	261	51,300	$12,728 (N) $15,573 (P)	Draft since 2009	Gov.-No Independent	Pub.-Indefinite	130/120	Only Wind, Solar PV in NEVLEC	0.30	98%Fossil Fuel and 2%Wind Energy	Hydro: NO Wind:5 Geo:300 Solar PV: >>16 Biomass: Low Ocean: Med	2% Wind	Wind Energy	Very small Solar PV systems-SWH	95
St. Lucia	617	173,765	$7,435 (N) $12,607(P)	Yes-NEP Adopted in 2010	Gov.-No Independent	Private-Lic 2045	340/320	YES	0.32	99.6%Fossil Fuel <1% Solar	Hydro:0.2 Wind:40 Geo:680 Solar PV:36 Biomass: Low Ocean: Med	<1%Solar	Solar	Solar PV technology -SWH	100
St. Vincent and the Grenadines	389	120,000	$6,342 (N) $11,700(P)	Yes - NEP Adopted in 2009	Gov.-No Independent	Public-Act.-to 2033	130/120	By License from utility	0.36	90%Thermal 10%Hydro	Hydro:10 Wind:8 Geo:890 Solar PV:23 Biomass:4	10% Hydro	Hydro	Isolated small PV systems -SWH	99

Caribbean	Total area – Size (Km^2)	Population (2009)	GDP Nominal (N) and PPP (P) per capita (US$)	Energy Policy	Regulation	Elect Utility	Net Electricity Generation / Consumption (GWh) (2009)	Self-Generation Allowed (yes/no)	Average Electricity Tariff (US$/Kwh (2009)	Energy Resource in use for electricity	RE potential available by RE sources (MW) or any other data available	% of electricity from RETs	Primary RES utilized	RETs in use	% of Household with access to electricity
											Ocean: Med				
Suriname	163,821	560,157	$7,096 (N) $9,475 (P)	Draft since 2009	Gov.-No Independent	Public-Act.- to 2022	1,600/1,460		0.15-hinterlands~ 0.6	73% Hydro 27% Thermal	Hydro: High Wind: Med Geo: NO Solar PV: High Biomass: High Ocean: Med	73% Hydro	Hydro	Small pilot project in solar PV	85
Trinidad and Tobago	5,131	1,227,505	$17,158 (N) $20,053 (P)	Draft since 2009	Independent Multi Sectorial	Pub and Private-Indefinite	7,220/7050	NO	0.05	100% Thermal-Fossil Fuel	Hydro: Low Wind:50 Geo: NO Solar PV: 308 Biomass: Low-Med Ocean: Med	0%	-	Small pilot project in solar PV	95

Renewable Energy Source Potential by Technologies in the Caribbean SIDS

Today, more than 90% of the electricity generated in the SIDS DOCK Caribbean countries is fueled by oil products, despite the fact that some of these countries have wind energy turbines, solar panels, and hydroelectric plants in operation. The current use of renewable energy (RE) in the region is far below the true potential. The only exception among the SIDS DOCK Caribbean member states is Suriname, because of the land mass and presence of rivers; it generates 73% of the nation's electric demand from hydro power. Table 15 summarizes the renewable energy potential per country expressed in potential installed capacity in MW derived from the limited information available based on technologies currently available. The data was collected from publically available reports and where possible by survey or presentations, please see Annex II for more detail.

Table 15 Summary of RE potential by Technology in Caribbean SIDS

Caribbean Sea RE Potential (MW) (unless otherwise indicated)	Solar		Biomass	Wind	Hydro	Geothermal-med. term	Ocean Energy –Long term				TOTAL per Country
	PV	**Cooling**					**OTEC**	**Tidal**	**Wave**	**Current**	
Antigua and Barbuda	>>27	*High*	*Low*	*400*	*NO*	*NO*	*High*	*Med*	*Low*	*High*	N/A
Bahamas	58	*High*	*Low*	*15*	*NO*	*NO*	*High*	*Med*	*Low*	*High*	N/A
Barbados	>>26	*High*	*Low*	*>10*	*NO*	*NO*	*Med*	*Med*	*Low*	*Med*	N/A
Belize	High	*High*	*High*	*High*	*High*	*NO*	*Low*	*Med*	*Med*	*Med*	N/A
Dominica	>>45	*High*	*Med*	*30*	*17*	*1,390*	*High*	*Med*	*Low*	*High*	N/A
Dominican Republic	2,900	*High*	*High*	*3,200*	*210*	*NO*	*High*	*Med*	*Low*	*High*	N/A
Grenada	>>>8	*High*	*NO*	*5*	*0.5*	*1,100*	*High*	*Med*	*Low*	*High*	N/A
Jamaica	High	*High*	*70*	*60*	*>80*	*NO*	*High*	*Med*	*Low*	*High*	N/A
St. Kitts and Nevis	16	*High*	*Low*	*5*	*NO*	*300*	*High*	*Med*	*Low*	*High*	N/A
St. Lucia	>>36	*High*	*Low*	*40*	*0.2*	*680*	*High*	*Med*	*Low*	*High*	N/A
St. Vincent and the Grenadines	>>23	*High*	*4*	*8*	*10*	*890*	*High*	*Med*	*Low*	*High*	N/A
Suriname	High	*High*	*High*	*Med*	*High*	*NO*	*Low*	*Med*	*Med*	*Low*	N/A
Trinidad and Tobago	308	*High*	*Low*	*50*	*Low*	*NO*	*Med*	*Med*	*Low*	*Low*	N/A
TOTAL Region per Technology	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

Table 15 summarizes the RE potential by sources. Among the RES with potential to be extracted, converted and used with present commercially available energy technologies, the following can be concluded:

- **Solar and Wind Energy** - solar and wind energy, are available and useable in all the SIDS in the Caribbean;
- **Geothermal energy** - as an attractive energy source for base load power generation it's mainly available and useable in the eastern Caribbean, including SIDS DOCK members as Dominica, Grenada, St. Kitts and Nevis, St. Lucia, and St. Vincent and the Grenadines;
- **Biomass Energy** - in the larger Antilles and low-lying continental countries, as Belize, the Dominican Republic, Jamaica and Suriname the biomass resources are expected to be plentiful for conversion into energy; and
- **Hydro Energy** - the range of countries where hydropower is already being used and/or where there is the potential to use as an energy source is broader, but can be sub-divided in SIDS that are using hydropower but have limited expansion potential including Dominica, Grenada, St. Lucia, and St. Vincent and the Grenadines, while other SIDS with high use and expansion potential as Belize, the Dominican Republic, Jamaica, and Suriname.

Among the RES that have the potential to be extracted, converted and used with future commercially available energy technologies, the analysis included ocean energy resources. Ocean Energy entails four sub-categories defined as Ocean Thermal Energy Conversion (OTEC), tidal, wave and current energy resources whereby although limited commercial applications are in place, have significant potential to be used when the required technologies are demonstrated or become commercially available to be used to use the ocean energy in the territorial waters of SIDS. Based on the data gathering process, the following can be concluded:

- **Ocean Thermal Energy Conversion (OTEC)** – is a promising alternative as an energy source for base load power generation. The OTEC resources are more attractive when there are adequate bathometric conditions (deep waters in close vicinity to the coastline with high temperature differences), which is the case for all SIDS in the Caribbean, except in continental SIDS as Belize and Suriname;

- **Tidal and Wave Energy** – these two ocean energy sources although available in the Caribbean the potential to extract, convert or use these energy sources is considered medium to low; and
- **Current Energy** – is based on gathering information considered available and with high potential to be used in almost all SIDS in the Caribbean, except in continental SIDS as Belize and Suriname.

Please see Chapter 6 for more details regarding the specific energy technologies that can be used to extract, convert, and/or use the RES analyzed and explanation regarding conclusions drawn in this section.

5.2 The Pacific Ocean Region

This section includes twelve countries from the Pacific Region that are currently SIDS DOCK members. The Pacific is a diverse region made up of countries and territories with varying land sizes, populations, natural resources, economies and cultures. Although they share several similarities as SIDS, they are also different in terms of size (e.g., ranging from 21 to 28,400 km²), population (e.g., ranging from 9,378 to 837,271), economic status (e.g., low, middle, and high income), geographical, and political situation (e.g., independent, and US and French Overseas Territories). Figure 4 shows the SIDS located in the Pacific Ocean.

Figure 4 Map of the location of SIDS in the Pacific Region[33]

All the 12 SIDS DOCK members are independent states and members to the Pacific Islands Forum (PIF). The PIF, established in 1971 serves as a regional multilateral organization to stimulate economic growth and enhance political governance and security for the region, through the provision of policy advice; and to strengthen regional cooperation and integration through coordinating, monitoring and evaluating implementation of Leaders' decisions.[34]

The data presented in Table 16 is gathered from past studies, research, and reports from a wide range of sources (please see Annex II of this report). Where data is not available, 3TIER[35] and Solar and Wind Energy Resource Assessment (SWERA)[36]were used in order to have some clue of the potential. We recall that RE resources are so dispersed in the regions that without an accurate, high resolution assessment of RE potential per country, and based on all the types of resource assessments described in Section 3.2, the deployment of RETs will continue to be a difficult challenge to overcome. Please note that the units are listed at the top of the table; except for those specified in the table.[37]

[33] Map retrieved from: http://www.forumsec.org/pages.cfm/strategic-partnerships-coordination/disability/disability-in-pacific.html (visited October, 2012)
[34] Pacific Islands Forum Secretariat, website: http://www.forumsec.org/pages.cfm/anniversary/ (visited October, 2012)
[35] 3TIER is a web based solar and wind energy data provider. 3TIER uses weather science to provide data anywhere on earth and across all time horizons. For details please see: http://www.3tier.com (visited October, 2012)
[36] SWERA is an open web based solar and wind data provider. For details please see: http://maps.nrel.gov/SWERA (visited October, 2012)
[37] See for all remaining sources Annexes to this report

Table 16 Characteristics of and Energy Sector conditions in Pacific SIDS

Pacific Ocean	Total Land area –Size Km^2	Pop.-2009	GDP Nominal (N) and PPP (P) per capita capita (US$)	Energy Policy/Action Plan	Regulation	Elect Utility	Net Electricity Generation / Consumption (GWh) (2009)	Self--Generation Allowed	Average Electricity Tariff (US$/Kwh)	Energy Resource in use for electricity	RE potential available by RE sources (MW) or any other data available	% of electricity from RETs	Primary RES utilized	RETs in use	% of Households with access to Electricity
Cook Islands	240	17,791	$14,188 (N) $9,100 (P)	Yes-NEP2003 AP 2005	Gov.-No independent	Pub.-indefinite.	30/30	NA	0,22 (main island-2005) 0.27-0.62 (outer islands – 2005)	Fossil Fuel: 71% Hydro: 28% Wind: 1% Solar: 1%	Hydro: NO Wind: Med Geo: Low -Possible for heat uses- Solar PV: High Biomass: N/A Ocean: Med	Wind 1% Hydro 28%	Hydro Wind Solar	- Hydro-Run off - Wind Turbines - Solar PV panels	100
Fiji	18,300	837,271	$4033 (N) $4784 (P)	Yes NEP 2006	Gov. / private(Licensed by FEA)	Pub.-indefinite. Some IPPs Licensed	869/750	NA	0.20 (main island 2010) 0.20-0.90 (outer islands-2004)	Fossil Fuel: 39% Hydro:58% Biomass: 2% Wind:<1% Solar:<<1%	Hydro:160 Wind:10 Geo:>>15 (High Potential-53 thermal areas) Solar PV: High Biomass:55 Ocean: Med	Hydro Wind Solar PV	Hydro Wind Solar PV	- Hydro-Run off - Wind Turbines - Solar PV panels	80
Kiribati	811	103,500	$1592 (N) $5721(P)	Yes NEP-2009	Gov.	Statutory Authority	22/20	NA	0.30 (2005)	Fossil Fuel: 99% Solar <<1%	Hydro: NO Wind: Med Geo: Very low--Possible for heat uses- Solar PV: 956,020 MWh/yr Biomass: Low Ocean: Med		-Stand-alone PV systems. -Biomass is largely used for cooking purposes		45
Federated States of Micronesia	702	111,111	$1,832(N) $2,664(P)	N/A	Gov.-No independent	Pub.-indefinite.	69/65	N/A	0.20 (2005)	Fossil Fuel:96% Solar: 1% Biomass; 3%	Hydro: 7 MW Wind: Med Geo: NO Solar PV: High Biomass: Low Ocean: Med	-	-	-	65
Marshall Islands	188	68,000	$2,851(N) $2,900(P)	Yes-NEP-2003	Gov.-No independent	Pub.-indefinite.	70/67	N/A	0.30 (2009)	Fossil Fuel: 100%	Hydro: Low Wind: Med Geo: NO Solar PV: High Biomass: NO Ocean: Med	-	-	-	

Pacific Ocean	Total Land area –Size Km^2	Pop.-2009	GDP Nominal (N) and PPP (P) per capita capita (US$)	Energy Policy/Action Plan	Regulation	Elect Utility	Net Electricity Generation / Consumption (GWh) (2009)	Self--Generation Allowed	Average Electricity Tariff (US$/Kwh)	Energy Resource in use for electricity	RE potential available by RE sources (MW) or any other data available	% of electricity from RETs	Primary RES utilized	RETs in use	% of Households with access to Electricity
Nauru	21	9,378	$2,187(N) $2,500 (P)	Yes – NEP 2008	Gov.-No independent	Pub.-indefinite.	30/30	N/A	Flat rate. 50 $US/month	Fossil Fuel 100% Biomass is used for non-electrical purposes.	Hydro: NO Wind: Med Geo: NO Solar PV: High Biomass: Low Ocean: Med	-	-	-	100
Palau	459	21,000	$8,100 (N) $8,941(P)	Yes NEP 2010	Gov.-No independent	Pub.-indefinite.	85/84	Yes	0.37 (2012) New rates proposed will increase avg. 20% the current rates	Fossil Fuel 100% <<1% solar	Hydro: NO Wind: Med Geo: NO Solar PV: High Biomass: Low Ocean: Med	<<1% Solar	Solar	Solar PV	96
Samoa	2,850	177,000	$3,451 (N) $5,966 (P)	Yes – NEP 2007	Gov.-No independent	Pub.-indefinite. (operates commercially)	108/107	N/A	*include fuel surcharge 0.42 (2012)	Fossil Fuel 52% Hydro 48%	Hydro: 23.6 GWh/year Wind: Med Geo: Moderate – prospective Rift Valley- Solar PV: High Biomass: very low Ocean: Med	Hydro 48%	Hydro Biomass	Hydro run-off	98
Solomon Islands	28,400	523,000	$1,553(N) $3,191(P)	Yes – NEP-2006	Gov.-No independent	Pub.-indefinite. (operates commercially)	84/84	N/A	0.18 (2004)	Fossil Fuel:97% Hydro: 2% Solar: <<1%	Hydro: Med Wind: Med Geo: High -8 thermal areas- Solar PV: High Biomass: low Ocean: Med		Hydro Solar Solid biomass	Solar PV Hydro Run-off	15
Tonga	748	103,000	$4,220(N) $7,340(P)	Yes - Renewable Energy Act-2009	Gov.-No independent	Pub.-indefinite.	51/50	N/A	0.23 (1999)	Fossil Fuel 99.7% Solar: 0.3%	Hydro: NO Wind: Med Geo: Moderate -hot Springs- Solar PV: High Biomass: Low Ocean: Med	Solar: 0.3%-	Solar Biomass	Solar PV	77
Tuvalu	26	10,500	$3,190(N) $3,400(P)	Yes NEP-2009	Gov.-No independe	Pub.-indefinite.	7/7		0.97 (2000)	Fossil Fuel: 99% Solar: <<1%	Hydro: NO Wind: Med Geo: NO	Solar <<1%	Solar Biomass	Solar PV	100

Pacific Ocean	Total Land area –Size Km^2	Pop.- 2009	GDP Nominal (N) and PPP (P) per capita capita (US$)	Energy Policy/Action Plan	Regulation	Elect Utility	Net Electricity Generation / Consumption (GWh) (2009)	Self--Generation Allowed	Average Electricity Tariff (US$/Kwh)	Energy Resource in use for electricity	RE potential available by RE sources (MW) or any other data available	% of electricity from RETs	Primary RES utilized	RETs in use	% of Households with access to Electricity
					nt						Solar PV: High Biomass: Low Ocean: Med				
Vanuatu	12,190	225,000	$3,036(N) $4,916(P)	No-Only an Energy Road Map - 2011	Gov regulated (URA)-Concession	Private-Lic 2020 (two companies)	65/64		0.35 (2004)	Fossil Fuel 93% Hydro 6% Wind <2%	Hydro: Very low Wind: Med Geo: High – 20 thermal areas- Solar PV: High – 26,310,294 MWh/yr Biomass: Very low Ocean: Med	Hydro 6%	Hydro	Hydro run-off Wind Turbine	<30

Renewable Energy Potential by Technologies in the Pacific SIDS

As in the case of the Caribbean Region, almost 90% of the electricity generated in the SIDS DOCK Pacific member states is fueled by oil products. The RES use in SIDS located in the Pacific Region is far below their true potential. Table 17 shows a detailed level of the renewable energy potential per country based on technologies currently available and is expressed in installed capacity in MW. The data was collected from publically available reports and where possible from surveys or presentations.

Table 17 Summary of RE potential by technology in Pacific Region SIDS

Pacific Ocean	Solar		Biomass	Wind	Hydro	Geothermal	Ocean Energy				TOTAL per Country
RE Potential (MW – unless otherwise indicated)	PV	Cooling					OTEC	Tidal	Wave	Current	
Cook Islands	*High*	*High*	*N/A*	*Med*	*NO*	*Low – possible for heat uses-*	*High*	*Med*	*Med*	*Low*	N/A
Fiji	*High*	*High*	*55*	*10*	*160*	*15*	*High*	*Med*	*Med*	*Low*	N/A
Kiribati	*High*	*High*	*Low*	*Med*	*N/A*	*-*	*High*	*Med*	*Med*	*Low*	N/A
Federated States of Micronesia	*High*	*High*	*Low*	*Med*	*7*	*-*	*High*	*Med*	*Med*	*Low*	N/A
Marshall Islands	*High*	*High*	*Low*	*Med*	*Low*	*-*	*High*	*Med*	*Med*	*Low*	N/A
Nauru	*High*	*High*	*Low*	*Med*	*Low*	*-*	*High*	*Med*	*Med*	*Low*	N/A
Palau	*High*	*High*	*Low*	*Med*	*Low*	*-*	*High*	*Med*	*Med*	*Low*	N/A
Samoa	*High*	*High*	*Low*	*Med*	*23.6 GWh/yr*	*High*	*High*	*Med*	*Med*	*Low*	N/A
Solomon Islands	*High*	*High*	*Low*	*Med*	*Med*	*High*	*High*	*Med*	*Med*	*Low*	N/A
Tonga	*High*	*High*	*Low*	*Med*	*NO*	*High*	*High*	*Med*	*Med*	*Low*	N/A
Tuvalu	*High*	*High*	*Low*	*Med*	*NO*	*-*	*High*	*Med*	*Med*	*Low*	N/A
Vanuatu	*High*	*High*	*Low*	*Med*	*Very low*	*High*	*High*	*Med*	*Med*	*Low*	N/A
TOTAL Region per Technology	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

Table 17 summarizes the RE potential by sources. Among the RES with potential to be extracted, converted and used with present commercially available energy technologies, the following can be concluded:

- **Solar Energy** - solar energy is available and highly useable in all the SIDS DOCK members in the Pacific;
- **Wind Energy** – as a source it's widely available in Pacific SIDS, but the quality is considered lower compared to other regions in the globe;
- **Geothermal energy** - as an attractive energy source for base load power generation it's being used in Fiji with furthermore high potential in other Pacific SIDS, as Samoa, Solomon Islands, Tonga, and Vanuatu. There is unfortunately no or limited publically available information regarding the geothermal energy potential in the remainder of the Pacific SIDS;
- **Biomass Energy** - in the larger islands of Fiji, biomass resources are already being converted into energy and expected to be sufficiently available for further expansion, in the remainder of the Pacific SIDS DOCK members no significant biomass energy potential is identified; and
- **Hydro Energy** - the range of countries where hydropower is already being used includes Fiji, Federated States of Micronesia (FSM) and Samoa. The hydropower potential in the remaining Pacific SIDS is considered low.

Ocean energy sources have the potential to be extracted, converted and used with future commercially available energy technologies. Based on the data gathering process, the following can be concluded:

- **Ocean Thermal Energy Conversion (OTEC)** – is a promising alternative as an energy source for base load power generation. The OTEC resources are more attractive when there are adequate bathometric conditions (deep waters in close vicinity to the coastline with high temperature differences), which is the case for all SIDS DOCK members in the Pacific;
- **Tidal and Wave Energy** – these two ocean energy sources although available throughout the Pacific the potential to extract, convert or use these energy sources is considered medium; and
- **Current Energy** – although available throughout the Pacific the potential to extract, convert or use this energy source is considered low.

Please see Chapter 6 for more details regarding the specific energy technologies that can be used to extract, convert, and/or use the RES analyzed and explanation regarding conclusions drawn in this section.

5.3 The Atlantic Ocean Region

This section includes two countries from the Atlantic Region; please see Figure 5 for a map of the location of SIDS in the Atlantic Region. The two islands share several similarities, economic status (low), geographical location, and constitutional status (independent). Some differences are in terms of size (e.g., ranging from 1,001 to 4,033 km²) and population (e.g., ranging from 183,176 to 491,575).

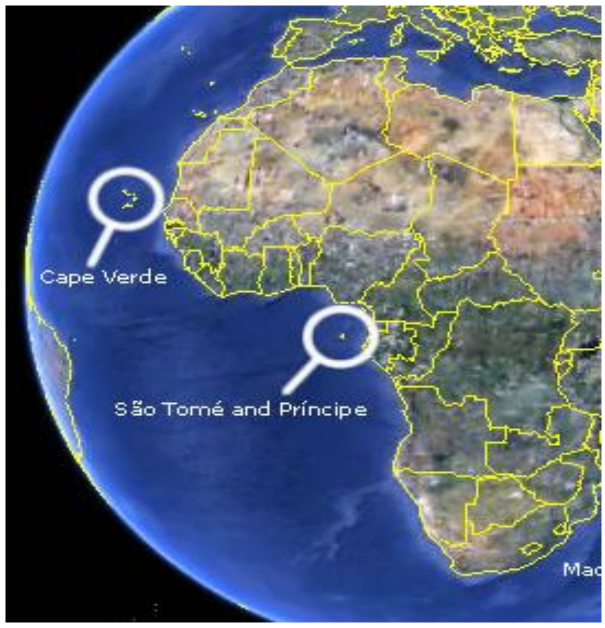

Figure 5 Map of the location of SIDS in the Atlantic Region[38]

Cape Verde and Sao Tome & Principe are members of the African Union. The African Union, established in 1999, serves as the principal regional multilateral organization to rid the continent of the remaining vestiges of colonization and apartheid; to promote unity and solidarity among African States; to coordinate and intensify cooperation for development; to safeguard the sovereignty and territorial integrity of Member States and to promote international cooperation within the framework of the United Nations.[39]

The data presented in Table 18 is gathered from past studies, research, reports from a wide range of sources (please see Annex II of this report). Where data is not available, 3TIER[40] and Solar and Wind Energy Resource Assessment (SWERA)[41] were used in order to have some clue of the potential. We recall that RE resources are so dispersed in the regions that without an accurate, high resolution assessment of RE potential per country, and based on all the types of resource assessments described in Section 3.2, the deployment of RETs will continue to be a difficult challenge to overcome. Please note that the units are listed at the top of the table; except for those specified in the table.[42]

[38] Retrieved and adapted from Google Earth (2012)
[39] African Union, website: http://www.au.int/en/about/nutshell (visited October, 2012)
[40] 3TIER is a web based solar and wind energy data provider. 3TIER uses weather science to provide data anywhere on earth and across all time horizons. For details please see: http://www.3tier.com (visited October, 2012)
[41] SWERA is an open web based solar and wind data provider. For details please see: http://maps.nrel.gov/SWERA (visited October, 2012)
[42] See for all remaining sources Annexes to this report

Table 18 Characteristics of and Energy Sector conditions in Atlantic Region SIDS

Atlantic Ocean	Total area –Size Km²	Pop.	GDP Nominal (N)/ PPP (P) per capita (US$)	Energy Policy	Regulation	Elect Utility	Net Electricity Generation / Consumption (GWh) (2009)	Self-Generation Allowed	Average Electricity Tariff (US$/Kwh)	Energy Resource in use for electricity	RE potential available by RE sources (MW) or any other data available	% of electricity from RETs	Primary RES utilized	RETs in use	% of Households with access to Electricity
Cape Verde	4,033	491,575 (2009)	$3,682(N) $4,112(P)	Yes – National Energy Plan 2003-2012 ECOWAS Centre for RE and EE (2010)	Government and private. Private	Public-Private Gov. is owner of the 51%.	287/278	Yes. But there is "No" feed in tariff	0.36	-Diesel: 72% -Wind: 22% -Solar: 6%	-Hydro: Low -Wind: High (10m/s average) -Geo: High – 18 GJ/m2- -Solar PV: High – 2000 kWh/m2/yr -Biomass: Very low -Ocean: Med	-Wind: 22% -Solar: 6%	-Sola PV -Wind -Basic Biomass	-PV panels -Wind turbines	94%
Sao Tome and Principe	1,001	183,176 (2011)	$1,473(N) $2,251(P)	NO- The Gov. has developed a RE plan 2010-2020	Government and private. Private	Public-Private Gov. is owner of the 51%.	30/30	Yes.	0,30	-Diesel: 79% -Hydro: 21% (Hydro has a huge variability due to Global Atmospheric Process for that reason the % may fluctuate time to time. *Wind farm in construction with an install capacity of 27.2 MW.	-Hydro: Med -Wind: Very Low -Geo: N/A -Solar PV: High 5.5 kWh/m² -Biomass: Low -Ocean: Med	-Hydro: 21%	-Hydro -Small solar PV projects	-Hydro run-off -PV panels	51%

Renewable Energy Potential by Technologies in the Atlantic SIDS

In Cape Verde and Sao Tome & Principe almost 70% of the electricity generated is fueled by oil products. They use wind and hydro as sources to reduce oil dependence. However, the total RE potential is still untapped. Table 19 shows the renewable energy potential per country based on technologies currently available in SIDS in the Atlantic region. The data was collected from publically available reports and where possible from surveys or presentations.

Table 19 Summary of RE potential by technology in Atlantic region SIDS

Atlantic Ocean RE Potential (MW - unless otherwise indicated)	Solar		Biomass	Wind	Hydro	Geothermal	Ocean Energy				TOTAL per Country
	PV	**Cooling**					**OTEC**	**Tidal**	**Wave**	**Current**	
Cape Verde	*High – 2,000 kWh/m2/yr*	*High*	*Very Low*	*High (10 m/s avg.)*	*Low*	*High – 18 GJ/m²*	*High*	*Med*	*Med*	*Low*	N/A
Sao Tome and Principe	*High 5.5 kWh/m2*	*High*	*Low*	*Very low*	*Med*	*N/A*	*High*	*Med*	*Med*	*Low*	N/A
TOTAL Region per Technology	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

Among the RES with potential to be extracted, converted and used with present commercially available energy technologies, the following can be concluded:

- **Solar Energy** - solar energy is available and highly useable in the two SIDS DOCK members in the Atlantic region;
- **Wind Energy** – the wind energy resource potential is only in Cape Verde considered high with average wind speeds of 10 m/s;
- **Geothermal energy** - as an attractive energy source for base load power generation Cape Verde is blessed with this resource. There is unfortunately no or limited publically available information regarding the geothermal energy potential in Sao Tome & Principe;
- **Biomass Energy** – among the Atlantic SIDS DOCK members no significant biomass energy potential is identified; and
- **Hydro Energy** - The hydropower potential in the Atlantic SIDS is considered medium to low.

Ocean energy sources have the potential to be extracted, converted and used with future commercially available energy technologies. Based on the data gathering process, the following can be concluded:

- **Ocean Thermal Energy Conversion (OTEC)** – is a promising alternative as energy source for base load power generation. The OTEC resources are more attractive when there are adequate bathometric conditions (deep waters in close vicinity to the coastline with high temperature differences), which is the case for both SIDS DOCK members in the Atlantic;
- **Tidal and Wave Energy** – these two ocean energy sources although available in the Atlantic region, the potential to extract, convert or use these energy sources is considered medium; and
- **Current Energy** – although available throughout the Atlantic the potential to extract, convert or use this energy source is considered low.

Please see Chapter 6 for more details regarding the specific energy technologies that can be used to extract, convert, and/or use the RES analyzed and explanation regarding conclusions drawn in this section.

5.4 The Indian Ocean region

This section includes three SIDS DOCK member states located in the Indian Ocean, please see Figure 6. The three islands share several similarities, economic status (low), geographical location, and constitutional status (independent). Some differences are in terms of size (e.g., ranging from 298 to 2,040 km²) and population (e.g., ranging from 84,000 to 1.3 million).

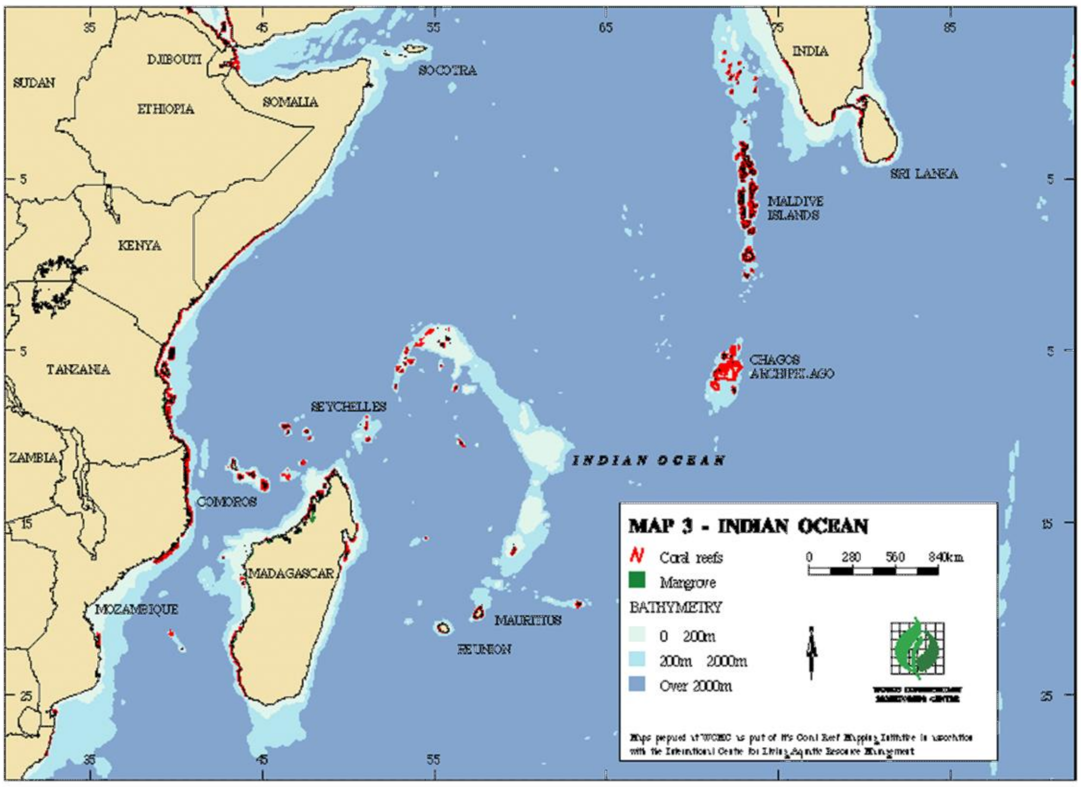

Figure 6 Map of the location of SIDS in the Indian Ocean[43]

Unlike the other major SIDS regions, the SIDS located in the Indian Ocean region are not bounded through a single regional multilateral organization or body. The Seychelles and Mauritius are members of the African Union (AU) while the Maldives is a member of the South Asian Association for Regional Cooperation (SAARC).

The African Union, established in 1999, serves as the principal regional multilateral organization to rid the continent of the remaining vestiges of colonization and apartheid; to promote unity and solidarity among African States; to coordinate and intensify cooperation for development; to safeguard the sovereignty and territorial integrity of Member States and to promote international cooperation within the framework of the United Nations.[44]

The SAARC, established in 1985, is a multilateral association to promote the welfare and quality of life of the peoples of South Asia and accelerate economic growth, social progress and cultural development in the region. It also aims to promote and strengthen collective self-reliance among the countries of South Asia; to contribute to mutual trust, understanding and appreciation of one another's problems; to promote active collaboration and mutual assistance in the economic, social, cultural, technical and scientific fields; to strengthen cooperation with other developing countries; to strengthen cooperation among themselves in international forums on matters of common interests; and to cooperate with international and regional organizations with similar aims and purposes.[45]

The data presented in Table 20 is gathered from past studies, research, reports from a wide range of sources (please see Annex II of this report). Where data is not available, 3TIER[46] and Solar and Wind Energy Resource Assessment (SWERA)[47] were used in order to have some clue of the potential. We recall that RE resources are so dispersed in the regions that without an accurate, high resolution assessment of RE potential per country, and based on all the types of resource assessments described in Section 3.2, the deployment of RETs will continue to be a difficult challenge to overcome. Please note that the units are listed at the top of the table; except for those specified in the table.[48]

[43] U.S. National Oceanic and Atmospheric Administration (NOAA), Source: http://www.ncdc.noaa.gov/paleo/outreach/coral/sor/sor_indian.html (Visited October, 2012)
[44] African Union, website: http://www.au.int/en/about/nutshell (visited October, 2012)
[45] The South Asian Association for Regional Cooperation (SAARC), website: http://www.saarc-sec.org/ (visited October, 2012)
[46] 3TIER is a web based solar and wind energy data provider. 3TIER uses weather science to provide data anywhere on earth and across all time horizons. For details please see: http://www.3tier.com (visited October, 2012)
[47] SWERA is an open web based solar and wind data provider. For details please see: http://maps.nrel.gov/SWERA (visited October, 2012)
[48] See for all remaining sources Annexes to this report

Table 20 Characteristics of and Energy Sector conditions in Indian Ocean region SIDS

Indian Ocean	Total area – Size Km^2	Pop.	GDP Nominal (N)/ PPP (P) per capita (US$)	Energy Policy	Regulation	Elect Utility	Net Electricity Gen. or Cons. (GWh) (2009)	Self-Generation Allowed	Average Electricity Tariff (US$/Kwh)	Energy Resource in use for electricity	RE potential available by RE sources (MW) or any other data available	% of electricity from RETs	Primary RES utilized	RETs in use	% of Households with access to Electricity
Maldives	298	330,000 (2011)	$5,973(N) $8,731(P)	Yes – NEP 2010	Government and private.	Public-Private	796,1/790	Yes	0,35 (0,20 electric tariff and 0,15 fuel surcharge)	-Diesel: 99,9% - Solar PV: <<0.1 -Wind: <<0.1	-Hydro: N/A -Wind: Med -Geo: N/A -SolarPV: High -Biomass: Med -Ocean: Med	- Solar PV: <<0.1 -Wind: <<0.1	-Wind -Solar -Biomass for cooking	-Wind turbines -PV panels	100
Mauritius	2,040	1,290,000 (2011)	$8,654 (N) $15,595 (P)	Yes – NEP 2007 (2007-2025)	Government	Government owned	2,689/2,600	Yes	0,20 (fuel surcharge N/A)	-Diesel: 76.7% -Hydro:8% -Wind: 0.3 -Biomass – bagasse-:15%	-Hydro: Already in use (about 60MW) -Wind: High -Geo: N/A -SolarPV: High -Biomass: Med -Ocean: Med	-Hydro:8% -Wind: 0.3 -Biomass –bagasse-:15%	-Hydro -Wind -Solar -Biomass for cooking	-Hydro run-off -Wind turbines -Small system based on PV panels	99,4
Seychelles	451	90,000 (2011)	$11,170 (N) $24,726 (P)	Yes –EP 1999 A NEP drafted in 2010	Government	Government owned	276/274	Yes	0,36 (0,17 electric tariff and 0,19 fuel surcharge)	-Diesel: 100% *Wind farm In construction to supply 10% of power* **needs to be further investigated*	-Hydro: NO -Wind: Med -Geo: N/A -SolarPV: High -Biomass: Low -Ocean: Med	-	-	-	96

Renewable Energy Potential by Technologies in the Indian Ocean SIDS

In the Indian Ocean Region as for the other major SIDS region, SIDS DOCK members are for more than 90% dependent on imported oil products for electricity generation, despite the significant RE potential in this region. Table 21 shows the renewable energy potential per country in the Indian Ocean region based on currently available energy technologies.

Table 21 Summary of the RE potential by technology in Indian Ocean SIDS

Indian Ocean RE Potential (MW)	Solar		Biomass	Wind	Hydro	Geothermal	Ocean Energy				TOTAL per Country
	PV	**Cooling**					**OTEC**	**Tidal**	**Wave**	**Current**	
Maldives	*High*	*High*	*Med*	*Med*	*N/A*	*N/A*	*Med*	*Low*	*Med*	*High*	N/A
Mauritius	*High*	*High*	*Med*	*High*	*60*	*N/A*	*High*	*Low*	*Med*	*Med*	N/A
Seychelles	*High*	*High*	*Low*	*Med*	*NO*	*N/A*	*High*	*Med*	*Med*	*Med*	
TOTAL Region per Technology	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

Among the RES with potential to be extracted, converted and used with present commercially available energy technologies, the following can be concluded:

- **Solar Energy** - solar energy is available and highly useable in the three SIDS DOCK members in the Indian Ocean region;
- **Biomass Energy** – the bio-energy potential among SIDS DOCK members in the Indian Ocean is considered medium to low;
- **Wind Energy** – the wind energy resource potential is only in Mauritius considered high;
- **Hydro Energy** – Mauritius already is using hydropower but its continued expansion is limited to the availability of rivers and space, furthermore no significant hydropower potential is identified in the remaining Indian Ocean SIDS; and
- **Geothermal energy** - there is unfortunately no or limited publically available information regarding the geothermal energy potential in the Maldives, Mauritius and Seychelles.

Ocean energy sources have the potential to be extracted, converted and used with future commercial energy technologies. Based on the data gathering process, the following can be concluded:

- **Ocean Thermal Energy Conversion (OTEC)** – is a promising alternative as energy source for base load power generation. The OTEC resources are more attractive when there are adequate bathometric conditions (deep waters in close vicinity to the coastline with high temperature differences), which is the case for Mauritius and Seychelles;
- **Tidal and Wave Energy** – these two ocean energy sources although available in the Indian Ocean region, the potential to extract, convert or use these energy sources is considered medium to low; and
- **Current Energy** – although available throughout the Indian Ocean the potential to extract, convert or use this energy source is only in the Maldives considered high.

Please see Chapter 6 for more details regarding the specific energy technologies that can be used to extract, convert, and/or use the RES analyzed and explanation regarding conclusions drawn in this section.

5.5 General RES potentials in SIDS DOCK member states

Table 22 provides a summary of the RES potential among all SIDS DOCK member states based on collected data and information originating from publically available sources, as website, technical reports, surveys, and presentations (please see Annex II to this report). Please note that the presented RES potential is a reflection of the written and published information available, and does not at any moment suggest the "real" technical, economic, or implementation potential, as defined and explained in Section 3.2.

Table 22 RE potential by technology in the SIDS DOCK Member States[49]

RES Category		High	Medium	Low	N/A or NO
Solar Energy	PV	All SD-MS[50]			
	Cooling	All SD-MS			
Biomass Energy		Belize, Dominican Republic, Jamaica, Suriname	Dominica, Maldives, Mauritius	Most Pacific SD-MS, most Caribbean SD-MS, except Fiji, Seychelles, Cape Verde, Sao Tome & Principe	Cook Islands, Grenada
Wind Energy		Antigua & Barbuda, Bahamas, Barbados, Belize, Cape Verde, Dominica, Dominican Republic, Fiji, Grenada, Jamaica, Mauritius, St. Kitts & Nevis, St. Lucia, St. Vincent & the Grenadines, Trinidad & Tobago	Most Pacific SD-MS, Suriname, Maldives, Seychelles	Sao Tome & Principe	
Hydro Energy		Belize, Dominican Republic, Fiji, Jamaica, Mauritius, Samoa, Suriname	Dominica, St. Vincent & the Grenadines, Sao Tome & Principe, Solomon Islands	Cape Verde, [51]FSM, Grenada, Marshall Islands, Nauru, Palau, St. Lucia, Trinidad & Tobago, Vanuatu	Antigua & Barbuda, Bahamas, Barbados, Cook Islands, Kiribati, Maldives, Seychelles, St. Kitts & Nevis, Tonga, Tuvalu
Geothermal Energy		Dominica, Cape Verde, Fiji, Grenada, Samoa, Solomon Islands, St. Kitts & Nevis, St. Lucia, St. Vincent & the Grenadines, Tonga, Vanuatu		Cook Islands	Antigua & Barbuda, Bahamas, Barbados, Belize, Dominican Republic, FSM, Jamaica, Kiribati, Marshall Islands, Mauritius, Maldives, Nauru, Palau, Sao Tome & Principe, Seychelles, Suriname, Trinidad & Tobago, Tuvalu
Ocean Energy	OTEC	Most SD-MS	Barbados, Maldives, Trinidad & Tobago	Belize, Suriname	
	Tidal		All Caribbean SD-MS, All Pacific SD-MS, Cape Verde, Sao Tome & Principe, Seychelles	Maldives, Mauritius	
	Wave		All Pacific SD-MS, Belize, Cape Verde, Maldives, Mauritius, Sao Tome & Principe Seychelles, Suriname	Most Caribbean SD-MS	
	Current	Most Caribbean SD-MS, Maldives	Barbados, Belize, Maldives, Mauritius	All Pacific SD-MS, Cape Verde, Sao Tome & Principe, Suriname, Trinidad & Tobago	

Some conclusions based on the gathered data and information of the RE potential by technology in the SIDS DOCK Member States (including the four major SIDS region, Atlantic, Indian Ocean, Pacific, and Caribbean regions), are as follows:

- **Solar Energy** - solar energy is available and highly useable in all the SIDS DOCK members;
- **Biomass Energy** – the bio-energy potential is highest among the larger Antilles and continental low-lying SIDS DOCK member states, including Belize, Dominican Republic, Jamaica, and Suriname;
- **Wind Energy** – the wind energy resource potential is in general higher in the Caribbean SIDS, with addition of SIDS as Cape Verde (Atlantic), Fiji (Pacific), and Mauritius (Indian Ocean);
- **Hydro Energy** - The hydropower potential is generally site-specific and highest potential is identified in larger Antilles and low-lying continental states, as Belize, Dominican Republic, Fiji, Jamaica, Mauritius, Samoa, and Suriname; and
- **Geothermal energy** – the highest identified potential are in the eastern Caribbean states, including Dominica, Grenada, St. Kitts & Nevis, St. Lucia, St. Vincent & the Grenadines, and additional SIDS from other major SIDS regions, including Cape Verde (Atlantic), Fiji, Samoa, Solomon Islands, Tonga, and Vanuatu from the Pacific. There is unfortunately no or limited publically available information regarding the geothermal energy potential in a large number of SIDS DOCK member states.

[49] additions in red were added using info from tables 15, 17, 19, 21
[50] SD-MS: SIDS DOCK Member States
[51] FSM-Federated States of Micronesia

Ocean energy sources have the potential to be extracted, converted and used with future commercial energy technologies. Based on the data gathering process, the following can be concluded:

- **Ocean Thermal Energy Conversion (OTEC)** – is a promising alternative as energy source for base load power generation. The OTEC potential is high in almost all SIDS DOCK member states, except or to lesser extent, in Barbados, Belize, Trinidad & Tobago, and Suriname in the Caribbean, and in the Maldives (Indian Ocean);
- **Tidal** – although available in all the major SIDS regions, the potential to extract, convert or use these energy sources is considered medium in almost all SIDS DOCK member states, with lower potentials in the Maldives and Mauritius, both from the Indian Ocean region;
- **Wave Energy -** although available in all the major SIDS regions, the potential to extract, convert or use these energy sources is considered medium in almost all Pacific SIDS DOCK member states, in Belize and Suriname in the Caribbean, in Cape Verde and Sao Tome & Principe in the Atlantic, and Maldives, Mauritius, and Seychelles in the Indian Ocean with lower potentials in most Caribbean SIDS DOCK member states; and
- **Current Energy** – although available throughout the major SIDS regions, the potential to extract, convert or use this energy source is considered high in most Caribbean SIDS DOCK member states and in the Maldives (Indian Ocean). With Barbados and Belize in the Caribbean, and Maldives and Mauritius in the Indian Ocean having medium current energy potential, and where the remainder of SIDS DOCK members have low current energy potential.

In general terms:

- After decades of investments in project preparation activities, feasibility studies, and energy planning studies, there is still a critical lack of research regarding the specific assessment of RES potential in the Caribbean region;
- There is lack of a commonly agreed and proper methodology to assess the technical potential for RES in a standardized and uniform format in all the SIDS major regions;
- There is a significant lack in data and statistics related to renewable energy resources and technology application potential in all SIDS DOCK member states;
- There is a lack of transparency or open access to energy data being generated in all the SIDS major regions;
- The geothermal potential is on the short- to medium term a relevant and critical resource for the eastern Caribbean sub-region and several Pacific SIDS to achieve sustainable energy development since it can serve as a clean energy source alternative for base load power generation which is needed next to intermittent renewable energy power generation systems;
- Solar energy as a source is available in all SIDS, and its conversion into power is possible in all SIDS DOCK member states, although on short- to medium term, solar energy technologies are considered intermittent energy supply options, developments in energy storage and parallel development of base load energy supply alternatives can significantly increase the potential deployment of solar energy technologies. Because of the wide-spread availability of solar energy it is possible to develop common policies and mechanisms to pool all the resources, efforts and instruments to accelerate transfer of solar energy technologies to make solar energy use in all SIDS possible;
- Wind energy as a source is available in many SIDS in the Caribbean and lesser extent in other major SIDS regions for conversion into power; and
- There is a significant lack of Research & Development activities regarding non-commercial energy technologies that have the potential of becoming critical to address the energy needs of SIDS in the Caribbean (e.g. Ocean Energy Technologies).
- Additionally, once a fair idea is projected of the renewable energy market scale, it can act as a driver for significant, positive economic growth and can incentivize the creation of more jobs per unit of energy delivered locally compared to 'business as usual' fossil-fuel economies since many of these jobs will be required domestically as they involve construction, installation and maintenance activities.[52]

[52] Jobs in Renewable Energy Expanding, Product Number: VST113. Retrieved from: http://www.worldwatch.org/node/5821 (visited November, 2012)

5.6 General characteristics and energy sector conditions in SIDS DOCK member states

All SIDS DOCK members have a clear commonality, which is an absolute limit in available space. This limitation of space determines the maximal carrying capacity of an island community to develop, prosper and sustain a good quality of life. Like availability of space, SIDS have other unique characteristics that pose a challenge to the deployment and transfer of RETs.

General characteristics

In this section an overview is provided of indicators that help describe the conditions in the SIDS around the globe.

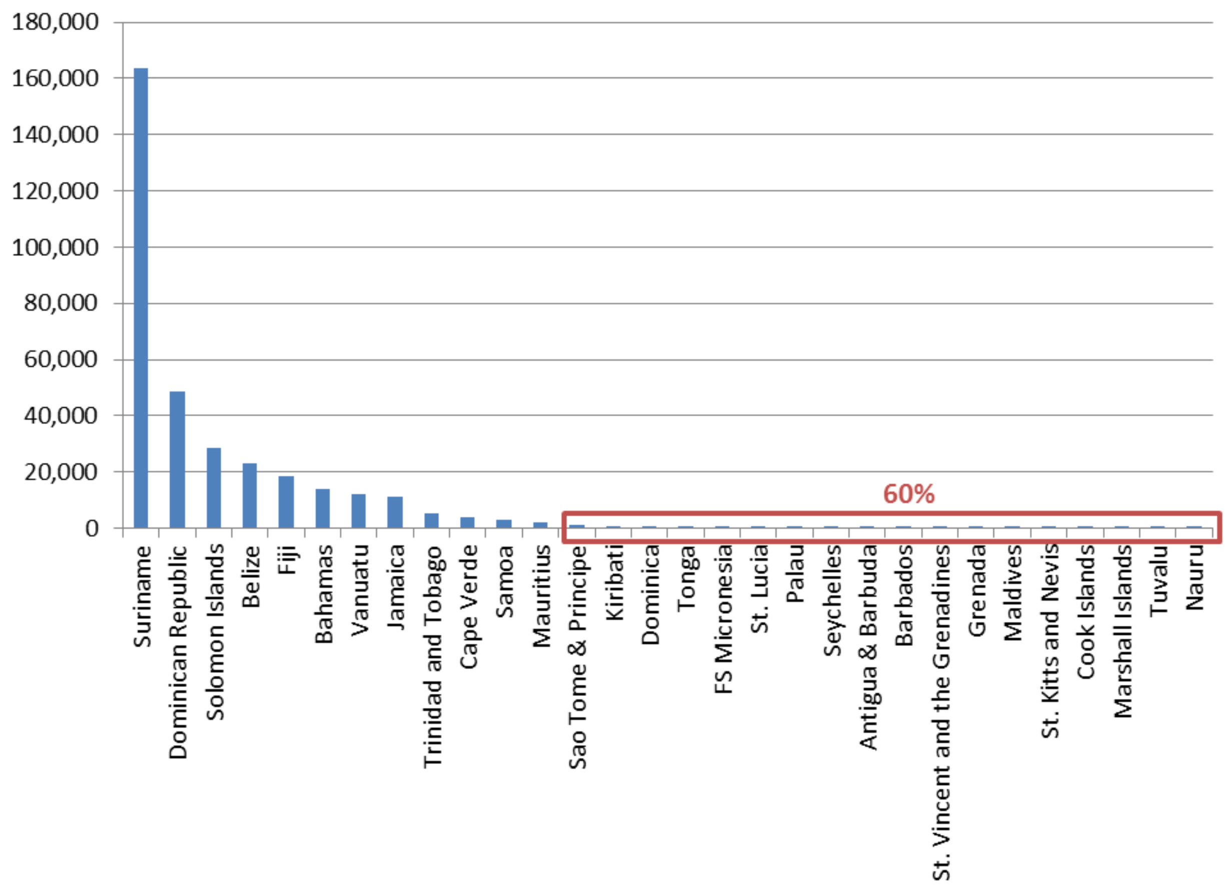

Figure 7 SIDS DOCK Member States Surface Area (km^2)[53]

Figure 7 describes the sizes of the SIDS DOCK member states expressed in square kilometers. This shows that among the SIDS there are clear differences in available land surface, for example 60% of the SIDS DOCK membership is smaller than 1,000 km^2 signifying in essence less availability of resources to the community of these respective islands. The difference in size and its varied implications are better reflected when looking at the population density per island nation.

Based on latest available data, the overall population of the SIDS DOCK membership sums up to about 20.3 million (2012 *est.*) people which are spread over 30 SIDS located around the globe.

[53] Derived from tables 14, 16, 18 and 20

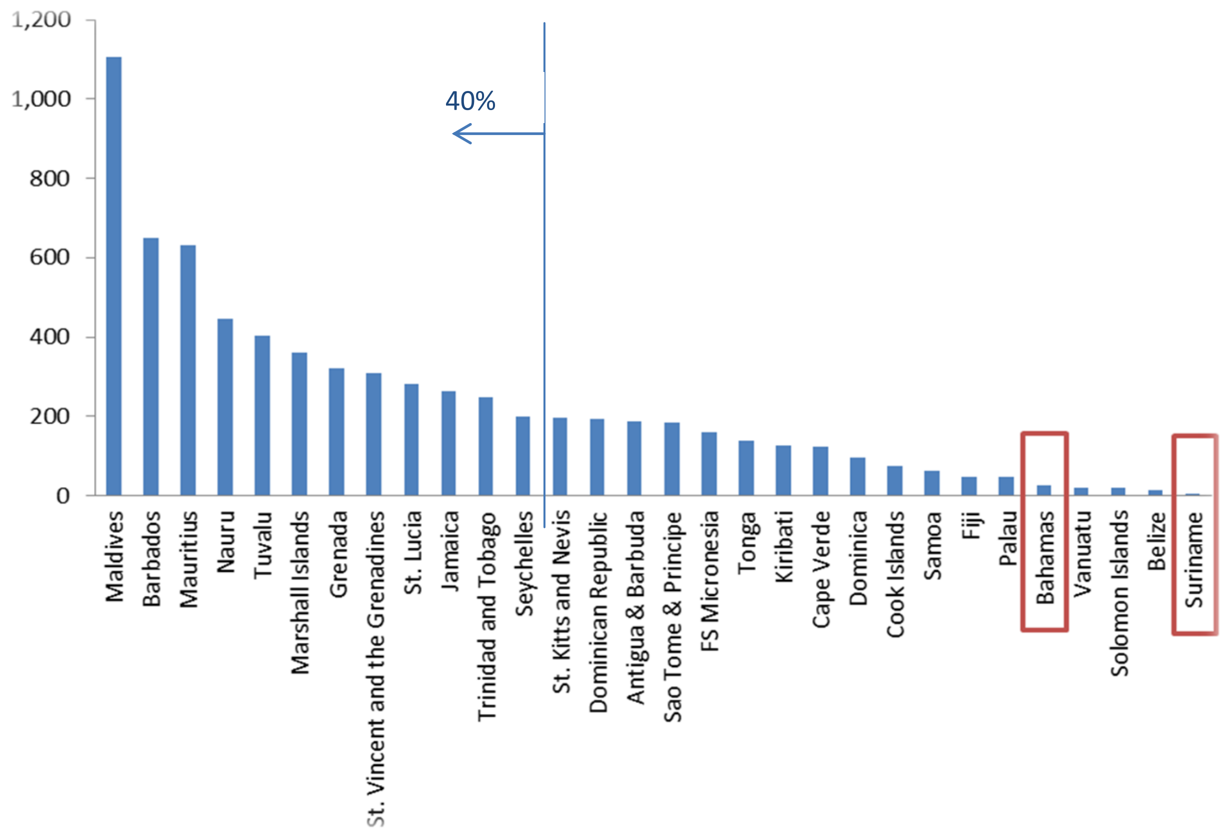

Figure 8 Population density in SIDS DOCK Member States (pop/km^2)[54]

Figure 8 shows the population density in each of the SIDS DOCK Member States as per 2009. When simply dividing the population by the available surface area, this results in about 40% of the SIDS having a population density beyond 200 persons per square kilometer with the low-lying coastal nations of Belize and Suriname having the lowest density levels. The problem of using such a simplistic approach is that it does not reflect the reality of some of the SIDS. Two key data misinterpretations can be derived from, (1) the Bahamas being the only archipelago of the SIDS in the Caribbean composed of about 3,000 islands or atolls of which only 14 are inhabited meaning that the complete population of 353,658 is spread among these 14 islands leading to much higher population densities than reflected in the figure above; and (2) in the low-lying coastal countries, in particular Suriname, the population is highly concentrated in the coastal zone, representing a very high population density in a narrow coastal strip.

The point being made here is that adequately gathered, analyzed and presented statistics are critical to be able to reflect the "real" conditions in each SIDS. The necessary data gathering and detailed statistical analysis is beyond the scope of this study, but will increasingly become critical to be able to properly identify needs and challenges and set priorities and targets for future interventions to transition to a sustainable energy development in each respective SIDS.

Figure 9 depicts the differences among the SIDS DOCK member states regarding their GDP per capita. Using GDP per capita is simply an indicator for comparison between the SIDS DOCK members regarding their total national economic activity, and does not reflect the standard of living of citizens in these nations. Nevertheless an income classification is made of the SIDS based on their Gross National Income per Capita figures prepared by the World Bank.[55] None of the SIDS DOCK members are classified as "low income" countries, meaning all have GNI per Capita of US$1,025 and above.

The United Nations (UN) instead, relies on a more complex classification that includes geographic regions as well as such categories as *least developed countries* (like Afghanistan and Malawi), *landlocked developing countries* (e.g., Botswana, Azerbaijan), *small island developing states* (e.g., Bahamas, Mauritius), *transition countries* (e.g., Belarus, Croatia), *developed regions* (Japan, Northern America), and *developing regions* (Central America, Asia excluding Japan.)[56] The grouping and classification of small island developing states (SIDS)

[54] Derived from tables 14, 16, 18 and 20

[55] Classification of Countries is from the World Bank, July 2012, on the basis of 2011 GNI per capita, derived from http://www.gfmag.com/tools/global-database/economic-data/12066-countries-by-income-group.html#axzz2DUnidxCH

[56] World Economic Situation and Prospects, Statistical Annex, United Nations (UN), see: http://www.un.org/en/development/desa/policy/wesp/wesp_current/2012country_class.pdf (visited November 2012)

recognizes the unique characteristics and challenges facing small island developing countries in general and highlights the need to address the development needs of SIDS in a non-conventional manner.

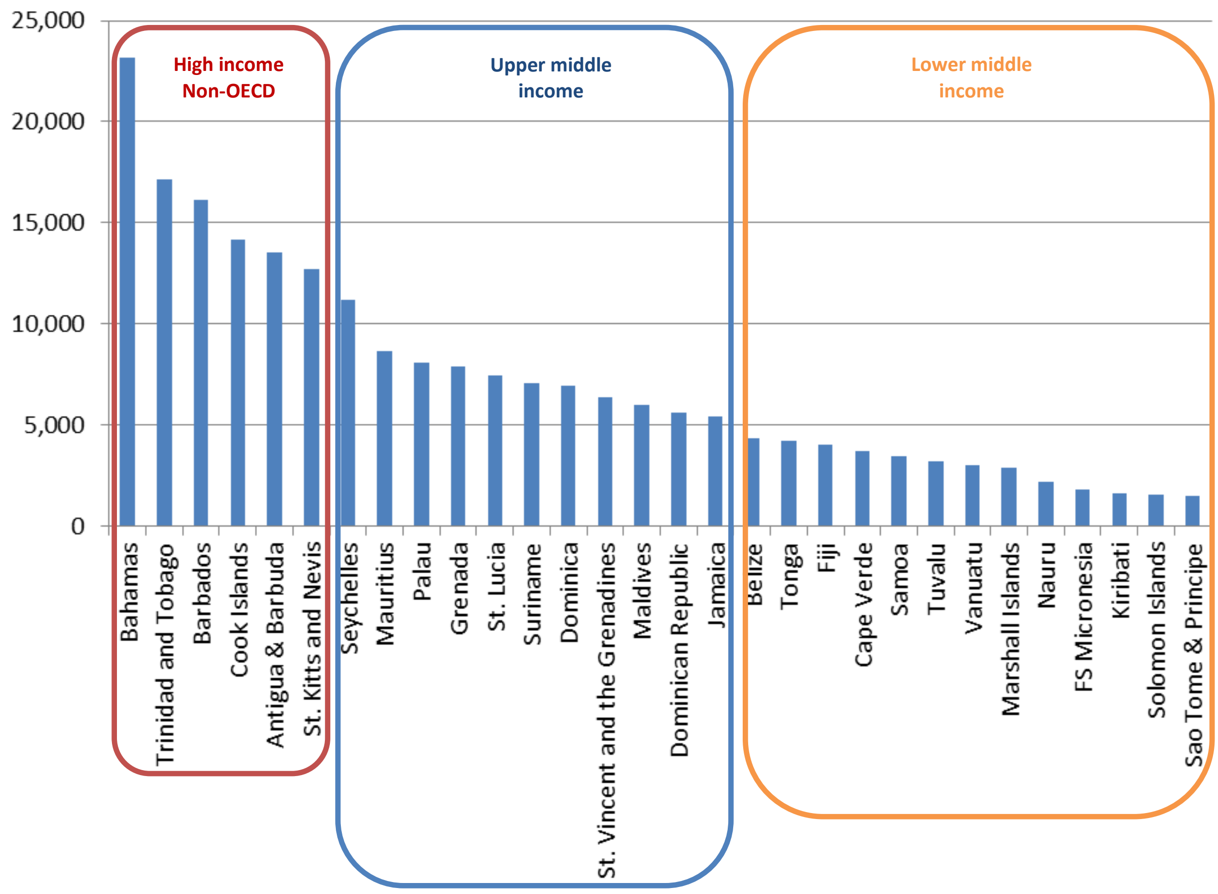

Figure 9 GDP per Capita in SIDS DOCK Member States[57]

The point made here is that even though Figure 9 depicts that none of the SIDS are classified as "low income" countries as per 2012, the average citizen may be relatively less wealthy due to the higher costs of imported consumer goods and commodities (such as energy). Furthermore the limited carrying capacity of SIDS defines a clear limit in economic growth and expansion, thus this level of Gross National Income is not guaranteed in the near to long term future. The economic status of SIDS is based on the continuous growth in production and selling of goods and services within a country (thus based on the continuous economic expansion). This means that especially SIDS require a different development paradigm, which recognizes the resource limits defined by the carrying capacity, and base the economic development on improving the quality of goods and services instead of the quantity.

Energy Sector conditions

As mentioned earlier, achieving low carbon economic development by focusing on the use of renewable energy and energy efficiency technologies is not only important to mitigate climate change impacts, but more so a critical development tool to offset the SIDS dependency on imported fossil fuels to reduce the foreign exchange losses to generate savings to allocate on other development priorities, including adaptation to climate change. Recognizing energy is a key factor to achieving sustainable development it is important to review the current energy conditions in SIDS to assess the energy needs and determine suitable instruments to address these needs.

Energy is an integral and critical part of an economy where energy is converted into electricity for lighting, powering appliances and communication technologies; heat for industrial processes, mobility, and other uses in the society that drive the economy. These energy carriers on their turn are consumed to satisfy energy needs at residential areas, for productive activities, public infrastructure, and mobility. During the conversion from energy carriers energy is "lost" as heat. The majority of SIDS do not have the primary energy readily available. Most are net energy importers, highly dependent on imported fossil fuels for power generation and

[57] Classification of Countries is from the World Bank, July 2012, on the basis of 2011 GNI per capita, derived from http://www.gfmag.com/tools/global-database/economic-data/12066-countries-by-income-group.html#axzz2DUnidxCH

transportation, and as mentioned before, are dealing with steadily increasing electricity and fuel prices that challenge the economic development.

In most SIDS DOCK members diesel generator sets are used and are generally supplied in prefabricated units and scale, and can be deployed at any time and location without much investment needed in, preparing the infrastructure to host these, their delivery, and installation. The fuel types used, generally of high energy density liquid forms as diesel, are easier to dispatch when needed. But in order to reduce energy supply disruptions, particularly in SIDS, investments have to be made in fuel storage capacity.

These conditions, allow for lower initial capital investment when comparing RET projects. But due to the dependence on fuel supply for the power generation over the project's lifetime, the fuel becoming increasingly scarce and its cost more volatile and expensive, leads to high operational and maintenance costs of such systems that on project lifecycle basis result to be generally more expensive than RET projects. Even though these systems generate socio-economic benefits (e.g. job creation and reliable energy services), due to the fuel type used they emit greenhouse gasses (contributing to climate change) and cause other environmental impacts to the community.

Critical information required to properly assess the energy balance in SIDS includes (1) quantifying the amount of heavy fuel oil (HFO), distillate #2 and #6, diesel, gasoline, or other imported; and (2) determining what fraction of the imported fuels are used for power generation, as fuel for transportation or other in each respective SIDS. Based on somewhat outdated data, the average share of imported petroleum used for power generation in SIDS is about 30%, where the remainder is principally consumed in the transportation sector.[58] But this ratio can vary significantly between SIDS; see for example Figure 10 for the share of imported petroleum used for power generation in the Indian Ocean SIDS.

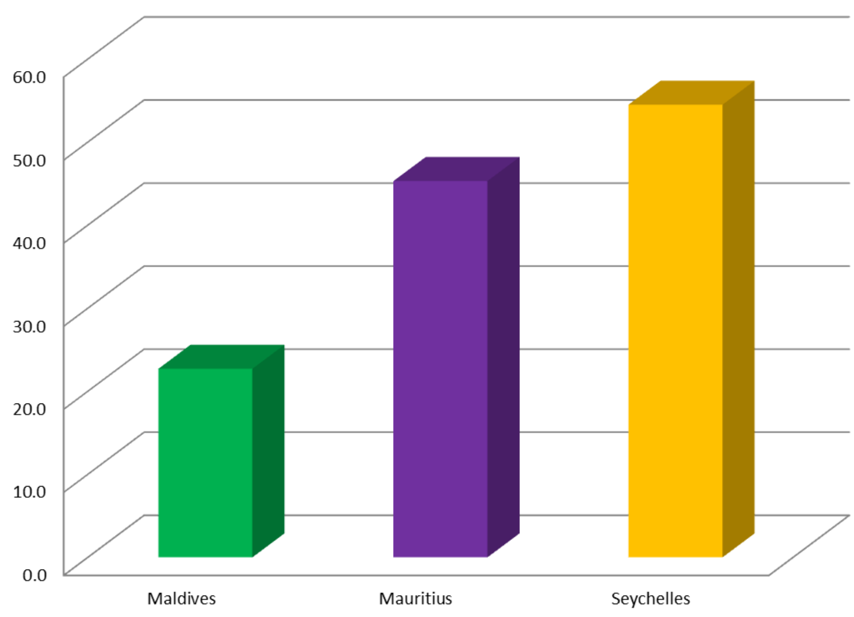

Figure 10 Share of Petroleum import used for power generation in the Indian Ocean (1992)[59]

This level of analysis is beyond the scope of this study, therefore the SIDS DOCK Secretariat is highly recommended to address the lack of basic energy statistics in the SIDS to gather a better data and capacity to perform proper energy analysis and determine the energy balance in each respective SIDS DOCK member states.

In the case of the transport sector, part of the imported fuel is centrally stored and then further distributed through retail gasoline stations to supply gasoline or diesel for vehicles used on the islands, while other fractions of this fuel is used for maritime transportation (including boats, ferries, cruise ships, etc.). Remaining energy uses include using imported gas for cooking, industrial uses and to a smaller extent for power generation and use in vehicles.

[58] Commission on Sustainable Development, 4th Session (18 April – 03 May, 1996), Sustainable Development of energy resources in small island developing states, see: http://islands.unep.ch/d96-20a2.htm (visited November 2012)
[59] Commission on Sustainable Development, 4th Session (18 April – 03 May, 1996), Sustainable Development of energy resources in small island developing states, see: http://islands.unep.ch/d96-20a2.htm (visited November 2012)

The larger islands, archipelagos, and continental low-lying nations have an additional factor which is; communities living further inland, in remote atolls, or at a critical distance from the urban centers that are not electrified and deal with very high cost of fuel import and power generation. In these cases alternative fuel supply options are used as transporting diesel in smaller quantities via boat or airplane to isolated areas and converting this into power using stand-alone diesel-fueled power generation and supplying users or a handful of public services buildings with electricity directly or via mini-grid infrastructure. Generally rural electrification with renewable energy technologies in these areas is to a lesser extent available or in place.

The critical problem of the current "generalized" energy sector outline in SIDS is that this energy life cycle is highly (>95%) dependent on imported fossil fuels that are increasingly becoming expensive and lead to (1) high cost of electricity rates, and (2) high gasoline and diesel prices for the consumers. This impacts the ability of households to afford basic energy services and challenge commercial users to remain competitive. Furthermore most of the conventional energy technologies lead to unintended environmental and socio-economic impacts as emitting GHGs contributing to climate change, generating public health issues or nuisance, or lead to unsustainable use of other natural resources (as fresh water, available space, and other resources) essential to the sustainable development of SIDS. The need to invest in storage infrastructure to store imported fossil fuels to guarantee the continued supply of energy, because of the remoteness of many SIDS, represents an additional cost and land use competition challenge.

Figure 11 shows the amount of consumed petroleum[60] (for power generation, transportation, or other) by the SIDS DOCK membership in 2006, 2009 and 2011.

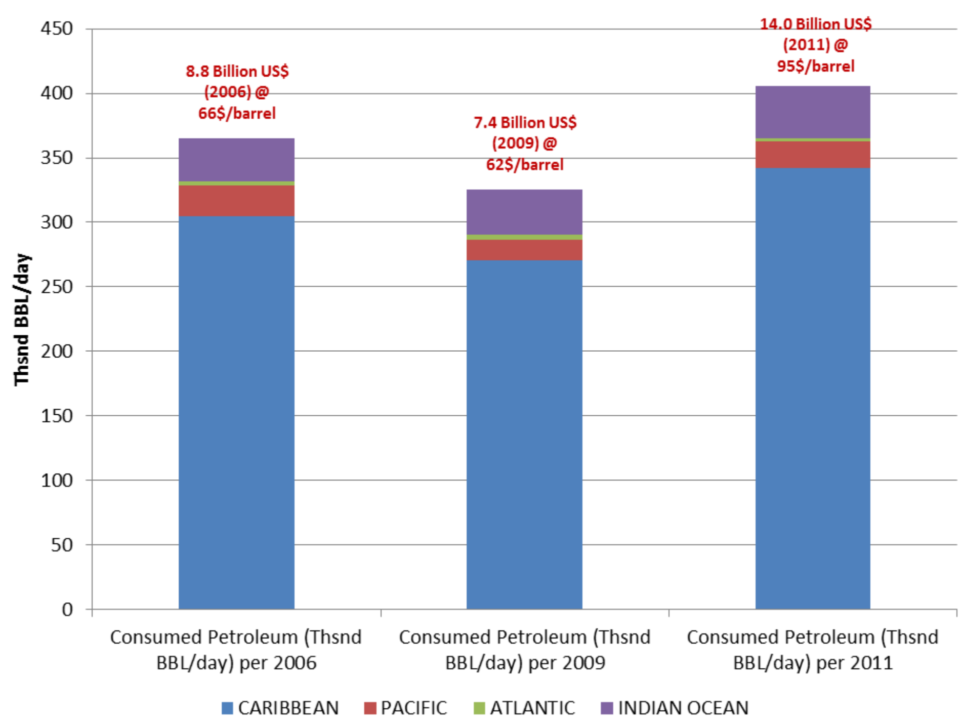

Figure 11 Consumed petroleum by SIDS major groups (Thousand barrels/day)[61]

As can be seen in Figure 11, the SIDS DOCK membership[62] has consumed about 364,970 barrels per day in 2006; 325,240 barrels per day in 2009; and about 405,400 barrels per day in 2011, costing the SIDS about US$24.1 Million/day (with an average annual petroleum price of US$66/barrel); US$20.2 Million/day (with an average annual petroleum price of US$62/barrel); and US$38.5 Million/day (with an average annual petroleum price of US$95/barrel), in these respective years. On an annual basis this signifies about US$8.8 Billion (2006), US$7.4 Billion (2009), and US$14.0 Billion (2011)[63].

[60] The petroleum includes among other distillate #2, distillate #6, diesel, gasoline and other petroleum products consumed for both power generation and used as transportation fuel. Please note that these are indicative values where more detail is required to assess composition of the "Petroleum" and how each petroleum products is consumed in each respective SIDS.
[61] U.S. Energy Information Administration, Country Analysis Brief, see: http://www.eia.gov/countries/ (visited November 2012)
[62] No data was found for the Federal State of Micronesia, Marshall Islands, Palau, and Tuvalu regarding the petroleum consumption expressed in thousand barrels per day.
[63] U.S. Energy Information Administration, Crude WTI SPOT Prices, EIA website: http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RWTC&f=D (Visited October, 2012)

A significant fraction of the consumed petroleum in the SIDS DOCK member states is utilized for power generation (estimated to be about 25% of total imported petroleum products). This is imported in the form of diesel, fuel oil #6 of HFO to run diesel generators and/or fuel oil boilers using rankine-steam systems. Figure 12 shows the net electricity generation and consumption in each SIDS DOCK member as per 2009.

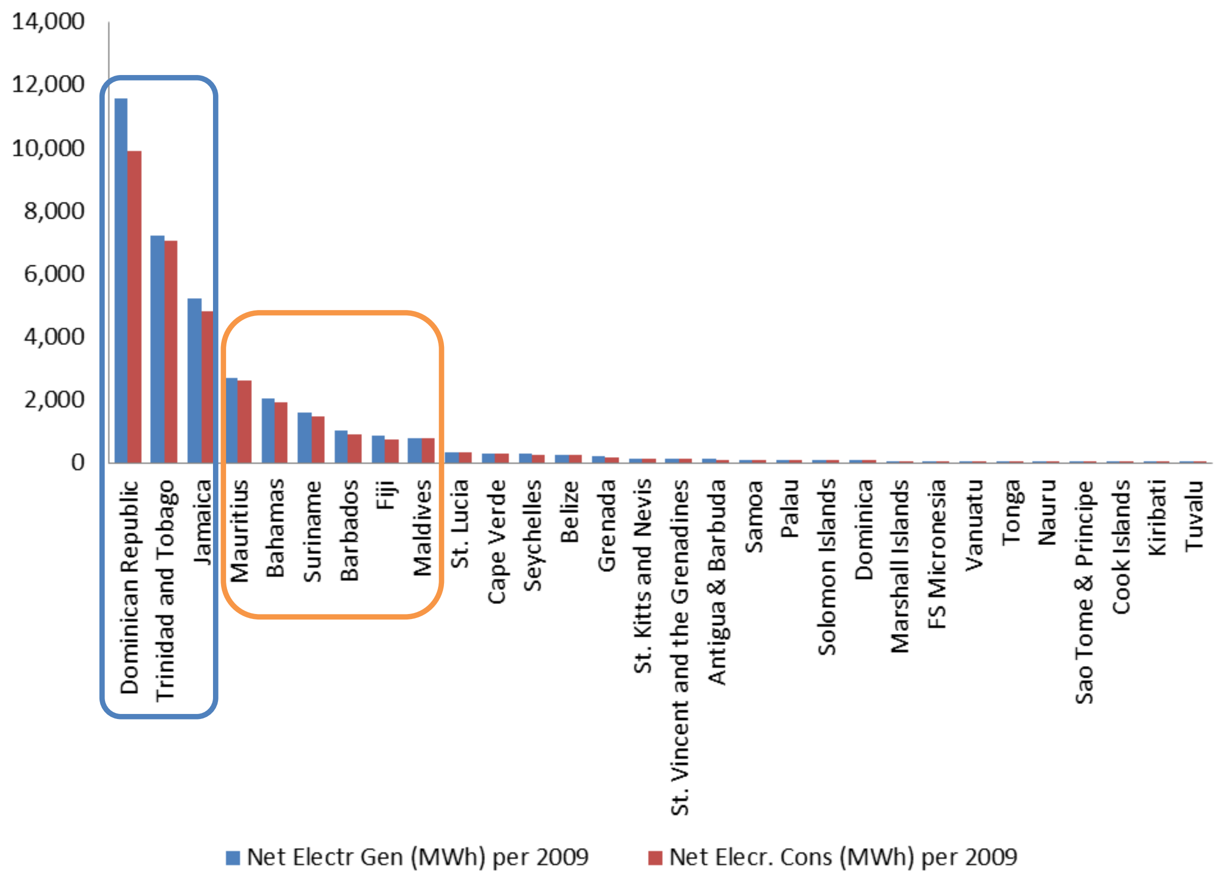

Figure 12 Net Electricity Generation and Consumption (2009) per SIDS DOCK Member State (MWh/year)

There is a clear difference in power generation capacity between the SIDS DOCK members, with the Dominican Republic having the largest electricity generation capacity in place. In general the SIDS can be categorized in three major groups defined by the electricity market size, (1) large size power market (the large Antilles, including the Dominican Republic, Trinidad & Tobago and Jamaica), (2) medium size power market (including Mauritius, Bahamas, Suriname, Barbados, Fiji and Maldives), and (3) small size power market (the remainder of the SIDS DOCK members).

A unique feature of the Dominican Republic is that it has the largest gap between the power generation and consumption rate which can signify multiple things, including significant losses in transmission and distribution, and/or lack of proper capacity expansion planning possibly leading to high costs of electricity rates in the nation. Unfortunately no official statistics are publically available regarding the electricity rates in the DR. The electricity rates in 2009 are shown for the remainder of the SIDS DOCK members in Figure 13.

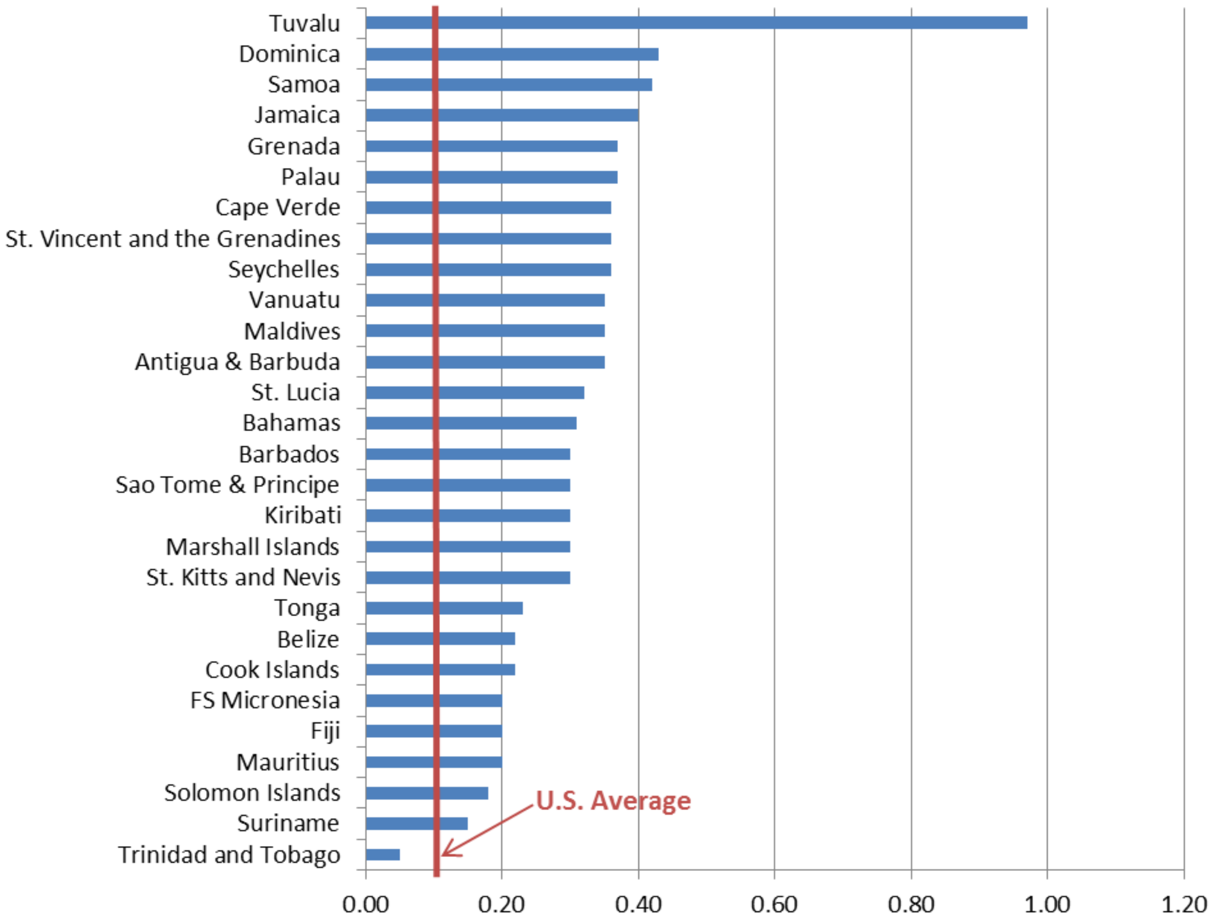

Figure 13 Average 2009 Electricity Rates in SIDS DOCK Member States ($/kWh)[64]

The high cost of imported fossil fuels among other factors as small economies of scale and inefficiencies in power generation, transmission and/or distribution leads to SIDS around the globe having the highest average electricity rates in the world. All except Trinidad and Tobago have average electricity prices higher than the U.S. average electricity rate. This has significant implications on the cost of living, in particular households and the competitiveness of businesses in SIDS. It is therefore important to re-iterate the reason and aim to promote the deployment of energy technologies that enable island communities to transition away from this scenario.

Figure 14 depicts the crude oil price evolution since 1974 and clearly showcases that from 2005 forward the crude oil prices have not returned below the US$36 per barrel price. This was the turning point into the new reality, where the global community is nowadays confronted with a steadily increasing price trend and higher volatility.

[64] Aruba Sustainable Development Foundation (ASDF), SIDS-appropriate Sustainable Energy Technology Assessment, chapter 5, November 2012

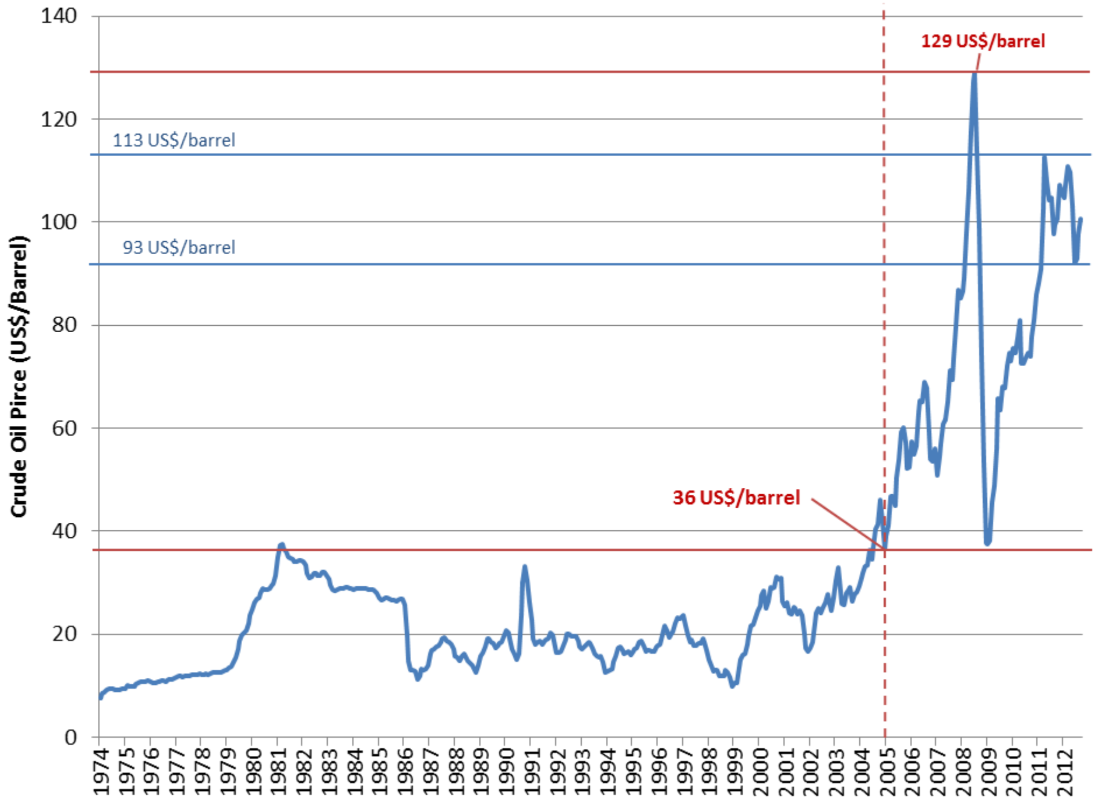

Figure 14 Refiner Acquisition Cost of Crude Oil, Composite (1974-2012)[65]

In the past two years (2011-2012) the price has been hovering between the US$93-113 per barrel. The price development trend is progressing into a direction away from what was once considered the era of cheap oil with prices below $40 per barrel. This is a critical reason for SIDS to invest in renewable energy supply technologies to become less dependent on imported fossil fuels.

Next to energy supply and generation, access to energy is another important element of guaranteeing the provision of proper services to all citizens in a SIDS. Some SIDS, as the low-lying coastal nations and larger islands have the potential to improve their electrification rate and achieve full coverage and interconnection to the national grid in future, while other isolated and remote islands or atolls of archipelagos will have to operate with stand-alone energy generating systems or build isolated mini-grids to allow for the optimal deployment and use of renewable energy technologies. This scenario is particularly relevant to the Pacific region and some archipelagos in other major regions, where most consist of many and very small islands or atolls requiring completely different energy development needs compared to larger single islands or low-lying coastal nations. This automatically leads to the need to differentiate between centralized and decentralized strategies and technological solutions. Please see Figure 15 for an overview of the electrification rates in each respective SIDS DOCK member.

[65] U.S. Energy Information Administration, November 2012 Monthly Energy Review, Released November 28, 2012, see: http://www.eia.gov/totalenergy/data/monthly/index.cfm (Visited November 2012)

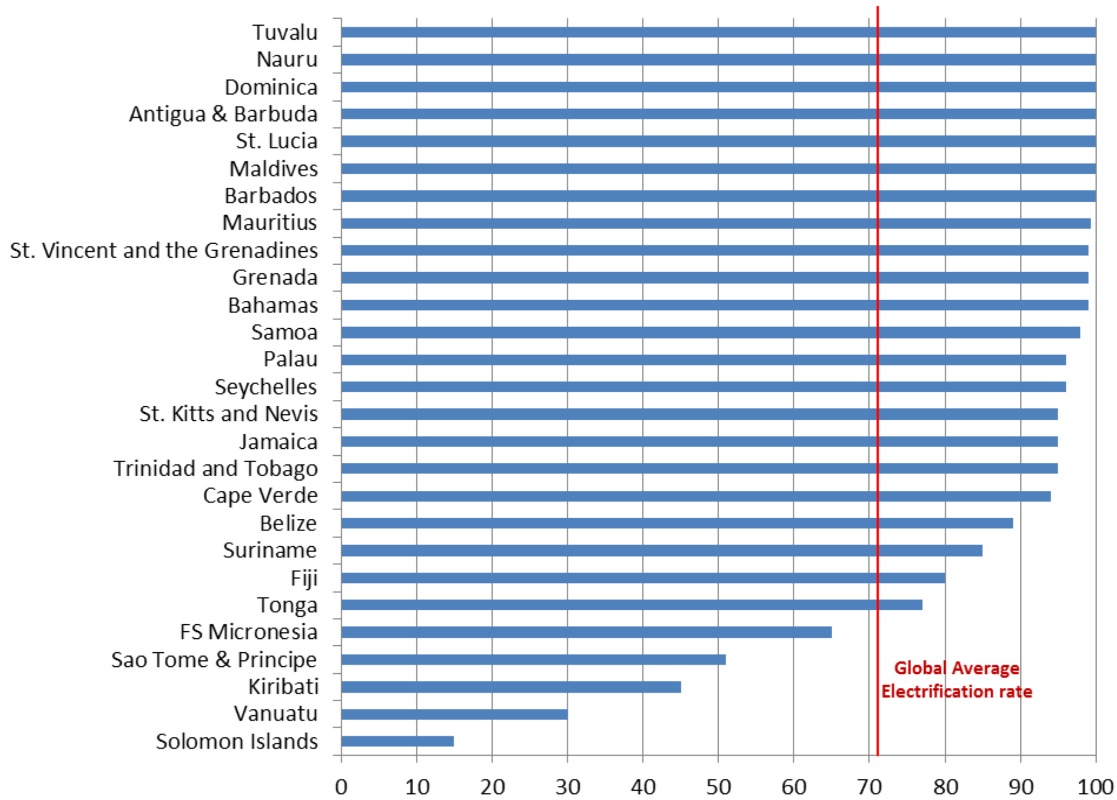

Figure 15 Electrification Rate (%) in SIDS DOCK Member States[66]

Among the SIDS, Tonga, Federated States of Micronesia, Sao Tome & Principe, Kiribati, Vanuatu and Solomon Islands have electrification rates below the global average electrification rate. No information was found regarding the electrification rates in Cook Islands, the Dominican Republic, and the Marshall Islands. Furthermore there is a significant fraction of the SIDS DOCK membership that has not achieved 100% electrification rates. Among these are not only archipelagos of many atolls and outer islands, but also include low-lying coastal countries and larger Antilles. Based on the known population sizes and the electrification rates in each SIDS, a rough indication of population not electrified is estimated to be about 1.4 million people (~7%) of the 20.3 million citizens of the SIDS DOCK membership.

Summary of findings

The 30 SIDS DOCK member states analyzed in this report represent a population of about 20.3 million people. The SIDS are very different in size and have diverse environmental and physical conditions where 60% of the SIDS DOCK membership is smaller than 1,000 km^2, and therefore different levels of capacity and RESs are available. At the macro level none of the SIDS DOCK members are currently considered low income countries, but are challenged to maintaining this status as they all are reaching their maximal carrying capacity which can or will significantly impact the socio-economic development in these nations. This same carrying capacity is being impacted by among other the population growth, climate change, and un-sustainable extraction of resources.

Next to SIDS reaching their maximal carrying capacity, energy supply, generation, distribution and use is increasingly becoming expensive (with electricity rates ranging between US$0.05 – 0.97 per kWh), unreliable, and leading to unintended local, regional and global socio-environmental impacts. Only the larger and high-income SIDS have power market sizes that may attract private sector interest, 21 of the 30 SIDS DOCK members have very small power markets with electricity generations levels below 340 MWh/year. In order to better understand and prepare strategies and technological solutions that are suitable to addressing the energy needs in SIDS, the following issues are to be taken into account when developing a strategic plan to transfer SIDS-appropriate sustainable energy technologies to SIDS.

Imported fossil fuels

The amount of consumed petroleum in the SIDS DOCK membership was about 133.2 Million Barrels (2006), 118.7 Million barrels (2009), and 148.0 Million barrels (2011) signifying about US$8.8 Billion (2006), US$7.4

[66] Derived from Energy Access in the World: Facts and Scenarios, Alliance for Rural Electrification (ARE), see: http://www.ruralelec.org/9.0.html (visited November 2012)

Billion (2009), and US$14.0 Billion (2011)[67] in costs, respectively. In the case of the SIDS DOCK membership about 95% of this consumed petroleum is imported from elsewhere outside the country. Of this amount of imported petroleum about 30% is used for power generation and about 70% for transportation in SIDS.[68] This represents a significant amount of expenditure or foreign exchange deficit and is one of the most critical factors impacting the national financial budgets to be able to invest in the sustainable development of SIDS. Please note that these are just indicative values and can only be verified and properly analyzed at the national level.

This particular cost factor (cost for imported fossil fuels) is one of the principal impediments to the sustainable development of SIDS and is therefore the reason that all three principal targets set by SIDS DOCK have a focus on the reduction of consumption of imported fossil fuels in SIDS by (1) increasing energy efficiency by 25 percent (2005 baseline) by 2033, (2) generating a minimum of 50 percent of electric power from renewable sources by 2033, and (3) achieving 25 percent decrease in conventional transportation fuel use by 2033.

SIDS DOCK recognizes that the increased deployment and use of SIDS-appropriate sustainable energy supply and end-use energy technologies is needed to achieve these set goals, therefore the need for a *plan to identify, assess and transfer technologies that are SIDS-appropriate*. In the following chapters focus is placed on addressing the barriers to the transfer of RETs to SIDS and recommendations made regarding how to optimize this process of *Transfer of Technology* to SIDS and what role SIDS DOCK can take in facilitating this process.

Energy needs in SIDS
In summary all SIDS DOCK members require energy technology solutions that can enable them to:
(1) Lower electricity rates;
(2) Reduce the cost of import of energy that burdens the national budgets of SIDS; and
(3) Achieve practical, reliable, affordable, and sustainable energy services to its citizens.

These elements contribute to addressing Energy Security, Energy Costs and Climate Change that is confronted by all SIDS DOCK members.

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[67] U.S. Energy Information Administration, Crude WTI SPOT Prices, EIA website: http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RWTC&f=D (Visited October, 2012)
[68] Commission on Sustainable Development, 4th Session (18 April – 03 May, 1996), Sustainable Development of energy resources in small island developing states, see: http://islands.unep.ch/d96-20a2.htm (visited November 2012)

6. Description of Renewable Energy Supply Technologies

In the following sections, an overview is provided of RETs regarding how they work, their current status of development and use, and where possible their costs are provided. The different energy supply technologies that will likely play a role in a sustainable SIDS' future have been extensively reviewed in different studies.[69,70,71] The usual list includes renewable energy technologies (e.g., wind, solar and biomass) and some advanced fossil-fuel systems with carbon capture and sequestration. Natural gas systems are widely viewed as a crucial 'bridge' technology. In addition, energy efficiency is often cited as a critically important and an often lower-cost complement to improvements on the energy supply side.

However, given the terms of reference for this report, only RE sources (wind, solar, biomass, geothermal, and ocean energy) and RETs are presented in this section. This is also in line with the definition of renewable energy sources in Article III of the Statutes of the International Renewable Energy Agency (presently the highest global authority regarding renewable energy development).[72] In principle, all our energy needs, both now and into the future, can be met by energy from renewable sources utilizing RETs without compromising the ability of future generations to meet their own energy need. Such technologies that convert renewable energy sources to modern energy carriers or directly into desired energy services reducing SIDS dependency on finite fossil fuel, reducing pollution and improving energy security, exist and are widely available.[73] The goal is to select among these SIDS-appropriate energy technologies and making them increasingly available in SIDS to address specific energy needs to provide affordable, reliable and clean energy.

6.1 Solar Energy Technologies [74,75,76]

Solar thermal systems

Solar thermal power systems use various techniques to focus sunlight to heat an intermediary fluid, known as heat transfer fluid that then is used to generate steam. The steam is then used in a conventional steam turbine to generate electricity. At present, there are three solar thermal power systems being developed: parabolic troughs, power towers, and dish/engine systems. Because these technologies involve a thermal intermediary, they can be readily hybridized with fossil fuels and in some cases adapted to utilize thermal storage. One advantage of hybridization and thermal storage is that the technology can provide dispatchable power and operate during periods when solar energy is not available. In some cases, hybridization and thermal storage can enhance the economic value of the electricity produced, and reduce its average cost.

Parabolic trough solar thermal systems are commercially available. These systems use parabolic trough-shaped mirrors to focus sunlight on thermally efficient receiver tubes that contain a heat transfer fluid. This fluid is heated to about 390° C. (734° F) and pumped through a series of heat exchangers to produce superheated steam that powers a conventional turbine generator to produce electricity. In average, the systems can be sized between 14 and 100 MW, are hybridized with up to 25 percent natural gas in order to provide dispatchable power when solar energy is not available.

Power tower solar thermal systems are in the scale-up phase to commercial use. They use a circular array of heliostats (large individually-tracking mirrors) to focus sunlight onto a central receiver mounted on top of a tower. The first power tower, Solar One, was built in Southern California and operated in the mid-1980s. This initial plant used a water/steam system to generate 10 MW of power. In 1992, a new system was developed to demonstrate a molten-salt receiver and thermal storage system. The addition of this thermal storage capability makes power towers unique among solar technologies by allowing dispatchable power to be provided at load

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[69] Renewables in Global Energy Supply, International Energy Agency, 2007. Retrieved from: http://www.iea.org/papers/2006/renewable_factsheet.pdf

[70] MacGill, L., Assessing Australia's Sustainable Energy Technology Options: Key Issues, Uncertainties, Priorities and Potential Choices, Centre for Energy and Environmental Markets University of New South Wales, Australia, 2008. Retrieved from: http://www.ceem.unsw.edu.au/sites/default/files/uploads/publications/apjel-macgill.pdf (visited October, 2012)

[71] Sustainable Energy Technology at Work, Daugaard N., et al., CPL Press, Newbury UK, 2008. Retrieved from: http://www.zreu.de/images/Unternehmen/Publikationen/TatW_final_report_080331.pdf (visited October, 2012)

[72] International Renewable Energy Agency (IRENA), Statute of the International Renewable Energy Agency (IRENA), January 2009, see: http://www.irena.org/documents/uploadDocuments/Statute/IRENA_FC_Statute_signed_in_Bonn_26_01_2009_incl_declaration_on_further_authentic_versions.pdf (visited October, 2012)

[73] Ibid. 69

[74] Renewable Energy: Power for a Sustainable Future, Second Edition, Godfrey Boyle, Oxford University Press; 2nd edition (May 6, 2004), ISBN-10: 0199261784.

[75] Handbook of Renewable Energy Technology, Ahmed F Zobaa and Ramesh C Bansal, World Scientific Pub Co Inc., 1 edition (January 26, 2011), ISBN-10: 981428906X.

[76] Renewable Energy Technology Characterizations, U.S. Department of Energy, 1997. Retrieved from: http://www.nrel.gov/docs/gen/fy98/24496.pdf (visited October, 2012)

factors of up to 65 percent. In this system, molten-salt is pumped from a “cold” tank at 288° C. (550° F) and then cycled through the receiver where it is heated to 565° C. (1,049° F) and finally returned to a “hot” tank. The hot salt can then be used to generate electricity when needed. Current designs allow storage ranging from 3 to 15 hours.

Dish/engine solar thermal systems, currently in the prototype phase to scale-up phase, use an array of parabolic dish-shaped mirrors to focus solar energy onto a receiver located at the focal point of the dish. Fluid in the receiver is heated to 750° C (1,382° F) and used to generate electricity in a small engine attached to the receiver. Engines currently under consideration include Stirling and Brayton-cycle engines. High optical efficiency and low startup losses make dish/engine systems the most efficient of all solar technologies, with electrical conversion efficiencies of up to 29.4 percent. In addition, the modular design of dish/engine systems makes them a good match for both remote power needs, in the kilowatt range, as well as grid-connected utility applications in the megawatt range. However, the amount of electricity generated is small if it is compared with other concentrating technologies, in the range of 3 to 25kW.[77]

Costs

System capital costs for these systems are presently about US$4-5 per watt for parabolic trough and power tower systems, and about US$12-13 per watt for dish/engine systems. However, future cost projections for trough technology are higher than those for power towers and dish/engine systems due in large part to their lower solar concentration and hence lower operating temperature and efficiency. By 2030, the U.S. Department of Energy forecasts costs of US$2.70 per watt, US$2.50 per watt, and US$1.30 per watt, respectively, for parabolic trough, power tower, and dish engine systems.[78]

Solar photovoltaic systems

Solar PV modules are solid-state semiconductor devices with no moving parts that convert sunlight into direct-current electricity. The basic principle of PV modules dates back 100 years, but significant development really began following Bell Labs’ invention of the silicon solar cell in 1954. The first major application of PV technology was to power satellites in the late 1950s, and this was an application where simplicity and reliability were paramount and cost was a secondary concern. Since that time, enormous progress has been made in PV performance and cost reduction, driven at first by the U.S. space program’s needs and more recently through private/public sector collaborative efforts in the U.S., Europe, China and Japan.

Most modern solar cells use semiconductor materials, whereby silicon wafer based technologies dominate today’s market. The large variety of PV applications allows for a range of different technologies to be present in the market, from low-cost, lower efficiency technologies to high-efficiency technologies at higher cost. Figure 16[79] gives an overview of the cost and performance of different PV technologies.

[77] Dish/Engine Systems for Concentrating Solar Power, U.S. Department of Energy. Retrieved from: http://www.eere.energy.gov/basics/renewable_energy/dish_engine.html (visited October, 2012)
[78] Annual Energy Outlook 2007 with projections for 2030, U.S. Department of Energy and Energy Information Administration, 2007. Retrieved from: ftp://tonto.eia.doe.gov/forecasting/0383%282007%29.pdf (visited October, 2012)
[79] Technology Road Map, Solar Photovoltaic Energy, International Energy Agency, 2010. Retrieved from: http://www.iea.org/papers/2010/pv_roadmap.pdf (visited October, 2012)

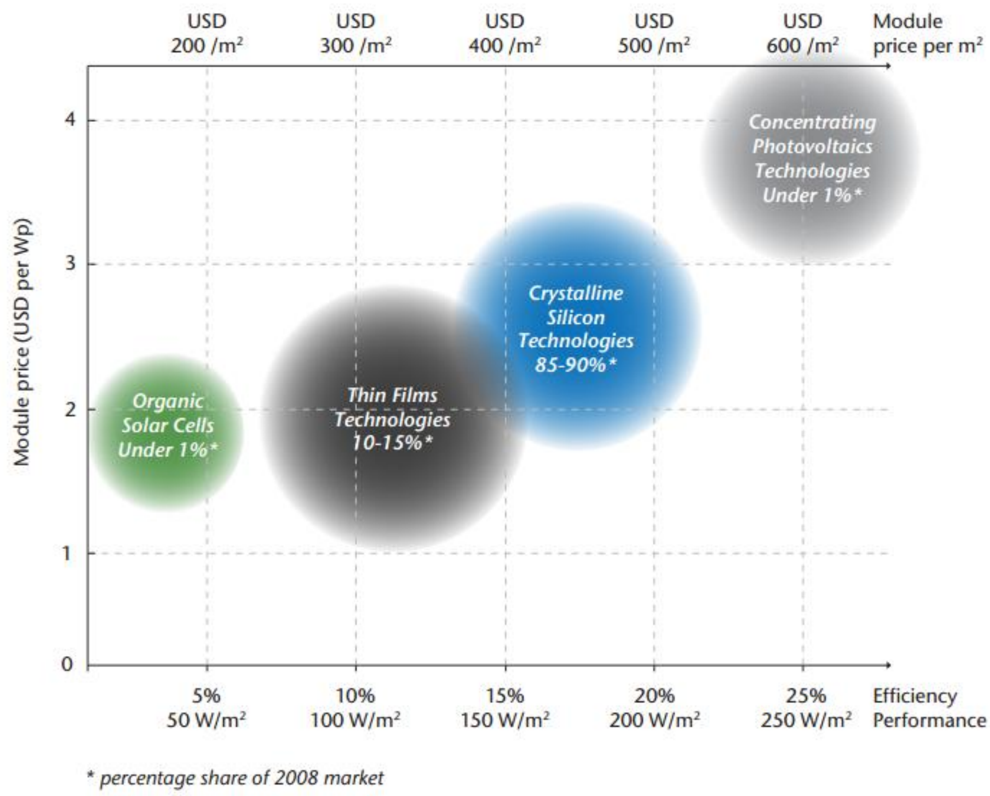

Figure 16 Cost and performance of solar photovoltaic technologies

Photovoltaic modules have followed a well-documented historical trend of price decline. Since 1976, global module prices declined about 20% on average for every doubling of cumulative global production, resulting in a price decline of roughly 95%—from about \$60/W to about \$2/W—between 1976 and 2010, for details please see Figure 17.[80]

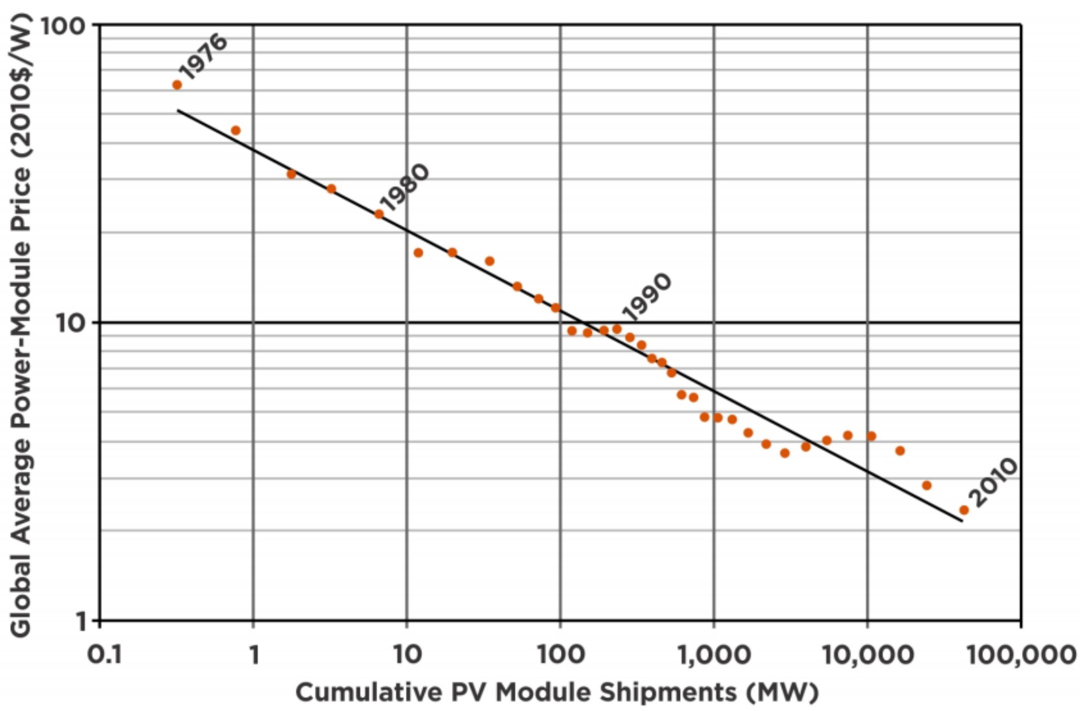

Figure 17 Decline in Factory-Gate PV Module Prices with Increasing Cumulative Module Shipments

The installed price of a commercial system in 2010 was roughly \$5/W, about 20% lower than for a residential system. Utility-scale PV systems typically have the lowest installed price: roughly \$4/W in 2010. These systems are large enough to realize significant economies of scale in component purchasing and installation labor, significantly reducing installed system prices. Many module manufacturers act as the engineering, procurement, and construction (EPC) firm for large-scale utility installations, achieving an improvement in supply chain costs over traditional third-party installers.

The technical and economic driving forces that favor the use of PV technologies in these widely ranging applications will be equally diverse. However, common among them will be the durability, high efficiency, quiet

[80] SunShot Vision Study, U.S. Department of Energy, 2012. Retrieved from: http://www1.eere.energy.gov/solar/pdfs/47927_chapter4.pdf

operation, and lack of moving parts that PV systems offer, and the fact that these attributes combine to provide a power source with minimum maintenance and unmatched reliability. Additionally, the huge potential reductions in cost in the near future, combined with the simplicity, versatility, reliability, and low environmental impact of PV systems, should help them to become increasingly important sources of economical premium-quality power over the next 10 years.

6.2 Wind Energy Technologies [81,82]

Wind energy production is dependent on wind speed, which varies on a global, regional and even local basis, often following seasonal patterns. This means that detailed wind resource assessments must be carried out at potential sites before the feasibility of a wind energy project can be determined. In general, wind resources are good in higher latitudes to poor in lower latitudes close to equatorial areas.[83] SIDS are located in low latitudes and for that reason a feasible wind project needs confirmation through measurements for at least 1-2 years. Besides, given constraints on land availability, the difficulty in obtaining land leases and the large risk of damage to turbines posed by hurricanes or cyclones (in particular large-scale wind farms), many challenges exist to sort the quality of wind regimes in SIDS for wind energy generation. However, there are many SIDS with enough or significant potential to justify the use of this resource.

Larger units, more efficient manufacturing, and careful siting of wind turbines have brought wind power costs down from $1,600 per kilowatt (kW) in 1997 to $900-$1,400 per kW in 2011, see Figure 18. Today, wind energy is currently one of the most cost-competitive renewable energy technologies. When large scale wind farms were first set up in early 1980s, wind power was costing as much 30 cents per kWh. Presently (2012), new installations located in the "most" favorable locations (with good quality wind regimes) can produce electricity for less than 5 cents per kWh.[84]

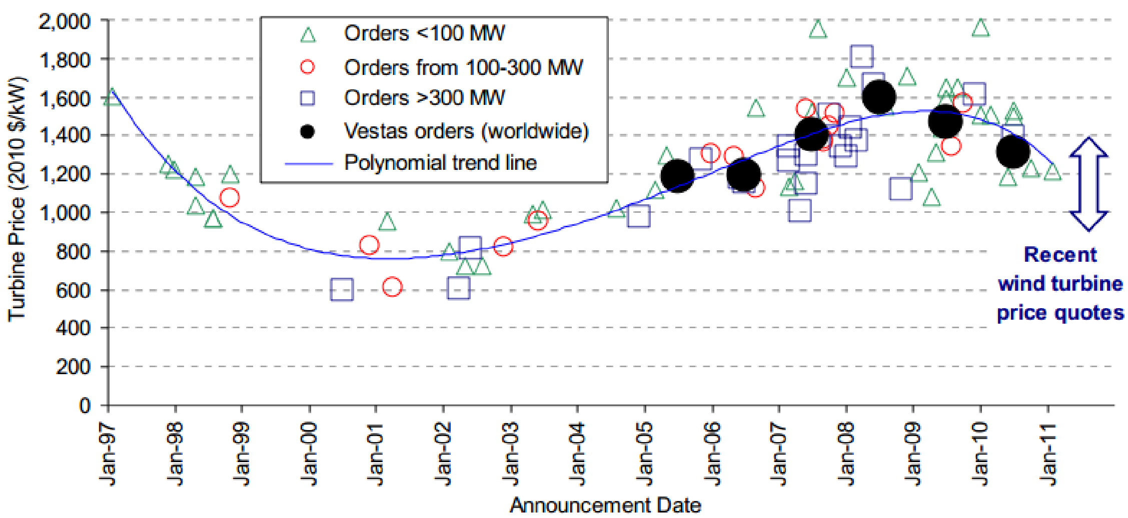

Figure 18 Wind Turbine Price development between 1997 and 2011[85]

Resource and Environmental Issues

The main technical parameter determining the economic success of a wind turbine system is its annual energy output, which in turn is determined by parameters such as average wind speed, statistical wind speed distribution, distribution of occurring wind directions, turbulence intensities, and roughness of the surrounding terrain. Of these the most important and sensitive parameter is the wind speed (where the power in the wind is proportional to the third power of the momentary wind speed), which increases with height above the ground. As a result vertical axis wind turbines have mostly been abandoned in favor of the taller traditional horizontal axis configuration. As accurate meteorological measurements and wind energy maps become more commonly available, wind project developers are able to more reliably assess the long-term economic performance of wind farms.

[81] Renewable Energy: Power for a Sustainable Future, Second Edition, Godfrey Boyle, Oxford University Press; 2nd edition (May 6, 2004), ISBN-10: 0199261784.
[82] Handbook of Renewable Energy Technology, Ahmed F Zobaa and Ramesh C Bansal, World Scientific Pub Co Inc., 1 edition (January 26, 2011), ISBN-10: 981428906X.
[83] Latitude is "0 degree" in the equator and then it increases to 90 degrees in the poles. For that reason in earth sciences the phenomenology location is described in terms of latitude. In the case of SIDS majority are located in low latitudes and have in general poor wind regimes compared with regions close to the poles. This is based on the pressure gradient due to the non-homogeneous distribution of the solar energy in the earth.
[84] Economics of Wind Energy, University of Illinois at Urbana-Champaign, 2012. Retrieved from: https://netfiles.uiuc.edu/mragheb/www/NPRE%20475%20Wind%20Power%20Systems/Economics%20of%20Wind%20Energy.pdf
[85] Understanding Trends in Wind Turbine Prices Over the Past Decade, Lawrence Berkeley National Laboratory, 2011. Retrieved from: http://eetd.lbl.gov/ea/ems/reports/lbnl-5119e.pdf

Some of the problems with wind power involve siting wind turbines. In densely populated countries where the best sites on land are occupied there is increasing public resistance making it impossible to realize projects at acceptable cost. This is one of the main reasons that countries like Denmark and the Netherlands are concentrating on offshore projects, despite the fact that technically and economically they are expected to be less favorable than "good" on-shore sites. On the other hand, in countries like the United Kingdom and Sweden offshore projects are being planned not due to scarcity of suitable land sites, but because preserving the landscapes are considered such an important national value. Another obstacle can be that the best wind site locations are not in close proximity to populations with the greatest energy needs, making such sites impractical due to the high cost of transmission over long distances. These factors are relevant and must be evaluated under SIDS circumstances.

Wind energy although considered an environmentally sound energy option has a limited amount of negative environmental aspects connected to its use. These include: acoustic noise emission, visual impact on the landscape, impact on bird's life, shadow caused by the rotor, and electromagnetic interference influencing the reception of radio, TV and radar signals. In practice the noise and visual impacts appear to cause the most problems for siting projects. Noise issues have been reduced by progress in aero-acoustic research providing design tools and blade configurations that have successfully made blades considerably quieter.

In addition to being cost-competitive and environmentally sound, wind energy has several additional advantages over conventional fossil fuel power plants and even other renewable energy sources. First it is modular: that is, the generating capacity of wind farms can easily be expanded since new turbines can be quickly manufactured and installed, not true for either coal-fired or nuclear power plants. Second, a repair to one wind turbine does not affect the power production of all the others. Third, the energy generated by wind turbines can pay for the materials used to make them in as short as 3 - 4 months for good wind sites. Fourthly, during normal operation they produce no emissions.

Despite these advantages wind's biggest drawback continues to be its intermittence and mismatch with power demand. *However, there are many R&D initiatives focused on developing new energy storage technologies, for example superconducting magnetic energy storage system or super-capacitors. Nearly all kinds of superconducting power products are anticipated to reach the commercialized use in about 2015.*[86]

6.3 Hydro Energy Technologies [87,88]

Historically Hydropower has been the largest renewable resource used for electricity generation. In many regions it is the main source of energy for electricity generation. Hydropower produces around 16 % of the world's electricity and over four-fifths of the world's renewable electricity. Currently, more than 25 countries in the world depend on hydropower for 90 % of their electricity supply (99.3 % in Norway), and 12 countries are 100 % reliant on hydro. Hydro produces the bulk of electricity in 65 countries and plays some role in more than 150 countries.[89]

Hydropower is the only large-scale and cost-efficient storage technology available today. The global technically useable hydropower potential is estimated at more than 16,400 Tera-Watt-hour (TWh) per year. This potential is unevenly distributed. The five countries with the highest potential (China, United States, Russia, Brazil and Canada) could produce about 8,360 TWh per year, and the next five countries (DR Congo, India, Indonesia, Peru and Tajikistan) have a potential of about 2,500 TWh per year. These ten countries account for about two-thirds of the global hydropower potential. Globally, around 19% of the potential has been developed (2010). Countries which have actively developed hydropower use around 60% of their potential. Numerous other countries have a huge amount of untapped hydropower potential.[90]

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[86] Theory and Application of Superconducting Magnetic Energy Storage, Jian X. Jin et al., 2006. Retrieved from: http://itee.uq.edu.au/~aupec/aupec06/htdocs/content/pdf/51.pdf

[87] Renewable Energy: Power for a Sustainable Future, Second Edition, Godfrey Boyle, Oxford University Press; 2nd edition (May 6, 2004), ISBN-10: 0199261784.

[88] Handbook of Renewable Energy Technology, Ahmed F Zobaa and Ramesh C Bansal, World Scientific Pub Co Inc., 1 edition (January 26, 2011), ISBN-10: 981428906X.

[89] Hydropower, IRENA, 2012. Retrieved from: http://www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-HYDROPOWER.pdf

[90] Renewable Energy Essentials: Hydropower, Energy International Agency, 2010. Retrieved from: http://www.iea.org/papers/2010/Hydropower_Essentials.pdf

Economics

The construction costs depend on the size of the plant. New hydropower projects in OECD countries are usually less than $US 2 million/MW for large scale hydro (> 300 MW), and $US 2 to 4 million/MW for small- and medium-scale hydro (< 300 MW). However, initial investment needs for any project must be studied individually due to the unique nature of each hydropower project.[91] According to the International Energy Agency, the investment cost based on plant size can be classified as shown in Table 23.

Table 23 Classification of Hydropower

CATEGORY	OUTPUT/UNIT	STORAGE	POWER USE (LOAD)	INVESMENT COST ($US M/MW)
1 SMALL	<10 MW	RUN-OF-RIVER	BASE LOAD	2-4
2 MEDIUM	10-100 MW	RUN-OF-RIVER	BASE LOAD	2-3
3 MEDIUM	100-300 MW	DAM AND RESERVOIR	BASE AND PEAK	2-3
4 LARGE	>300 MW	DAM AND RESERVOIR	BASE AND PEAK	<2

Environmental and social impacts of large Hydropower

In the last decade a large number of hydropower projects have been scrutinized. A report entitled "Dams and Development: A New Framework for Decision Making (2000)"[92] drew from eight detailed case studies, 125 surveys, hundreds of consultations worldwide, and over 900 evaluative submissions. While acknowledging the historical contributions dams have made to economic growth, it concluded that "in too many cases an unacceptable and often unnecessary price has been paid to secure those benefits, especially in social and environmental terms, by people displaced, by communities downstream, by taxpayers and by the natural environment." To build a dam significant amounts of land need to be flooded often in densely inhabited rural areas, involving large displacements of usually poor, indigenous peoples. Mitigating such social impacts represents a significant cost to the project, which if it is even taken into consideration, often not done in the past, can make the project economically and socially unviable. For that reason, today to implement hydropower projects in a sustainable manner, all environmental and social impacts need to be explored and anticipated early in the planning process so that appropriate steps can be taken to avoid, mitigate, or compensate for impacts.

The International Hydropower Association has developed a Draft Hydropower Sustainability Assessment Protocol[93] for large Hydropower plants aimed to improve sustainability as a main component of large hydropower plants.

Small hydropower

Small, mini and micro hydro plants (usually defined as plants less than 10 MW, 2 MW and 100kW, respectively) also play a key role in many countries for rural electrification. An estimated 300 million people in China, for example, depend on small hydro.[94]

Small-scale hydro is mainly 'run of river,' so does not involve the construction of large dams and reservoirs. It also has the capacity to make a more immediate impact on the replacement of fossil fuels since, unlike other sources of renewable energy, small hydropower can generally produce some electricity on demand, especially at times of the year when an adequate flow of water is available, with no need for storage or backup systems. It is also in many cases cost competitive with fossil-fuel power stations, in particular in remote rural areas.

Small hydropower has a large, and as yet untapped, potential in many parts of the world. It depends largely on already proven and developed technology with scope for further development and optimization. Least-cost hydro is generally high-head hydro since the higher the head, the less the flow of water required for a given power level, and so smaller and less costly equipment is needed. Low-head hydro on the other hand is relatively common, and also tends to be found in or near concentrations of population where there is a demand for electricity.

The International Energy Agency has developed a guide to support and improve sustainability of small hydro projects. The report is called "Assessment Methods for Small-hydro Projects".[95]

[91] Ibid.90

[92] Dams and Development: A New Framework for Decision Making, World Commission on Dams (WCD), IUCN-WB, 2000. Retrieved from: http://www.unep.org/dams/WCD/report/WCD_DAMS%20report.pdf

[93] Hydropower Sustainability Assessment Protocol, 2012. Retrieved from: http://www.hydrosustainability.org/Hydropower-Sustainablility-Assessment-Protocol.aspx

[94] World Energy Outlook, Energy International Agency, 2011. Retrieved from: http://www.iea.org/Papers/2011/weo2011_energy_for_all.pdf

It is absolutely necessary to invest in more R&D to improve the efficiency for turbines, generators, substations, transmission lines, and environmental mitigation technology if small hydropower's role as a clean renewable energy source is to continue to be supported in and for SIDS.

6.4 Geothermal Energy Technologies [96,97,98]

Geothermal energy, the natural heat within the earth, arises from the ancient heat remaining in the Earth's core, from the decay of radioactive elements that occur naturally in small amounts in all rocks and from friction where continental plates slide beneath each other.

A geothermal system requires heat, permeability, and water. The heat from the Earth's core continuously flows outward. Sometimes the heat, as magma, reaches the surface as lava, but it usually remains below the Earth's crust, heating nearby rock and water sometimes to levels as hot as 700°F. When water is heated by the earth's heat, hot water or steam can be trapped in permeable and porous rocks under a layer of impermeable rock and a geothermal reservoir can form. This hot geothermal water can manifest itself on the surface as hot springs or geysers, but most of it stays deep underground, trapped in cracks and porous rock. This natural collection of hot water is called a geothermal reservoir.

The global amount of geothermal energy is enormous. It is estimated that only 1 percent of the heat contained in just the uppermost 10 kilometers of the earth's crust is equivalent to 500 times the energy contained in all of the earth's oil and gas resources.[99] Despite the heat being present in inexhaustible quantities, it is unequally distributed, occasionally concentrated and often at depths too great to be used industrially and economically. Useable geothermal systems occur in a number of environments. High temperature fields used for conventional power production occur mainly in areas of high geological activity. Low temperature resources for direct heating can be found in most countries and can now also be accessed using recently developed ground source heat pumps.

Types of Geothermal plants for Electricity generation[100,101,102,103,104]

There are four commercial types of geothermal power plants: a. flash power plants, b. dry steam power plants, c. binary power plants, and d. flash/binary combined power plants.

a. Flash Power Plant: Geothermally heated water under pressure is separated in a surface vessel (called a steam separator) into steam and hot water (called "brine" in the accompanying image). The steam is delivered to the turbine, and the turbine powers a generator. The liquid is injected back into the reservoir. Figure 19 shows a simplified version of a flash power plant.

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[95] Assessment Methods for Small-hydro Projects, Energy International Agency, 2000. Retrieved from: http://www.ieahydro.org/reports/AnnexII_smallhydro_assessment_methods.pdf

[96] The future of Geothermal Energy, Idaho National laboratory, 2006. Retrieved from: http://web.mit.edu/mitei/research/studies/documents/geothermal-energy/geothermal-energy-1-3.pdf

[97] Renewable Energy: Power for a Sustainable Future, Second Edition, Godfrey Boyle, Oxford University Press; 2nd edition (May 6, 2004), ISBN-10: 0199261784.

[98] Handbook of Renewable Energy Technology, Ahmed F Zobaa and Ramesh C Bansal, World Scientific Pub Co Inc., 1 edition (January 26, 2011), ISBN-10: 981428906X.

[99] Schnell J., Geothermal Energy, Volcanoes of the Eastern Sierra Nevada: Geology and Natural Heritage of the Long Valley Caldera, 2007. Retrieved from: http://www.indiana.edu/~sierra/papers/2007/schnell.html

[100] Geothermal Power Generation, Oregon Institute of Technology, 2000. Retrieved from: http://geoheat.oit.edu/pdf/powergen.pdf

[101] The future of Geothermal Energy, Idaho National laboratory, 2006. Retrieved from: http://web.mit.edu/mitei/research/studies/documents/geothermal-energy/geothermal-energy-1-3.pdf

[102] Renewable Energy: Power for a Sustainable Future, Second Edition, Godfrey Boyle, Oxford University Press; 2nd edition (May 6, 2004), ISBN-10: 0199261784.

[103] Handbook of Renewable Energy Technology, Ahmed F Zobaa and Ramesh C Bansal, World Scientific Pub Co Inc., 1 edition (January 26, 2011), ISBN-10: 981428906X.

[104] Zoe, Y., Bynary Power Plants, Stanford University, 2011. Retrieved from: http://large.stanford.edu/courses/2011/ph240/yan2/

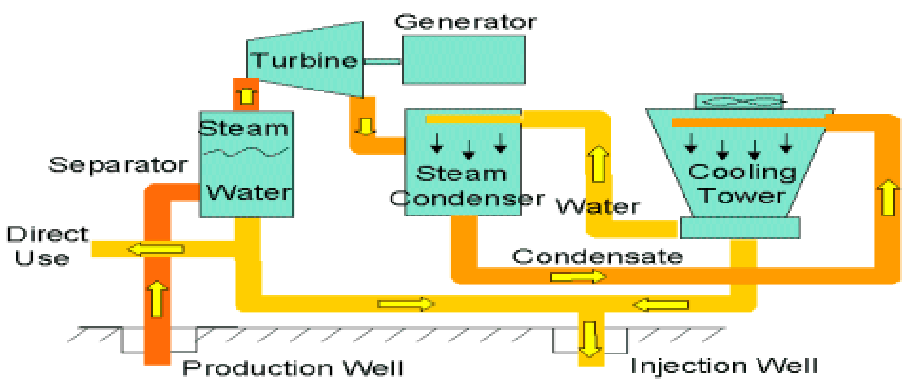

Figure 19 Standard Flash Power Plant

b. Dry Steam Power Plant: Steam is produced directly from the geothermal reservoir to run the turbines that power the generator, and no separation is necessary because wells only produce steam. Figure 20 shows a simplified version of a dry steam power plant.

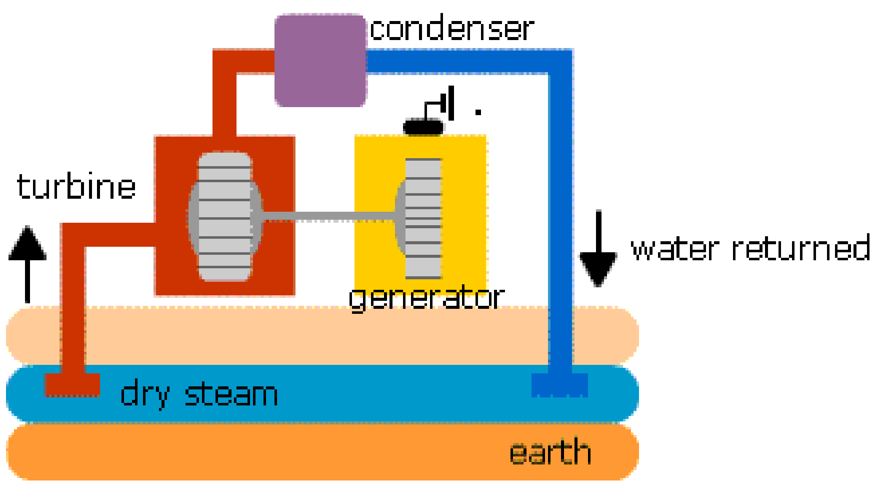

Figure 20 Standard Dry Steam Power Plant

c. Binary Power Plant: Binary plants specifically use a second working fluid (hence, "binary") with a much lower boiling point than water. This technology makes the economic production of electricity from geothermal resources lower than 150°C (302°F) possible. The binary fluid is operated through a conventional Rankine cycle. The geothermal fluid usually heats in this case a hydrocarbon (binary) such as iso-pentane, iso-butane or other organic fluids such as penta-fluoro-propane. The two liquids are kept completely separate through the use of a heat exchanger, which transfers the heat energy from the geothermal water to the working fluid. The secondary fluid expands into gaseous vapor. The force of the expanding vapor, like steam, turns the turbines that power the generators. All of the produced geothermal water is injected back into the reservoir. Figure 21 shows a simplified version of a binary power plant.

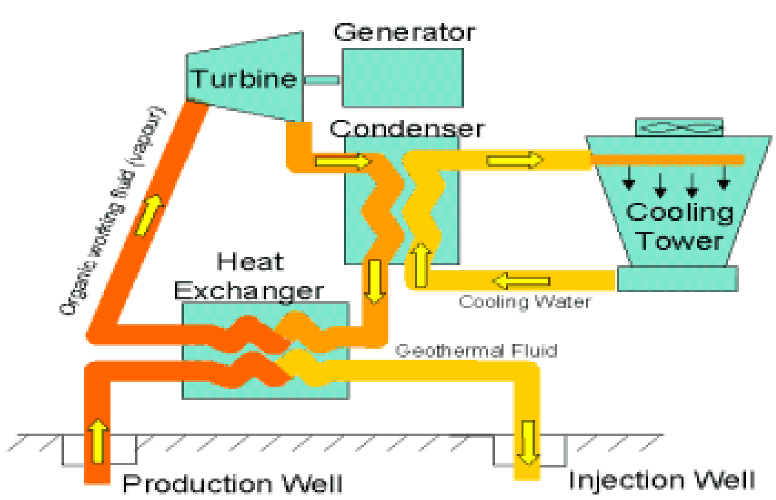

Figure 21 Standard Binary Power Plant

d. Flash/Binary Combined Cycle Plant: This type of plant, which uses a combination of flash and binary technology, has been used effectively to take advantage of the benefits of both technologies. In this type of plant, the portion of the geothermal water which "flashes" to steam under reduced pressure is first converted to electricity with a backpressure steam turbine and the low-pressure steam exiting the backpressure turbine is condensed in a binary system.

Economics[105]

In 2008 capital costs for green-field geothermal flash plant developments ranged from US$ 2,000/kWe to US$ 4,500/kWe , with lower temperature binary developments at US$ 2,400 - 5,900/kWe. Capital cost pay-back times for ground source heat pumps (GSHP) typically range from four to eight years in Europe. Recent electricity generation costs for flash plant developments range from US$ 0.05/kWh to US$ 0.12/kWh for higher temperature resources and US$ 0.07/kWh to US$ 0.20/kWh for lower temperature binary developments. Production costs for district heating in Europe vary between US$ 0.06/kWh_t and US$ 0.17/kWh_t. Average GSHP costs amount to US$ 0.08/kWh.

According to the International Energy Agency the capital cost (2008) for geothermal power development typically amounted to about US$ 2,000–4,000/kWe for flash plant developments and US$ 2,400-5,900/kWe for binary developments.

Environmental Impacts

Geothermal technology (a) and (b) shown above, lead to minimal amount of geothermal fluids leached to the environment. The fluid contains variable concentrations of gases, largely nitrogen and carbon dioxide with some hydrogen sulfide and smaller proportions of ammonia, mercury, radon and boron. However, concentrations are low because disposal water is re-injected back to the holes and toxic gases are managed with current technology keeping it low enough at a non-harmful level. Additionally, carbon dioxide (CO_2) is the major component of the non-condensable gases in the steam, but its emission into the atmosphere per kWh is well below the figures for natural gas, oil, or coal-fired power plants.[106] Hydrogen sulfide is the pollutant of most concern in geothermal plants yet even the sulfur emitted with no controls is only half of what is emitted from a coal-fired plant. Overall, current technology (a) and (b) are able to control the environmental impact of geothermal energy development, it is considered to be a relatively benign source of energy.

Advances in binary plants (technology "c" described above) provide key advantages in that they do not release geothermal fluids into the environment. Binary plants skip altogether issues mentioned above by returning the cooled geothermal gas back to its underground reservoir. Additionally they reduce the cost.

6.5 Biomass to Energy Technologies [107,108]

There are a variety of technologies for generating modern energy carriers (electricity, gas, and liquid fuels) from biomass, which can be used at the household (~10 kW), community (~100 kW), or industrial (~ MW) scale. The different technologies tend to be classed in terms of either the conversion process they use or the end product produced.

Combustion

Direct combustion remains the most common technique for deriving energy from biomass for both heat and electricity production.

The predominant technology in the world today for electricity generation from biomass, at scales above one megawatt, is the steam-Rankine cycle. This consists of direct combustion of biomass in a boiler to raise steam which is then expanded through a turbine. The steam-Rankine technology is a mature technology introduced into commercial use about 100 years ago.[109] The typical capacity of existing biomass power plants ranges from 1 – 50 MWe with an average around 20 MWe. Energy conversion efficiencies are relatively low, 15 – 25 percent, due to their small size, although technologies and processes to increase these efficiencies are being developed. Steam cycle plants are often located at industrial sites, where the waste heat from the steam turbine is

[105] Renewable Energy Essentials, Energy International Agency, 2010. Retrieved from: http://www.iea.org/papers/2010/Geothermal_Essentials.pdf
[106] CO_2 emissions from geothermal technology are generally around 13-380 g/kWh, which is small compared to the 906 g/kWh from oil, 453 g/kWh from natural gas, or the 1042 g/kWh from coal.
[107] Renewable Energy: Power for a Sustainable Future, Second Edition, Godfrey Boyle, Oxford University Press; 2nd edition (May 6, 2004), ISBN-10: 0199261784.
[108] Handbook of Renewable Energy Technology, Ahmed F Zobaa and Ramesh C Bansal, World Scientific Pub Co Inc., 1 edition (January 26, 2011), ISBN-10: 981428906X.
[109] http://www.poweronsite.org/appguide/chapters/chap4/4-5_steam_turbines.htm

recovered and used for meeting industrial process heat needs. Such combined heat and power (CHP), or cogeneration systems provide greater levels of energy services per unit of biomass consumed than systems that only generate power and can reach overall efficiencies of greater than 80 percent.

The most significant installation of steam-Rankine capacity in developing countries is at factories making sugar and/or ethanol from sugarcane, using bagasse, the fiber residue that remains after juice extraction from sugarcane. The costs of steam-Rankine systems vary widely depending on the type of turbine, type of boiler, the pressure and temperature of the steam, and other factors. An important characteristic of steam turbines and boilers is that their capital costs (per unit of capacity) are scale-sensitive. This, together with the fact that biomass steam-Rankine systems are constrained to relatively small scales (due to biomass fuel transport cost limitations), typically leads to biomass steam-Rankine systems that are designed to reduce capital costs at the expense of efficiency. For example, biomass-fired systems are typically designed with much more modest steam pressure and temperature than is technologically feasible enabling lower grade steels to be used in boiler tubes. This lowers both the costs and efficiency. Even with such measures to reduce costs, however, capital costs for small-scale systems are still substantial and lead to relatively high electricity generating costs compared to conventional fossil energy power plants.

Gasification

Combustible gas can be produced from biomass through a high temperature thermo-chemical process. The term gasification commonly refers to this high-temperature thermo-chemical conversion with the product gas called producer-gas, and involves burning biomass without sufficient air for full combustion, but with enough air to convert the solid biomass into a gaseous fuel. Producer-gas consists primarily of carbon monoxide, hydrogen, carbon dioxide and nitrogen, and has a heating value of 4 to 6 MJ/Nm, or 10 – 15 percent of the heating value of natural gas. The intended use of the gas and the characteristics of the particular biomass (size, texture, moisture content, etc.) determine the design and operating characteristics of the gasifier and associated equipment. After appropriate treatment, the resulting gases can be burned directly for cooking or heat supply, or can be used in secondary conversion devices such as internal combustion engines or gas turbines for producing electricity or shaft work. The systems used can scale from small to medium (5 –100 kW), suitable for the cooking or lighting needs of a single family or community, up to large grid connected power generation facilities consuming several thousands of kilograms of woody biomass per hour and producing 10-100 MW of electricity.

One technology that has generated wide interest is the biomass integrated gasification combined cycle (IGCC) technology for larger scale power and combined heat and power (CHP) generation in the range of 5 to 100 MWe. An IGCC system involves sizing and drying of the feedstock, followed by thermochemical gasification to produce a combustible gas, cooling and cleaning of the gas, and combustion in a gas turbine. Steam is raised using the hot exhaust of the gas turbine to drive a steam turbine that generates additional power and/or delivers lower pressure steam for heating purposes. The cascading of a gas turbine and a steam turbine in this manner is commonly called a combined cycle. The IGCC technology enables electricity to be produced at double the efficiency of the steam cycle, and the capital cost per installed kW for commercially mature IGCC units are lower than for comparably-sized steam cycles. Thus, the overall economics of biomass-based power generation are expected to be considerably better with an IGCC system than with a steam-Rankine system, especially in situations where biomass fuel is relatively expensive.

At the intermediate scale, gas from biomass gasification can be used in modified internal combustion engines (typically diesel engines), where it can replace 70-80 percent of the conventional fuel required by the engine. These smaller scale biomass gasifiers, coupled to diesel/gas internal combustion engines, operate in the 100-200 kWe range with efficiencies on the order of 15 – 25 percent, and have been made available commercially. They have, however, had only limited operation success due to, gas cleaning, relatively high costs and the required careful operation, which has so far blocked application in large numbers. Thus, practical operation has often been limited to direct heating applications and no electricity, where gas cleanup and its associated problems become an issue. Generally, these smaller gasification/engine systems are targeted toward isolated areas where grid-connections are either unavailable or unreliable and so they can be cost competitive in generating electricity. Some systems have been applied relatively successfully in rural India and some other countries.

The greatest technical challenge for electricity generating gasifier systems, at all scales, continues to be adequately cleaning the tars and oils from the producer-gas, such that the system operates efficiently, is economical, and has minimal toxic byproducts and air emissions.

Anaerobic Digestion

Combustible gas can also be produced from biomass through the low temperature biological process called anaerobic (without air) digestion. Biogas is the common name for the gas produced either in specifically designed anaerobic digesters or in landfills by capturing the naturally produced methane. Biogas is typically about 60 percent methane and 40 percent carbon dioxide with a heating value of about 55 percent that of natural gas. Almost any biomass except lignin (a major component of wood) can be converted to biogas. Animal and human wastes, sewage sludge, crop residues, carbon-laden industrial processing byproducts, and landfill material have all been widely used.

Anaerobic digesters generally consist of an inlet, where the organic residues and other wastes are fed into the digester tank; a tank, in which the biomass is typically heated to increase its decomposition rate and partially converted by bacteria into biogas; and an outlet where the biomass of the bacteria that carried out the process and non-digested material remains as sludge, can be removed. The biogas produced can be burned to provide energy for cooking and space heating or to generate electricity. Digestion has a low overall electrical efficiency (roughly 10-15 percent, strongly dependent on the feedstock) and is particularly suited for wet biomass materials. Direct non-energy benefits are especially significant in this process. The effluent sludge from the digester is a concentrated nitrogen fertilizer and the pathogens in the waste are reduced or eliminated by the warm temperatures in the digester tank.

Anaerobic digestion of biomass has been demonstrated and applied commercially with success in a multitude of situations and countries. In India biogas production from manure and wastes is applied widely in many villages and is used for cooking and power generation. Small-scale digesters have been used most extensively in India and China. Over 1.85 million cattle-dung digesters were installed in India by the mid-1990s, but about one-third of these are not operating for a variety of reasons, primarily insufficient dung supply and difficulties with the organization of dung deliveries. A mass popularization effort in China in the 1970s led to some 7 million household-scale digesters being installed, using pig manure and human waste as feed material. Many failed to work, however, due to insufficient or improper feed characteristics or poor construction and repair techniques. Estimates were that some 3 to 4.5 million digesters were operating in the early 1980s. Since then, research, development, and dissemination activities have focused greater attention on proper construction, operation, and maintenance of digesters. Most industrial and municipal digesters are used predominantly for the environmental benefits they provide, rather than for fuel production or electricity generation. But since most SIDS are confronted with waste management problems, this technology could fit as a multi-faceted solution to address waste production, while producing an energy carrier that can be used for household cooking, in gas vehicles, or power generation.

Liquid Biofuels

Biofuels are produced in processes that convert biomass into more useful intermediate forms of energy. There is particular interest in converting solid biomass into liquids, which have the potential to replace petroleum-based fuels used in the transportation sector. However, adapting liquid biofuels to our present day fuel infrastructure and engine technology has proven to be challenging.

Alternative biofuels to petroleum-based fuels are alcohols produced from biomass, which can replace gasoline or kerosene. The most widely produced today is ethanol from the fermentation of biomass. In some industrialized countries ethanol is most commonly produced from food crops like corn, while in other parts of the world it is produced from sugarcane. Its most prevalent use is as a gasoline fuel additive to boost octane levels or to reduce dependence on imported fossil fuels. The Brazilian Proalcool ethanol program, initiated in 1975, has been successful due to the high productivity of sugarcane, although initially subsidies were still required. Two other potential transportation biofuels are methanol and hydrogen. They are both produced via biomass gasification and may be used in future fuel cell technologies. U.S. ethanol production is corn based and till today requires some level of subsidy.

Another alternative is organic oil production from plants, such as soybeans, palm oil trees and oilseeds like rapeseed that can produce compounds similar to hydrocarbon petroleum products, and have been used to replace small amounts of diesel. Another family of petroleum-like liquid fuels that is produced from acidified biomass which is a type of synthesized hydrocarbons are called Fischer-Tropsch (F-T) liquids. The process synthesizes hydrocarbon fuels (C10 - C12 hydrocarbons (kerosene) or C3 - C4 hydrocarbons (LPG)) from carbon monoxide and hydrogen gas over iron or cobalt catalysts. F-T liquids can be used as a sulfur-free diesel or blended with existing diesel to reduce emissions, an environmental advantage, but it has yet to be produced efficiently and economically on a large scale, but progress is expected since research and development (R&D) efforts are ongoing. In addition to use as an automotive fuel, F-T liquids can potentially be used as a more efficient, cleaner cooking fuel than traditional wood fuels from which it is synthesized.

While ethanol production from maize and sugarcane (both agricultural crops) has become successful, it can suffer from commodity price fluctuations determined by the fuels market and climatic conditions (e.g. severe droughts). Therefore, the production of ethanol from lignocellulosic biomass (such as wood, straw and grasses) called cellulosic ethanol has gained serious attention, particularly because enzymatic hydrolysis of lignocellulosic biomass will open the way to lower cost and lead to the efficient production of ethanol. While the development of various hydrolysis techniques has gained attention in recent years, particularly in Sweden and the United States, cheap and efficient hydrolysis processes are still under development.

In some SIDS (e.g. Pacific region) coconut oil has been used for the production of alternative renewable and environmental friendly biodiesel as an alternative to conventional diesel fuel.[110] However, it is arguable that because of the size of many SIDS, the amount of biomass from coconut available for biodiesel will be a limitation for the development of large commercial coconut biodiesel production. Coconut can be easily affected by pests and on many SIDS there is no land available for mono-cropping because large plantations could potentially reduce biodiversity and impact other native species. In addition fuel vs. food competition needs to be addressed in each respective SIDS through a more detailed assessment for each and every case.[111]

Environmental Impacts and Benefits

While biomass is in principle renewable and can have positive environmental impacts if managed properly it also shares many characteristics with fossil fuels, both good and bad. While it can be transported and stored allowing for heat and power generation on demand, modernized bioenergy systems can also have negative environmental impacts associated both with the growing of the biomass and with its conversion to energy carriers.

Environmental impacts of biomass production must be viewed in comparison to the likely alternative impacts (locally, regionally, and globally) without the bioenergy system in place. For example, at the local or regional level, the relative impacts of producing bioenergy feedstock will depend not only on how the biomass is produced, but also on what would have happened otherwise. Through life cycle analysis (LCA) studies it has been found that where biomass displaces fossil energy systems there will be a reduction in the impact on global climate through reduction in overall greenhouse gas emissions, but for other types of emissions (e.g., NOx, SO2, N2O) the picture is less clear and is heavily dependent on the source of the biomass (type of feedstock), technical details of the conversion process, and the fossil fuel being displaced. Also, in the SIDS context there is the need to avoid problems associated with monocultures and the use of food crops for energy purposes.

Challenge

Raw biomass has several disadvantages as an energy source. It is bulky with a low energy density and direct combustion is generally highly inefficient (other than advanced domestic heaters) producing high levels of indoor and outdoor air pollution. The goal of modernized biomass energy is to increase the fuel's energy density while decreasing its emissions during production and use. Modernizing biomass energy production however faces a variety of challenges that must be adequately addressed and dealt with before the widespread implementation of bioenergy systems can occur. These issues include technical problems (just discussed), resource availability, environmental impacts, and economic feasibility.

[110] Jan Cloin, Coconut Oil as a Biofuel in Pacific Islands, 2005. Retrieved from: http://www.unesco.org/csi/smis/siv/Forum/CoconutOilFuelPacific_JanCloin.pdf

[111] Authors' conclusions

Countries where commercialized bioenergy applications have started to play a significant role in the energy system have all implemented strong policies. A carbon tax, price support, long running R&D programs can lead to a powerful combination of gaining experience, building an infrastructure, developing technology and at the same time developing the national market. The Scandinavian countries, Brazil and to a somewhat lesser extent Northwest Europe and the U.S., show that modernization is essential to realize the promise of biomass as an alternative energy source. Modernization requires environmentally friendly and sustainable high yield biomass production, efficient conversion to clean energy carriers, and efficient end use.

6.6 Ocean Energy Technologies [112,113,114]

The ocean covers 71% of the Earth's surface.[115] The ocean contains untapped mechanical and thermal energy. Mechanical in the form of: waves powered by the wind, tidal powered by the gravitational pull effect of the moon, currents powered by both wind and solar heating process, and thermal by the solar energy flux that is stored as heat energy (e.g. Ocean Thermal Energy Conversion (OTEC)). Ocean energy technology is still not fully commercially available and many of these technologies are near commercial deployment. However, government's support and market policies to reduce the current cost gap and help accelerate the rate of commercialization are still necessary. This review will attempt to provide a summary of current ocean energy technologies.

Mechanical energy-technologies

Wave energy

Waves are generated by winds blowing over the ocean surface. Wave energy is effectively a stored and concentrated form of solar energy since the winds that produce them are caused by pressure differences in the atmosphere caused by the sun's differential heating of the earth's surface. Waves can efficiently transport energy for thousands of miles and retain their energy long after the winds that first created them have died down, which makes waves one of the most concentrated and consistent sources of renewable energy.

Wave energy conversion is a comparatively young technology, among a wide variety of energy technologies that have been developed. Most of these remain in the research stage but a significant number of shoreline, near-shore, and offshore demonstration projects have been built around the world and a number of companies are planning their first commercial schemes. Basically the machines use the vertical displacement of the waves to generate electricity. In general wave energy technology can be defined by common characteristics.
These characteristics are:

a. Structure interacts with incoming waves, converting this energy to electricity through a hydraulic, mechanical or pneumatic power take-off system;
b. Structure is kept in position by a mooring system or placed directly on seabed/seashore; and
c. Power is transmitted to shore by a sub-sea cable.

Many devices have been proposed to achieve the conversion of wave energy into electricity. For off-shore technology, four technology concepts are among the most promising designs.[116] These are the following:

1. Point absorber

The "point absorber" is a small device compared with a typical wave useful for energy production (a typical wave varies from 40 to over 300 m in length).

Power conversion systems can have several forms. The form will depend on the selected configuration and design. Typically point absorbers are bottom-mounted or floating structures that absorb energy from all directions (e.g. a bottom-standing device with an upper floater element). Figure 22 shows for example a floating buoy.

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[112] Ocean Energy Technology Overview, U.S. Department of Energy, 2009. Retrieved from: http://www.nrel.gov/docs/fy09osti/44200.pdf
[113] Renewable Energy: Power for a Sustainable Future, Second Edition, Godfrey Boyle, Oxford University Press; 2nd edition (May 6, 2004), ISBN-10: 0199261784.
[114] Handbook of Renewable Energy Technology, Ahmed F Zobaa and Ramesh C Bansal, World Scientific Pub Co Inc., 1 edition (January 26, 2011), ISBN-10: 981428906X.
[115] Ocean, National Oceanic Atmospheric Administration. Retrieved from: http://www.noaa.gov/ocean.html
[116] Oceanography, Volume 23, Number 2, Overview of Ocean Renewable Energy Technologies, 2010. Retrieved from: http://www.tos.org/oceanography/archive/23-2_bedard.pdf

Figure 22 A Power Buoy

2. Over-topping Terminator

A "terminator" is a large device oriented perpendicular to the direction of the wave, see Figure 23. The infrastructure includes a stationary component and a component that moves in response to the wave. The "stationary" part could be fixed to the sea floor or shore. It must remain still, in contrast to the movable part. The moving part works like a piston in car, moving up and down. This motion pressurizes air or oil to drive a turbine. This means that instead of using a wave's kinetic energy to generate power like other wave energy devices, the terminator captures waves and takes advantage of their potential energy.

Figure 23 An overtopping terminator[117]

3. Linear absorber or attenuator

An "attenuator" is a device oriented parallel to the direction of the wave. One of the most well-known examples of this is the "Pelamis", Figure 24. A pelamis consist of a series of long cylindrical floating devices connected to each other with hinges and anchored to the seabed (it looks like a giant worm). The cylindrical parts drive hydraulic rams in the connecting sections and those in turn drive an electric generator. The devices send the electricity through cables to the sea floor where it then travels through a cable to shore.

Figure 24 The Pelamis - attenuator[118]

[117] Retrieve from: http://coastalenergyandenvironment.web.unc.edu/files/2012/07/wave-drag1.jpg

4. *Oscillating water column*

An oscillating water column (OWC) device can be used on-shore and off-shore, see Figure 25. An “OWC” device is a typically partially submerged hollow structure trapping water and air (a column of air above a column of water). The water driven is moved by the waves through a submerged aperture compressing and decompressing the column of air which in turn drives a turbine while it moves back and forth.

Figure 25 Oscillating water column[119]

Potential for wave energy

The highest energy waves are concentrated off the western coasts in the 40°–60° latitude range north and south. The power in the wave fronts varies in these areas between 30 and 70 kW/m; with peaks to 100kW/m in the Atlantic SW of Ireland, the Southern Ocean, and off Cape Horn. The capability to supply electricity from this resource is such that, if harnessed appropriately, 10% of the current level of world supply could be provided. For SIDS countries the power in wave varies in the range of 10-30 kW/m. Figure 26 describes the global wave potential. Areas in circle indicate SIDS location and wave potential. In general the wave energy potential near SIDS is between 10-20 kW/m.

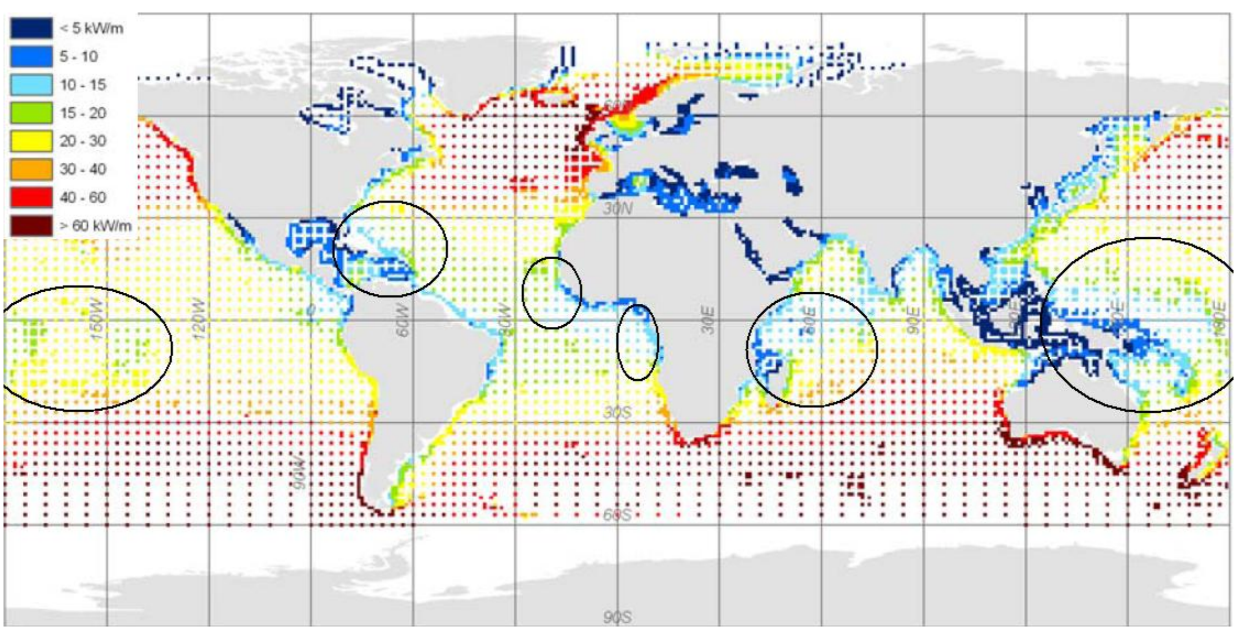

Figure 26 Annual global gross theoretical wave power[120]

Tidal Energy[121,122]

Tidal energy is the utilization of the variations in sea level caused primarily by the gravitational effects of the moon, combined with the rotation of the Earth. The rise and fall of the sea level can power electric-generating equipment. The gearing of the equipment is tremendous to turn the very slow motion of the tide into enough

[118] Retrieved from: http://www.pelamiswave.com/upload/image/image_27_2529.jpg
[119] Retrieved from: http://www.sciencebuddies.org/science-fair-projects/project_ideas/Energy_p037.shtml#background
[120] Mørk, G., et al. Assessing the global wave energy potential, 2010. Retrieved from: http://www.oceanor.no/related/59149/paper_OMAW_2010_20473_final.pdf
[121] Chang, J., Ph.D. Thesis, Hydrodynamic modeling and feasibility study of harnessing tidal power at the bay of Fundy, 2008. Retrieved from: http://digitallibrary.usc.edu/assetserver/controller/item/etd-Chang-20080312.pdf
[122] Gorlov, A., Tidal Energy, 2001. Retrieved from: http://www.umaine.edu/mecheng/peterson/classes/design/2007_8/project_webs/tidal_test/pdf/tidalenergy.pdf

displacement to produce energy. Tidal barrages, built across suitable estuaries, are designed to extract energy from the rise and fall of the tides, using turbines located in water passages in the barrages. The potential energy, due to the difference in water levels across the barrages, is converted into kinetic energy in the form of fast moving water passing through the turbines.

Currently, three countries have tidal energy schemes in operation: France, with the 240 MW tidal barrage at Rance, the largest tidal power station in the world and the only one in Europe, built in 1966; Canada, with the 20 MW Annapolis tidal barrage; and China, with an 11 MW tidal power scheme of small tidal plants.

Experimental tidal energy projects are being tested in Russia, UK, Australia, USA, Argentina, Canada, India, Korea, and Mexico. Potential sites for tidal energy stations are few and far between, but a number have been identified in the UK, France, Eastern Canada, and the Pacific coast of Russia, Korea, China, Mexico, and Chile. Other sites have been identified along the Patagonian coast of Argentina, Western Australia, and Western India. During the preparation of this report, ***no*** research has been identified for SIDS.

Tidal energy Potential

Tidal energy is widely distributed around the world. Figure 27 shows in red the regions with higher tidal potential. SIDS have a relevant tidal energy potential that should be studied, e.g. SIDS located next to Australia have a considerable high tidal energy potential.

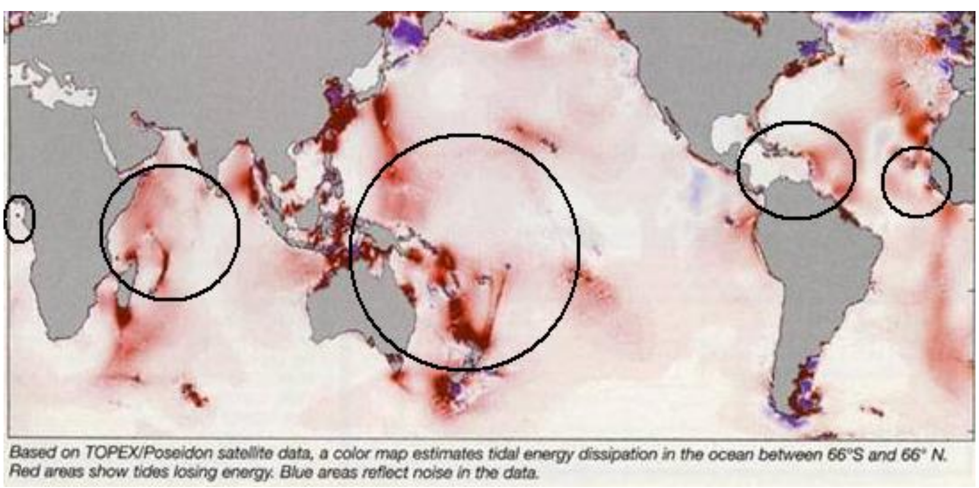

Figure 27 Tidal energy taken from satellite data (dark red indicate greatest tidal energy potential)[123]

Tidal energy technologies

There are three main tide energy technologies:

a. **Tidal Fences**: Tidal fences block a channel, forcing water to go through it and turning its turbines to generate electricity, see Figure 28.

Figure 28 Examples of a Tidal Fence[124,125]

b. **Barrage Tidal Plants**: Barrage tidal plants are the most common type of tidal plant. A dam or barrage is installed, usually where there is a narrow water channel, with gates and turbines at certain points. As water

[123] Goreau, T., Tidal energy and low-head river power, 2005. Retrieved from: http://globalcoral.org/Tidal%20Energy%20and%20Low-Head%20River%20Power.htm
[124] Retrieved from: http://www.eepe.murdoch.edu.au/resources/info/Tech/tidal/image009.png
[125] Retrieved from: http://infranetlab.org/blog/wp-content/uploads/2008/07/08_07_21_tidal_fence1.jpg

flows through the turbines, the plants turn a generator that produces electricity, see Figure 29. In general, tidal fences will block a channel, forcing water to go through it and turning its turbines to generate electricity.

Figure 29 Barrage tidal plant[126]

Barrage tidal plants - Environmenental impacts[127]

Most of the well-known environmental impacts by the construction of a barrage tidal plat are related with the flow of saltwater in and out of estuaries, which changes the hydrology and salinity and possibly negatively affects the marine mammals that use the estuaries as their habitat. Similarly, migratory fish may be impeded to pass through the barrage and in some cases fish may suffer some damage by a collision with turbines.

c. Tidal Turbines: Tidal turbines work like an underwater wind turbine, using the tides to turn blades and generate electricity. Compared to the air that acts on the windmill, the density of seawater passing through a current-turbine is about 800 times denser than the air. That means that a current-turbine produces 800 times more energy than a windmill with the same wind/current velocity, or, a current-turbine requires lower current velocity to produce the same amount of energy.

An advantage compared with barrage design, is that the tidal turbine does not require blocking the water way, reducing infrastructure size, costs, and potential environmental impacts. The design of the turbines depends upon the data collected and characteristics of the tide current. Figure 30 shows two different turbines designs.

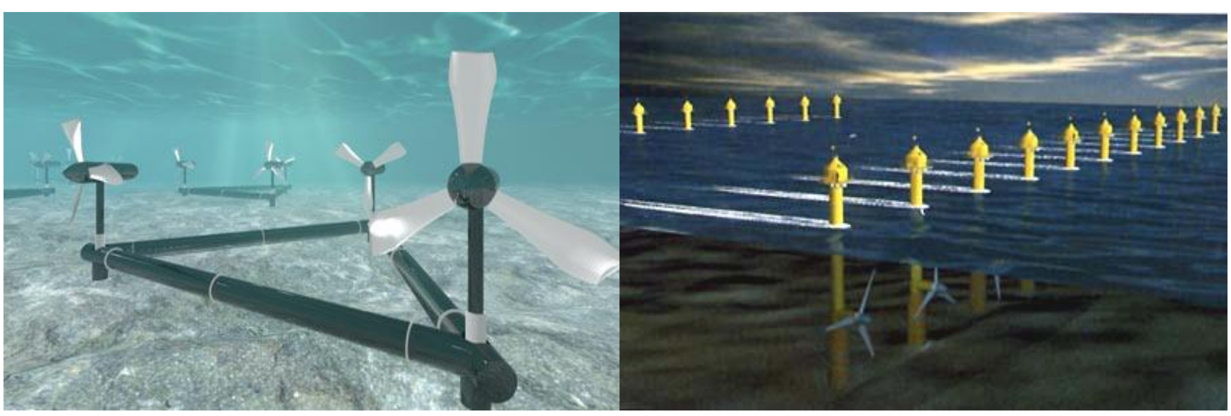

Figure 30 Examples of Tidal Trubines[128]

Environmental impacts

Studies to date suggest that local environmental impacts are likely to be minor, but further research is required into device-environment interactions, particularly the impact of tidal stream energy generators on flow momentum. Although the generators create no noise audible to humans, they do create "modest" noise underwater. Manufacturers maintain that this is important to help marine wild-life to have an awareness of the presence of the turbine.

[126] Retrieved from: http://www.tidalenergy.eu/images/page4image.jpg
[127] Wolf, J., Environmental impacts of tidal power schemes, 2008. Retrieved from: http://www.liv.ac.uk/media/livacuk/engineering/burrows/WOLF_et_al_ICE_final.pdf
[128] Retrieved from: http://www.alt-energy.info/wp-content/uploads/2009/01/deltastream-turbine.jpg and http://www.fujitaresearch.com/reports/_img/tidal-turbines.jpg

***Ocean circulation currents energy-Marine currents energy*[129,130]**

Ocean currents energy is a promising technology. Marine currents as kinetic energy can be converted into electric energy or other type of energy. Energy from marine currents offers the promise of regular and predictable electrical generation at higher power densities than other renewables. Energy potential is dependent on the flow of ocean waters. The stronger the flow the more energy can be generated. Strong flows tend to occur within straits, between islands, and at entrances to large bays and harbors.[131] Dissimilar to wave power, ocean currents occur on a frequent, regular, predictable schedule. Ocean circulation currents are both continuous and reliable. However, ocean current energy is at an early stage of development, with only a small number of prototypes and demonstration units having been tested to date.[132]

Energy contained in all fluids is proportional to the cube of their velocity. Because of the friction, the ocean current velocity is inferior to wind. However, water is about 835 times denser than wind, so for the same area of flow being intercepted, the energy contained in a 12-mph water flow is equivalent to that contained in an air mass moving at about 110 mph. Thus, ocean currents represent a potentially significant, currently untapped, reservoir of energy. The minimum current required to operate a hydrokinetic device is typically 2–4 knots (1–2 m/s), but may be as low as 1 knot (0.5 m/s), depending on the particular technology approach. Optimum currents are in the 5–7 knot (1.5–3.5 m/s) range. Water depth is an important factor in determining the total energy that can be extracted from a site, since the cross-sectional area over which a turbine can extract energy is dependent on adequate water level above the installed device. Additionally, ocean current energy is attracting more attention since the resource is available 24/7. The main surface currents in the world can be observed in Figure 31.

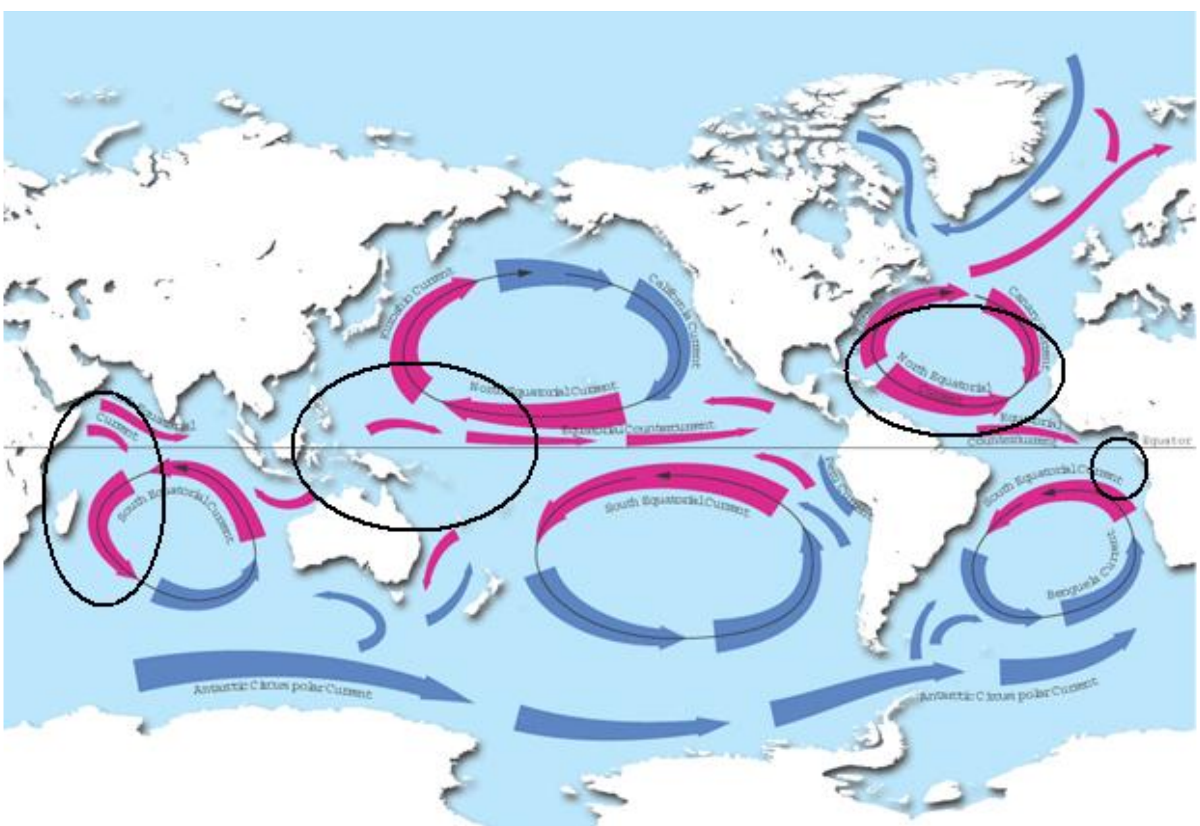

Figure 31 Principal ocean surface currents (red arrows reflect transportation of warm masses of water and blue arrows reflect transportation of cold masses of water)

The kinetic energy contained in the ocean circulation currents can be harnessed using various technologies. Ocean currents technology is different from tidal currents turbines. The primary design concepts for ocean currents energy are based on submarine turbines, deployed in arrays. Some of these generic technologies used for electricity generation can be divided into two categories: rotating devices and reciprocating devices.

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[129] Ocean Current Energy Potential on the U.S. Outer Continental Shelf, U.S. Department of the Interior, 2006. Retrieved from: http://ocsenergy.anl.gov/documents/docs/OCS_EIS_WhitePaper_Current.pdf

[130] Ocean Current Energy, CS Alternative Energy Programmatic EIS. Retrieved from: http://ocsenergy.anl.gov/guide/current/index.cfm

[131] Rachmayani, R., et al., Marine Current Potential Energy for Environmental Friendly Electricity Generation in Bali, Lombok and Makassar Straits, 2006. Retrieved from: http://www.environmental-expert.com/Files/0/articles/19698/marinecurrentextraction.pdf

[132] Ibid. 129

Rotating devices are similar to wind turbines used to convert the kinetic energy of the wind to electricity. This device has two variants: horizontal axis or vertical axis turbine.[133] Both consist of a number of blades connected to a support hub (together known as a rotor) which rotate about a horizontal axis or vertical axis. Figure 32 shows a prototype of a horizontal axis and a conceptual design of a vertical axis.

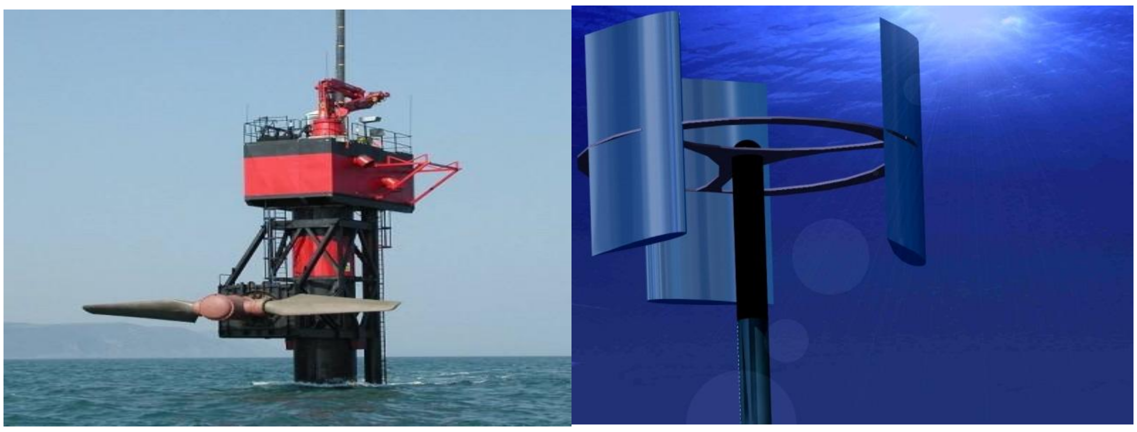

Figure 32 Rotating device with horizontal axis and a Rotating device with vertical axis

Reciprocating devices oscillate due to the hydrodynamic lift force created by the flow over the hydrofoil. Reciprocating devices produce a high torque and low speed output. Similar to an airplane's wing but in water, to collect energy from the tide, these devices are generally hydraulic power take-off systems utilizing high-pressure oscillating rams. The high-pressure oscillating rams pressurize and transfer the high-pressure oil to drive a hydraulic motor. See Figure 33, for examples of a conceptual design and prototype of an oscillating hydrofoil/reciprocating device.

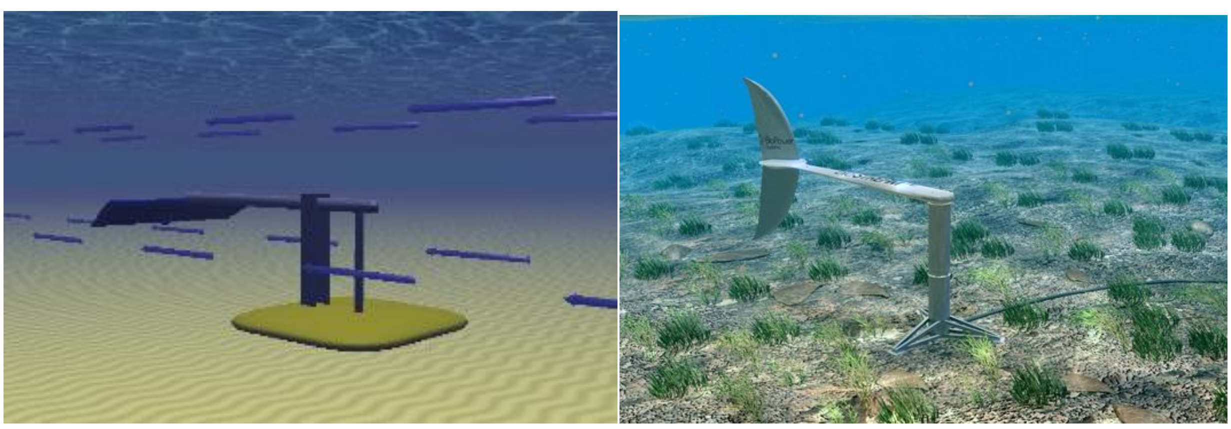

Figure 33 A reciprocating device (left - conceptual design) and (right - testing prototype) [134,135]

Economics and Environmental impacts

There is no reliable information about cost of marine current energy. R&D is necessary to develop this technology. It is necessary to investigate the current velocity characteristics, reliability of overall system and the cost of electricity generated through different technologies.

There are various issues which need to be addressed to assist the development of this technology, including design and installation challenges, maintenance, electricity transmission and environmental impact assessments.

[133] Marine Current Energy, Marine current resource and technology methodology, University of Strathclyde. Retrieved from: http://www.esru.strath.ac.uk/EandE/Web_sites/05-06/marine_renewables/background/marinecurrents.htm
[134] Retrieved from: http://www.emec.org.uk/wp-content/uploads/2012/03/reciprocating-hydrofoil.gif
[135] Retrieved from: http://tommytoy.typepad.com/.a/6a0133f3a4072c970b0162fd2f9800970d-550wi

Thermal energy-technologies

Ocean Thermal Energy Conversion (OTEC)[136,137]

Oceans are massive natural storage basins for solar energy. The solar energy is storage in the forms of vertical temperature gradients. Once the solar energy is collected and stored it is available 24/7, so it is usable as a base load, which is unique among renewable energy sources (RES). OTEC technology uses these temperature gradients. The temperature gradients (differential) between the deep cold and relatively warmer surface waters of the ocean are used to generate base load electricity. In the tropics, surface water temperatures can exceed 26.7°C (80°F). At ocean depths of 915 m (3,000 ft), more or less, water temperatures are usually less than 4.4°C (40°F). This temperature differential can drive a Rankine thermodynamic cycle to generate electricity.

OTEC was originally proposed by French Engineer Jacques Arsene d'Arsonval in 1881, OTEC is not a new technology.[138] Since then many advancements have been made in the development of this technology. The three most common OTEC systems are: open-cycle, closed-cycle and hybrid cycle, all requiring a working fluid, condenser and evaporator within the system. For OTEC a temperature difference of 20^{o}C is adequate, which embraces very large ocean areas, and favors islands and many developing countries. Based on Figure 34, in the particular case of SIDS almost all have huge or relevant potential for OTEC (except Cape Verde which is located between 18 and 20 Celsius degrees-which is still a value located on the technical limit of suitability to be useed).

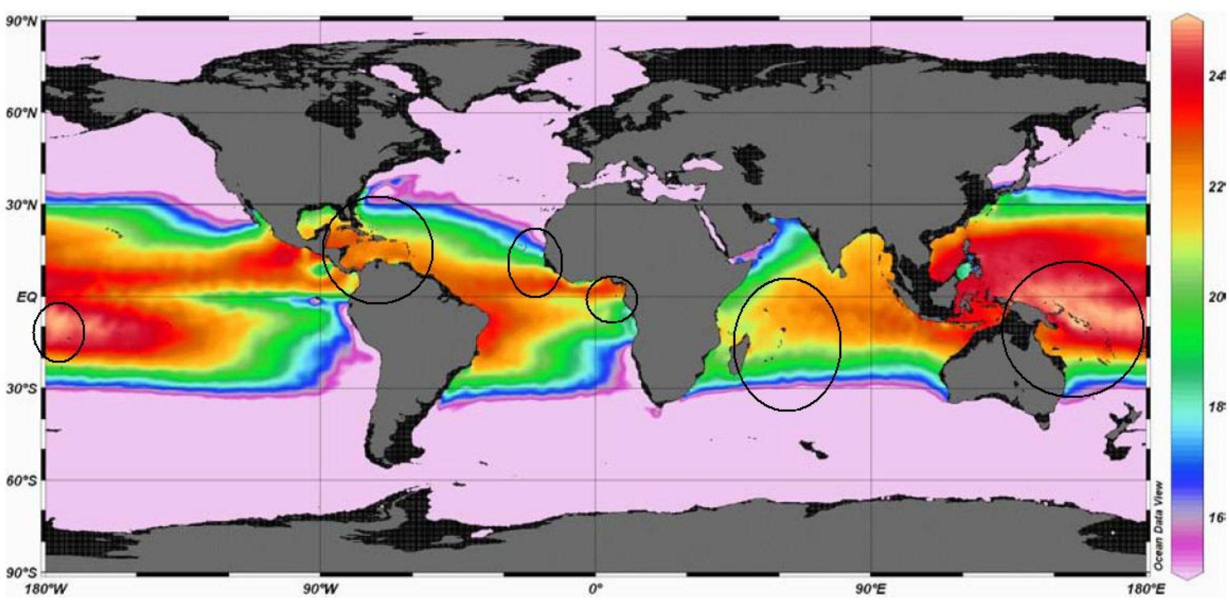

Figure 34 Average ocean temperature differences (between 20 m and 1000 m water depths) from WOA 2005 (1/4°) data (the color palette is from 15°C to 25°C)[139]

This report describes the most well-known OTEC technology: open-cycle, closed-cycle and hybrid cycle.

Open-cycle[140,141,142]

The Open-cycle system (see Figure 35) operates by drawing warm surface water (the working fluid) into a partially evacuated chamber (evaporator) maintained at a reduced pressure by a vacuum pump. The lower pressure in the chamber causes the warm ocean water to boil which generates steam to drive a turbine connected to a turbo generator. Once the steam passes through the turbine, it enters a heat exchanger (condenser) cooled by cold water pumped from deep below the ocean's surface where it is condensed back into a liquid. The condensate, which is now desalinated water, is then vented from the system either to the ocean or to an isolated storage tank.

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[136] Technical Readiness of Ocean Thermal Energy Conversion (OTEC), NOAA. Retrieved from: http://coastalmanagement.noaa.gov/otec/docs/otectech1109.pdf

[137] Ocean Thermal Energy Conversion and The Pacific islands, SOPAC Report, 2001. Retrieved from: http://www.clubdesargonautes.org/energie/sopacotec.pdf

[138] U.S. Department of Energy, OTEC. Retrieved from: http://www.eere.energy.gov/basics/renewable_energy/ocean_thermal_energy_conv.html

[139] Ocean Thermal Resources off the Hawaiian Islands, The University of Hawaii. Retrieved from: http://hinmrec.hnei.hawaii.edu/wp-content/uploads/2009/12/Ocean-Thermal-Resource-offshore-Hawaiian-Islands.pdf

[140] Florida Solar Energy Center, Open-Cycle Ocean Thermal Energy Conversion. Retrieved from: http://www.fsec.ucf.edu/en/publications/pdf/FSEC-FS-28-83.pdf

[141] Finney, K., Ocean Thermal Energy Conversion, 2008. Retrieved from: http://www.soe.uoguelph.ca/webfiles/gej/articles/GEJ_001-017-023_Finney_Ocean_Thermal_Energy.pdf

[142] Masutani, S. M., et al. Ocean Energy Thermal Conversion, 2001. Retrieved from: http://curry.eas.gatech.edu/Courses/6140/ency/Chapter2/Ency_Oceans/OTEC.pdf

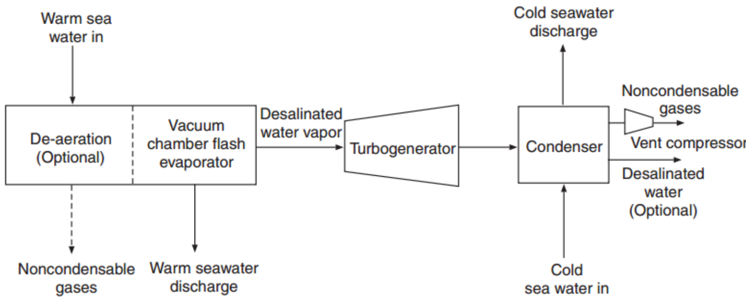

Figure 35 Schematic diagram of an open-cycle OTEC system[143]

Closed-cycle[144,145]

In the closed-cycle system, shown in Figure 36, warm surface water is used to heat an evaporator containing a working fluid with a low-boiling point, such as ammonia. The heat from the surface water causes the working fluid to boil and evaporate. The expanding vapor from the boiling working fluid drives the turbine which is connected to a generator. After passing through the turbine, the vapor enters a condenser cooled by cold ocean water pumped from deep below the surface where it is condensed back into a liquid and re-circulated through the system.

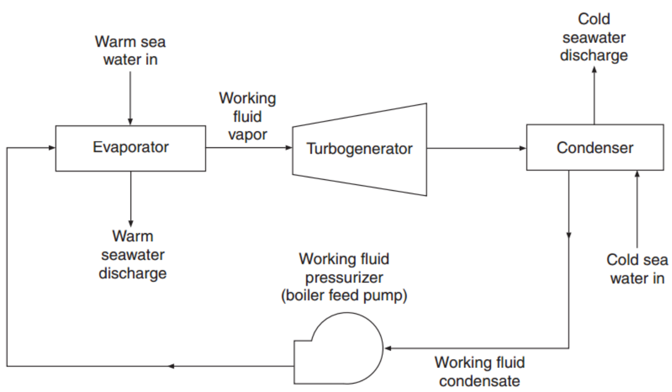

Figure 36 Schematic diagram of a closed-cycle OTEC system[146]

Hybrid-cycle[147,148]

A hybrid-cycle is basically the combination of an open and closed system. Similar to the open cycle system, warm surface water is guided in a low pressure container and evaporates and it is possible to produce potable water from the open cycle. The steam vaporizes a low-boiling medium via a heat exchanger in its turn – as in a closed cycle system – and electricity is generated through a turbine. Finally, the system offers the best of both systems, electricity from the closed system and potable water from the open. There have been several designs proposed; still it remains necessary to have more testing.

Potential Environmental impacts[149,150]

OTEC systems are, for the most part, environmentally benign. However, some potential impacts need more research. This includes among other:

- Impacts related to emission of trace gases mainly during the construction phase. The emissions are limited only to that particular phase;
- Impact of construction and infrastructure;
- CO and CO_2, released per unit of power produced for OTEC systems is one-third of the minimum released by conventional power plants burning fossil fuel. In addition, those CO and CO_2 are not new emissions, because those gases are not produced by the combustion of any fuel; and
- Redistribution of native species.

There is not much research available about environmental impacts by OTEC. All these potential impacts need to be investigated. However, open-cycle has less potential impacts compared with open-cycles.

[143] Ibid. 142
[144] Ibid. 141
[145] Ibid. 142
[146] Ibid. 142
[147] Ibid. 141
[148] Ibid. 142
[149] Quinby-Hunt, M., et al., Potential environmental impacts of open-cycle thermal energyconversion, 1987. Retrieved from: http://www.marscigrp.org/EnvImpact86.pdf
[150] Ibid. 142

Economics of OTEC
Studies conducted to date on the economic feasibility of OTEC systems suffer from the lack of reliable cost data. Commercialization of the technology is unlikely until a full-scale plant is constructed and operated continuously over an extended period of time to provide the data on capital, personnel, and maintenance expenses.[151]

However, because of the high cost of oil, OTEC is today presumably a highly competitive technology. This assertion is based on results of a 1992 report about the economics of OTEC.[152] This report claimed that in a scenario with oil prices over US$ 50 per barrel, OTEC is fully competitive. In year 2011, the oil prices have on average remained around US$ 90 per barrel.

6.7 Summary of findings

There is no doubt that renewable energy technologies (RETs) are the most likely technological solutions for SIDS's energy independence. However, not all renewable energy technologies (RETs) are suitable for all SIDS. Different characteristics among SIDS e.g. land availability, population density, RE resources, and social and cultural differences make it hard to identify and determine the most suitable RETs for SIDS. Additionally, RE resources are very disperse, both within and among the SIDS regions and without an accurate, high resolution assessment of the RE potential per country, the deployment of RETs will continue to be a difficult challenge to overcome.

Based on the assessment performed on RETs in this chapter we can argue that low-cost and low-risk technologies are available, like geothermal, solar, wind, bagasse, and ocean energy technologies. This suggests there are potential suitable RETs available on short, medium, and long term, to relieve SIDS of the burden of cost of importing oil while complying with the principles of sustainable development. In order to select suitable energy supply technologies for SIDS a new methodology is introduced in this report, with the goal of using this methodology to assess and categorize energy technologies as SIDS-appropriate sustainable energy technologies. After an extensive literature review and application of the "SIDS-appropriate ETA"-method, a matrix is provided (see Table 24) that lists the most suitable RETs per SIDS DOCK member state (based on a qualitative analysis).

RET transfer requires more quantitative data regarding the potential viability of technological approaches for the production of energy from all the renewable energy sources (RES) in or near SIDS. The "SIDS-appropriate ETA" assessment approach should therefore be considered a 1st-order selection method applied to evaluate the potential viability and suitability of RETs for SIDS.

The qualitative judgment, performance or conclusion of each of the "SIDS-appropriate ETA" indicator is expressed by using the following categories:

Category
Excellent
Good
Good – Fair
Fair
Fair – Not acceptable
Not acceptable

When a single category does not sufficiently represent the potential of a specific RET for a particular indicator, a combination of these categories is used as means to express a "range" and are given a different color.

Table 24 summarizes the qualitative results of the evaluation of each RET based on the "SIDS-appropriate ETA" method.

[151] Ibid. 142
[152] Vega, L., Economics of Ocean Thermal Energy Conversion, 1992. Retrieved from: http://hinmrec.hnei.hawaii.edu/wp-content/uploads/2010/01/OTEC-Economics-circa-1990.pdf

Table 24 – Summary of results of the “SIDS-appropriate ETA” assessment

Indicators / Technology	Technical Evaluation	Energy Efficiency conversion	Environmental Impacts	Economic Viability	Socio Political	Land use Requirement	Reliability	Adequacy of Energy Services	Deployment potential		
									Short Term	*Med. Term*	*Long - Term*
Solar thermal	Excellent	Good	Good	Not Acceptable	Good	Not Acceptable	Fair	Good			
Solar photovoltaic	Excellent	Fair	Good	Good	Good	Good	Fair	Good	Excellent To reduce peak demand – houses self-generation of electricity	Good New storage technology is expected by 2015-2020	
Wind	Excellent	Fair	Good	Good	Good	Good	Fair	Good	Excellent To reduce peak demand – houses self-generation of electricity	Good New storage technology is expected by 2015-2020	
Hydro-dam (Large hydro)	Excellent	Good	Fair - Not Acceptable	Good	Good	Not Acceptable	Excellent	Excellent			
Hydro - run-of-river	Excellent	Good	Good	Good	Good	Good	Good	Excellent *Vulnerability due to climate variability and climate change	Excellent *only where this energy resource is available		
Geo. Flash	Excellent	Good	Fair	Fair - Not Acceptable	Good	Good	Excellent	Excellent			
Geo. Dry Steam	Excellent	Good	Fair	Fair - Not Acceptable	Good	Good	Excellent	Excellent			
Geo. Binary	Excellent	Good	Good	Good	Good	Good	Excellent	Excellent		Excellent After technical evaluation. Initially a small plant to learn about the resource behavior.	Excellent
Biomass – Combustion	Excellent	Fair	Not Acceptable	Good	Good	Good	Good	Good			
Bio.-Gasification	Excellent	Fair - Good	Good	Good	Good	Good	Good	Good		Good	
Bio. – Anaerobic digestion	Excellent	Good	Good	Good	Good	Good	Good	Fair			
Bio.-Liquid biofuels *Traditional liquid	Excellent	Fair - Good	Fair - Good	Fair - Good	Fair- Not Acceptable	Good	Good	Good	Good		

Indicators / Technology	Technical Evaluation	Energy Efficiency conversion	Environmental Impacts	Economic Viability	Socio Political	Land use Requirement	Reliability	Adequacy of Energy Services	Deployment potential		
									Short Term	*Med. Term*	*Long - Term*
biofuels 1st and 2nd generation.					*for commercial scale extensive land resources are needed **only larger SIDS could use this RET						
Ocean – Wave	Fair	More Assessment is needed	More Assessment is needed	More Assessment is needed	More Assessment is needed	Good	More Assessment is needed	More Assessment is needed			Excellent
Ocean - Tidal	Fair	More Assessment is needed	More Assessment is needed	More Assessment is needed	More Assessment is needed	Good	More Assessment is needed	More Assessment is needed			Excellent
Ocean – Current tech.	Fair	More Assessment is needed	More Assessment is needed	More Assessment is needed	More Assessment is needed	Good	Excellent	Good			Excellent **More assessment-R&D is needed. Significant potential
Ocean Thermal Energy Conversion (OTEC)	Fair - Good	Good	More Assessment is needed	Good *for land-based and near-shore facilities	Fair – Good *more assessment is needed	Good	Excellent	Excellent		Excellent **Promising technology-A pilot project is needed as a final test	Excellent

Among the technologies reviewed the following can be concluded:

- As sub-technologies under the category "Solar Energy", the solar thermal energy technologies do not qualify as SIDS-appropriate because of the current and anticipated costs of electricity production per watt being significantly high to become cost-effective and compete with the current and future possible portfolio of energy supply technologies in SIDS. The U.S. Department of Energy forecasts costs by 2030 of US$2.70 per watt, US$2.50 per watt, and US$1.30 per watt, respectively, for the parabolic trough, power tower, and dish engine systems. Furthermore these technologies require significant amount of space and their space footprint is not anticipated to become sufficiently reduced in the future to qualify as SIDS-appropriate.
- Solar PV and Wind Turbine technologies perform almost similar regarding the evaluation indicators. Both perform good to excellent on most indicators, but perform "fair" under the "energy efficiency" and "reliability". This is because both technologies use RES of intermittent nature (solar –because of the 24 hour day/night cycles), and (wind – because of the fluctuations of the monthly, daily, hourly and even instantaneous wind speeds and direction changes) and are considered less reliable to guarantee 100% power supply on a year basis. The conversion efficiency of both technologies is also considered lower than conventional fossil fueled power generation systems.
- Although large hydro systems, using dams, perform excellent regarding several criteria, in particular as a reliable source of power for base load supply, it performs low to not acceptable in term of the land use requirement and the environmental performance in SIDS. This is because large hydro dams require the flooding of significant amounts of land, whereby in most cases leading to displacements of people and destruction of ecosystems and habitats. Since land availability in SIDS is scarce with high population densities, it is anticipated that other future land use needs will be more critical than flooding valuable lands to produce hydropower in the context of SIDS.
- Two specific sub-technologies, namely the run-of-river hydro system and the geothermal binary cycle systems score high to excellent in all categories to be considered SIDS-appropriate. The only limiting factor is that both these RES are very site-specific and are therefore not in all SIDS DOCK member states available and applicable.
- Unlike the geothermal binary cycle system, the two other geothermal sub-technologies do not perform optimally in terms of economic viability and environmental performance.
- While biomass combustion technology performs well in most categories, the environmental impacts associated with the biomass feedstock lifecycle (as dedicated energy feedstock) can significantly impact the local or regional environment, the relative impacts of producing bioenergy feedstock do not only depend on how the biomass is produced, but also on what alternative land use it is obstructing that may be or become more critical to future island needs. Although it is known that biomass use can lead to a reduction in the impact on global climate through reduction in overall greenhouse gas emissions, still other types of emissions (e.g., NOx, SO_2, N_2O) with different environmental impacts are observed. Also, in the SIDS context there is the need to avoid problems associated with monocultures and the use of food crops for energy purposes.
- On the other hand, bio-anaerobic digestion and bio-gasification both perform good in all categories, with anaerobic digestion scoring "fair" on the adequacy of the service since in some cases manure and human waste is/can be used to run the system, and this is not always accepted by the community. But if designed properly and with proper public awareness this and the bio-gasification sub-technology can be categorized as SIDS-appropriate.
- Liquid Biofuel production is among the limited options of energy carriers (next to bio-gas, methanol and hydrogen that can be produced via biomass gasification and be used in future fuel cell technologies) that can be consumed as fuel in conventional vehicles for transportation. There is a mixed picture since liquid biofuels technologies are multiple and dependent on a large amount of factors. Among the sub-technologies or processes, lignocellulosic ethanol production is anticipated to perform well in SIDS. This is because the feedstock can originate from residues from non- and food crops (agricultural sector), from wood trimming and other woody material (forestry sector) and from the organic fraction of municipal solid and liquid wastes (waste management sector). But a critical threshold level needs to be secured for making the technology viable, and therefore is most likely to be suitable to larger and low-lying coastal SIDS.
- Among the pre-commercial ocean energy technologies, the ocean thermal energy conversion (OTEC) is the sub-technology with most promise to become commercially deployed in the near term. For the

remainder ocean energy sub-technologies significant assessment and R&D activities are needed to address outstanding technical issues and gather a better sense of the development and learning curves. Nevertheless all ocean energy technologies could be categorized as SIDS-appropriate, since they all perform well regarding land use, the OTEC and Current Energy sub-technologies could function as base load energy supply options in the future, and all ocean technologies are with adequate RD&D investment and activities foreseen to becoming commercially deployed in the medium to long term and suitable to address energy needs in SIDS.

7. Energy Efficiency and Sustainable Transport in the context of SIDS

Energy use has increased worldwide during the last century and it continues to do so. As explained earlier in this report, energy is critical for supporting the modern society. The technology base, including appliances, mobile phones, computers, transportation vehicles, and all other devices that consume energy has significantly expanded to un-imaginary levels. More and more technology and products are being used or consumed by a larger fraction of the global population, which is exponentially growing. Unfortunately the gap between the rate of the population growth versus the supply of energy is increasingly growing. The continuous and reliable energy supply is being challenged by many factors, including natural resource depletion and climate change.

In the case of SIDS, as for the rest of the world, next to the continuous efforts and investments in identifying primary energy sources to supply energy to communities around the globe, a more rational and critical strategy is energy conservation and the improvement of the energy conversion and use efficiency. Energy efficiency (EE) is defined by ***how much of a given task or product (be it the heating of a building for a specified time, the miles driven by a car, or the tons of iron smelted) is achieved per unit of energy used for that task or product.***[153]

It is important to clarify the difference between energy conservation and energy efficiency. Energy conservation is the avoidance of energy use by opting for not taking action, or finding alternative activities or solutions that consumes less energy. In the case of EE efforts are made to reduce the amount of energy required to provide products and services. For SIDS it is critical to state the importance of energy efficiency, which is nearly always a cost effective solution (in the mid to long run), helps cut emissions, and most importantly contributes to enhancing the energy security of SIDS.

The design and use of any equipment, machinery, vehicle, appliance or electronic system is almost always constrained by power and energy considerations; whether it is the battery life of a mobile device, the thermal power dissipation in a high-performance processor, or ultra-low power consumption of a wireless sensing application.

In addition, recent economic forces and increased environmental awareness have changed the landscape for new product design. Nowadays, energy efficiency is often one of the principal issues of discussion, as companies formulate new product strategies and manufacturers realize that the market will not allow them to compromise on performance.

The application of energy efficiency measures is widespread and sometimes complicated. Therefore, besides the need for improvements in energy management, education, and development of policies to support energy efficiency measures; much attention must be placed on the role that technological improvements can play in using energy more efficiently, reducing carbon emissions, and lowering costs to generate savings.

7.1 Energy Efficiency Technology review

Some of the key discussions about EE Technologies deployment lie in the energy efficiency vs. economic efficiency dispute.[154] For example, consider two air conditioners that are identical except that one has a higher energy efficiency and, as a result, is more costly to manufacture since high-efficiency units require more cooling coils, a larger evaporator, a larger condenser, as well as a R&D effort. Whether it makes sense for an individual to invest in more energy efficiency depends on balancing the value of energy that will be saved against the increased purchase price. This depends on the value of the additional materials and labor that were used to manufacture the high-efficiency unit. Additionally, the value to society of saving energy should also include the value of reducing any associated environmental externalities; but again this must be weighed against the costs.

New equipment or assets, can be purchased either to replace worn out and obsolete units, or as a first-time purchase. A primary driver of replacement purchases for durable energy-using goods is their useful lifetime. The rate of economic growth is also important, especially for first-time durable goods purchases where the rate of home construction is particularly relevant for residential equipment. The typical lifetimes for a range of energy-using assets are given in Table 25.

[153] The National Academy Press, Definitions of Energy Efficiency. Retrieved from: http://www.nap.edu/openbook.php?record_id=12621&page=315
[154] William H. Golove and Joseph H. Eto, 1996, Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency. Retrieved from: http://eetd.lbl.gov/ea/emp/reports/38059.pdf

Table 25 Typical Technology Life Times[155]

ASSET	Average Life –years-
Household appliances	*8-12*
Automobiles	*10-20*
Industrial machinery - equipment	*10-70*
Aircraft	*30-40*
Electricity generators –diesel-	*50-70*
Commercial – Industrial buildings	*40-80*
Residential buildings	*60-100*

Based on the professional experience of the authors, the real cost of implementing "energy efficiency (EE)" in the context of SIDS is commonly misinterpreted and underrated. Usually experts refer to EE as the cheapest alternative[156] to reduce energy consumption and CO_2 emissions compared to the direct deployment of RETs. However, there are many relevant hidden costs; in particular when observing the wide range of technologies and sectors that EE involves. At the end of the day, EE is not simply the development of a policy, law or measure, EE is the implementation and deployment of a series of innovations from building codes to the import and use of new technologies (EE appliances, electronics, etc.).

In the case of SIDS, there is simply no other more rational option than to introduce energy efficient technologies, products, and measures, in all aspects of the island community due to the lack of available conventional energy resources, climate change impacts, and limited carrying capacity of SIDS.

EE technology categorization

There are many ways to categorize EE technology that could have some relevance for SIDS. Table 26 summarizes currently commercial available technologies based on a categorization of generic technology areas.

Table 26 Generic categorization of commercially available technologies

Appliances	Buildings/Residential	Hi Tech	Industry	Transportation[157]
Clothes dryers - Clothes washers	Heating	OLED/FED TV and PC screens	Energy Technologies	Motor vehicle fleet
Dishwashers	Cooling	Laptops/Computers	Process control	Public – mass transportation
Refrigerators and freezers	Lighting	Cellphones	Materials	Maritime
Kitchen ranges and ovens	Energy management systems		Waste heat recovery	Aviation
	Integrated building design		Cogeneration	Railway
	Insulation of walls and windows		Smart grid	

The deployment of these technologies in SIDS requires a tremendous effort since the challenges besides political and social, are mainly of economic nature. This is because investments are necessary for capacity building, rebuilding or retrofitting infrastructure, and the import of new equipment (appliances, equipment for utilities and industry).

A very incipient summary-analysis of some EE technologies suitable for SIDS is listed in Table 28. The technology was assessed based on the following categories described in Table 27.

[155] Jaffe A., et al., Energy-efficient technologies and climate change policies: issues and evidence, 1999. Retrieved from: http://www.hks.harvard.edu/fs/rstavins/Selected_Articles/RFF_Energy_Effiient_Tech_and_Climate_Change_Policies.pdf

[156] (e.g.) Matthew Dornan and Frank Jotzo, Renewable Technologies and Risk Mitigation in Small Island Developing States (SIDS): Fiji's Electricity Sector, 2012. Page 08, section 3.1. Retrieved from: http://devpolicy.anu.edu.au/pdf/papers/DP_13_-_RET_and_Risk_mitigation_in_SIDS.pdf

[157] Transportation is analyzed in general in section 7.2

Table 27 Energy Efficiency Technology Evaluation criteria

Category	Description
Excellent	Technology is fully commercially available and it is fully cost competitive for SIDS
Good	Technology is commercially available and cost competitive for SIDS
Fair	Technology is commercially available and it is not cost competitive for SIDS–more R&D is necessary
Not acceptable	Technology is not commercially available – Potential availability only in the long term

The categories described in Table 27 help the evaluator to determine what the deployment rate is of each respective energy end-use technology (which can range from computers, light bulbs, to air conditioning) and other materials or technologies that although are not energy consuming products or devices can significantly contribute to the reduction of energy consumption or energy efficiency improvement.

Table 28 Summary of EE technologies deployable to SIDS[158]

EE Technology	Deployment rate on SIDS	Implementing Timeframe	Summary
Home networking	Good	Mid-term	Home networking is a type of control system that monitors all energy consuming equipment in a residence. It is able to identify when equipment is not being used and switch off the power supply, thereby removing the possibility of standby and wasted energy.
Computer/TV screen - OLED	Excellent	Short-Term	Organic Light Emitting Diode (OLED) screens. OLED technology uses a screen where the active picture elements (pixels) are comprised of organic materials. These pixels emit light once energized to form an image.
Integrated Window Design	Excellent	Short-Term	It refers to the combination of various services within window structures. The particular services considered here are integration of ventilation and/or heat recovery into the window unit. There are a number of options depending on the type of window structure utilized. The integrated system could be a prefabricated window unit or, in the case of commercial buildings, generally a double layer glazing façade.
Solar Thermal Air Conditioning	Good	Mid-term	The technologies currently available are predominantly vapor compression systems, and utilize refrigerants that are harmful to the atmosphere. The technologies looked at here are free of harmful refrigerants, use solar energy as the energy source and produce air conditioning indirectly through integrating with other systems, i.e. desiccant or evaporative cooling.
Alternative light technologies-Solid-state lighting - LEDs	Excellent	Short-Term	This technology topic is light emitting diode (LED) lighting systems, moving beyond current architectural uses into mainstream lighting.
Innovative Glazing	Fair	Long-term	This technology for glazing includes switchable (chromogenic) glazing and transparent insulating materials. Switchable (chromogenic) glazing varies the transparency of the glazing to automatically control the light and heat transfer, and transparent insulating materials are insulating materials that allow the passage of light.
Holistic Optimum design	Excellent	Short-Term	This technology topic is a simple software package that architects or others can use. It needs to be simple, and highlight day lighting, natural ventilation and other ventilation options, thermal properties and heat loss. *****only for new constructions***
Second-stage waste heat recovery from high-temperature processes	Good	Mid-term	This technology is concerned with extraction of the remaining heat, principally from 'dirty' but still reasonably high-temperature waste gas streams. They have been described as second-stage waste heat recovery in order to differentiate from existing, primary waste heat recovery technologies.
Innovative approaches to enhance recovery and use of waste heat from steam condensate and hot boiler flue gases	Good	Mid-term	This technology change involves the adaptation and integration of known techniques and technologies to increase the efficiency of steam systems. This includes improvements to heat exchanger technology, adaptation of heat storage and transport technologies and application of heat conversion technologies.
Innovative insulation materials - Vacuum Insulated Panels	Fair	Long-term	Vacuum Insulation Panels (VIP) are emerging as an effective method of insulating both existing and new buildings in both the commercial and domestic sectors. They would enable greater levels of insulation to be installed without increasing the thickness of the building fabric and also enable the insulation of previously un-insulated building elements, such as doors.

[158] Table adapted from "Assessment of Emerging Innovative Energy Efficient Technologies as part of the Energy Efficiency Innovation Review ". Retrieved from: http://www.decc.gov.uk/assets/decc/what%20we%20do/supporting%20consumers/saving_energy/analysis/fes-report.pdf

EE technologies for SIDS

The literature review shows a small number of publications focused on EE technologies for SIDS beyond the classic "change of bulb projects". Binger (2011)[159] provides an assessment of EE potential for Jamaica, and Escalante (2007)[160] provides some insights for the Caribbean region, which more or less are applicable to other SIDS. The EE Technologies reviewed are categorized in the following manner:

- Low Cost/No Cost Solutions
- Engineering Services
- Engineered Solutions/Design/Build Projects (no data available – only text)
- Design/Product Development Services (no data available – only text)
- Financial Services

Table 29 and Table 30 provide a summary per sector of the main findings from Escalante (2007).

Table 29 Low Cost Energy Efficiency and Savings Solutions

Technology	*Use*	*Unit Cost US$*	*Annual Energy Savings US$*	*Payback (Yrs.)*	*Remarks*
Compact Florescent Lamps (CFL)	Lighting	$3.50 to 8	Per unit 197.1 kWh -12 hrs. use/day-	0.08	Greater life of the CFL over the incandescent bulb.
Electronic Timers	Pool pump, AHU automatic switch off after hours.	$100	$876	0.12	Savings for a 1kW motor
Occupancy Sensors	Lamps off when no person in Washroom / office	$100	$200	0.5	
T-12 (40W) to T-8 (32W) or T-5 (28W) florescent lamp retrofit	Offices florescent lamp retrofit	$30	$15	2	Good for new buildings design.
Premium Efficiency Motors	Pumps, air handling units,	$100	$131	0.76	Based on 1 kW @ 24/365
Low flow Shower heads	Showers 1.5 gpm	$ 5	$96.8	0.05	Water – US$3.5/$m^3$ saving 1.0 gpm
Faucet aerators	1.5 gpm	$1	$75	0.01	Water – US$3.5/$m^3$ saving 0.5 gpm
Low flush toilets	1.6gpf instead of 3.0 gpf	$120	$70	1.7	
Refrigerant retrofit	Replace existing refrigerant with new hydrocarbon refrigerant	$100/ton	$150	0.75 to 1.5 years	Saves 10% to 15% of energy

Table 30 Engineering services

Technology	*Use*	*Unit Cost US$*	*Annual Energy Savings US$*	*Payback (Yrs.)*	*Remarks*
Absorption Cooling Systems	Air condition houses or large commercial buildings	N/A	N/A	1	Operate with solar, geothermal, gas, etc.
Solar Hot water Systems	Heat water for shower or other uses	~$2000	N/A	2 to 6	New local produced SHWS will cost around $US 1.000-1.5000
Chilled Beams	Air condition	N/A	N/A	N/A	80% fan motor savings
High Efficiency Air Conditioning Systems	Air condition	N/A	N/A	N/A	Use between 15% to 30% less energy than standard systems
Building Envelope	Wall insulation and double paned glass	N/A	N/A	N/A	Saves energy in air conditioning houses-buildings
Desiccant Heat Recovery Systems	Humidity control purposes	N/A	N/A	N/A	Savings of 30% - Ideal for large buildings

Escalante (2007) provides some insights about cost per technology. Table 31 and Table 32 summarize those findings.

[159] Binger A., Energy Efficiency Potential in Jamaica, 2011. Retrieved from: http://www.eclac.cl/publicaciones/xml/1/43261/Lcw394i.pdf
[160] Escalante A., Energy conservation in the Caribbean – a profitable industry for regional and foreign entrepreneurs, 2007. Retrieved from: http://energydynamics-lac.com/home/files/file/Energy%20Conservation10_12_07.pdf

Table 31 Residential Energy technologies cost

Technology	Qty. per household	Unit Cost US$
Solar Water heaters	1	2,000 – 1,500
CFL	6	3.5
Low flow shower heads	1	5
Faucets Aerators	2	1
Radiant barrier Roofs	1000 ft^2	0.75
Low flush toilets	1	120

Table 32 Commercial (hotels and offices)

Technology	Number units/room	Unit Cost US$
CFL	5	3.5
Electronic Timers	2	100
Air Conditioning Systems	1	2,000
Guest Room Controls	1	250
Double Paned Glass	1	500
Solar Water Heater	0.5 - 1	1,500

Summary of findings

Besides all the technology available today to improve EE in SIDS, there is still a significant potential to reduce the demand for energy. Acknowledging that many of the SIDS are tourism destinations, EE improvements in the services sector (hotels, restaurants, etc.) should be among the priority sectors of the economy for action.

There is no systematic approach regarding the identification and classification of high energy efficiency products and devices that are imported to SIDS. Only recently (2012), initiatives in the Caribbean and the Pacific SIDS were launched to specifically address the need to assess household energy consuming appliances.[161,162] These initiatives are critical to establish a proper baseline to be able to measure progress and success in the future.

In addition more cooperation on R&D between countries is necessary. R&D cooperation among SIDS will allow each participant to benefit from each other's efforts. This cooperation will magnify and accelerate results and help to disseminate best practices and EE technologies and energy technology policies ***"from research to deployment"***. These actions can contribute to improving the economic efficiency by increasing the use of clean and more efficient technologies in SIDS. Specifically, they will help reduce the costs by Regional/Local R&D and enable the sharing of results, avoid the duplication of efforts, and enable the resulting increased rate of technological progress.

7.2 Sustainable Transportation

Dependence on transportation systems based on fossil fuels lead to negative effects such as air pollution, and high infrastructure costs. Alternatives like Biodiesel, Electric utility vehicles, "The Veggie Car", Mass Transit Options and Incentives, Incentives for Carpooling, Car Sharing, and Efficient Vehicles, and Electric Plug-in Passenger Cars can help reduce these environmental impacts, and also help promote other benefits like physical wellness through increased daily activity (such as walking and biking). All these technologies or alternative means of transport can contribute to making transportation in SIDS more sustainable. Unfortunately there is no universal definition for "sustainable transportation".[163]

The European Union Council of Ministers of Transport defines "sustainable transportation"[164] as:

- Transportation that allows for the basic access and development needs of individuals, companies and society as a whole, to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations;

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[161] Carstens, J. and Scheutzlich, T., Eastern Caribbean Energy Labeling Project (ECELP), Bridging the gap through Energy Labels and Standards to enhance Domestic Sector Energy Efficiency, GIZ-CREDP, CARILEC Renewable Energy Forum 2012, Bermuda, See: http://www.carilec.com/members2/uploads/RE2012_Presentations/Day2/2.30-3.15_Thomas_CARILEC%20REF%20ECELP_TS%2020120919.pdf (visited November 2012)

[162] Secretariat of the Pacific Community (SPC), Launch of the Home First Programme, see: http://www.spc.int/en/component/content/article/216-about-spc-news/1011-spc-partners-with-paradise-technologies-to-improve-its-corporate-carbon-footprint.html (visited November 2012)

[163] Timothy Beatley, 1995, "The Many Meanings of Sustainability," Journal of Planning Literature, Vol. 9, No. 4, May, 1995, pp. 339-342. Retrieved from: http://jpl.sagepub.com/content/9/4/339.extract

[164] European conference of ministers of transport. Urban travel and sustainable development: overview of the project; August 19, 2004. Retrieved from: http://www.cemt.org/UrbTrav/overview.htm.

- Transportation that is affordable, operates fairly and efficiently, offers a choice of transport mode, and supports a competitive economy, as well as balanced regional development; and
- Transportation that limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise.

The Minister responsible for Transport in Canada defines "sustainable transportation"[165] as:
- A transportation system and transportation activity in general, must be sustainable on three counts — economic, environmental and social. Practically, this means ensuring that decisions are no longer made with the environment as an afterthought.

The "needs" for sustainable transportation that must be preserved for future generation are not clear and are usually related to economic development, social and human development, and environmental and ecological health. Unfortunately, different stakeholders and groups have different interests making the definition of "transportation needs" complicated.

For example the transportation sector does consume resources that can be depleted: energy, human and ecological habitats, atmospheric carbon loading capacity, and individuals' available time. But solutions that reduce depletion of one of these may exacerbate depletion of another. Moreover, transportation decisions tend to be made in the service of larger policy goals: economic growth and job creation, the character and intensity of land use, and socioeconomic and geographic transfers of wealth.[166]

Sustainable transportation and environment pillars
Sustainable transportation and environment pillars include among other[167]:

- Vehicle Efficiency:

Vehicle efficiency essentially translates as kilometers per liter or miles per gallon (MPGs). In order to introduce these technologies in SIDS the adoption of fuel economy standards needs to be mandated by SIDS governments. Enhancements in vehicle technology, such as regenerative braking and automatic "start/stop technology," should be deployed to increase the overall fuel efficiency, among other technologies.

- Alternative Fuels:

A key aspect to make the transport sector in SIDS sustainable is by replacing fossil fuel based transportation technologies with alternatives as: all-electric vehicles, gas/electric hybrids (including plug-in hybrids), and other technologies that can significantly improve fuel efficiency while offsetting the use of imported fossil fuels. The future may also include vehicles powered by hydrogen and natural gas.

- Travel Activity

Travel patterns are altered and multimodal transportation alternatives are encouraged to reduce travel in cars. This may be accomplished via pricing measures, improvements in bicycle, pedestrian and transit service alternatives, and (in the long term) changes in land use. Many of these options should be assessed in a SIDS context.

- Transportation System Performance

Improving the transportation system's performance through the use of operational strategies and new traffic technologies is one of the many options for those SIDS that need a mass transportation system or have one in place. These include synchronized and adaptive signal timing at intersections; Active Traffic Management (ATM) systems providing variable speed limits and dynamic lane control; traffic incident and emergency management systems; transit signal priority systems; real-time traffic and multimodal travel information; dynamic routing; integrated corridor management; smart transit and parking systems; electronic and open road toll collection and

[165] Transport Canada strategies for Sustainable Development. Retrieved from: http://www.tc.gc.ca/programs/Environment/SD/strategy97/menu.htm
[166] Sustainable urban transport: Four innovative directions, Todd Goldman and Roger Gorham, 2006. Retrieved from: http://www.thepep.org/ClearingHouse/docfiles/Sustainable.Urban.Transport.pdf
[167] ITS Technology and Sustainable Transportation. Retrieved from: http://documents4sharing.itsa.wikispaces.net/file/view/2K+ITS+Tech+++Sustainability+Transpo.pdf

more. Intelligent Transportation System (ITS) technologies are an integral part of the strategies and their successful operation.

Review of some "sustainable transportation" technologies

There are many technologies suitable to SIDS. Some examples are:

- Intelligent Vehicles – vehicles that manage spacing between the adjacent cars could become a reality in the market and could significantly increase the capacity of existing infrastructure; and
- Telecommuting/Telecommunications – not only are demographics driving this change of mobility, but innovations in technology are making it possible for people to work from home and prevent the need to commute.

Table 33[168] shows a summary of new technologies that will be available in the short term. However, the lack of R&D and assessment of most suitable transportation technologies for SIDS make it very challenging to provide a qualitative assessment.

Table 33 New technologies that will be available in the short term to achieve sustainable transportation in SIDS[169, 170]

Some Emerging Technologies	
Biofuels Based Pavements	Improvement to Reduce Rolling Resistance for Pavements
Carbon Nano Fiber Reinforced Cement	Inherently Low Emission Vehicles (ILEV)
Carbon-neutral Roadways	ITS Technologies for Traffic Management
Car Plug-in Stations	ITS Technologies for vehicular spacing & speed (IVHS)
Design for Deconstruction	Natural Gas and/or Biofuel Fueling Stations
Electrified Freight Railways (if applicable)	Online Electric Vehicle (OLEV)
Electric Vehicles (EVs)	Pavement Heat Exchangers
Glass Highways	Photo-catalytic Concrete (Self-Cleaning Concrete)
Glass Materials in Highways	Solar Highway Energy Generation
Green Cement	Solar Roadway Marking and Signs
High Speed Rail Passenger Systems (if applicable)	Solar, Wind Power in Jersey Barriers
Heated Bridge Decks	Sustainable Roadway Rest Stops
Hydrogen Highway	

Summary of findings

We can conclude that there is no available information regarding sustainable transportation for SIDS. However, we can argue that because of the land availability limitations and population density, smart solutions will be needed and mandated through new and innovative regulations and policies to improve the quality of vehicles imported to SIDS. Furthermore there is the need to assess the introduction and deployment potential and/or rate of electric and hybrid vehicles in SIDS. Also there is a need to evaluate the potential introduction of state-of-the-art mass transport technology to provide a comprehensive and integrated solution. In the context of maritime and air transportation currently the only possibilities are the use of biofuels for jets and a focus on improving the cargo facilities in SIDS ports to reduce local environmental impacts and prevent dumping of waste from ships in SIDS waters. The international nature of the transport sector limits SIDS to take actions in their own hands regarding the "greening" of the air and maritime freight transportation.

[168] Sustainable Transportation Solutions and Emerging Technologies, 2011, I-15 Mobility Alliance. Retrieved from: http://www.i15alliance.org/pdfs/tech_memos/sustainability_emerging_technologies/I-15CSMP_Sustainability_FINAL.pdf (visited November, 2012)

[169] Adapted from Sustainable Transportation Solutions and Emerging Technologies, 2011, I-15 Mobility Alliance. Retrieved from: http://www.i15alliance.org/pdfs/tech_memos/sustainability_emerging_technologies/I-15CSMP_Sustainability_FINAL.pdf (visited November, 2012)

[170] http://www.unep.org/pdf/OP_sept/EN/OP-2009-09-en-FULLVERSION.pdf (visited November, 2012)

8. The Characteristics of SIDS-Appropriate Sustainable Energy Technologies

Renewable Energy Supply Technologies

With current oil prices, solar and wind energy conversion technologies are fully competitive to the point where they can now provide electricity at very attractive costs in SIDS. There is a broad range of categories of renewable energy sources available in most SIDS—biomass, wind, solar, hydro, geothermal and ocean energy. They can be tapped using a variety of conversion technologies or processes to produce a range of energy services, including electricity, heat (or cooling), fuels, mechanical power and illumination. The competitiveness of different renewable technologies in SIDS depend first of all on the local RE resources availability and their cost and performance. Both factors still vary widely and depend strongly on local conditions.

Renewable Energy Source (RES) potential by technology

Based on the gathered data and information of the RES potential by technology in the SIDS DOCK Member States (including the four major SIDS region, Atlantic, Indian Ocean, Pacific, and Caribbean regions), the following can be concluded:

- **Solar Energy** - solar energy is available and highly useable in all the SIDS DOCK members;
- **Biomass Energy** – the bio-energy potential is highest among the larger Antilles and continental low-lying SIDS DOCK member states, including Belize, Dominican Republic, Jamaica, and Suriname;
- **Wind Energy** – the wind energy resource potential is available in all the SIDS DOCK members, but the potential in the Caribbean SIDS is generally higher compared with other major SIDS regions, The exceptions are SIDS as Cape Verde (Atlantic), Fiji (Pacific), and Mauritius (Indian Ocean) with good quality wind regimes;
- **Hydro Energy** - The hydropower potential is generally site-specific and the highest potentials are identified in larger Antilles and low-lying continental states, as Belize, Dominican Republic, Fiji, Jamaica, Mauritius, Samoa, and Suriname; and
- **Geothermal energy** – the highest identified potentials are in the eastern Caribbean states, including Dominica, Grenada, St. Kitts & Nevis, St. Lucia, St. Vincent & the Grenadines, and additional SIDS from other major SIDS regions, including Cape Verde (Atlantic), Fiji, Samoa, Solomon Islands, Tonga, and Vanuatu from the Pacific. There is unfortunately no or limited publically available information regarding the geothermal energy potential in a large number of SIDS DOCK member states.

Ocean energy sources have the potential to be extracted, converted and used with future commercial energy technologies. Based on the data gathering process, the following can be concluded:

- **Ocean Thermal Energy Conversion (OTEC)** – is a promising alternative as energy source for base load power generation. The OTEC potential is high in almost all SIDS DOCK member states, except or to lesser extent, in Barbados, Belize, Trinidad & Tobago, and Suriname in the Caribbean, and in the Maldives (Indian Ocean);
- **Tidal** – although available in all the major SIDS regions, the potential to extract, convert or use these energy sources is considered medium in almost all SIDS DOCK member states, with lower potentials in the Maldives and Mauritius, both from the Indian Ocean region;
- **Wave Energy -** although available in all the major SIDS regions, the potential to extract, convert or use these energy sources is considered medium in almost all Pacific SIDS DOCK member states, in Belize and Suriname in the Caribbean, in Cape Verde and Sao Tome & Principe in the Atlantic, and Maldives, Mauritius, and Seychelles in the Indian Ocean with lower potentials in most Caribbean SIDS DOCK member states; and
- **Current Energy** – although available throughout the major SIDS regions, the potential to extract, convert or use this energy source is considered high in most Caribbean SIDS DOCK member states and in the Maldives (Indian Ocean). With Barbados and Belize in the Caribbean, and Maldives and Mauritius in the Indian Ocean having medium current energy potential, and where the remainder of SIDS DOCK members have low current energy potential.

Renewable Energy Technologies

Based on the assessment performed on RETs we can conclude that low-cost and low-risk technologies are available, like geothermal, solar, wind, bagasse, and ocean energy technologies. This suggests there are potential suitable RETs available on short, medium, and long term, to relieve SIDS of the burden of the cost of importing oil while complying with the principles of sustainable development.

Among the technologies reviewed the following can be concluded:

- Among the sub-technologies under the category "Solar Energy", the solar thermal energy technologies do not qualify as SIDS-appropriate because of the current and anticipated costs of electricity production per watt being significantly high to become cost-effective and compete with the current and future possible portfolio of energy supply technologies. The U.S. Department of Energy forecasts costs of US$2.70 per watt, US$2.50 per watt, and US$1.30 per watt, respectively, by 2030 for the parabolic trough, power tower, and dish engine systems. Furthermore these technologies require significant amounts of space and their space footprint is not anticipated to become sufficiently reduced in the future to qualify as SIDS-appropriate.
- Solar PV and Wind Turbine technologies perform almost similar regarding the evaluation indicators. Both perform good to excellent on most indicators, but perform "fair" under the "energy efficiency" and "reliability". This is because both technologies use RES of intermittent nature (solar –because of the 24 hour day/night cycles), and (wind – because of the fluctuations of the monthly, daily, hourly and even instantaneous wind speeds and direction changes) and are considered less reliable to guarantee 100% power supply on a year basis. The conversion efficiency of both technologies is also considered lower than conventional fossil fueled power generation systems. Nevertheless both technologies are expected to have a significant role and potential in SIDS, since it is expected that by 2015 forward new storage technologies will become available revolutionizing solar and wind technology (e.g. using super capacitor and super magnetic technologies). These new technologies will enable the accommodation of a large-scale penetration of current intermittent RE sources.
- Although large hydro systems, using dams, perform excellent regarding several criteria, in particular as a reliable source of power for base load supply, they perform low to not acceptable in terms of the land use requirement and the environmental performance in SIDS. This is because large hydro dams require the flooding of significant amounts of land, whereby in most cases leading to displacements of people and destruction of ecosystems and habitats. Since land availability in SIDS is scarce with high population densities, it is anticipated that other future land use needs will be more critical than flooding valuable lands to produce hydropower in the context of SIDS.
- Two specific sub-technologies, namely the run-of-river hydro system and the geothermal binary cycle systems score high to excellent in all categories to be considered SIDS-appropriate. The only limiting factor is that both these RES are very site-specific and are therefore not in all SIDS DOCK member states available and applicable.
- Unlike the geothermal binary cycle system, the two other geothermal sub-technologies do not perform optimally in terms of economic viability and environmental performance.
- While biomass combustion technology performs well in most categories, the environmental impacts associated with the biomass feedstock lifecycle (as dedicated energy feedstock) can significantly impact the local or regional environment, the relative impacts of producing bioenergy feedstock do not only depend on how the biomass is produced, but also on what alternative land use it is obstructing that may be or become more critical to future island needs. Although it is known that biomass use can lead to a reduction in the impact on global climate through reduction in overall greenhouse gas emissions, still other types of emissions (e.g., NOx, SO_2, N_2O) with different environmental impacts are observed. Also, in the SIDS context there is the need to avoid problems associated with monocultures and the use of food crops for energy purposes.
- On the other hand, bio-anaerobic digestion and bio-gasification both perform good in all categories, with anaerobic digestion scoring "fair" on the adequacy of the service since in some cases manure and human waste is/can be used to run the system, and this is not always accepted by the community. But if designed properly and with proper public awareness this and the bio-gasification sub-technology can be categorized as SIDS-appropriate.
- Liquid Biofuel production is among the limited options of energy carriers (next to bio-gas, methanol and hydrogen that can be produced via biomass gasification and be used in future fuel cell technologies) that can be consumed as fuel in conventional vehicles for transportation. There is a mixed picture since liquid biofuels technologies are multiple and dependent on a large amount of factors. Among the sub-technologies or processes, lignocellulosic ethanol production is anticipated to perform well in SIDS. This

is because the feedstock can originate from residues from non- and food crops (agricultural sector), from wood trimming and other woody material (forestry sector) and from the organic fraction of municipal solid and liquid wastes (waste management sector). But a critical threshold level needs to be secured for making the technology viable, and therefore is most likely to be suitable to larger and low-lying coastal SIDS.

- Among the pre-commercial ocean energy technologies, the ocean thermal energy conversion (OTEC) is the sub-technology with most promise to become commercially deployed in the near term. For the remainder ocean energy sub-technologies significant assessment and R&D activities are needed to address outstanding technical issues and gather a better sense of the development and learning curves. Nevertheless all ocean energy technologies could be categorized as SIDS-appropriate, since they all perform well regarding land use, the OTEC and Current Energy sub-technologies could function as base load energy supply options in the future, and all ocean technologies are with adequate RD&D investment and activities foreseen to becoming commercially deployed in the medium to long term and suitable to address energy needs in SIDS.

Energy end-use technologies

Besides all the technology available today to improve EE in SIDS, there is still significant potential to reduce the demand for energy, by introducing energy efficient goods, appliances, and devices, both in the services industry (hotels, restaurants, offices, etc.) and households. There is currently no systematic approach regarding the identification and classification or labeling of high energy efficiency products and devices that are imported to SIDS.

As for the transportation sector, it can be concluded that there is no or very limited available information regarding assessments of making transportation in SIDS sustainable. However, we can argue that because of the land availability limitations and population density in SIDS, smart solutions will be needed and should be mandated through new and innovative regulations and policies to improve the quality of vehicles imported to SIDS and explore alternative means of mobilization. These alternative means of mobilization include the potential introduction of state-of-the-art mass transport technology to provide a comprehensive and integrated solution.

An attempt was made to categorize the multiple energy end-use technologies (appliances, devices, goods, apparatus, vehicles, etc.) both for household and transportation sectors. But due to the significant scale of technologies imported and used in SIDS, and the limited time and resources for performing such a comprehensive study, and lack of information and data regarding the technologies and assessments of improving the energy efficiency performance and their use in SIDS, it is concluded that in this stage it is not possible to draw any further conclusions regarding *SIDS-appropriate energy end-use technologies*. Therefore no energy end-use technology was further included in the analysis for the categorization of these technologies as SIDS-appropriate SETs using the SIDS-appropriate ETA method.

Finally, based on the availability of the renewable energy resources and on the “preliminary” results on “SIDS-appropriate ETA” methodology, Table 34 summarizes the suitable Sustainable Energy Technologies per SIDS’s country. However as part of the R&D needs, a detailed life cycle assessment is still needed per technology under SIDS conditions.

Table 34 SIDS-appropriate Sustainable Energy Supply Technology per SIDS DOCK member state

Technology / Countries	Solar photovoltaic	Wind	Hydro - run-of-river	Geo. Binary	Bio.- Gasification	Bio.- Anaerobic	Bio.- Liquid biofuels (lign.cell)	Ocean Thermal Energy Conversion (OTEC)	Ocean – Current tech.
Caribbean									
Antigua and Barbuda	x	x			x	x		x	x
Bahamas	x	x			x			x	x
Barbados	x	x			x	x		x	x
Belize	x	x	x		x	x	X *		

Technology / Countries	Solar photovoltaic	Wind	Hydro - run-of-river	Geo. Binary	Bio.-Gasification	Bio.-Anaerobic	Bio.-Liquid biofuels (lign.cell)	Ocean Thermal Energy Conversion (OTEC)	Ocean – Current tech.
Dominica	x	x	x	x	x	x		x	x
Dominican Republic	x	x	x		x	x	X *	x	x
Grenada	x	x	x	x	x	x		x	x
Jamaica	x	x	x		x	x	X *	x	x
St. Kitts and Nevis	x	x		x	x	x		x	x
St. Lucia	x	x	x	x	x	x		x	x
St. Vincent and the Grenadines[171]	x	x	x	x	x	x		x	x
Suriname	x	x	x		x	x	X*		
Trinidad and Tobago	x	x	x		x	x		x	
Pacific Ocean									
Cook Islands	x	x		x	x	x		x	
Fiji	x	x	x	x	x	x		x	
Kiribati	x	x			x	x		x	
Federated States of Micronesia	x	x	x		x	x		x	
Marshall Islands	x	x			x	x		x	
Nauru	x	x			x	x		x	
Palau	X	x			x	x		x	
Samoa	X	x	x	x	x	x		x	
Solomon Islands	x	x	x	x	x	x		x	
Tonga	x	x		x	x			x	
Tuvalu	x	x			x	x		x	
Vanuatu	x	x	x	x	x	x		x	
Atlantic Ocean									
Cape Verde	x	x		x	x	x		x	
Sao Tome and Principe	x		x		x	x		x	
Indian Ocean									
Maldives	x	x			x	x		x	x
Mauritius	x	x	x		x	x		x	x
Seychelles	x	x			x	x		x	x

X * indicate the need for a detailed LCA to prevent environmental impacts and clarify food vs. food issues.

After assessing RETs with the SIDS-appropriate ETA method (qualitative analysis) it can be concluded that among all the reviewed renewable energy supply technologies only 9 sub-technologies are categorized as SIDS-appropriate, i.e. (1) Solar PV technology, (2) Wind Turbines technology, (3) Run-of-River hydro power technology, (4) geothermal binary cycle technology, (5) Bio-gasification, (6) Bio-anaerobic digestion, (7) Liquid biofuels – lignocellulosic ethanol, (8) Ocean Thermal Energy Conversion (OTEC), and (9) Ocean Current technology. These are presented in order of number of SIDS DOCK member states where the technology is applicable, see Table 35.

[171] *=Large SIDS

Table 35 SIDS-appropriate RETs ranking

Ranking	SIDS-appropriate Renewable energy supply technology	Applicable in:	# of SIDS DOCK MS	Comment:
1.	Solar PV technology	All SIDS DOCK members	30	Good RES, modular technology
1.	Bio-gasification technology	All SIDS DOCK members	30	Good WTE option, small scales available
2.	Wind Energy technology	Majority of SIDS DOCK members except Sao Tome & Principe	29	Mature technology, good wind regimes
3.	Ocean Thermal Energy Conversion (OTEC)	Majority of SIDS DOCK members except Belize and Suriname	28	Base load alternative, low space footprint, large RES potential
3.	Bio-anaerobic technology	Majority of SIDS DOCK members except Bahamas and Tonga	28	Good WTE option, small scales available
4.	Run-of-River Hydro power technology	Majority of SIDS DOCK members except Antigua & Barbuda, Bahamas, Barbados, St. Kitts and Nevis, Cook Islands, Kiribati, Marshall Islands, Nauru, Palau, Tonga, Tuvalu, Cape Verde, Maldives and Seychelles	16	Where RES available, highly recommended
5.	Geothermal binary cycle	In Dominica, Grenada, St. Kitts and Nevis, St. Lucia, St. Vincent & the Grenadines, Cook Islands, Fiji, Samoa, Solomon Islands, Tonga, Vanuatu, Sao Tome & Principe, and Mauritius	13	Where RES available, highly recommended
5.	Ocean Current Technology	In all the Caribbean, except Belize, Suriname and Trinidad & Tobago; in Maldives, Mauritius and Seychelles	13	Base load alternative, low space footprint, large RES potential
6.	Liquid biofuels – lignocellulosic ethanol	In Belize, Dominican Republic, Jamaica and Suriname	4	Only alternative to conventional transport fuel

Future efforts are needed to fully assess quantitatively the RES Potential for SIDS to fully deploy RETs in a sustainable way and long term. Efforts should be focused on R&D for OTEC and Current Ocean technology because these energy supply technologies could function as critical technologies to use RE sources that can supply base-load power besides geothermal. In addition both solar and wind energy technologies are expected soon (2015-2020) to become non-intermittent technologies thanks to the new energy storage technology developments and applications.

9. Conclusions and Recommendations

- After decades of investments in project preparation activities, feasibility studies, and energy planning studies, there is still a critical lack of research regarding the specific assessment of RES potential in most of SIDS DOCK members;
- There is lack of a commonly agreed and proper methodology to assess the technical potential for RES in a standardized and uniform format in the all the major SIDS regions;
- There is a significant lack of data and statistics related to renewable energy resources and technology application potential in all SIDS DOCK member states;
- Use of inappropriate or no recognized methodologies to assess the technical and economic potential for RE deployment and RETs transfer inexorably leads to a distortion of RE market potential in SIDS and generates distraction from where the SIDS' authorities and international investors should focus on;
- There is a lack of transparency or open access to energy data and statistics being generated in all the SIDS major regions;
- The geothermal potential is on the short- to medium term a relevant and critical resource for the eastern Caribbean sub-region and several Pacific SIDS to achieve sustainable energy development since it can serve as a clean energy source alternative for base load power generation which is needed to provide reliable, affordable and clean energy services in SIDS;
- Geothermal and OTEC have the greatest potential to supply base load power to significantly offset the SIDS dependency on imported fossil fuels;
- Solar energy as a source is available in all SIDS, and its conversion into power is possible in all SIDS DOCK member states, although on short- to medium term, solar energy technologies are considered intermittent energy supply options, developments in energy storage, grid stability management, and parallel development of base load energy supply alternatives can significantly increase the potential deployment of solar energy technologies. Because of the wide-spread availability of solar energy it is possible to develop common policies and mechanisms to pool all the resources, efforts and instruments to accelerate transfer of solar energy technologies to the make solar energy use in all SIDS possible;
- Wind energy as a source is available in many SIDS in the Caribbean and lesser extent in other major SIDS regions for conversion into power; and
- There is a significant lack of Research & Development activities regarding non-commercial energy technologies that have the potential of becoming critical to address the energy needs of SIDS in the Caribbean (e.g. Ocean Energy Technologies, as OTEC, wave, currents, and tidal energy).
- It is necessary to understand the energy uses of the SIDS populations before introducing RETs, in other words a proper national energy balance and analysis is required to have a fair judgment on the energy needs in each respective SIDS;
- The social-political acceptance of RETs cannot be underestimated. Lack of considering social and cultural differences and issues for the deployment of RETs led in the Federated States of Micronesia to the following example, i.e. the biogas is bled off, because people find the concept of using biogas from manure for cooking offensive (Wade, H. et al., 2005)[172];
- Most SIDS have some experience with different renewable energy technologies. However, the contribution of renewable energy sources still remains low. Besides hydropower, some SIDS like those that are rich in RES like for instance the Dominican Republic, Fiji and Samoa, still remain dependent on diesel generators as the principal source and technology for power generation. In these cases it's not the lack of RES potential that impedes the RET deployment;
- Additionally, once a fair idea is projected of the renewable energy market scale, it can act as a driver for significant, positive economic growth and can incentivize the creation of more jobs per unit of energy delivered locally compared to 'business as usual' fossil-fuel economies since many of these jobs will be required domestically as they involve construction, installation and maintenance activities.[173]
- Governments must consider providing incentives for households to invest in Solar PV systems (decentralized power generation) to decrease cost and peak demand of the expensive diesel generators; and,
- Finally, but not less important, deployment of RETs it is not merely a question of technology issues, assessment and sources. The need for a transparent, long term mechanism to provide finance for

[172] http://www.sprep.org/attachments/000480_Regional_Overview_Rpt_Vol.1.pdf
[173] Jobs in Renewable Energy Expanding, Product Number: VST113. Retrieved from: http://www.worldwatch.org/node/5821 (visited November, 2012)

assessment, development and deployment of RETs in SIDS is still lacking. SIDS DOCK may be in the position to address this gap. SIDS DOCK's capacity will depend on its ability to develop a suitable and long term plan to finance and deploy RETs now and in the future to address the energy development needs of its membership.

10. Annex

10.1 Annex I

Please find here the Terms of Reference as background for the preparation of this SIDS-appropriate sustainable energy technology assessment report.

Terms of References

SIDS DOCK Support Programme - Development and Implementation of the SIDS DOCK Platform Building Component – Activity 2.1 (c) and (e): Development of a Strategic Plan to Identify, Assess and Transfer Technologies that are SIDS-Appropriate

1.0 Introduction

SIDS DOCK is a SIDS–SIDS institutional mechanism established to facilitate the development of a sustainable energy economy within the small island developing states. Transforming the energy sector away from petroleum dependency is the pathway for SIDS to generate the significant levels of financial resources that will be needed for adaptation to the impacts of climate change. It is estimated that SIDS consume in excess of 220 million barrels of fuels, annually, and emit some 38 million tons of carbon. The ultimate goal of SIDS DOCK is to increase energy efficiency by 25 percent (2005 baseline) and to generate a minimum of 50 percent of electric power from renewable sources and a 20-30 percent decrease in conventional transportation fuel use by 2033.

Some SIDS governments have announced more ambitious goals for the reduction of fossil fuel use in order to reduce greenhouse gas (GHG) emissions. An energy sector focused on promoting sustainable development rather than just providing energy to meet economic needs is essential to the SIDS addressing critical long-term development challenges, particularly in the areas of global climate change, food security, waste management and fresh water resources. SIDS DOCK provides a model mechanism with the objective of transforming the current fossil fueled-based economy to a low carbon economy in SIDS, with the ultimate goal of improved livelihoods through access to affordable energy services. By providing SIDS with a dedicated and flexible mechanism to pursue sustainable energy, SIDS DOCK will make it easier for SIDS Development Partners to invest across multiple island States, and to more frequently reach investment scale that can be of interest to commercial global financing.

SIDS DOCK will serve as a "DOCKing station" to increase SIDS access to international financing, technical expertise and technology, as well as a link to the multi-billion dollar European and United States carbon markets – within which the potential value of trading avoided GHG emissions is estimated to be between USD 100-400 billion, annually. The funds generated will help countries develop and implement long-term adaptation measures. SIDS DOCK has four principal functions:

1. Assist SIDS transition to a sustainable energy sector, by increasing energy efficiency and development of renewable energy;
2. Providing a vehicle for mobilizing financial and technical resources to catalyze clean economic growth;
3. Provide SIDS with a mechanism for connecting with the global carbon market and taking advantage of the resource transfer possibilities that will be afforded, and;
4. A mechanism to help SIDS generate the financial resources to invest in climate change adaptation.

In December 2010, in Cancun, Mexico, SIDS DOCK was launched with four Partners: the Alliance of Small Island States (AOSIS), the United Nations Development Programme (UNDP), the World Bank, and the Government of Denmark, which announced a grant of USD14.5 million in start-up contributions for the *SIDS DOCK Support Programme*. Over the period July 2011 to September 2011, the SIDS DOCK Organizational structure was finalized in a series of meetings between the Partners. On December 8, 2011, the SIDS DOCK Steering Committee designated Belize as the Host Country for the SIDS DOCK Secretariat. On 13 February 2012, the SIDS DOCK Steering Committee held its first meeting for 2012. The committee approved a number of decisions relevant to the timely implementation of the SIDS DOCK Support Program, and in particular the SIDS DOCK Program Platform Building Component. Key decisions include the formal recording of Belize as Host Country of the SIDS DOCK, and agreement for the registration of the SIDS DOCK as an international organization in keeping with *Article VII of the SIDS DOCK Memorandum of Agreement (MoA),* which, as of July 2012, has been signed by 30 SIDS Governments. Under the SIDS DOCK Support Program supported by the Government of Denmark, the Caribbean Community Climate Change Centre is responsible for developing the SIDS DOCK Platform in 2012, and includes *Supporting Technical Assistance Services SIDS DOCK* and *Institutional Design and Strengthening*. These items are listed as Activities 2.1-2.6 in the Program proposal. This Terms of Reference (ToR) is for preparation of *Activity 2.1 – Country energy planning capacities strengthened, focus on policy-makers*, *(e) Development of* a *Strategic Plan to Identify, Assess and Transfer Technologies that are SIDS-Appropriate*. SIDS DOCK is focused on developing deep expertise around specific types of low-carbon energy projects that can be deployed across states, but at the same time allow close cooperation and relationship building with government officials and private sector participants in individual countries. One initial focus is on SIDS-Appropriate Technologies where more research and/or demonstration, survey work and trials are needed before commercial-scale SIDS projects can be initiated. These include OTEC, lingo-cellulosic biofuels, geothermal, and energy storage. SIDS DOCK would seek to forge alliances with major research institutions, non-profits, and private sector entities to facilitate SIDS-specific research and in-situ technology trials.

Two key characteristics of the energy technologies to provide services to a low carbon economy are for the production of base load and peak electric power from sources other than petroleum, and for its efficient use in the production of goods and services. While PV and wind energy technologies are making and will make significant contribution, these generation of current technology does not provide competitive base load power which is critical for sustainable economic growth. The renewable energy resources that have potential to directly provide base load and/or peak power are hydro, geothermal, biomass and ocean thermal energy. Of these sources, only geothermal, hydro, and ocean thermal has this capability – of these sources only ocean thermal is applicable to the vast majority of SIDS. Ocean thermal also addresses other critical inputs into a sustainable low carbon economy such as increasing freshwater availability and improving food security.

SIDS need to undertake an assessment of potential sustainable SIDS-appropriate energy technologies based on prioritized needs and the renewable resources and then collectively negotiate for their timely development/deployment as the situation demands. There is need for a plan to identify, assess and transfer technologies that are SIDS-appropriate. SIDS needs to put in place capacity to undertake assessment of these SIDS-appropriate technologies and prioritize their needs and then collectively negotiate for their timely development/deployment as the situation demands. In this regard, the CCCCC is seeking a qualified and highly motivated individual or professional agency to develop the *Strategic Plan to Identify, Assess and Transfer Technologies that are SIDS-Appropriate*.

2.0 Scope of Work

The scope of work under this ToR covers Activities 2.1 (c) and (e) under the SIDS DOCK Support Programme, and will be implemented by the Consultant, supervised by the CCCCC on behalf of the SIDS DOCK Secretariat.

3.0 Deliverables

(a) SIDS-appropriate Renewable Energy Technology Assessment Report
(b) Draft Strategic Plan
(c) Strategic and Implementation Plan

Please find here the **Draft Outline for Concept Paper** that was shared as suggested concept paper outline.

1.1 Draft Outline for Concept Paper

Strategy for the Identification, Assessment, Development and Deployment of SIDS Appropriate Technologies with Potential to Assist SIDS DOCK Member States Transition to Low Carbon Economies by 2033

1.0 Introduction

The purpose of the strategy
1.1 Background Information
- SIDS DOCK and its Purpose – goals: 25-50-25 by 2033
- Energy and Climate Change and Adaptation –the importance of technology transfer in building a low carbon economy
1.2 Overview - State of Sustainable Development in SIDS
1.2.1 Socio-economic Status in SIDS – debt, unemployment, crime and violence, HIV AIDS, off track to achieve MDGs

1.2.2 State of the SIDS Environment – beach erosion, land degradation, coral bleaching, biodiversity threats, fisheries stressed, marine resources diminishing, other CC impacts
1.2.3 Sustainable Energy Situation in SIDS – access, affordability, policies, fossil fuel shocks, institutional capacity

2.0 Need for SIDS-Appropriate Technologies
2.1 State of the Energy Technological Environment in SIDS
2.2 The Technological Needs Necessary to Promote a Low Carbon Energy Sector in SIDS
2.2.1 Power Generation
2.2.2 Energy Service Provision
2.2.3 Institutional Capacity
2.2.4 Financing of priority technological needs

3.0 Objectives of the Strategy
3.1 To identify, assess and compile a list of energy technologies that are SIDS appropriate, technically feasible, consistent with SIDS development objectives, cost-effective, environmentally sustainable, culturally compatible and socially acceptable;
3.2 To create a database and directory of the technologies and the technology vendors, manufacturers, brokers, institutions, academia, civil society organizations, etc.;
3.3 To develop an implementation plan for the transfer, development and deployment of SIDS-appropriate technology;
3.4 To develop a strategy for a collective SIDS-wide policy approach with regards to aggregate purchasing to get better prices, collective approaches to technology developers, collective approaches to seeking investment financing, and in research, development, and demonstration.
3.5 To develop a monitoring and evaluation programme of SIDS-appropriate technologies to continually monitor and evaluate these technologies, allow for adjustments, course corrections, and further innovation and feedback;
3.6 To develop SIDS DOCK Secretariat capacity to coordinate and facilitate the achievement of a low carbon economy in SIDS by 2033.
3.7 To develop a SIDS-wide public education and awareness programme to sensitize and get buy-in from the public about the benefits of SIDS-appropriate energy technologies in a low carbon economy, and to encourage renewable energy use and support for energy efficiency efforts in pursuit of sustainable energy for all and improved livelihoods.

4.0 Methodology
Methodology to achieve outputs mentioned in 3.0 – literature reviews, elite and other interviews with key energy vendors and manufacturers, stakeholder consultations, surveys, site visits, assessment of the needs and priorities of the SIDS DOCK members for meeting energy for sustainable development objectives, assessment of SIDS DOCK member countries renewable energy potential

5.0 Overview of Energy Technologies
5.1 Technical, economic, and social aspects of energy technologies
5.2 Current Systems of Technology Development and Transfer
5.3 Sources of Sustainable Energy Technologies
5.3.1 Renewable Energy
5.3.2 Solar
5.3.3 Wind
5.3.4 Hydro
5.3.5 Geothermal
5.3.6 Biomass
5.3.7 Ocean
5.4 Energy Efficiency and Conservation
5.5 Transportation
5.6 Household

6.0 The Characteristics of Energy Technologies in SIDS

6.1 Power Generation
6.0.1 Thermal
6.0.2 Renewables
6.0.3 Waste to energy
6.1 Provision of Energy Services
6.1.1 Transportation
6.1.1.1 Marine
6.1.1.2 Commercial
6.1.1.3 Passenger Vehicle
6.1.1.4 Aviation
6.1.2 Lighting
6.1.3 Cooling
6.1.4 Refrigeration
6.1.5 Shaft Power

7.0 Recommended Activities and Programmes

8.0 Proposed Timeline and Milestones

10.2 Annex II

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