



Renewable energy roadmap for the Republic of Maldives

Copyright (c) IRENA 2015

Unless otherwise stated, this publication and material featured herein are the property of the International Renewable Energy Agency (IRENA) and are subject to copyright by IRENA.

Material in this publication may be freely used, shared, copied, reproduced, printed and/or stored, provided that all such material is clearly attributed to IRENA and bears a notation that it is subject to copyright (© IRENA 2015).

Material contained in this publication attributed to third parties may be subject to third party copyright and separate terms of use and restrictions, including restrictions in relation to any commercial use.

About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy in the pursuit of sustainable development, energy access, energy security and low carbon economic growth and prosperity.

Acknowledgement

The renewable energy roadmap was developed by IRENA upon request of the Ministry of Environment and Energy, the Republic of Maldives. This report includes details the key findings of the roadmap analysis and the insights developed at the 17 September 2015 final roadmap workshop, opened by H.E. Mohamed Muizzu, Minister of Housing and Infrastructure, acting Minister of Environment and Energy and the Director-General of IRENA. IRENA extends thanks to all workshop participants for their valuable input.

This report has been made possible by a voluntary contribution from the government of the Federal Republic of Germany.

Authors: Peter Journey-Kaler and Emanuele Taibi, IRENA. For further information please contact IRENA at info@irena.org

Disclaimer

This publication and the material featured herein are provided "as is", for informational purposes.

All reasonable precautions have been taken by IRENA to verify the reliability of the material featured in this publication. Neither IRENA nor any of its officials, agents, data or other third-party content providers or licensors provides any warranty, including as to the accuracy, completeness, or fitness for a particular purpose or use of such material, or regarding the non-infringement of third-party rights, and they accept no responsibility or liability with regard to the use of this publication and the material featured therein.

The information contained herein does not necessarily represent the views of the Members of IRENA, nor is it an endorsement of any project, product or service provider. The designations employed and the presentation of material herein do not imply the expression of any opinion on the part of IRENA concerning the legal status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

Unless otherwise indicated, all photographs are from Shutterstock.



Contents

Introduction	3
Technology solution: Interconnection.....	4
Technology solution: Overcoming land constraints.....	5
Technology solution: Renewable energy heating and cooling.....	6
Technology solution: High shares of renewable energy.....	7
Policy solution: Ambitious renewable energy targets.....	8
Policy solution: Private renewable energy.....	9
Policy solution: Encouraging renewables on resort islands.....	10
Policy solution: Improving energy data collection and access.....	11
Recommendations from the final roadmap workshop	12





Introduction

The Renewable Energy Roadmap for the Republic of Maldives, developed by the International Renewable Energy Agency (IRENA) at the request of the Ministry of Environment and Energy of the Republic of Maldives, identifies opportunities and challenges in the country's transition to large-scale renewable energy use. This booklet highlights main findings of the roadmap analysis and covers the recommendations developed by key stakeholders during the final roadmap workshop.

Opportunity: The Maldives has significant renewable energy resources. If properly developed, these could greatly reduce dependence on imported fuel and lower the country's high electricity costs.

Challenge: The current, planned and proposed renewable energy projects identified by IRENA would not achieve the full potential of renewable energy in the Maldives.

The roadmap details technologies that would support large-scale renewable energy deployment:

- » Interconnection between islands
- » Technologies addressing land constraint issues in the Maldives
- » Heating and cooling from renewable energy
- » Technologies supporting high shares of renewable energy

Challenge: High investment costs, along with obstacles in the policy and regulatory framework, have limited renewable energy deployment in the Maldives.

The roadmap highlights **policy solutions** to overcome these barriers and accelerate renewable energy deployment:

- » Ambitious but achievable renewable energy targets
- » Supporting private renewable energy deployment
- » Encouraging renewable energy solutions on resort islands
- » Improving energy data collection and access

Technology solution: **Interconnection**

Large-scale deployment of renewable energy across Greater Malé will require interconnection between islands with undersea electrical cables. Interconnections support renewable energy by connecting islands with space for large renewable energy projects to demand centres like Malé, where land constraints limit deployment. Interconnections to nearby uninhabited islands would support the deployment of large-scale wind-power projects.

The government's *Greater Malé Region Renewable Energy Integration Plan* and the USAID *Maldives Submarine Cable Interconnection Pre-feasibility Study* provide detailed analysis that can help to determine the best options for undersea electrical interconnections in Greater Malé. However, these studies do not analyse how interconnections contribute to a least-cost power system or maximize renewable energy deployment.

Before investing in interconnections the government should complete a comprehensive study that includes a cost comparison of interconnection versus decentralized renewable energy and energy storage and other measures to determine the optimal combination of technologies for supporting large-scale renewable energy deployment.



Potential interconnection options for Greater Malé

Technology solution: **Overcoming land constraints**

The strong solar resource of the Maldives makes solar photovoltaics (PV) an attractive option, however land constraints limit the deployment of ground mounted PV. Rooftop PV represents an attractive alternative to overcome these constraints. In addition, there are several commercially-available technologies that can increase the electricity generation of PV when space is the constraint. High efficiency and concentrating PV modules are more expensive but increase the amount of electricity generated using the same area. Solar trackers move panels so that they directly face the sun throughout the day; these systems increase cost and maintenance requirements but boost generation in a given area compared to fixed panels. Wind turbines are more complex to install and maintain than PV but provide significantly more output for a given area and can produce electricity also at night, unlike PV.

Where land constraints limit rooftop PV deployment another option is to install solar PV on floating platforms, anchored close to shore and connected to the electricity grid using undersea cables. A private PV developer has installed 15 kilowatt-peak (kWp) and 28 kWp platforms in the Maldives and is also rolling out a four-platform, 100 kWp system. Estimated generation cost for these projects, less than USD 0.20 per kilowatt-hour, is below local diesel generation costs, although higher than rooftop. Key drivers are the cost of capital and project scale: utility scale roof-mounted PV generation cost in the Maldives can be USD 0.10 or less if government-guaranteed concessional finance is used to finance the project. Space constraints apply also to lagoons, as they support a series of economic activities and in certain occasions part of the lagoon area is reclaimed to increase land area. It is essential that the cost, applicability, environmental impact, long-term performance and survivability of these systems in the context of the Maldives is monitored based on these first pilot installations.



Swimsol 28 kWp floating PV platform, Photo: Swimsol GmbH

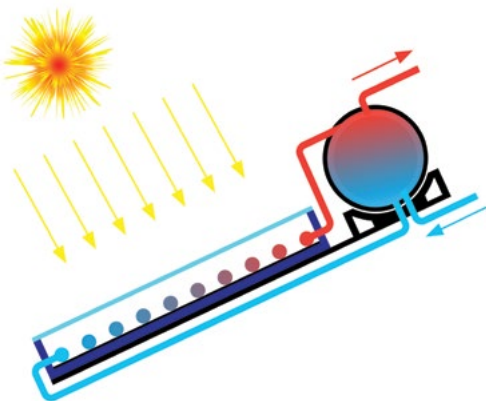
Technology solution: Renewable energy heating and cooling

Solar water heating (SWH), seawater air conditioning (SWAC) and solar air conditioning (SAC) technologies provide significant opportunities to lower electricity demand in the Maldives. These non-electrical technologies can be significantly less expensive to operate versus conventional heating and cooling systems that consume diesel-generated electricity. They can reduced can reduce the need to invest in more power generation capacity, boost the share of renewable energy and lower hot-water and air-conditioning bills.

SWH is established technology with global deployment and a clearly demonstrated ability to lower the cost of water heating. SWH offers an excellent option for resorts, which have a high demand for hot water. SWAC and SAC have a more limited deployment: projects using these technologies require case-specific feasibility studies to confirm that the systems can deliver cost competitive air conditioning services. With easy access to deep water and high demand for air conditioning SWAC has a high potential in the Maldives. To be economical SWAC requires a large cooling load. As such, a high priority should be placed on examining SWAC based district cooling for the urban development projects currently underway in Greater Malé.

An overview of these technologies, including case studies and cost estimates, can be found in the IRENA report *Renewable Energy Opportunities for Island Tourism*. A report from Japan's New Energy Industrial Technology Development Organization (NEDO), *Multistage Deep Sea Water Utilization Infrastructure in the Republic of Maldives*, details a proposed SWAC project in Greater Malé.

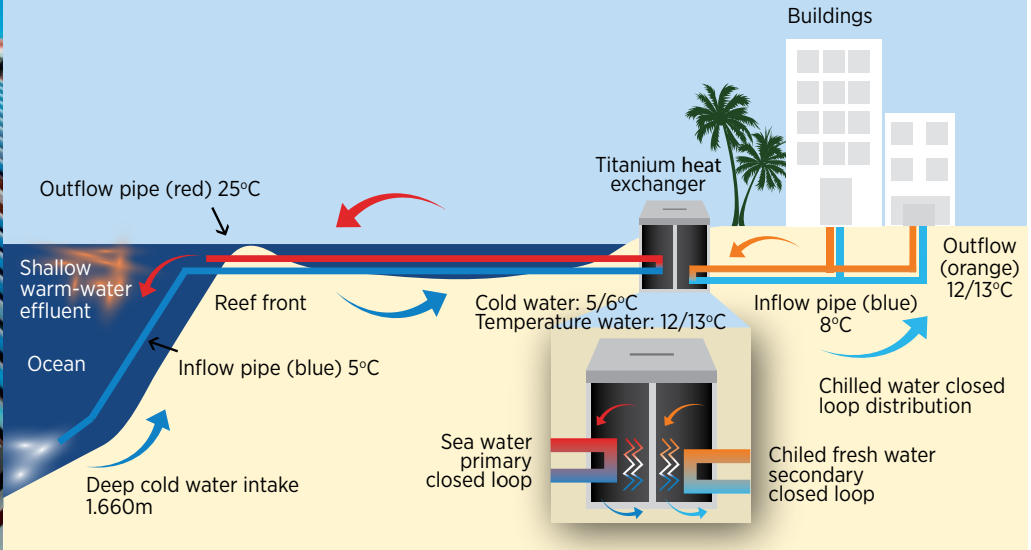
Solar collectors can power water heating and air conditioning



Vacuum tube solar collectors



Seawater air conditioning



Technology solution: High shares of renewable energy

Achieving high shares of PV and wind generation can require energy storage, flexible generators or other measures to compensate for the variable nature of solar and wind resources. Significant PV and wind generation can be deployed without these measures and the specific combination of technologies that can best support high shares of renewables needs to be evaluated for each island.

Battery storage supports high shares of PV and wind, however, the costs needs to be carefully evaluated. A possible lower cost options is ice storage, where excess PV and wind generation produces ice that serves as a cooling source for air conditioning. Details on energy storage options can be found in the IRENA report Renewables and Electricity Storage, a technology roadmap for Remap 2030.

High levels of PV and wind require that diesel generators are properly maintained and operated. Any new or replacement generators should have low loading and fast response capabilities that support high shares of variable renewable energy. Additional measures such as modern inverters and control systems, solar and wind forecasting and demand side management can provide lower cost alternatives for increasing shares of PV and wind. The IRENA report Renewable Energy Roadmap for the Republic of Cyprus provides details on measures supporting variable renewables.

Other generation technologies can also increase the share of renewable energy. Biogas for from municipal wastewater can generate electricity using proven, commercially available technology. Given the strong potential resource, Ocean thermal energy conversion (OTEC) should be analysed to determine the economics of this emerging technology.

High shares of renewable energy generation can also be achieved through the importation of renewable fuels such as biodiesel for use in existing generators or solid biomass, which would require new power plants. These options would not address energy security issues as fuel imports would still be required. Waste-to-energy plants can also reduce fuel import but require a complex and well maintained waste sorting and pollution control systems.



Electricity generation from wastewater biogas
Photo: NREL

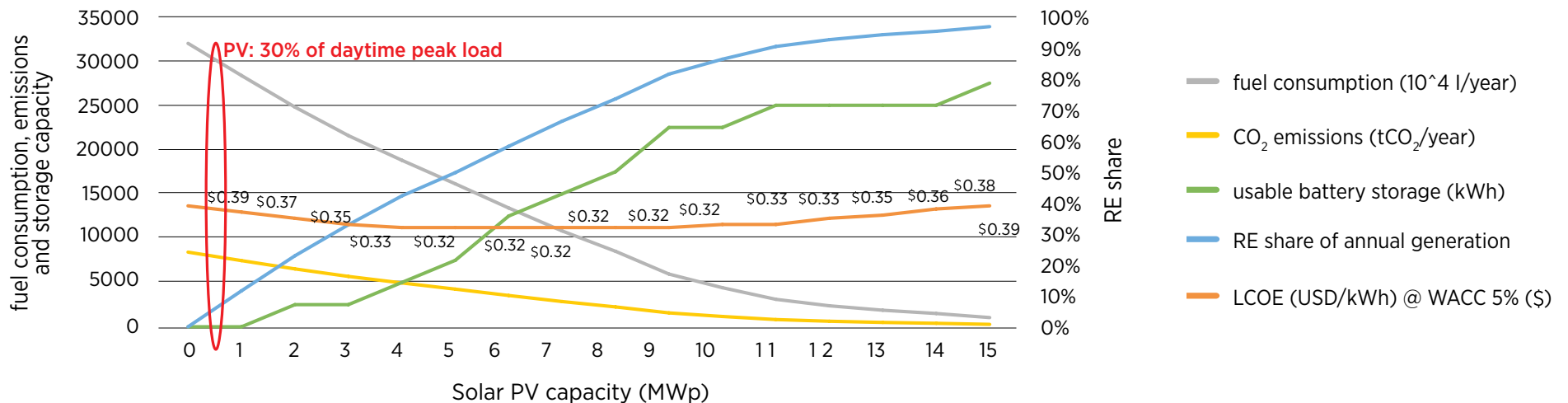


Policy solution: Ambitious renewable energy targets

The government should set official renewable energy targets that are both ambitious and achievable. Official targets should be based on an analysis of economically optimal and technically feasible options for renewable energy deployment, including aspirational, 100% renewable options. This would help to identify the key cost drivers, determine the technologies required and highlight the cost and performance trade-offs between a range of renewable energy targets. Wide consultations will be needed to ensure the renewable energy targets are feasible and have strong support. Targets must be embodied in official legislation or mandates and clearly communicated to all stakeholders.

The current target, calling for renewable electricity generation of at least 30% of daytime peak load on all inhabited islands by 2019, can serve as a first step in driving the deployment of renewables. However this target is below the economically optimal deployment level for the Maldives and does not have a significant impact on reducing fuel imports or lowering electricity costs, with a typical reduction in diesel consumption well below 10%, much less in islands with limited use of air conditioning during the day. The 30% target also creates a risk that the deployed systems, suitable for low solar PV penetration, will have to be retrofitted at significant cost to support higher shares of renewables, including control systems and possibly requiring replacement of inverters to make them controllable and compatible with battery storage systems. There are already systems, e.g. in Gdh. Thinadoo, that reach 50% PV share on daytime peak without storage, using modern controls. These systems may serve as better model for the initial target to use while a long-term target based on detail analysis of least cost solutions is being developed. It is essential that standards are adopted, to ensure that the equipment (power electronics in particular) deployed in the process of reaching 30% of uncontrolled PV penetration are compatible with further deployment, capable of providing grid support services and to be integrated with battery storage systems.

Impact of rising shares of solar PV in Villingili, Maldives



Policy solution: Private renewable energy

Current studies and reports focus primarily on deployment of publicly owned and operated renewable energy systems. Supporting private sector investment would greatly increase renewable energy deployment in the Maldives. However, risk mitigation instruments should be established to reduce the cost of capital and consequently the generation cost from renewable energy.

The recently approved feed-in-tariff, the soon-to-be-approved net metering regulation provide strong opportunities to boost private sector investment in renewables. The government should also consider additional policies such as allowing third-party ownership and leasing of renewable energy projects, which can greatly reduce initial costs for private investors. Current policies should be closely monitored and adjusted as necessary to ensure that they are supporting private investment in a low-risk, level playing field. It is essential that the policy details are transparent and effectively communicated to potential investors. It is also critical that no retroactive policy changes are made as this can have a major negative impact on investor confidence.

Building codes should mandate minimal requirements for renewable energy and energy efficiency in all new construction. Including renewables and energy efficiency in the planning and design phases lowers their cost and improves their performance. Special attention should be focused on large urban development projects where economies of scale greatly reduce the cost of renewables and support district cooling based on SWAC.

Large-scale renewable energy deployment will also require significant local capacity for renewable energy installation, operation and maintenance. The government should work with development partners and local educational institutions and companies to ensure that a sufficient number of properly trained professionals are in place to support a large-scale private sector investment in renewables.

Addu High School PV project
Photo: Swimsol GmbH



Policy solution: Encouraging renewables on resort islands

Power generation on resorts amounts to at least 100 MW, equal to more than half of the country's total publicly owned power generation capacity. Resorts are almost entirely dependent on diesel for electricity. As a result, any significant reduction in national fuel imports will require a widespread deployment of renewables in island resorts. As such, the government should reach out to resorts to determine if any policy, regulatory or financial barriers limit investment in renewable.

Several resorts in the Maldives have invested significantly in renewable energy, e.g. the Finolhu Villas Resort aims to produce 100% of its electricity from PV. However, adoption of renewables across the tourism sector is lacking. The government should cooperate with tourism companies to develop an active forum for sharing case studies and best practice to increase interest in investing in renewables. To incentivize resorts, this forum could include a renewable energy ranking system or competition with awards and promotion for resorts demonstrating leadership in renewables.

IRENA's report, *Renewable Energy Opportunities for Island Tourism*, provides guidance on deployment options for the tourism sector.



Policy solution: Improving energy data collection and access

Modelling and planning for a large-scale renewable energy deployment requires regularly collected, easily accessible energy data. Roadmap analysis found numerous issues surrounding the quality and availability of energy data in the Maldives. A comprehensive strategy for improving data collection and handling would ensure all stakeholders have access to the data required to make key policy, regulatory, financial and operational decisions. In addition, the information from completed studies should be easily available to support continued efforts and prevent any duplication of previous work.

At a minimum, data collection needs to include:

- » Renewable resource assessments
- » National and island-specific energy balances, updated at least yearly
- » Reliability and performance of current generation and grid assets, including distributed, off-grid and renewable power generation
- » Hourly electricity demand for each island
- » Fuel consumption at a variety of loads for every generator
- » Forecasts of demand growth nationally, per island, per sector and per end-user, updated at least yearly

Adequately funded and staffed data collection and management units should be established within STELCO, FENEKA and all institutions handling energy sector data, and their performance should be closely monitored for ensuring that comprehensive overview of the energy sector is established and regularly updated, in support of policy making and energy planning efforts.



Recommendations from the final roadmap workshop

National renewable energy policy should specifically define roles for all players and increase transparency and efficiency of developing renewable energy projects. Given the rapid changes in the cost and capabilities of renewable energy and technologies supporting the integration of renewables into the grid renewable energy policy should be flexible and technology neutral.

There should be a regular energy sector stakeholder meeting that supports dialogue between government, civil society and national and international financial institutions. This meeting could serve as a venue to judge the effectiveness of current policies, regulations and business practices in supporting renewable energy.

The Addu High School PV project, winner of the 2015 Zayed Future Energy Prize, provides a model for engaging and informing local communities about the benefits of renewable energy. In addition, energy brokers distributed across Maldives could help to support renewables by serving as a focal point for local interest in renewables.

To deal with the large number of islands, the MEA could benefit from a decentralized model using remote monitoring and data collection to incentives compliance. Tonga serves as a case study; the national target on line losses was backed with remote data collection and allowed the utility to exceed the target.

Renewable energy production should be assessed on supplier side versus consumer side, to understand which is more beneficial. The impacts of renewable energy investment done by utilities vs. IPPs should also be analyzed. There is a need for risk mitigation mechanisms to reduce WACC for IPPs. Utilities should solicit IPPs directly without waiting for donor support through government. E.g. STELCO already has a PPA with a local company, RE Maldives. It is essential that the MEA confirm that such PPAs do not increase electricity costs.

The current and upcoming regulatory framework needs clarification to increase investor confidence. Specifically the MEA's PPA approval process should be reviewed. A new electricity law is needed to address the changing energy sector framework, now that renewables are being deployed. This law should empower the MEA with the necessary independent authority, capacity and resources to develop regulations and monitor compliance.

There is a need to discuss how the money going into fossil fuel subsidies, including direct and cross subsidies, could be better utilized to support energy efficiency and renewables. These subsidies affect the viability of renewable energy projects and their financing cost. A potential solution could be allocating a percentage of current subsidies to support a rebate scheme for renewable energy investment.

A wide-ranging study examining the tariff impact of current renewable energy policy should be conducted to ensure that cost reduction benefits of renewables are achieved. Renewables could greatly reduce electricity sector subsidies by allowing customers to produce their own unsubsidized electricity. Utility investment in renewables would reduce subsidies to support their operations. The study should cover the impact of net metering for large commercial customers, different rates for self-consumption versus supplying the grid and a separation between customer types, by monthly consumption.



Finolhu Villas PV walkway,
Maldives
Photo: CDE Consulting

