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RENEWABLE ENERGY OPPORTUNITIES
FOR ISLAND TOURISM

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Renewable Energy Opportunities for Island Tourism

International Renewable Energy Agency

CONTENTS

LIST OF FIGURES V

LIST OF TABLES......VI

LIST OF BOXES......VI

EXECUTIVE SUMMARY......1

1 INTRODUCTION......3
  1.1 Energy trends in the tourism sector and in Small Island Developing States...... 4
  1.2 An opportunity for the tourism sector to increase profitability and reduce socio-economic vulnerability...... 9

2 TECHNOLOGY ASSESSMENT: INVESTMENTS, AVOIDED COSTS AND ADDED BENEFITS......11
  2.1 Solar water heating systems......14
  2.2 Solar Air Conditioning systems......17
  2.3 Sea Water Air Conditioning systems......20
  2.4 Solar Photovoltaic systems......23

3 BARRIERS, ENABLING CONDITIONS AND BEST PRACTICES......31
  3.1 Barriers to technology deployment......32
  3.2 Enabling policies......33
  3.3 Review of best practices......38

4 MODELING THE OUTCOMES OF RET ADOPTION IN ISLAND TOURISM......43
  4.1 Model specifications......43
  4.2 Main results......45

5 RELEVANT CASE STUDIES......47
  5.1 Turtle Beach Resort, Barbados......47
  5.2 Intercontinental Bora Bora Resort & Thalasso Spa......48
  5.3 Turtle Island Resort, Fiji......49
  5.4 Rethymno Village Hotel, Crete......50

6 CONCLUSIONS......51

ANNEX I: TECHNOLOGY DETAILS 53
  Solar water heating (SWH) systems 53
  Solar air conditioning (SAC) systems 55
  Sea water air conditioning (SWAC) systems 55
  Solar photovoltaic (PV) systems 56

ANNEX II: REVIEW OF RENEWABLE ENERGY POLICIES IN SIDS 59

REFERENCES 61

List of Figures

Figure 1. Inbound tourism by mode of transport. Global average (left), SIDS (right) 5

Figure 2. Breakdown of energy use for an average hotel. 5

Figure 3. Breakdown of electricity consumption in the hotel sector of Barbados, by hotel size. 6

Figure 4. International tourism receipts in SIDS (% of total export and GDP)...7

Figure 5. Tourist arrivals in SIDS, total and as share of world tourist arrivals. 7

Figure 6. Average renewable energy consumption in SIDS, including hydro (% of TFEC). 8

Figure 7. Typical Levelized Cost of Electricity ranges with weighted average for 2013.
Graphs assume a 10% cost of capital. 10

Figure 8. Range of LCOE estimations for PV, SWH, SAC and SWAC,
under different CAPEX assumptions, compared to the business-as-usual solutions 13

Figure 9. Range of LCOE estimations for PV, SWH, SAC and SWAC, under different Weighted
Average Cost of Capital (WACC) assumptions, compared to the business-as-usual solutions............... 13

Figure 10. Schematic representation of a solar water heater. Source: Australian Government......................14

Figure 11. Range of LCOE estimations for SWH, under different Weighted Average Cost
of Capital (WACC) assumptions, and compared to the cost of electric water heaters
based on island electricity prices.. 15

Figure 12. Schematic representation of a SAC system with parabolic trough. 18

Figure 13. Range of LCOE estimations for SAC, under different Weighted Average Cost of Capital
(WACC) assumptions, and compared to the cost of electric chillers, based on island electricity
prices and COP of 2.8 20

Figure 14. Schematic representation of the sea water air conditioning (SWAC) system installed at
The Brando resort, French Polynesia. 21

Figure 15. Range of LCOE estimations for SWAC, under different Weighted Average
Cost of Capital (WACC) assumptions, and compared to the cost of electric chillers,
based on island electricity prices and COP of 2.8 22

Figure 16. Main components of grid-connected solar PV systems...24

Figure 17. Main components of an off-grid solar PV systems 24

Figure 18. Range of LCOE estimations for solar PV, under different Weighted Average
Cost of Capital (WACC) assumptions, and compared to the electricity price range i
n islands (diesel generators)...26

Figure 19: Causal Loop Diagram (CLD) representing the main feedback loops and indicators
included in the model...44

Figure20: Avoided energy bill minus investment annual (million USD/year)
and cumulative (million USD)...45

Figure A1. Schematic active SWH, showing pumps and controllers to transfer heat from
collector to storage: (a) direct system (no heat exchangers); (b) indirect system with two
heat exchangers. 54

Figure A2. Schematic passive system, with no pumps/controllers to circulate heat.
Top: integral collector storage system. Bottom: thermosiphon system..54

List of Tables

Table 1. Summary table of key assumptions used for LCOE calculation of SWH systems 16

Table 2. Summary table of key assumptions used for LCOE calculation of SAC systems, and results 19

Table 3. Summary table of key assumptions used for LCOE calculation of SWAC systems, and results 23

Table 4. Summary table of key assumptions used for LCOE calculation of solar PV rooftop systems, and results 26

Table 5. Indicators and costs of renewable energy investments in small island tourism facilities, by technology type 27

Table 6. Avoided costs resulting from renewable energy investments in tourism facilities, by actor type. 29

Table 7. Indicators of added benefits resulting from renewable energy investments in tourism facilities, by actor type. 30

Table 8. Renewable energy deployment in island tourism: main barriers, intervention options and relevant case studies by island context, hotel ownership and technology option 42

List of Boxes

Text Box 1 – Required investment and the Levelized Cost of Electricity of renewable energy technologies 12

Text Box 2 – The solar water heater industry in Barbados 15

Text Box 3 – Ice: a cost-effective thermal energy storage solution 17

Text Box 4 – Solar air conditioning in Aegean islands hotels 17

Text Box 5 – Installation and operation of SWAC systems in island hotels 22

Text Box 6 – Solar PV installations in island hotels 25

Text Box 7 – Avoided costs and added benefits from RET uptake and use 28

Text Box 8 – International cooperation on renewable energy in SIDS 33

EXECUTIVE SUMMARY

Tourism represents an important economic driver for island economies, and is at the same time highly dependent on a reliable, affordable and environmentally friendly energy supply. Energy supply in islands is still dominated by fossil fuels, in particular oil products. As a consequence, this makes the tourism sector – and the whole economy – of islands vulnerable to the volatility of oil prices, and to the impacts deriving from the use of fossil fuels in a fragile environment.

In island tourism facilities, energy services such as air conditioning, lighting, cooking and water heating are often provided by fossil fuels, primarily from electricity produced by diesel generators. The high price of diesel fuel used for power generation results in commercial electricity tariffs that are much higher than the global average. In 2012 the average electricity price was USD 0.33/kWh in Caribbean islands and Mauritius, and USD 0.43/kWh in Hawaii. In 2010 the electricity price in Pacific Island Countries ranged between USD 0.17 and 0.51/kWh .This is in comparison to an average price of about USD 0.26/kWh in EU member states, and USD 0.09/kWh in China and Canada (European Commission, 2014). Since the electricity bill is an important cost item for island hotels, the island tourism sector faces difficulties in offering competitive prices compared with the majority of non-island destinations, which have much lower energy costs.

This report analyzes in detail the potential contribution to the island tourism sector of four renewable energy technologies (RETs):

- *Solar water heating (SWH)* systems use solar heat to warm up domestic water, usually replacing electric water heaters.
- *Solar air conditioning (SAC)* systems use solar heat to provide cooling and heating, usually replacing traditional electric chillers.
- *Sea water air conditioning* (SWAC) systems use cold water from the ocean depths to provide air conditioning in hotel rooms and facilities, usually replacing traditional electric chillers.
- *Solar photovoltaic* (PV) systems produce electricity from the sun, usually replacing diesel-generated electricity, either purchased from the local power grid, or self-produced with private diesel generators.

Island hotels are increasingly investing in RETs, which are now cost-competitive in most island contexts (IRENA, 2013a; IRENA, 2012a). The four technologies analyzed in this report have been compared to the typical alternative found in most island hotels, and proved to be cost-effective, with attractive payback periods. The case studies show a range of less than one year for SWH, and up to 11 years for small-scale SWAC systems.

In addition to the economic benefits directly derived from reduced energy costs, case studies indicate that the transition to renewable energy will bring additional gains by attracting eco-friendly travelers who are willing to pay a premium for sustainable tourism experiences. The well-being of island communities will also be improved through the reduction of air and water pollution from fossil fuel combustion and spillages, as well as through the creation of additional employment opportunities for the installation, operation and maintenance of RETs.

However, the pace and scale of investment in RETs in island tourism is currently well below its potential.

Three key barriers that limit RET deployment in the tourism sector of islands are:

- Competitiveness of RE options (technical and economic barriers)
- Access to capital and cost of financing (ownership and financial barriers)
- Institutional and technical capability (knowledge gaps)

Enabling policies are discussed to provide solutions to remove these barriers and accelerate the deployment of RETs in island tourism. These include capital investment, incentives and disincentives, public targets mandated by law, and institutional and technical capacity building. Best practices and case studies that illustrate successful deployment of each of these four RETs in island tourism facilities are also presented, to show their benefits and provide concrete examples for replication.

1 INTRODUCTION

With the exception of a few countries, small island states rely heavily on fossil fuels for their energy supply. While diesel generators provide flexibility for power generation, diesel prices are high, especially in Small Island Developing States (SIDS), as a result of the distance from major oil refining and distribution hubs, high fuel prices and import costs, lack of modern port and fuel storage facilities, and the use of outdated technologies in some countries.

Tourism represents an important economic driver for a small island economy, and is at the same time highly dependent on reliable, affordable and environmentally friendly energy supply. This makes SIDS' tourism, and SIDS' economies as a consequence, vulnerable to fossil fuel availability and energy price shocks.

In addition, although of less concern in the short term, environmental sustainability plays an important role in tourism. The less the environmental impact of a tourism activity, the longer that service can be available to future tourists and also create revenue. Furthermore, as tourists are becoming more aware about their environmental footprint, the demand for sustainable tourism is growing.

This report assesses the business case for the deployment of Renewable Energy Technologies (RETs) in island tourism. A systemic approach is adopted for the analysis of the challenges and opportunities in the energy and tourism sectors, with consideration of the potential synergies that renewable energy deployment strategies can create with other sectors key to the socio-economic development of islands.

High energy prices have several direct and indirect impacts on the profitability of the tourism sector, which also affect the social and economic development of islands and SIDS. Tourism operators make use of electricity for cooling, water heating, lighting and other key services provided in hotels and resorts. Energy is also used for transportation and for food preparation. To compensate for increasing energy costs, tourism companies operating in islands are forced to raise the price of accommodation and transport services. This often results in a drop in tourism demand and a consequent loss of revenue. Thus, increasing fossil fuel prices have a direct impact on island tourism competitiveness.

RETs can generate significant savings for tourism operators by offsetting or replacing the use of diesel-based electricity. In contrast to volatile diesel-based electricity prices, RETs provide stable operating costs to assist hotels and resorts with long-term business planning. RETs also contribute to improving the state of the environment and support efforts to position islands as sustainable tourism destinations. All of these factors increase the competitiveness of the island tourism sector. This study assesses the potential contributions that four commercially available RETs can provide to the island tourism sector.

- Solar water heating (SWH)
- Solar air conditioning (SAC)
- Sea water air conditioning (SWAC)
- Solar photovoltaic (PV) systems.

These four RETs are evaluated considering their contribution to energy generation (for cooling, water heating and lighting), the investment required, as well the cost savings and benefits they create. Considering that the cost of fossil fuel imports in most islands results in commercial electricity tariffs that are higher than the global average (in the range of USD 0.33/kWh to USD 0.44/kWh in islands, against USD 0.26/kWh in European Union member states), these technologies can be economically attractive, generating considerable cost savings. SWH systems offset or replace the cost of electric water heaters, SAC and SWAC systems lower or eliminate diesel-based heating and cooling services, and PV systems reduce or eliminate the cost of electricity from national utilities or onsite diesel generation. In addition, RETs provide stable power generation costs that increase resilience and reduce vulnerability of island economies, and create a more conducive investment environment. As an added value to tourism operators, RETs improve branding by showcasing (sustainable) facilities and activities, and by reducing environmental degradation (*e.g.,* air and water pollution), both of which respond to the growing demand for ecotourism.

Despite the advantages of RETs, their deployment in island tourism faces several barriers:

- Competitiveness of RE options (technical and economic barriers)
- Access to capital and cost of financing (ownership and financial barriers)
- Institutional and technical capability (knowledge gaps).

Four main policy tools are available to create the required enabling conditions to overcome the barriers mentioned above:

- Capital investment
- Incentives (such as tax reductions)
- Public targets mandated by law
- Institutional and technical capacity building.

This report discusses these policy tools and best practices in detail, including *new leasing models for RETs*, such as the 2013 partnership between Starwood Hotels & Resorts Worldwide and NRG Energy, and the *net metering policies and variable-accelerated depreciation* implemented by the Virgin Islands Water and Power Authority (WAPA) in the Virgin Islands, and by Grenada Solar Power Ltd (GRENSOL) in the Eastern Caribbean.

This report also details input received from island tourism stakeholders and includes relevant case studies for deployment of RETs.

1.1 Energy trends in the tourism sector and in Small Island Developing States

1.1.1 Global energy trends in the tourism sector

Considering direct and indirect impacts, tourism accounts for approximately 9% of global gross domestic product (GDP) – tourism is a major contributor to GDP in SIDS, reaching 45.5% in Aruba and 47.4% in Maldives (Hampton & Jeyacheya, 2013). In many developing countries, tourism is a key source of local employment opportunities and contributes to poverty eradication. At the global level, it is estimated that international tourist arrivals surpassed the 1 billion mark in 2012, and are likely to reach 1.8 billion by 2030 (UNWTO, 2012).[1] According to the World Travel & Tourism Council, the tourism sector contributes to one in every eleven jobs worldwide (WTTC, 2012). Tourism represents a key driver of global economic growth, and is a crucial component of the effort to alleviate poverty and achieve the other development objectives in many developing countries.

On the other hand, the approach adopted for tourism development largely influences the sustainability of the sector; intensive use of resources, high amounts of waste generation, growing negative impacts on local terrestrial and marine ecosystems, and mounting threats to local cultures and traditions represent the main challenges faced by tourism worldwide (UNEP, 2011). In particular, the intensive use of energy in tourism is a serious concern for the long-term economic, social and environmental sustainability of the sector, as many tourism-based economies rely heavily on fossil fuels for energy supply, resulting in the tourism sector's contribution of about 5% of global greenhouse gas (GHG) emissions (75% of which is due to travel and 21% to accommodation, air conditioning and heating systems) (UNEP, 2011). In particular, it is estimated that the hotel sector's contribution to global warming includes annual emissions of between 160 and 200 kg of CO_2 per square metre of room floor area (Hotel Energy Solutions, 2011).

Most of the energy consumption in the tourism sector is attributable to transport and accommodation, which account for 75% and 21% of sectoral GHG emissions, respectively (UNEP, 2011). Using renewable energy, efficient technologies and sustainable practices in aviation, road transport and accommodation design and operations are key in order to mitigate climate change impacts in tourism. For example, one tourist travelling on a one-week holiday from Amsterdam to Aruba would require energy consumption of between 21 and 30 Gigajoules (GJ), of which 20 GJ would correspond to flight energy use (potentially declining to 4 GJ with the use of biofuels), while hotel energy use would fall in a range between 1 and 10 GJ, depending on hotel size and category. As stated by UNEP's Green Economy Report, high energy consumption for tourism transport and accommodation is mainly due to the growth in international and domestic travel, combined with the increasing use of energy-intensive transport modes. In particular, over

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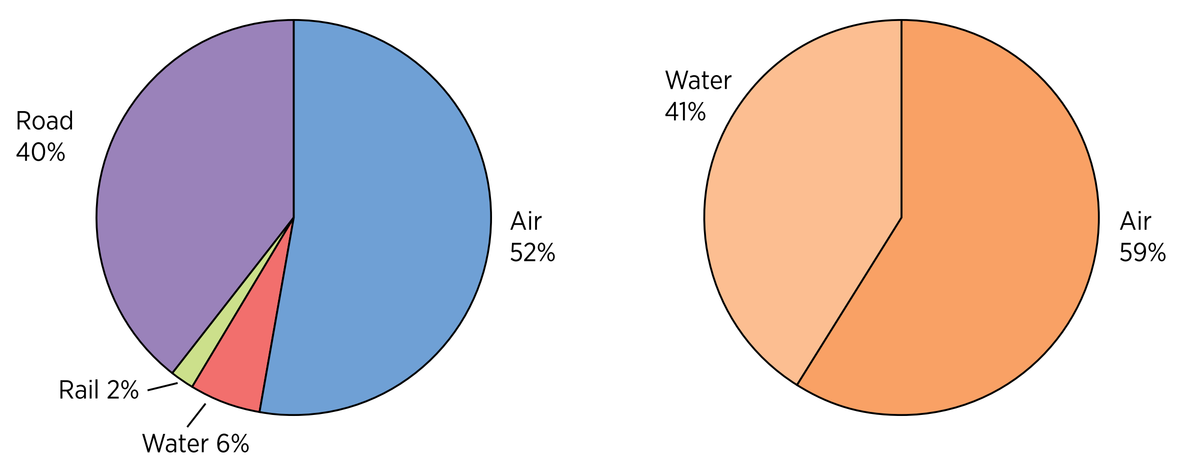
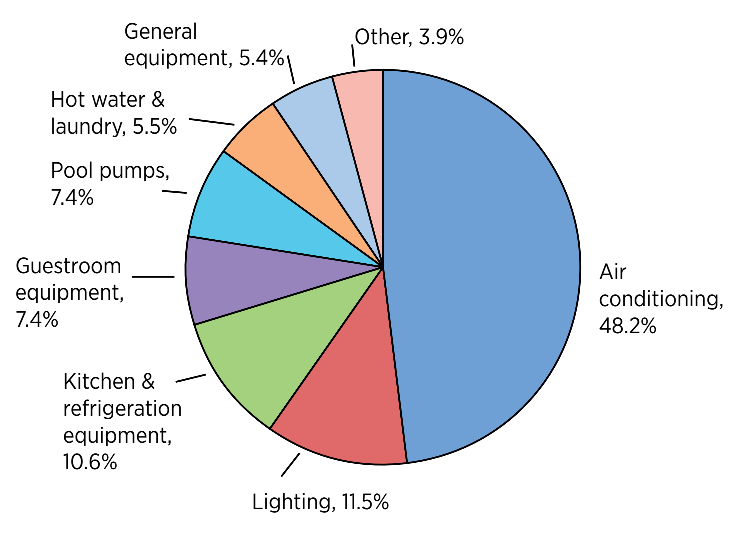
[1] *http://media.unwto.org/en/press-release/2012-01-16/international-tourism-reach-one-billion-2012*

Figure 1. Inbound tourism by mode of transport. Global average (left), SIDS (right)



Source: (UNWTO, 2013)

Figure 2. Breakdown of energy use for an average hotel.



Source: (CHENACT, 2012)

half of all travelers prefer to arrive at their destination by air, or choose destinations most easily reached by plane (Figure 1). In fact, the global share of tourism traveling by air grew from 42% to 52% between 2007 and 2012, and the share is naturally higher in the case of island tourism.[2] On the other hand, road travel for tourism purposes experienced a slight decline between 2007 and 2012, going from 42% to 40% of total travel, while water and rail transport decreased from 11% to 8% over the same period (UNWTO, 2008; UNWTO, 2013).

The use of energy in hotels and resorts, *e.g.,* for heating and cooling, lighting, cooking, cleaning, ranges between 25 and 284 MJ per guest per night (UNEP, 2011). Overall, the weighted global average of energy consumption for international tourism activities is estimated at 135 MJ per guest per night (UNEP & UNWTO, 2012). The drivers of energy use in the accommodation sub-sector vary considerably depending on the geographical area and the size of the hotel. In the Caribbean, for example,

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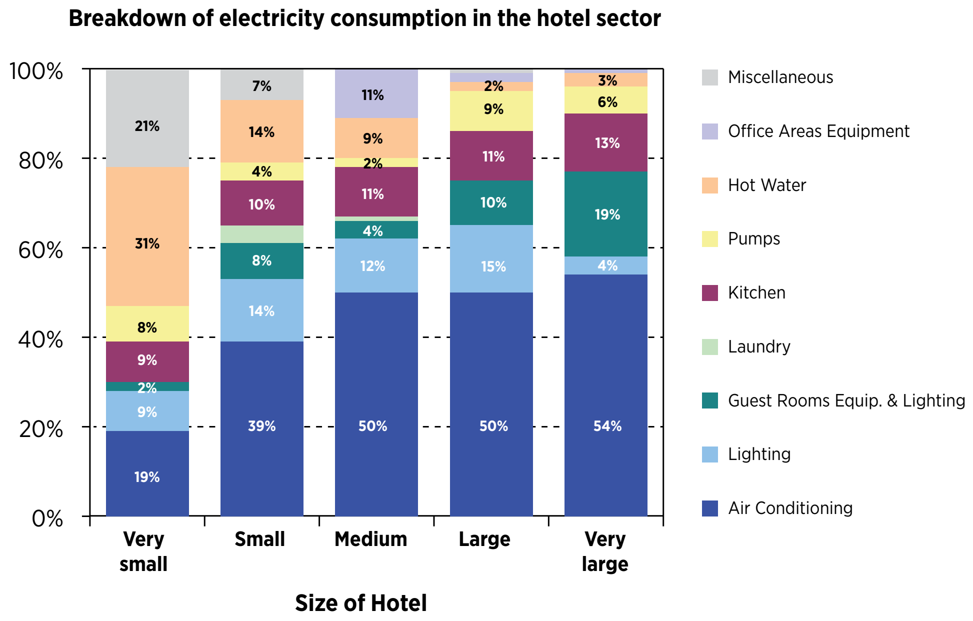
[2] For example, tourist arrivals by air in 2012 accounted for 97% of total arrivals in Fiji, 96% in Grenada and 98% in Mauritius (UNWTO, 2014).

Figure 3. Breakdown of electricity consumption in the hotel sector of Barbados, by hotel size.



Source: (CHENACT, 2012)

the main driver of energy consumption in hotels is air conditioning (48%), followed by lighting (11.5%), refrigeration (10.6%), guestroom equipment (7.4%) and pool pumps (7.4%), as shown in Figure 2 (CHENACT, 2012). In the case of Barbados, air conditioning is the main driver of electricity consumption, being responsible for about 50% of total energy use in medium to large hotels, and 39% in small hotels. Water heating is instead the main driver of energy consumption in very small hotels (Figure 3). Globally, hotels and resorts use up to 50% of their energy consumption for heating and cooling, followed by water heating and cooking (Beccali, La Gennusa, Lo Coco, & Rizzo, 2009). This is also due to low energy efficiency and high energy waste, which account for a large share of final consumption, thereby leaving room for considerable improvements and savings (UNEP & UNWTO, 2012). According to the World Economic Forum, improvements in energy efficiency and reductions in carbon emissions in the accommodation sub-sector are primarily targeting the use of existing technologies and practices, such as insulation, efficient lighting and appliances, change in room temperatures and increased awareness by consumers, but also include renewable energy use (WEF, 2009).

1.1.2 Energy and tourism trends in SIDS

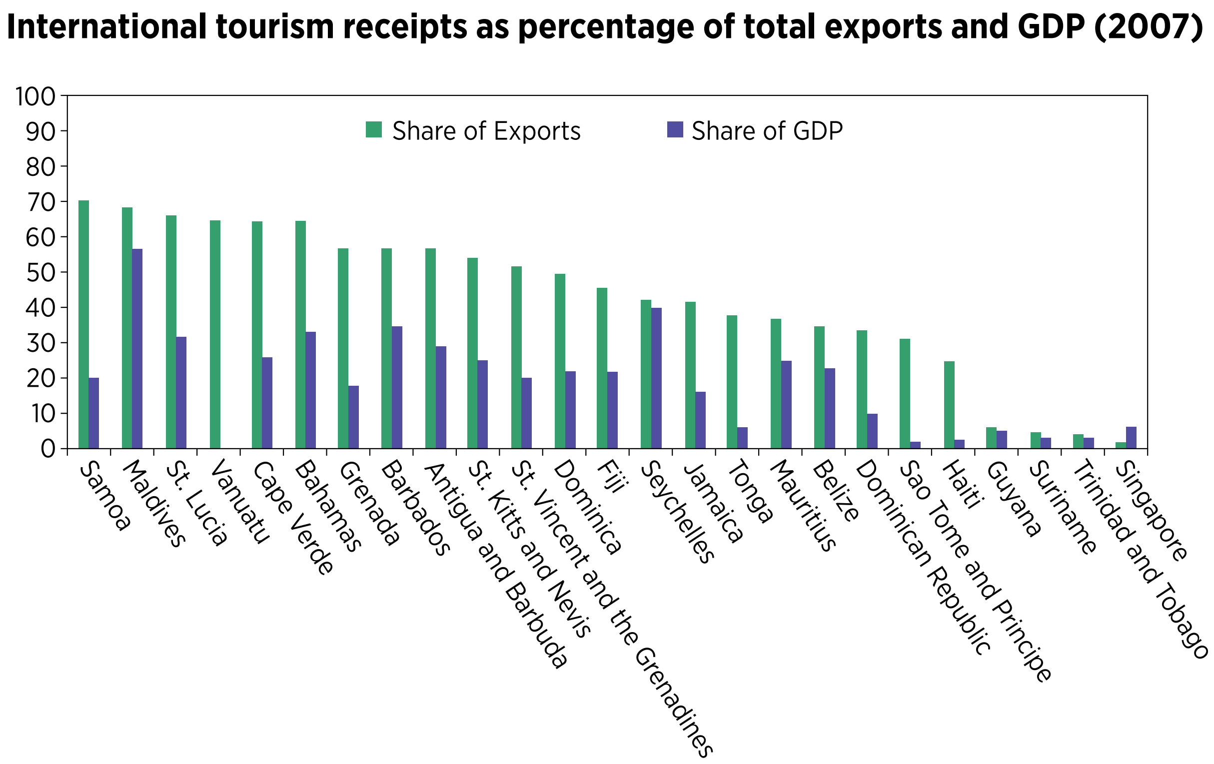
In the last decades, islands have gradually adopted tourist activity as one of their development mainstays. Nowadays, if we take into account the total number of tourists, islands represent the second largest ensemble of tourist destinations in the world, after the block made up by big cities and historical towns.

Tourism is a key sector for most SIDS. As an example, international tourism receipts contributed to 51% of the total value of exports of SIDS in 2007 (Figure 4), compared to 10% in other developing countries (UNDESA, 2010).

Tourist arrivals in SIDS have increased by almost 32% over the last decade, going from 22.9 million in 2000 to 30.19 million in 2010. However, the performance of the tourism sector in SIDS lagged behind the global trend, which grew by 39.3% over the same period (Figure 5) (UNWTO, 2012).

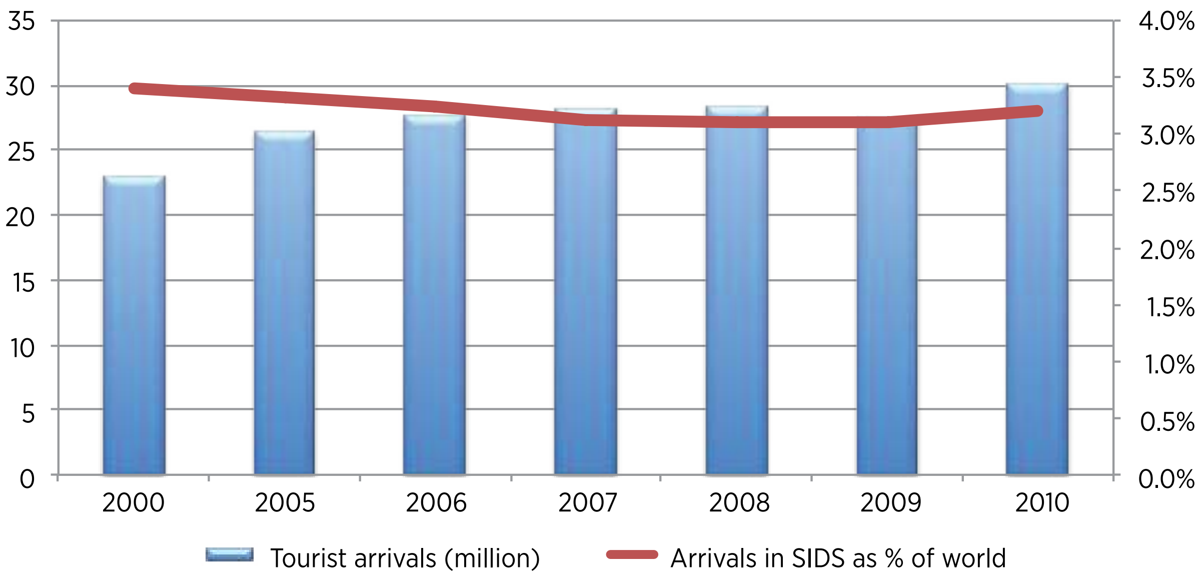
Figure 6 shows that the average share of renewable energy (including hydro) in total final energy consumption of SIDS has declined between 2000 and 2009,

Figure 4. International tourism receipts in SIDS (% of total export and GDP).



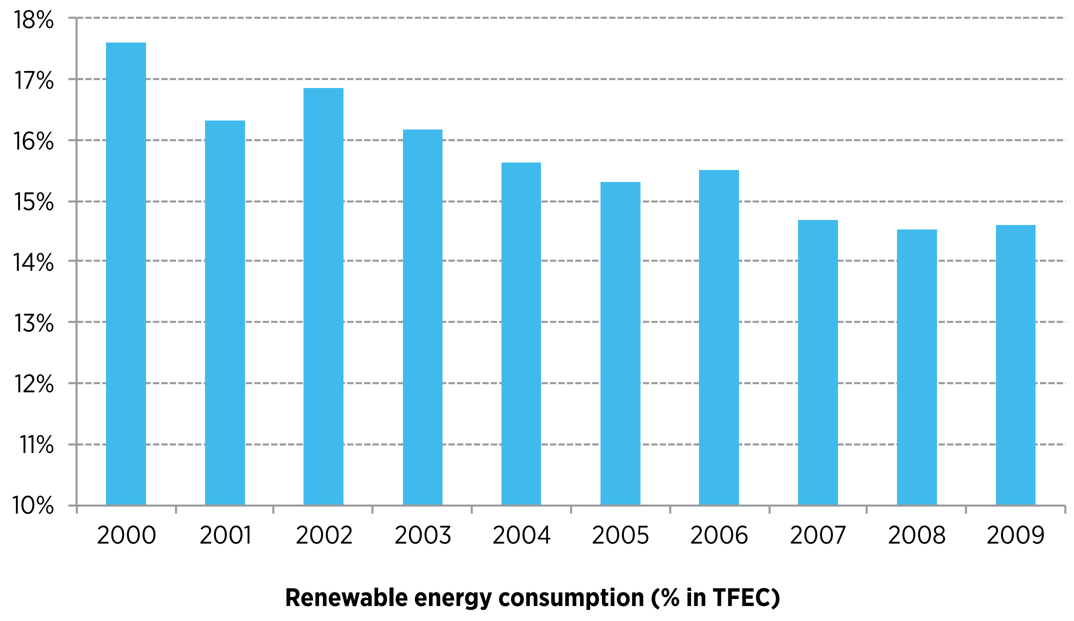
Source: (UNDESA, 2010)

Figure 5. Tourist arrivals in SIDS, total and as share of world tourist arrivals.



Adapted from: (UNWTO, 2012)

Figure 6. Average renewable energy consumption in SIDS, including hydro (% of TFEC).



Data from World Bank SE4ALL

going from about 17.6% to 14.6%. This indicates that energy needs of SIDS increased at a faster pace than their deployment of RETs. As a result of the continued reliance of SIDS on the use of imported fossil fuels, their economies, including the tourism sector, are particularly vulnerable to energy price variability. In particular, with the rise of oil prices over the last few years, fuel import bills currently represent approximately 20% of annual imports for 34 of the 38 SIDS countries,[3] and between 5 and 20% of their GDP.[4]

Pacific islands, for example, are reliant on fossil fuel imports for 95% of commercial energy use. High import costs result in very high electricity tariffs, which averaged USD 0.44/kWh for commercial users in 2010 (IRENA, 2013a). UNDESA estimated that an increase of USD 10 in average crude oil price produces a 1.5% decrease in GDP in Pacific SIDS (UNDESA, 2010). As a result, seven Pacific island states are ranked by the Asian Development Bank among the ten economies most vulnerable to oil price volatility in the Asia-Pacific region (ADB, 2009).

Given the economic, social and environmental impacts of fossil fuel imports, governments of SIDS have expressed interest in shifting towards a low-carbon economy by increasing investments in renewable energy and energy efficiency, as well as by establishing sound regulatory and policy frameworks for sustainable tourism. Examples of the adoption of RETs do exist. In the Caribbean, examples include: a 20 MW PV system announced by the Dominican Republic; investments in the construction of several wind farms in Aruba and a 20 MW wind capacity investment announced by Haiti; 160 MW of geothermal capacity addition planned in Saint Kitts and Nevis; and the advanced development of SWH systems in Barbados (Shirley & Kammen, 2013; IRENA, 2012a; IRENA, 2012b). In the Pacific, Fiji is using hydropower extensively (over 200 MW of capacity) and promoting the installation of PV systems (more than 3,000 SHS installed in 2012); Palau has 540 KWp of grid-connected solar PV systems; and the Federated States of Micronesia have planned the conversion of outer island diesel generators to mini-grid solar systems by 2014 (IRENA, 2013a). In the Indian Ocean, solar PV micro-power stations are being installed in villages in Comoros, while Mauritius is increasingly investing in the use of commercial biomass, to the point that 15% of its energy requirements are being met from bagasse

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[3] 38 SIDS are UN member countries, while another 19 are Non-UN Members or Associate Members of the Regional Commissions

[4] *http://sidsenergy.wordpress.com/tag/wave/*

derived from the production of sugarcane (UNDESA, 2010). At the Rio+20 Conference in June 2012, Heads of State formally adopted the 10-Year Framework Programme on Sustainable Consumption and Production (10YFP), a global action framework to enhance international cooperation to accelerate the shift towards sustainable consumption and production patterns in both developed and developing countries. Due to its increasing economic importance, sustainable tourism (including ecotourism) has been recognised as a key vehicle for sustainable development and has been integrated as one of the five initial programmes under the 10YFP. Finally, 30 SIDS have joined the SIDS DOCK, a collective institutional mechanism created in 2012 to support the transition towards sustainable energy in SIDS, in line with the UN Secretary-General's Sustainable Energy for All (SE4All) initiative.

1.2 An opportunity for the tourism sector to increase profitability and reduce socio-economic vulnerability

SIDS are highly reliant on fossil fuels for their energy supply. Tourism represents an important economic driver for SIDS economies, and is at the same time highly dependent on a reliable, affordable and environmentally friendly energy supply. As a consequence, this makes SIDS' tourism, and SIDS' economies, vulnerable to changes in fuel import prices. Further, recent trends show that global spending on ecotourism has increased by 20% every year in the past few years (TEEB, 2009); 6% of international tourists pay extra for sustainable tourism options; and 25% would be willing to pay more for environmentally friendly destinations (WEF, 2009). In the case of Crete, Greece, a survey showed that 86% of the respondents would prefer to stay in hotels equipped with RETs, and 75% of them would be willing to pay higher fees for staying in a hotel with RETs installed (Tsagarakis, Bounialetou, Gillas, Profylienou, Pollaki, & Zografakis, 2011). According to Tripadvisor,[5] to stay at an environmentally friendly hotel, 25% of tourists are willing to pay a 5-10% premium, and 12% are willing to pay a 10-20% premium. This is also confirmed by the case of the Lady Elliot Island Eco Resort in the Great Barrier Reef World Heritage Site, Australia, where renewable energy is considered to be part of the tourist attraction.[6]

RETs could address existing challenges and turn them into opportunities by lowering the cost of energy and guaranteeing stable generation costs. This in turn would increase the profitability of the tourism sector, support environmental preservation, and improve the contribution of the sector to the socio-economic development of SIDS.

Figure 7 compares the cost of electricity generation in islands for a variety of RETs with that of diesel-fired generators. Electricity costs are currently high in most SIDS, generally above USD 0.33/kWh in islands, and up to more than USD 1/kWh in particularly small islands (*e.g.,* Levanzo in Italy and remote outer islands in the Pacific) against USD 0.26/kWh in European Union member states, as result of several related factors, including (IRENA, 2013a):

- Long distance from major oil refining and distribution hubs;
- Lack of modern port facilities on some islands;
- Lack of fuel storage facilities on smaller islands, mainly due to their limited size and economic resources;
- High costs of diesel-based power generation, also due to the use of outdated technology.

However, the deployment of RETs in island tourism still faces a variety of barriers, which can be summarised in three main categories:

(1) Competitiveness of renewable energy options (technical and economic barriers);
(2) Access to capital and cost of financing (ownership and financial barriers); and
(3) Institutional and technical capacity (policy and knowledge gaps).

These barriers will be discussed in detail in section 3 of the report.

Moreover, climate change is already having a negative impact on natural capital and ecosystems, on which island tourism extensively relies (Millennium Ecosystem

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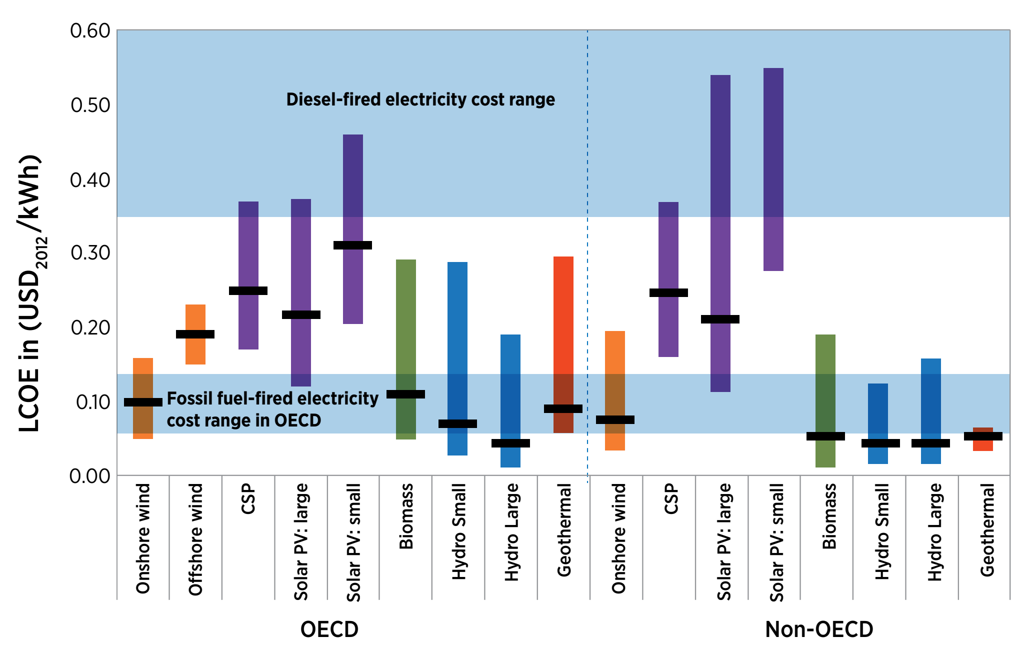
[5] *http://www.tripadvisor.com/PressCenter-i134-c1-Press_Releases.html*

[6] For more information, see *http://195.76.147.227/renforus/site/?p=2783*

Figure 7. Typical Levelized Cost of Electricity ranges with weighted average for 2013. Graphs assume a 10% cost of capital.



Source: (IRENA, 2014)

Assessment, 2005; IPCC, 2007). A study conducted by UNDP estimated that sea-level rise of 1 metre is likely to compromise the activities of 266 out of 906 tourism resorts and 26 out of 73 airports in the Caribbean, and that 49% of tourism resorts in the Caribbean Community (CARICOM) would be damaged by extreme weather events and coastal erosion (Simpson, *et al.,* 2010). In particular, costal and marine ecosystems provide services to the tourism sector in islands, including healthy reef attractions, sheltered beaches, protection of infrastructure from extreme weather events such as storms and floods, as well as provision of fish and other seafood. The progressive reduction of these essential services caused by climate change-related phenomena – coastal erosion, sea-level rise, coral bleaching, changes in fish species, alteration of mangrove and reef ecosystems, reduced rainfall and the likelihood of more frequent and more intense seasonal storms – is reducing the attractiveness of island tourism destinations. Extreme weather events are increasing in frequency due to climate change, which creates the perception that islands are risky tourism destinations.

Regional organisations and national governments are increasingly aware of the challenges fossil fuel-dependent energy production poses to the long-term profitability and environmental sustainability of the island tourism sector (IRENA, 2012c; AOSIS, 2012). The commitment of island nations to increase renewable energy penetration and reduce energy waste through energy efficiency improvements is demonstrated by the numerous policies and strategies that have been adopted for the enhancement of energy security (see Annex III). However, there is still much to be done in order to accelerate the transition to renewable energy and reduce dependency on fossil fuel imports.

Building on these considerations, the following section analyzes the main technology options available for renewable energy deployment in island tourism facilities. Subsequently, the main barriers to a transition to renewable energy are discussed, together with enabling conditions and best practices. Finally, several case studies are proposed where challenges were turned into opportunities for the island tourism sector.

2 TECHNOLOGY ASSESSMENT: INVESTMENTS, AVOIDED COSTS AND ADDED BENEFITS

Most island tourism energy needs are fulfilled through technologies powered by diesel based electricity. The high cost of fossil fuel imports in most islands results in commercial electricity tariffs that are higher than the global average. In 2012 the average electricity price was USD 0.33/kWh in Caribbean islands,[7] USD 0.43/kWh[8] in Hawaii and USD 0.33/kWh in Mauritius.[9] In 2010 the electricity price in Pacific Island Countries ranged between USD 0.39 and 0.44/kWh for both households (200 kWh/month) and commercial users (500 kWh/month) (IRENA, 2013a). This is in comparison to an average price of about USD 0.26/kWh in European Union member states, and USD 0.09/kWh in China and Canada (European Commission, 2014). Since electricity is intensively used in hotels and other tourism facilities for basic services such as air conditioning, lighting, cooking and heating, the island tourism sector faces difficulty competing with the majority of non-island destinations, which have much lower energy costs.

In response to this challenge, island hotels are increasingly investing in RETs, which, thanks to declining costs, are now cost-competitive in most island contexts compared to the high price of fossil fuel-based electricity (IRENA, 2013a; IRENA, 2012d; IRENA, 2012e). The levelized cost of electricity (LCOE) of SWH, SAC, solar PV and SWAC systems in islands ranges between USD 0.04 and 0.26/kWh. The average upfront investment for these technologies varies depending on several factors, including the materials used, resource availability, and the distance of the island from technology producers. Considering average costs for island settings, investments amount to approximately USD 300/kW for SWH, USD 1,800/kW for SAC, USD 3,750/kWp for solar PV, and USD 4,000/kW for SWAC. The payback period of each technology depends on a number of factors, such as the amount of energy consumed by hotels and the availability of renewable resources (*e.g.,* solar radiation). In general, several case studies show that renewable energy investments in island hotels have a payback period between 1 and 11 years.

In addition to the economic benefits directly derived from reduced energy costs, the transition to renewable energy will bring additional gains from the increased attractiveness of sustainable hotel businesses in the eyes of eco-friendly travelers, whose choices are largely driven by hotels' sustainability practices. Also, the well being of island communities will be improved through the reduction of air pollution from fossil fuel combustion, as well as the creation of additional employment opportunities for the installation and maintenance of RETs. Encouraging global trends are being observed, with potential also for job creation in SIDS, as the number of people directly and indirectly employed in the renewable energy sector grew by 14% between 2010 and 2011 (REN21, 2012; REN21, 2013).

Overall, the shift to renewable energy production in island tourism facilities implies the adoption of a new investment model that takes into account the short-, medium- and long-term financial returns from fuel savings and from access to the sustainable tourism market. Moreover, renewable energy investments bring environmental, social and economic benefits from a public sector perspective. Indeed, more secure and cleaner energy in islands is expected to increase economic resilience, reduce expenditures on fossil fuel imports, improve air quality, and create employment opportunities for the local population. This is where the interest of the private and public sectors come together to shape a more sustainable future.

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[7] *http://blogs.iadb.org/caribbean-dev-trends/2013/11/14/the-caribbean-has-some-of-the-worlds-highest-energy-costs-now-is-the-time-to-transform-the-regions-energy-market/*

[8] *http://www.hawaiianelectric.com/heco/Residential/Electric-Rates/Average-Electricity-Prices-for-Hawaiian-Electric,-Maui-Electric,-and-Hawaii-Electric-Light-Company*

[9] *http://ceb.intnet.mu/*

Text Box 1 – Required investment and the Levelized Cost of Electricity of renewable energy technologies

High electricity prices, mainly driven by the cost of imported fossil fuels, negatively impact the competitiveness and profitability of island tourism activities. Consequently, investments in renewable energy production in hotels and resorts located in islands are likely to generate positive returns, while reducing the vulnerability of the sector to increases in fossil fuel prices.

Investments are needed for the purchase, installation and maintenance of RETs. To assess their viability hotel owners and other operators should conduct a cost-benefit analysis to estimate the payback period of alternative technology options, and to quantify expected returns in the short, medium and long terms. The accurate estimation of the total costs associated with the adoption of renewable energy solutions in hotels should consider a variety of factors, which often change depending on the country context. In general, the key factors influencing the final investment costs include: quality of the technology chosen; transportation cost from factory to hotel; ease of installation; complexity and duration of bureaucratic procedures (*e.g.,* for the import and installation of technologies); cost of import tariffs; and existing in-country knowledge (*e.g.,* knowledge level of hotel personnel) regarding the installation and use of RETs (Hotel Energy Solutions, 2011b).

The levelized cost of electricity (LCOE), a measure of the overall competitiveness of energy technologies, can be used to assess the economic viability of the investment. In particular, the LCOE method consists of comparing the cost to install and operate an energy system and its expected life-time energy output. The calculation is done using the net present value method, in which upfront capital investments and payment streams over the technology's lifetime are calculated based on discounting from a reference date (Kost, *et al.,* 2013). The cash values of all the expenditures are divided by the cash values of power generation, yielding a final value measured in, for instance, USD/kWh. For this reason, the LCOE is increasingly used as a reliable indicator for comparing different energy technologies.

A dedicated LCOE calculator was developed by IRENA in order to compare the competitiveness of RETs with respect to diesel-powered systems in island tourism facilities. The tool allows the full customisation of renewable energy projects, including technology and financial assumptions. For illustrative purposes, the LCOE was calculated for a set of renewable energy projects that might be suitable for island hotels. The technologies assessed include roof mounted solar PV systems, SWH systems with 200 litres of capacity, SAC systems powered with evacuated tubes, trough solar thermal collectors, and SWAC.

Assuming a solar radiation of 1,700 kWh/m^2/year, the LCOE of these solar energy technologies is calculated to be in the range of USD 0.04 – 0.26/kWh (see also Annex II for a detailed list of assumptions and additional results). As presented in Figure 8 and 9, this value should be compared with the price of diesel-generated electricity (*e.g.,* the commercial electricity tariff in Fiji was USD 0.37/kWh in April 2014). More precisely:

- **Solar PV Rooftop:** the LCOE of solar PV rooftop systems with a capacity factor of 18.5%, capital cost of USD 3,750/kW, and fixed annual O&M costs of USD 25/kW is USD 0.262/kWh, or USD 72.65/GJ.
- **SWH:** the LCOE of an SWH system with capacity of 200 litres, capacity factor of 16%, capital cost of USD 300/kW, and fixed O&M costs of USD 30/kW is USD 0.042/kWh, or USD 11.68/GJ.
- **SAC:** the LCOE of a SAC system powered with evacuated tubes, capacity factor of 30%, capital cost of USD 300/kW for evacuated tubes and USD 1,500/kW for a single-effect absorption chillers, and fixed O&M costs of USD 30/kW is USD 0.113/kWh, or USD 31.5/GJ.
- **SWAC:** the LCOE of a SWAC system with a capacity factor of 100%, capital cost of USD 4,000/kW, and fixed O&M costs of USD 80/kW is USD 0.055/kWh, or USD 15.39/GJ.

Figure 8. Range of LCOE estimations for PV, SWH, SAC and SWAC, under different CAPEX assumptions, compared to the business-as-usual solutions

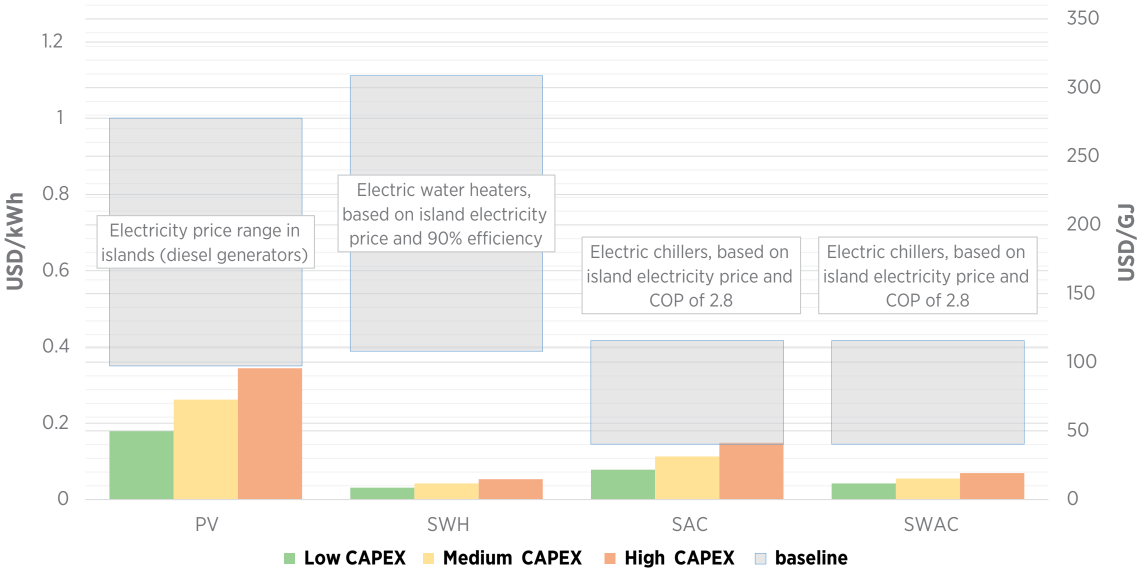
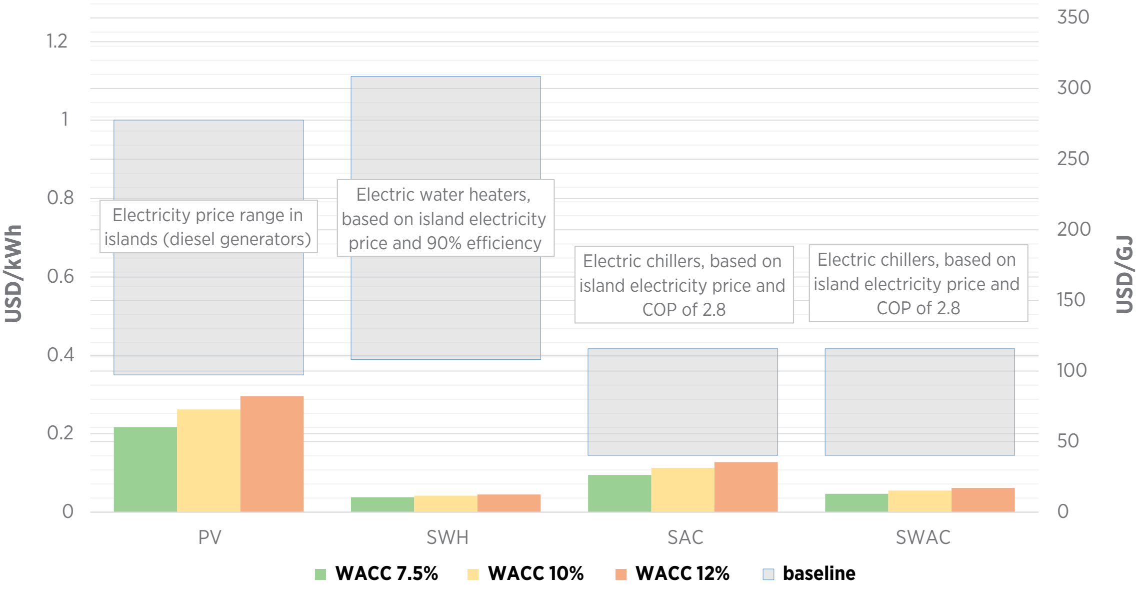


Figure 9. Range of LCOE estimations for PV, SWH, SAC and SWAC, under different Weighted Average Cost of Capital (WACC) assumptions, compared to the business-as-usual solutions



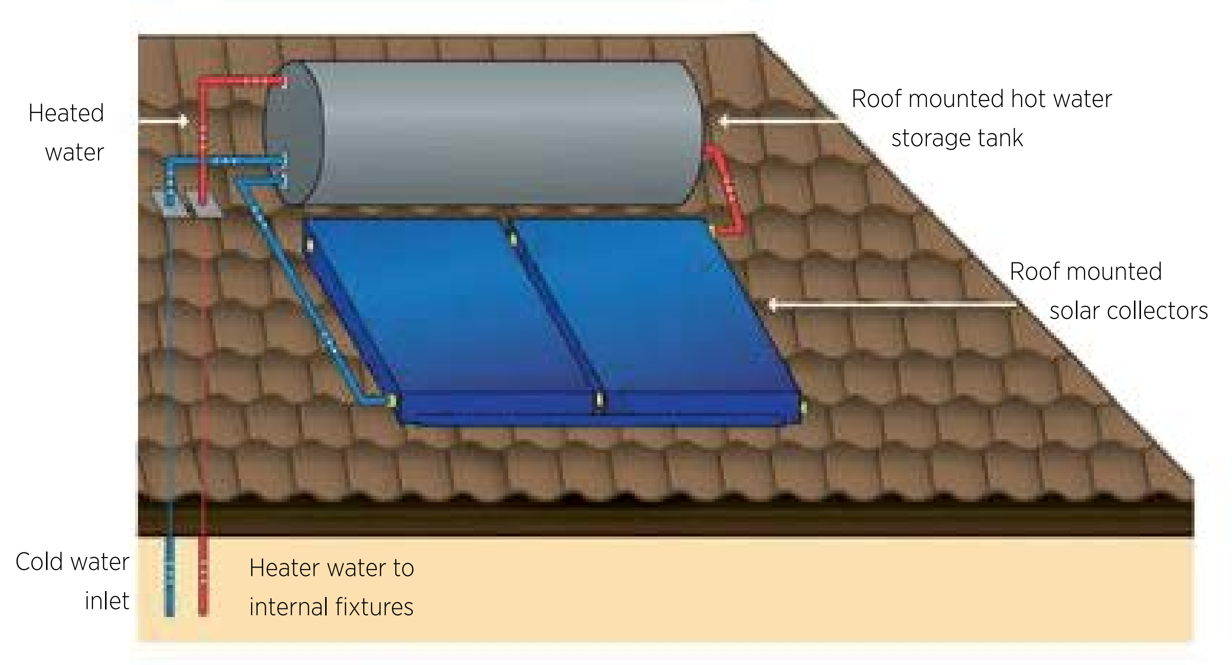
2.1 Solar water heating systems

SWH systems use solar heat to warm domestic water, offsetting the cost of gas/electric water heaters. The average investment required to purchase an SWH system in the islands is about USD 300/kW, and the payback period can be as short as a few months (*e.g.,* Turtle Beach Resort in Barbados) (Husbands, 2014). The LCOE of an SWH system with capacity of 200 litres is USD 0.042/kWh in islands with good solar radiation (1,700 kWh/m^2). SWH systems are generally commercially available, and are already extensively used in tourism facilities on many islands, including the majority of small Pacific islands (IRENA, 2013a), an increasing number of islands in the Caribbean (Barbados being the regional champion) (Shirley & Kammen, 2013), and islands in the Indian Ocean, such as Mauritius (GoM, 2009). Nevertheless, there are still significant opportunities for expansion.

The main components of an SWH system include the solar collector and the balance of system, which includes the collector-storage loop, the storage tank and, depending on system type, heat exchanger(s), pump(s), auxiliary devices and/or controllers. The balance of system and installation both generally cost more than the collector (IRENA, Forthcoming 2014). The collector is the key component of the SWH system as it converts the sun's radiant energy to heat. SWH systems can use a variety of solar collector types for capturing solar radiation, including unglazed flat plate, glazed flat plate, integral collector storage (ICS), evacuated tube, and parabolic trough. Hotels located in islands with high solar radiation can use less expensive flat plate or evacuated tube collectors for capturing solar radiation. Flat plate collectors consist of a single flat-plate absorber, while evacuated tube systems are composed of multiple evacuated glass tubes. Flat plates are generally less expensive and require less maintenance than evacuated tubes. On the other hand, evacuated tubes minimise heat losses due to the insulating effect of the vacuum, and are particularly suited for cloudy, colder climates with limited annual solar radiation. Figure 10 shows a type of SWH system commonly used in island hotels, consisting of roof-mounted flat-plate solar collectors paired with a water heater/solar storage tank.

There are two main classifications of SWH systems: "active" and "passive." Active systems use an electrically driven pump and an electronic controller to circulate a heat transfer fluid between the collector and solar storage when solar energy is available. Passive systems, including ICS and "thermosiphon" types, use no pumps or controls, relying instead on water main pressure to

Figure 10. Schematic representation of a solar water heater. Source: Australian Government



Text Box 2 – The solar water heater industry in Barbados

In Barbados the SWH industry emerged in the early 1970s, thanks to the perseverance and awareness-raising campaigns of industry champions (*e.g.,* the company Solar Dynamics) and to financial incentives provided by the government (*e.g.,* tax breaks on raw materials and preferential loans) (CDKN, 2012). As a result, over 40,000 solar water heaters had been installed on the island by 2008, and over 50 hotels have solar water heating units (Commonwealth Secretariat, 2012). It was estimated that, between 1974 and 1992, SWH produced total energy savings of USD 50 million (Perlack & Hinds, 2008). In comparison, the estimated cost of the government incentive program (*i.e.,* consumer deduction and duty-free importation of raw materials) over the same period was approximately USD 6.6 million (Perlack & Hinds, 2008).

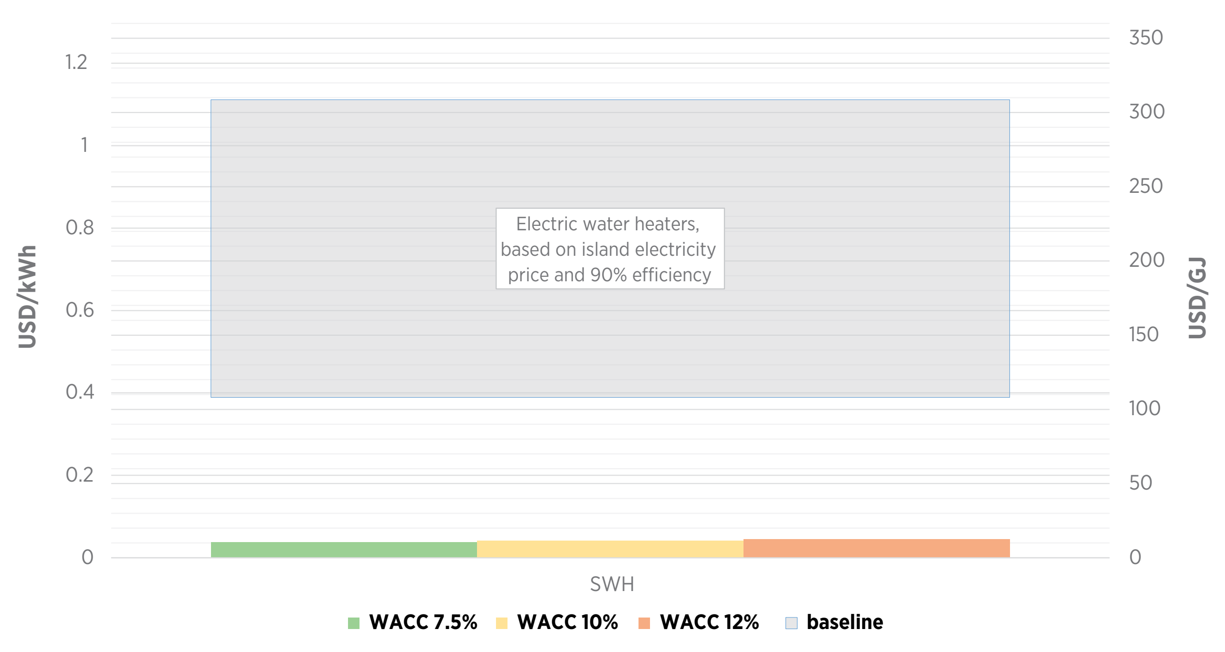
move heated potable (drinking) water to the delivery point (faucet or shower).

Systems can be further classified as either "direct" or "indirect." Direct SWH systems have no collector loop heat exchanger; potable water is heated directly in the solar collector. ICS and most thermosiphon systems are direct/passive systems, and are dominant in warm climates because they are less expensive and perform about the same as active systems (IRENA, Forthcoming 2014). In a tropical or sub-tropical island context, a passive/direct system would be the most cost-effective solution.

In climates where freezing can occur, active/indirect systems are used, utilizing a heat exchanger between the solar collector piping loop and the solar storage containing potable water. The heat exchanger separates the collector loop fluid (usually propylene glycol, a freeze-resistant non-toxic antifreeze) from potable water in the solar storage tank. Indirect systems are generally freeze-resistant and are dominant in cold climates (IRENA, Forthcoming 2014).

The size of an SWH system required for supplying hot water to hotel facilities depends on hotel capacity, average hot water consumption, and the site's solar

Figure 11. Range of LCOE estimations for SWH, under different Weighted Average Cost of Capital (WACC) assumptions, and compared to the cost of electric water heaters based on island electricity prices



resource. SWH systems are cost-effective, especially for hotels on islands with consistent sunshine throughout the year. The payback period largely depends on total annual solar radiation, the exposure of the tourism facility to solar radiation, and on the alternative options available for water heating. In the case of hotels on islands, the payback period is usually less than one year. This is due to the high costs of electricity (when produced with diesel generators) and the abundant solar energy resource in most SIDS.

The investment required to install and produce hot water from SWH systems depends on various factors, including the amount of solar radiant energy reaching the surface on which the technology is installed. Since many islands are endowed with abundant solar radiation, the cost-effectiveness of solar energy technologies is relatively high. The average capital investment cost for flat plates and evacuated tubes (thermosiphon and pumped) systems with plant size of 2.1-4.2 kW varies between USD 150/kW and 635/kW in China, and between USD 1,100/kW and 2,200/kW in OECD countries (REN21, 2013). In general, costs can vary greatly depending on the insulating materials and methods, the construction materials, the effectiveness of bonding between collector tubes and fins, the thermal conductivity of tubes and fins, the corrosion resistance of the exposed parts and water contacts, and the life span of the entire system under different climatic conditions (Raisul Islam, Sumathy, & Ullah Khan, 2013).

In order to assess the cost competitiveness of SWH systems installed on island hotels, the LCOE was calculated using different assumptions. Figure 11 shows the range of LCOE for SWH systems under different assumption scenarios. Results show that the LCOE would be USD 0.031/kW, USD 0.042/kW and USD 0.053/kW under low, medium and high CAPEX scenarios, respectively, and assuming a discount rate of 10%. In the case of lower or higher cost of financing, an SWH system with medium CAPEX would have an LCOE of USD 0.038 and 0.045/kW (discount rate of 7.5% and 12.1%, respectively). These LCOE results are calculated assuming solar radiation of 1,700 kWh/m²/year and capacity factor of 16% (see Table 1).

Table 1. Summary table of key assumptions used for LCOE calculation of SWH systems

Technology Assumptions	
Collector Area (m²)	3
Capacity (kW/m²)	0,75
Solar Radiation (kWh/m²/year)	1700
Capital Cost (USD/kW)	150 – 300 – 450
Fixed O&M (USD/kW)	30
Variable O&M (USD/kWh)	0
Capacity Factor	16%
Degradation	0.5%
Financial/Economic Assumptions	
Debt Percentage	70%
Debt Rate	6% – 8% – 10%
Debt Term (years)	10
Economic Life (years)	25
Cost of Equity	11% – 14.7% – 17%
Discount Rate	7.5% – 10% – 12.1%
LCOE	
USD 0.031-0.053/kWh	

Text Box 3 – Ice: a cost-effective thermal energy storage solution

A promising and cost-effective thermal energy storage solution is the making of ice. Ice storage systems freeze large amounts of water using thermal energy when the price of electricity is low, usually at night. The ice is then used to cool the glycol solution contained in chillers and provide air conditioning to buildings when daytime electricity costs are much higher. Ice tanks represent an opportunity to maximise the capacity of solar PV systems by storing energy using technology that is less expensive than batteries. In this sense, ice storage is a low-cost option to overcome technical problems related to the intermittency of solar thermal energy.

Approximately 8,000 ice storage systems for air conditioning are in use worldwide. The total capacity of refrigerated warehouses was about 460 million cubic metres in 2012 (IRENA, 2014). Ice storage is particularly effective in island tourism contexts, especially considering that most island hotels provide continuous air conditioning to their rooms, and that peak time is in the evening, when solar energy is not available. An example of hotel application is the Ritz Carlton Plaza of Osaka, where 16 sets of ice storage tanks with unit capacity of either 140 or 70 m^3 were installed. With a total thermal storage capacity of 80,750 kWh, the system reduces energy consumption for pumps and air conditioning by 33%. Because there are no moving parts, maintenance costs for ice storage tanks are minimal; water level and glycol concentration should be checked annually.

2.2 Solar Air Conditioning systems

SAC systems use thermal energy to provide cooling and heating, thereby offsetting the cost of diesel-generated electric heating and cooling services in island hotels. The average cost of a SAC system is about USD 1,800/kW, and the payback period ranges between five and ten years, depending on the technology used and the annual energy consumption for heating and cooling services in each hotel. The LCOE of a SAC system powered with evacuated tubes and using a single effect absorption chiller is 0.113 USD/kWh in islands with good solar radiation (1,700 kWh/m^2).

SAC is an established and commercially available technology that has been deployed in hotels and resorts as it significantly reduces the peak electricity demand associated with conventional cooling. Well-insulated storage tanks for chilled water also allow the system to operate at night and on cloudy days. Moreover, waste heat from the cooling circuit can be used to provide domestic hot water, if a closed-circuit cooling system is used for the chiller, instead of an evaporative tower. This can provide input for a heat pump, which will increase the temperature of waste heat to the level necessary for domestic hot water. Costs, efficiency levels, capacities and operating temperatures vary depending on the type of tech-

Text Box 4 – Solar air conditioning in Aegean islands hotels

The use of solar air conditioning in island hotels has proved successful in reducing energy costs and emissions. A study conducted in three hotels in the northeast Aegean area in Greece estimated average energy savings of 6,820 MWh/year per hotel, corresponding to an emission reduction of 7.2 tCO_2/year per hotel (Mamounis & Dimoudi, 2005). In Crete, Rethymno Village Hotel has installed a closed-cycle SAC system with an absorption chiller, powered by 450m^2 of solar thermal collectors installed on the roof of the hotel. According to the hotel owner, the cooling system (purchased and installed at a total cost of €146,000, or USD 200,000) has a payback time of five years, saving 70,000 kWh of electricity for cooling and 20,000 liters of diesel oil for heating every year (Mamounis, N., & Dimoudi, A. (2005)).

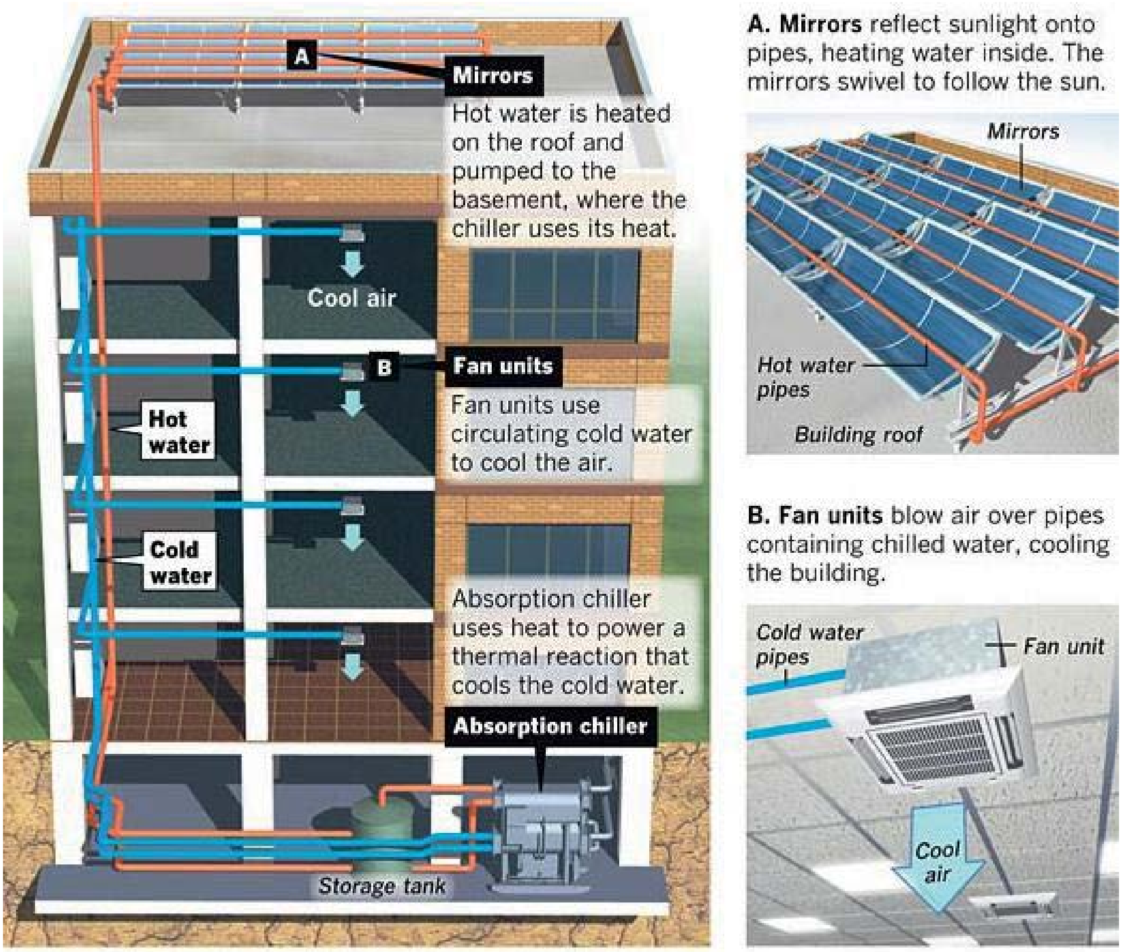
nology. Systems deployed in warmer regions such as resort islands are cost-competitive and highly efficient when compared to electric chillers driven by expensive diesel-generated electricity. In islands with high solar radiation the payback period for solar air conditioning is estimated at about ten years (Hotel Energy Solutions, 2011a).

SAC consists of a solar thermal system composed of solar collectors, storage tank, electronic controls, pipes, pumps and a thermally driven cooling machine (see Annex I for more details). Like SWH, SACs can use flat plates or evacuated tube solar collectors. For higher-efficiency chillers, concentrating solar thermal (CST) technologies can be used to reach higher temperatures, which are not necessary for domestic hot water production.

Thermally driven chillers can be divided into two categories: adsorption and absorption chillers.

- Adsorption chillers can be driven by hot water at temperatures as low as 55-60 °C, with optimal efficiency usually reached at around 80 °C. These machines do not require toxic refrigerants, as they use water as a refrigerant along with a solid, adsorbent material as a "sorbent" (*i.e.,* silica gel or zeolites). Typical size ranges between 5 and 500 kW of cooling power.
- Absorption chillers work using both a refrigerant and a sorption material in liquid phases. For air conditioning and refrigeration, the refrigerant is water, while the sorption material is often a solution of Lithium bromide (LiBr) and water, or Lithium chloride (LiCl) and water. For

Figure 12. Schematic representation of a SAC system with parabolic trough.



Source: *http://www.china-aircon.com/*

freezing applications, water cannot be used as a refrigerant, therefore water can be used as sorption material, while the refrigerant is commonly ammonia (NH3). Where substantial freezing needs exist in the tourism sector, an NH3/water absorption chiller can provide deep freezing, refrigeration and air conditioning. Once a properly sized solar thermal system is in place, it is also possible to drive separate thermally-driven chillers for different applications, as they all require hot water and a very limited amount of electricity to run.

Figure 12 shows a schematic representation of a SAC system installed in a five-floor building. The system represented in the image uses parabolic trough concentrating collectors and an absorption chiller.

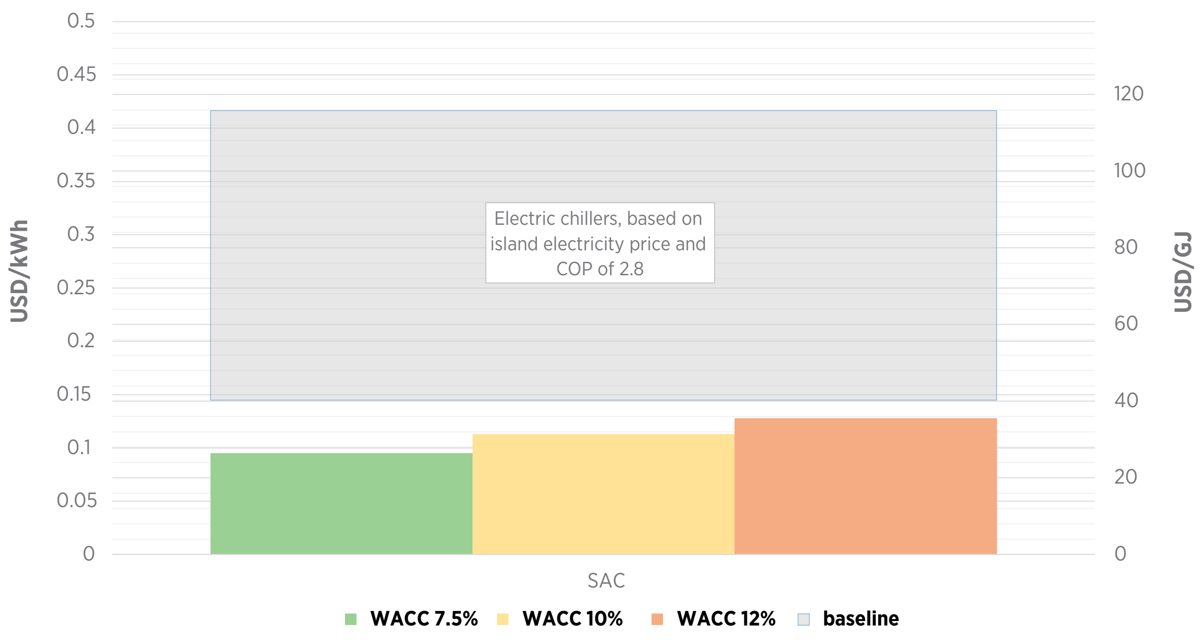
The cost of SAC systems varies greatly depending on the level of sophistication of the technology. In particular, flat plates and evacuated tubes are the least expensive solar collectors that can be installed in hotels and resorts for cooling purposes (the average cost of flat plates and evacuated tubes is the same indicated for SWH systems). On the other hand, more advanced CST technology is required to power double and triple-effect absorption chillers. The average cost of installing a solar air conditioner is estimated at about USD 8,000/kW (Woerpel, 2012) and the average capital investment for CST technologies is between USD 4,600/kW and 7,700/kW (see Table 5).

In order to assess the cost competitiveness of SAC systems installed in island hotels, the LCOE was calculated using different assumptions. Figure 13 shows the range of LCOE for SAC systems under different assumption scenarios. Results show that the LCOE would be USD 0.078/kW, USD 0.113/kW, or USD 0.149/kW under low, medium and high CAPEX scenarios, respectively, assuming a discount rate of 10%. In the case of lower or higher cost of financing, a SAC system with medium CAPEX would have an LCOE ranging between USD 0.095/kW (discount rate of 7.5%) and USD 0.128/kW (discount rate of 12.1%). These LCOE results are calculated assuming solar radiation of 1,700 kWh/m²/year and capacity factor of 30% (see Table 2).

Table 2. Summary table of key assumptions used for LCOE calculation of SAC systems, and results

Technology Assumptions	
Concentrator Area (m^2)	40
Capacity (kW/m^2)	0,75
Solar Radiation (kWh/m^2/year)	1700
Capital Cost evacuated tubes (USD/kW)	150–300–450
Capital cost absorption chiller single effect (USD/kW)	1,000-1,500-2,000
Fixed O&M (USD/kW)	30
Variable O&M (USD/kWh)	0
Capacity Factor	30%
Degradation	0,5%
Financial/Economic Assumptions	
Debt age	70%
Debt Rate	6%–8%–10%
Debt Term (years)	10
Economic Life (years)	25
Cost of Equity	11%–14.7%–17%
Discount Rate	7.5%–10%–12.1%
LCOE	
USD 0.078-0.149/kWh	

Figure 13. Range of LCOE estimations for SAC, under different Weighted Average Cost of Capital (WACC) assumptions, and compared to the cost of electric chillers, based on island electricity prices and COP of 2.8



2.3 Sea Water Air Conditioning systems

SWAC systems use cold water from the ocean depths to provide air conditioning service in hotel rooms and facilities. The average investment required is about USD 4,000/kW of air conditioning load, and the payback period is between 5 and 11 years (*e.g.,* see Section 5.2). The LCOE is USD 0.055/kWh. This technology, which has been installed in few island hotels so far, requires an upfront investment higher than SAC systems, but it is viable (and overall more economical) if the tourism facility is close to a deep-water resource and has a large cooling demand, generating considerable savings that offset the higher capital costs.

In SWAC systems, cold water is pumped up from the ocean and passed through a heat exchanger to cool the hotel building's chilled water down to 7°C for air conditioning (Hotel Energy Solutions, 2011a). Figure 14 gives an illustration of SWAC function. The cost of installing SWAC systems is driven primary by the depth required to reach sufficiently cold sea water and the distance required to pump the chilled fresh water from the near shore heat exchanger to the hotel. In this context, hotels in islands have a comparative advantage, since they are generally located at reasonable distance from the sea. Also, the upfront investment is repaid faster in hotels that have a large, year-round air conditioning load. SWAC heat exchangers are generally expensive due to the fact that they are made of titanium to avoid corrosion from salt, with the average cost of a titanium heat exchanger reaching about USD 2,600 per kW of cold water pumping power.[10] Investments in SWAC in islands are likely to be paid back in a shorter time than elsewhere, given the high electricity tariffs and intensive use of air conditioning in the majority of island tourism facilities. According to the UNWTO-led Hotel Energy Solutions project, SWAC systems can satisfy up to 90% of the cooling load, with a proportionate reduction in electricity bills for air conditioning, in most hotels (Hotel Energy Solutions, 2011a).

The upfront investment for the purchase and installation of a SWAC system depends on several variables, includ-

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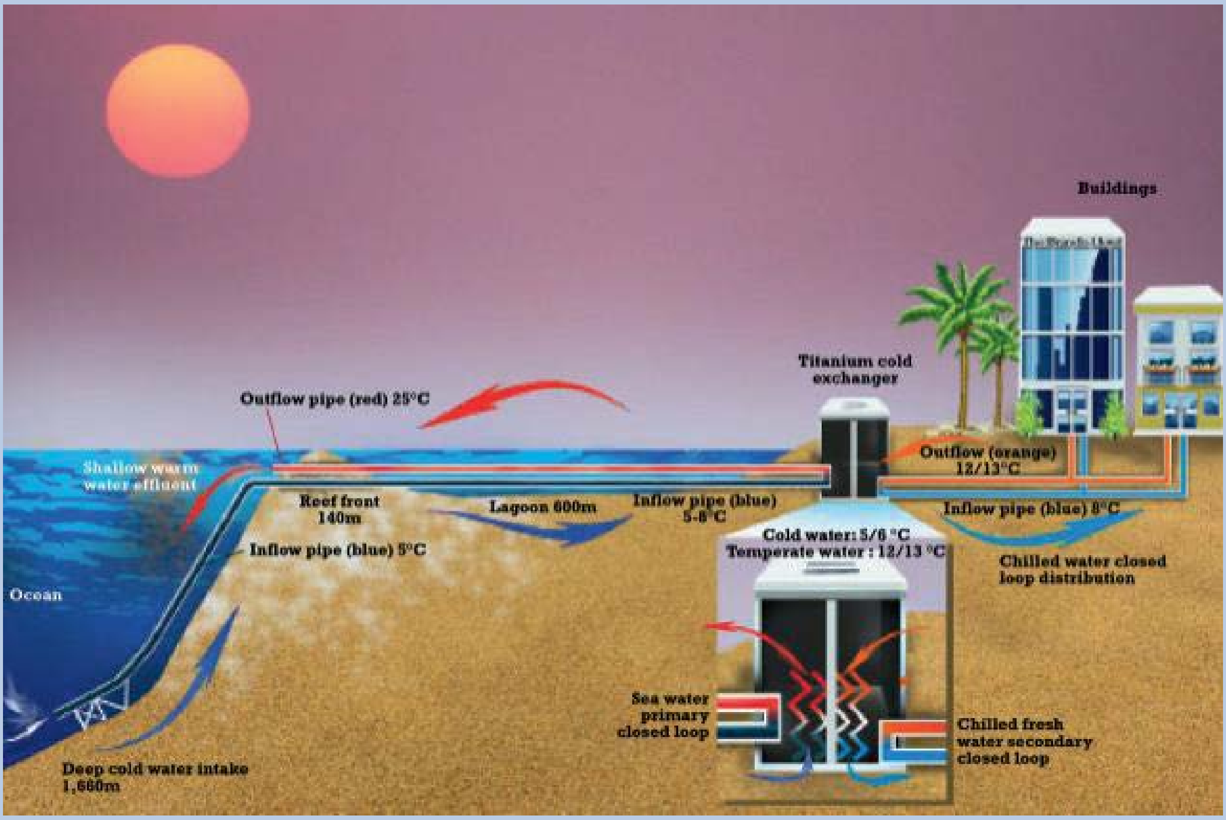
[10] *http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.301.2280&rep=rep1&type=pdf*

Figure 14. Schematic representation of the sea water air conditioning (SWAC) system installed at The Brando resort, French Polynesia.



Source: *http://eandt.theiet.org/*

ing the required water flow rate, the length of pipes, and the measures needed to protect the pipes. In general, SWAC systems require high initial investments but have very low operations and maintenance (O&M) costs. Feasibility studies conducted in the island of Curacao showed that a capital investment of between USD 2 and 5 million would be required to provide air conditioning loads from 2 to 7.5MW (corresponding to cooling of 540 to 2,100 hotel rooms), assuming a seawater intake pipeline length of between 1.6 and 3.6 km. The payback period for these systems was estimated at between five and six years for sites close to the sea and with high air conditioning requirements, and from 9 to 17 years for the sites with the smallest air conditioning loading (Broeze & ven der Sluis, 2009).

Having multiple investors join forces to purchase and install SWAC systems might be an effective way of sharing high upfront costs. An example of this investment model is the Honolulu Seawater Air Conditioning project, which aims to develop a 25,000-ton (about 88 MW) seawater air conditioning district cooling system for commercial and residential buildings (including hotels) in downtown Honolulu. Both private actors and public institutions fund the HSWAC project, which has a total estimated cost of about USD 250 million. Private investors from Hawaii, Minnesota and Sweden are providing USD 17 million, and the remainder of the project is funded with public debt.[11]

In order to assess the cost-competitiveness of SWAC systems installed in island hotels, the LCOE was calculated using different assumptions.

Figure 15 shows the range of LCOE for SWAC systems under different assumption scenarios. Results show that the LCOE would be USD 0.042/kW, USD 0.055/kW and USD 0.069/kW under low, medium and high CAPEX

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[11] *http://www.honoluluswac.com/*

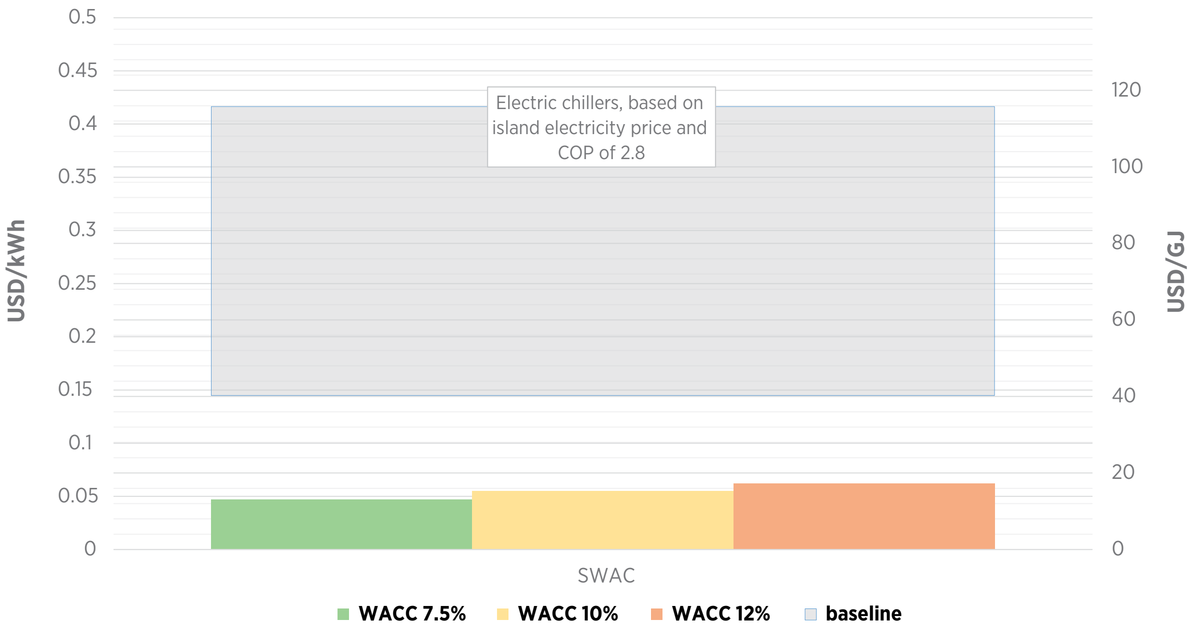
Text Box 5 – Installation and operation of SWAC systems in island hotels

Although SWAC systems are relatively new, they have been planned or already installed at island hotels and resorts in Aruba, Hawaii, Mauritius, Tahiti (Honolulu) and Tetiaroa atoll in French Polynesia. For example, the Intercontinental Bora Bora Resort and Thalasso Spa in Bora Bora, Tahiti installed the first operational SWAC system in 2006. This system extracts ocean water from a depth of 900 metres, and uses it for providing air conditioning to the entire resort complex. The SWAC system allowed the hotel to save about 80-90% of the electricity used by the electric cooling systems, with total electricity consumption savings estimated at 2.4 GWh/year (Neiva de Figueiredo & Guillén, 2014). Another SWAC system was successfully installed in The Brando resort, located in the Tetiaroa atoll. The system, which is represented in Figure 14, extracts cold water from a depth of 1,660 metres, and provides air conditioning service to its 35 private villas.

Other projects are under development; in Mauritius the Sustainable Energy Fund for Africa has approved a USD 1 million project preparation grant to support the Deep Ocean Water Application Project, which is expected to prevent 40,000 tons of CO_2 emissions every year, and create direct and indirect employment opportunities (AfDB, 2014).

In Aruba, a joint venture has been established between international private companies for the development of the Aruba District Cooling system, a USD 100 million project. The SWAC system will have 10,000 tons of cooling capacity (about 35 MW), and will provide air conditioning to the major resorts on Aruba's western coast. The expected energy savings are about 50 million kWh every year, or USD 6 million per year (6% of Aruba's total electricity consumption). The project, which is in line with the government's target of Aruba becoming 100% oil-independent by 2020, is expected to reduce CO_2 emissions by about 35,000 tons every year (Dalin, 2012).

Figure 15. Range of LCOE estimations for SWAC, under different Weighted Average Cost of Capital (WACC) assumptions, and compared to the cost of electric chillers, based on island electricity prices and COP of 2.8



scenarios, respectively, and assuming a discount rate of 10%. In the case of higher cost of financing, a SWAC system with medium CAPEX would have an LCOE ranging between USD 0.047/kW (discount rate of 7.5%) and USD 0.062/kW (discount rate of 12.1%). These LCOE results are calculated assuming a capacity factor of 100% (see Table 3).

2.4 Solar Photovoltaic systems

Solar PV electricity systems consist of panels that are exposed to light in order to generate direct current (DC) electricity, which is then converted to alternating current (AC) electricity through an inverter. These systems allow hotels to fulfill their electricity needs through on-site electricity generation, reducing the purchase of electricity from utilities or on-site diesel generation. The average investment required for the purchase of grid-connected solar PV systems in islands is USD 3,750/kW, and the payback period is estimated in a range between three to six years (Hotel Energy Solutions, 2011a). The LCOE of solar PV rooftop systems in an average tropical island setting is about USD 0.262 /kWh.

PV systems can be mounted in three main modalities:

- **Roof mounted:** PV panels are mounted onto the existing roof space of a hotel or other resort building;
- **Building integrated:** PV panels are directly integrated into the building during construction or remodeling, for example PV on parking shade structures;
- **Ground mounted:** PV panels are mounted on a dedicated structure in available land near the hotel or resort.

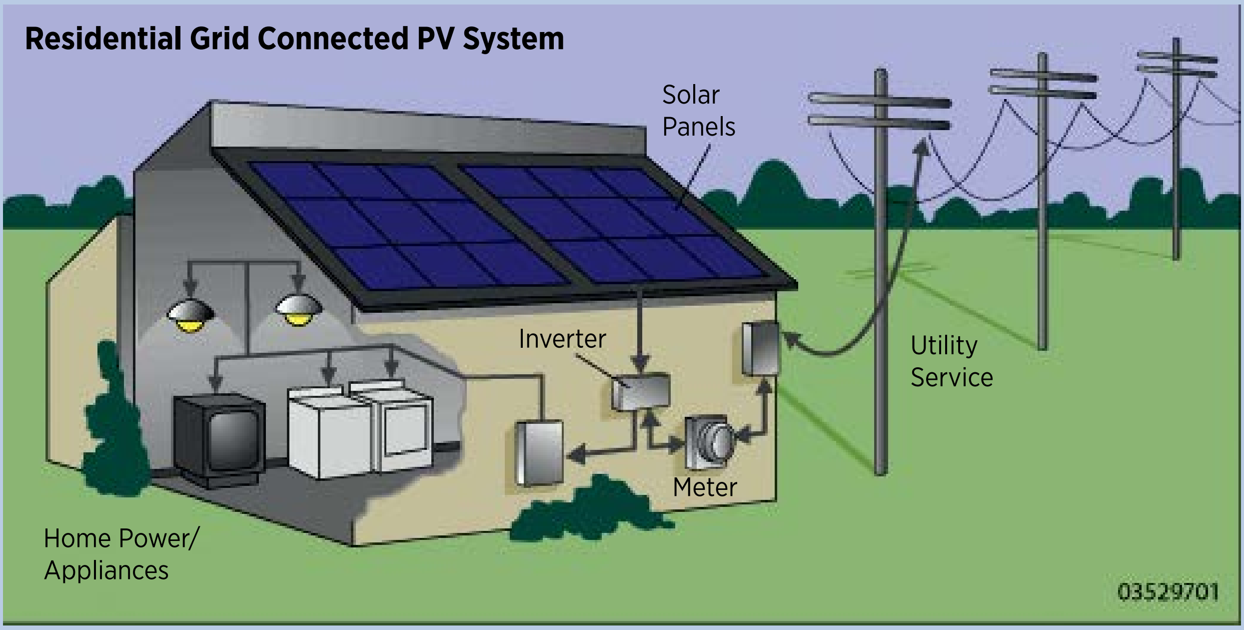
Solar PV systems can be connected (on-grid, see Figure 16) or not connected (off-grid, see Figure 17) to the electricity grid.

For hotels and resorts that are connected to an electrical grid, the PV system will directly offset the cost of purchasing electricity from the utility. When sun is available the PV system will supply electricity to the hotel, and feed any excess into the electrical grid. At night, when the PV system is not producing, electricity will be drawn from the electrical grid. For islands with a net metering policy, hotels can offset up to 100% of their electricity bill with PV. For islands that do not allow private generators to feed back electricity into the grid – or do not give adequate credit for it – the optimal size of the PV

Table 3. Summary table of key assumptions used for LCOE calculation of SWAC systems, and results

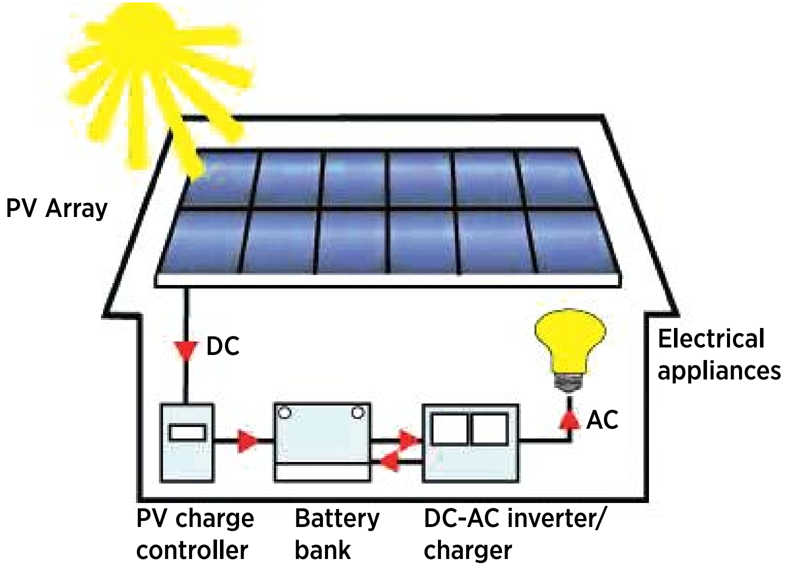
Technology Assumptions	
Project Capacity (MW)	1
Capital Cost (USD/kW)	3,000-4,000-5,000
Fixed O&M (USD/kW)	80
Variable O&M (USD/kWh)	0
Capacity Factor	100%
Degradation	0,0%
Financial/Economic Assumptions	
Debt Percentage	70%
Debt Rate	6%–8%–10%
Debt Term (years)	10
Economic Life (years)	25
Cost of Equity	11%–14.7%–17%
Discount Rate	7.5%–10%–12.1%
LCOE	
USD 0.042-0.069/kWh	

Figure 16. Main components of grid-connected solar PV systems



http://www.greenrhinoenergy.com/solar/technologies/pv_systems.php

Figure 17. Main components of an off-grid solar PV systems



http://www.greenrhinoenergy.com/solar/technologies/pv_systems.php

system is limited (*i.e.*, offsetting maximum 10-20% of the electricity bill).

For hotels that are not connected to a utility grid, for example an isolated resort with its own diesel genera-

Text Box 6 – Solar PV installations in island hotels

The use of solar PV in households and commercial activities is expanding considerably in many islands, including both grid-tied and off-grid applications. In Grenada, for example, the electricity utility company GRENLEC installed 18 rooftop grid-connected PV systems in hotels and households soon after the introduction of "feed-in tariffs" in 2007 (Schwerin, 2010). Solar PV systems are increasingly common in tourism facilities in Barbados; for example, the Harrison's Cave tourist attraction has installed a grid-tied 60.1 kWp system to supply electricity to its lighting system (Commonwealth Secretariat, 2012). An example of an off-grid solar PV system successfully installed in an island resort is the 70 kWp system at Soneva Fushi resort in the Maldives. According to the resort managers, the cost for the purchase and maintenance of batteries did not reduce the overall profitability of the investment and further investments will be made to expand the resort's solar capacity in the upcoming years (Sloan, Legrand, & Chen, 2013).

Another example of a successful solar PV installation in island tourism facilities is the Solar Power Project at Turtle Island resort in the Yasawa Islands, Fiji. This 228 kWp system is composed of 968 solar panels that produce 630 kWh of electricity every day, thus providing 56% of the island's power needs. The project, which was completed in 2013 for a total cost of USD 1.065 million, reduces annual diesel costs for hotel electricity by USD 124,000 and prevents 205 tons of CO_2 emissions every year.

Source: *http://www.turtlefiji.com/pretct/solar-project/*

tor, PV-generated electricity directly offsets the cost of diesel fuel. The amount of PV generation for off-grid systems is limited by the need to keep the diesel generator running reliably to provide a stable electricity supply. Off-grid hotels wishing to drastically reduce or eliminate their diesel fuel consumption will need to install a PV system that includes storage, typically batteries. This increases the cost of the system compared to the on-grid option. However, large PV systems with storage are usually economically viable given that the cost of electricity from small diesel generators in remote islands is generally very high.

The payback time for PV systems largely depends on electricity and/or fuel costs, solar radiation intensity, and the cost of importing technology when not locally available; the payback time for Crystalline Silicon PV modules installed in a location with solar radiation of 1,700 kWh/m^2/a is estimated in a range between three and six years (Hotel Energy Solutions, 2011a).

Over the past three decades, the global average cost of PV modules has declined by 18-22% with each doubling of the cumulative installed capacity, and specifically by 70% between 2009 and 2013 (IEA-ETSAP & IRENA, 2013a); large-scale deployment drove the prices down rapidly. It is noteworthy that the LCOE generation from solar PV has dropped by more than 50% over the last five years, and continues to decline (BNEF, 2013), while total installed capacity grew from 40GW in 2010 to 100GW in 2012 (REN21, 2013). By 2020, PV module prices might further be reduced by 40-60% (IRENA, 2012g; IEA-ETSAP & IRENA, 2013a).

Where islands have good solar radiation and high electricity tariffs, residential solar PV systems have already reached parity with electricity retail prices, especially due to the simultaneous reduction in technology costs and increase in global fossil fuel prices (IEA-ETSAP & IRENA, 2013a). As a result, investments in solar PV systems have increased considerably in recent years.

The cost of solar PV modules generally amounts to 30-50% of the total cost of the system, while the remaining investment is in Balance of System components and installation, whose cost varies between on-grid (50-60% of the total cost) and off-grid systems (around 70%, including energy storage and back-up power). In 2013, the price of wafer-based monocrystalline silicon (c-Si) modules was about USD 600/kW (down from USD 4,000/kW in 2008). The price of thin film modules is slightly lower than c-Si modules, but price differences

Figure 18. Range of LCOE estimations for solar PV, under different Weighted Average Cost of Capital (WACC) assumptions, and compared to the electricity price range in islands (diesel generators)

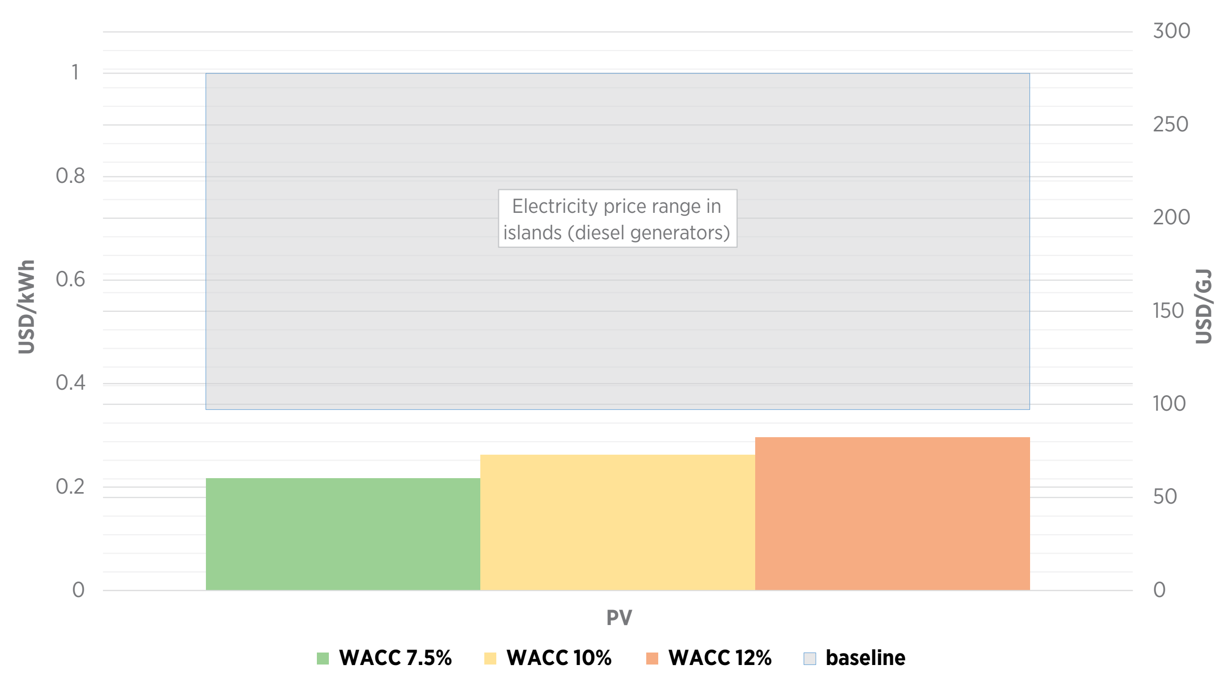


Table 4. Summary table of key assumptions used for LCOE calculation of solar PV rooftop systems, and results

Technology Assumptions	
Project Capacity (MW)	1
Capital Cost (USD/kW)	2,500-3,750-5,000
Fixed O&M (USD/kW)	25
Variable O&M (USD/kWh)	0
Capacity Factor	18.5%
Degradation	0,5%
Financial/Economic Assumptions	
Debt Percentage	70%
Debt Rate	6%–8%–10%
Debt Term (years)	10
Economic Life (years)	25
Cost of Equity	11%–14.7%–17%
Discount Rate	7.5%–10%–12.1%
LCOE	
USD 0.179-0.344/kWh	

between the two technologies are expected to converge in the long term (IEA-ETSAP & IRENA, 2013a).

In order to assess the cost competitiveness of solar PV systems installed in island hotel applications, the LCOE was calculated using different assumptions. Figure 18 shows the range of LCOE for solar PV rooftop systems under different assumption scenarios. Results show that the LCOE would be USD 0.179/kW, USD 0.262/kW and or USD 0.344/kW under low, medium and high CAPEX scenarios, respectively, and assuming a discount rate of 10%. In the case of lower or higher cost of financing, a solar PV system with medium CAPEX would have an LCOE ranging between USD 0.217/kW (discount rate of 7.5%) and USD 0.296/kW (discount rate of 12.1%). These LCOE results are calculated assuming solar radiation of 1,700 kWh/m^2/year and capacity factor of 18.5% (see Table 4).

Table 5 provides an overview of key indicators of investment that should be considered in the analysis of the four technologies presented in this study. These include capital costs for the purchase, installation and maintenance of RETs, as well as LCOE estimates.

The indicators presented in the table are neither exhaustive nor fully applicable to all island contexts. Rather, the table reflects a generic set of indicators that can be customised (*i.e.,* expanded or narrowed down) to the requirements and objectives of specific assessments.

Table 5. Indicators and costs of renewable energy investments in small island tourism facilities, by technology type

Technology	**Upfront capital investment**		**Maintenance cost**	
	Indicators	***Costs***	***Indicators***	***Costs***
Solar water heating	Cost of technology USD/kWp; USD/MJ (litres/day) Cost of installation USD/kWp	**Flat plate/evacuated tube:** USD 150-300/kW Technology costs are lower for climates that do not require anti-freezing precautions. Anti-freeze (glycol) also slightly reduces the efficiency of the heat transfer. They also vary depending on existing hotel plumbing systems, and locations of solar collectors and existing water heaters.	Cost of periodic maintenance (USD/kW)	USD 30/kW
	LCOE: USD 0.031-0.053/kWh			
Solar air conditioning	Cost of technology USD/kWp; USD/MJ (ton) Cost of installation USD/kWp	**Solar collectors:** Parabolic trough: USD 4,600-7,100/kW Solar towers: USD 6,300-7,700/kW Fresnel Reflectors (FR) and Solar Dishes (SD): n/a **Chillers:** Single effect absorption chillers: USD 1,000- 2,000/kW Installation costs: USD 8,000/kWp Technology costs are lower for warmer climates. They also vary depending on existing hotel plumbing systems.	Cost of periodic maintenance (USD/year)	USD 30/kW
	LCOE: USD 0.078-0.149/kWh			
Sea water air conditioning systems	Cost of technology USD/kWp; USD/MJ (ton) Cost of installation USD/KW	**Complete system:** USD 4,000/kW Cost of installation and technology depend on the distance from the sea. Small systems have higher technology costs, but lower installation and transport costs.	Cost of maintenance for salt corrosion (USD/year)	USD 80/kW
	LCOE: USD 0.042-0.069/kWh			

Technology	Upfront capital investment		Maintenance cost	
	Indicators	*Costs*	*Indicators*	*Costs*
Solar PV	Cost of technology USD/kWp; Cost of installation USD/KWp	**On-grid systems**: USD 2,500-5,000/kW for rooftop installations in islands. Utility scale projects in larger countries are characterised by lower costs. **Off-grid systems**: USD 4,671/kW for a 228 kWp PV-diesel hybrid (56% PV) system with 1.1 MWh storage (*e.g.,* the system installed at Turtle Island resort, Fiji. Actual cost depends for off-grid systems depend heavily on the amount of storage installed).	Cost of maintenance for cleaning from dust and sand (USD/year)	USD 25/kW
	LCOE: USD 0.179-0.344/kWh			

Text Box 7 – Avoided costs and added benefits from RET uptake and use

Avoided costs

An important outcome of investments in RETs is the accrual of cost savings. An increase in the use of renewable energy is likely to:

(1) Reduce costs currently incurred by public and private entities as a result of the avoided purchase of imported fossil fuels; and
(2) Avoid potential future costs deriving from the depletion of natural capital and ecosystem degradation.

Consequently, an integrated analysis of the impacts of shifting to renewable energy production in island tourism facilities should include the estimation of potential avoided costs, using historical and current data on the environmental, social and economic performance of the island.

First, avoided costs should be measured in relation to the energy bill of an establishment, and how it would change when RETs are deployed. Secondly, sustainable energy production curbs social costs (*e.g.,* cost derived from health impacts caused by fossil fuels combustion) associated with air and water pollution. Finally, reduced CO_2 emissions will contribute to climate change mitigation, thereby indirectly reducing costs associated with climate change impacts.

Relevant studies that quantify social and environmental avoided costs of installing RETs in island tourism facilities are still missing, mainly due to a lack of reliable data. However, the devastating impacts of oil spills are known. On the other hand, several case studies demonstrate the direct cost reduction impact of RETs in island hotels and resorts. For example, the SWH systems installed at Turtle Beach resort in Barbados contribute to a reduction in energy consumption of 372,040 kWh every year, corresponding to annual savings of about USD 103,427 (at 2013 electricity prices) against an upfront investment of USD 200,000 (Husbands, 2014). Similarly, the installation of solar PV panels in the Soneva Fushi Resort, Maldives, which required an initial investment of USD 300,000 for the fulfillment of 3% of total energy supply, has a payback time estimated at seven years (UNESCAP, 2012).

Table 6 presents a sample of indicators for measuring economic, social and environmental avoided costs originating from renewable energy investments in island tourism.

Table 6. Avoided costs resulting from renewable energy investments in tourism facilities, by actor type.

	Economic Avoided Costs	Social Avoided Costs	Environmental Avoided Costs
Private	Energy bill savings (USD/year)	Avoided compensation to local communities for damages caused by pollution (USD/year)	Reduced losses from ecosystem deterioration (USD/year) Reduced costs of damages from climate change related disasters (USD/year) Reduced cost of fines in case of local pollution, like fuel spills (USD/year)
Public	Reduced fossil fuel import costs (USD/year; % of GDP) Avoided fossil fuel subsidies to tourism sector (USD/year) Improvement of the trade balance due to reduced import of fossil fuels (USD/year)	Avoided loss of employment and income due to an underperforming economy (USD/year) Reduced costs of public health care (USD/year)	Reduced costs of replacement of ecosystem services (USD/year) Reduced costs of damages from climate change related disasters (USD/year)

Added benefits

The correct estimation of economic returns is an essential step for the assessment of RETs. In order to fully appreciate the advantages of renewable energy investments, an integrated and cross-sectoral analysis should be carried out that also considers the socio-economic, environmental and reputational returns that might not be visible in the short term. These outcomes of investments in RETs are increasingly featured in Corporate Social Responsibility reports, and are becoming a core pillar of sustainability strategies. Furthermore, the avoided costs could be reinvested in socially and environmentally responsible local activities, such as local transportation and staff training, increasing the indirect and induced effects of tourism expenditure on local development.

In addition to economic returns deriving from market dynamics, the assessment of the impacts of RETs should include an estimation of societal and environmental benefits. In particular, additional local employment can be generated by the installation and maintenance of clean energy technologies. As a result, new opportunities for income creation and expertise development will be created for local communities. Worth noting, the number of people directly and indirectly employed in the renewable energy sector grew by 14% yearly between 2010 and 2013, going from 5 million to 6.5 million people (REN21, 2012; REN21, 2013; IRENA, 2014). The total number of people working in the solar PV sector (manufacturing and installation/maintenance) amounted to 2.3 million in 2013; total employment in solar heating and cooling expanded from 120,000 in 2005 to 500,000 in 2013; and 43,000 people were employed in the concentrating solar power sector in 2013 (IRENA, 2014).

Added benefits deriving from improved environmental management should be quantified. In particular, economic advantages would derive from the preservation of healthier ecosystems – such as coral reefs, beaches and forests – which are inextricably linked to the attractiveness and profitability of island tourism. Quantifying the economic value of natural capital and ecosystem services, and how these values are affected by the import and use of fossil fuels, will inform decision making and lead to strategies that deliver multiple benefits to visitors, tourism companies and, in general, island economies.

One example of added benefits derived from the use of RETs in island tourism is the case of the Soneva Fushi by Six Senses Resort and Spa, located in the Maldives. In 2009, the Soneva Fushi installed a 70kW off-grid PV power plant and five SWH systems as a first step in achieving a net-zero carbon footprint (Soneva Resorts, 2013). The environmentally friendly vision of this Maldivian hotel generated additional business and increased customer loyalty, thereby bringing additional economic benefits (WWF, Horwarth HTL & HICAP , 2010). Table 7 provides a sample of indicators for measuring economic, social and environmental benefits of RETs. A distinction is made between benefits directly accruing to hotel businesses (*e.g.,* increase in tourist arrivals) and the indirect advantages enjoyed by the public sector and island residents as result of improvements in local economies and sustainability practices.

Table 7. Indicators of added benefits resulting from renewable energy investments in tourism facilities, by actor type.

	Economic Benefits	**Social Benefits**	**Environmental Benefits**
Private	Increased access to global ecotourism markets (% or USD/year) Premium price for sustainable tourism (%; USD/year) Additional revenues from improved hotel reputation/customer loyalty (USD/year). New revenues from the sale of self-produced electricity to utility companies (USD/year)	Improved relationships with island communities (n. of protests against hotel pollution or noise/year)	Increased tourist arrivals due to healthier ecosystems (tourists/year; USD/year)
Public	Increased revenues from taxes on tourism as result of increased private profits (USD/year; % of GDP).	Income generation for local population as result of a growing tourism industry (USD/year). Poverty reduction (% poor population).	Improved air quality (Air Quality Index) from reduced emissions.

3 BARRIERS, ENABLING CONDITIONS AND BEST PRACTICES

Increasing the use of renewable energy in the tourism sector of islands can improve the sector's profitability while creating employment and reducing environmental impacts. While these considerations have led many island tourism businesses to invest in RETs, the majority of island hotels and resorts still rely on expensive, diesel-based electricity, and the share of renewable energy use has been declining in islands in recent years. Although islands present very different geographical, social, economic, environmental and cultural features that require specific and customised analysis of challenges and opportunities for each context, it is still possible to identify broad categories of potential barriers to renewable energy deployment in island tourism facilities, and to identify existing policy options and best practices to overcome those barriers and accelerate the transition to a more sustainable and profitable tourism sector in islands.

There are three main barriers to be considered for the deployment of renewable energy in island states:

- Competitiveness of RE options (technical and economic);
- Access and cost of capital (ownership and financial);
- Institutional and technical capacity (policy and knowledge gaps).

Each of these barriers can be addressed with the proper tools. The estimation of the LCOE of RETs tackles competitiveness concerns, and informs financing considerations by showing that the cost of RETs is lower than diesel-generated electricity over the lifetime of the investment. Policies can be designed and implemented to improve access to capital and bridge knowledge gaps, so that the benefits of RETs extend to the broader community rather than be confined to the tourism sector. Finally, best practices can demonstrate activities that can be undertaken to create and improve the institutional knowledge base and policy design.

Four policy instruments are available to island governments to overcome these barriers. One or more of them can be combined to create enabling conditions for the purchase of RETs:

- **Capital investment**, *e.g.,* the expansion of the power grid in order to allow independent power producers to sell surplus electricity to utilities, thereby reducing the payback periods of renewable energy investments, or the purchase of an equity stake on RET projects;
- **Incentives and disincentives** to increase technology competitiveness, lower upfront investment costs and improved access to credit. Examples include the introduction of feed-in tariffs or tax rebates, as well as preferential loan terms for the purchase of RETs;
- **Public targets mandated by law**, such as the establishment of renewable energy quotas, or the setting of mandatory renewable energy targets for hotels; and
- **Institutional and technical capacity building**, *e.g.,* the promotion of educational programs and specialised training on RETs, the establishment of dedicated institutional bodies such as coordinating agencies for renewable energy deployment, and the strengthening of international and regional cooperation mechanisms on renewable energy in order to overcome technical and institutional capacity barriers (Bassi, Deenapanray, & Davidsen, 2013).

In the following sections, four best-practice examples are profiled of the effective use of policies to stimulate investments in RETs in the tourism sector of islands. In particular, net metering policies, innovative leasing schemes and low-interest loans are discussed as a means of improving access to credit and lowering the barriers posed by the principal-agent problem.

3.1 Barriers to technology deployment

3.1.1 Competitiveness of RET options (technical and economic barriers)

Renewable energy options are not always perceived to be competitive with diesel-based power generation. The main barriers include their at times more limited range of use and a potentially challenging integration with the existing electricity grid.

The cost of RETs is directly related to the access to financing and its cost, especially if money needs to be borrowed to purchase and install RETs. On the other hand, given the lifetime of these technologies, the viability of the investment should not be based only on the upfront capital cost. The LCOE offers an assessment of the incidence of capital and O&M as well as financing costs throughout the lifetime of the investment. This approach allows the fixed and variables costs of energy generation RETs to be compared, as well as to determine how these would change in the short, medium and longer terms, and compare them with diesel-based electricity production.

The limited range of use of RETs relates to their capability to generate electricity when it is needed (*e.g.,* in the evening, after sunset, in relation to the use of PV). While challenges do exist, as indicated in Section 2, most RETs have the capability to generate power at all hours of the day and night (*e.g.,* SWAC). With solar energy, SWH has the capacity to store energy, and batteries can be added in PV systems. Also in this case the LCOE can inform the estimation of the levelized cost of energy supply, supporting investment decisions.

The challenge of integration relates to local policies (*e.g.,* whether a feed-in tariff is provided) and to possible technical challenges (on top of variations in costs) for on-grid and off-grid installations. This challenge is closely related to knowledge gaps, in the context of institutional and technical capacity, which will be discussed in Section 3.1.3

Another important factor that might affect the competitiveness of RETs in island tourism is the vulnerability of the island tourism sector to climate change impacts (Contreras-Lisperguer & de Cuba, 2008). While it could be argued that on-site energy production increases resilience, it is also worth considering that islands are particularly vulnerable to climate change, including sea-level rise, extreme weather events, and changes in wind speed, which could affect solar energy installations, and fluctuating rainfall patterns, which are likely to influence the production of hydropower. Therefore, public and private investments in renewable energy should be informed by in-depth assessments of current and expected climatic conditions in each island context (IRENA, 2013a).

3.1.2 Access to capital and cost of financing (ownership and financial barriers)

The competitiveness of RETs also creates challenges for the mobilisation of financial resources needed to purchase, install and use them. In particular, hotel owners and other tourism operators in islands generally have limited access to credit lines for the financing of small-scale renewable energy projects. Considering the high upfront investment needed for the purchase and installation of RETs (*e.g.,* solar PV and SWAC systems) and the limited cash flow of small tourism activities, access to loans at concessional interest rates is key to remove financial barriers to the deployment of RETs. In addition to restricted access to national credit by private tourism companies, smaller islands often lack the domestic expertise in applying to international funding mechanisms for renewable energy development. For example, it was reported that only 10% of SIDS were able to apply for funding in the framework of the European Union Energy Facility (Strachan & Vigilance, 2011).

Another key challenge for the shift to sustainable energy production and consumption in the tourism sector is related to the ownership status of hotels and resorts, and especially to the so-called principal-agent problem (Jaffe & Stavins, 1994). Since the managing company (agent) of many resorts and hotels is a different entity than the owners (principal), there is difficulty in motivating the principal to invest in the development of renewable energy solutions, as the energy bill is paid by the agent, which would be the one benefitting from the savings generated by the installation of RETs. On the other hand, the agent might consider it more convenient to pay for a service instead of investing in infrastructure, which carries an upfront capital cost. As a result, the different interests of the principals and agents create a roadblock to the greening of the sector (IEA, 2007).

3.1.3 Institutional and technical capacity (policy and knowledge gaps)

The technical and human capacity necessary to design effective energy policies, as well as to install and manage RETs in tourism facilities, is still lacking in many island states. In particular, most of the higher education institutions in SIDS do not offer capacity building programs in the renewable energy field, thereby creating a gap between demand and supply of skills needed by the renewable energy market (IRENA, 2012f). In addition, installations performed by unskilled personnel may lead to under-performance and failure of technologies, leading to misperception of the real benefits by hotel owners (IRENA, 2013b). Several educational programs are being implemented at the international and national levels to fill the education and training gap in renewable energy. In particular, the IRENA Renewable Energy Learning Partnership (IRELP) is offering support to countries for improving access to renewable energy education and adapting education and training curricula. Also, specific training programs have been implemented, such as the global initiative on Vocational Training and Education for Clean Energy, which includes a regional program to provide education for solar PV energy equipment and technology to up to 12 Pacific Island nations.

Concerning policies, the lack of clear regulatory and policy instruments to encourage the purchase of power generation technologies by public or private utilities represents another barrier to private investments in RETs. Power Purchase Agreements, for example, are essential to define all the legal and commercial aspects for the sale of electricity between independent power producers (IPPs) and utilities, and to improve mutual trust between the two parties. Moreover, only a limited number of island utilities have implemented net metering policies to encourage private investments in grid-connected renewable energy systems (IRENA, 2013a). In this respect, building capacity and involving utilities and local regulators in the policy design phase are essential, as shown by the case of Sicilian islands in Italy. Despite strong potential for the use of renewable energy, uncertainty about the applicability of landscape protection laws and the hesitance of utilities (mostly due to concerns in relation to feed-in tariffs) are limiting the expansion of RETs.

3.2 Enabling policies

The effective introduction of innovative technologies suggested in the previous sections requires that governments, in collaboration with other key stakeholders and local communities, create or reinforce a variety of enabling conditions. As defined by UNEP, "enabling conditions consist of national regulations, policies, subsidies and incentives, as well as international market and legal infrastructure, trade and technical assistance" (UNEP, 2011).

As previously mentioned, there are four main ways to create the required conditions and stimulate investments to promote the deployment of RETs: capital investment; incentives and disincentives (such as tax reductions); public targets mandated by law; and institutional and technical capacity building. Each of these interventions has strengths and weaknesses. Given the variety of actors considered in the study, and the range of challenges they face at the local level and within the tourism sector, several policy interventions are presented. These should not be perceived as confined to the tourism sector, as their outcomes would be felt across society, and will positively impact several development goals.

Targets and mandates ensure that a given policy goal will be reached, and allow the total cost to be borne

Text Box 8 – International cooperation on renewable energy in SIDS

SIDS are actively engaged in global and regional platforms for sustainable tourism and renewable energy development. At the global level, the United Nations Programme of Action on the Sustainable Development of Small Island Developing States, commonly known as Barbados Program of Action (BPOA), represents the first strategic document for the transition towards sustainable economies in SIDS. The BPOA, approved in 1994 at the First Global Conference on the Sustainable Development of Small Island Developing States, encouraged the development and promotion of renewable energy sources and identified ecotourism as a key opportunity for sustainable development. In 2005, the "Mauritius Strategy for the further implementation of the Programme of Action for the Sustainable Development of Small Island Developing States" (Mauritius Strategy) was endorsed by 129 countries, and is considered to be the continuation of the BPOA for 2005-2015. The Mauritius Strategy reiterates the need for developing integrated energy programs, including the promotion and use of renewable energy, and encourages the international community and local stakeholders to invest in sustainable tourism.

In line with the Mauritius Strategy, various regional strategies and initiatives have been designed to promote low carbon growth in SIDS. In particular, regional organizations and associations such as CARICOM, the Association of Caribbean States, the Indian Ocean Commission, the Secretariat of the Pacific Community (SPC), and the Pacific Islands Forum Secretariat have developed programs and initiatives to support the transition to more sustainable economic models, including in the tourism sector. Moreover, dedicated regional platforms for the promotion of tourism, such as the Caribbean Tourism Organization and the South Pacific Tourism Organization, are active in the promotion of sustainable tourism in island states.

In the Caribbean region, CARICOM has approved a Regional Energy Policy (2013), which aims to transform the energy sectors of Member States "through the provision of secure and sustainable supplies of energy in a manner which minimizes energy waste in all sectors, to ensure that all CARICOM citizens have access to modern, clean and reliable energy supplies at affordable and stable prices". A Caribbean Sustainable Energy Roadmap and Strategy (C-SERMS) has been developed to accelerate the implementation phase of the Regional Energy Policy. C-SERMS highlights that "the tourism sector presents unique opportunities for rapid and significant impact because of its high energy consumption and enormous economic importance regionally". In response to the need for technical advice and capacity building in the tourism sector, the Caribbean Hotel and Tourism Association established the Caribbean Alliance for Sustainable Tourism (CAST). Moreover, the Caribbean Hotel Energy Efficiency Action Programme (CHENACT) was designed to provide assistance to hotel owners for moving towards energy-efficiency improvements and renewable energy deployment.

In the Pacific region, the SPC and other regional stakeholders have developed a Framework for Action on Energy Security in the Pacific (FAESP), which was endorsed by regional leaders in 2010. The Implementation Plan for Energy Security in the Pacific (IPESP) was subsequently developed to implement the provisions contained in the FAESP. In particular, the FAESP stresses the need for immediate action to enhance energy security in Pacific Island Countries and Territories, and highlights the challenges posed by "inadequate understanding of locally available renewable energy sources" (SPC, 2011). Further, in September 2013 the leaders of the Pacific Islands Forum signed the Majuro Declaration for Climate Leadership, a high-level declaration of commitment to a renewable energy transition, with specific targets indicated by each island country (Pacific Islands Forum, 2013). The Declaration captures the Pacific's political commitment to be a region of Climate Leaders, and to spark a "new wave of climate leadership" that can deliver a safe climate future for all.

The Indian Ocean Commission launched the ISLANDS Project in 2011, which aims to accelerate the implementation of the Mauritius Strategy in the Eastern and Southern Africa –Indian Ocean region. The ISLANDS Projects, which supports the creation of a strategic program for sustainable development in the islands of the region and its active and coordinated use by all relevant stakeholders, gives central importance to energy security and the development of renewable sources of energy.

In addition to participating in regional and international platforms and initiatives on renewable energy development, several SIDS have developed national strategic documents for the improvement of energy sustainability across sectors, including tourism (see Annex III). In order to facilitate exchanges across countries and help islands accelerate their renewable energy uptake, IRENA has launched GREIN, a platform for pooling knowledge, sharing best practices, and seeking innovative solutions for the accelerated update of clean and cost-effective RETs on island states and territories.

by households and the private sector for meeting the targets to be estimated. If savings are not sufficient, or if access to financing is not available, incentives as well as (public) capital investments support cost sharing across the key actors in the economy. On the other hand, the provision of incentives will only be successful if there is buy-in from households and the private sector. Since this cannot be forecasted, the cost to the government cannot be confidently estimated. As a result, creating a comprehensive package would allow making the best of all the options analyzed, to reach stated goals while sharing and monitoring costs (UNEP, 2011).

3.2.1 Capital investments

In the tourism sector the majority of currently installed renewable energy systems have been privately funded. While private investment in RETs can be profitable for most island tourism facilities, the number of systems deployed has been limited due to certain financial and regulatory barriers. As such, it is important for the public sector to play a decisive role in directing private investments towards renewable energy development, including through targeted incentives and policy reforms that facilitate access to credit and the development of innovative financial instruments for small private companies.

Public policies consisting of capital investment include grants, the purchase of RETs, or alternatively the acquisition of an equity stake in an RET project. As indicated by the World Economic Forum, *"Public action to either take an equity stake in projects or create attractive investment conditions for potential equity providers can help raise additional capital through other financing mechanisms by absorbing potential losses to other financiers"* (WEF, 2013). As a result, equity acquisition by the public sector helps create more attractive conditions for other investors, reducing the risk of the investment, and reducing its cost.

The acquisition of equity can also be coupled with debt, or hybrid financing. The key characteristic of equity is that it allows the holders of shares of a particular company (or project) to have some special rights regarding the operations of the company and management of its assets. In other words, the shareholder of the company is entitled to play a role while making business decisions.

Debt instruments instead do not provide the right to take part in the management of the particular company. On the other hand, the debt instruments confirm a permanent claim on the assets of the company (*i.e.,* if debt payments cannot be made, the institution that did lend the funding can claim ownership of the assets of the company).

3.2.2 Incentives and disincentives

Public authorities can use incentives and disincentives – such as taxation and the granting, or removal, of subsidies – to influence the market and to stimulate, or dissuade, private investments in keeping with policy objectives. In particular, instruments such as tax deduction for imports of RETs, feed-in tariffs, net metering policies and other forms of economic incentives might attract new investments from private tourism companies willing to start green businesses, thereby playing a central role in the achievement of renewable energy targets and overall growth of island tourism economy. Given the viability of RETs, which are often more economical than other diesel-based options, incentives such as tax cuts should not be seen as interventions aimed at promoting technologies that are not economically viable. Instead, tax cuts would be primarily used to further shorten the payback time of these investments, increasing installations and generating benefits that can be accrued within and beyond the tourism sector. Supporting investments would also help in situations where access to credit is limited and costly.

Alternative incentive/disincentive options that could be implemented to facilitate access to RETs for tourism companies include:

- **Redirection of perverse subsidies**. The removal of perverse subsidies, such as harmful fossil fuels and electricity subsidies, could contribute to creating fiscal space in order to direct additional public financial resources towards the renewable energy market. Fossil fuel subsidies create market distortions and discourage private investments in energy efficiency and renewable energy (UNEP, UNDESA and FAO, 2012). In particular, existing subsidies provided to utility companies and tourism facilities for reducing the cost of electricity generation and consumption create harmful market distortions, which encourage the continuation of current fossil fuel import trends. Public resources used to subsidise fossil fuels could be redirected towards the development of the renewable energy market, especially to support upfront investments in renewable energy infrastructure, as well as capacity building and research and development programs on specific RETs in different island contexts. In this respect, redirecting subsidies from fossil fuels to RETs may support utilities in adapting to a new business model, designed to support decentralisation of supply and the management of a more diversified energy supply mix.

- **Access to credit for tourism business**. The collaboration between credit institutions and public authorities is essential to facilitate access to credit for tourism companies willing to invest in RETs. In order to secure financing streams and overcome financial barriers for the achievement of renewable energy targets, a combination of private debt (*e.g.,* preferential loans from banks to the tourism businesses) and public debt (*e.g.,* raised through the issuing of public bonds for the expansion of the electric grid) might be a suitable option in some cases. Also, microfinance could be used as an effective instrument for the financing of small tourism businesses, especially in SIDS (REN21, 2013). For example, the Australian government has introduced a Renewable Energy Loan Scheme – including low-interest loans under a USD 30 million Renewable Energy Loan Fund and associated top-up grants (capped at USD 100,000) – to assist businesses with the purchase and installation of renewable energy generation facilities or manufacture in the island of Tasmania.[12]
- **Tax credit**. An annual income tax credit can be provided to hotel owners that invest in RETs. The amount of money would be proportionate to the investment made in the tourism facility, or to the amount of clean energy produced annually (Mitchell, *et al.,* 2011). In Hawaii, for example, a Renewable Energy Technologies Income Tax Credit is provided under article 235-12.5 of the Hawaii Revised Statutes. Under this provision, individuals, hotels and resorts that install an SWH system, solar PV system or wind energy system can claim a credit for a portion of the cost. For a solar energy system, the credit is 35% of the cost, up to a certain maximum amount depending on how the system is used. For a wind system, the credit is 20% of the cost up to a maximum credit of USD 1,500.[13]
- **Tax rebate.** A reduction in taxes on the purchase of RET is an effective instrument to drive private investments. This measure might be particularly important in the case of imported technologies, where high transport costs require a significant upfront investment by tourism companies. Public revenue losses could be compensated by an increase in taxes on fossil fuel imports, and use. Tax reliefs are already implemented in many islands. For example, the government of Barbados introduced an exemption from import duties and environmental levy for various RETs such as wind turbines, PV components and systems, biofuel systems, hydropower systems, solar thermal systems, wave or tidal power systems, fuel cell systems and geothermal heat pump systems.[14] Similarly, tax exemptions applicable to renewable energy equipment have been introduced by the government of Mauritius, together with the exemption of the Land Conversion Tax on power stations for renewable energy (Deloitte, 2012).
- **Feed-in tariffs.** An increasingly common regulatory instrument used by governments to boost renewable energy development is the setting of a guaranteed price over a fixed-term period when renewable electricity can be sold to the electricity network. With this policy instrument, tourism businesses willing to generate their own energy supply might have an additional incentive for selling surplus electricity to the national grid. Globally, 65 governments had already introduced feed-in tariffs by early 2012 (REN21, 2013). Also islands are increasingly using this regulatory instrument to encourage private investments. For example, the British Overseas Territory of the Cayman Islands has approved a pilot feed-in tariff for utility-customer-sited renewable generation of less than 50kW (Shirley & Kammen, 2013).
- **Net metering**. A net metering policy consists of an electricity payment scheme under which the electricity generated by building owners (*e.g.,* hotels with on-grid solar PV systems) and deliv-

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[12] *http://www.development.tas.gov.au/economic/funding/loans/Industry_funding_programs/renewable_energy_loan_scheme*

[13] *http://tax.hawaii.gov/geninfo/renewable/*

[14] *http://www.bidc.com/index.php?option=com_content&view=article&id=145:green-business-incentives&catid=87:news-archives&Itemid=167*

ered to a distribution utility can be used to offset the cost of electric energy provided by the utility to the building owner during the applicable billing period. Since the LCOE from renewable energy sources is lower than electricity tariffs in most islands, net metering policies can be extremely effective in encouraging private investments in renewable energy deployment. GRENELEC, the public utility company of Grenada, has successfully implemented a one-to-one net metering plan. This policy allows grid connection of IPPs with the public utility, and buy-back rates for energy generated at a one-to-one ratio. The same policy option has been adopted on the island of Palau since the approval of the Palau Net Metering Act (2012), which requires electricity service providers to offset charges for electricity by the amount of electricity supplied by the customer from its own energy-powered generation system.[15]

- **Variable/accelerated depreciation.** This measure consists of a reduction in income tax burden in the first years of operation of renewable energy equipment (Mitchell, *et al.,* 2011). It has the objective of reducing the investment costs of renewable energy generation in tourism facilities, gradually phasing out the incentives as investments are repaid by lower electricity costs and overall added benefits and avoided costs deriving from RETs. An example of the successful introduction of this policy instrument is the Accelerated Depreciation for Investments with Environmental Benefits (Depreciación Acelerada para Inversiones que Reportan Beneficios Ambientales), a law approved by the Mexican Congress to favour new investments in renewable energy. Under this regime, companies that invest in RETs may deduct up to 100% of the total investment in a single year (Davis, Houdashelt, & Helme, 2012).

3.2.3 Public targets mandated by law

The implementation of specific rules and the enactment of mandates on renewable energy targets ensure that the stated goals are reached and expenditures are kept under control. Only a limited number of island countries have an appropriate legislative framework to regulate the energy sector (UNEP, UNDESA and FAO, 2012). In this sense, the introduction of regulatory instruments, and their combination with incentive measures, can drive the renewable energy transition in island tourism.

Possible regulatory frameworks that could be introduced in on islands to institutionalise renewable energy targets and accelerate the transition to the adoption of RETs in the tourism sector include:

- **Mandatory targets/quota obligations.** Governments and local authorities can decide to introduce mandatory national renewable energy targets. However, it is important that their work is coordinated, to avoid the creation of an uncertain policy environment. Based on the definition of a realistic target, possibly decided after wide stakeholder consultations and assessment studies, specific quota obligations can be imposed on key economic sectors, including tourism. Most SIDS have already set renewable energy targets (*e.g.,* Mauritius: 35% by 2025; Palau: 20% by 2020; Saint Vincent and Grenadines: 60% by 2020). As previously mentioned, in September 2013, the leaders of the Pacific Islands Forum signed the Majuro Declaration for Climate Leadership, a high-level declaration of commitment to a renewable energy transition, with specific targets indicated by each island country. The introduction of quota obligations and associated incentive schemes could be required to achieve the national renewable energy targets within the aggressive timeframes set by many island governments.
- **Emission limits**. As an alternative to setting quotas for renewable energy generation, governments might introduce mandatory emission limits for tourism facilities. Such regulations would require hotels, resorts and other facilities to report periodically on their energy use, and relative emission levels, thereby encouraging the adoption of energy efficiency and RETs and associated practices.
- **Standards and guidelines.** The development of standards and guidelines for connecting IPPs to the national grid is key to increase confidence among hotel owners willing to invest in grid-tied renewable energy systems. Since many islands still lag in the establishment of clear procedures

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[15] *http://pidp.eastwestcenter.org/pireport/2012/January/01-10-13.htm*

and regulations for effective grid connection, potential investors might feel at risk and decide not to undertake investments in renewable energy projects.

3.2.4 Institutional and technical capacity building

The success of renewable energy deployment is strongly linked to the creation of an environment conducive to the concrete implementation of high-level policies and plans. To achieve this, it is necessary to develop domestic skills at different levels, including institutional capacity (*e.g.,* for policymaking), technical skills (*e.g.,* for renewable energy assessments, installation and maintenance of technologies), and capacity of civil society, including individuals and local organisations (*e.g.,* for participation in open policy processes). The following capacity-building domains and initiatives might be considered for boosting renewable energy deployment in island tourism:

- **Technical capacity**. Many islands still lack educational programs and specialised training in RETs. In order to exploit the employment generation potential of the renewables sector, training courses should be developed at different educational levels, from high school to university. Also, tourism facilities should be encouraged to provide adequate training to their personnel before introducing RETs. Tourism bodies like hotel associations should also be involved in the capacity-building efforts on renewable energy, as they can convey the information effectively to their members. An example of a capacity-building program on renewable energy is IRELP, which aims to improve access to specialised training courses on RET installation, operation, maintenance, etc.[16] Moreover, IRENA provides technical capacity-building programs on a variety of topics, including resource assessments, data collection and harmonisation, renewable energy planning, policy and regulatory frameworks, and financing (IRENA, 2012f).
- **Institutional capacity**. The development of institutional capacities is key to ensure the correct design of renewable energy policies and targets, as well as to facilitate the implementation of such provisions. In particular, many SIDS do not have a coordinating agency for renewable energy deployment. Also, slow and complex bureaucratic procedures prevent the prompt implementation of incentive schemes and other policy measures. Therefore, capacity-building programs for governmental agencies and institutions on renewable energy innovation should be prioritised, focusing in particular on relevant skills for: designing effective and customised policies, especially by adopting a systemic approach to identify cross-sectoral synergies; attracting foreign direct investments; and coordinating official development assistance flows.
- **International cooperation**. SIDS have already established a number of international and regional cooperation mechanisms and institutions to support renewable energy deployment (*e.g.,* SIDS DOCK). Several international organisations and non-governmental organisations have started dedicated projects in support of sustainable development in small island states (*e.g.,* Global Sustainable Energy Islands Initiatives). IRENA has launched GREIN, a platform for island stakeholders that seeks to facilitate the sharing of knowledge and best practices for accelerated uptake of RETs in island countries and territories.17 Such organisations and initiatives should be further strengthened in order to enhance the cooperation between islands at regional and global scales for sharing best practices, standards and lessons learned on private-public collaboration for sustainable tourism development.

3.3 Review of best practices

Several policies and initiatives have been already implemented in islands to support the deployment of RETs in tourism facilities. The impact of policy interventions largely depends on the barrier(s) addressed, the type of technology supported as well as the specific island context.

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[16] *http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=35&atID=110&SubcatID=156&RefID=156&SubID=161&MenuType=Q*

[17] *https://www.irena.org/DocumentDownloads/Publications/Global%20Renewable%20Energy%20Islands%20Network%20brochure.pdf*

Four best practices are presented based on their capacity to overcome the barriers identified:

- Net metering policies and variable-accelerated depreciation, to address the competitiveness of RET options;
- Leasing schemes and low-interest loans for the purchase of RETs, to provide a solution to access to capital and the cost of financing;
- Power Purchase Agreements, to tackle technical capacity gaps, access to capital and cost of financing; and
- Awareness raising and training programs, to fill institutional and technical capacity gaps.

3.3.1 Best practice: net metering policies and variable-accelerated depreciation

The most effective way to encourage and accelerate renewable energy deployment in island tourism is to create the enabling conditions for hotel owners to rapidly recuperate their upfront investments. The implementation of incentive policies such as net metering and variable-accelerated depreciation is very effective in triggering private investments, especially considering that the LCOE from renewable energy sources is lower than electricity tariffs in most islands. On the other hand, variable-accelerated depreciation is effective in reducing the initial investment burden of hotel owners. In this context, the incentive is gradually phased out as investments are repaid by lower electricity costs.

Context: Net metering policies are particularly suited for islands where the cost of electricity from utilities is higher than the cost of electricity generation from independent renewable sources. This is the case in most island contexts, and especially in SIDS and remote island countries and territories. Variable-accelerated depreciation is especially suited for the owners of large hotels, as they would benefit from a reduction in annual income taxes. On the other hand, this intervention would lower government revenues in the short term, with possible increases (especially if profits for hotels increase due to lower costs) in the medium and longer terms.

Case study: The Grenada Solar Power Ltd (GRENSOL) was founded in 2005 with the aim to promote the use of solar energy on islands. Since 2007, the company has implemented a 1:1 metering policy at retail rates for systems less than 10kW. The introduction of this policy has contributed to the success of GRENSOL, which is now a leading solar PV company in the Eastern Caribbean. In 2009, only two years after the implementation of the net metering policy, GRENSOL had installed 25 grid-tied systems on the island of Grenada (Shirley & Kammen, 2013).

Another example of successful net metering policy is the one implemented by the Cook Islands (IRENA, 2013a) and the Virgin Islands Water and Power Authority. In 2007, the U.S. Virgin Islands Public Services Commission approved a limited net metering program for residential and commercial PV, wind-energy or other renewable energy system up to 10 kW in capacity. In light of the success of this policy, including for the hotel sector, a new legislature passed in 2009 that raised capacity limits for commercial activities up to 100 kW. In 2013, the program had 285 customers, most of whom had systems operating at below 10 kW, according to the Water and Power Authority.[18] Net metering, among others, represents an important incentive for private investments in grid-connected installations.

3.3.2 Best practice: leasing schemes and low-interest loans for the purchase of RETs

Island tourism operators willing to invest in RETs are often constrained by difficulties in obtaining access to credit from commercial banks at a rate that would make the investment pay back in a reasonable time. An effective approach to overcome this barrier is the provision of leasing schemes and low-interest loans targeting the purchase of RETs. Leasing schemes allow tourism businesses to lease renewable energy systems (*e.g.,* solar PV) from a private provider. Users can opt for a "pre-paid" lease with an upfront payment for the entire lease, a "partial-pay" lease with an initial payment and monthly payments over the contract period, or a "month to month" lease with the price of the lease being paid on a monthly basis, without upfront payments. At the end of the lease period, the customer can decide to remove the system, to purchase it, or to enter into a new lease. Preferential loans are also very effective in encouraging private investments in renewable energy.

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[18] *http://virginislandsdailynews.com/news/wapa-eliminates-requirement-for-net-metering-1.1462067*

Context: Leasing schemes are particularly useful for small hotels that have limited financial resources and are interested in assessing the real economic returns deriving from the installation of RETs. Third-party financing is also effective at overcoming the barriers posed by the principal-agent problem common to many island tourism facilities (see section 3.1.2). The pre-defined time period associated with leasing models encourages hotel managers to install RETs in their facilities, so as to fully appreciate the economic advantages of renewable energy for the duration of their management period, without having to negotiate with hotel owners on the purchase of the technologies. Low-interest loans instead are a proven and effective instrument in all island and tourism contexts, as they reduce the burden of financing costs and allow tourism businesses to pay back the loan using the economic returns deriving from reduced electricity costs.

Case study: The private company Sunetric, based in Hawaii, offers leasing schemes for solar PV systems to households and businesses. The leasing scheme, which includes system installation, maintenance and insurance, is provided at low monthly payments with a zero down payment option, and with flexible end-of-lease options, including the possibility of further expanding the system. Thanks to the flexibility of its leasing scheme, Sunetric has provided 40% of the net-metered PV installations in Hawaii, including to tourism facilities. Sunetric has installed a 1.2 MW roof-mount PV system at the Wyndham Kona Coast Resort, and a 200 kW roof-mount system at the Kukui Plaza Apartments and Condos.[19]

On Prince Edward Island, the company Solar Island Electric Inc. offers the ability to lease solar panels. The company estimated that the savings realised on customers' electricity bills are higher than the lease payments for solar panels. As a result, several customers have demonstrated interest in this leasing program, as it eliminates the upfront installation costs.[20]

3.3.3 Best practice: Power Purchase Agreements

Similar to leasing models, partnerships can be created between power sector companies and hotels to share responsibilities related to the purchase, installation and maintenance of RETs and their use. In this case the ownership of the system resides with the power sector company, which partly overcomes the problems related to financing for upfront investment since the company can work at cost, rather than market price. Hotel agents can therefore harness the benefits of renewable energy technologies upon the signature of a Power Purchase Agreement that sets a fixed-lease period (normally several years) and rate for the electricity purchased, without being responsible for installation and maintenance.

Context: The high cost of diesel-based electricity on many islands allows for a positive return on investment for the developer and reduced energy costs for the hotel. As with a conventional lease, at the end of the term hotel agents may decide to uninstall the renewable energy system, upgrade to a newer model or, when allowed by the leasing company, purchase the system at a reduced rate.

Case study: In 2013 Starwood Hotels & Resorts Worldwide announced the establishment of a global partnership with NRG Energy, a leading power sector company at the global level. The agreement will begin with NRG building and operating a 1.3 MW solar PV system at Westin Saint John Resort & Villas in the U.S. Virgin Islands. NRG will own the solar arrays while Starwood will be the enabling partner through a multi-year agreement to purchase electricity from the solar arrays.[21] This global partnership was announced during the 2013 Caribbean Summit of Political and Business Leaders as a way to reduce the negative economic impacts of high diesel-based electricity costs on Caribbean tourism, and it will apply to other Starwood properties located in Arizona and Hawaii. This innovative type of purchasing agreement helps to overcome the limitations in relation to access to affordable financing, policy and knowledge gaps, especially in the case of the principal-agent problem.

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[19] *http://sunetric.com/press/post/sunetric-makes-sunpower-lease-available-in-hawaii/*

[20] *http://www.theguardian.pe.ca/Business/2014-01-20/article-3583256/Affordable-option-for-solar-energy/1*

[21] *http://development.starwoodhotels.com/news/2/577starwood_hotels_resorts_and_nrg_energy_introduce_an_industry-leading_alliance_to_develop_solar_power_at_hotel_properties*

3.3.4 Best practice: awareness raising and training programs for institutional and technical capacity

Devising awareness-raising and capacity-building strategies is an effective method to overcome the skepticism of tourism operators with regard to renewable energy. Awareness campaigns should focus on the economic benefits to the island tourism businesses from the deployment of RETs. Capacity-building activities should provide skills to both decision-makers (*e.g.,* for creating the enabling policy conditions), tourism operators (*e.g.,* to develop renewable energy deployment strategies and investment plans), as well as technical workers (*e.g.,* for increasing the number of specialised workers in the renewable energy sector).

Context: All island contexts and tourism operators are potential targets of capacity-building and awareness-raising activities. The specific focus of each campaign and training program would need to be adapted to local specificities. In some island contexts tourism operators are fully aware of the benefits deriving from the shift to renewable energy, but they might lack the technical skills to plan for renewable energy deployment. In other cases, tourism operators might be reluctant to invest in renewable energy, as they erroneously perceive fossil fuel as the safest and most convenient energy source. Also, the owners of small hotels might consider the shift to renewable energy as an unnecessary investment, considering their lower annual business volume. Finally, hotel managers might be afraid of investing in RETs when they do not own the hotel. For each of these contexts, targeted interventions can be designed, all having the final goal of showing the multiple advantages and expected returns of a renewable energy transition.

Case Study: Samsø is a small Danish island whose two main economic activities are farming and tourism. The island was able to convert all of its energy supply to renewable energy within ten years, from 1997 to 2007, thanks to the successful implementation of the Samsø Renewable Energy Island Project. Initially, local people (including tourism operators) were reluctant to invest in RETs. To address this barrier, project leaders generated awareness among households and private actors by conducting several campaigns to give knowledge and practical abilities to save energy and become acquainted with RETs. The intervention methods included (Saastamoinen, 2009):

Education and certification of local blacksmiths and plumbing and heating service providers, so that they could install renewable energy equipment and systems;

- Energy exhibition in 1998, where RE was presented;
- Personalised approaches and advice in the form of calls by energy advisors, who evaluated the insulation and energy solutions of buildings and gave recommendations; and
- Demonstration of alternative materials for insulation, which included insulation of selected buildings and presenting the results to interested parties.
- Another example of awareness-raising activity on renewable energy and energy efficiency is the series of training workshops and audits in energy management conducted in 2004 in Saint Lucia, and directed to island tourism stakeholders. The initiative, which was supported by the Ministry of Physical Development, Environment and Housing, and funded by the Climate Change Development Fund of the Canadian International Development Agency, brought together hoteling stakeholder groups with an interest in energy management to share ideas and experiences, thereby disseminating knowledge on the cost and benefits of available technologies (Lewis Engineering Inc., 2004).

Table 8 summarises the main barriers to RET deployment in island tourism, the relevant policy options to overcome these barriers, and selected best practices. This table provides only an overview of barriers and policy options, with the understanding that each island tourism context requires a more detailed and customised analysis.

Table 8. Renewable energy deployment in island tourism: main barriers, intervention options and relevant case studies by island context, hotel ownership and technology option

		Effective Policy Solutions			
		Capital investments	**Incentives and disincentives**	**Public targets mandated by law**	**Institutional and technical capacity building**
Barriers	**Competitiveness of RE options (technical and economic barriers)**	● Leasing schemes* ● Purchase of RET ● Capital subsidies or grants	● Net metering* ● Variable-accelerated depreciation* ● Power Purchase Agreements* ● Tax credits and rebates ● Feed-in tariffs	● Emissions quotas ● Emissions limits ● Renewable Energy Standards	● Standards and guidelines ● Capacity building for lending institutions to properly assess the risks related to RET financing ● Capacity building for local installers of RETs, to reduce risks of underperformance due to poor installation
	Access to capital and cost of financing (ownership and financial barriers)	● Leasing schemes*	● Preferential and low interest loans* ● Feed-in tariffs		
	Institutional and technical capacity (policy and knowledge gaps)		● Capacity supplementation to develop policies and regulations for the promotion of renewable energy, ensuring they are applicable to tourism and create a level playing field for the private sector		● Awareness raising* ● Training programs for institutional and technical capacity*

* Best practices presented in Section 3.3.

Based on analysis of data from DNV GL (2014)

4 MODELING THE OUTCOMES OF RET ADOPTION IN ISLAND TOURISM

The interconnections between socio-economic development and the environment have become more visible over the past decade. This has urged policy makers in islands to improve the policy-making process to explicitly consider climate change and the impact of other external shocks (such as the volatility of oil prices) to find durable solutions. In this context, the analysis of historical data and future scenarios is crucial to inform decision-makers on the strengths and weaknesses, as well as synergies and bottlenecks, of possible renewable energy intervention.

A simple quantitative simulation model was developed specifically to provide quantitative support to this report to illustrate the several contributions that RETs can provide in the tourism sector and at the national level in islands. This model integrates the main pillars of sustainable development and allows the performance of several indicators – social, economic and environmental – to be evaluated.

The approach proposed uses the System Dynamics methodology as its foundation, serving primarily as a knowledge integrator. System Dynamics in fact allows stocks and flows of human, built and natural capital to be represented explicitly, and for linkages among them to be created through the use of feedbacks, delays and non-linearity.

4.1 Model specifications

The model is customised to an ideal island, representative of a generic small island context, considering an initial total population of 100,000 and GDP per capita of USD 10,000. Further, it is assumed that the electricity consumed by the tourism sector is about 10% of the total and that only diesel generators are used in the Business As Usual (BAU) case. In the RET scenario instead it is assumed that during the next ten years all the needs of air conditioning and water heating, as well as 50% of other electricity consumption, will be supplied by RETs. Specifically, air conditioning will be provided by SAC (30%) and SWAC (70%) systems; water heating will be supplied by SWH; and other electricity needs by PV.

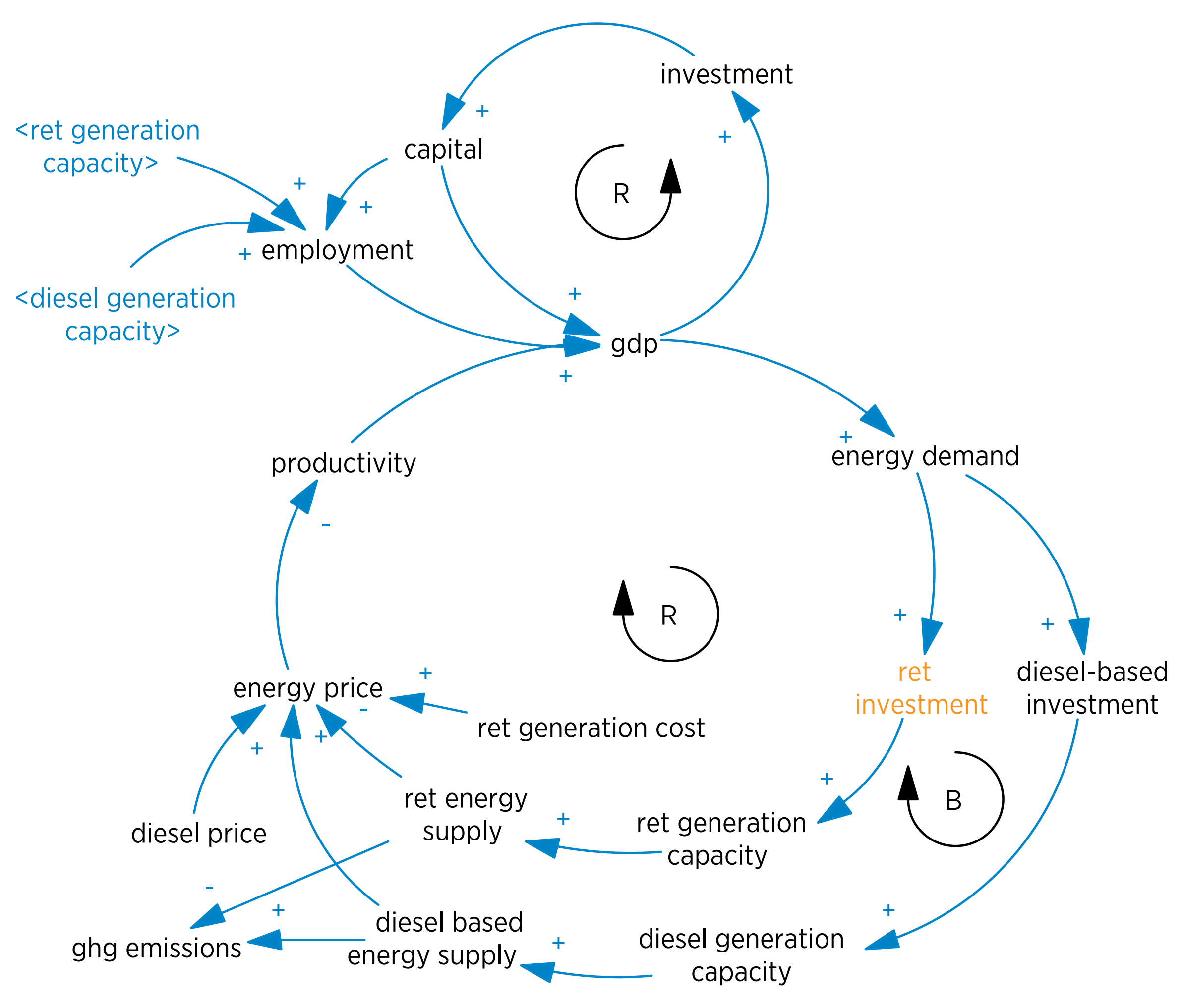
Boundaries: Variables that are considered an essential part of relevant development mechanisms are endogenously calculated. For example, GDP and its main determinants, electricity demand and supply, as well as related generation cost and emissions are endogenously determined. Variables that have an important influence on the issues analyzed, but which are only weakly influenced by the issues analyzed, such as population, are exogenously represented.

Granularity: The model is customised to represent a sample small island national setting. Data are aggregated at such level, with no spatial disaggregation. Data assumptions include an initial GDP per capita of USD 10,000 per person per year; initial electricity demand of 2,000 kWh per person per year; and the following consumption of electricity in the tourism sector: 48.2% for air conditioning, 5.5% for how water and the remaining 46.3% for other services.

Time horizon: The model is built to analyze medium- to long-term scenarios. The simulation starts in 2000 (for validation purposes) and ends in 2035.

Structure and main indicators: The model includes several feedback loops, with the most important representing the link between energy and economy (see Figure 19). More specifically, GDP in the model influences electricity demand, which can be satisfied using diesel generators or renewable energy. Electricity supply is estimated by technology, considering specific capacity factors. The energy mix determines the average electricity generation cost and the electricity bill (consumption times cost per kWh). The electricity bill is then compared to GDP (as a ratio) to assess the incidence of energy costs on economic activity: when the *energy bill to GDP* ratio increases, productivity declines; when the ratio becomes lower, productivity increases. Productivity, together with capital (driven by investments, also affected by GDP) and employment (also

Figure 19: Causal Loop Diagram (CLD) representing the main feedback loops and indicators included in the model



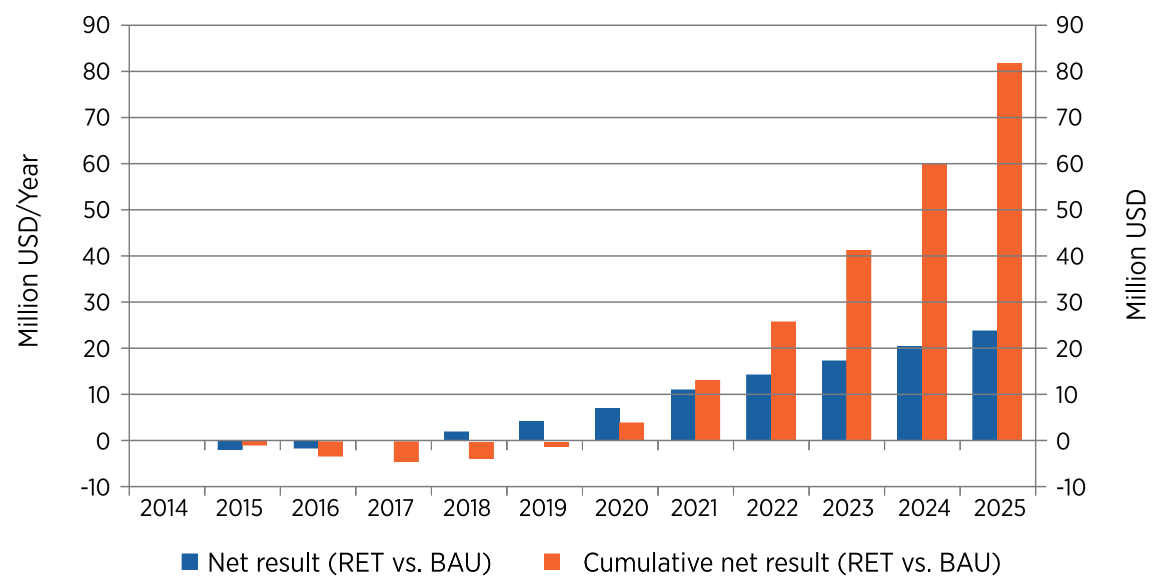
driven by investment, including in renewable energy), have an impact on GDP, closing the feedback loop.

The main outputs of the model include power capacity, generation and the investment required to meet the desired capacity target (*e.g.,* 100% of diesel generators for air conditioning), and the resulting added benefits and avoided costs. Among the benefits, indicators include GDP, direct employment creation (for construction and O&M) and relative income generated. Avoided costs include savings from avoided consumption (*e.g.,* diesel, through the use of renewable energy). These indicators are estimated starting from a desired expansion of the use of renewable energy for power generation. This target leads to estimation of the investment required and to construction of capacity (measured in kW). Electricity generation considers a given capacity factor and LCOE for the four RETs considered (set at USD 0.262/kWh for PV, USD 0.113/kWh for SAC, USD 0.055/kWh for SWAC and USD 0.042/kWh for SWH).

Investments, avoided costs and added benefits are then compared to estimate the annual impact on energy-related expenditure for the tourism sector, as well as the break-even point, and the return on investment for the expansion of electricity generation from renewable energy.

Figure 19 presents the main feedback loops and indicators included in the model, in a highly summarised

Figure20: Avoided energy bill minus investment annual (million USD/year) and cumulative (million USD)



Causal Loop Diagram (CLD).[22] The CLD indicates that the use of RETs allows to turn a Balancing Loop (B) (originating from the use of more and more expensive diesel-based energy generation) into a Reinforcing Loop (R) (in which the use of RETs allows energy costs to be lowered, and productivity and GDP to be increased).

Scenarios: Two main scenarios were simulated and analyzed.

- A *Business as Usual (BAU)* case that assumes the continuation of historical and present trends, including the reliance on diesel for electricity generation.
- A *Renewable Energy Technology (RET)* scenario that simulates a penetration target of 100% for renewables regarding air conditioning and water heating, and 50% for other electricity use by 2025.

4.2 Main results

The expansion of electricity generation from renewable energy in islands is expected to lead to the installation of 10.8 MW by 2025 and 14 MW by 2035. This requires a total (cumulative) investment of USD 20 million by 2025 and USD 26 million by 2035 and represents approximately 70% of tourism power consumption.

This investment will increase electricity generation from renewables, reducing the use of diesel generators as well as lowering the corresponding capital investment required to expand capacity in the years to come. In fact, as a result of the use of renewables, and displacement of increasingly expensive diesel power generation, the average cost of electricity is projected to decline by approximately 50% in 2025 and 60% by 2035 for the tourism sector. This leads to a decline in the energy bill and an increase in profits for the tourism sector, freeing up resources for other investments (and also improving the balance of payments of the country due to reduced fuel imports). Considering the investment required to expand renewable energy capacity and the cost of energy production, it is estimated that the average payback time is approximately four to five (considering all RETs). In addition, the savings that will be accrued over time (comparing the energy bill in the BAU and

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[22] How to read a causal diagram: CLDs include variables and arrows (called causal links), with the latter linking the variables together with a sign (either + or −) on each link, indicating a positive or negative causal relation:

- A causal link from variable A to variable B is positive if a change in A produces a change in B in the same direction
- A causal link from variable A to variable B is negative if a change in A produces a change in B in the opposite direction

RET scenarios), amounting to approximately 50% of the BAU annual electricity bill in 2025, reach up to 1% of GDP in 2035.

Figure21 shows the difference between the investment (extra cost incurred to install RETs) and the avoided energy bill resulting from this investment (estimated as the BAU minus RET energy bill of the tourism sector). As a result, this figure indicates the net impact on the financial resources of the sector, considering annual flows and their cumulative value. In particular, the figure indicates that the investment in RETs, reaching a total of USD 20 million, will generate cumulative savings of over USD 80 million by 2025, or a positive annual flow of over USD 20 million in 2025 alone. This amount is projected to increase beyond 2025, as the price of diesel is expected to increase while the generation cost from RETs remains constant.

Further, the simulations indicate that the investment in renewable energy will not only (1) reduce electricity generation costs, (2) lower the electricity bill and (3) stimulate the economy by increasing GDP relative to BAU. In fact, the use of renewable energy is projected to (4) lower emissions from power generation by over 70% by 2035 (or 7% at the national level), and (5) create new local jobs (for the installation and O&M of renewable energy power generation capacity).

5 RELEVANT CASE STUDIES

Four relevant case studies are presented in this section to showcase the effectiveness of RET deployment in island tourism. The case studies were selected based on geographic representation (Barbados, Fiji, French Polynesia and Greece) and focus on best practices adopted by hotels for the deployment of SWH, SWAC, PV and SAC systems.

5.1 Turtle Beach Resort, Barbados

Summary of Turtle Beach Resort Case Study

Hotel name, location and size

Turtle Beach Resort. Located at Dover, on the southern coast of Barbados. It has 167 suites.

Context and challenges

Prior to 1997, hot water was produced entirely from electric water heating systems powered with diesel-generated electricity. However, electricity in Barbados is very expensive due to the high cost of fossil fuel imports, amounting to about USD 0.278/kWh in 2013 (electricity tariffs grew by 40% from 1997 to 2013). In addition, the price of electricity is extremely volatile due to the Fuel Clause Adjustment mechanism, through which the Public Utilities Board allows utility companies to adjust the electricity tariff as the international price of fossil fuels rises and falls.

RET installed

In 1997, the management of the Turtle Beach Resort decided to explore alternative solutions to supply hot water to hotel rooms and facilities, and invest in anSWH system. The total capacity is 7,800 gallons (40 gallons of water per room plus 1,120 gallons for ancillary services). The system heats water up to 55-60°C and produces energy equivalent to 1,048 kWh every day.

Investment and financing

- Capital investment: USD 200,000
- Maintenance costs: USD 6,250 per year
- Policy support: 35% tax credit provided by the government of French Polynesia

Economic benefits

- Payback period: about eight years, from 1997 and 2004 (about one year when considering 2013 electricity prices)
- Energy savings: USD 1.48 million between 1997 and 2013

Other benefits

- Carbon emissions avoided: 655 tCO_2 between 1997 and 2013 (41 tons per year)

Lessons learned

Investing in SWH technology makes business sense for island hotels, especially when electricity tariffs are high due to expensive fuel imports.The capital investment and maintenance costs of a SWH system are lower than the financial returns deriving from avoided electricity costs over the lifetime of the technology.

5.2 Intercontinental Bora Bora Resort & Thalasso Spa

Summary of Intercontinental Bora Bora Resort & Thalasso Spa Case Study

Hotel name, location and size

Intercontinental Bora Bora Resort & Thalasso Spa. Located on the island of Bora Bora, French Polynesia. The resort has 83 large villas.

Context and challenges

Electricity prices of about USD 0.48 per kWh represented a challenge for hotel profitability, especially considering the significant demand for air conditioning in Bora Bora. Based on these considerations, the management decided to carry out a cost-benefit analysis to identify the most convenient RET options to replace fossil fuel consumption.

RET installed

A SWAC system was installed, consisting of a 2,000 metre long pipeline extracting seawater from a depth of 900 metres. The system uses a 13 kW pump for transferring water to a thermal exchanger. The heat exchanger is made of corrosion-resistant titanium. A 13 kW pump is used to transfer the water for 50 metres from the shore to a heat exchanger that is used to cool a separate freshwater circuit, while keeping corrosive sea water away from the air conditioning system. Finally, the cooled freshwater is used to supply 450 tons (or 1.6 MW) of air conditioning to the rooms and facilities of the whole resort, while warmer seawater is returned to the ocean at a depth of 40 metres, to avoid impacts on ecosystems due to the difference in temperature with surrounding sea water.

Investment and financing

- Capital investment: USD 7.9 million
- Maintenance costs: very low, due to the use of corrosion-resistant titanium heat exchangers
- Policy support: 35% tax credit provided by the government of French Polynesia

Economic benefits

- Payback period: 11 years
- Energy savings: 2.5 million litres of diesel fuel every year (90% of total consumption), corresponding to annual energy savings of USD 720,000

Other benefits

- Carbon emissions avoided: 2,500 tCO_2 every year
- Branding:
    - First hotel in the southern hemisphere offering thalassotherapy, thus exploiting the benefits of nutrient-rich water extracted from deep sea
    - The desalinated deep sea water, which contains a complement of mineral salts, will be bottled under the label “Vai Moana” right at the Spa

Lessons learned

- Although they require high upfront investment cost, SWAC systems offer positive returns for large hotels located at short distance from the sea.
- The payback period of SWAC systems is relatively short for hotels in tropical islands, where air conditioning is consumed all day throughout the year.Incentive policies, such as tax credit from the government, can play a significant role in encouraging private investment in SWAC systems.

5.3 Turtle Island Resort, Fiji

Summary of Turtle Island Resort Case Study

Hotel name, location and size

Turtle Island Resort. Located on Turtle Island, 50 miles northwest of Fiji's main island, Viti Levu, in the group of the Yasawa islands. It has 14 cottages, and accommodates a maximum of 28 people.

Context and challenges

Mr. Richard Evanson purchased Turtle Island in 1972 and opened the Turtle Island Resort in 1980. Respect for local communities, biodiversity and ecosystems has always been the core value of Mr. Evanson's tourism development strategy. Since the Yasawa chain is not connected to the national grid run by the Fiji Electricity Authority, each island has to produce electricity from generators powered with costly imported diesel. In response to this challenge, Mr. Evanson launched the Solar Water Project, a solar PV investment project to exploit the abundant solar radiation for electricity generation, eventually making Turtle Island completely independent from imported fossil fuels. The Solar Water Project was launched in 2012 and completed in 2013.

RET installed

A solar PV system was installed with total capacity of 228 kWp and 1.1 MWh of battery storage. The system was installed by Clay Energy in 2013 and is composed of 968 solar panels that produce 630 kWh per day, providing 56% of the island's annual power needs. It is the largest off-grid solar PV installation in the South Pacific for a resort, and it made the Turtle Beach Resort one of the first clean energy resorts in the world.

Investment and financing

- Capital investment: USD 1.065 million

Economic benefits

- Payback period: 8.6 years
- Energy savings: diesel consumption for electricity generation reduced by 77,405 litres per year, corresponding to annual savings of USD 124,000

Other benefits

- Carbon emissions avoided: 205 tCO_{2e} per year

Lessons learned

- Producing electricity through off-grid solar PV systems has a short payback time in islands with good solar radiation and high price of diesel.
- Battery storage allows solar electricity to be used when the sun is not shining, including at night.
- Hotels and resorts on islands can generate their entire electricity needs from off-grid solar PV systems, improving energy security and obtaining considerable economic and reputational benefits.

5.4 Rethymno Village Hotel, Crete

Summary of Rethymno Village Hotel Case Study

Hotel name, location and size

Rethymno Village Hotel. Located on the island of Crete, in northern Greece. It has 110 rooms and hosts up to 260 guests.

Context and challenges

During the 1990s, the management of the hotel noticed that the costs of electricity for air conditioning were growing due to increasingly high summer temperatures (up to 40°C) and rising electricity costs. Consequently, the hotel owner, Mr. Letzakis, decided to invest in a thermally driven air conditioning system in the framework of the National Operational Programme for Energy of the Greek Ministry of Development, which provided subsidies of up to 50% of the capital investment costs of renewable energy projects.

RET installed

A closed-loop chilled water system with an absorption chiller was installed, providing air conditioning services and hot water. The thermal chiller has a capacity of 105 kW and provides cooling to an area of 3,000 m^2. In wintertime, the system is used to provide space heating. The thermal energy is provided by 450m^2 of solar thermal collectors installed on the roof of the buildings. The system also comprises seven tanks for hot water storage, each of 7 m^3 of volume. Moreover, a 290 kW gas boiler is used as an auxiliary heating support. The electricity needed to pump the LiBr solution is 0.5 kW, and the pump for the water circulation has a capacity of 1.5 kW. The average COP was 0.52 during its first year of operation.

Investment and financing

- Capital investment: USD 146,000
- Policy support: 50% subsidy on the capital cost of the project, provided by the National Operational Programme for Energy of the Greek Ministry of Development

Economic benefits

- Payback period: five years
- Energy savings: electricity savings for cooling: 70,000 kWh per year; diesel oil saved for heating: 20,000 litres per year

Other benefits

- Carbon emissions avoided: 100 tCO_2 annually

Lessons learned

- Thermal cooling systems can fulfill customers' air-conditioning needs even in non-tropical islands, with relatively short payback periods.
- SAC systems can be used for space-heating purposes in wintertime, maximizing efficiency and improving economic returns.

6 CONCLUSIONS

This report shows that renewable energy technologies (RETs) represent an economically attractive option for the island tourism sector. The cost of air conditioning and water heating from RETs is considerably lower than using electricity generated from diesel for the same service, while solar PV can generate electricity more cheaply than utility tariffs or self-generation from diesel in most islands. Evidence from case studies and the analysis developed in this report show that a strong business case exists for hotels and tourism facilities in islands to invest in renewable energy.

Barriers limiting the deployment of renewable energy in island tourism facilities remain to be addressed, for widespread deployment to take place.

First, renewable energy options are not always perceived to be competitive with diesel-based power generation. The main barriers include the requirement for capital to make an upfront investment (as opposed to paying for the use of a monthly electricity or fuel bill), the perception of lower reliability of supply and a potentially challenging integration with the existing electricity grid. Solutions exist, such as the design and implementation of leasing schemes that would limit the requirement of upfront capital, or the enactment of incentives and disincentives (such as net metering, variable-accelerated depreciation, power purchase agreements and tax credits and rebates).

Second, hotel owners and other tourism operators in islands generally have limited access to affordable financing and credit lines for the purchase and installation of small-scale renewable energy projects. This is also exacerbated by the principal-agent problem, where the ownership and management of facilities are disjointed, reflected by a separation between who could invest in RETs and who pays O&M costs (including electricity bills). Preferential and low-interest loans, as well as feed-in tariffs, would help overcome this barrier, together with public targets (*e.g.,* renewable energy standards). To address the principal-agent problem, leasing schemes or "captive power purchase agreements" can convert the need for a capital investment into an operational cost and provide immediate savings.

Third, the technical and human capacity necessary to design effective energy policies, as well as to install and manage RETs in tourism facilities, is still limited in many SIDS. Awareness-raising campaigns, as well as training programs for institutional and technical capacity, would allow all actors, from policy to purchase and installation, to familiarise themselves with the benefits of using RETs.

Several policy interventions have been successfully implemented in islands, and this report analyzes some of the best practices that have been applied with good results: (1) net metering policies and variable-accelerated depreciation, to address the competitiveness of RET options; (2) leasing schemes and low-interest loans for the purchase of RETs, to provide a solution to access to capital and the cost of financing; (3) Power Purchase Agreements, to tackle technical capacity gaps, access to capital and cost of financing; and (4) awareness raising and training programs, to fill institutional and technical capacity gaps.

Many stakeholders stand to gain from the deployment of RETs: the private sector, as their electricity bills would decline (tourism sector) or their revenues would increase (suppliers and utilities); governments, because RETs create employment and improve trade balances and environmental quality; and development partners, because RETs reduce the environmental footprint of the tourism sector and strengthen the economies of SIDS. In order to realise the multiple benefits of RETs, coordinated action is required at all levels, using a collaborative and multi-stakeholder approach.

This report constitutes the starting point for discussion on the subject of accelerating the deployment of RETs in island tourism. More RETs can be analyzed, which can prove to be competitive in specific island contexts (*i.e.,* technologies using wind, hydro, geothermal, biomass and ocean for electricity). Island tourism consumes energy not only in the accommodation sector, but also most prominently in the transport sector. Although sometimes not cost-effective yet, options for replacing oil products with renewable energy in island transport are already available today: biofuels for air transport;

biofuels and electric vehicles charged using renewable energy for road transport; and wind, solar and biofuels for sea transport. IRENA is exploring all of these options from the technology, policy and costing perspectives, to provide up-to-date, authoritative and comprehensive information to its member countries and to the general public.

ANNEX I: TECHNOLOGY DETAILS

Solar water heating (SWH) systems

SWH technologies use the radiant energy from the sun to heat water. The main components of SWH systems are the solar collector and the balance of system, which includes the collector-storage loop, storage tank, heat exchanger(s), pump(s), auxiliary devices, and/or controllers. The collector is the key component of the SWH as it converts the sun's radiant energy to heat. The balance of system and installation both generally cost more than the collector.

There are many collector technologies, with different efficiency levels and adaptability to diverse climatic conditions. In the case of island tourism, two main types of collectors are considered: flat plate and evacuated tubes. A flat plate collector is composed of a glass or plastic cover (called glazing) on top and an absorber plate that is usually a sheet of high-thermal-conductivity metal with tubes or ducts either integral or attached. The collector is usually insulated to minimise heat loss. Evacuated tube collectors are composed of several glass or metal tubes containing water or heat transfer fluid, surrounded by larger glass tubes. A vacuum space is left between the tubes in order to minimise heat losses.

Evacuated tube collectors can cost twice as much per KW as flat plate collectors (about USD 300/kW and USD 150/kW, respectively). Evacuated tube collectors are adequately efficient in cold climates, but they are less cost-efficient in warm climates, where the energy needed for heating water is lower. In general, both flat plates and evacuated tubes provide useful energy at SWH operating temperatures, which range from 0°C to 60°C. In an island context with solar radiation of 1,700 kWh/m^2, a 200-litre SWH system with flat plate solar collectors would probably be the most cost-effective solution to provide hot water to a hotel room. In particular, the system would have a capacity factor of 16%, and a total capital cost of between USD 350 and USD 1,000.

There are two main SWH classifications: active versus passive systems and direct versus indirect systems.

Active and passive systems

Active systems use a pump plus controller to circulate a typically freeze-resistant heat fluid between collector and storage when solar energy is available, and are dominant in hard-freeze climates. Two active system schematics are shown in Figure A1. Most active systems are indirect, as in Figure A1 (b), with a heat exchanger between the non-potable heat transfer fluid and the potable water storage. In non-freezing climates, the active system will likely circulate potable water to the collectors, with no heat exchanger, as in Figure A1 (a).

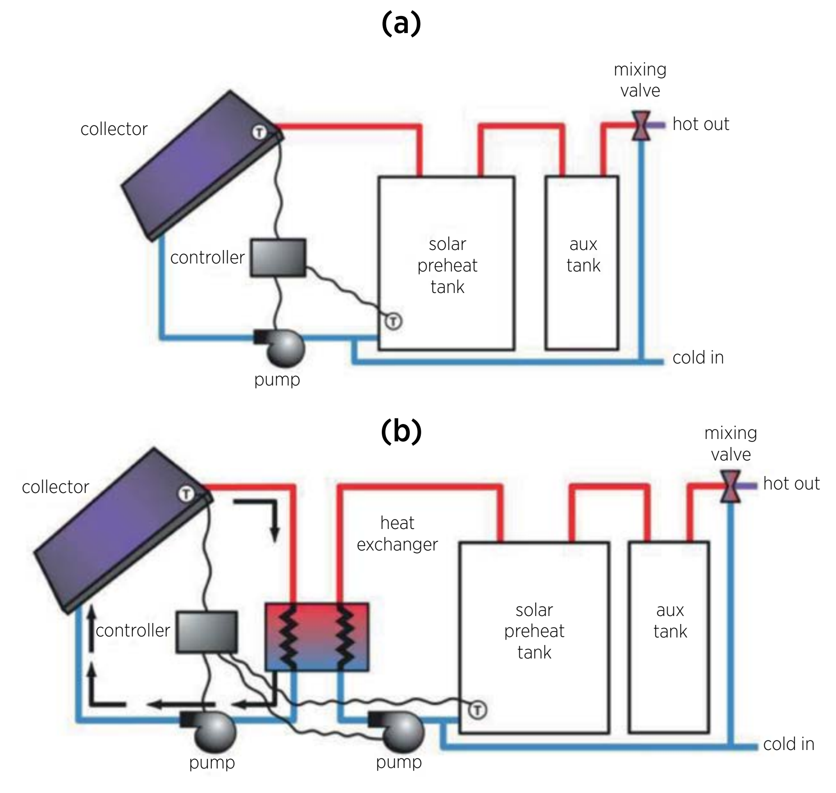
Passive systems use no pumps or controls to move heated fluids between collector and storage and include thermosiphon and integral-collector-storage. Thermosiphons are the most popular passive system worldwide, with natural convection moving hot water from the collector to the storage tank above, and cold water flowing from tank bottom down to the collector inlet. Passive systems are dominant in warm climates because they are less expensive and perform about the same as active systems. However, they are currently not employed in cold climates due to issues with freeze damage.

Direct and indirect systems

Direct systems have no collector loop heat exchanger and use potable water directly in the collector loop, as in Figure A1 (a) and both systems in Figure A2. Direct systems are not suitable for cold climates, as they are subject to freeze damage. On the other hand, they are the most used SWH systems in warm climates, due to their lower cost.

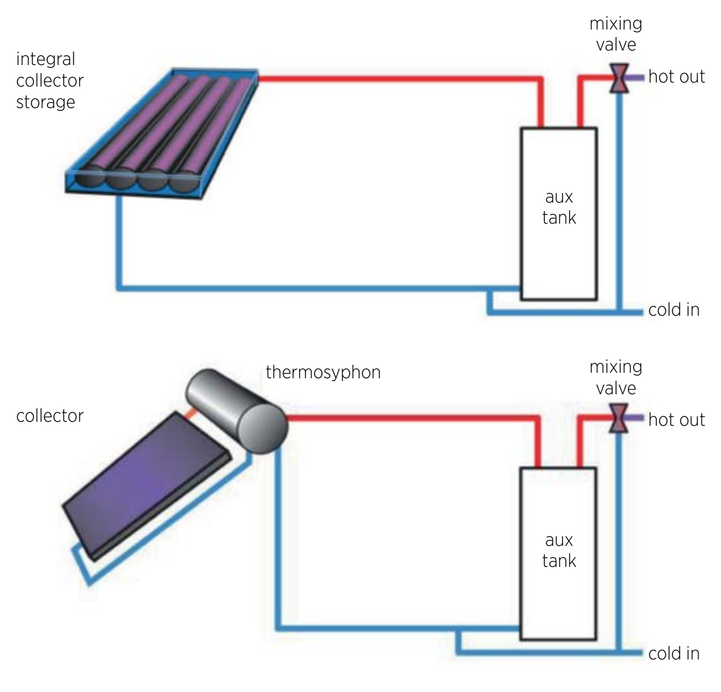
Indirect systems use a heat exchanger between the collector loop and the storage to separate the collector loop fluid (usually a freeze-resistant fluid like glycol) from potable water in the tank, as in Figure A1 (b). Indirect systems are generally freeze-resistant and are dominant in cold climates. As a result, most solar water heaters in cold climates are active/indirect systems, while most solar water heaters in warm climates are passive/direct systems.

Figure A1. Schematic active SWH, showing pumps and controllers to transfer heat from collector to storage: (a) direct system (no heat exchangers); (b) indirect system with two heat exchangers.



Source: Technical Resources for Implementing Energy Independence and Security Act of 2007 (EISA 2007 Section 532), Walker *et al.*, DOE/GO-102011-3354

Figure A2. Schematic passive system, with no pumps/controllers to circulate heat. Top: integral collector storage system. Bottom: thermosiphon system



Solar air conditioning (SAC) systems

SAC systems use solar thermal energy to power chillers and provide cooling to buildings. They are composed of solar collectors, storage tank, control unit, pipes and pumps and a thermally driven cooling machine. Like SWH, SAC systems can use flat plates or evacuated tubes as solar collectors. For higher-efficiency chillers, CST technologies can be adopted (Kalkan, Young, & Celiktas, 2012).

Four variants of CST technologies can be used (IEA-ETSAP & IRENA, 2013b):

- Parabolic Trough. This is the most common CSP technology and uses parabolic mirrors to concentrate solar radiation on heat receivers. PT systems are up to 100 metres long, with a capacity ranging between 14 and 80 MW-electric, efficiencies of around 14-16%, and maximum operating temperatures of 390°C.
- Fresnel Reflectors. They are similar to parabolic troughs, but they use a series of curved mirrors placed at different angles to concentrate the heat onto a fixed receiver located above the mirror field.
- Solar Towers. They are composed of several computer-controlled mirrors that track the sun individually and concentrate the heat onto a receiver. They can use water steam, synthetic oil, molten salt or natural gas as the primary heat transfer fluid. Their maximum operating temperatures can range between 250°C (water-steam) and above 800°C (using gases).
- Solar Dishes. They consist of a parabolic dish-shaped concentrator that reflects sunlight into a receiver placed at the focal point of the dish. They are highly efficient and do not need cooling systems for the exhaust heat. This makes them particularly suitable for water-constrained areas.

Unlike flat plate and evacuated tube collectors, which can use both direct and diffuse solar radiation, CST technologies only use direct radiation, which makes them suitable only for locations with particularly low frequency of cloudy weather.

Absorption chillers can be classified in terms of the number or "effects", with increasing efficiency and increasing hot water temperature requirements:

- Single-effect absorption chillers: the fluids are transferred through the system using low-pressure steam or hot water as the heat source. These systems are widely used and tested, and available in capacities from 7.5 to 1,500 tons. Water temperature required is usually above 80°C, and COP ranges from 0.6 to 0.8. This is similar to adsorption machines, with a higher minimum temperature requirement but slightly higher efficiency. Minimum size tends to be larger compared to adsorption chillers. However, smaller units have been recently developed.
- Double-effect absorption chillers: these chillers can use concentrating solar thermal technologies or evacuated tube systems, and are composed of two condensers and two generators to allow for more refrigerant boil-off from the absorbent solution. A higher performance is obtained by utilising the first heat input into the high-temperature generator effectively in two steps, gradually from high temperature level to low temperature level (Yabase & Makita, 2012). These systems are more thermally efficient than the single-effect chillers, but they have a higher cost. Driving temperature is usually at least 140°C, but the COP is usually above 1, and up to 1.2.
- Triple-effect absorption chillers: they use three condensers and three generators, or two condensers and two absorbers, in order to maximise thermal efficiency. As with the second-effect chillers, they can be driven by concentrating solar thermal systems or evacuated tubes. In this case, COP can reach up to 1.9, with optimal driving temperature of 250°C.

Double- and triple-effect absorption chillers require a high temperature heat source steam, which can be supplied by CST technologies.

Sea water air conditioning (SWAC) systems

The main components of a basic SWAC system are the seawater supply system, the heat exchanger or cooling station, and the fresh water distribution system. The technical specificities of each component will largely depend on the size of the project and the distance of buildings from the sea. For this reason, the technical conception of SWAC systems is the most delicate phase, which involves a detailed analysis of the temperatures and water quantities that will run through the system. More specifically, detailed knowledge is required of (1) the water source (*i.e.,* temperatures, depths, currents); (2) air conditioning requirements (*i.e.,* number of buildings, intensity of cooling effort throughout the year); and (3) pipeline requirements (*i.e.,* diameter, length and consequent temperature losses during seawater transfer).

The seawater supply system is composed of seawater intake and outtake pipelines, and a pump that is used to transfer water from deep sea to the heat exchanger or cooling station. The intake pipeline brings water from deep seawater into the heat exchanger, and the outtake pipelines transfer the seawater back to the sea (usually at higher depths in order to avoid negative ecosystem impacts from the discharge of heated water). Intake depths vary depending on specific projects: for example, in the SWAC system of Intercontinental Bora Bora Resort and Thalasso Spa, pipelines have a diameter of 400mm and extract water from 900m of depth. On the other hand, the system of the Natural Energy Laboratory of Hawaii has an intake depth of 650m, and pipelines with diameter ranging between 300mm and 1 metre. Pipelines are the most critical components of a SWAC system, and the most expensive technology. They are made out of seawater-resistant material, such as 13 polyethylene, and adequate filters are required to prevent accumulation of solid particles in the system. The pump is the only electrical component of a SWAC system, and it has a capacity proportioned to the distance of the buildings from the sea, as well as to the overall size of the SWAC system. In the case of the Intercontinental Bora Bora Resort and Thalasso Spa, a 15 kW pump is used, compared to a capacity of 300kW that would be needed for cooling hotel rooms through conventional chilling systems.

The fresh water distribution system is used to provide air conditioning to buildings, through a closed-loop chilling system. The freshwater circulating through the system is chilled using cold deep seawater, but it is never mixed with seawater in order to avoid corrosion, siltation and contamination. The fresh water loop extracts heat from the building and dumps it into the heat exchanger. This lowers the fresh water temperature before it is returned to the building cooling system. The seawater loop typically flows countercurrent to the fresh chill-water loop from the buildings. Chilled fresh water moves through buildings with the same temperatures and flows used in a conventional air conditioning system.

The heat exchanger allows the cold seawater to cool the re-circulating fresh chill-water loop used for air conditioning application. In a typical SWAC system, the cold seawater is pumped at 5°C, arrives at 6-7°C in the heat exchanger, goes through the heat exchanger, and leaves at 12- 13°C. The fresh water of the air conditioning system does the exact opposite, arriving at 12°C and leaving at 7°C. Titanium heat exchangers are commonly used, since they combine resistance to salty water with high thermal conductivity. Once the seawater passes through the heat exchanger, it is returned to the ocean through another pipeline.

Importantly, SWAC is not technically complex; neither does it involve a high technical risk. Rather, it is an established technology being applied in an innovative way. All the components necessary exist and have been operated under the conditions required.

Solar photovoltaic (PV) systems

A solar PV system uses solar cells to convert solar energy into DC electricity. A PV module consists of several solar cells assembled and electrically interconnected. Depending on the size of the system, PV modules con be connected in a series and/or in parallel to increase voltage and/or current, respectively (IEA-ETSAP & IRENA, 2013a). In addition to modules, solar PV requires the balance of system, which comprises an inverter, racking, power control, cabling and batteries (if needed). The inverter converts DC into AC, thereby allowing the connection to the grid and the use of solar PV with most electrical appliances. Batteries might be needed for off-grid systems to store PV-produced electricity and release it when the sun is not shining (*i.e.,* at night or during cloud cover). Depending on the size of the system, solar exposure, and overall climatic conditions, solar PV systems can be mounted on existing roofs or dedicated structures on nearby open land or integrated directly into new construction.

The balance of system consists of mature technologies and components, whose prices have been steadily declining. Inverters are available with different capacities, reaching up to 2 MW for use in large-scale systems. Either single or numerous inverters can be used for a single PV system. Regarding electricity storage, the most common technologies are lead-acid batteries and pumped hydro storage systems (suitable for large-scale only). New types of storage technologies are being developed (*e.g.,* new batteries, electric capacitors, compressed air systems, superconducting magnets and flywheels) with the aim to improve the cost-effectiveness of off-grid solar PV systems.

- A variety of PV technologies are either commercially available or under development. A description of some of them follows.

Wafer-based crystalline silicon (c-Si)

In c-Si technology, silicon is used in three forms: mono crystalline silicon (mono-c-Si), multi-crystalline silicon (multi-c-Si) and ribbon-sheet grown silicon. Multi-c-Si cells have lower efficiency than mono-c-Si cells, but they are less expensive. A standard c-Si module is typically made up of 60-72 cells, has a nominal power of 120-300 Wp and a surface of 1.4-1.7 m^2 (up to 2.5 m^2 maximum). The cost of c-Si technology has decreased considerably over the last years, especially due to improvements in production processes, which have enabled the amount of silicon required to be reduced. The target is to further cut prices by reducing silicon from 5-10 g/Wp in 2013 to 3 g/Wp or less by 2050. The maximum theoretical efficiency for c-Si is currently estimated at around 29%. However, the majority of commercial mono-c-Si modules have an efficiency of between 13 and 19%, and multi-c-Si have an efficiency ranging between 12 and 17 %.

Thin-films (TF)

The TF technology consists of the deposition of a thin layer of active materials on large-area substrates of materials such as steel, glass or plastic. There are four main variants of TF technology:

- Amorphous silicon (a-Si) films are deposited on very large substrates (5-6 m^2), have low manufacturing costs but also low efficiency (4-8%).
- Amorphous and micromorph silicon multi-junctions (a-Si/_c-Si) films absorb more light in red and near-infrared spectrum, and may reach an efficiency up to 11%.
- Cadmium-Telluride (CdTe) films are chemically stable and offer relatively high module efficiencies (up to 11%).
- Copper-indium-[gallium]-[di]selenide-[di]sulphide (CI[G]S) films have the highest efficiency among TF technology, reaching up to 14% for prototypes, and up to 12% for commercial modules. However, they have higher manufacturing costs than the other TF modules.

Standard TF modules have a typical 60-120 Wp capacity and a size between 0.6-1.0 m^2 for CIGS and CdTe, and 1.4-5.7 m^2 for silicon-based TF. Overall, TF modules have an efficiency ranging between 4 and 12%, much lower than c-Si modules. However, they have lower production cost, and shorter payback time than c-Si. Moreover, plastic TF are usually frameless and flexible and can easily adapt to different surfaces. In recent years, TF technology has lost market share due to decreasing costs of c-Si modules. State-of-the-art TF modules can reach 14% efficiency, with record modules at 17% and record cells at more than 20%.

Emerging and new PV technologies

A variety of innovative PV technologies are being developed and tested in order to assess their potential to increase current efficiency levels, at the same time reducing costs and payback periods. The most important include:

- Concentrating PV (CPV): this is the most mature of the new technologies, and it uses optical sun-tracking concentrators (*i.e.,* lenses, reflection and refraction systems) to focus the direct sunlight on highly efficient solar cells (c-Si modules with efficiency of 20-25%, or III-V semi-conductors and multi-junction solar cells).
- Organic solar cells: they are made of low-cost organic layers, but they have low efficiency (currently 4% for commercial applications). They include hybrid dye-sensitised solar cells (DSSC) and fully-organic cells (OPV). Their feasibility and cost-effectiveness have yet to be proved.
- Advanced inorganic thin-films: examples include the spheral CIS approach (*i.e.,* glass beads covered by a thin multi-crystalline layer with a special interconnection between spheral cells) and multicrystalline silicon thin films obtained from high-temperature deposition process.
- PV concepts relying on nanotechnology and quantum effects to provide high-efficiency solar cells: the objective for nanotechnology PV concepts is to reach cell efficiency higher than 25% by 2015. On the other hand, quantum effects aim to increase efficiency of existing technologies (TF or c-Si) by 10% through photon absorption and re-emission to increase energy capture.

ANNEX II: REVIEW OF RENEWABLE ENERGY POLICIES IN SIDS

Country	RE Policy/Strategy	RE Target	RE Incentives/Regulatory Instruments
Barbados	Sustainable Energy Framework for Barbados	2026: 20% of national consumption	● Income Tax Relief ● Import-Tax Exemptions on RET ● Autonomous generation allowed
Comoros	Comoros Renewable Energy Policy (2008)	No specific target	● Capital subsidy, grant or rebates
Cook Islands	Renewable Energy Chart (2011) and Implementation Plan (2012)	2015: 50% 2020: 100%	● Net metering
Dominica	Energy Development Program (2009)	2015: 60-70% of installed capacity 2020: 100%	● Autonomous generation allowed ● No tax on imported equipment and components ● Injection by IPPs
Federated States of Micronesia	Energy Policy 2010	2020: 30% on energy production	● Net metering
Fiji	Fiji's National Energy Policy (2006)	2015: 90%	● Grant and rebates for RETs ● Tax incentives ● Obligation and mandates
Grenada	National Energy Policy of Grenada: A Low Carbon Development Strategy for Grenada, Carriacou and Petite Martinique (2011)		● Autonomous generation allowed (net metering) ● Tax exemption for hotels importing equipment and components ● Injection by IPPs
Kiribati	Kiribati National Energy Policy (2009)	Being approved	
Republic of the Marshall Islands	National Energy Policy and Energy Action Plan (2009)	2020: 20%	
Mauritius	Long-Term Energy Strategy 2009-2025 Energy Strategy 2011-2025 Action Plan	2025: 35%	● No customs duty applicable on equipment for renewable energy ● Minimum energy performance prepared and enforced for electric appliances, including water heaters, refrigerators, ovens, dish-washers, washing machines, air conditioners
Nauru	Nauru Energy Framework (2009); Nauru Energy Roadmap (2014)	2020: 50% of electricity generation	
Niue	Niue Energy Policy and Action Plan (2005)	2020: 100%	

Country	RE Policy/Strategy	RE Target	RE Incentives/Regulatory Instruments
Palau	Palau National Energy Policy (2010)	2020: 20%	● Subsidies and preferential loans (and equity for commercial projects) for RETs for households and businesses
Samoa	Samoa Energy Sector Plan 2012-2016	2016: +10%	
Seychelles	Second National Energy Policy (2010)	2020: 5% 2030: 15%	● Incentives to grid-connected PV power systems
Solomon Islands	National Energy Policy Framework (2007)	2015: 50%	● Incentives to financial institutions to finance equipment purchase
St. Lucia	National Energy Policy (2010)		● Autonomous generation allowed (only off-grid) ● Income tax relief ● Import tax exemption ● Incentives to investors in energy-efficient tourism facilities
Saint Vincent and Grenadines	National Energy Policy (2009) Energy Action Plan (2010)	2015: 30% 2020: 60%	● Renewable energy incentives granted on a case-by-case basis
Tokelau	Tokelau National Energy Policy and Strategic Action Plan (2004)	2012: 100% (reached)	● Solar PV incentives ● Biofuels (coconuts) incentives
Tonga	Tonga Energy Roadmap 2010-2020	2020: 50%	● Financing of solar home systems
Tuvalu	Enetise Tutumau 2012-2020	2020: 100%	● Financial incentives to grid-connected solar PV deployment
Vanuatu	Vanuatu Energy Roadmap (2012)	2020: 65%	

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