IRENA
International Renewable Energy Agency

NATIONAL ENERGY ROADMAPS FOR ISLANDS

INTRODUCTION

Since its inception in 2011 the International Renewable Energy Agency (IRENA) has actively supported small island developing states (SIDS) in their transition to a renewable-energy future. National Energy Roadmaps provide clear pathways for the deployment of renewables that cover the necessary technical, economic and policy elements.

Roadmaps are the final product of cooperation between IRENA, the government and key national stakeholders, such as the local utility company. They feature analysis on shifting current energy use to a least-cost energy system with a significant contribution from renewable alternatives.

The roadmap analysis is usually centred on a long-term capacity expansion model that identifies the least-cost power system, with additional assessments of how this system would be optimally dispatched. This analysis is supported by an examination of the potential for renewables in end uses and other sectors, such as heating, cooling and transportation. The roadmap also contains specific policy recommendations to enable its implementation.

IRENA has worked with the island states of the Dominican Republic, Barbados, Cyprus, Kiribati, Nauru, the Maldives and Mauritius to deliver roadmaps that identify a future energy mix dominated by renewable energy. The roadmaps have been developed using a variety of tools to meet the diverse needs of island states, and will be explained in this brochure.

ROADMAP PROCESS

The roadmap process starts with a member country's formal request to IRENA's Director-General asking for assistance and presenting the rationale for the development of a National Energy Roadmap. Country engagement takes place through the SIDS Lighthouses Initiative, which brings together more than 50 partners, including SIDS and development organisations, to accelerate the deployment of renewable energy in these countries.

IRENA then collaborates with the government on a scope of work, defining the analysis to be undertaken. The type of analysis depends on the government's policy drivers, which can include accelerating renewables deployment, determining the optimal energy mix, strengthening energy security, lowering energy costs and reducing the environmental impact of energy supply.

IRENA then undertakes a techno-economic analysis based on the scope of work to determine a least-cost energy system. The quantitative insights from this analysis are used to develop specific policy recommendations to support roadmap implementation.

Once finalized, the roadmap analysis is presented at a final workshop for the government and key stakeholders. Any findings from this workshop are then incorporated into a final report covering the full details of the roadmap, which is delivered to the government for official endorsement. The roadmap report is delivered along with any software models developed in the roadmap process and with presentations and infographics useful for communicating the findings.

The roadmap exercise serves as an opportunity for local capacity building, in which IRENA can introduce models, tools and processes to assist with future energy planning efforts and provide training in using them. The models developed for the roadmap can also serve as valuable inputs for further work, such as the preparation of the nationally determined contributions under the Paris Agreement, grid integration studies, and market design.

ROADMAP ANALYSIS

The core of the roadmap is a techno-economic analysis that aims to determine a least-cost, technically sound energy mix that meets the government's policy priorities. The depth of analysis and the specific modelling tools used are determined by the complexity of the energy sector and the type and quality of data available. For most islands this analysis focuses on electricity generation, the activity in which renewables can have the greatest impact and where the required data is normally available. Figure 1 is a flowchart for an analysis focused on optimizing electricity generation.

As shown in Figure 1 the techno-economic analysis is based on two types of models: capacity expansion, and dispatching. The capacity expansion model examines both investments in generation technologies and operational costs such as fuel and maintenance. This is to determine how to meet future demand using a least-cost mix of generation assets. This analysis normally investigates a period covering 10 to 20 years, or longer. Ideally it uses an electricity demand forecast covering every hour of the period examined.

A dispatching model is then used to determine any potential operational constraints that could result in the optimal generation mix generating insufficient power to meet demand. This modelling normally covers one year, with a higher time resolution to provide more insight on operational cost impacts and to identify specific situations in which the optimal generation mix could face difficulty in meeting electricity demand.

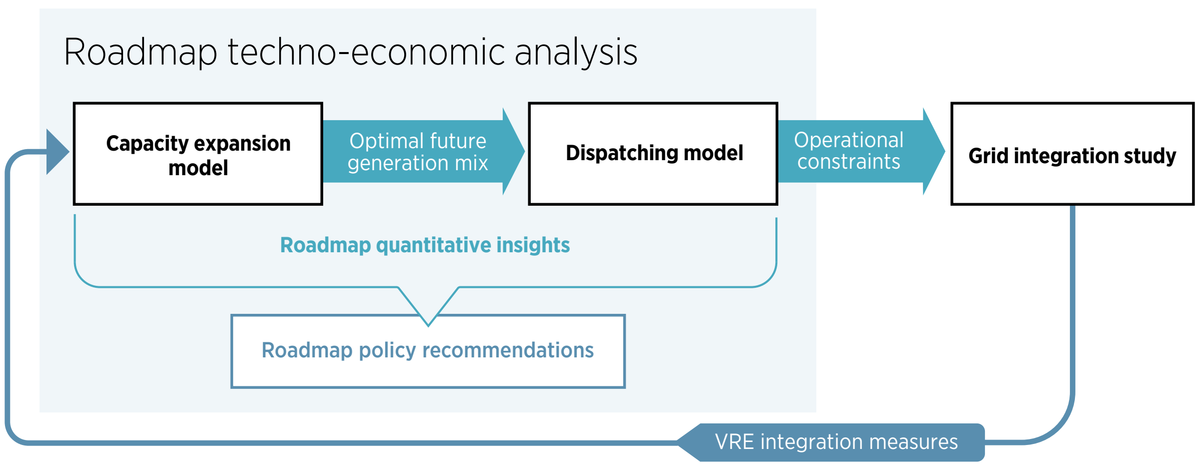


Figure 1. Roadmap electricity sector techno-economic analysis

These operational constraints may justify a grid integration study, conducted as a separate analysis and complementing the roadmap. This study would identify specific measures to address any operational issues identified by dispatching model. Ideally the specification of any identified measures, including their costs, are fed back into the techno-economic analysis to estimate their impact on system cost and operation and determine how this would affect the optimal generation mix.

For smaller power systems in which the total investment required is limited, the capacity expansion and dispatching analyses can be combined. In some cases, an entire electricity system can be replaced in a single project, delivering an optimal system capable of meeting demand in all years covered by the roadmap.

For larger systems, the overall cost of reaching the optimal generation mix is often too high to be allocated to one project. In these cases, the capacity expansion model delivers a timeline detailing specific generation investments required to meet electricity demand over the period covered by the roadmap. The dispatching model can be used to investigate the impact of each of these capacity additions, or can examine the completed optimal mix to determine any operational constraints that might require a grid study.

Analysis in a National Energy Roadmap considers all renewable generation technologies that are cost competitive and can be supported by available resources. However, variable renewable energy (VRE) technologies such as PV and wind generation are often identified as the primary options for introducing high shares of renewables to islands.

Dispatching models and grid integration studies can provide detailed insights into the operational impacts and required measure for successfully integrating high shares of VRE. The case studies provided in this brochure give further insight into how VRE can be deployed in islands.

Where data is available, roadmap analysis can be expanded to investigate the deployment of renewables in other sectors such as transportation or industry, and for specific uses such as heating, air conditioning and refrigeration.

The availability of data and the strong engagement of national stakeholders have proved to be the key preconditions for a meaningful, insightful roadmap.

POLICY RECOMMENDATIONS

Quantitative insights from the analysis are used to develop policy recommendations that support implementation of the roadmap. Recommendations typically address the challenges of transitioning from a power system based on fossil fuels, in which costs are driven by fuel consumption, to a system dominated by renewables and in which costs are driven by upfront investments that greatly reduce fuel consumption. Additional policy concerns can be defined in advance to be addressed with dedicated quantitative analysis. The following section provides examples of specific policy recommendations developed from island roadmaps.

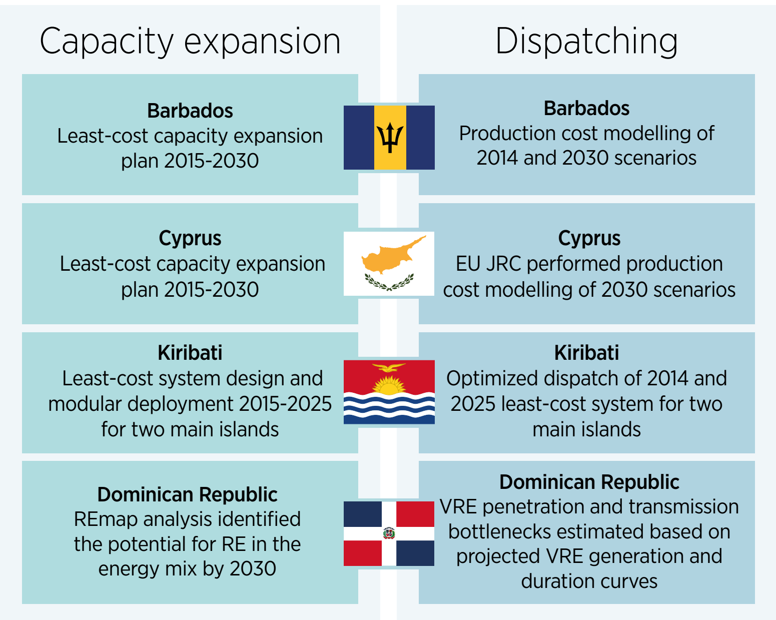
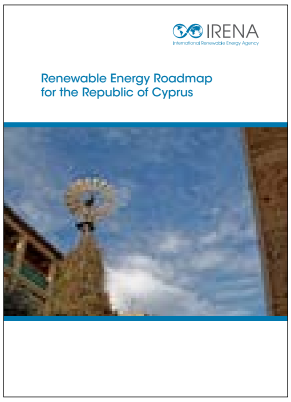


Figure 2. Breakdown of techno-economic analysis for each roadmap

OVERVIEW OF SELECTED PAST ROADMAPS

The next section of this paper reviews four selected roadmaps, to provide practical examples of the type of analysis performed and the results obtained. Figure 2 describes the techno-economic analysis performed in each, followed by specific key points from them.



CYPRUS ROADMAP

The Cyprus roadmap analysis began with the development of national energy balances for 2012 and 2013, covering the entire energy sector. These energy balances were used to forecast demand across all sectors from 2014 to 2040, including a detailed examination of several options for the evolution of electricity demand.

The expansion of electricity generation capacity was modelled from 2014 to 2030 to meet the forecasted demand. The model included six scenarios designed to provide the government insight on the impact of key energy sector decisions, including deploying an undersea cable for electrical interconnection and the potential for generation using natural gas. The model showed renewables playing a key role in all scenarios. Figure 3 shows generation in 2013 and the model results for the least-cost generation mix in 2030, with renewables accounting for at least 26 percent and up to 40 percent of the total.

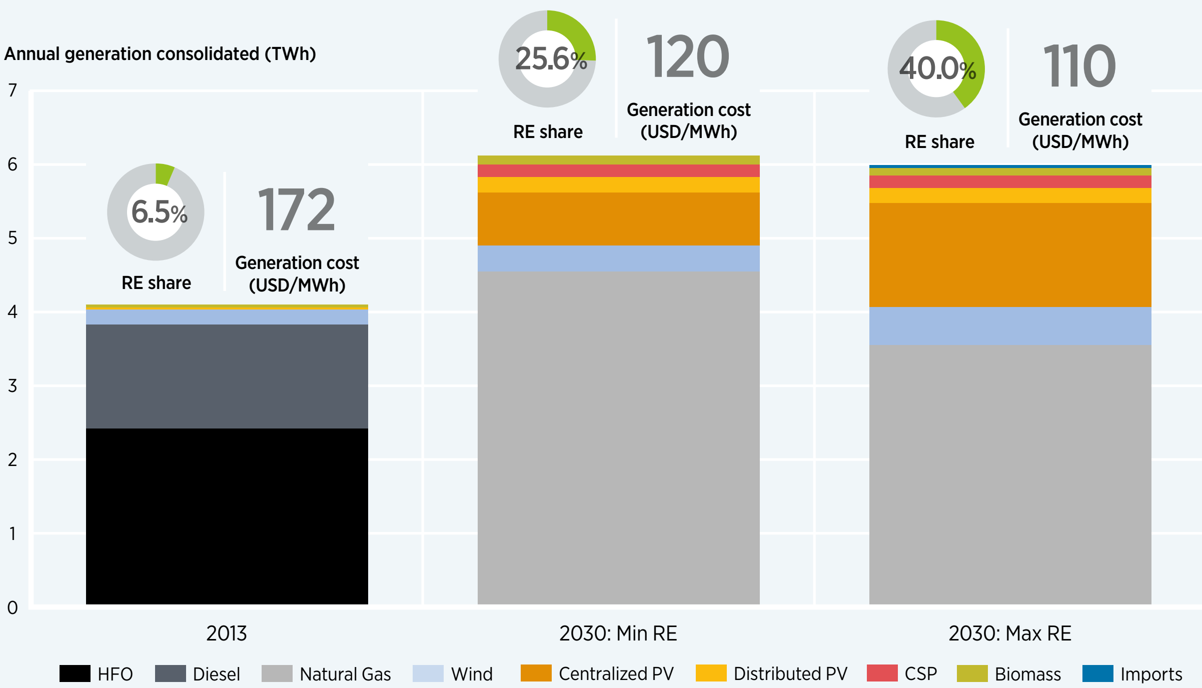
The Cyprus roadmap included complementary analysis on technologies supporting VRE integration. This included recommendations on how VRE forecasting could be deployed in Cyprus and options for VRE to provide grid support services. These insights supported the national electricity market design study ongoing at the same time of the development of the roadmap, which will have significant impacts on how renewables are deployed in Cyprus.

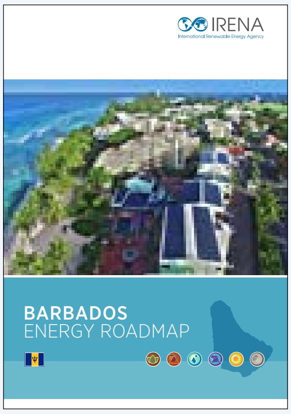
In coordination with government of Cyprus, the results of the roadmap were used by the European Commission's Joint Research Centre (JRC) as an input to a follow up study. This was critical to understanding the full impact of the generation system identified in the roadmap and the operational and technical steps required to support the large scale deployment of renewables in Cyprus.

JRC, preparing a dispatching study, used the generation capacity forecasts in the roadmap to explore the operations of the power system in detail. JRC's results were used as an input for a grid study, to determine what grid integration measures could be required to support the future electricity systems envisioned in the roadmap. The three studies were necessary to support a comprehensive plan for the transformation of the power sector.

The Cyprus roadmap analysis was a key input for the revision of the National Renewable Energy Action Plan, the revision of solar PV compensation scheme, and for designing the electricity market.

Figure 3. Cyprus annual generation 2013 and 2030





BARBADOS ROADMAP

The core of the Barbados roadmap analysis is a model used to optimize generation capacity expansion from 2014 to 2030, and to simulate unit commitment and economic dispatch of the 2030 system. This model allowed for a detailed examination of four scenarios designed to provide insights for critical power-sector decisions. The scenario results and the 2014 baseline are given in Figure 4.

The Reference Scenario shows that the 2030 least-cost electricity system would have a 76 percent share of renewables in the generation mix, primarily using PV and wind. The energy efficiency (EE) scenario examined an EE programme to reduce electricity demand by 30 percent from the 2014 level. It showed that EE savings would cover the programme cost, deliver additional savings, and allow for an 80 percent share for renewables. The low oil price scenario indicated that reduced fuel costs would delay renewables investment and ultimately increase electricity cost.

The Barbados roadmap also included an assessment of the impact of electric vehicle deployment in the transportation and electricity sectors. The impact of EV charging on power system dispatching was modelled, with the result being that renewables could handle up to 75 percent of EV charging if align with PV generation.

The dispatching model also indicated that battery storage would be critical to increase the reliability of the electricity system and to support the integration of renewables. Figure 5 shows policy actions that could encourage investment in battery storage.

The roadmap included an assessment of the potential for solar water heating, seawater air conditioning and solar air conditioning in the tourism sector. In addition, the roadmap analysis provided input for a review of the grid integration studies undertaken by the local utility.

The Prime Minister of Barbados has called the roadmap an essential component of the government strategy to use only renewable energy in its power sector, and stated that the roadmap "indicates that the island can increase the renewable energy penetration level in the electricity supply to a target of 76 per cent of peak generation. The Cabinet will therefore, in 2017, review and increase the allocation of licenses for intermittent renewable energy generation connected to the national electricity grid."

Figure 5. Battery storage policy recommendations

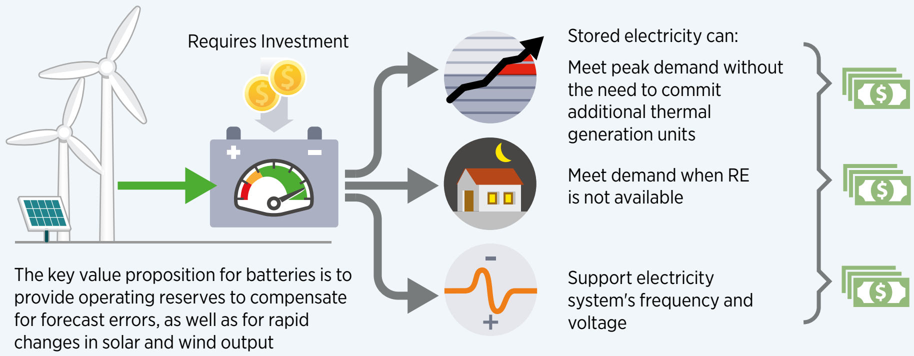
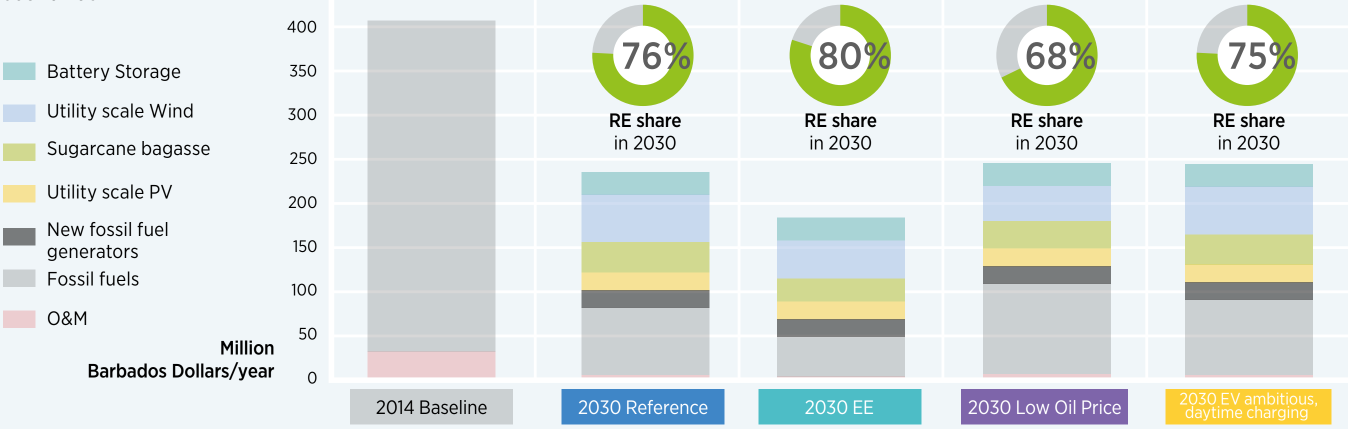


Figure 4. Power sector costs: 2014 baseline versus roadmap scenarios



KIRIBATI ROADMAP

The Government of Kiribati, IRENA, the Pacific Community (SPC), and the Pacific Power Association (PPA) cooperated to develop a roadmap that addresses government targets for renewable energy, energy efficiency and fossil fuel supply from 2015 to 2025. IRENA's analysis focused on least-cost options for renewable energy in all islands of the country.

Due to the nature of the Kiribati power systems, capacity expansion and dispatching could be simplified and combined to determine the optimal power system. For Kiritimati this combined methodology was used to identify a single transformative project to replace the current high-cost diesel-based system with a least-cost hybrid system based on PV, wind and battery storage, including modular-expansion options to meet any future increase in demand.

For South Tarawa, which has an installed generation capacity of about 5 megawatts (MW), a model was developed to investigate options for a least-cost system for 2025 including the impacts of system dispatching. This analysis was necessary to identify possible operational challenges and necessary measures for economic and reliable operation of the system. Figure 6 shows the dispatching for the currently 1.5 MW of installed PV as of 2016 versus demand. It shows a high level of curtailment due to the limited flexibility of existing diesel generators.

The analysis identified a least-cost system that includes battery storage and about 4 MW of PV capacity, while reducing curtailment and supporting a renewables share of 35 percent in 2025. Figure 7 compares annual generation for this optimal system against the 2016 baseline. The roadmap also provides a modular deployment strategy using available funding that supports a technically sound evolution from the current system to the identified least-cost system.

The roadmap analysis also examined the impact of VRE on grid operations and recommended strategies for the allocation of reserves to support VRE integration. A follow-up grid study was developed by the PPA with support from IRENA, to identify the impact of the near-term PV deployment on Tarawa's power grid.

The Kiribati roadmap included a complementary analysis examining options for renewable energy based desalination. This analysis determined that reverse osmosis desalination power using solar PV is the most promising option to increase water supply.

Figure 7. Tarawa annual generation 2016 and 2025

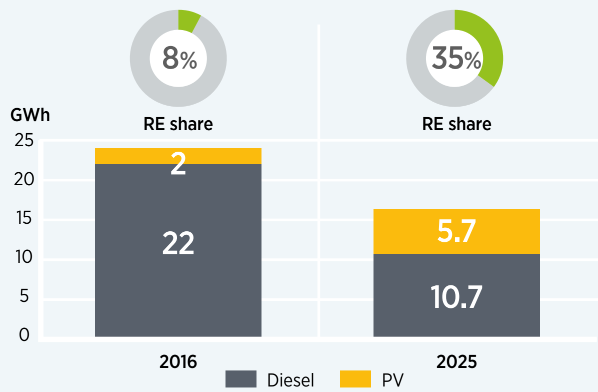
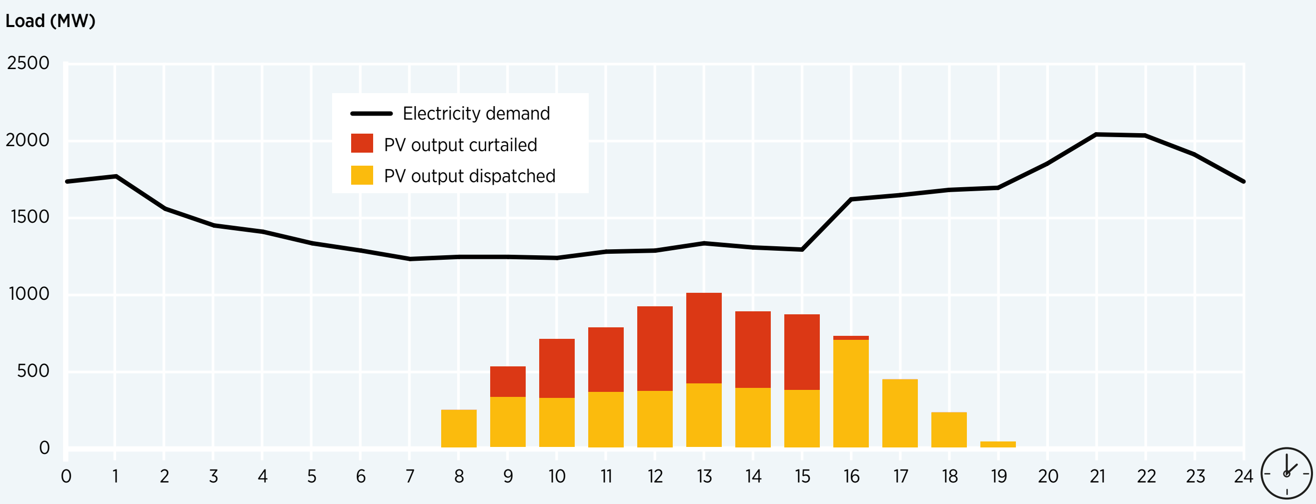
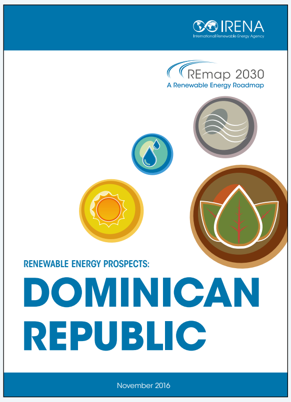


Figure 6. Hourly dispatching of 1.5 MW PV systems without storage





DOMINICAN REPUBLIC ROADMAP

Dominican Republic is one of the largest and most diverse economies in the Caribbean region, and its energy consumption is growing rapidly. The country has targeted a 25% reduction in greenhouse gas (GHG) emissions by 2030, to reduce its fuel import dependency and fossil fuel impacts on the environment. Renewable energy can play a key role in achieving these goals.

At the request of the Dominican Republic, IRENA developed a REmap country study called Renewable Energy Prospects: Dominican Republic. REmap is IRENA's renewable energy roadmap, which elaborates on how renewable technology options can raise the renewables share beyond current energy targets in the global energy mix. The analysis quantifies what can realistically be achieved by 2030 in the Dominican Republic's energy system in maximizing renewable energy potential, and assessing costs and savings.

REmap analysis shows that implementing the identified additional renewable options would increase the 2030 renewables share to 27 percent in the total final energy mix. Figure 8 provides an overview of the recommended renewable generation capacity to achieve a 44 percent renewable share in power sector.

The REmap analysis for Dominican Republic included the country's first quantitative assessment to determine the technical challenges of integrating the identified PV and wind systems, with one of the results shown in Figure 9.

Technical challenges identified by the analysis included generation adequacy and proper utilisation of fossil fuel generation capacity, management of high and instantaneous levels of penetration of PV and wind, the provision of flexibility requirements to manage the variability and uncertainty of PV and wind, and the adequacy of the transmission network. Recommended actions include:

- Setting clear and consistent renewable energy targets
- Designing appropriate incentives and market mechanisms for conventional and renewable energy generation to guarantee development of adequate and flexible generation capacity able to meet growing electricity demand at all times
- Coordinating the planning of generation and transmission expansion to develop a power system with the flexibility needed to integrate the targeted renewable energy shares.

A more detailed integration study based on the REmap options is planned with the government of the Dominican Republic in 2017.

Figure 8. Dominican Republic REmap 2030 renewables capacity expansion

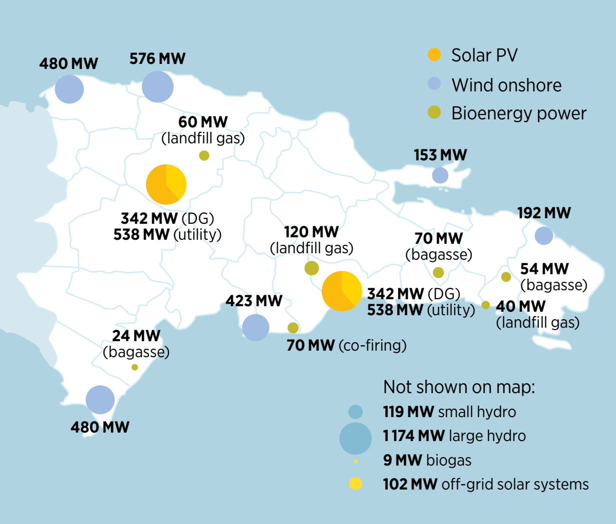
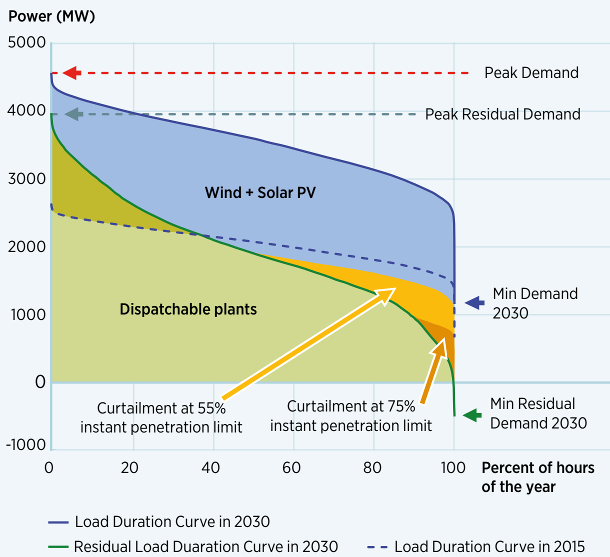


Figure 9. REmap PV and wind integration analysis results



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 co-operation, 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.

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