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International Renewable Energy Agency

REmap 2030
A Renewable Energy Roadmap

RENEWABLE ENERGY PROSPECTS:

DOMINICAN REPUBLIC

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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.

About CNE

The National Energy Commission (CNE) is the institution responsible of the formulation of the National Energy Plan with a holistic approach, that covers all energy sources to promote an environmentally sustainable and economically sound development, and contributes to national energy policy development. CNE promotes investments according to the strategies defined by the energy plan and the Law 57-07, to promote investments in renewable energy technologies.

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FOREWORD FROM IRENA

The Dominican Republic, like many island nations, is grappling with a number of challenges, such as fuel import dependence, exposure to oil price volatility and uncertain energy supplies that constrain its economic development. Although one of the largest and most diverse economies in the Caribbean, it still relies on imported fossil fuels for nearly all of its energy needs.

However, the Dominican Republic has set out to tackle these challenges by scaling up its renewable energy resources, which can help meet energy demand while delivering significant socio-economic benefits. It aims to use 25% more renewable power by 2025.

Accelerated deployment of renewables in the Dominican Republic would cut energy costs for consumers, create new employment opportunities, stimulate economic activity and help meet international climate commitments, in line with the Paris agreement. In addition, it would reduce local pollution, improve public health and strengthen energy security.

The International Renewable Energy Agency (IRENA) supports countries in achieving their sustainable energy transition through realistic, achievable technology and resource options. REmap – IRENA's global renewable energy roadmap – offers valuable insights on the opportunities and challenges ahead.

The Dominican Republic should establish an enabling institutional and regulatory framework for renewables, along with adequate financial incentives to attract investment. With the right measures in place, variable sources like solar and wind can be smoothly integrated into the grid, and the country can tap into its vast potential for renewables in the heating, cooling and transport sectors.

The key actions outlined in this report can help accelerate the energy transition. Moreover, the experience of the Dominican Republic can provide useful lessons for other island nations seeking to achieve sustainable energy future.

Adnan Z. Amin

Director-General

International Renewable Energy Agency

FOREWORD FROM CNE

The Dominican Republic is one of the ten most vulnerable countries to the effects of climate change. At the same time, our country needs to treat the specific contributions pledged under the Paris Agreement extremely seriously.

For our part, we fully recognise that achieving the objectives of those accords depends on the fulfilment of our own commitments. These mainly involve renewable energy development, as well as improving energy efficiency across the board.

This roadmap, therefore, is vitally important to the Dominican Republic reinforcing political decisions and identifying the main challenges to be faced in pursuit of our objectives. Along with adopting specific commitments, such analysis is essential to enable us to meet our goals.

This report on the Dominican Republic should be the first of many opportunities for collaboration through the National Energy Commission (CNE) and IRENA, with the aim of putting us on course for the development of renewable energy projects, especially in the electricity sector, and to ensure that by 2030 we have reliable, efficient, environmentally sustainable energy.

Juan Rodríguez Nina

Executive Director

National Energy Commission, Dominican Republic

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LIST OF ABBREVIATIONS

°C	degrees Celsius
BRGM	French National Geological Survey (Bureau de Recherches Géologiques et Minières)
CEB	Electricity Company of Bayahibe
CEC	Energy Control Center
CEPM	Punta Cana-Macao Electricity Consortium (Consorcio Eléctrico Punta Cana-Macao)
CCGT	combined cycle gas turbine
CCS	carbon capture and storage
CDE	Dominican Electric Company (Corporación Dominicana de Electricidad)
CDEEE	Dominican Corporation of State Electrical Companies (Corporación Dominicana de Empresas Eléctricas Estatales)
CH_4	methane
CHP	combined heat and power
CNE	National Energy Commission of the Dominican Republic (Comisión Nacional de Energía)
CO_2	carbon dioxide
COP21	21st session of the Conference of the Parties to the United Nations Framework Convention on Climate Change
CRI	cash recovery index
CSP	concentrated solar power
CST	concentrated solar thermal
CSTPC	Punta Cana Touristic Services Corporation (Corporación Servicios Turisticos Punta Cana)
DG	distributed generation
EDE	Electricity distribution company (Empresa distribuidora de electricidad)
EE	Energy Efficiency
EGEHID	Dominican hydropower generation company (Empresa de Generación Hidroeléctrica Dominicana)
ERCOT	Electric Reliability Council of Texas
ETED	Dominican Power Transmission Company (Empresa de Transmisión Eléctrica Dominicana)
EUROSTAT	Statistical Office of the European Union
EV	electric vehicle
excl.	excluding
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GHG	greenhouse gas
GJ	gigajoule
GW	gigawatt
GWh	Gigawatt-hour
H&C	heating and cooling
hr	hour
IEA	International Energy Agency
incl.	including
INDC	Intended Nationally Determined Contribution
INECON	Ingenieros y Economistas Consultores
IRENA	International Renewable Energy Agency

km	kilometre
km²	square kilometres
ktoe	thousand tonnes of oil equivalent
kV	kilovolt
kW	kilowatt
kWh	kilowatt-hour
LCOE	levelised cost of energy
LPG	liquefied petroleum gas
m	metre
m²	square metres
m³	cubic metres
MEM	Ministry of Energy and Mines (Ministerio de Energía y Minas)
mi	mile
MJ	megajoule
Mt	megatonne
MVA	megavolt amperes
MW	megawatt
MWh	megawatt-hour
MW_{th}	megawatt-thermal
NA	not available/applicable
n.d.	no date
OECD	Organisation for Economic Co-operation and Development
OC-SENI	National grid Coordinating entity (Organismo Coordinador del Sistema Eléctrico Nacional Interconectado)
OLADE	Latin American Energy Organisation (Organización Latinoamericana de Energía) (OLADE)
PEN	Domincan Republic's National Energy Plan
PHEV	plug-in hybrid electric
PJ	petajoule
p-km	passenger kilometre
ppm	parts per million
PV	photovoltaic
RE	renewable energy
SE4All	Sustainable Energy for All
SENI	National Interconnected Electrical System (Sistema Eléctrico Nacional Interconectado)
SIDS	Small Island Developing State
SIE	Superintendence of Electricity (Superintendencia de Electricidad)
SWAC	solar water air conditioning
T&D	transmission and distribution
TFEC	total final energy consumption
toe	tonne of oil equivalent
TPES	total primary energy supply
trad	traditional
TWh	terawatt-hour
U-HVDC	Ultra High-Voltage Direct Current
UN	United Nations
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USD	United States dollar
VRE	variable renewable energy
W	watt
yr	year

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EXECUTIVE SUMMARY

International Renewable Energy Agency REmap programme

By 2014, renewable energy use amounted to 18% of global total final energy consumption (TFEC). If existing and proposed energy plans and targets of countries are aggregated, the global renewable energy share by 2030 would increase to 21%. This represents a continuation of past growth trends in renewable energy share.[1]

The International Renewable Energy Agency (IRENA) REmap programme shows it is possible to actually double the global share of renewable energy by 2030 compared to 2014. Such accelerated growth helps fulfil the Sustainable Development Goal (SDG) for affordable and clean energy, and contributes to climate change mitigation.

REmap is a roadmap based on close cooperation and consultation with experts (energy statisticians, energy modellers and energy policy experts) nominated by governments. It is an analysis of the potential, costs and savings of renewable energy technology options. REmap provides a perspective on the technology options available at the sector level that represent the realistic potential of renewables beyond national energy targets and plans. These technology options are aggregated to build technology cost curves. As of July 2016, REmap works with more than 40 countries responsible for over 80% of current global energy demand.

Context

The Dominican Republic is one of the largest and most diverse economies in the Caribbean region, and its energy consumption is growing rapidly. The country relies heavily on fossil fuel imports, which account for nearly all of its primary energy supply at present.

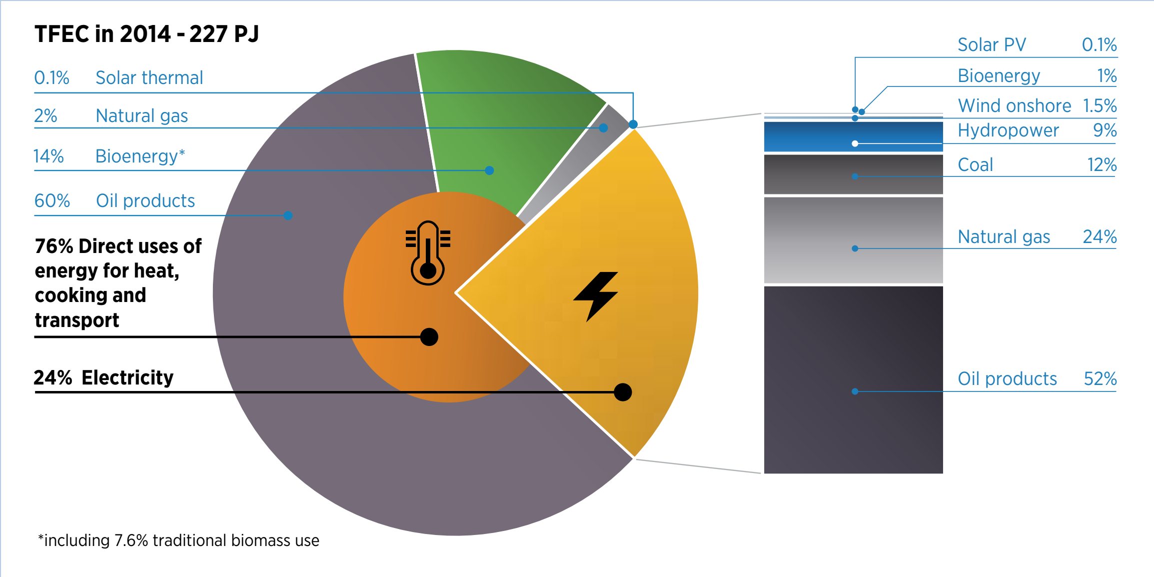
The Dominican Republic has set ambitious targets to reduce its per capita greenhouse gas (GHG) emissions. Another objective is to reduce import dependency and the local and global impacts of fossil fuel combustion on the environment, including those associated with climate change. The target is to reduce GHG emissions by 25% by 2030 compared to 2010. Realising this target will require a shift in the country's energy mix. Renewable energy can play a key role in achieving the climate policy objectives as well as energy supply diversification. Moreover, accelerated renewable energy deployment can reduce energy cost for consumers and reduce the fuel imports bill. In 2014, renewable energy share in total final energy of the Dominican Republic stood at 16.3% (8.7% modern renewables and 7.6% traditional biomass use, Figure ES2).

The power sector is key for an increase in the share of renewable energy. At the moment power generation is predominantly based on hydrocarbons, as shown in Figure ES1. In recent years the sector has gone through a series of reforms to ensure secure and affordable electricity supply to consumers. This has been met with mixed success so far. As part of these reforms, Law 57-07[2] sets specific targets for the power sector to increase its share of renewables in the power generation mix to 25% by 2025. To achieve this target, a number of policy instruments have been introduced, including tax incentives and feed-in tariffs. A rural electrification programme also supports the deployment of renewable off-grid projects, and the country is extending its grid infrastructure to ensure universal electricity access. Furthermore, a blackout reduction programme aims to improve the quality of the power supply service to the population.

1 Renewable energy includes bioenergy, geothermal, hydropower, ocean, solar and wind energy.

2 Law 57-07 of 7 May 2007 on Renewable Sources of Energy Incentives and its Special Regimes.

Figure ES1: Dominican Republic final energy mix, 2014



Source: IRENA estimates based on national energy balances

Note: 1 kilotonne of oil equivalent (ktoe) = 41.868 megajoules (MJ)

In this evolving environment characterised by increasing electricity demand, the pipeline of new power generation projects amounts to 2.4 gigawatts (GW). Of this total, 66% is renewable energy capacity – mainly onshore wind and hydropower. The country has significant additional renewable energy potential to go beyond what is being planned. This relates not only to power but also to direct uses of renewables for residential and commercial buildings, industry and transport.

This roadmap was developed in close co-operation with the National Energy Commission (Comisión Nacional de Energía or CNE). It quantifies what can realistically be achieved by 2030 in the Dominican Republic's total energy system in terms of renewable energy technology potential, cost and savings. CNE has provided the background energy and economic data for the analysis, and the potential has been worked out by IRENA with CNE's experts. This is the first report prepared for the Dominican Republic covering its entire energy system. As described in this roadmap, each sector has a number of specific challenges relating to the accelerated deployment of renewable energy technologies. With the right policy framework and technical solutions, the Dominican Republic can be a key country in the region attracting significant investment in renewable energy.

A rapidly developing power system

The Dominican Republic power sector is developing rapidly. The reforms that started in the late 1990s have shaped its current structure. As a result of these reforms, activities across the power supply chain have been unbundled, and private sector participation has increased.

The national interconnected system (Sistema Eléctrico Nacional Interconectado de la República Dominicana or SENI) supplies 87% of all the electricity consumed in the country. The high voltage transmission network belongs to a single, state-owned company (Empresa de Transmisión Eléctrica Dominicana or ETED). Three public sector companies distribute 78% of all the electricity consumed, with concessions in three different geographical zones. Seven smaller, mostly privately owned companies, generate and distribute electricity in noninterconnected zones. High electricity losses, at the distribution level in the three main concessions, currently affect the power system. This situation is being addressed by the government because it jeopardises the economic viability of the system.

Total national demand for electricity has experienced a rapid growth of approximately 45% over the past decade. Electricity generation reached 18 terawatt-hours (TWh) in 2014 from a total installed power generation capacity of around 4.9 GW (including SENI, off-grid installations and autoproducers).[3] More than 60% of the installed capacity runs on oil products, mainly heavy fuel oil which is especially polluting.

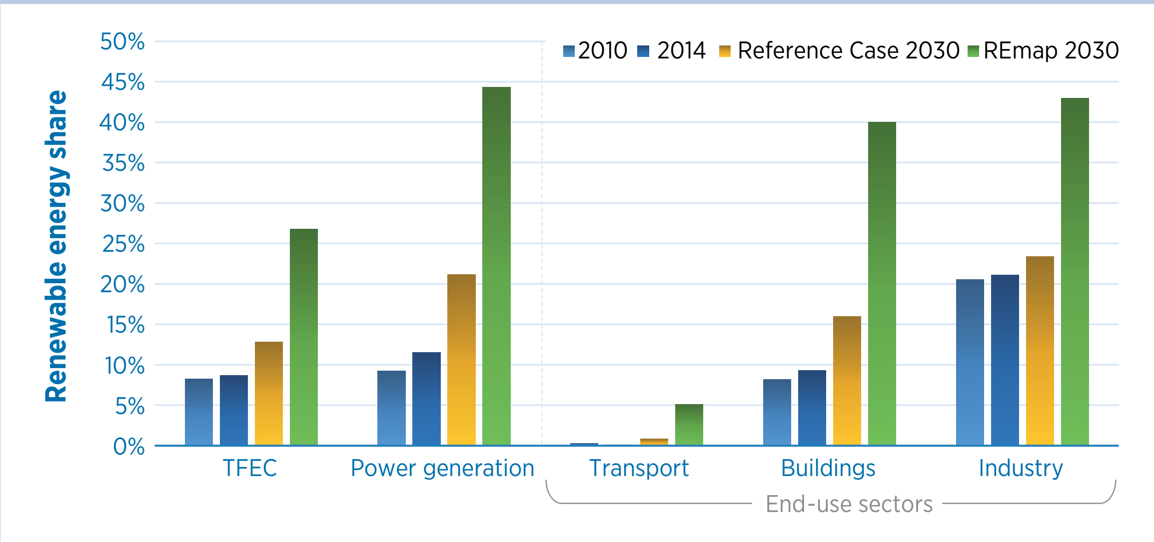
Renewable energy technologies account for 15% of total installed capacity. The national share of renewable energy in the power sector is about 11.5% of total electricity generation. This consists of 9% hydropower, 1.5% onshore wind and 1% bioenergy. The remaining 0.1% is met by solar photovoltaic (PV). This is displayed in Figure ES1. Installed capacity and generation from renewables is rising at the same rate as demand for electricity.

The renewables share in non-power sectors is thus far limited to bioenergy for industrial heating (amounting to 27% of direct uses of energy in industry) as well as cooking and water heating in buildings (representing 41% of traditional biomass plus 8% of modern bioenergy use, in the non-power energy demand in this sector). Deployment in these sectors has been mainly driven by private initiatives. No policy directed at these sectors exist yet.

REmap analysis: renewable energy prospects for the Dominican Republic

The Dominican Republic's total demand for final energy will grow by 2.2% per year between now and 2030, reaching 7 677 ktoe per year. These figures are based on the preliminary results of the CNE energy demand

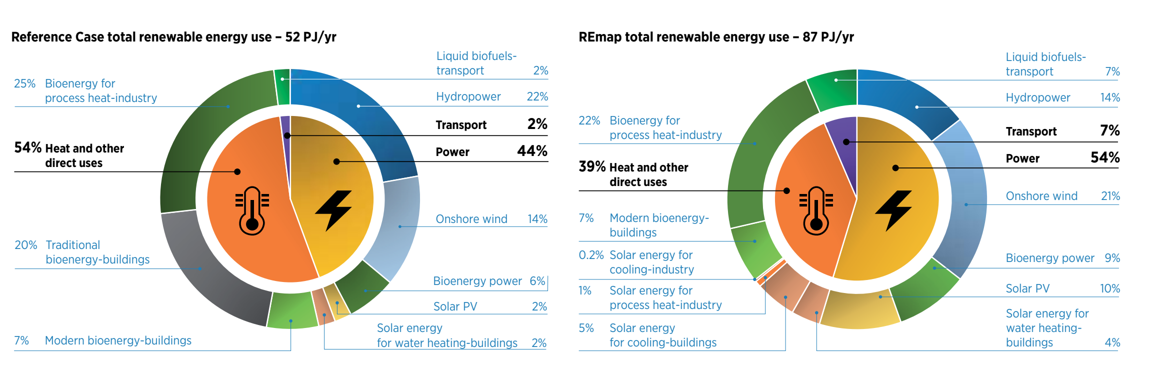
Figure ES2: Modern renewable energy share, 2010–2030



Note: End-use sectors include renewable energy consumption from direct uses and electricity

3 From the total installed capacity in this year, the SENI accounts for 3.7 GW and the autoproducers and off-grid installations represented about 0.9 GW and 0.3 GW respectively

Figure ES3: Modern final renewable energy use in Dominican Republic according to Reference Case and REmap in 2030



projections for 2013-2030, worked out with Fundación Bariloche, which form the basis of the Reference Case (or business as usual). In the Reference Case, the share of modern renewable energy would be 13% of the total final energy mix by 2030, compared to 9% in 2014 (excluding traditional uses of bioenergy).

The Dominican Republic has abundant solar and wind resources. Several sources of small hydropower are not utilised. Agricultural residue and waste are the predominant potential sources of bioenergy supply. These can be used to meet growing demand and raise the share of renewables beyond the Reference Case.

Meanwhile, the renewable energy share of total electricity generation in the Reference Case rises from around 12% in 2014 to 21% by 2030 if all renewable energy projects in the pipeline come online. This would imply that the target of 25% of renewable electricity generation by 2025 set in Law 57-07 might be missed in the Reference Case, thus there is a need for additional policies. According to the Reference Case, the share of renewable energy in end-use sectors experiences a slight increase between 2014 and 2030, from 21% to 23% in industry, 9% to 16% in buildings and 0.3% to 0.8% in transport. This is displayed in Figure ES2.

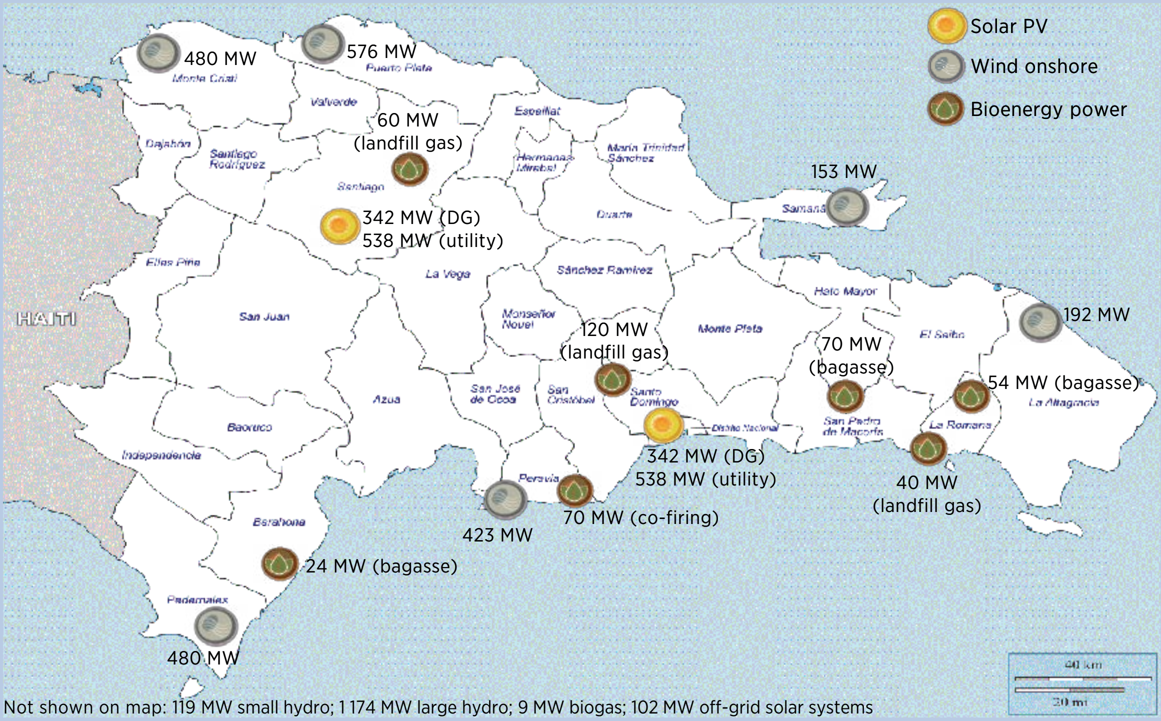
Implementing the potential additional renewable energy technology options identified in REmap would increase the renewable energy share to 27% by 2030 in the Dominican Republic's total final energy mix. Industry and the power sector could have the highest renewable energy share, estimated at 43% and 44% respectively. This would be followed by buildings and transport at 40% and 5% each.

Under REmap, final renewable energy use could double to 2 080 ktoe per year by 2030 compared to the Reference Case. Bioenergy would be the largest source of renewable energy accounting for almost half of total final renewable energy use in 2030. This is explained by its various uses across all energy sectors, including power generation. Solar energy for power generation, heating and cooling would account for 20%. Finally, wind and hydropower would represent 21% and 14% of the total final renewable energy use, respectively.

Wind and solar lead renewable power generation

Under REmap, 54% of all final renewable energy use is related to the consumption of power from renewables in 2030 as shown in Figure ES3. Data provided by CNE and IRENA estimates show that the Dominican Republic could generate 16 TWh of electricity from renewables by 2030. This would be produced from a renewable power generation capacity of 6 GW (from a total installed capacity of 10 GW, including non-renewable technologies). Renewable electricity generation under REmap is higher than current levels by a factor of eight and significantly higher than the country's planned expansion in the Reference Case (7.7 TWh

Figure ES4: Location of renewable power generation capacity in 2030 under REmap



DG: distributed generation; km: kilometre; mi: mile

mainly from hydropower and onshore wind). To realise the potential identified in Remap, the country's major onshore wind and solar resources need to be utilised. These are also among the most cost-effective options in the mix.

Onshore wind would be the single largest source of renewable power producing 6.1 TWh electricity per year. The total wind capacity if all REmap Options are implemented is 2.3 GW in 2030. This translates into the construction of about 45 wind farms between now and 2030. Wind projects would be spread across the northern, eastern and southern parts of the country as shown in Figure ES4.

Solar PV could contribute 3 TWh from a total of 1.7 GW capacity under REmap by 2030. This potential includes both on-grid (utility-scale and decentralised) and off-grid capacity. About 60% of this potential is related to utility-scale plants, which would require an average annual installation rate of about 77 megawatts (MW) between now and 2030. Decentralised on-grid generation comprises 685 MW capacity by 2030 for residential and commercial systems that would cover about 8% of all electricity demand in buildings. According to REmap, these solar projects would be split between the two major demand centres of Santo Domingo and Santiago as shown in Figure ES4. Solar home systems totalling 102 MW of installed capacity would supply electricity to 2% of the population, which will still lack access in 2030 (about 70 000 units).

Bioenergy and waste constitute other important source of renewable power generation. There is potential to increase total bioenergy capacity from landfill gas, bagasse and biogas, as well as through co-firing. By 2030, total installed capacity could reach 448 MW under REmap. This is divided into four sources. Firstly, landfill gas from the large Duquese and the other major landfills could supply 220 MW. The four largest sugar mills in the country could reach 148 MW bagasse based combined heat and power. Finally, animal manure could supply 9 MW in biogas and co-firing of biomass in coal fired power plants could supply another 70 MW. Most bioenergy projects would be in the southern parts of the country.

Key role of end-use sectors

The other half of final renewable energy use under REmap, besides renewable power, comes from the direct use of renewables in end-use sectors. However, until now the national energy plans of the Dominican Republic do not make use of this potential.

Renewables for industrial heating offers the greatest potential among all end-use applications. Medium-temperature process heat can be generated from industrial combined heat and power based on bagasse. Likewise, solar thermal systems can be employed to deliver low-temperature heat and cold. Under REmap, 100 heating and about 85 cooling installations can be implemented in the industry plants by 2030, representing a total capacity of 125 MW.

In buildings, solar water heating capacity could reach 1.4 GW to deliver half of all energy demand for water heating in residential and commercial buildings – mainly hotels, under REmap. Demand for cooling has increased considerably. The main drivers for cooling are increased income, growing population and the hospitality sector. Solar cooling and seawater cooling systems can cover 20% and 5% of the total space cooling demand of the buildings respectively.

Hostelries generate significant amounts of organic waste among others, from cooking and from collected waste food that can be reconverted into biogas, using anaerobic digestion, usable as an energy source for cooking. About 100 such digesters can be installed by 2030 into hotels in the Dominican Republic, supplying the equivalent of 10% of the energy used for cooking in hostelry.

Under current policies, only limited growth is forecast for renewable energy in transport, which only includes biodiesel usage. Ethanol and electric mobility provide significant additional potential. This would be an important step for a sector that represents the largest share of total final energy demand in the Dominican Republic. Thousands hectares of land were previously used for sugar cane production. A share of now fallow arable land can once again be used for sugar cane production for ethanol. By 2030, more than 170 million litres of conventional ethanol could be produced, allowing a blending rate of 15%, which requires flex-fuel vehicles. For biodiesel, a blending rate of 5% is estimated, for a total consumption of 50 million litres. The production of conventional liquid biofuels must be derived from sustainable sources and not compete with resources required for food production.

The number of four-wheel electric vehicles by 2030 could reach 220 000, representing 15% of the total passenger car stock. Two and three-wheeled electric vehicles have major potential, especially in congested parts of cities and in tourist resorts. Realistically, 500 000 such vehicles can be deployed by 2030. In summary these are opportunities to combine electric mobility with renewable power supply.

The energy storage offered by all types of electric vehicles represent a total capacity of 1.4 gigawatt-hours. This can provide significant flexibility to facilitate the management of the variability from wind and solar generation.

Significant savings to renewable energy mix in 2030

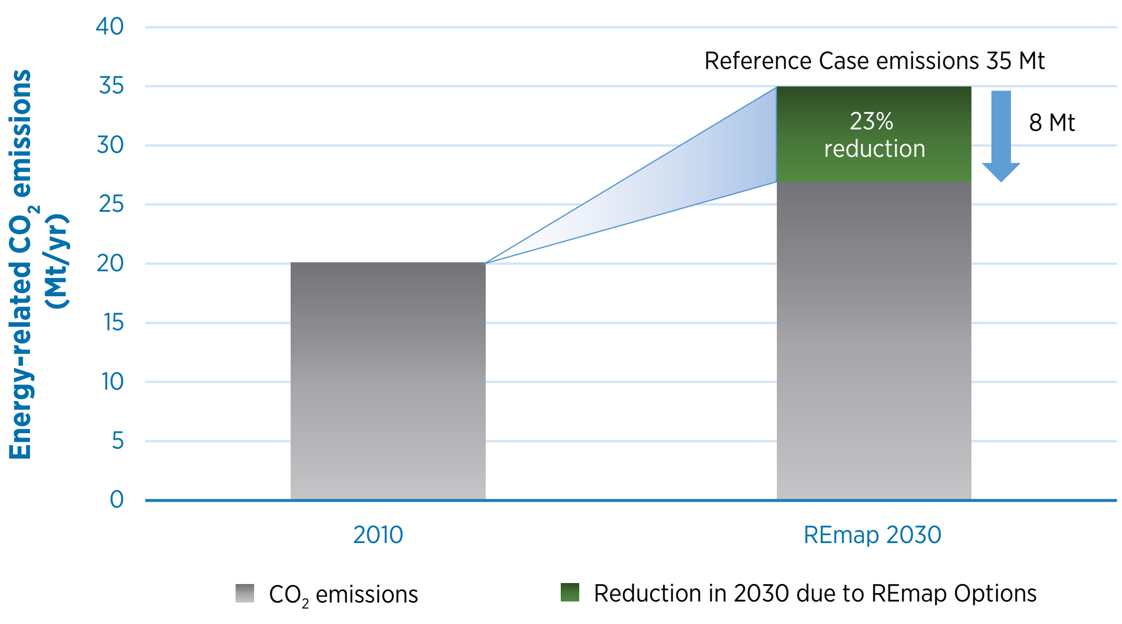
Increasing the Dominican Republic's renewable energy share to 27% of its final energy mix would result in financial savings. In the REmap analysis, the cost and savings of renewables are estimated from both business and government perspectives. The business perspective is based on national energy prices which include local taxes and subsidies and uses a national discount rate of 12%. The government perspective is based on standard international commodity prices and a fixed 10% discount rate. The cost analysis in this roadmap is based on 2030 capital cost projections for energy technologies. It assumes an average increase of 40% in local fossil fuel prices between 2010 and 2030 (in real terms) and also no change to present energy pricing schemes. Assessment excludes the costs for infrastructure (*e.g.* additional generation or transmission capacity) and enabling technology costs (*e.g.* grid integration).

Under REmap, more than 80% of all renewable energy technology options could be deployed with financial savings when compared with the non-renewable technology counterparts they replace. From the business perspective, the mix of renewable energy technologies identified on top of the Reference Case translates into savings across all sectors of USD 62 per megawatt-hour of final renewable energy (or USD 17 per gigajoule – GJ). From a government perspective, this results in savings of USD 68 per megawatt-hour of final renewable energy (or USD 19/ GJ). This translates into total annual savings of USD 1 billion in the Dominican Republic energy system. A small proportion of the technologies will incur additional costs and will require total investment support of about USD 160 million per year.

Savings are also achieved due to reduced externalities from avoided carbon dioxide (CO_2) and air pollutant emissions as estimated in this roadmap. When accounting for these reduced externalities, additional annual savings could range from USD 1.1-4.3 billion by 2030. This would result in total savings of USD 2.1 billion-5.3 billion per year.[4]

The health savings are estimated on the basis of the unit external costs of the five major outdoor air pollutant emissions caused by fossil fuel combustion in power generation, heating and transport.[5] Traditional bioenergy use in households for cooking and water heating also results in indoor air pollution. These unit external costs are specifically applied to the case of the Dominican Republic by accounting for the expected

Figure ES5: CO_2 emissions from energy use, 2010–2030



4 The costs of renewables have been compared with the non-renewable energy technologies assuming a relatively high growth in crude oil prices to 2030 and the assessment of externalities has been carried out based on a set of standard parameters that may overestimate the savings in the context of islands. Therefore, a sensitivity analysis of these findings is provided in the full report.

5 The five air pollutants assessed include: ammonia, mono-nitrogen oxides, particulate matter, sulphur dioxide and volatile organic compounds.

developments in its gross domestic product by 2030. In addition, the calculation assumed a price range of USD 17–80 per tonne of CO_2 with the same range applied to all other countries in the REmap programme.

In addition to these savings, the replacement of non-renewable technologies by renewables in REmap cuts fossil fuel demand by almost 2 170 ktoe by 2030 compared to business as usual. Much of this reduced demand is imported fossil fuel that lowers the annual energy bill by USD 1.6 billion in 2030.

Total investments in renewable energy technologies needed to attain the 27% renewable energy share would require USD 566 million in investment per year. Of this, USD 337 million would come from the REmap Options and USD 229 million from investments taking place in the Reference Case.

Lower fossil fuel combustion reduces CO_2 emissions by around 8 megatonnes (Mt) per year of CO_2 by 2030. This amounts to a 23% cut compared to the Reference Case in 2030. These reductions would be an important step for the country to realise GHG emission reduction targets in its Nationally Determined Contribution. Around 70% of that total mitigation potential comes from the power sector.

Challenges to accelerated renewable energy growth

If renewable energy use is to grow rapidly along the lines suggested in this report, a number of challenges need to be overcome. A Consultation with CNE and other stakeholders in the Dominican Republic energy sector has identified barriers to rapid growth of renewable energy technologies. The independent power system operator, project developers and equipment manufacturers were some of the institutions involved in the consultation. These challenges relate specifically to the national circumstances of the Dominican Republic today. In the case of the power sector, the main challenges are related to current institutional and regulatory framework and whether the required investment can be attractive to realise the REmap Options. In addition, there are technical challenges associated with integrating large amounts of variable renewables that have to be overcome.

Challenges in the power sector

Institutional and economic challenges

It is important to acknowledge that a long-term vision needs to emerge with intermediate renewable energy targets and necessary incentives to realise the potential according to the REmap Options. This means maintaining consistency between the national energy plan and national development strategies to bring legitimacy.

Strong institutional and regulatory frameworks need to be adopted to provide a stable and attractive environment for the required investments. The regulatory framework needs to allow the implementation of the changes required in the planning and operational procedures of the power sector, including the electricity market. The purpose of these changes should be to integrate a high share of variable renewables.

Technical challenges associated with high share of variable renewables

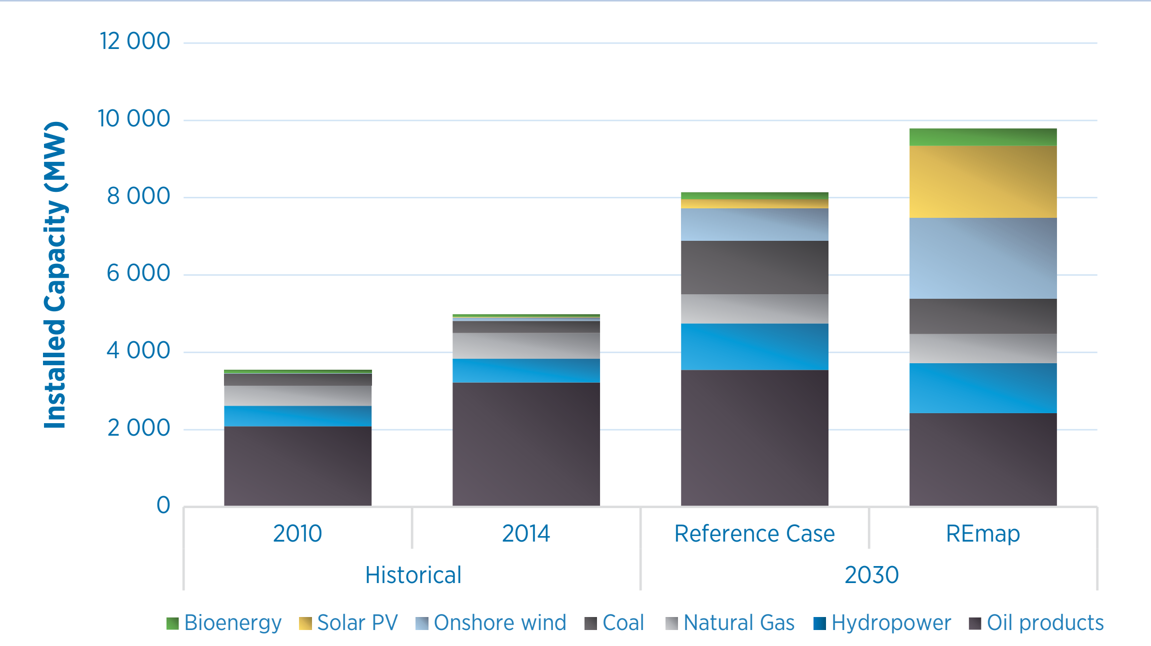
Generation adequacy and flexibility: to fulfil the potential identified in REmap at least 4 GW of dispatchable generation (both renewable and non-renewable) would be required to cover peak power demand in 2030 in periods of low variable renewable energy generation. Long-term generation expansion plans with corresponding intermediate targets will be essential to achieve this condition. They will need to take the requirements for flexibility and firm dispatchable generation capacity into consideration. Appropriate financial mechanisms are required in order to guarantee that the firm capacity, alongside flexibility services from certain thermal plants, are available when necessary. The financial mechanisms should consider the new reduced utilisation conditions imposed by increasing shares wind and solar energy.

Adequate electricity grid development: Santiago and Santo Domingo are the two major load centres. Both are at a considerable distance from the rich resource areas of wind in the North, West and Southwest of the country. Fulfilling the potential under REmap would require transmission capacity expansion to avoid uneconomic wind power curtailment. Planning for this expansion will require co-ordinated action with the development of renewable energy capacity targets. Long-term transmission plans and annual operational restriction studies may need to incorporate the new renewable energy projects and the evaluation of alternative local balancing options. Long-term plans may need to look beyond transmission capacity expansion in order to find optimal ways of managing potential congestion in the transmission grid. The definition of clearer and attractive rules for financing the connection of new renewable generation and required reinforcements in the transmission system should also be considered.

Management of variability and limited predictability of variable renewable power: the operational procedures of the power system may need to be reviewed and adapted to the new conditions imposed by the variability and limited predictability of variable renewables. The adaptation of the power system operation and the corresponding market procedures should be in line with the mid-term generation expansion targets and the implementation of new renewable energy projects. Benefiting from advanced forecasting tools to reduce system operation costs would require an increased frequency in generation scheduling updates and the use of available flexibility options to respond to the updated schedules. Adapting the operational and market procedures may mean extending the existing grid codes. At the same time, incentives would be needed to implement flexibility options (outside generation), flexible generation and better forecasts of variable renewables to make them more predictable.

Management of instantaneous penetration levels for variable renewable power: in the isolated power system of the Dominican Republic, very high instantaneous penetration levels of variable renewables can create challenges to the security and stability of the electricity supply. This assessment suggests that under REmap,

Figure ES6: Installed power generation capacity, 2010-2030



up to 10% of total electricity generated by renewables by 2030 may need to be curtailed to guarantee system security. This assumes current state-of-the art technologies and operational procedures not currently implemented in the Dominican Republic. The use of the most up-to-date technologies and operational practices in the future may help reduce curtailment to less than 2%. This ratio was calculated taking the specific characteristics of SENI into consideration as far as possible but is largely based on parameters in line with international experience. Future developments in SENI's characteristics and economics may change these estimates. Hence, there is a need to understand and identify the maximum penetration levels for different system configurations. The necessary measures to efficiently manage possible curtailments need to be defined in line with the mid- and long-term generation expansion targets.

Challenges in end-use sectors

Buildings: a wide range of renewable heating and cooling technologies exists to replace fossil fuels for households, commercial buildings and hotels. Even when externalities are not considered, REmap suggests that solar thermal technologies are cost-effective although investment support may be required for low-income families. There is a need to raise more awareness among consumers of the opportunities offered by renewables. For example, the waste generated in the hostelry sector is a valuable resource that can be turned into biogas for in-house consumption. Current energy plans overlook this potential in both existing as well as expanding building stock.

Industry: this is still the largest renewable energy user in the country to generate process heat. This is due the availability of waste and residues utilised for heat generation by the plant owners. There is a further potential to supply low- and medium temperature process heat from solar thermal and bioenergy. However, to maintain cost competitiveness and security of operation, the fuel supply needs to be affordable and continuous. This poses a specific challenge to seasonal residual biomass feedstocks. Solar thermal systems will also require additional storage capacity. Moreover, not all industrial plants are designed to be retrofitted with solar thermal, which requires advanced planning for space and necessary process modifications.

Transport: this sector consumes the most energy in the Dominican Republic yet national energy plans do not consider renewables deployment for the sector. Liquid biofuels could replace gasoline and diesel but no market exists. Demand needs to be created by setting targets. Planning for the major potential from the sugar industry will also be essential but food security and sustainability concerns will need to be resolved. The major potential and reduced externalities (specifically related to air pollution) achievable by implementing the various forms of electric mobility identified in REmap need to be considered. Planning is required to work out the related infrastructure, how this can be financed and its potential implications for the power sector.

Challenges to bioenergy deployment

Under REmap, bioenergy is a key technology for power generation, heating and transport. However, the supply potential and range of arable feedstocks is limited. There is thus a need to prioritise the most resource-efficient and cost-effective uses of bioenergy across different sectors. On the supply side, waste and residues will be the key feedstocks as they do not compete with resources required for food production. Efficient and environmentally friendly feedstock collection systems will be essential to mobilise their availability. Large areas of arable land once used by the sugar cane industry is also available. Provided that sustainability and resource concerns are addressed, the potential offered by this land is achievable. Agricultural yields could reach the level set by the international best practice, particularly for ethanol production for transport.

Policy suggestions

The full REmap Dominican Republic report covers the country's policy landscape in detail and includes specific suggestions by sector. In this summary, these suggestions are outlined for each challenge identified in the previous section:

Taking into consideration the vision set in REmap, establish clear and consistent renewable energy targets. Ensure they are consistent with other national energy strategies and a stable institutional and regulatory framework with the right financial incentives to attract renewables investments.

- Ensure enough dispatchable generation is available to provide the firm capacity and flexibility required by the power system. Design appropriate incentives for this purpose supported by updated generation expansion plan with intermediate targets.
- Align transmission planning with renewable energy targets and assess the cost and benefits of grid expansion and other local balancing measures to efficiently manage possible grid congestion.
- Define measures in line with planning for renewable energy deployment and transmission capacity to guarantee economic levels of curtailment. Explore the feasibility of flexibility measures to manage it efficiently.
- Devise and introduce appropriate incentives and market mechanisms to promote a flexible power system able to deal with the new operational conditions imposed by the expected high share of variable renewables.
- Define codes and standards for buildings construction and renovation that consider renewables, such as solar water heating and cooling. Integrate renewables into energy and urban planning to accelerate its uptake by ensuring cost-effective supply of energy to the population.
- Plan and develop a strategy for renewables use in industry by paying particular attention to the technical/ economic design, operational hours and temperature levels of industrial processes.
- Create a market for liquid biofuels in transport and promote electric mobility in congested urban areas and touristic parts of the country. This market also needs to make use of synergies with the power sector and plan for related infrastructure and financing needs.
- Set targets for bioenergy use in applications lacking any other renewable energy alternative and where bioenergy creates added value to the system. Promote the uses of its most resource-efficient and cost-effective pathways to ensure sustainability.

This roadmap provides a detailed overview of the realistic potential of renewables in the Dominican Republic by 2030. Realising REmap Options by 2030 will require significant efforts to plan the intermediate targets and measures to achieve them, particularly in the power sector. The findings of this roadmap thus need to be complemented by detailed technical and economic studies focusing on operating and planning the interconnected systems containing a high share of variable renewables.

Upon request, IRENA can further support the Dominican Republic government by producing the necessary in-depth technical/ economic studies supporting the accelerated deployment of solar and wind power as outlined in this analysis.

HIGHLIGHTS

- The Dominican Republic's energy system largely relies on fossil fuels imports, which amount to around USD 5 billion per annum. This accounts for approximately 7% of the country's gross domestic product (GDP) and 90% of its primary source of energy.

- The country's Intended Nationally Determined Contribution (INDC) sets an ambitious national target to reduce the country's GHG emissions by 25% by 2030 compared to the 2010 level. Renewable energy and energy efficiency could play an important role in realising these targets.

- Law 57-07 of Renewable Energy Incentives and Special Regimes is the country's main legislative instrument promoting renewable energy, including a number of measures across all energy sectors, particularly the power sector. The law set a target of 25% of electricity from renewable energy sources by 2025.

- Total demand for energy across the country has been growing at about 1% per year for more than a decade. Total final energy demand reached 5 433 ktoe (227 petajoules/PJ) per year by 2014. Fossil fuels meet 62% of this demand. Traditional and modern forms of bioenergy provide 14%, and electricity 24% – of which only 11.5% is renewable energy (mainly hydropower). On average, 8.7% of the country's total final energy demand is covered by modern renewables.

- The structure of the power sector is the result of a reform process that started in the late 1990s. This process unbundled the activities within the power supply chain, enabling private sector participation. The Ministry of Energy and Mines (MEM), formed in 2013, is responsible of formulating and managing energy policies. CNE, established in 2001, contributes to national energy policy development, including national energy planning.

- Total installed renewable electricity generation capacity in 2014 reached 795 MW to generate 2.1 TWh per year of renewable electricity. This included 613 MW of hydropower, 85 MW of onshore wind, 70 MW of bioenergy and 27 MW of solar PV (including autoproducers). About two-thirds of planned new generation capacity is based on renewable energy, which includes 588 MW of hydropower plants over 10 MW, 715 MW of onshore wind, 175 MW of solar PV and 9 MW of mini-hydropower.

- Compared to the promising developments in the power sector, end-use sectors are lagging behind in renewable energy deployment. Current use of renewable energy is mainly concentrated in households in the form of traditional bioenergy for water heating and cooking.

- This roadmap shows that the Dominican Republic has the potential to raise its renewable energy share to 27% by 2030 in the whole energy mix. This would result in an annual consumption of 2 080 ktoe (87 PJ) of final renewable energy in that same year. This compares with the share of 13% if the Dominican Republic merely follows its current plans and targets for renewable energy.

- If the potential of technologies in REmap is realised, the renewable energy share in the power sector reaches 44%. This is significantly higher than the 25% target in Law 57-07.

- Total installed capacity of solar PV and onshore wind increases to 1.7 and 2.3 GW in 2030 respectively. Solar PV capacity is split between rooftop and utility-scale, and it is expected to be located mainly in Santo Domingo and Santiago provinces. Wind would be developed in the regions with the highest wind potential – the northern, southern and eastern provinces.

- In end-use sectors, renewable energy share reaches 43% in buildings, 41% in industry and 5% in transport in 2030. The key renewable energy technology options are bioenergy for industry, solar water heaters for buildings and a mix of electric mobility (including two- and three-wheelers) and biofuels for transport.

- Under REmap, more than 80% of all renewable energy technology options could be deployed with financial savings when compared with the non-renewable technology they replace. Savings are also achieved as a result of reduced externalities from avoided CO_2 and air pollutant emissions. When accounting for these, total savings reach USD 2.1 billion-5.3 billion per year.

- Total annual average investment needed in renewable energy technology deployment in 2016-2030 amounts to USD 695 million. USD 245 million is required each year to fulfil the Reference Case, and an extra USD 450 million per year is needed to implement the REmap Options.

- If renewable energy use is to grow rapidly along the lines suggested in this report, a number of challenges need to be overcome. A consultation with CNE and other stakeholders in the Dominican Republic energy sector has shed light on barriers to rapid growth of renewable energy technologies and the challenges ahead. In addition, this REmap report has further analysed the technical challenges for the integration of variable renewable energy technologies in the power sector.

- High-level suggestions are provided for dealing with the identified challenges, including the institutional and regulatory perspective, energy planning, technical challenges in the power sector, bioenergy market and specific measures to promote the use of renewables in end-use sectors.

1 REMAP PROGRAMME AND REMAP DOMINICAN REPUBLIC

1.1 IRENA's REmap programme

REmap aims at paving the way to promote accelerated renewable energy development through a series of activities, including global, regional and country studies. REmap analysis and activity also informs IRENA publications on specific renewable technologies or energy sectors.

The REmap programme collaborates closely with governmental bodies and other institutions responsible for energy planning and renewable energy development. The analysis relies on broad consultations with energy experts and stakeholders from numerous countries around the world.

At its inception, REmap emerged as IRENA's proposal for a pathway to support the United Nations' (UN) Sustainable Energy for All (SE4All) initiative, in its objective to double the global share of renewable energy from 18% in 2010 to 36% by 2030 (UN and World Bank, 2016). Since then, the 21st Conference of the Parties (COP 21) adopted the Paris Agreement in 2015 with a target to minimise the earth's temperature increase to below 2 degrees Celsius (°C) by 2050. The widespread development of renewables is a critical lever to fulfilling this objective.

To double the renewable energy share across the world, REmap takes a bottom-up approach. Country-level assessments are carried out to determine the potential contributions that each of them could make to the overall renewable energy share. The first global REmap report, published in 2014, included a detailed analysis of 26 major energy-consuming countries representing around 75% of global energy demand. The REmap programme has since expanded to 40 countries accounting for 80% of world energy use. The Dominican Republic joined the programme in 2015.

The REmap evaluation of the national plans of 40 countries (which could be considered the business-as-usual case, referred in this study as the reference case) suggests that under current conditions and policy approaches the global share of renewables only increases to 21% by 2030. This indicates a 15 percentage-point shortfall in relation to the target to double the global renewables share by 2030 (IRENA, 2016a). As one of the largest energy users in the Caribbean, the Dominican Republic plays a critical role in transforming the region's energy consumption.

The Dominican Republic has implemented institutional and operational changes in its energy sector, including the formation of the Ministry of Energy and Mines (MEM) in 2013. One of its mandates is to formulate and manage the country's energy policy.

Classified by the UN as a Small Island Developing State (SIDS), the country faces several economic and environmental challenges ranging from climate change to high dependency on imported fossil fuels. As a consequence, the government and policy makers have been directing more attention to the extended deployment of renewable energy for electricity generation and in direct uses, such as cooling or transport. Raising awareness of the socioeconomic, environmental, and energy security benefits of renewables contributes to this effort. Improving energy efficiency and power sector operations are also core measures supporting the transition to more sustainable and affordable energy in the Dominican Republic.

In January 2016, the government of the Dominican Republic represented by the National Energy Commission of the Dominican Republic (Comisión Nacional de Energía), CNE, requested a REmap study from IRENA. Its aim was to explore the potential difference renewables could make to achieving the country's energy policy and objectives to 2030 and beyond. The government asked IRENA to examine the following areas:

(i) Role of renewables for heating, cooling, and transport, as well as electrification to provide energy services in end-use sectors;

(ii) Further potential for increasing the share of variable renewables in the power sector;

(iii) Cost and benefits of renewables; and

(iv) Identification of challenges to raising the renewables share in the power sector and high-level suggestions about how to overcome them.

This report presents the detailed REmap analysis carried out for the Dominican Republic. REmap elaborates on the renewable technology options the country could deploy further to raise the renewables share by 2030. To fulfil this aim, the Dominican Republic has the opportunity to extract more out of its wind, solar, and biomass potential in particular.

1.2 REmap approach

This section explains the REmap methodology and summarises the background data used for the Dominican Republic analysis. The annexes provide more detailed information.

REmap is a roadmap of technology options to increase the global share of renewables. It is a bottom-up, iterative analysis. By March 2016, IRENA's REmap programme had assessed the renewables potential of 40 countries in 2030, which accounts for 80% of total global energy demand. These are Argentina, Australia, Belgium, Brazil, Canada, China, Colombia, Cyprus, Denmark, **the Dominican Republic**, Ecuador, Egypt, Ethiopia, France, Germany, India, Indonesia, Iran, Italy, Japan, Kazakhstan, Kenya, Kuwait, Malaysia, Mexico, Morocco, Nigeria, Poland, Republic of Korea, the Russian Federation, Saudi Arabia, South Africa, Sweden, Tonga, Turkey, Ukraine, the United Arab Emirates, the United Kingdom, the United States, and Uruguay.

REmap identifies the realistic potential for accelerating renewable energy deployment. This can be fulfilled with existing technologies and is economically practical and achievable by 2030.

It starts by building a country's energy balance, using 2010 as the base year built on national data and, in the case of the Dominican Republic, CNE statistics. To the extent data availability allows, information for more recent years (*e.g.* 2013 and 2014) is provided where relevant. The country then provides its latest national energy plans and targets for renewables and fossil fuels, collated to produce a business-as-usual perspective of the energy system. This is referred to as the **Reference Case.** This TFEC for each end-use sector (buildings, industry and transport). It distinguishes between power, district heating, and direct uses of energy[6] with a breakdown by energy carrier for 2010-2030.

Once the Reference Case is ready, the additional renewable energy potential by technology is investigated for each sector. The potential of these technologies is described as **REmap Options.**[7] Each REmap Option replaces a non-renewable energy technology[8] to deliver the same energy service. The resulting case when all these options are aggregated is called **REmap.**

Throughout this study the renewable energy share is estimated in relation to TFEC.[9] Modern renewable energy excludes traditional uses of bioenergy.[10] The share of modern renewable energy in TFEC is equal to total modern renewable energy consumption in end-use sectors (including consumption of renewable electricity and district heat, and direct uses of renewables), divided by TFEC. The share of renewables in power generation is also calculated. The renewable energy share can be also expressed in terms of the direct uses of renewables only. The renewable energy use by end-use sector covers the areas described below.

6 Final energy use/consumption from direct uses excludes electricity and district heat consumption.

7 An approach based on options rather than scenarios is deliberate. REmap 2030 is an exploratory study and not a target-setting exercise.

8 Non-renewable technologies encompass fossil fuels, non-sustainable uses of bioenergy (referred to here as traditional bioenergy) and nuclear power. As a supplement to this report's annexes, a detailed list of these technologies and related background data are provided on the REmap website.

9 TFEC is the energy delivered to consumers as electricity, heat or fuels that can be used directly as a source of energy. This consumption is usually subdivided into transport, industry, residential, commercial and public buildings, and agriculture. It excludes non-energy uses of fuels.

10 The Food and Agriculture Organization of the UN defines traditional biomass use as woodfuels, agricultural by-products, and dung burned for cooking and heating purposes." In developing countries, traditional biomass is still widely harvested and used in an unsustainable, inefficient and unsafe way. It is mostly traded informally and non-commercially. Modern biomass, by contrast, is produced in a sustainable manner from solid wastes and residues from agriculture and forestry and relies on more efficient methods (IEA and World Bank, 2015).

- **Buildings** include the residential, commercial and public sectors. Renewable energy is used in direct applications for heating, cooling or cooking purposes or as renewable electricity.

- **Industry** includes the manufacturing and mining sectors, in which renewable energy is consumed in direct use applications (*e.g.* process heat or refrigeration) and electricity from renewable sources.

- **Transport** sector, which can make direct use of renewables through the consumption of liquid and gaseous biofuels or through electricity generated using renewable energy technologies.

Metrics for assessing REmap Options

To assess the costs of REmap Options, **substitution costs** are calculated. This report also discusses the costs and savings of renewable energy (RE) deployment and related externalities due to climate change and air pollution. Experts devised four main indicators. These are **substitution costs, system costs**, **total investment needs** and **needs for renewable energy investment support**.

Substitution cost

Each renewable and non-renewable technology has its own individual cost relative to the non-renewable energy it replaces. This is explained in detail in the REmap methodology (IRENA, 2014a) and is depicted in the following equation:[11]

Cost of Technology/ REmap Options USD/year in 2030 = **Equivalent annual capital expenditure** USD/year in 2030 + **Operating expenditure** USD/year in 2030 + **Fuel cost** USD/year in 2030

For each REmap Option, the analysis considers the cost of substituting a non-renewable energy technology to deliver an identical amount of heat, electricity or energy service. The cost of each REmap Option is represented by its **substitution cost:**[12 13]

Substitution cost USD/GJ in 2030 = (**Cost of REmap Options** USD/year in 2030 − **Cost of substituted conventional technology** USD/year in 2030) / **Energy substituted by REmap Options** GJ/year in 2030

This indicator provides a comparable metric for all renewable energy technologies identified in each sector. Substitution costs are the key indicators for assessing the economic viability of REmap Options. They depend on the type of conventional technology substituted, energy prices and the characteristics of the REmap Option. The cost can be positive (additional) or negative (savings) because many renewable energy technologies are or could by 2030 be more cost-effective than conventional technologies.

System costs

On the basis of the substitution cost, inferences can be made as to the effect on **system costs**. This indicator is the sum of the differences between the total capital and operating expenditures of all energy technologies based on their deployment in REmap and the Reference Case in 2030.

System costs USD/year in 2030 = **Substitution cost: government perspective** All technologies USD/GJ in 2030 X **REmap Options** All technologies GJ/year in 2030

Investment needs

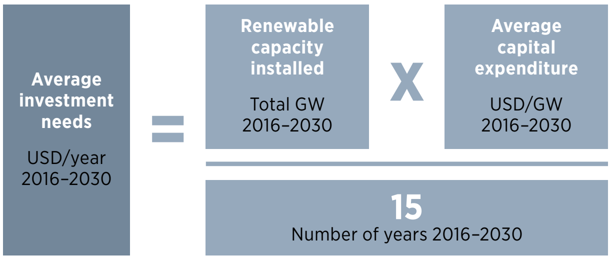
Investment needs for renewable energy capacity can also be assessed. The total **investment needs** of technologies in REmap are higher than in the Reference Case due to the increased share of renewables. On average, these have greater investment needs than

11 USD = United States (US) dollar

12 Substitution cost is the difference between the annualised cost of the REmap Option and the annualised cost of the substituted non-renewable technology used to produce the same amount of energy. This is divided by the total renewable energy use substituted by the Remap Option.

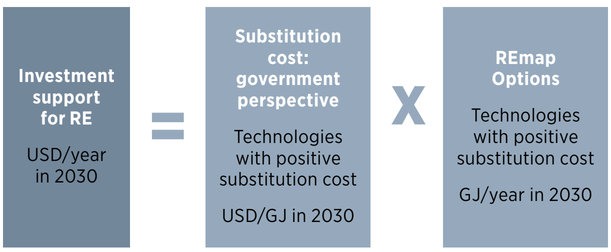
13 1 gigajoule (GJ) = 0.0238 tonnes of oil equivalent (toe) = 0.238 gigacalories = 278 kilowatt-hours (kWh); 1 USD was on average equivalent to 37 Dominican pesos in 2010.

the non-renewable energy technology equivalent. The capital investment cost in USD per kilowatt (kW) of installed capacity in each year is multiplied with the deployment in that year to arrive at total annual investment costs. The capital investment costs of each year are then added up for the period 2016-2030. Net incremental investment needs are the sum of the differences between the total investment costs for all renewable and non-renewable energy technologies in power generation and stationary applications in REmap and the Reference Case in the period 2010-2030 for each year. This total was then turned into an annual average for the period.



Renewable investment support

Renewable investment support needs can also be approximated on the basis of the REmap tool. Total requirements for renewable investment support in all sectors are estimated as the difference in the delivered energy service cost (*e.g.* in USD/kWh or USD/GJ from a government perspective) for the renewable option against the dominant incumbent in 2030. This difference is multiplied by the deployment for that option in that year to arrive at an investment support total for that technology. The differences for all REmap Options are added together to provide an annual investment support requirement for renewables. The renewable option is not subtracted from the total if it has a lower delivered energy service cost than the incumbent option. By 2030, this is an increasing trend.



Government and business perspectives

Based on the substitution cost and the potential of each REmap Option, country cost-supply curves are developed for 2030 from two perspectives: **government** and **business.**

- **Government perspective:** cost estimates exclude energy taxes and subsidies. In the latest global REmap study (IRENA, 2016a), a standard 10% (for non-OECD member countries) or 7.5% (for OECD member countries) discount rate was used. This approach allows a comparison across countries and a country cost-benefit analysis; it shows the cost of the transition as governments would calculate it.

- **Business perspective:** this considers national prices (including, for example, energy taxes, subsidies and the cost of capital) in order to generate a localised cost curve. This approach shows the cost of the transition as businesses or investors would calculate it. A discount rate of 12% is assumed in the case of the Dominican Republic.

- By estimating the costs from two perspectives, the analysis shows the effects of accounting for energy taxes and subsidies while all other parameters are kept the same. The assessment of all additional costs related to complementary infrastructure are excluded from this report (*e.g.* grid reinforcements, fuel stations). IRENA analysis suggests that these would be of secondary importance to countries only just embarking on their energy system transformation.

Externality analysis

Several externality reductions obtained through REmap Options are considered. They include health effects from outdoor or indoor exposure to pollution in the case of traditional bioenergy, as well as effects on agricultural yields. In addition, the external costs associated with the social and economic impacts of carbon dioxide (CO_2) are estimated (IRENA, 2016b).

Further documentation and a detailed description of the REmap methodology can be found at *www.irena.org/remap.* Further details on metrics for assessing REmap Options can be consulted in the appendix of the 2016 global report (IRENA, 2016c).

Units

Energy supply and demand numbers in this report are generally provided in petajoules (PJ), gigajoules (GJ) and terawatt-hour (TWh). In the Dominican Republic, commonly used units are tonnes of oil equivalent (toe). The relevant conversion factors are listed below:

- 1 GJ = 0.0238 tonnes of oil equivalent (toe)
- 1 GJ = 277.78 kilowatt-hour (kWh)
- 1 PJ = 23.88 kilotonne of oil equivalent (ktoe)
- 1 PJ = 277.78 gigawatt-hour (GWh)
- 1 PJ = 1 000 000 GJ
- 1 ktoe = 1 000 toe
- 1 TWh = 1 000 GWh = 1 000 000 MWh = 1 000 000 000 kWh

1.3 Main sources of information and assumptions in REmap Dominican Republic

The main sources and assumptions from background data and literature used to prepare REmap Dominican Republic are summarised below for each case:

- **Base year 2010:** the starting point of the analysis is Dominican Republic's energy balances for 2010. The data are based on the national energy balances provided by the Dominican Republic government up to the year 2014.[14] For the REmap analysis, all end-use demand is broken down into the following three sectors: industry[15], transport and buildings.

- **Reference Case:** this is based on the data provided by CNE in its preliminary results of energy demand projections for 2013-2030 prepared in collaboration with Fundación Bariloche(CNE, 2014a). For the power sector, other data complemented these projections, mainly based on estimates provided by CNE.

- **REmap:** this is based on IRENA's analysis (details of sources and assumptions can be found in Chapter 3 and in the annexes) combined with the data provided in CNE's alternative scenario (*escenario alternativo*). This covers a higher penetration of certain renewable technologies.

This report is structured as follows: Chapter 2 introduces the overall energy and power sector context in the Dominican Republic and presents the main renewable energy developments so far. Chapter 3 describes the renewable energy developments in the Reference Case and in REmap. Chapter 4 discusses how the renewable energy potential identified in the REmap case could be fulfilled. Chapter 5 describes in detail the costs and benefits of realising this REmap potential. Finally, Chapter 6 includes key recommendations for larger renewable energy uptake.

14 Original data expressed in higher heating values (gross calorific value) were converted to lower heating values (net calorific value) to be consistent with the REmap methodology.

15 The boundaries of REmap analysis typically include agriculture, fishery and all primary sector activities in a separate category. However, the Dominican Republic aggregates energy demand for agriculture with mining and construction sectors so all these have been included in the energy consumption of industry.

2 CURRENT PICTURE – ENERGY AND RENEWABLES DEVELOPMENT IN THE DOMINICAN REPUBLIC

2.1 Renewable energy drivers

The Dominican Republic is one of the largest and most diverse economies in the Caribbean region. Its Intended Nationally Determined Contribution (INDC) sets an ambitious national target to reduce its GHG emissions by 25% by 2030 compared to the 2010 per capita level of 3.6 tonnes of CO_2 equivalent (CO_2e) (UNFCCC, 2015). Reaching this target depends on whether the Dominican Republic can wean itself off unsustainable energy sources. It currently relies on expensive fossil fuel imports while demand for energy is growing rapidly. There is no doubt that improvements in infrastructure will be required in the years ahead to meet the country's growing energy demand.

Fossil fuel imports now amount to around USD 5 billion per annum, which accounts for approximately 7% of country's GDP. Fossil fuel imports account for 90% of the country's primary source of energy (Central Bank of the Dominican Republic, 2016; Killeen, 2015). Electricity generation is very much dependent on fossil fuel imports so operating costs are high. Oil products, natural gas and coal account for about 50%, 27% and 15% of electricity generation respectively (CNE, 2016a). The high cost of electricity production is not reflected in the electricity tariffs because government-led pre-tax subsidies, amounting to USD 1 billion per annum, help keep tariffs relatively low. These subsidies account for about 2% of the Dominican Republic's GDP.[16] About 0.1% is applied to the fuels while the remaining 1.9% is directly applied to the electricity tariffs (Di Bella *et al.*, 2015).

Diversifying the electricity generation portfolio could be key to reducing the country's dependence on fuel imports and improving its energy supply security in light of its growing energy demand. It would be decarbonising the economy at the same time. Renewable energy technologies offer a cost-effective path for the future. Wind and solar resources are abundant in the Dominican Republic. According to several estimates, wind power potential is around 30 GW while solar potential is similar to the southwestern US. The average global horizontal irradiance (GHI) amounts to 5-7 kWh per square metre per day (kWh/m^2/day), and in some regions this can rise to 8 kWh/m^2/day (Worldwatch Institute, 2015). Renewable energy technologies can also play an important role in providing electricity to the low share of households which lack access so far. This is less than 5% of the total (Cruz Castillo, 2014).

The Dominican Republic government has demonstrated its commitment towards renewable energy technologies, particularly for the power sector. Article 21 of Law 57-07, enacted in 2007, set a non-binding target of 10% and 25% of electricity consumed in 2015 and 2025 respectively to be supplied from renewable energy sources. This would imply that 25% of the electricity purchased by the distribution and retail companies should be sourced from renewable energy. Since not enough renewable power generation was available to meet the ambitious 2015 goal, the country is committed to increase its efforts to set itself on the path to meet the 2025 target. This REmap study prepared in close collaboration with CNE is one of the tasks aimed at achieving this goal.

2.2 Renewable energy policies

The main legislative instrument promoting renewable energy in the Dominican Republic is Law 57-07 on Renewable Energy Incentives and Special Regimes, enacted in 2007. This includes some provisions for renewable energy technologies across all energy sectors, particularly the power sector.

16 Fuel tax exemption for the fuel used for power generation is not included in the public budget.

A number of measures are included in Law 57-07. It provides a broad range of tax incentives, including a 100% exemption for renewable energy technologies from import taxes and taxes on the Transfer of Industrialised Goods and Services[17]. It also gives a tax reduction on external financing and a 40% tax credit to autoproducers, which are defined as systems smaller than 1.5 MW.[18] In addition, it enables low interest loans for community projects, which cover up to 75% of the cost of equipment for small-scale installations (less than 500 kW). Finally, the law establishes a reference tariff for the remuneration of grid-connected renewable energy installations and sets the basis to have a remuneration scheme for the excess energy of autoproducers. The law is supplemented by the Regulation for the Implementation of the Renewable Energy Incentives and Special Regimes Law, enacted on 2008. More details on the law are provided in the description of the institutional and regulatory framework in section 2.3.

In addition to the renewable energy law, a net-metering programme was devised in 2011 for residential wind or solar PV installations (the latter applicable to installations smaller than 25 kW and commercial facilities under 1 MW). This makes them eligible to receive credits for excess power exported to the grid. Under this programme, 1 002 customers had connected 21.3 MW of solar PV to the grid by December 2015 (CNE, 2016b).

The use of renewable energy technologies for electricity generation has also expanded through energy access efforts. In 2009, the government launched a rural electrification programme with renewable energy sources that was operational during four years. Small hydropower and PV installations were deployed for off-grid electrification (SE4All, n.d). Some of these were run by CNE, which is subject to a government goal to install 500 PV systems in households not connected to the grid. The grid has also been extended in certain places throughout the Dominican Republic. The national level of electrification is now around 96%, and around 120 000 (CNE, 2014a) households lack electricity access. Nearly all of these are in rural areas, and only a minimal number are in suburban zones.

17 *Impuesto sobre Transferencia de Bienes Industrializados y Servicios* (ITBIS).

18 This rate applicable today had been previously modified by Law 253-12 (law to reinforce the tax collection capacity of the State for Fiscal sustainability and sustainable development).

2.3 Recent trends in total final energy consumption

The average total final energy demand of the Dominican Republic has grown by 1% per year between 2000 and 2014, reaching 227 PJ (5 433 ktoe). The growth was notable in the industry, commercial and services sector, whose annual growth rate rose to almost 3% per year over the period. By comparison, transport sector demand has remained about the same with a slight decline. Residential sector demand increased by approximately 1% per year (CNE, 2014b).

Transport is the largest consumer of final energy, representing 40% of the country's total energy demand in 2014. This is followed by buildings, which accounted for a third of total final energy use in that year. Finally, industry demand accounted for a quarter of the total. Agriculture and fisheries also use energy, especially for pumps and transport but this is less than 3% of the country's total energy demand. (CNE, 2014b)

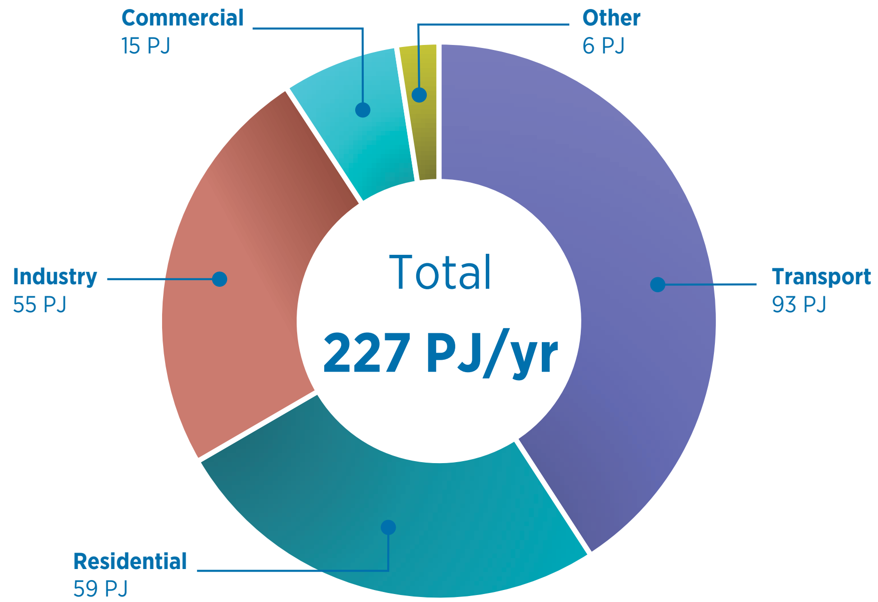
In 2014, about 62% of the country's **total final energy demand** was supplied by fossil fuels, mostly in the form of oil products, while electricity accounted for 24% of final energy use. Direct uses of renewables reached around 14% (mostly from wood fuel for cooking and water heating in the residential sector, and bagasse for process heat in the industry sector) (CNE, 2014b).

In terms of **total primary energy supply**, the country reached 8 219 ktoe (344 PJ) in 2014. Since most energy needs are covered by fossil fuels, and the country lacks local fossil resources, more than 90% of the country's total primary energy supply is based on imports.

Peak electricity demand reached 2.63 GW in 2015, and about a quarter of the total final energy demand is related to electricity. This rate is higher than the average in the rest of Latin America and the Caribbean. However, consumption across the various regions of the country varies significantly. For example, per capita consumption in Punta Cana – one of the touristic regions – differs from the rest of the country by almost a factor of ten. The difference is higher when compared with the demand of the population in isolated areas.

Industry has an exceptionally high ratio of electricity use to total energy consumption, amounting to 38% in 2014. By contrast, the share is less than 1% in transport

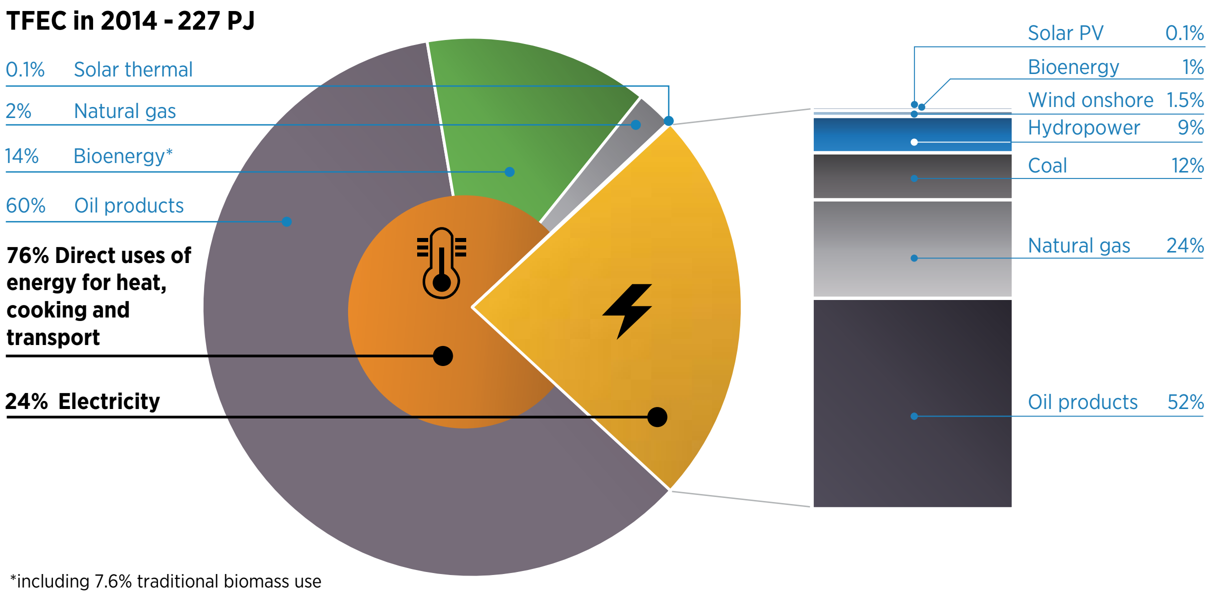
Figure 1: Breakdown of TFEC by sector, 2014



Based on CNE (2014b)

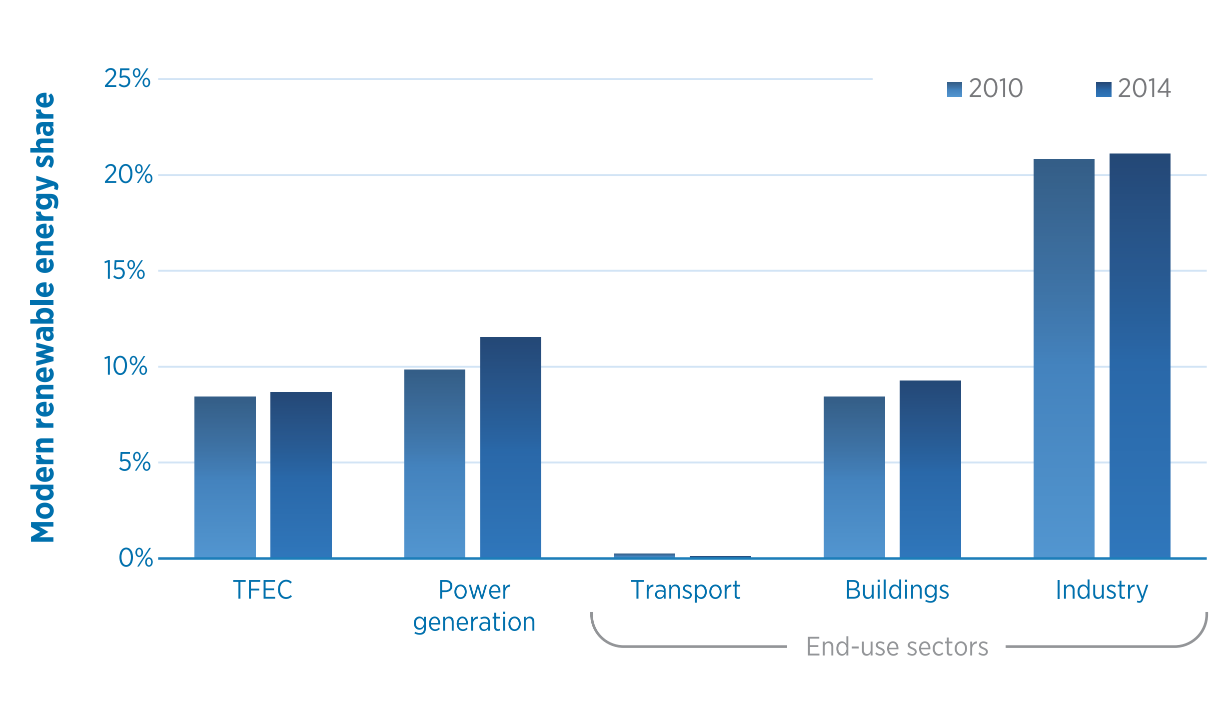
Note: the commercial sector includes services and the public sector; other includes agriculture, fishing and mining.

Figure 2: Breakdown of Dominican Republic's final energy mix, 2014



– the lowest consumer of all sectors (CNE, 2014b). Within the buildings sector these proportions differ greatly. In the residential sector, the share amounts to around 30% whereas the commercial and services sector has a share of more than 80%. The potential for increasing electrification rates in some of these sectors is an important factor when considering the further deployment of renewable electricity.

Figure 3: Share of modern renewable energy use by sector, 2010 and 2014



Note: the share of renewable energy in end-use sectors includes electricity from renewable sources.

The **share of modern renewable energy in** the Dominican Republic's **TFEC** amounted to 8.7% in 2014, as shown in Figure 3 (if traditional uses of bioenergy are included, this increases to 16.3%[5]) (CNE, 2014b). The largest contributors are biomass in the residential and industry sectors while solar thermal energy in buildings and liquid biofuels in transport make a very small contribution. Most renewable energy consumed is used for heating in industry and buildings. A low share of renewable energy use corresponds to energy consumed through renewable electricity coming mostly from hydropower.

The **industry** sector has the greatest renewable energy share of all sectors at 21% (including electricity sourced from renewables). If electricity consumption is excluded, 27% of renewable energy consumption arises from the direct use of fuels in the industry sector, all based on bioenergy.

The **power sector** has the second highest share of renewable energy in the Dominican Republic. Renewable energy technologies accounted for 12% of total electricity generation in 2014, mostly based on hydropower.

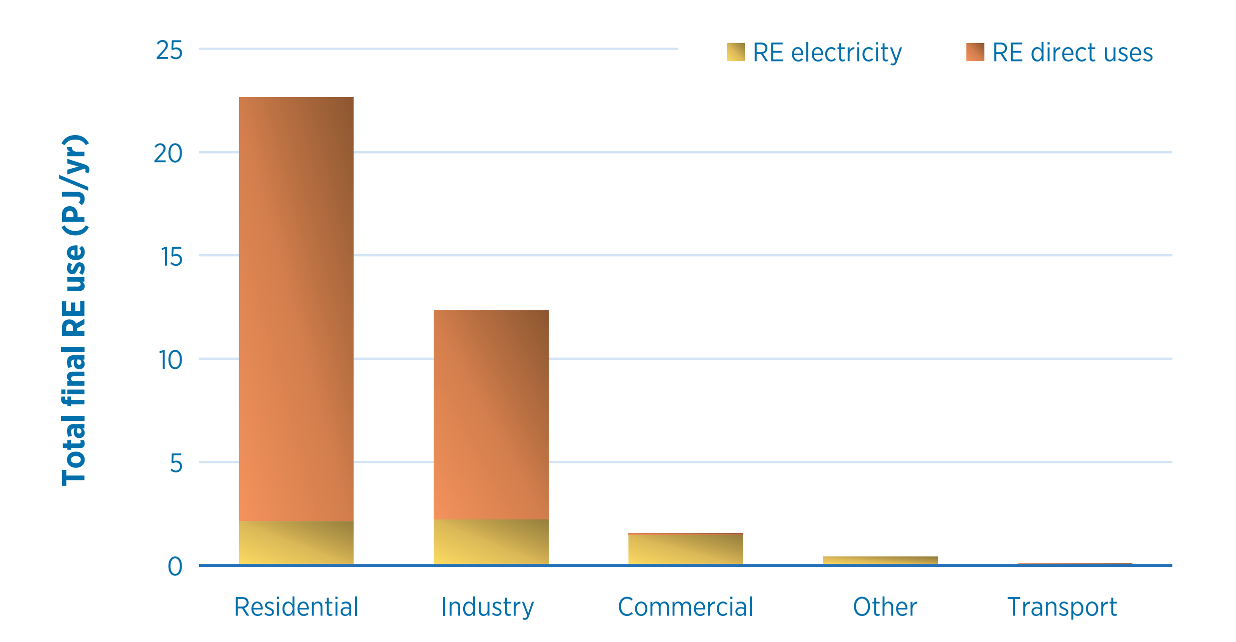
The **buildings** sector meets 8% of its direct fuel demand from modern renewable energy; if traditional uses of bioenergy are included, this share rises to 48%. This is mostly bioenergy with a minor contribution from solar thermal. Around 9% of total sector energy demand (including electricity) is met with modern renewables.

Transport has the lowest share at just 0.1%, coming entirely from biodiesel in 2014.

2.4 Power sector

In 2014, electricity accounted for nearly a quarter of the Dominican Republic's TFEC. About 10% of the electricity was generated with renewable energy technologies (including hydropower plants over 5 MW). The share of renewable energy in the power sector is likely to increase, and every day its deployment is attracting more attention from the national policy makers.

Figure 4: Breakdown of renewable energy use by sector and application, 2014



Based on CNE (2014b) data

The following sections briefly describe the institutional and regulatory framework as well as roles and activities of the main stakeholders within the power sector in the Dominican Republic. These sections are descriptive and aim to facilitate the understanding of the local context.

Institutional and regulatory framework

The structure of the power sector in the Dominican Republic is the result of a reform process that started in the late 1990s. Until then, the state-owned Dominican Electric Company (Corporación Dominicana de Electricidad) (CDE) was in charge of electricity generation, transmission, distribution and retail. Only a few private companies participated in the generation business through Power Purchase Agreements (PPAs).

A general reform in state-owned companies was implemented through the enactment of Law 141-97 on the Reform of Public Enterprises adopted in June 1997, which sets the basis for allowing private companies to participate in power sector activities. Later, the general electricity Law 125-01 adopted in July 2001 and its application rules defined the regulatory framework for the activities in the power sector. The reform aimed to address issues related to high electricity costs, tariffs driven by political interests, non-delivered electricity and operational inefficiency (CNE, 2008). As part of this process, the MEM was created in 2013. The aim was to formulate and manage policies for the entire exploitation of the national energy and mining resources under the principles of transparency and sustainability. The reform process unbundled activities within the power supply chain, enabling private sector participation and producing the following set-up:

- **Generation** activity is structured within a competitive wholesale market (*mercado eléctrico mayorista*) with participation from privately owned and public-private partnership generation companies.

- The **transmission** grid, **hydropower** generation and most of the **distribution** system **assets** remain under the ownership of the Dominican Republic government.

- Three **distribution** concessions have been granted to three different state-owned companies, which deliver the electricity to the consumers connected at distribution level. The same companies are in charge of the electricity retail activities for their regulated customers.

- Through CNE, the government is in charge of preparing indicative **long-term planning of the generation, transmission and distribution** systems. The indicative planning aims to provide appropriate signals to stakeholders in order to promote adequate investments in and development of the sector.

- **Operation of the interconnected power system** – the operation of the National Interconnected Electrical System (Sistema Eléctrico Nacional Interconectado), SENI – is planned and co-ordinated by the independent co-ordination entity OC-SENI. It also administers the transactions in the wholesale power market.

- **Real-time operation** of the national interconnected system, SENI, is carried out by the Energy Control Centre (Centro de Control de Energía) (CCE), a division of the Dominican Electric Transmission Company (Empresa de Transmisión Eléctrica Dominicana) ETED, in co-ordination with OC-SENI.

- Energy transactions in the **wholesale electricity market** are made through over-the-counter long-term contracts between producers and large consumers (*i.e.* distribution companies and non-regulated consumers) or through the spot market.

Law 57-07 and its application rules defined the regulatory framework to promote investment and generation of energy with renewable sources, including provisions for power sector technologies. The law set a target for a renewable power share of 10% and 25% of total electricity produced in the Dominican Republic by 2015 and 2025 respectively. However, this target is not binding but does demonstrate the government's commitment to renewable energy technologies.

As stated above, Law 57-07 also defined a special regime for renewable energy production, aiming to foster its deployment across the country. The grid-connected renewable energy installations in this regime (*plantas de régimen especial*) have the right to a ten-year feed-in tariff until 2018, which adds a premium payment to the wholesale electricity price. The feed-in tariff incentive levels (defined in US dollars but paid in Dominican pesos) are differentiated by technology and system size. Autoproducers also have the right to be paid for their excess generation at a regulated price.

Five types of power plants are currently subject to this special regime. They include: 1) wind power installations with an initial installed capacity of less than 50 MW; 2) hydropower installations of less than 5 MW; 3) all types and sizes of solar PV as well as 4) concentrated solar power (CSP) systems lower than 120 MW; and 5) power plants using bioenergy as main fuel for at least 60% of their fuel supply and with a maximum installed capacity of 80 MW. The installation size limits applicable for some technologies can be duplicated provided that the projects have been developed at least at 50% of the initial planned capacity. The details of plant size limits and possible project expansion are described in Article 5 of the renewable energy Law 57-07.

In addition to this incentive, favourable conditions encourage system entry and market participation, namely priority of interconnection and dispatch, and fiscal incentives. These are described in section 2.1 as part of renewable energy policies.

Besides the legislation and main regulatory conditions, a set of technical rules developed by CNE, the Electricity Superintendency (Superintendencia de Electricidad) (SIE) and OC-SENI are enforced to allow the secure and efficient operation of the interconnected system. These technical rules include the connection code for generators, distribution systems and non-regulated consumers and the rules for the connection of distributed generation[19].

Figure 5 summarises the timeline for the main institutional and legislation changes in the power sector of the Dominican Republic up to 2011.[20]

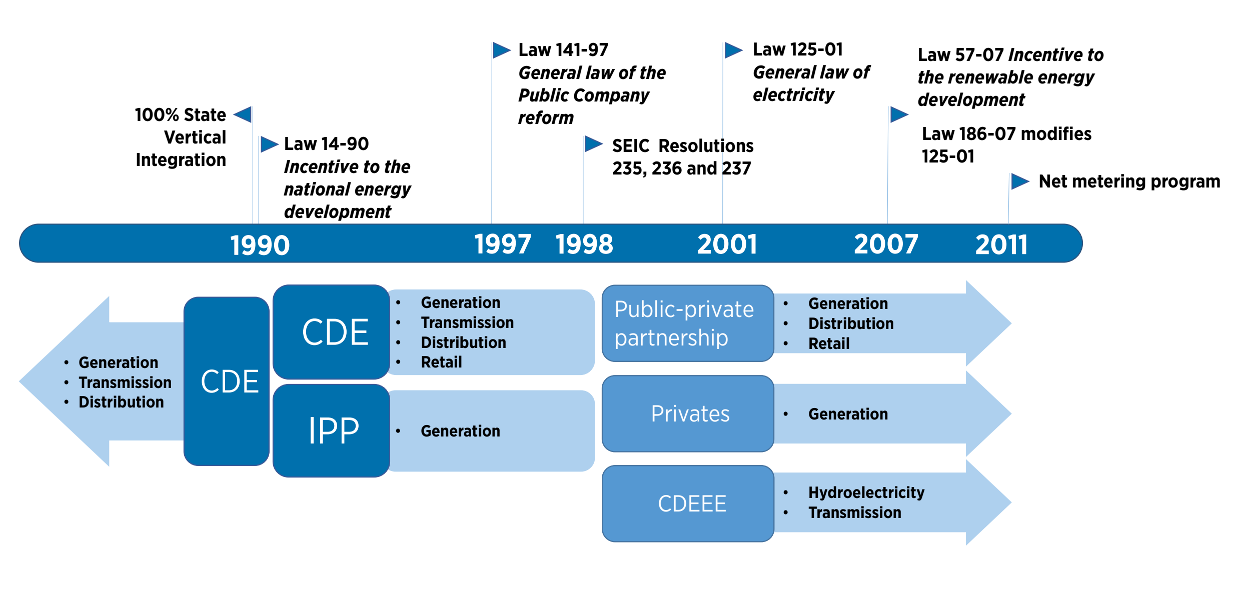
Main actors and activities in the power sector

The main stakeholders within the institutional framework of the power sector in the Dominican Republic include (CNE, n.d.):

19 Or *Reglamento para la Interconexión de la Generación Distribuida* in Spanish.

20 After this year no other major legislation or reform has been implemented, apart from some adjustments to the existing regulation.

Figure 5: Main institutional and legislation developments in the Dominican Republic power sector



Based on CNE (2015)

Note: each of the agents in the figure above are described below.

- **Ministry of Energy and Mines – MEM:** this was created by Law 100-13 adopted in July 2013. MEM is in charge of the energy and mines sector and responsible for developing the related energy policies.

- **National Energy Commission – CNE:** this was created by Law 125-01 in 2001. Amongst its other functions, the commission contributes to national energy policy development. For this purpose, CNE develops and updates a national energy plan. It is CNE's responsibility to promote investments according to the strategies defined by the plan. In the power sector, CNE is in charge of the development and update of long-term indicative (non-binding) expansion plans for the generation, transmission and distribution systems. It also administers Law 57-07 to promote the investment of renewable energy technologies.

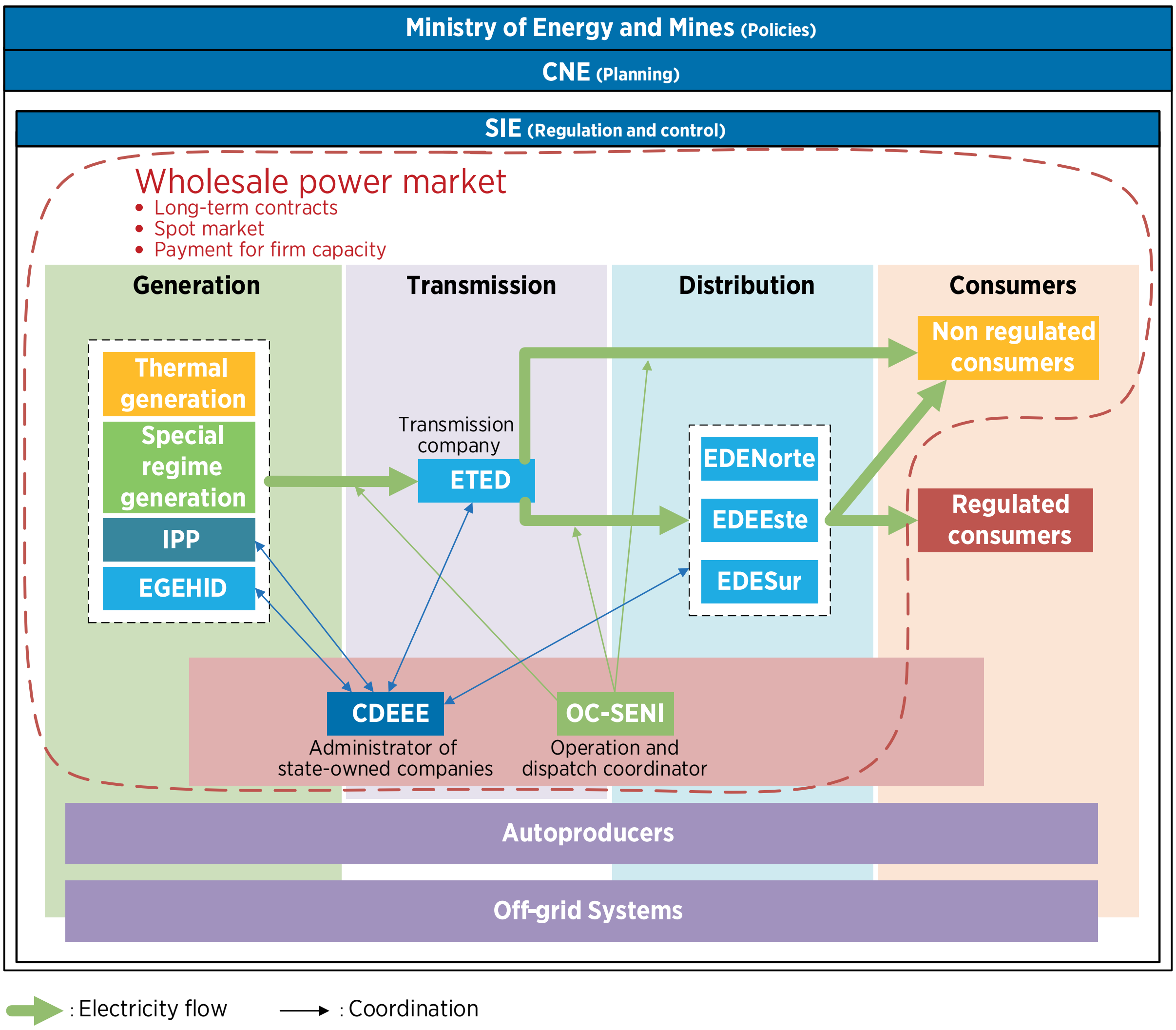
- **Electricity Superintendency (Superintendencia de Electricidad) – SIE:** Created through Law 125-01 in 2001, it is the regulatory body in charge of the economic and technical norms related to the generation, transmission, distribution and retail of electricity.

- **SENI Co-ordination Unit (Organismo Coordinador del Sistema Eléctrico Nacional Interconectado) – OC-SENI:** formally established through Law 125-01 in 2001, OC-SENI plans and co-ordinates the operation of the interconnected system as well as co-ordinating and supervising commercial transactions between agents in the wholesale power market.

- **Dominican Corporation of Public Electrical Companies (Corporación Dominicana de Empresas Eléctricas Estatales) – CDEEE*:*** this is the umbrella company responsible for co-ordinating the strategies, objectives and actions of all the electricity companies owned or controlled by the government. Additionally, CDEEE is responsible for the government's rural electrification programmes and the administration of existing PPAs with independent power producers.

- **Dominican Electric Transmission Company (Empresa de Transmisión Eléctrica Dominicana) – ETED:** ETED is the state-owned company responsible for operating, maintaining and administering the high-voltage transmission network (345-69 kilovolts – kV).

Figure 6: Institutional structure in the Dominican power market



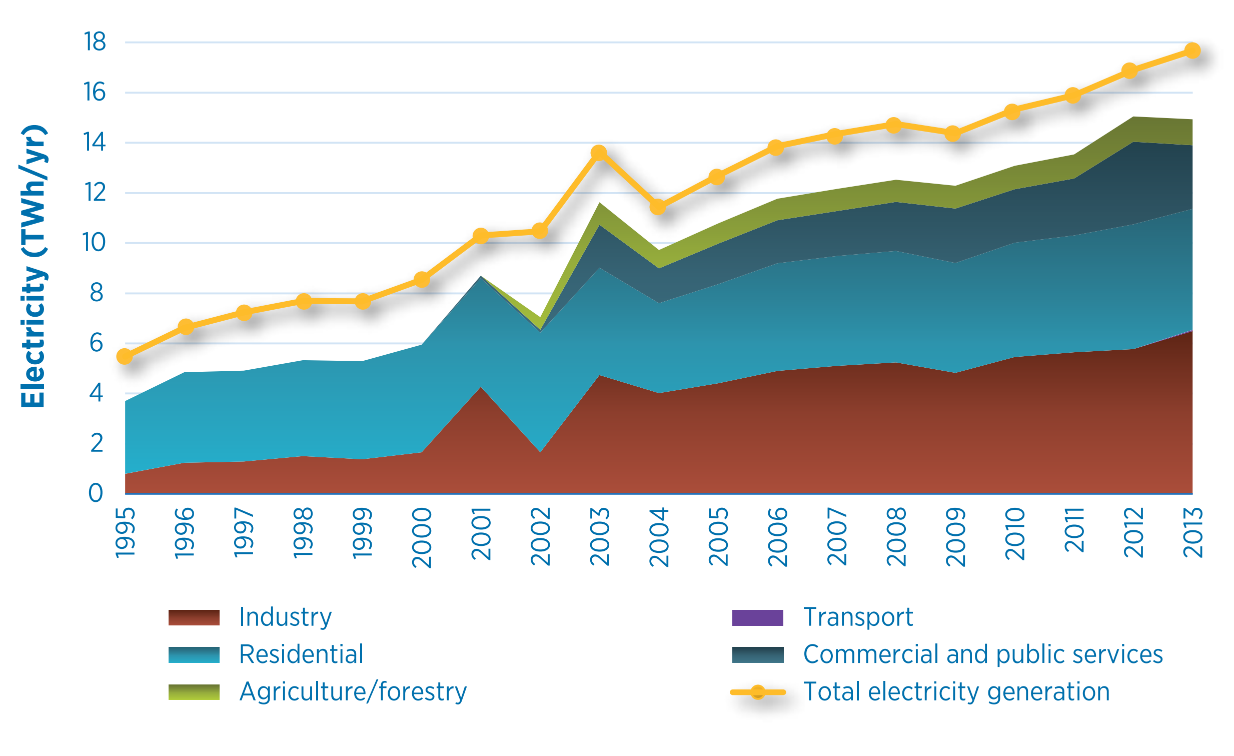
Based on OLADE (2013)

- **Distribution companies – EDENORTE, EDESUR and EDEESTE:** the distribution of electricity within SENI is carried out by three state-owned companies which administer three different concessions across the national territory, as shown in Figure 13. The distribution companies also control the retail of electricity for regulated customers.

- **Generation companies:** as of December 2014, 16 power generation companies were associated with OC-SENI. All the major hydropower generation assets belong to the state-owned Dominican Hydroelectric Generation Corporation (Empresa de Generación Hidroeléctrica Dominicana) (EGEHID). Two independent power producers, Compañía de Electricidad de San Pedro de Macorís and Generadora San Felipe, deliver power under PPAs administered by CDEEE. The remaining 13 companies own the thermal power plants and participate with the Dominican Hydroelectric Generation Corporation, EGEHID, in the wholesale market through energy and power transactions.

- **Consumers:** these are classified as regulated or non-regulated. Regulated consumers are represented in the wholesale market by the

Figure 7: Electricity demand by sector and total generation, 1995-2013



Based on IEA (2015)

distribution companies. Electricity retail for regulated consumers is carried out by the distribution companies according to the tariff regime and rules established by the regulator, SIE. Consumers with demand of more than 1 MW can cover their electricity needs through direct transactions with generators in the wholesale market.

- Figure 6 summarises the roles and the interactions between these agents of the power sector of the Dominican Republic and the following sections describe the activities carried out by them. Before describing the activities, a brief discussion is presented on electricity demand to provide the context.

Electricity and power demand

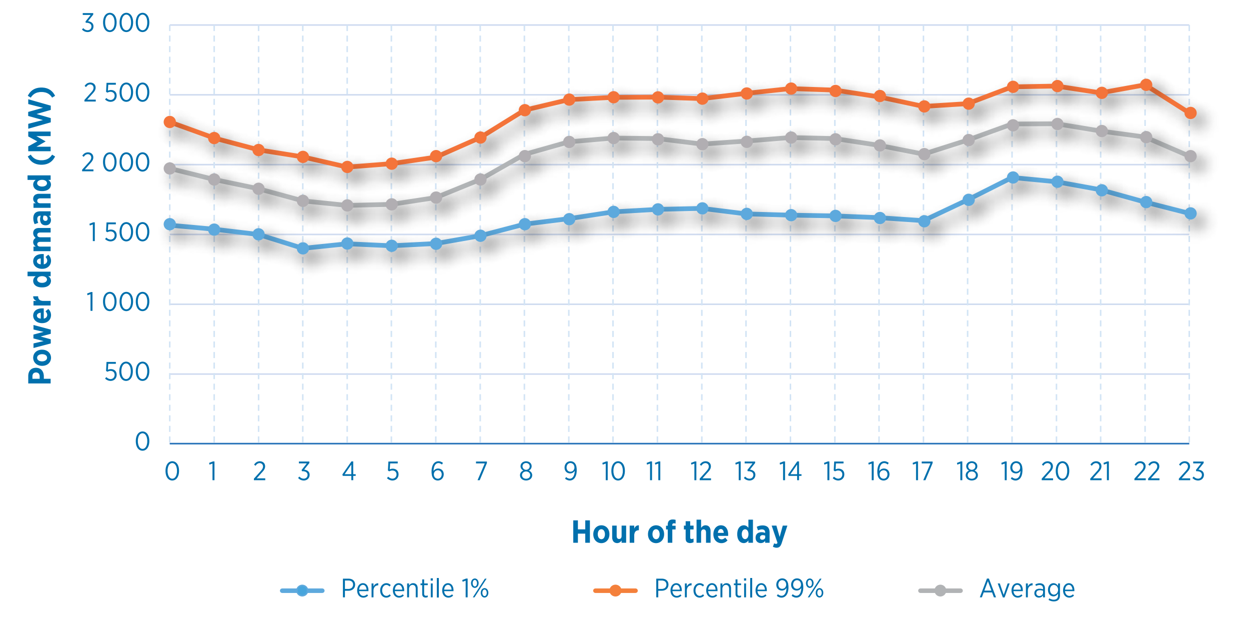
Demand for electricity reached 15 TWh in 2014, with annual generation approaching 18 TWh in the same year (including autoproduction). Roughly 40% of this total is used in the industry sector. The remaining 60% is consumed in buildings and is split into 35% for residential and 25% for commercial buildings. Demand for electricity has grown by 7% per year on average in the past decade.

The power demand profile changes according to days of the week and climate conditions. Typically, peak demand for power occurs in the evenings during the warmer months of the year. In 2015, the peak demand of the interconnected system reached 2.63 GW (OC-SENI, 2015a).[21] Figure 8 shows significant values for the demand profiles in 2015. The orange curve shows the percentile 99 of the demand profile for 2015, the blue one shows the percentile 1 and the grey curve shows the average.

21 This figure includes projections of power demand not delivered due to programmed customer disconnections.

22 Considering the hourly electricity demand as the generation plus power outage reported for SENI.

Figure 8: SENI hourly demand profiles for 2015[22]



Based on OC-SENI (2015b)

Generation

The total installed generation capacity in the country, including autoproducers and off-grid installations, was 4.9 GW in 2014 (CNE, 2016c, 2014b; CNE and Fundación Bariloche, 2014; IRENA, 2016d). SENI contributed about 3.7 GW to this total. The evolution of generation capacity for SENI is presented in Figure 9. The annual average growth of installed capacity within SENI in the last five years has been around 5.2% (OC-SENI, 2014a).

As shown in the figure, the growth in installed capacity in SENI in the last few years has been dominated by internal combustion engine technologies. Most of these power plants can be operated with both oil products and natural gas. Due to lower fuel prices, internal combustion engine generators were up until 2015 operated with oil products, mainly fuel oil and diesel.

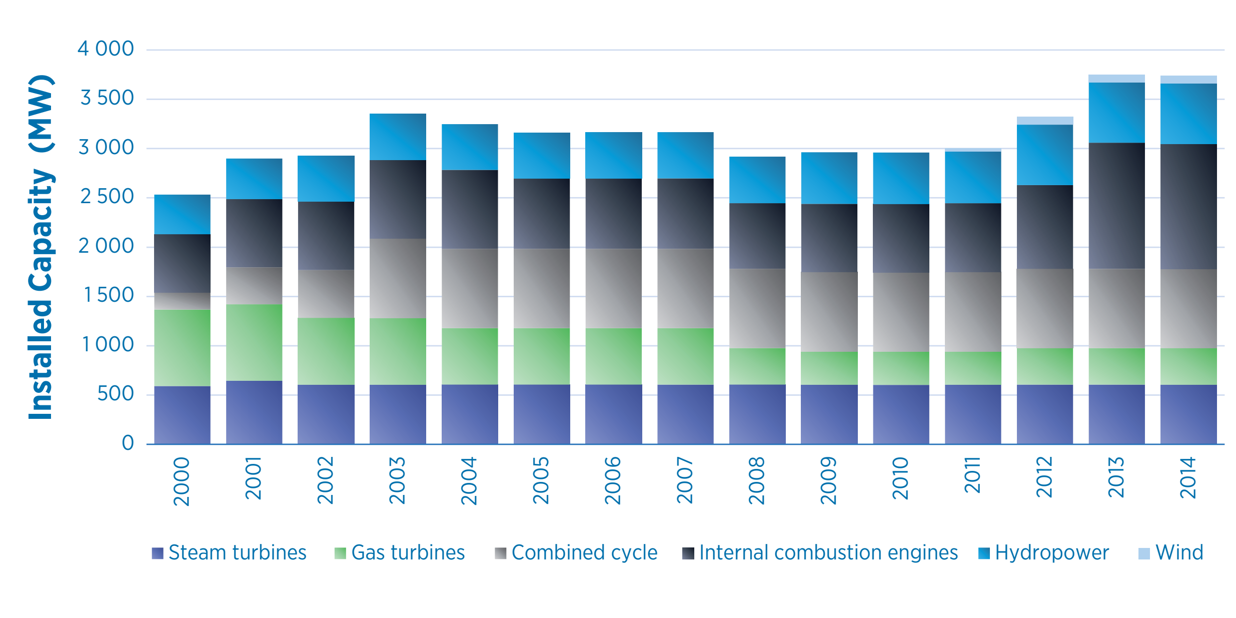
Currently, 65% of the generation capacity within SENI is owned and operated by private companies. The largest market participant in terms of installed capacity is the privately owned AES Dominicana, with a share of 21% (815 MW). All the major hydropower generation assets, with a share of 16% of the total installed capacity, belong to the state-owned hydropower company EGEHID. Public-private partnerships such as Haina and Itabo own also significant shares of the installed capacity (CNE, 2015).

Of the 18 TWh of electricity generated in 2014, 14.3 TWh (about 79% of the total) was produced within SENI (OC-SENI, 2014a). Oil products make up the largest share of fuel in electricity production within SENI, amounting to 45.6%.[23] Natural gas and coal accounted for 28.5% and 15.4% of the total respectively. Renewable resources had a share of 8.8% and 1.7% for hydropower and wind power respectively (OC-SENI, 2014a). Figure 10 shows the breakdown of electricity generation in SENI by fuel type for 2010-2014. The variability in hydropower production is explained by the effects of the El Niño-Southern Oscillation phenomenon which periodically affects the rainfall in the country.

In response to the fast growing demand, several new generation projects have been planned and received a development concession from the government.

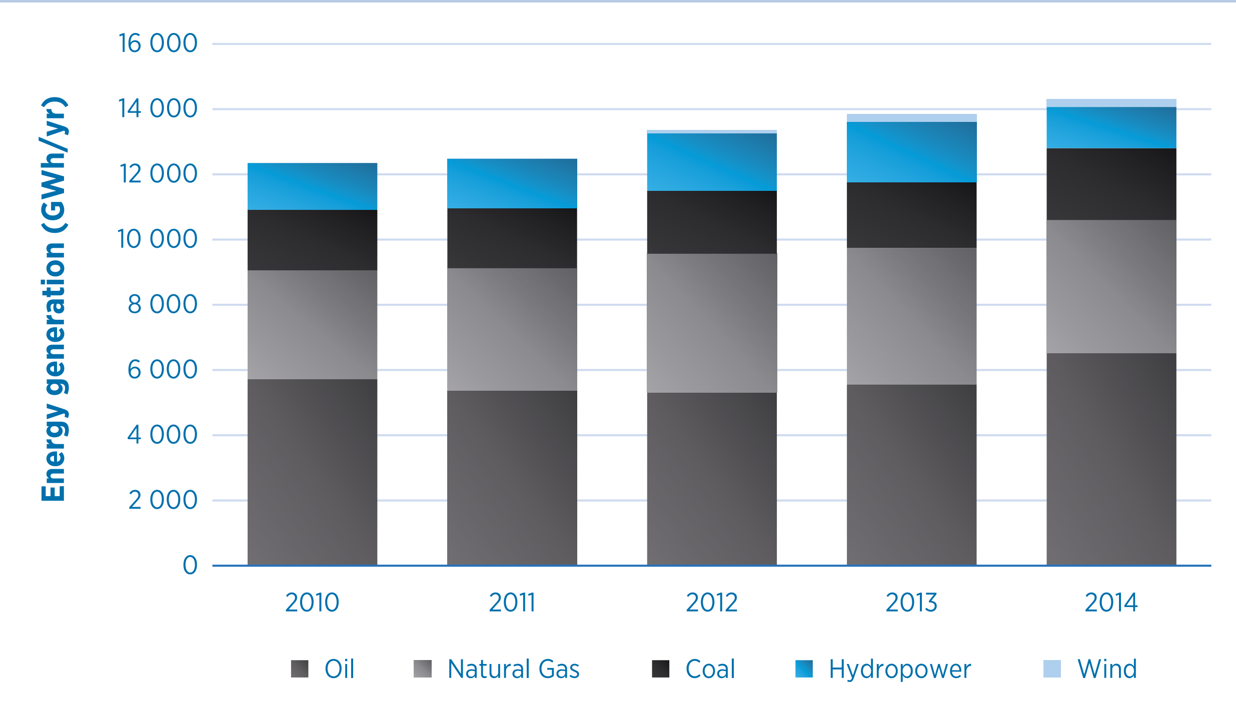
23 A number of dual fuel power plants exist in the country. These can either use liquefied natural gas or oil. The generation from these power plants was aggregated according to the fuel consumption breakdown of each plant provided by SENI (OC-SENI, n.d).

Figure 9: Total installed generation capacity in SENI by technology in Dominican Republic, 2000-2014



Based on OC-SENI (2012, 2014a)

Figure 10: Breakdown of annual electricity generation in SENI by fuel type in Dominican Republic, 2010-2014



Based on OC-SENI (2010, 2011, 2012, 2013, 2014a) data

Given that construction has not yet started on all the projects with final concessions, it cannot be said that all this planned capacity will be realised. However, this still reflects the interest in expanding the generation capacity. The combined capacity of the projects with a final concession totals 2 385 MW (CNE, 2016c, 2015,

p. 16). About a quarter of this capacity is expected to be developed by state-owned companies, and 64% corresponds to renewable energy technologies, with wind, large hydropower and solar PV having the largest share. Table 1 provides an overview of the projects with final concession.

Transmission

ETED is responsible for operating and maintaining the high-voltage transmission grid in the SENI. Up to 2014, more than 85% of total electricity demand in the Dominican Republic was met through SENI based on the ETED transmission network. Table 3 provides details about the existing infrastructure.

The transmission system mainly has a radial configuration in the most remote zones in the North, South and East of the country. These zones are connected with each other at 138 kV and 69 kV. The two main electricity consumption centres, Santo Domingo and Santiago, are supplied through 138 kV rings and are interconnected through 345 kV and 138 kV circuits.

For planning operations, the system is divided into four areas: Central, East, South and North. A diagram of the transmission system and its operational areas and sub-areas is provided in Figure 11. The Central area, which includes the capital city Santo Domingo, has the greatest power demand. Its peak load represents around 47% of the national peak load. This is followed by

Table 1: Generation expansion plans, projects with final concessions by technology and owner

Owner	Technology	Total capacity
Total non-renewable capacity		**866 MW**
CDEEE	Coal	752 MW – 1 project
AES Dominicana	Combined cycle	114 MW – expansion (2017)
Total renewable capacity		**1 489 MW**
Bioenergy capacity		**1 MW**
Koar Energy Dominicana	Bioenergy	1 MW – 1 project (Monseñor Nouel)
Hydropower capacity		**599 MW**
EGEHID	Hydropower	590 MW – 8 projects
Evyp Caribe	Small hydropower	4 MW – 1 project (La Vega)
Shanti Investment	Small hydropower	5 MW – 1 project (Monseñor Nouel)
Solar PV capacity		**175 MW**
Isofotón	Solar PV	50 MW – 1 project (Santo Domingo Norte)
Montecristi Solar	Solar PV	58 MW – 1 project (Monte Cristi)
Phinie Corp & Co. Development	Solar PV	17 MW – 1 project (Azua)
WCG Energy	Solar PV	50 MW – 1 project (Santo Domingo Norte)
Wind capacity		**715 MW**
Compañía de Electricidad de Perto Plata	Wind	50 MW – 1 project (Puerto Plata)
Dominican Renovables	Wind	50 MW – 1 project (Puerto Plata)
EGE Haina	Wind	50 MW – 1 project (2017, Pedernales)
Generación Eólica Internacional	Wind	100 MW – 2 projects (one in Peravia)
Grupo Eólico Dominicanar	Wind	50 MW – 1 project (Monte Cristi)
Jasper Caribbean Windpower	Wind	115 MW – 1 project (Puerto Plata)
Los Cuatro Vientos	Wind	50 MW – 1 project (Puerto Plata)
Parque Eólico del Caribe	Wind	50 MW – 1 project (Monte Cristi)
Poseidón Energías Renovables	Wind	200 MW – 2 projects

Note: In the column of total capacity, year expected for start of operation and location details have been provided when available, further details by project can be found in the CNE website

Table 2: Transmission system capacity and lines

Voltage level (kV)	Transmission lines (km)	Transformers installed capacity (MVA)
69	1 699	-
138	2 668	2 996
230	275	250
345	260	2 100
TOTAL	**4 903**	**5 346**

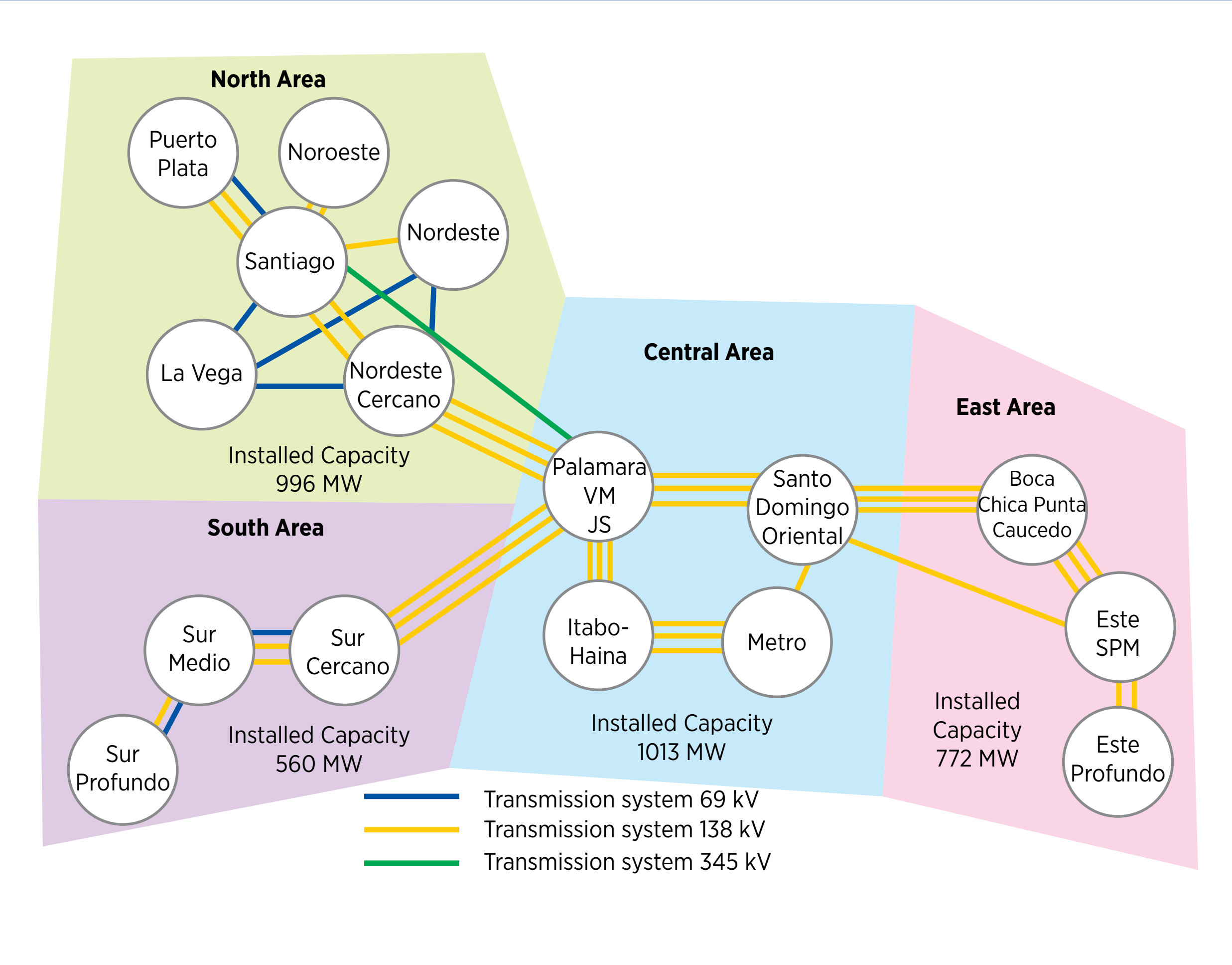
Source: CNE (2015)

MVA – megavolt amperes

the North area, which includes the city of Santiago, with a 32% share in the peak load. The energy losses at the transmission level are currently around 2% of the total generation feed-in.

In co-ordination with ETED Energy Control Centre, each year OC-SENI analyses and determines the restrictions in the transmission system for the medium term (one year) and long term (four years). These assessments identify

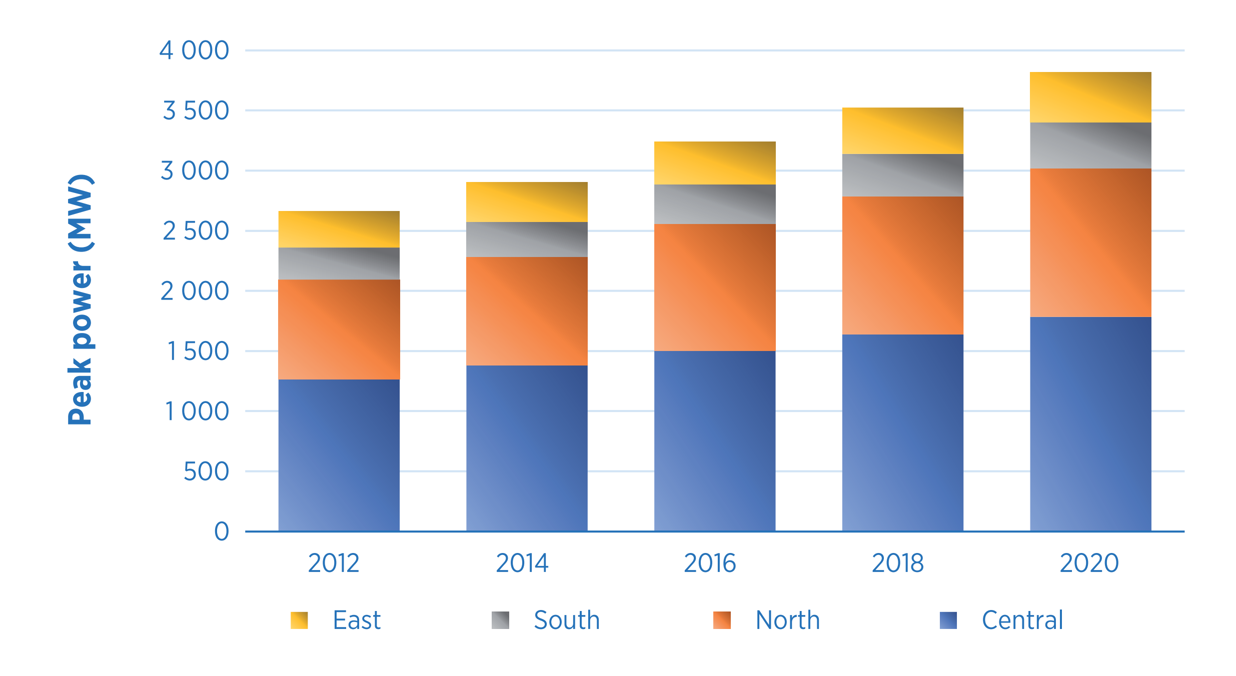
Figure 11: Overview of current transmission system



Source: OC-SENI (2015c)

Note: the diagram does not show a geographical representation of the grid, to see that in detail see CNE maps in annexes.

Figure 12: Peak power demand by transmission area



Based on ETED (2013) data

the security limits for transferring power between the systems' areas and sub-areas. The mid-term analysis is based on the present system topology. The long-term analysis includes transmission projects expected for the time horizon of the study according to existing Transmission Expansion Plans. The limits for maximum power transfer between operational areas according to the latest study are summarised in Table 3.

In 2014, there were 51 hours of congestion in the transmission system mainly related to scheduled maintenance works. After taking into consideration existing restrictions, planned generation projects and power demand growth forecasts in each area, ETED worked out a master plan for expanding the transmission system for 2013-2020 (ETED, 2013). That plan is currently under implementation. The main expansion projects are in the North area and summarised in the table below. The order of implementation is defined according to system needs and priorities identified by OC-SENI and ETED. Interconnections with the neighbouring country of Haiti are not planned for the moment.

Table 3: Transmission capacity of the system (towards the Central zone)

Transmission between areas	Maximum transmission at peak load (MW)
South → Central	314.4
East → Central	616.2
North → Central	564.7

Based on OC-SENI (2015c) data

The transmission infrastructure and ETED operation are financed through a regulated transmission fee. ETED is obliged by law to allow third-party access (generators, major consumers and distributors) to its high-voltage network. According to the current regulation, the generator initially bears the costs of connecting new generation and the corresponding reinforcements required in the existing grid. ETED compensates for these generator costs throughout the lifetime of the project.

Distribution

As of 2014, around 78% of all electricity demand in the country was distributed by the three state-owned

Table 4: Transmission expansion plan

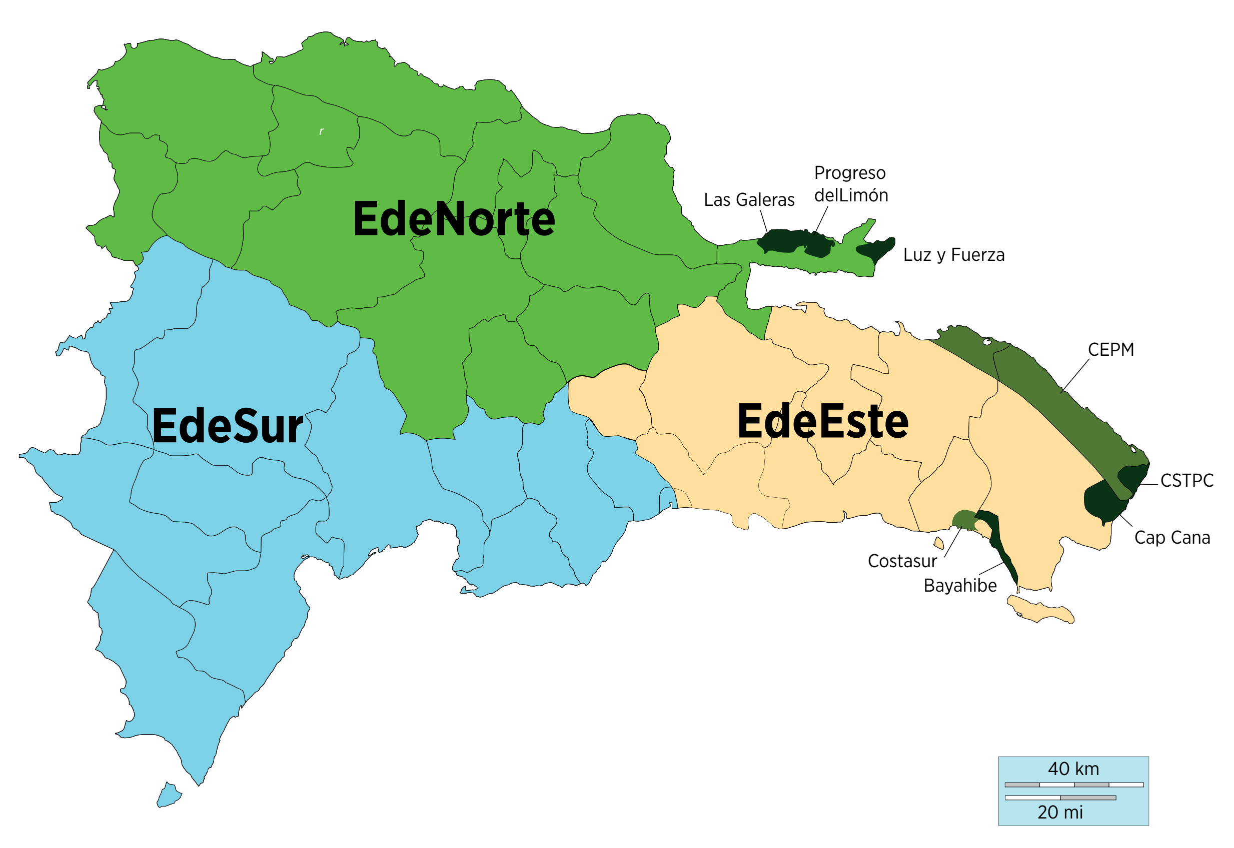
Components	Km of transmission line			Capacity of transformers (MVA)
	345 kV	138 kV	69 kV	
TOTAL	**221**	**911**	**134**	**3 035**
	Percentage of the total			No of substations
Central	19%	5%	0%	9
North	49%	46%	83%	35
South	32%	26%	9%	12
East	0%	23%	8%	8

Based on ETED (2013) data

companies, EDESUR, EDENORTE and EDEESTE, which are connected to SENI. In addition to the three main concessions are seven main non-interconnected zones.

Figure 13 shows the jurisdictions of each distribution concession and table 5 summarises key data for the three distribution companies connected to SENI.

Figure 13: Map of the three state-owned distribution companies EDESUR, EDENORTE, and EDEESTE and the larger off-grid systems



Source: CNE (2015); background map from d-maps (n.d.)

CEPM – Punta Cana-Macao Electricity Consortium (Consorcio Eléctrico Punta Cana-Macao); CSTPC – Punta Cana Touristic Services Corporation (Corporación Servicios Turisticos Punta Cana)

Table 5: Characteristics of the state-owned electricity distribution companies

Company	Concession surface (km²)	Clients	Provinces/ municipalities	Circuits	Substations	Transformation capacity (MVA)	Km of medium voltage lines (34.5-2.4 kV)
EDENORTE	16 274	805 107	14 / 67	192	79	1 336	11 170
EDESUR	17 943	610 055	11 / 63	194	50	1 300	6 629
EDEESTE	11 700	625 097	7 / 26	164	43	1 300	6 930

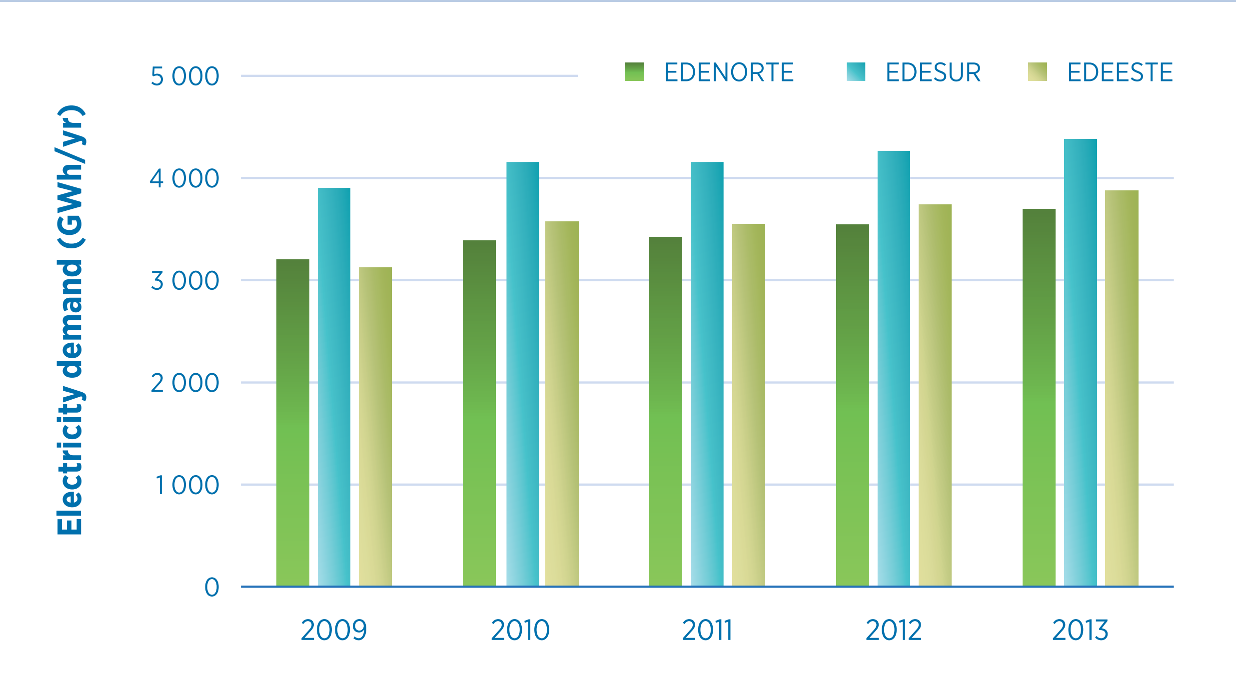
Source: CDEEE (2015), OLADE (2013) and Ingenieros y Economistas Consultores (INECON) (2016)

EDENORTE and EDEESTE have been distributing fairly equal amounts of electricity in recent years. In 2014, each supplied around 4 TWh of electricity. The National District and Santo Domingo province, which accounts for the most demand in the Dominican Republic, is supplied by EDESUR (for the municipalities of Santo Domingo West) and EDEESTE (for the municipality of Santo Domingo North and East). EDENORTE, EDEESTE and EDESUR are also in charge of the electricity retail for regulated costumers in their jurisdictions. Figure 14 shows the evolution of annual electricity distributed by the three main distribution companies for 2009-2013. Delivered electricity in each jurisdiction in Figure 14 does not correspond exactly to electricity demand because some of it has not been supplied due to programmed disconnections.

The high electricity losses at the distribution level explain one of the challenges faced by the Dominican Republic power sector. As reforms were introduced, the three main distribution companies were acquired by foreign electricity firms. In 2000-2010, the government repurchased the shares of the three companies due to financial difficulties associated with tariff collection and high levels of non-technical losses.

According to CDEEE estimates, the total annual losses in the distribution system are around 35.9% of the

Figure 14: Electricity distributed by each state-owned distribution company



Based on CDEEE and EDEs (2015) data

electricity purchased by the EDEs. This value includes electricity purchased by the distribution companies but not billed, as well as billed electricity with an uncollected tariff. Total losses in the Dominican Republic are well above regional levels, as in other countries these are around 15% (CDEEE and EDEs, 2015).

The majority of losses at distribution level are non-technical. This has affected the capacity of the distribution companies to recover their operational costs through tariffs. This situation poses a risk to the long-term future of the country's entire power supply chain and has resulted in a number of supply interruptions.

Figure 15 shows a breakdown of total distributed electricity for 2009-2013 with a breakdown of tariffs collected and uncollected as well as the volume of losses. The share of collected electricity has been increasing. The distribution company losses have decreased slightly. In addition, uncollected electricity has shown a slight fall over the same period.

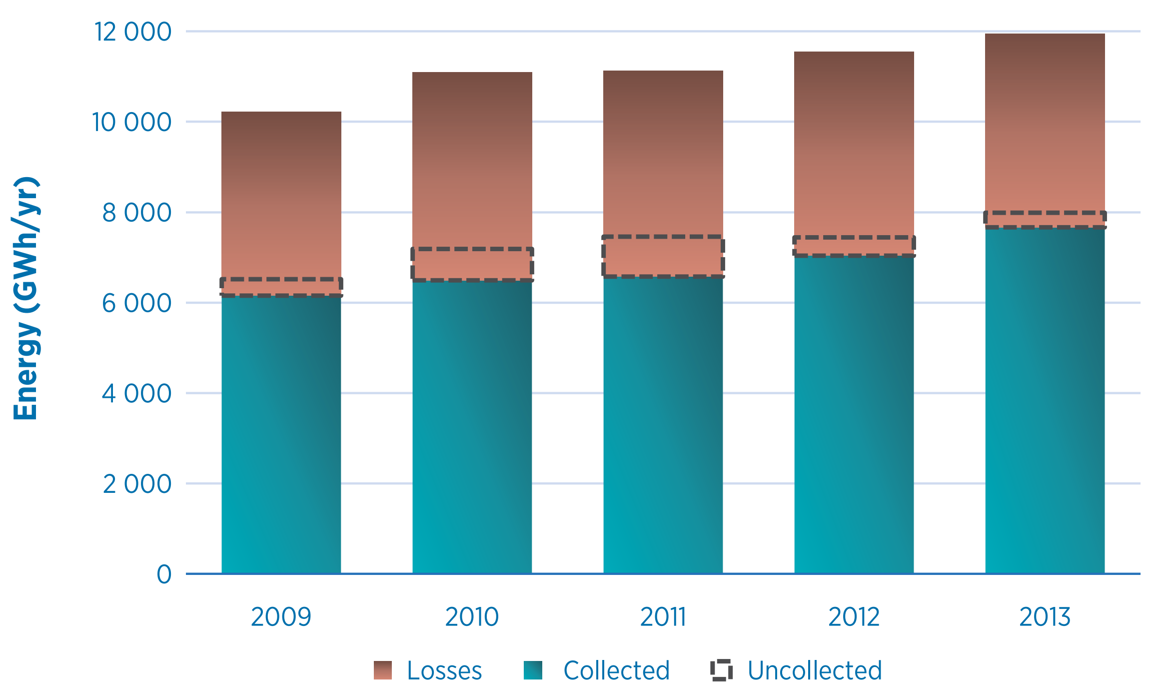
Independent system operation

OC-SENI is in charge of planning and co-ordinating the operation of the interconnected system in the Dominican Republic. The operation aims to deliver electricity at a minimal economic cost, fulfilling the reliability and quality criteria set in the regulation. The process involves five stages with different time horizons:

- Long-term operation planning (four years ahead, updated every year)
- Outage scheduling for major maintenances (one year ahead, updated every year)
- Mid-term operation planning (one year ahead, updated every month)
- Short-term operation planning (generation scheduling, day and week ahead)
- Redispatch of daily operation in co-ordination with the real-time operator (intraday)

The long- and mid-term operational plans assess the availability of generation resources to guarantee

Figure 15: Energy losses and energy billed in the electricity distribution system, 2009-2013



Based on CDEEE and EDEs (2015) data

enough power and energy to cover demand at minimum operational costs in the corresponding time horizons. Additionally, OC-SENI makes annual updates of the assessment of the transmission capacity in co-ordination with ETED. They identify secure limits for the transfer of power between the different operational areas of the transmission system.

The long- and mid-term plan results, as well as the updated information on network restrictions, power plant availability and operational costs, are used by OC-SENI for weekly and day-ahead generation scheduling. Generation is scheduled on a merit order basis with hourly resolution. This means the bids of available thermal plants with the lowest-declared variable operational costs are used to cover forecast hourly demand.[24] The resulting hourly marginal cost, the marginal short-term cost of energy, is used to value energy transactions in the spot market.

Renewable energy resources included in the special regime of Law 57-07, as well as run-of-river hydropower plants, take priority in the merit order. They are dispatched according to their declared availability. Hydropower plants with reservoir regulation are scheduled by OC-SENI according to the available weekly energy declared by EGEHID. According to current regulation, OC-SENI aims to use the available energy from the hydropower reservoirs during peak hours or when they can provide operational reserves or security-constrained generation. The operational costs of hydropower reservoirs are assumed at zero.

Due to security constraints in the system, out-of-merit order generation can be scheduled by OC-SENI. In these cases, generation is compensated with the declared variable operational costs as long as it is below the indexed price cap (*costo marginal tope*) defined by the regulator SIE. In December 2015, the indexed price cap stood at USD 93.56 per megawatt-hour (MWh) (OC-SENI, 2016).

During real-time operation, the day-ahead programme is rescheduled in case of grid contingencies or major deviations from forecast generation or demand. This includes generation outages or changes in the availability of special regime or run-of-river renewable generators.

Currently 3% of expected scheduled generation is allocated for primary and 3% for secondary reserves. Unless previously agreed, all the units in SENI are obliged to provide primary reserve services. Secondary reserve is provided only by selected units.

Wholesale power market

Electricity in the Dominican Republic interconnected system is traded between generators and large consumers through the wholesale power market. Large consumers include the non-regulated users and the distribution companies. Electricity is traded through long-term bilateral contracts or the spot market.

The amount, price and conditions of the long-term contracts are bilaterally agreed between generators and consumers. The spot market settles differences between contracted, produced (according to merit order) and consumed electricity. According to present regulation, at least 20% of total energy must be traded through the spot market.

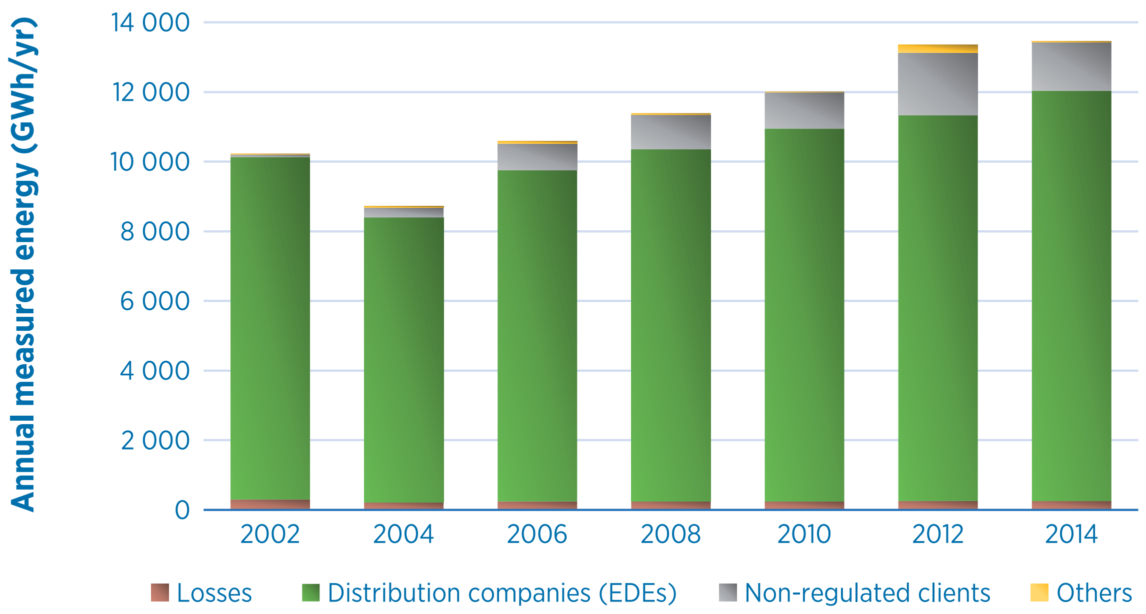
Figure 16 shows a breakdown of the amount of the electricity taken by distribution companies, non-regulated consumers connected at transmission level and losses in the transmission network. Figure 17 shows monthly energy traded through long-term contracts and spot market in 2014.

Figure 18 shows the monthly average price paid by the EDEs for an energy unit in 2014-2015. According to Martínez (2013), major factors influencing spot market behaviour include availability of thermal units, fuel costs, long-term contract prices, demand evolution, reservoir levels and water inflows.

Generators in the market are also remunerated for the firm power generation capacity they provide to the system. This is done through power transactions (*transacciones de potencia*) in proportion to firm power the generators can contribute to cover peak demand every month. As of 2014, the monthly payment for firm power was around USD 8.6/kW (OC-SENI, 2015d). According to the definition in Law 57-07 and its application rules, non-dispatchable renewable

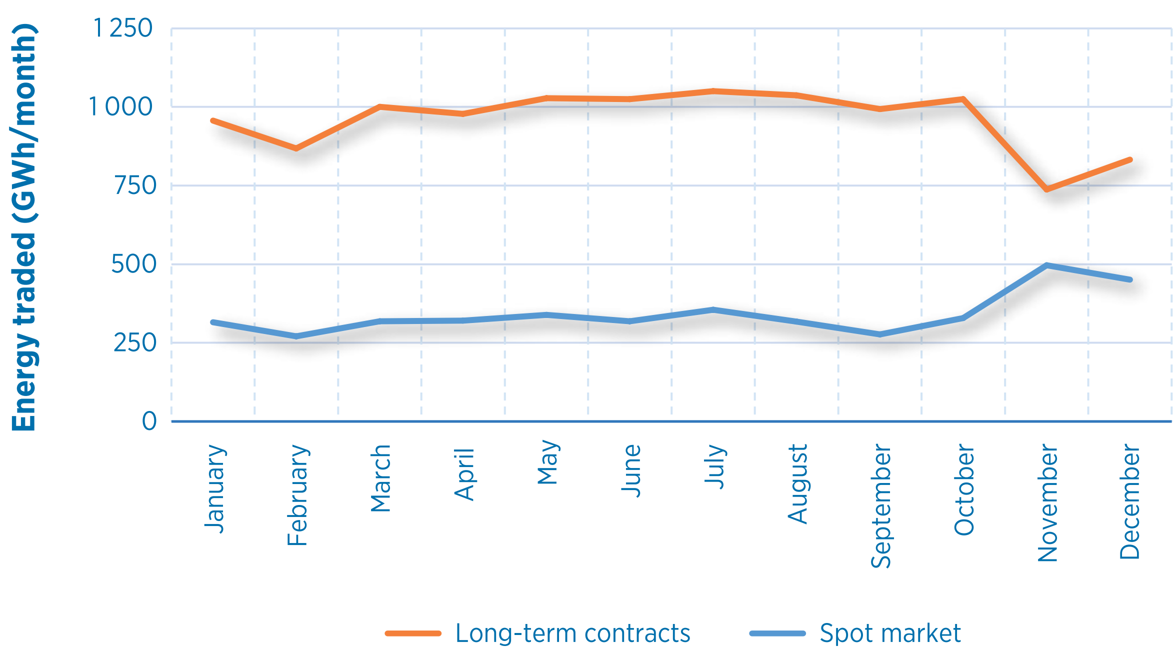
24 Hydropower availability is declared weekly by EGEHID, and power is dispatched by OC-SENI to minimise operational costs according to available energy.

Figure 16: Annual energy measured by SENI for selected years (2002-2014)



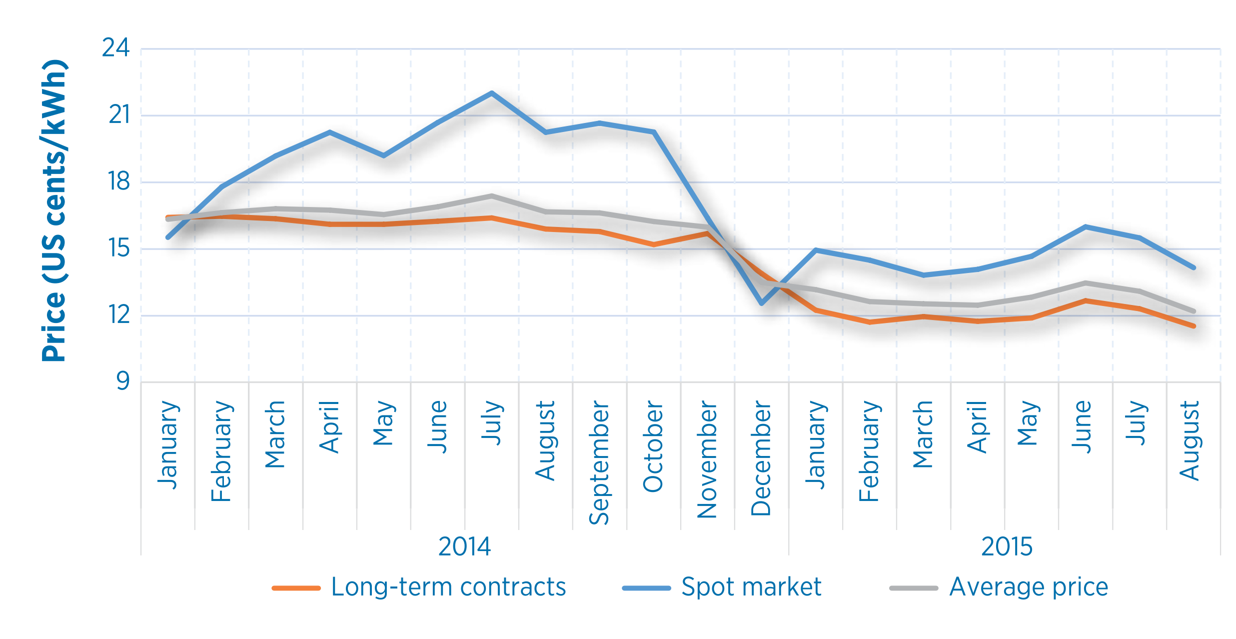
Based on OC-SENI (2014a) data

Figure 17: Breakdown of monthly energy traded by OC-SENI, 2014



Based on OC-SENI (2014b) data

Figure 18: Monthly average price at which EDEs purchased electricity between 2014 and mid-2015



Based on CDEEE (2015) data

energy generation is not considered as firm power and therefore does not participate in the power transactions.

Off-grid systems

There are seven large off-grid systems in the Dominican Republic (see Table 6). These are mainly located in touristic areas. Most are owned and operated by private companies. Total installed generation capacity in the isolated areas is around 270 MW at the moment – close to 6% of the country's installed capacity. The net electricity generated in these seven areas is estimated at around 1 TWh, representing approximately 7% of total national demand. Table 6 provides basic information about the largest off-grid systems in the whole country:

Table 6: Off-grid system characteristics

Region	Company responsible	Type of company	Installed capacity (MW)	Net generation (GWh)
Punta Cana	CEPM	Private	113 (181[25])	362 (854[25])
	Cap Cana	Private	23	49
	CTSPC	Private	19	50
Bayahibe	Electricity Company of Bayahibe (CEB)	Private	24	15
Pedernales	EGE Haina (generation), EDESUR (distribution	State-owned	5	16
Las Galeras	Luz y Fuerza	Private	19	21
Costasur	Costasur	Private	NA	NA

Source: CNE (2016d)

25 Total installed capacity and annual generation taking into consideration the interconnection with Sultana del Este (EGE Haina) in San Pedro de Macoris.

The off-grid system in the touristic area of Punta Cana, owned by the private company CEPM, is the largest in the country. The total installed capacity, mainly fossil fuels (heavy and light fuel oil), is around 181 MW, and annual electricity generation close to 855 GWh. CEPM provides electricity from its own generation resources and through a PPA with EGEHAIANA which injects power from the Sultana del Este power plant through a dedicated transmission line.

2.5 Current renewable energy status by sector

Renewable energy in the power sector

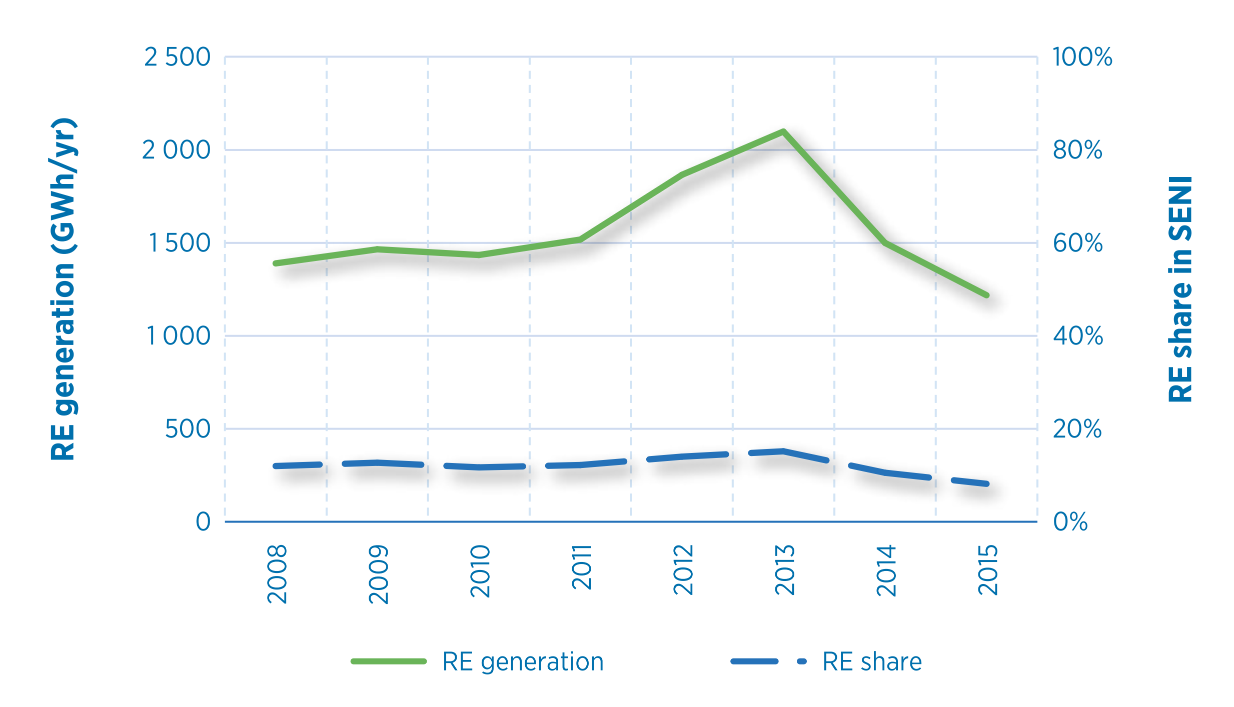
In 2014, total renewable generation installed capacity amounted to 795 MW. The installed renewable capacity in SENI was 717 MW – about 19.2 % of the total installed capacity in SENI. This included 613 MW of hydropower (66 MW of small-scale plants with capacity below 10 MW), 85 MW of onshore wind, 27 MW of solar PV (including autoproducers) and 70 MW of bioenergy (including residues and waste) (CNE, 2016c; IRENA, 2016d; Worldwatch Institute, 2011).

In the course of January to July 2016, 50 MW of wind power (Larimar I) and 30 MW of solar PV (Monte Plata) have been commissioned. In addition, 30 MW of bagasse cogeneration is expected to be online by the end of 2016.

According to projects with a final concession (see Table 1), about two-thirds of generation expansion capacity is based on renewable energy resources. The planned projects include 588 MW of hydropower plants over 10 MW, 715 MW of onshore wind, 175 MW of solar PV and 9 MW of mini-hydropower (CNE, 2016c, forthcoming).

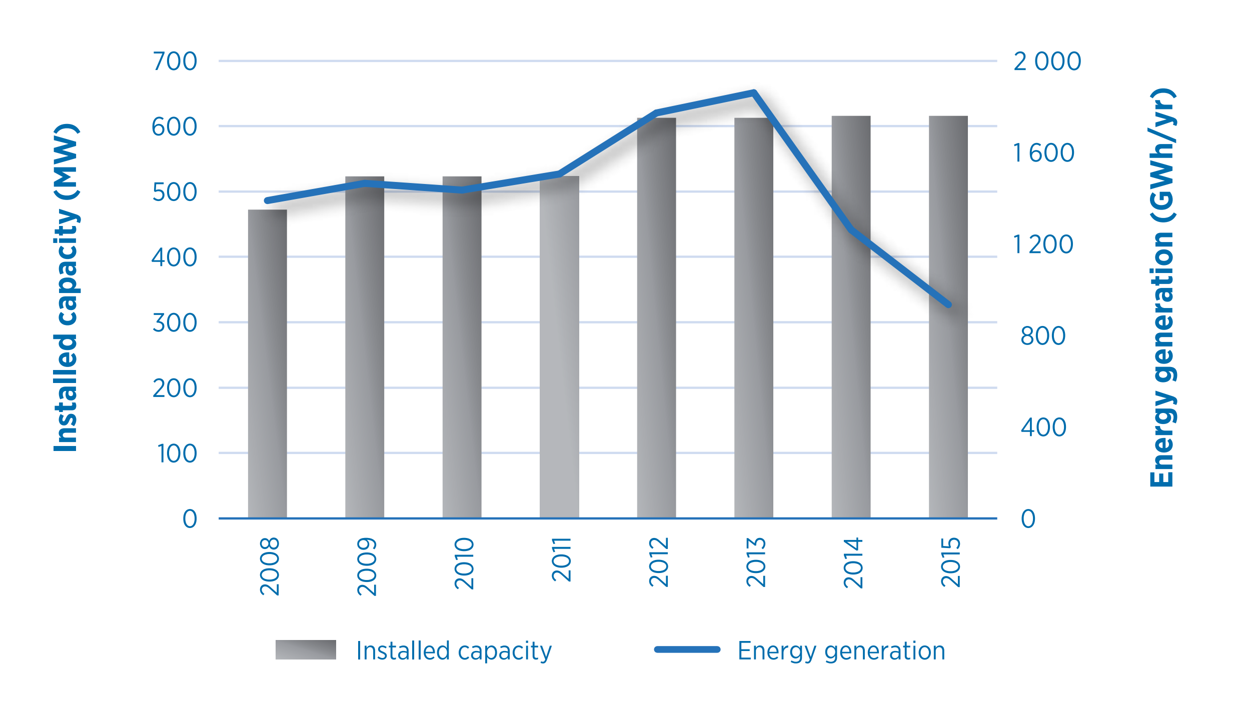
As previously discussed, renewable energy resources have priority in the order of dispatch determining the power system daily operation. The use of these resources for power generation thus mainly depends on their availability. In 2015, electricity generated from renewable resources in SENI was 1 217 GWh, representing 8.1% of the SENI total. Despite the increase in both total installed capacity and wind power production, the total share of renewables has not grown constantly over the last four years (see Figure 19). This has been attributed to the severe droughts of 2014 and 2015 (El Dinero, 2015).

Figure 19: Renewable energy generation and share in SENI, 2008-2015



Based on OC-SENI data (2008, 2009, 2010, 2011, 2012, 2013, 2014a, 2015a)

Figure 20: Hydropower installed capacity and annual generation, 2008-2015



Based on OC-SENI data (OC-SENI, 2008, 2009, 2010, 2011, 2012, 2013, 2014a, 2015a)

As shown in Figure 20, electricity generation from hydropower plants has decreased considerably over the last two years. While electricity production has fallen, installed capacity has increased from 2011 to 2015.. This is mainly due to 90 MW commissioned from the Tavera, Valdesia and Palomino plants in 2012.

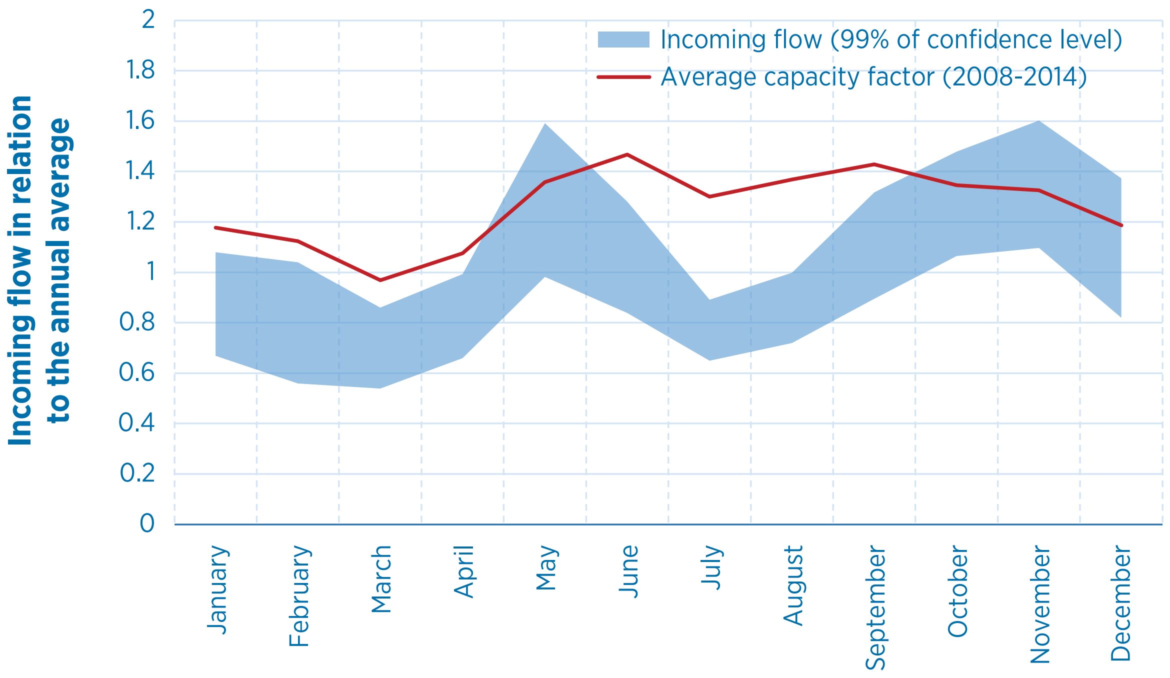
Figure 21 presents the statistics for the monthly incoming flow of five of the country's main dams (ACQ y Asociados, n.d.) and the hydropower figures reported by OC-SENI (OC-SENI, 2008, 2009, 2010, 2011, 2012, 2013, 2014a, 2015a). These were used to observe the seasonality of the hydropower resource availability and operation. The blue bars show the incoming flow times in relation to the annual average with a 99% confidence level while the red line shows the average monthly capacity factor in 2008-2014.

In 2010, there were 26 small hydropower plants of less than 5 MW with a total capacity of 15.4 MW. More than nine micro-hydropower plants have been built within the past two years, benefiting more than 4 000 families and ten schools. In total, more than 15 300 people benefited from this, and 665 kW micro-hydropower plants were have been installed (Liu *et al.*, 2013)

Installed wind power capacity is currently 135 MW (as of mid-2016). It consists of four power plants: Los Cocos I and II, Quilvio Cabrera and Larimar I, the plant commissioned in 2016 (CNE, 2016c; IRENA, 2016d). All the existing wind power plants are in the southwest of the country (CNE, forthcoming). Figure 22 details the evolution of installed wind power capacity and annual wind power generation in the Dominican Republic. In 2015, total wind power generation was 284 GWh, representing 1.9% of total electricity production in SENI (OC-SENI, 2015a). The annual average capacity factor has amounted to around 34% over the last three years of operation (OC-SENI, 2010, 2011, 2012, 2013, 2014a, 2015a).

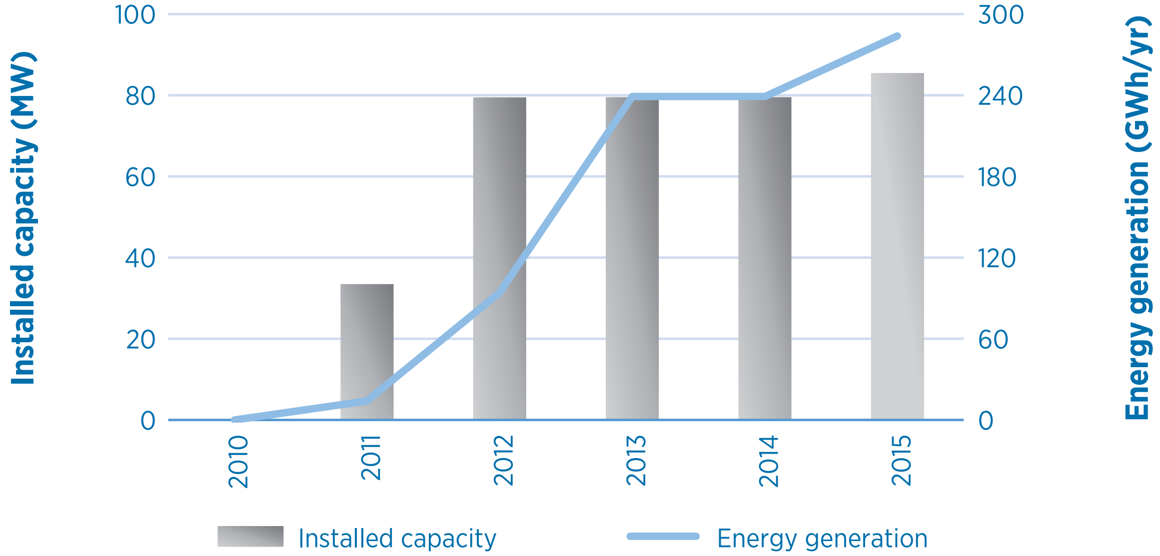
Figure 23 shows operational seasonality over the last few years (2012-2014) of the main renewable energy resources, wind and hydropower. The wind capacity factors are over 30% most of the months and at their maximum in December- January and June-July.

Figure 21: Hydropower resource availability and average capacity factor



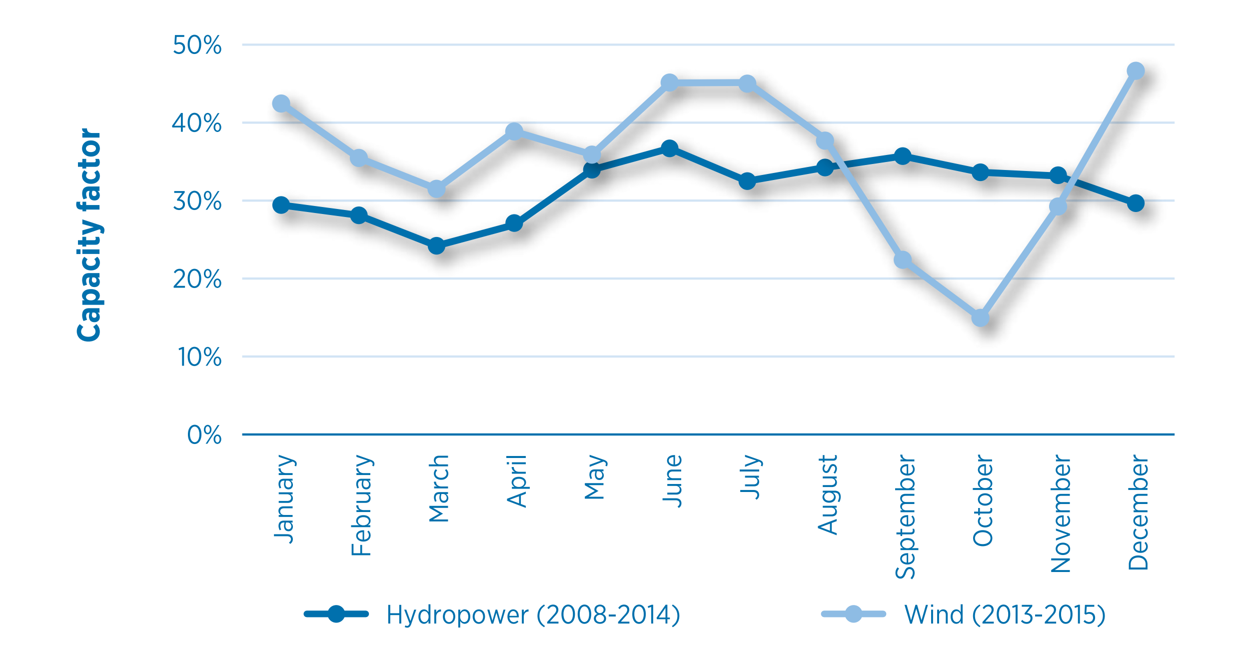
Based on ACQ y Asociados (n.d.) and OC-SENI (2008, 2009, 2010, 2011, 2012, 2013, 2014a, 2015a) data

Figure 22: Wind power installed capacity and annual generation, 2010-2015



Based on OC-SENI data (2010, 2011, 2012, 2013, 2014a, 2015a)

Figure 23: Monthly capacity factor for wind farms (2013-2015) and hydropower (2008-2014)



Based on OC-SENI data (2010, 2011, 2012, 2013, 2014a, 2015a)

However, a steep decline can be observed in September-October. The hydropower capacity factor and resource availability experiences one of its peaks during this period of low wind energy production. This behaviour suggests that the complementarity between both resources could be subject to more detailed analysis in future.

Direct uses of renewables in heating, cooling and transport

There have been as yet no major deployment in the use of renewables as direct fuel for heating or transport. Biodiesel or biogasoline (referring mainly to ethanol produced from biomass feedstocks) is hardly used at all for transport (biodiesel only represented around 0.1% in 2014). However, the country is developing biodiesel from vegetable oil. At least 11 pilot projects are growing the necessary feedstock crops, and two bioethanol projects are using sugar cane and sweet sorghum as feedstock (National Renewable Energy Laboratory, 2015). To date, they have not reached commercial scale.

Despite the low growth in renewables use for transport, there are electrification plans. Expansion of the existing Santo Domingo metro is planned. If renewables could meet the demand for new electricity, the transport sector's renewables share would increase accordingly.

Biomethane is another potential technology option in the Dominican Republic transport system but no production has taken place yet. Today, more than 15 000 natural gas vehicles refuel at 27 service stations. These figures are expected to increase and can increasingly be replaced with biomethane produced from various waste streams if cost-competitiveness allows (Institute of Americas, 2015).

Demand for heating (mainly for cooking and hot water) in Dominican Republic residential and commercials buildings is low, representing less than 20% of the total. Cooking and cooling account for the majority of the total energy use in residential buildings, which compares with significant demand for cooling and lighting in commercial buildings, notably hotels. There is still no market for cooling systems based on solar water heating and renewables. By comparison, other countries in the area, such as Barbados, have made important advances in deploying for instance solar thermal technologies for water heating thanks to long-term policies.

3 RENEWABLES POTENTIAL BY 2030 ACCORDING TO NATIONAL ENERGY PROJECTIONS AND REMAP

This section first describes the potential for renewable energy resources in the Dominican Republic (Section 3.1). This is followed by the Reference Case with a view on the renewable energy prospects assumed in the Dominican Republic's national energy planning (Section 3.2). By contrast, REmap proposes a more optimistic view of renewables, investigating the source of additional renewables potential and how it could be fulfilled. This takes into consideration the associated costs and savings arising from an accelerated renewable energy uptake (Section 3.3). The findings to 2030 for both cases are explained throughout this section.

3.1 Renewable energy resource potential

The Dominican Republic has abundant solar and wind resources. [26] Micro-hydropower also offers some remaining potential in certain parts of the country. Bioenergy potential is limited to several specific feedstocks but could benefit both from vast experience of sugar cane plantation and unexploited land without facing land use change or forestry resource concerns.

Solar potential is particularly large, with GHI levels at 5-7 kWh/m²/day across most parts of the country (Worldwatch Institute, 2015).[27] Irradiance is consistent throughout the year, offering a particular advantage (with the maximum difference in irradiation reaching 3 kWh/m²/day between December and July). For example, the irradiation levels in the two largest cities in the country, Santo Domingo in the South and Santiago de los Caballeros (Centre-North) average over 5 kWh/m²/day throughout the year. This provides favourable conditions for rooftop solar PV systems. Likewise, most tourist areas have at least the same level of resource availability for similar rooftop and/or off-grid systems to completely or partly replace diesel-based systems. Solar system deployment for heating and cooling in buildings and industry are another avenue because the Dominican Republic also experiences strong direct normal irradiance.

Wind potential in this country is also large. A zone-by-zone analysis of wind potential shows that around half the nearly 500 grid points assessed has a capacity factor of at least 20%. Meanwhile, 120 and 78 points have capacity factors of at least 25% and 30% respectively (Worldwatch Institute, 2011).

Much of the country's large hydropower potential has already been utilised. Potential exists to use this capacity more efficiently, thereby increasing individual plant capacity factors that are today limited by water dispatch regulation to prioritise water use for drinking and agriculture. By comparison, there is potential generation capacity from smaller hydropower plants amounting to tens or hundreds of kW, especially in the northern parts of the country.

IRENA's analysis of the bioenergy supply potential in 2030 and the related supply costs according to feedstock is displayed in Table 7. Waste from the agriculture sector provides the greatest potential, as well as animal manure and household waste for biogas. Typical sources of agricultural waste include sugar cane, rice, coffee, banana and cocoa plantations. Apart from harvesting residues that require additional collection costs, these feedstocks come at affordable costs of USD 1-3/GJ. There is some potential for woody biomass (both fuel wood and forestry residues). However, this is low and its costs are significant (IRENA, 2014b).

26 Further details on the distribution of renewable resources in Dominican Republic can be found online in IRENA's Global Atlas tool. One of the maps available can be consulted in the next link: *http://irena.masdar.ac.ae/?map=1694. Maps with GHI and wind speeds are also provided in the annexes of this report.*

27 This is double the GHI levels observed in Germany, which are around 3 kWh/m²/day.

Table 7: Bioenergy supply potential and costs in Dominican Republic, 2030[28]

	Bioenergy supply potential		Supply costs
	Low	High	
	(PJ per year)	(PJ per year)	(USD/GJ)
Harvesting residue	10	25	9
Agro-processing residue	0	18	1
Animal manure & post-consumer household waste	18	32	3
Energy crop from forest land	6	6	17
Wood logging and processing residue	2	2	17
Wood construction, demolition and furniture waste	1	1	17
Total	**38**	**84**	**6-8.1**

The country benefits from low- to high-temperature geothermal resources too but more studies are needed to determine the technical potential. To that end, MEM and the French National Geological Survey (BRGM) have signed an agreement to assess this in an initiative funded by the Inter-American Development Bank (DominicanToday, 2016). No data are yet available to work out the potential deployable geothermal capacity so this has not been not considered in the REmap Options assessment.

3.2 Reference Case 2030

As mentioned in section 1.3, the Reference Case for the Dominican Republic was prepared on the basis of the preliminary results of the energy demand projections between 2013 and 2030 calculated by CNE and Fundación Bariloche (CNE, 2014a). They used the baseline scenario (*escenario tendencial*).[29] The electricity demand and generation projections were scaled up to match total demand and supply estimated more recently for the period 2016-2030. These were provided by CNE.[30]

The Reference Case indicates the Dominican Republic's demand for energy will increase by 41% between 2010 (the base year for IRENA's REmap analysis) and 2030 from 220 PJ (5 254 ktoe) to 320 PJ (7 685 ktoe). This represents a growth of 1.9% per year in the same period.

Fuel consumption in transport increases by just under 45%, continuing to make it the country's largest energy-consuming sector with a total energy demand of 135 PJ (3 224 ktoe) in 2030. In industry, demand increases from 56 PJ (1 337 ktoe) in 2010 to 100 PJ (2 388 ktoe) in 2030. For those years, buildings sector energy demand increases from 68 PJ (1 624 ktoe) to 86 PJ (2 054 ktoe). Demand growth in buildings is significantly lower than for the transport and industry sectors. This is explained by the substitution of traditional uses of bioenergy for cooking and heating with more efficient fuels such as liquefied petroleum gas (LPG)/kerosene or modern bioenergy.

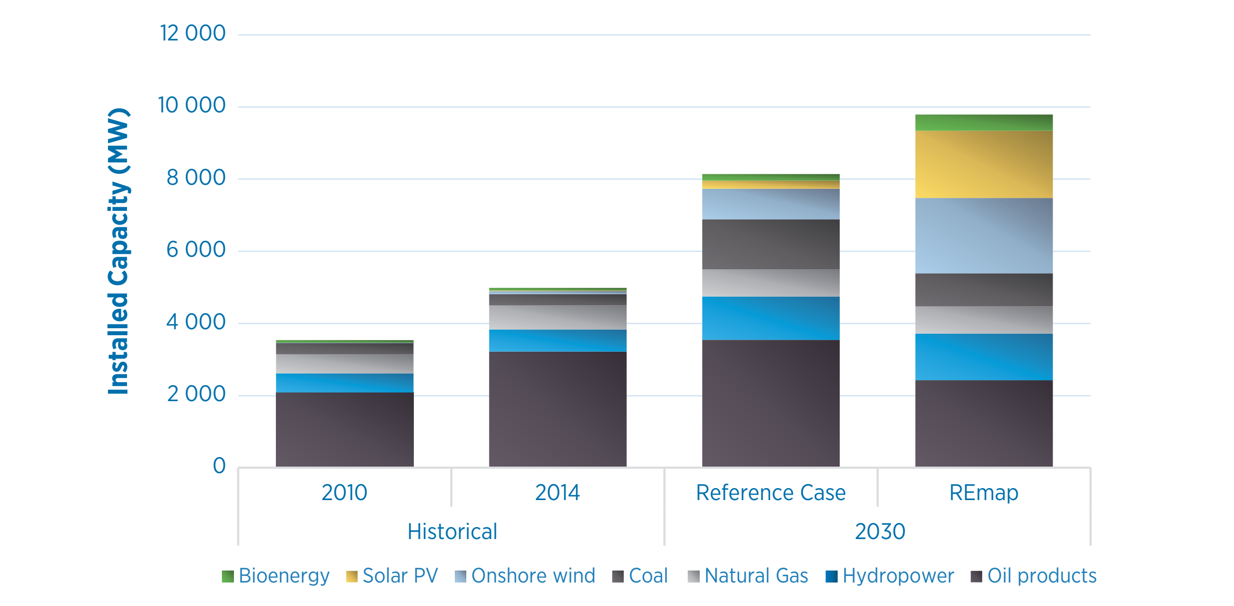
Total power generation also sees a significant increase. Annual generation doubles from 16 TWh to 35 TWh in 2010-2030 (taking into consideration the whole power system *i.e.* SENI, off-grid systems and grid-connected autoproducers). Electricity consumption grows at a similar rate, resulting in a rise in annual demand from

28 In addition, land suitable for sustainable sugar cane harvesting is available *i.e.* without affecting sugar cane for food production. This is estimated at around 100 000 hectares and also offers additional energy crop potential. For further details on supply potential and costs estimations, please refer to the IRENA paper on biofuels (IRENA, 2014b).

29 For bioenergy use in buildings, it was assumed that all woody bioenergy consumed in the residential sector corresponds to traditional uses of bioenergy. However, the minor amount of charcoal consumed was considered to be for modern uses. This assumption is maintained for the entire 2010-2030 period.

30 The projections provided were based on generator technology so the following assumption was made: all power generation capacity reported under the 'dual' category was considered a petroleum product (applies to power generation with combustion engine, combined cycle, open cycle etc.). However, this includes small volumes of natural gas during some generation periods.

Figure 24: Installed power generation capacity and annual demand, 2010-2030



about 14 TWh in 2010 to 31 TWh over the same period. The share of electricity consumption in the country's total energy demand grows from 22% in 2010 to 34% in 2030. It amounts to about a quarter of total energy demand today.

In the Reference Case, the share of modern renewable energy in TFEC (excluding traditional uses of bioenergy) increases only slightly from 8% in 2010 to 13% in 2030. The renewable energy share shows only minor growth in the entire period but this does not mean renewables use does not grow. Instead, this is an outcome of the major increase in the country's total energy consumption, which rises as fast as renewables demand.

When including traditional uses of bioenergy, the share of renewables in the total energy mix remains almost the same at around 16% throughout the period to 2030. This is because traditional uses of bioenergy are replaced by modern forms as well as other modern fuels such as LPG or kerosene. These tend to show higher technical efficiencies for cooking or water heating, thereby utilising less fuel.

Renewables experience only limited additional direct use applications for heating and transport. The main development is for bioenergy in the industry sector, with additions of around 4 PJ (96 ktoe) for process heating. This comes to 13 PJ of bioenergy and represents 13% of energy demand in this sector. There are minor additions of solar thermal for buildings and liquid biofuels for transport, amounting to 0.6 PJ (14 ktoe) and 0.8 PJ (19 ktoe) respectively.

The renewable energy share in the power sector rises from 10% to 21%. The Reference Case sees an increase in hydropower generation (2.3 TWh), onshore wind (2.3 TWh) and bioenergy (almost 1 TWh) which combined amounts to less than the increase in conventional generation of almost 12.8 TWh. In the Reference Case, coal generation would by 2030 reach 10 TWh, oil generation would reach 12.2 TWh (mainly fuel oil and diesel), and natural gas generation would reach 5.3 TWh.[31]

3.3 REmap

Power sector and potential for higher renewable energy uptake

The Reference Case projections indicate electricity demand growth will be increasingly covered by petroleum products, coal and natural gas generation capacity. REmap instead shows that a share of this new demand can actually by supplied by hydropower, onshore wind, solar PV and bioenergy. In the case of

31 Values for the base year 2010 are given in this section, being this year the base for the REmap analysis, nevertheless values for 2014 or 2015 when available have been provided in summary tables of results and annexes.

petroleum products, some existing generation capacity that would be decommissioned by 2030 could also be substituted with renewables.

Coal generation is the highest power capacity addition observed in the Reference Case and is estimated at four times higher than today. The renewables potential identified in REmap substitutes almost half of this additional capacity with small hydropower, utility-scale solar PV and landfill gas power generation. Moreover, all new petroleum-based generation capacity is substituted with onshore wind and solar PV.

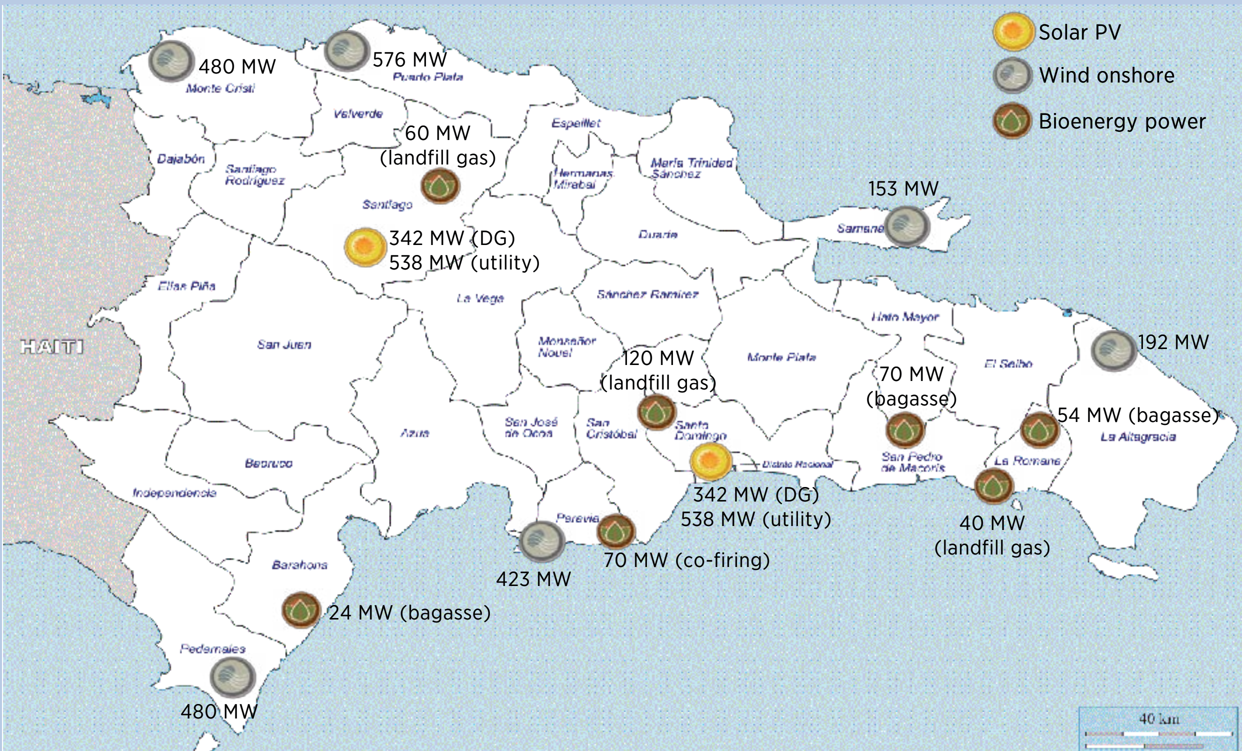
Figure 25 depicts the location of the main solar PV, onshore wind and bioenergy power capacity that would be in place in 2030 under the REmap case. The detailed assumptions and findings are presented by technology. The power generation sector capacity and generation mix are summarised below in Table 8.

- **Hydropower**: up to 90% of all potential hydropower resources for large hydropower plants have already been exploited (Worldwatch Institute, 2015). Small hydropower therefore provides the remaining potential, that is defined in the current Dominican Republic renewable energy law as plants with capacity lower than 5 MW. The 90 MW REmap addition implies building around than 20 small hydropower plants. Hydropower resources are spread across the country thus providing several opportunities where it is more environmental and economically feasible and where demand exists.

- **Onshore wind:** if the 50 MW limit for wind power capacity (explained above in section 2.3) is used as a reference, the total addition of REmap capacity of 1.5 GW translates to around 45 wind farms to be built between now and 2030. If each of the 78 points identified by the Worldwatch Institute (2011) can host a 50 MW wind farm, it would have a capacity factor exceeding 30%.

- **Bagasse based combined heat and power (CHP):** the country's sugar cane production is expected to increase by around 40% by 2024 (US Department of Agriculture, 2014). The main energy by-product from this industry is bagasse,

Figure 25: Location of renewable power generation capacity in 2030 under REmap



Not shown on map: 119 MW small hydro; 1 174 MW large hydro; 9 MW biogas; 102 MW off-grid solar systems

Background map from d-maps (n.d.)

which is today combusted to supply power and heat to the sugar mills. There is major potential to increase combustion efficiency. Combined with growing production and improved efficiency, the resulting additional bagasse-based cogeneration capacity is estimated at 48 MW. This would be installed in three of the largest four sugar mills across the country, namely Cristóbal Colón, Barahona and Porvenir. As there is some CHP capacity already existing or planned in the Reference Case, the total power generation capacity in sugar mills reaches 148 MW in REmap. This would be spread across the sugar mills as follows: 10 MW in Porvenir, 24 MW in Barahona, 54 MW in Central Romana and 60 MW in Cristóbal Colón.[32] It is assumed that the sugar mills would cogenerate electricity and heat mainly to prioritise their own energy needs, especially during the sugar cane harvest, which can last up to 200 days. Surplus electricity could be sold to the system.

- **Biomass co-firing for power generation:** agriculture and small amounts of forestry residues can be used in co-firing plants, increasing installed capacity to 70 MW in REmap by 2030.

- **Biogas for power generation:** in the Reference Case, no growth is assumed from existing biogas power generation capacity. Hence, under the Reference Case, 2030 continues to see an installed capacity of around 790 kW from nine installations. REmap shows a realistic potential of 9 MW by 2030, implying around 60 farms in the country using biogas for power generation integrated with anaerobic digesters fed from animal manure.

- **Landfill gas for power generation:** there is major potential for waste-to-energy from municipal solid waste, especially from the country's large landfills. Total daily urban solid waste amounts to around 8 000 tonnes, with the largest landfill (Duquesa) receiving more than 3 750 tonnes (OPD, 2015). In the Reference Case, landfill gas generation includes the planned power generation project based on landfill gas at the Rafey site. This 80 MW power plant (40 MW biogas and 40 MW natural gas) is due to operate a combined cycle gas turbine and a steam turbine based on the gasification of municipal solid waste. The project is estimated to consume 1 500 tonnes of waste per day (SIE, 2016).

  REmap assumes the construction of an 80 MW landfill gas-powered plant for the Duquesa landfill site. This plant would utilise around 3 000 tonnes of waste each day (assuming its design were similar to the planned Rafey landfill, which will have a gasifier). More than 350 landfills have been identified across the country (Ferreras, 2015). If the 10 major and formal ones are considered, it could be possible to deploy the potential for around 60 MW in capacity on top of the one proposed for Duqesa landfill, increasing the total to 220 MW (assuming around 80 MW are deployed in the Reference Case, including the capacity in Rafey landfill).

- **Solar PV utility-scale**: there is an addition of 871 MW for on-grid utility-scale solar PV. As shown in Figure 25, it is assumed that this will be located close to the main demand centres, namely in the provinces of Santiago and Santo Domingo. Considering the developments expected in the Reference Case, total installed capacity would be above 1 GW in REmap in 2030.

- **Solar PV decentralised (on-grid):** the alternative scenario in CNE demand projections considers 250 MW of installed decentralised solar PV capacity. This has been taken into account and further expanded to include a 665 MW REmap Option comprising on-grid installations for residential and commercial use added to the Reference Case. This can be split into rooftop and ground-mounted systems, and the resulting generation would cover around 25% of buildings electricity demand. Assuming all of this is for rooftop systems, 3.7 million m^2 in roof area is required for residential installations. This would represent about 2% of the available household rooftop area. Likewise, around 1.9 million m^2 would be used for commercial installations,

32 The sugar mills have the following existing power generation capacity to supply their own energy needs, according to the Worldwatch Institute (Worldwatch Institute, 2011): 3 MW in Porvenir, 6 MW in Barahona and 54 MW in Central Romana. In addition, the sugar mill Cristóbal Colón is commissioning a 30 MW plant.

representing around 7% of available rooftop area for this type of building.

It is assumed that some of the decentralised PV capacity will be integrated with battery electric storage. The corresponding energy storage capacity for this in REmap is 440 MWh, and 17% of decentralised PV installations are built. This is an average 4 kWh/kW in energy storage.

- **Solar PV for off-grid rural electrification:** energy access is enhanced by the addition of off-grid PV for rural electrification. In developing countries, PV with storage is becoming increasingly common to provide electricity to rural regions lacking access to transmission or distribution networks (IRENA, 2016a). This includes residential and public off-grid PV installations with electric batteries (equivalent to 400 MWh of energy storage) which would increase the Dominican Republic electrification rate for remote rural areas.

The electrification rate today stands around 96%. According to CNE (2014a), this will reach 98% in 2030 under the assumption that energy access programmes have greater coverage in the coming years. It identifies a solar PV potential of 102 MW for household electrification assuming that universal electricity access is achieved in 2030 *i.e.* around 70 000 installations of 1.3 kilowatt-peak. For public and commercial applications, 9 MW are added in.

Table 8: Summary of results by technology for the base year, Reference Case and REmap – power sector

		Unit	2010	2014	Reference Case 2030	REmap 2030
Installed power generation capacity	**Total installed power generation capacity**	MW	**3 538**	**4 995**	**8 156**	**9 913**
	Renewable capacity	MW	608	795	2 473	5 817
	Hydropower	MW	530	613	1 202	1 293
	Small hydropower (< 5MW)	MW	15	15	28	119
	Large hydropower (> 5 MW)	MW	515	598	1 174	1 174
	Onshore wind	MW	8	85	850	2 304
	Bioenergy (solid, liquid, gaseous)	MW	70	70	181	449
	Autoproducers, CHP (bagasse)	MW	70	70	100	148
	Biomass co-firing	MW	0	0	0	70
	Autoproducers, anaerobic digester	MW	0	0.0	0.8	9
	Landfill gas	MW	0	0	80	220
	Solar PV	MW	0	27	240	1 772
	PV utility scale	MW	0	0	205	989
	PV decentralised (on-grid)	MW	0	27	35	681
	PV decentralised with storage	MW	0	0	2	112
	PV rural electrification (off-grid)	MW	0	0	0	102
	Non-renewable capacity	MW	2 930	4 200	5 683	4 096
	Renewable energy share in total capacity	%	**17%**	**16%**	**30%**	**59%**
Electricity generation	**Total electricity generation**	TWh	**16.2**	**18.0**	**34.9**	**36.2**
	Renewable generation	TWh	1.6	2.1	7.4	15.8
	Hydropower	TWh	1.4	1.6	3.7	4.0
	Wind onshore	TWh	0.0	0.3	2.3	6.1
	Bioenergy (solid, liquid, gaseous)	TWh	0.2	0.2	1.0	2.7
	Solar PV	TWh	0.0	0.0	0.4	3.0
	Non-renewable generation	TWh	14.6	15.9	27.5	20.4
	Renewable energy share in electricity generation	%	**9.8%**	**11.6%**	**21.3%**	**43.6%**

Direct uses of renewable energy in industry and buildings

In addition to the power generation sector potential, there is major potential for renewables in direct use applications for heating and cooling. This has so far been overlooked in the Dominican Republic energy projections used for the Reference Case. REmap identifies opportunities for direct renewables use for heating, cooling and cooking in buildings and for heating and cooling processes in the industry sector. Table 9 provides the results of the Reference Case and REmap mix, and further details by technology and sector are discussed below:

- **Solar water heaters (SWH) in buildings:** the REmap Options estimate residential and commercial solar water heating potential of 2.1 PJ. This is equivalent to adding 1.4 million m^2 (around 960 megawatt-thermal – MWth) of solar collector capacity that would replace water heating boilers based on LPG or electricity. This is less than 1% of rooftop area available in 2030 or around 2 600 commercial installations and 328 000 household installations. Around 60% of the capacity is dedicated to installations in the commercial sector. This REmap Option concentrates on supplying 30% of energy demand for water heating in the residential and 35% in the commercial sector (nearly all to hotels).

- **Solar energy for cooling in buildings:** the REmap Option of 4.5 PJ for solar cooling would cover around 20% of the electricity demand used for space cooling in buildings in 2030. This 350 MW addition equates to 0.5 km^2 of thermal collectors or around 71 000 installations. Less than 0.5% of rooftop area available in 2030 is required to install the collectors. In that year, energy demand for cooling is estimated to amount to 20% of buildings total energy demand.

- **Solar energy for process heat in industry:** this REmap Option would represent an additional 85 MW in solar energy for industrial process heat. About half the capacity is based on flat plate solar and the rest on concentrated solar thermal (CST) collectors. This would imply around 77 and 16 installations respectively in different sites in the country's manufacturing plants. This provides over 0.7 PJ of heat in the form of hot water and steam, which would cover 15% of the energy required for low-temperature process heat generation (below 150 °C).

- **Solar energy for cooling in industry:** this REmap Option, amounting to 40 MW, is equivalent to around 85 solar cooling installations in the country's food sector, which is one of its largest energy consumers.

- **Anaerobic digester biogas for cooking in hospitality sector:** this REmap Option is calculated for the hospitality sector, in which organic waste from food and cooking can generate biogas reused for cooking. This REmap Option would imply around 100 installations of this type.

- **Seawater air conditioning (SWAC):** this REmap Option would provide 4 440 tonnes of cooling mainly for the hospitality sector. The potential identified means introducing seawater cooling in the touristic zone of Puerto Plata. The Remap Option of 0.4 PJ covers 5% of cooling demand in buildings.

- **Modern solid biomass for cooking:** the amount of traditional bioenergy used today in the residential sector (mainly for cooking and to some extent water heating) is almost a quarter of buildings energy use. According to a CNE study (Cruz Castillo, 2014), around 12% of Dominican Republic households still lack modern energy access for cooking, relying mainly on wood fuel and charcoal. Although demand for traditional forms of bioenergy declines significantly, the Reference Case also indicates it persists in 2030. Its share decreases to just above 10% of total energy use in buildings. In REmap, all traditional bioenergy use replaced by modern bioenergy divides into 40% biogas and 60% solid biofuels.[33] Each of these is two or three times more efficient.

33 The REmap methodology does not allow for the replacement of traditional biomass by fossil fuels such as LPG. However, this replacement is assumed to have occurred in the Reference Case because traditional biomass use declines by about 25%, and oil product use increases by around 75%.

Table 9: Summary of results by technology for the base year, Reference Case and REmap – direct uses in buildings and Industry

	Unit	2010	2014	Reference Case 2030	REmap 2030
Total direct uses of energy	**PJ**	**79**	**83**	**96**	**96**
Electricity consumption – buildings	TWh	7.4	8.7	13.7	13.2
Electricity consumption – industry	TWh	6.4	6.4	16.3	16.2
Direct uses of renewable energy	PJ	31	31	28	34
Solar energy for water heating – buildings	PJ	0.4	0.3	1.1	3.2
Solar energy for space cooling – buildings	PJ	0.0	0	0	4.5
Solar energy for process heat – industry	PJ	0.0	0	0	0.7
Solar energy for cooling – industry	PJ	0.0	0	0	0.2
Seawater air conditioning – buildings	PJ	0.0	0	0	0.4
Modern biomass – buildings	PJ	2.8	2.9	3.3	6.2
Cooking biogas (anaerobic digester) – hostelry	PJ	NA	NA	NA	1.2
Cooking biogas (anaerobic digester) – residential	PJ	NA	NA	NA	0.1
Cooking solid biomass – residential	PJ	NA	NA	NA	1.6
Not specified	PJ	2.8	2.9	3.3	3.3
Traditional biomass – buildings[34]	PJ	18	17.4	10	0
Bioenergy for process heat – industry	PJ	9	10.1	13	19
Non-renewable – buildings	PJ	21	22	29	26
Non-renewable – industry	PJ	24	28	36	29

- **Anaerobic digester biogas in the residential sector** – this REmap Option concerns modern energy access in the residential sector. This means substituting traditional uses of solid biomass for cooking in the Reference Case with biogas derived from anaerobic digesters for households.

- **Solid biomass for cooking (modern)** – this REmap Option concerns modern energy access in the residential sector. This means substituting traditional uses of solid biomass for cooking in the Reference Case with efficient biomass cook stoves in REmap 2030.

- **Not specified** – includes all modern biomass for cooking and heating purposes which is part of Reference Case, with no technology specified.

Role of renewables in the transport sector

The main results and related indicators for the REmap case in the transport sector are presented in Table 10. The two main options for transport based on renewables are electrification sourced with renewable power and biofuels – both liquid biofuels and biomethane. The resulting number of battery electric passenger road vehicles (60 000) in REmap would represent around 4% of total passenger road vehicle stock in 2030. Likewise, 160 000 plug-in hybrid electric (PHEV) passenger road vehicles would make up around 11% of the total.

The electrification of public transport has also been considered as an option which adds around 1 100 battery electric buses. This represents around 6% of public transport bus stock estimated for 2030. In addition, 375 000 two- and three-wheelers are estimated, raising the share of electric vehicles in the passenger road vehicle stock to 30%.

There is potential to deploy biogasoline from sugar cane (conventional ethanol) as well as from bagasse (advanced ethanol). Hundreds of thousands of hectares of land previously used for sugar cane production are no longer harvested so a fraction of this arable land

34 All traditional uses of biomass projected in the Reference Case are substituted with modern forms of biomass in REmap 2030 (40% with biogas and 60% with modern biomass cook stoves).

Table 10: Summary of results by technology for the base year, Reference Case and REmap – transport sector

		Unit	2010	2014	Reference Case 2030	REmap 2030
Transport	**TFEC in transport (including electricity)**	**PJ**	**96**	**93**	**135**	**133**
	Electricity consumption (road vehicles, railway etc.)	TWh	0.03	0.05	0.1	0.7
	Total number of electric vehicles	Units	NA	NA	NA	721 100
	Electric vehicles – passenger road	Units	-	-	-	60 000
	Plug-in hybrid electric vehicles – passenger road	Units	-	-	-	160 000
	Battery electric public transport buses	Units	-	-	-	1 100
	Two/three-wheelers	Units	-	-	-	500 000
	Liquid biofuels	PJ	0	0	1.0	5.7
	Biogasoline – conventional	PJ	0	0	0	3.6
	Biogasoline – advanced	PJ	0	0	0	0.4
	Biodiesel	PJ	0	0	1.0	1.7
	Non-renewable fuels (excl. electricity)	PJ	95	93	134	125

could be used for ethanol production. An initial estimate of 40 000 hectares for ethanol production yields conventional ethanol production of 173 million litres per year in 2030. This would mean a volumetric blend of 14% with gasoline.[35] In addition, 20 million litres of advanced ethanol from the remaining quantities of bagasse has been estimated for 2030. Finally, additional biodiesel potential in 2030 equating to 20 million litres per year and added to the 30 million litres in the Reference Case raises the blend to 5% in REmap.[36]

The increased use of electric vehicles provides a significant new potential source of mobile storage. This is one flexibility option for the Dominican Republic power sector, which will increasingly be required to accommodate a higher share of variable renewables because renewable electricity generation does not always match demand. In the Dominican Republic, this is particularly important given that the demand profile is rather flat (as shown in Figure 8 in Chapter 2) and is somewhat higher during the evening. Since PV generation reaches its peak at midday, a significant increase in electricity produced from this technology would change the residual load duration curve (see Section 4.1). This depends on the share and mix of variable renewable energy (VRE) (Ueckerdt *et al.*, 2015).

The energy storage offered by electric vehicles can be deployed under a range of schemes. It could provide services and flexibility measures for load shedding and dispatch to the power system. It could reduce curtailment in hours where renewables generation exceeds maximum penetration of VRE allowed in the system. According to REmap findings, electricity storage capacity from two- and three-wheelers, passenger road vehicles and electric buses for urban transportation could provide a 1.4 GWh in energy storage.

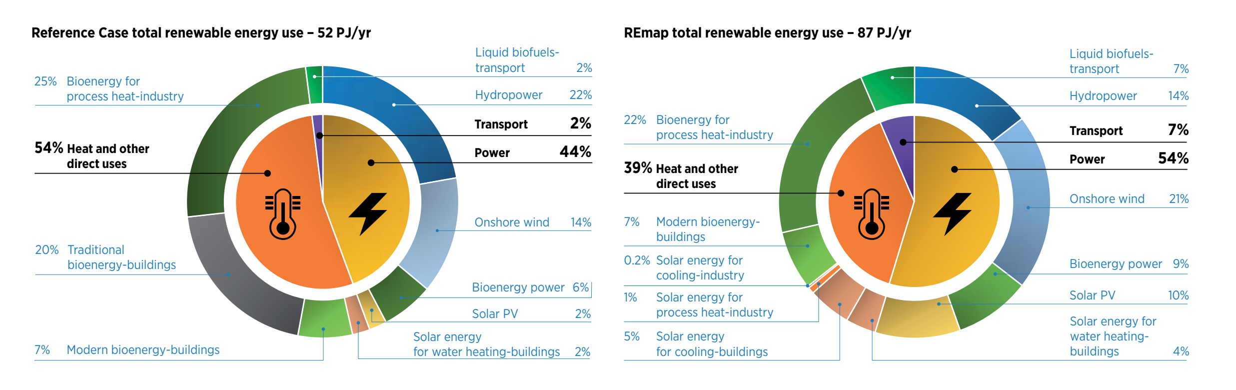
Summary of REmap Options

In the **Reference Case**, final renewable energy use is forecast to slightly increase from 37 PJ in 2010 and 38 in 2014 to 52 PJ in 2030 (1 234 ktoe, Figure 26). Bioenergy in 2010 accounted for 83% of total final renewable energy use and continues to dominate the mix in 2030 although its share is expected to decrease to 77% in 2030. The hydropower portion falls from 16.3% to 14.6% because of wind power growth, which rises from negligible use to 5% of total final renewable energy use. In the electricity sector, hydropower and wind account for most total renewable power production, followed by bioenergy. In the Reference Case, bioenergy remains the main heating and transport sector source. With

35 This is in line with the CNE alternative scenario projection for energy.

36 This addition is based on the CNE alternative scenario projection for demand.

Figure 26: Final renewable energy use in the Reference Case and REmap, 2030

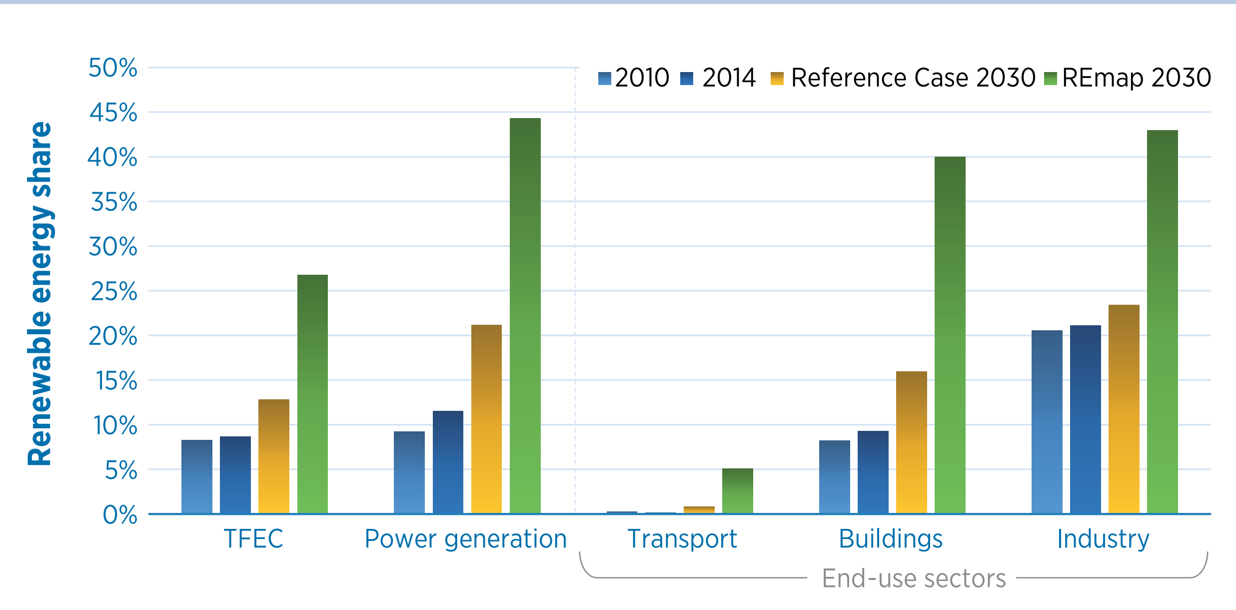


these developments, the power sector would account for nearly 30% of total final renewables use in 2030 under the Reference Case compared to 17% in 2010 at the expense of the heating/cooling sector. This sees its share of total final renewables use falling from 83% to 69% in the same period.

With all **REmap Options** implemented, total renewable energy use in the Dominican Republic TFEC would reach 87 PJ (2 080 ktoe) in REmap, double the 2010 level. More than 60% of this would be renewable power (57 PJ) and the remainder heating, cooling and transport fuels (30 PJ). Modern renewable energy use in the Dominican Republic TFEC would reach 27% in REmap compared to 8% between 2010 and 2014 and 13% in the Reference Case in 2030. Installed renewable power generation capacity would rise from 2.4 GW in the Reference Case to 5.8 GW in REmap. The increase comes mainly from wind (an additional 1 453 MW), solar PV (1 532 MW) and biomass power (268 MW).

Figure 27 shows renewable energy developments by sector in 2010-2030. Compared to their TFEC, buildings and industry would have the biggest renewable energy share in REmap, at 43% and 41% respectively, not including renewable electricity and district heating. When

Figure 27: Renewable energy share in TFEC, power generation and end-use sectors (including electricity and excluding traditional biomass use)



these are accounted for, each sector's renewable energy share is estimated at 45% and 44% respectively as shown in the figure below. The transport renewable energy share would rise to 5.1% in REmap from around 0.3% in 2010. In power generation, the renewable energy share increases to 44% in REmap from almost 10% in 2010 (12% in 2014) or from 21% in the Reference Case in 2030.

Biomass would remain an important source of renewables in the Dominican Republic, accounting for about half the total final renewable energy use in REmap. However, this is still significantly lower than the 83% in 2010. Solar and wind would account for 15% and 22% respectively. The share of hydropower compared to total renewable electricity would fall from more than 90% today to 26% by 2030. This is explained by the substantial growth in all other renewable energy sources in 2010-2030.

This section has focused entirely on the role of renewables in the Dominican Republic. However, demand for energy is growing rapidly so the renewables potential needs to be complemented by energy efficiency to reduce demand growth. This will enable a higher share of renewables and avoid energy-related CO_2 emissions and air pollution (see below in Section 5).

4 WHAT IS NEEDED TO FULFIL REMAP POTENTIAL?

The Dominican Republic has several main objectives for its energy future. It wishes to supply growing demand for energy securely and affordably, ensure actors involved in the power sector make a profit, meet power supply quality standards and shift to a lower-carbon system. However, like any other developing economy it could encounter a number of challenges while coping with growing energy demand.

This chapter provides more detail on the potential difficulties the Dominican Republic may face as its renewable energy share under REmap grows to 27% by 2030 in the total energy mix. It starts with the obstacles in the power sector (Section 4.1) by paying particular attention to institutional, regulatory, economic and technical issues. Potential concerns affecting end-use by buildings, industry and transport follow (Section 4.2). Given bioenergy is a cross-cutting resource offering potential for all sectors, its challenges are discussed separately.

Each main concern is matched with several suggestions for policy makers and other stakeholders to consider. The objective of this chapter is not to provide policy makers with a microscopic examination of challenges and potential solutions. Rather, it identifies and draws attention to the most significant areas affecting the delivery of a higher share of renewables. A detailed evaluation of each challenge would require further in-depth investigation, which is beyond the scope of this study. The purpose of this section is not to replace a detailed power or energy system analysis; the purpose of raising awareness of these challenges is to assist high-level decision-making.

4.1 Power sector

Institutional and economic challenges

Since the first reform in the late 1990s, the power sector in the Dominican Republic has gone through a number of difficulties. These have affected all the stakeholders in the power supply chain and have required government intervention to support the sector with different incentive schemes. According to the 2010 National Energy Plan (PEN 2010) (CNE, 2010), the main challenges to the sector more than a decade after the reform included (CNE, 2010):

- financial sustainability
- high dependency on oil products and vulnerability to price volatility
- loss of confidence by private investors
- loss of consumer confidence in the sector's ability to provide a reliable, sustainable and cost-effective service
- lack of engagement of private investors in the electricity distribution sector

According to CNE (2010, 2008) the main reasons for the problems are as follows: high dependency on fossil fuels coupled with increasing international oil prices; political difficulties in passing increased production costs onto the tariff; and difficulties in reducing non-technical electricity losses and increasing tariff revenue collection.

The Organic Law on National Development Strategy of the Dominican Republic 2030 enacted in 2012 establishes a reliable, efficient and sustainable energy supply as one of its general objectives (Ministry of Economy, Planning and Development, 2012). One specific aim is to ensure a reliable electricity supply with competitive prices and conditions for financial and environmental sustainability. To achieve this, six lines of action address the challenges currently experienced by the power sector to open up new opportunities for deploying renewables. The lines of action include:

1) Promote the diversification of the generation mix, focusing on the deployment of renewable and clean sources like solar and wind.

2) Strengthen the power sector institutional and regulatory framework to ensure competitive

tariffs and promote the investments for sector development.

3) Plan and promote the development of the generation, transmission and distribution infrastructure to operate the power system with the quality and reliability criteria set by the standards.

4) Promote the application of strong environmental regulation in power generation to adopt sustainable practices and mitigate climate change.

5) Develop the right culture to promote energy efficiency.

6) Promote a civic and private sector culture aiming for energy efficiency by introducing rational energy practices and encourage the usage of processes and equipment allowing more efficient use of energy.

In addition to this, the law on national development strategy foresees the completion of a pact between all stakeholders (known as *Pacto Eléctrico*) to solve the crisis that has affected the power sector. The pact was drafted in 2015, and discussions are ongoing.

This step forward is one of several indicating progress towards achieving the established targets. Measurable changes like reduced fuel oil consumption for power generation, the increase in the distribution company Cash Recovery Index (CRI) and reduced debt to the generation companies can be similarly interpreted. However, there is a long way to go yet.

Fulfilling the potential in REmap may not pose particularly great challenges from an institutional or regulatory perspective in relation to current experience and the Reference Case for 2030. However, the creation of an enabling environment for realising this potential will still be important.

A consultation with experts from the power sector has shed some light on the main barriers obstructing the development of renewables today. This consultation goes beyond reports performed by the government and other organisations. Some of these findings are presented below as perceived by stakeholders. This section does not provide a complete overview of all barriers. Its aim is to inform the reader of the view of stakeholders directly involved in day-to-day renewables implementation in the Dominican Republic's power system:

- **Stability of the regulatory framework.** Law 57-07 amended in 2012 is in the process of being amended again to revise the provisions relating to fiscal incentives. The incentives work as income tax credits that are equivalent to a share of the total investment to be redeemed in three years. The share of investment eligible to receive credits was cut from 75% to 40%. This modification has, on one hand, decreased renewables investment attractiveness to autoproducers, and on the other created uncertainty in the regulatory framework and in governmental decisions.

- **Co-ordination and a common vision among the different national institutions** is needed if they deal directly or indirectly with renewable energy regulation, implementation etc. This concerns the effective implementation of the existing legislation and incentives, as well as administrative procedures.[37]

- **Human capacity-building to implement effective regulation and planning for renewables deployment**. This needs to be expanded and improved in relation to renewable energy technology and potential and the use of modern fuels, especially for decision-makers or policy makers defining laws, regulations and planning. Policy makers and key decision-makers in the energy sector should also pursue a holistic vision of the needs and challenges arising in the energy system as a whole when renewables are included.

37 One example of the lack of co-ordination and common view among government institutions is the change to Law 57-07 on fiscal incentives for renewable investments. Some government bodies may be erroneously perceiving a decrease in tax collected due to a high fiscal incentive. This perception also relates to the approach used to estimate taxation. For example, an autoproducer decreasing its expenses with a lower energy bill earns a higher income and thus pays higher income taxes in the long term. Taking a more systemic approach, the reduction in the industry energy bill also stimulates its competitiveness, yielding accompanying economic benefits for the Dominican Republic. These are overlooked when discussing suitable incentives for renewables.

- **Effective implementation of existing and future regulation.** Law 57-07 established a good regulatory framework with general guidelines, yet there have been some limitations to effective implementation of its provisions. Coupled with a somewhat immature renewable energy sector, this has resulted in some less effective or efficient results than foreseen.

- **Development of regulations that fit the national context**. When drafting and implementing the renewable energy laws and its secondary legislation, some provisions are based on international practice and often benchmarked with developed countries, which successfully pioneered renewable energy. This approach is a good start to constructing the necessary frameworks but over the long term may not be effective because these frameworks need to adjust to national circumstances.

In general, stakeholders believe that the Dominican Republic needs to guarantee a stable regulatory framework and better co-ordination between the different governmental entities involved with renewable energy at all angles. This needs to start with policy and planning and continue all the way through to implementation. This is essential to ensure the sector functions correctly, and to incentivise private sector participation in future developments.

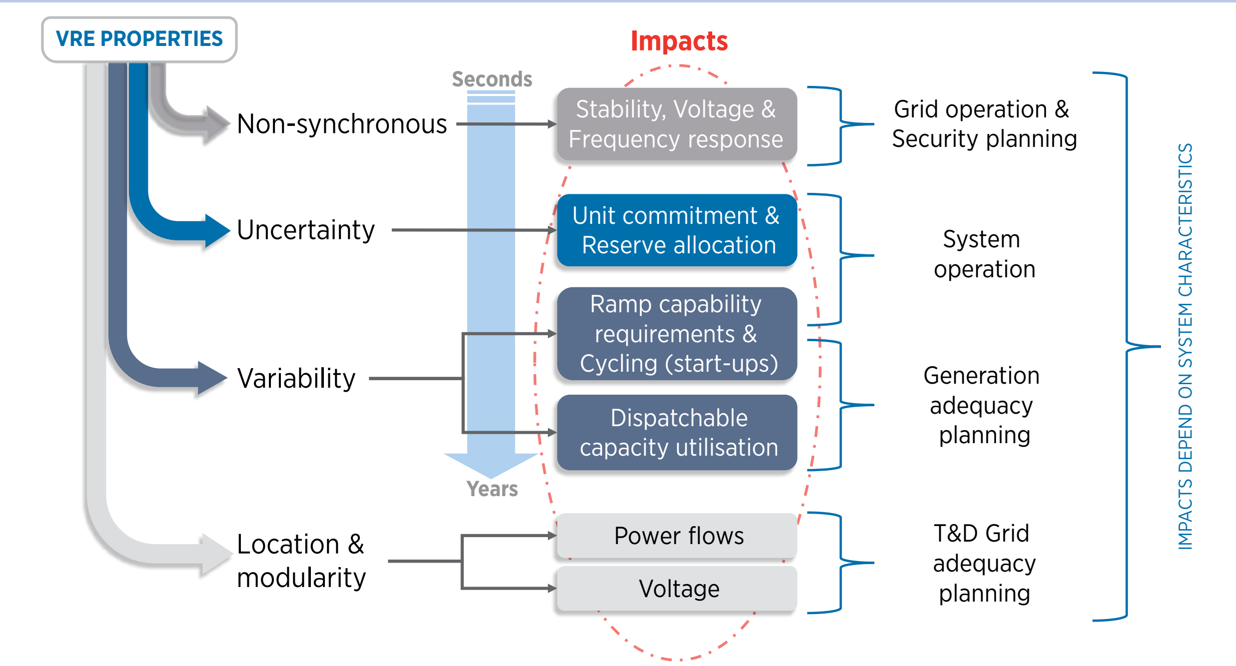
Deploying renewable resources in the Dominican Republic power system will mean overcoming existing and future institutional and technical challenges. As well as attaining the strategic targets in the energy plans to overcome current institutional difficulties, a new comprehensive action plan is needed. This should deal with potential future grid operation issues arising from a high share of VRE like wind and solar PV. This especially if VRE are to play a major role in the total national electricity production.

The technical challenges

VRE resources have different physical characteristics and are usually operated differently from conventional power generation plants. Depending on the share of VRE and the power system features, these differences may prompt changes in the way the systems are planned and operated to guarantee a reliable electricity supply.

Figure 28 summarises the characteristics of VRE technologies, and how these could impact the operation of the power systems.

Figure 28: Summary of VRE characteristics and impacts in system planning and operation



T&D – Transmission and distribution

The REmap Options include high amounts of VRE generation resources. Their integration into the electricity system of the Dominican Republic would make an impact at the technical level. System planners and operators should be aware of these impacts and be prepared to implement the required measures to guarantee the reliable and economic supply of electricity.

A qualitative and simple description of the main technical challenges to be expected from the integration of the VRE REmap Options in the power system of the Dominican Republic is given in the sections below. This description is not intended to replace a detailed power system simulation studies. It aims to provide a reference to identify potential issues that may require the attention of the sector planners, policy-makers, and operators.

Detailed grid integration studies are recommended to assess the challenges described below and identify their potential impact and appropriate measures to overcome them. This should precede any steps to implement high amounts of variable renewables. The challenges identified are explained further below.

Challenge 1: Generation adequacy and utilisation of conventional generation fleet

One potential problem is whether enough energy and power would be available to meet growing demand for electricity at any given time. The variability of the resources leads to low VRE firm capacity. This creates uncertainty associated with the amount of generation that these technologies could provide, and on the amount of installed capacity required.

According to the country's projections, peak power demand within SENI is to increase from about 2.63 GW in 2015 to about 4.5 GW in 2030. Figure 29 shows the projected demand growth for two scenarios and the corresponding hourly load duration curve. The 2030 medium- and low-growth scenarios were obtained by scaling 2015 demand according to the expected growth rate. Only the medium-growth case is analysed below, which looks at the expected production of power from VRE resources and the residual load duration curves for 2030 with Remap options.

The installed capacity under the REmap case for the power sector reaches 2.3 GW and 1.7 GW of grid-connected onshore wind and solar PV developments respectively. The location and size of the developments is summarised in *Table 11*. Both solar and wind developments were located using a resource assessment study carried out by the Worldwatch Institute (Worldwatch Institute, 2015). These figures represent the installed capacity for the regions rather than the installed capacity of individual power plants. For instance, the reported wind capacity for La Altagracia means 192 MW of wind could be installed in the region through one or more power plants.

The performance of the solar PV power plants was modelled using PVLIB, an open source modelling tool developed by the PV Performance Modelling

Figure 29: Power demand projections to 2030 (left) and load duration curves (right)

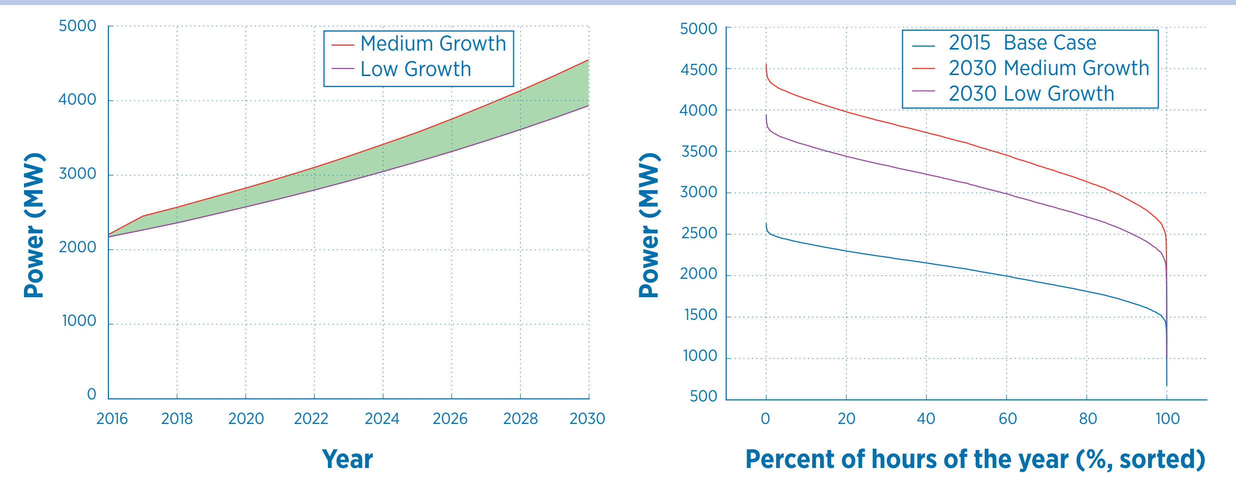


Table 11: Solar PV and wind plant sizing for the REmap Options

Grid-connected solar PV			Grid-connected wind	
Location	**Type**	**Capacity (MW)**	**Location**	**Capacity (MW)**
Santo Domingo	Distributed	342.5	Samaná	153
	Utility-scale	538	La Altagracia	192
Santiago	Distributed	342.5	Bani	423
	Utility-scale	538	Pedernales	480
Total		**1 761**	Montecristi	480
			Puerto Plata	576
			Total	**2 304**

Collaborative (Holmgren *et al.*, 2015; Holmgren and Groenendyk, n.d.; PV Performance Modelling Collaborative, 2014). Solar radiation, wind speed and ambient temperatures reported by the Worldwatch Institute were the inputs for the tool. In both Santiago and Santo Domingo, the utility-scale resources were modelled by ten power plants with 54 MW of installed capacity. Similarly, grid connected distributed generation was assumed to only occur in Santiago and Santo Domingo. These encompassed the aggregated modelling of 114 667 individual power plants with 3 kW nameplate capacity.

The performance of the wind developments was taken from the Worldwatch Institute report (Worldwatch Institute, 2011). This shows the aggregated performance of different power plants in six different regions based on hourly synthetically generated data. This performance is assumed to continue, and only installed capacity for each region was escalated. The share of installed capacity for each region was also retained.

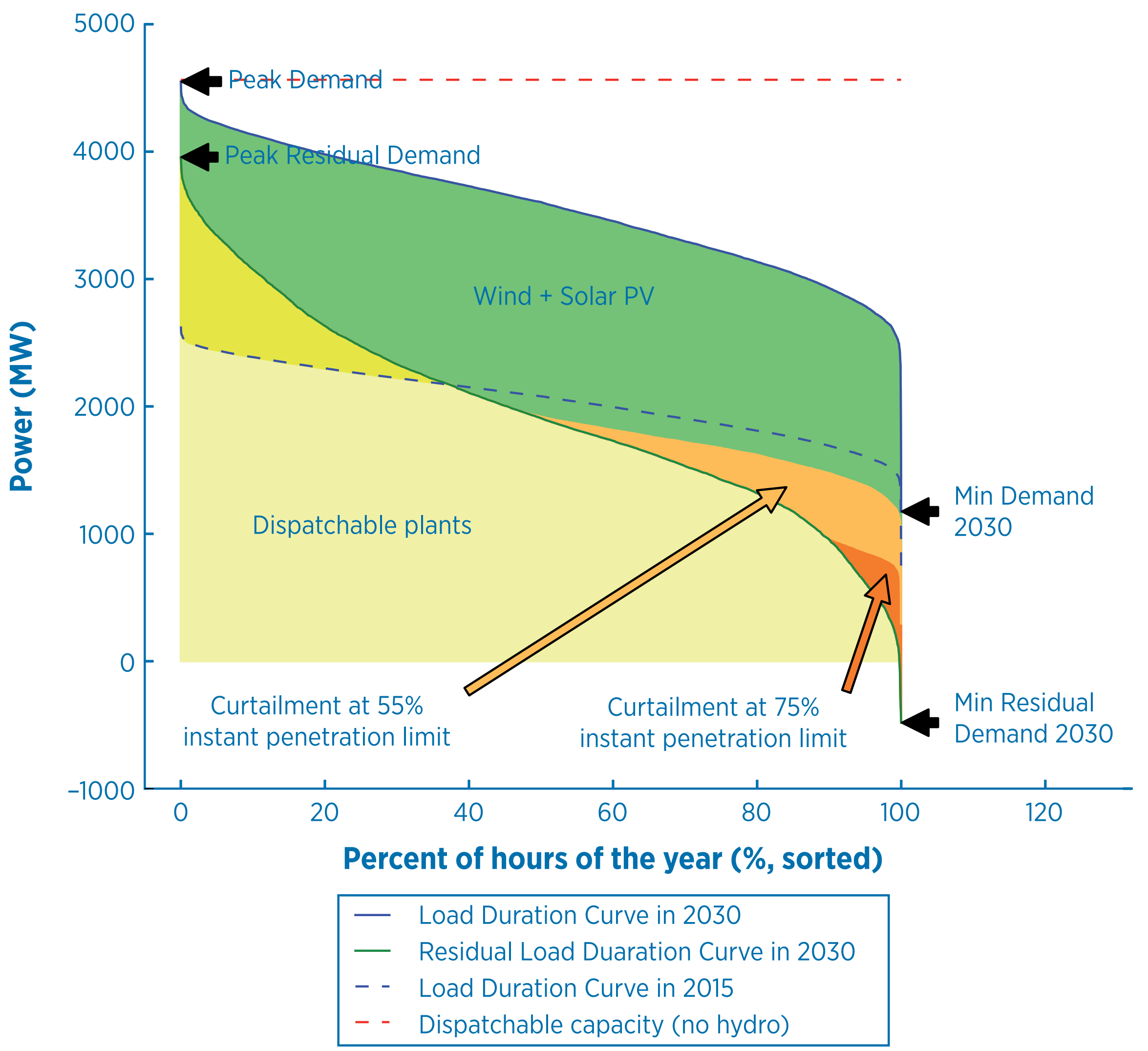
PV and wind production for the entire year were then modelled and compared to projected power demand. This allowed the calculation of load duration and residual load duration curves for the year 2030. Figure 30 shows the resulting curves, and compares them with the 2015 load duration curve.

Figure 30 shows that the residual peak demand is high when compared to peak demand – 3.95 GW and 4.55 GW respectively. This means there at least 3.95 GW of dispatchable generation capacity is needed to cover demand for electricity when production from VRE is available. This requirement increases to the full 4.55 GW when no production from VRE is available. The line represented by red dashes corresponds to the expected installed capacity without hydropower and without VRE in 2030. As can be seen, non-VRE installed capacity without hydropower is higher than peak demand. This in turn means that enough capacity would exist to cover demand at any given time even when no VRE resources are available. However, appropriate financial mechanisms need to guarantee that this firm capacity exists in 2030. If hydropower is taken into account, the system would have larger reserve margins. Nonetheless, a detailed generation adequacy study is strongly recommended to validate and strengthen these conclusions.

The area below the line represented by blue dashes in Figure 30 illustrates the amount of energy consumed in 2015, and generated with dispatchable power plants. Wind generation exists but its contribution to generation is very low, and therefore, not considered in this analysis. The amount of energy required by dispatchable plants in 2030 depends on the level of VRE curtailment imposed. In this analysis, it is assumed that the level of curtailment is defined by VRE maximum instantaneous power penetration restrictions, which associated with the system stability. These restrictions are further discussed in the next challenge. For this analysis, three possibilities were evaluated: curtailment at 55% and 75% instantaneous penetration levels, and no curtailment. Table 12 condenses the results of the three scenarios.

Under the no curtailment scenario, the amount of energy required from dispatchable (non-VRE) sources would be represented by the two yellow areas in Figure 30, while the energy generated from VRE would be the sum of the green and the two orange areas. Under this scenario, the share of VRE in electricity production would amount

Figure 30: Simulated wind and solar PV generation, projected demand, residual demand (left) and load duration curve (right)



Min - minimum

Table 12: Share of VRE and dispatchable plants, 2030

Instantaneous penetration limit	Share		VRE curtailed energy	Energy from dispatchable plants
	Dispatchable	VRE	(as % of 'no limit' scenario)	(as % of 2015)
	(%)	(%)	(%)	(%)
55%	59	41	9.82	2.80
75%	56	44	1.67	-3.56
No limit	55	45	0.00	-4.86

to 45% while the total energy produced by dispatchable plants would amount to 4.86% less than that produced in 2015. The dark yellow area at the left represents the energy that has to be generated by dispatchable power plants and not required in 2015. That area could be viewed as the required “growth” for dispatchable power plants. The height of this area represents the required installed capacity while the x axis dimension represents the amount of time this capacity would be required. The x axis is the percentage of hours in a year.

All this signals two important conclusions for the energy mix. Firstly, less energy from dispatchable plants is required. This means these plants would sell less energy, thus affecting their profitability or at least the revenue from sales of energy. This is even more accentuated if considering new thermal power plants planned or under construction. The profitability of these plants could also be affected by their low utilisation factors (as required by the system). Low utilisation factors could signify more frequent plant and engine start-ups, which can increase plant operating costs, and accelerate its degradation. Plant operating costs increases due to the need of running the power plants at sub-optimal efficiency operating points (Edmundus *et al.*, 2015; Trüby, 2014).

The ‘no limit’ scenario is more illustrative than realistic. Even power systems with the most advanced operational practices impose instantaneous penetration limits to non-synchronous generation. The amount of energy supplied by VRE under the 75% instantaneous penetration limit would equal the green plus the light orange area. The energy required from dispatchable plants would be represented by the two yellow areas added to the dark orange area (see Figure 30). Under this scenario, the total production of VRE would amount to about 44% of total electricity generated, while about 1.7% of the VRE generation would have to be curtailed. This curtailment is relatively small and would probably not jeopardise project development. The share of dispatchable plants under this scenario is 3.56% lower than the share in 2015. Again, this could affect the profitability of these power plants.

The last scenario analysed is within a 55% instantaneous penetration limit. Under this scenario, the share of electricity generated by VRE would be 41%. There is less VRE participation in electricity generation because up to 9.8% of possible VRE generation is curtailed. This curtailment could decrease the profitability of VRE projects but increase the profitability of dispatchable (non-VRE) projects. Electricity generation by dispatchable plants would be 2.8% higher than in 2015.

This simplified assessment of firm capacity requirements and conventional generation utilisation draws out the following conclusions:

- The energy required from dispatchable power plants depends on the production and need for VRE technology curtailment. Forecast models for long- and mid-term planning are thus essential and must be accurate. This could help size the amount of fuel required by thermal and hydropower plants, which in turn, could lead to better economic decisions in terms of when and how much fuel to buy. Long- and mid-term forecasts could also allow better reserve planning over that timeframe.

- At the level of penetration proposed in REmap relating to installed capacity, VRE could provide 41%-45% of electricity consumed in the Dominican Republic, depending on VRE curtailment. The latter is another important parameter because it could make a negative impact on VRE project profitability. Diminishing the amount of energy required by dispatchable power plants could also affect their profitability as well as reducing their utilisation factor, increasing cycling or requiring more frequent start-ups.

- The study suggests there could be enough installed dispatchable power plant capacity for 2030 under this scenario (REmap). The installed capacity of hydropower would probably mean some of the older non-hydro power plants could be decommissioned without affecting the system’s supply security (see Figure 30).

The previous conclusions require detailed generation adequacy studies in which seasonality, volatility of primary energy prices and other variables are stochastically managed. This type of study could strengthen the conclusions drawn here. Generation adequacy studies could also serve to size reserve allocation and assess the need for new generation scheduling practices.

Challenge 2: Managing high instantaneous VRE penetration levels

Regardless of the presence or share of VRE in a power system, balance between power generation and demand has to be achieved. Power imbalances may lead to system frequency diversions from its nominal value. If improperly handled, these could result in serious operational and stability problems, or even complete system blackouts.

Traditionally, balancing activities have been supported by large, fully controlled synchronous generators such as diesel and other thermal power plants. These generators provide inertia and governor response to the system, which help to manage contingency events without major impacts.

A system containing a high level of VRE would displace some of these conventional synchronous generators, thus lowering the rotating inertia. In turn, this means that the more VRE are in a system, the bigger and faster frequency excursions could occur. This especially critical in isolated power systems like in the Dominican Republic, and even more in the event of contingencies.

Measures to overcome this challenge exists, including, fast frequency response electricity storage, VRE production curtailment, interconnection with neighbouring power systems, designating must-run power plants for system reliability, or the requirement for VRE to support balancing activities. The latter is a requirement included in the most advanced grid codes (IRENA, 2016e). The most appropriate solution depends the country's particular grid characteristics, costs and economic projections.

The scale of the potential problem in the Dominican Republic under the REmap case was assessed by estimating the expected instantaneous penetration level of VRE (non-synchronous generation). This was achieved by dividing expected VRE generation by expected demand for each hour of the year in 2030, both calculated in the previous section.

Figure 31 depicts the estimated instantaneous penetration of VRE (non-synchronous generation) in 2030 under the REmap case. The figure shows an instantaneous VRE penetration range of 11.9%-125.4% of demand. Current practice in the most advanced isolated or nearly isolated power systems, such as Ireland, limit instant penetration to about 55% of demand (EIRGRID and SONI, 2016a) mainly because of grid stability issues. The limit to instantaneous VRE penetration in the system may result in VRE power curtailment. This means not all the potential available variable renewable electricity is utilised.

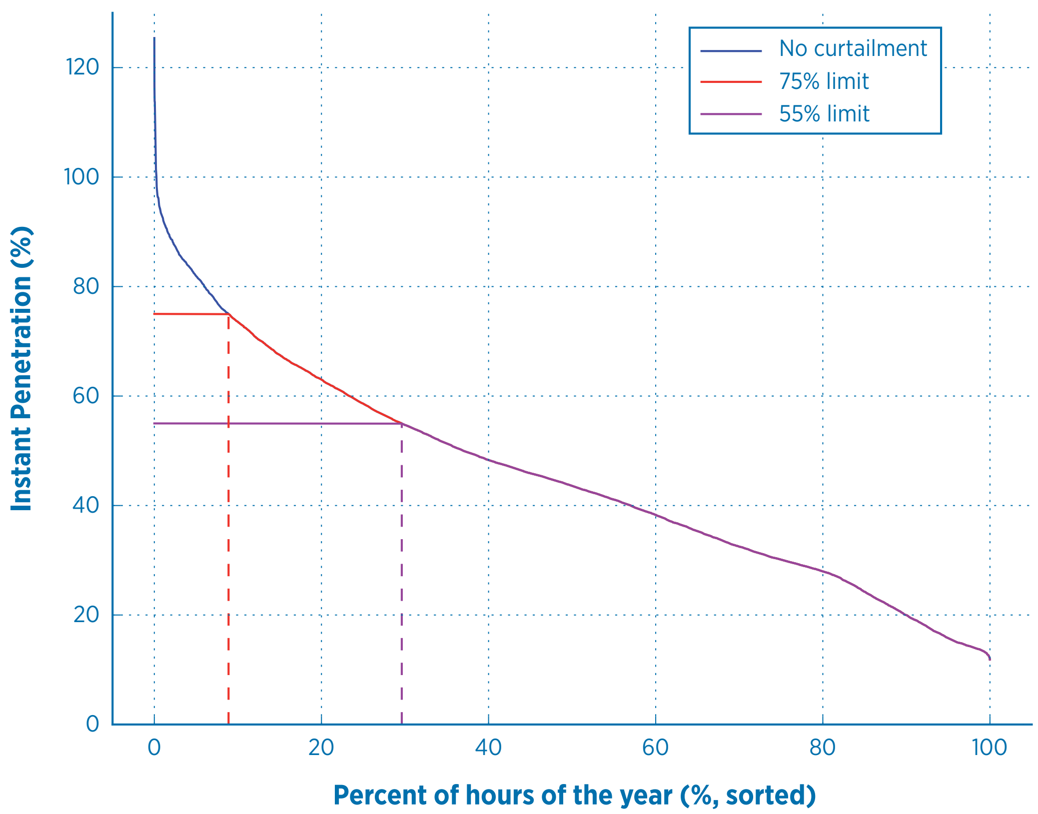
VRE curtailment is not necessarily unacceptable in a power system. When a large share of VRE is planned in a system, possible changes in infrastructure, regulation, market design and system operation are needed. Curtailment could then provide a temporary solution in anticipation of further adaptations to the system (NREL, 2013). These may include acquiring the necessary technical skill to manage a system with low inertia.

Renewable energy curtailment in the Dominican Republic could rise to as much as 10% if instant penetration is limited to 55% of demand. If instantaneous penetration is allowed to reach 75% of the demand, VRE curtailment could fall below 2% with REmap options. The 55% and 75% represent the current and future targeted instantaneous penetration limits in poorly connected front runner power systems (EIRGRID and SONI, 2016a, 2016b).

Figure 31 shows that a 55% instantaneous penetration limit would require VRE curtailment up to 29.6% of the time in a given year. The corresponding number for 75% instantaneous penetration is 8.8%.

This simplified assessment reveals the important message that instant VRE penetration (non-synchronous generation) could impose a technical challenge on the operation of the system. VRE power curtailment could act as a countermeasure to allow infrastructural, regulatory, operational and market design changes ushering in a reliable system at higher instantaneous VRE penetration levels. As with the previous challenge, in-depth analysis of the system and especially of its stability would disclose the actual limits to instantaneous penetration of non-synchronous generation and the consequent curtailment expected. The 55% and 75% limits used in this simplified analysis assume that state-of-the-art infrastructure, regulatory, market and operational measures are embedded in the Dominican Republic. All these measures have to be co-ordinated and built in line with the same vision of the sector, matching technical grid code specifications

Figure 31: Instant VRE penetration duration curve under the REmap scenario



std. - standard; dev. - deviation; hr - hour

with market incentives, regulatory framework and operational needs is key.

Challenge 3: Flexibility requirements due to change in the system net load and management of different and more uncertain ramp rates

In general terms, challenges associated with the balance between power demand and power generation within a timeframe of seconds and milliseconds are related with the instantaneous penetration levels of VRE. These challenges have been discussed above. Power balance (demand plus losses minus generation) within longer timeframes is managed through forward generation scheduling, which is planned ahead. This generation scheduling ensures that enough power can be generated to cover all demand.

System operators do not know the exact demand ahead of time. Thus, in order to create the generation scheduling, they rely on forecasts. Deviations between forecast and actual demand are resolved by adjusting the output of some generation units that are able to rapidly do so (or changing the demand by adjusting the load, which is often known as demand-side response). When demand exceeds the forecasts, balance is guaranteed by means of the so-called, operational reserves. The operational reserves are composed of power generation capacity that can be deployed within a short timeframe (shorter than the dispatch periods). Typically, the generation scheduling programmes are completed one day ahead with intervals that range between 15 minutes and one hour.

In building the generation scheduling programmes, system operators take into account several factors, including: the overall cost of power production of each generation unit and each unit's ability to change its power output (the speed at which a unit is able to change its power output depends on the particular technology and equipment used); previously committed power plants due to contracts; planned equipment maintenance; criteria for system reliability (probability of losing any equipment in the system due to unforeseen events); and uncertainty associated with the demand forecasts and VRE generation forecasts.

In an ideal scenario there would be no unforeseen events (such as plant outages), and no uncertainty in demand and generation, including the power produced by VRE. In reality, events do happen, and demand and VRE generation prediction models are not 100% accurate. Scheduling and dispatch practices therefore need to be reviewed to account for new uncertainties arising from the introduction of VRE. Within the timeframe of the dispatch intervals, the uncertainty and risks accompanying these technologies must be mitigated through operational reserves, or other means. This would compensate for potential differences between planned output generation and actual power demand.

The increased need for ramping capabilities to cover the forecasted demand for power is another challenge related to the incorporation of VRE into a power system. This also affects the generation scheduling programmes. The ramp of a power generating unit is defined as its ability to increase or decrease its power output within a certain amount of time. A power system with no VRE would still have ramping requirements. However, these requirements would only be a function of power demand (the extent to which power demand changes from one dispatch period to the next).

VRE power output can experience rapid, unexpected and steep changes. Thus, the ramping requirements of a system with a large share of VRE can be larger and more uncertain. The increased ramping requirement from dispatchable units caused by the presence of VRE can be explained by the speed of change of VRE power output. For instance, it is logically expected that at sunset the power generated from all PV power plants would decrease. At those times, dispatchable units would have to ramp up or increase their power production to account for the power that is no longer produced by the PV power plants. The uncertainty and variability of VRE power generation leads to higher and more uncertain ramping capabilities needs.

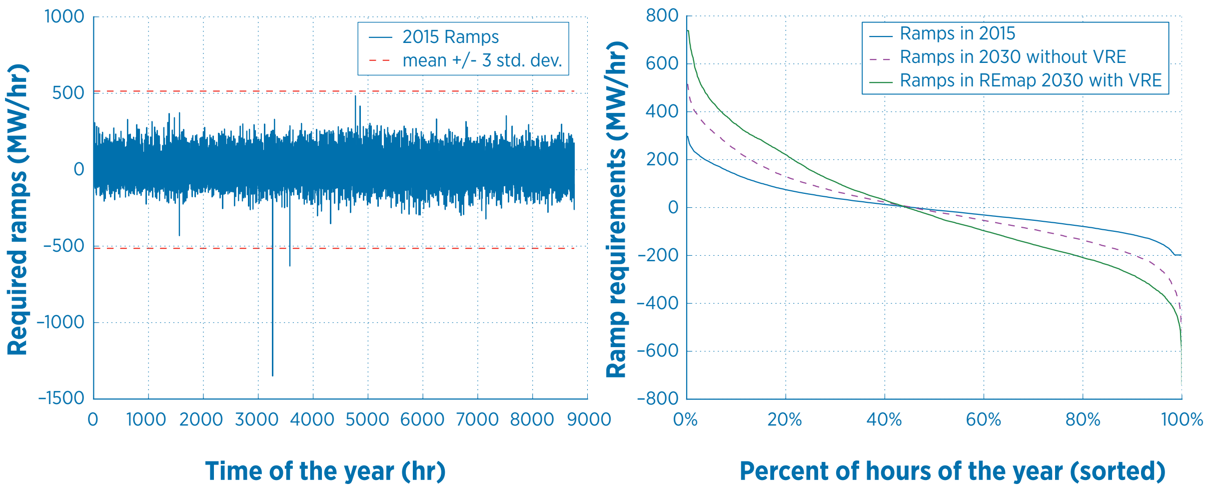
To assess whether the Dominican Republic could easily handle ramping requirements under the REmap scenario, the required ramps by the system in 2015 were calculated and compared to those required in 2030. Figure 30 shows the comparison. The 2015 ramps were obtained by analysing real operational data with one-hour resolution without demand-side management measures. Extreme events, such as blackouts were excluded from the analysis by applying a ± 3 standard deviation filter. The 2030 scenarios were constructed by analysing the estimated net load with REmap options and without new VRE generation – again with no demand-side management measures.

The maximum one-hour ramp requirement by the system changes from about 296 MW per hour in 2015 to about 514 MW per hour in 2030. This is a substantial increase in ramp requirements, but only represent the estimated changes in the demand profile. The big ramping requirement change can be explained by the expected growth of the demand (peak demand passes from 2.63 GW in 2015 to about 4.5 GW in 2030). The maximum one-hour ramp requirement by the system in 2030 with the REmap scenario is about 695 MW per hour, which represents about a 35% increase in ramping needs due to the introduction of VRE (comparing the two 2030 scenarios).

The 35% increase in ramp requirements in nominal terms (MW per hour) seems big. However, if the requirement is compared to as a percentage of the peak demand in the system, the increase in ramp requirement due to the introduction of VRE in the system is not as big. In 2015, the ramp requirements of the system are about 11.2% of the peak demand (296 MW per hour divided by 2.63 GW). Similarly, the ramp requirements by the system in 2030 is 11.2% and 15.4% of the peak demand without and with REmap Options (514 MW per hour divided by 4.5 GW, and 695 MW per hour divided by 4.5 GW).

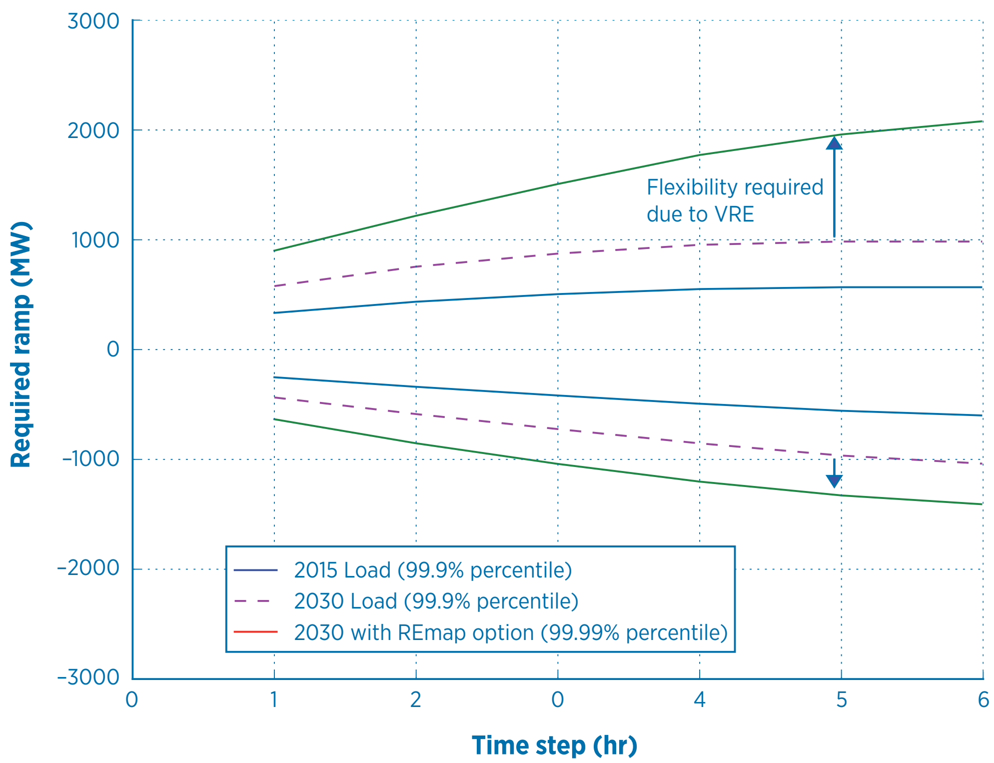
The green line in Figure 30, representing the system in 2030 with REmap Options, is steeper in the middle region when compared with the other scenarios (from about 20% to 80% of the hours of the year). This suggests ramp requirements would be more variable. The variability of ramp requirements should be assessed because of the implications on measures that the system operator would have to take. The green line is also much steeper than the blue one at around 0%-20% of the time, which suggests that steeper ramp requirements would be needed under the REmap scenario. In turn, this means that the high ramping capacity would be

Figure 32: Ramp duration curve for 2015 and 2030 with REmap VRE



std. - standard; dev. - deviation; hr - hour

Figure 33: Average ramp rate envelopes for 2015 and 2030



utilised for only very short periods of time. This should also be assessed in order to ensure that appropriate regulatory measures are taken to ensure the ramping capacity exists when needed.

The effects of VRE introduction in the Dominican Republic can also be assessed through ramp envelopes in Figure 31. These envelope curves indicate the ramp requirements of the system in a multi-hour timeframe. The multi-hour ramps are useful when allocating operational reserves and when designing the generation scheduling programmes. The line represented by magenta dashes in Figure 31 symbolises the ramping requirements of the system in 2030 due to the load. This is much wider than that of the 2015 envelope (solid blue line). Both of this lines, only represent how fast the load or demand for power changes in the system. The solid green line in Figure 31 shows the ramp requirements of the system in 2030 with VRE. This envelope is notably wider the other two. This means that under the REmap scenario, the power system would require much higher flexibility than that under the current system or in a future system with no VRE.

Three important conclusions can be drawn from this analysis. First, system operators and system planners need to take into account the following key elements: system has to be flexible enough to handle larger and more uncertain ramps; advanced forecasting algorithms are needed to reduce uncertainty in VRE power generation. Second, reserves are not the only means to add flexibility to the system. Storage units, fast ramping power plants and demand-side management are other options already commercially available. Future technologies may also emerge, and they need to be considered too. Third, a detailed and dedicated study to assess the flexibility of the system and the reserves allocation is advised.

Challenge 4: Adequacy of the transmission network

The optimal location in terms of availability of wind and solar resources does not necessarily coincide with high demand centres. This means that large-scale VRE projects may bring changes in the amount and direction of power flows within the transmission system.

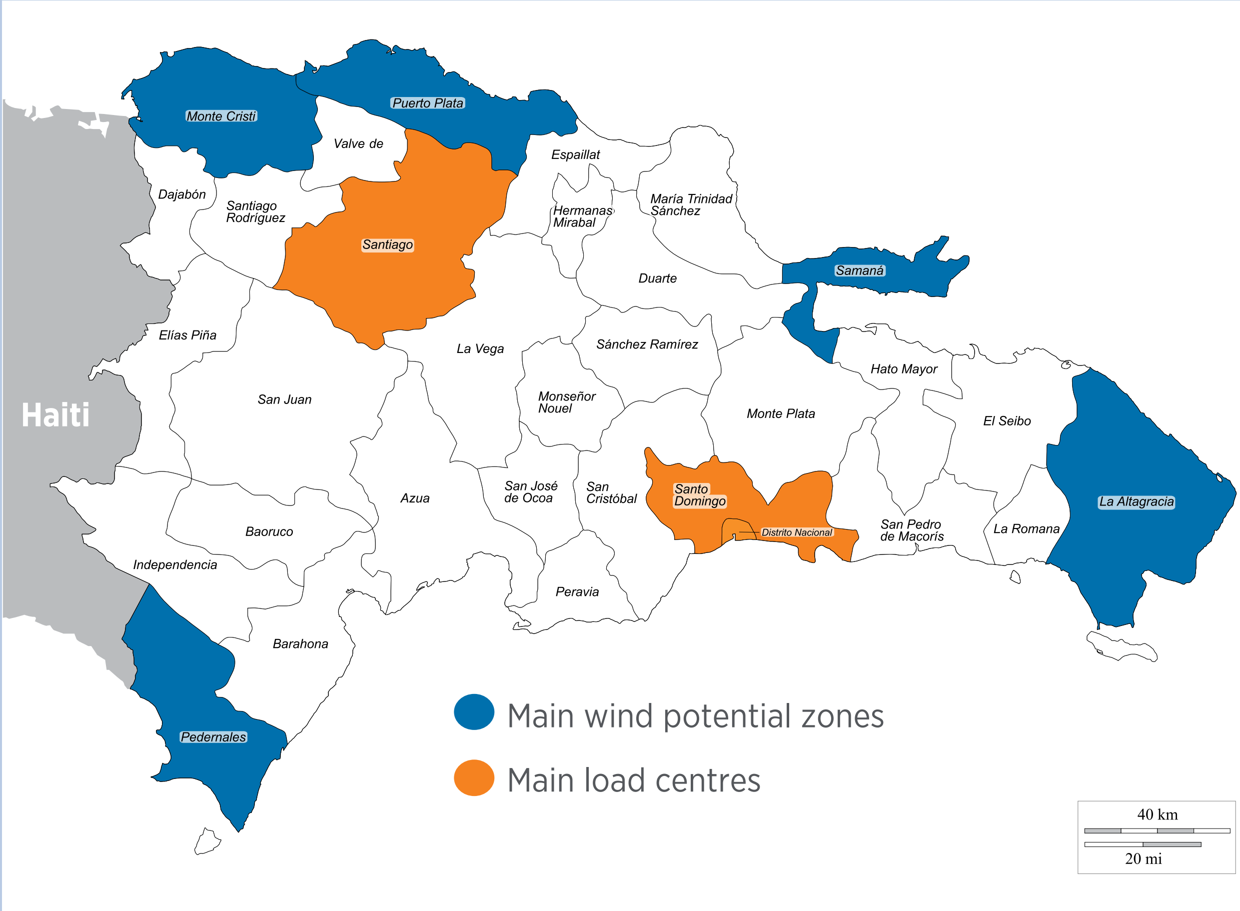
The REmap Options for the power sector include additions of 1 453 MW of onshore wind power capacity, 871 MW of utility-scale PV, 665 MW of distributed on-grid PV, 91 MW of small hydropower, 149 MW of biogas and landfill gas, 49 MW of bagasse-based power generation and 70 MW of biomass co-firing.

According to the Worldwatch Institute (2011) resource assessment, the locations with the highest potential for wind power are in the northern, southern and eastern provinces of the country (see map in Figure 34). These regions, with high wind resources, are a significant distance from the main load centres, which are located in the central region and in Santiago.

Harnessing energy from remote locations may require the construction of new transmission lines and reinforcements in other parts of the transmission system. This new infrastructure or reinforcements have to be carefully planned to maximise the utilisation and intrinsic benefits of renewable energy technologies. The expansion and reinforcements in the transmission network also have to take into account increasing demand and the reliability and power quality criteria defined in the country's legislation. National and international experience has demonstrated that expanding transmission networks could take several years (in average around 5 to 10 years). It is therefore important to plan and start expanding the network before it is actually fully required. Anticipating sites for development (grid expansion) when no committed projects exist has its risks. It is beyond the scope of this report to try to asses these risks in the Dominican Republic. However, different solutions around the world exist. One example is the Electric Reliability Council of Texas (ERCOT), which decided to invest in grid expansion to achieve high wind potential. ERCOT expects the private sector to invest and build wind farms on these sites (ERCOT, 2008).

A simplified assessment of the power transfer capacities required to evacuate potential wind and solar generation was conducted for this report. This illustrates the potential impact of the REmap Options on transmission system utilisation and needs. The assessment concentrated on the required transmission capacity and did not include a detailed representation of the electricity network. It excluded different voltage levels in the system and potential stability problems. The intention of this study is not to replace a detailed power system simulation but rather to identify potential

Figure 34: Potential locations for wind projects and main load centres



Based on Worldwatch Institute data (2015); background map from d-maps (n.d.)

requirements to increase the capacity of electricity transmission within the country.

This simple transmission system adequacy analysis identifies maximum capacities that may be required by the system in 2030, in order to be able transport all wind and solar generation to the load centres, with acceptable levels of curtailment due to congestions.

To carry out the analysis, the transmission system was aggregated according to current operational areas and sub-areas. Each node of the aggregated network represents a sub-area of the system (as in Figure 11). Trough load duration curves of the net load for each sub-area (projected to 2030 according to expected regional load growth and generation expansion), statistical significant, possible exchanges of power between areas and required transmission capacities were identified along with potential curtailment.

In previous sections, curtailment has been considered only in relation to instantaneous VRE penetration at a system level. In this section, curtailment of VRE is assumed to be caused by network congestion or limitations. Curtailment under these circumstances competes with the cost of expanding the grid. Full cost-benefit analysis methodologies should be employed to find the optimal solution.

The location of the renewable energy projects in the REmap scenario originated from a Worldwatch Institute study which detected sites with most wind and solar potential (2011). All these projects were allocated in an electrical node on the aggregated transmission network. Table 13 shows where the projects are located geographically and electrically (see also Figure 34).

After locating the projects and allocating them an electrical sub-area, the local residual demand for each

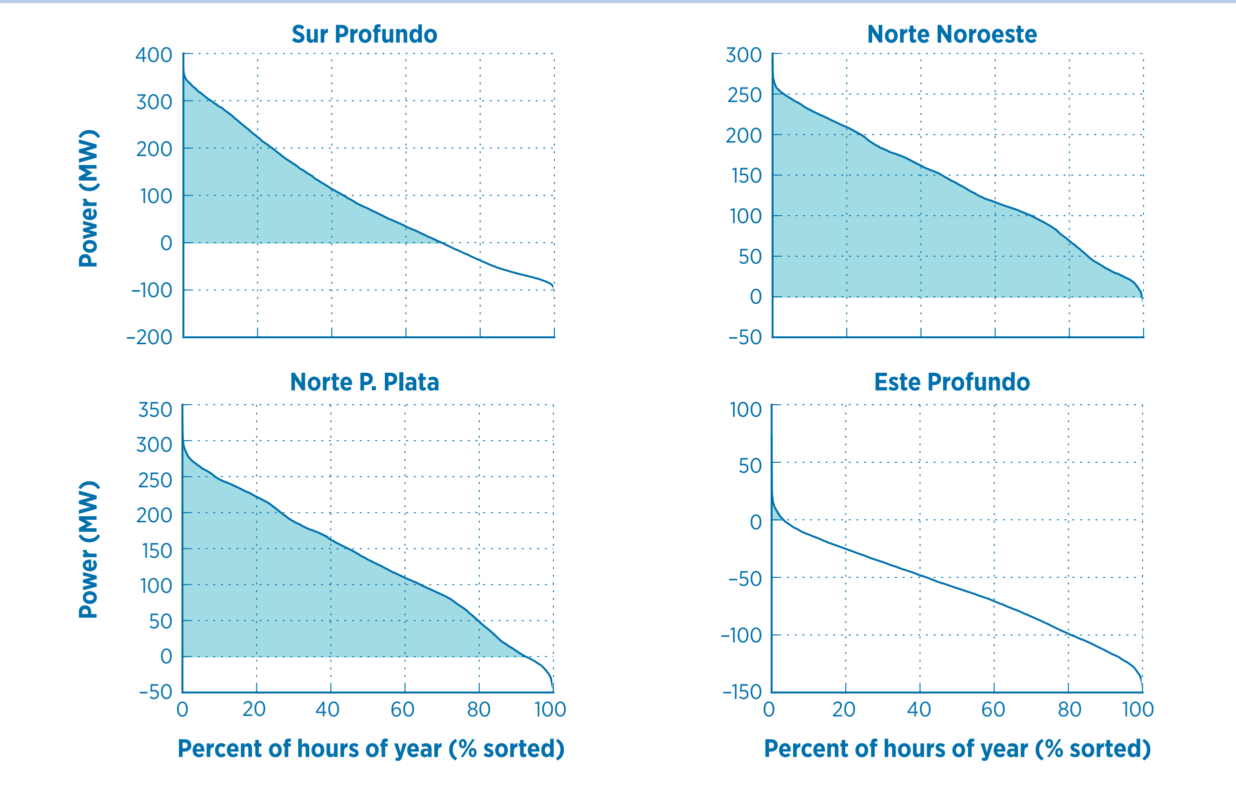
Table 13: Distribution of projects and their associated transmission node

Technology	Region	System sub-area	Capacity (MW)
Wind (2 304 MW)	Samaná	Norte Nordeste	153
	La Altagracia	Este_Profundo	192
	Bani	Sur_Cercano	423
	Pedernales	Sur_Profundo	480
	Montecristi	Norte Noroeste	480
	Puerto Plata	Norte p. Plata	576
Solar PV (1 761 MW)	Santo Domingo	Central_Metropolitana	440
		Central_Santo Domingo Oriental	440
	Santiago	Norte Santiago	881

node (sub-area) was obtained. Figure 35 shows the net load of the four outermost sub-areas in the country (in terms of distance to the load centres). As seen in the figure, the sub-areas are characterised by low local demand and high VRE generation. Positive numbers in the plot represent excess power while negative numbers signify a need to import power into the node.

Excess local VRE generation translates to a need to export power to another region or node. It occurs about 70% of the time for Sur Profundo and over 90% of the time for the Norte Noroeste and Norte P. Plata sub-areas. This means that the sub-areas would essentially need to evacuate most of their power production. The expansion of the network or required capacity has to

Figure 35: Local net load for the most critical nodes in 2030



Note: critical nodes are defined as those furthest away from the load centres and with high installed VRE capacity. The blue shaded area represents the electricity that would have to be transmitted or evacuated from the node.

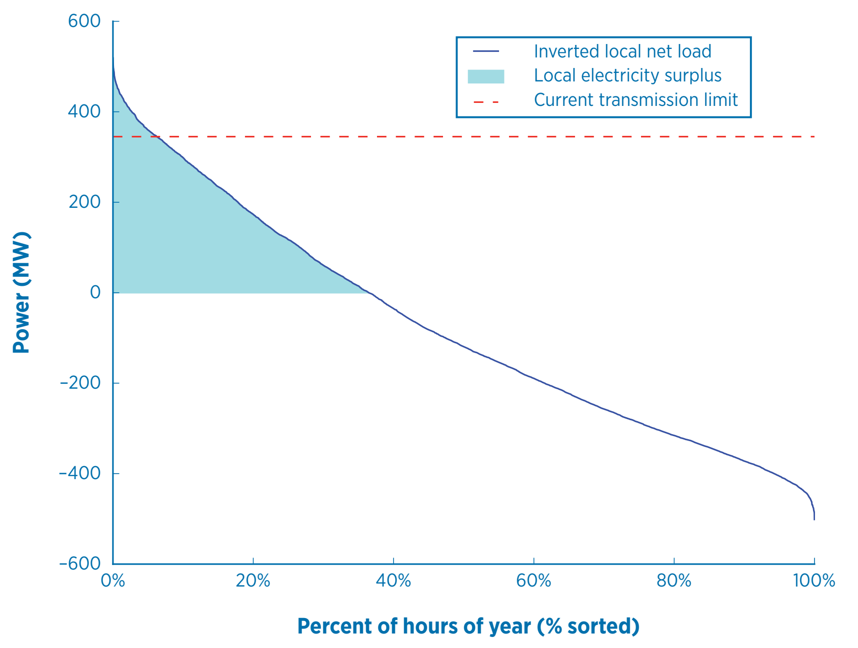
be assessed by comparing the cost of VRE curtailment against the cost of expanding the network. However, this cost comparison is beyond the scope of the present analysis.

As an illustration, the Sur Profundo sub-area (Figure 35 top left) is further analysed. According to the current transmission restriction analysis from OC-SENI, the sub-area transmission capacity is 45 MW (EIRGRID and SONI, 2016a). This means that under the REmap scenario and with no expanded network transmission capacity, VRE curtailment locally would be in the order of 55%. This would mean 730 GWh of clean power could not be utilised in the system. This level of curtailment would take place even if no other power plants were running. This is an optimistic scenario because conventional power plants may be required for reliability (instantaneous penetration) and local voltage regulation. This analysis clearly reveals the need to expand the grid in three of the four sub-areas analysed.

The South area was also further analysed (see Figure 36). This area can currently transfer a maximum 345 MW to the Central region (OC-SENI, 2015c). At current power transfer limits, VRE would have to be curtailed about 7% of the time even without considering that other power plants might be needed for reliability and other reasons. Again, this signals the requirement to expand the overall capacity to transfer power from the South area to the Central sub-area, the location predicted for most electricity consumption in 2030.

This simple assessment demonstrates the need to expand the electrical transmission network to accommodate and transfer power from the sites with the highest potential to demand centres. The South area, together with the Sur Profundo, Norte Noroeste, and Norte P. Plata sub-areas have been identified as locations for possible transmission capacity expansion. Current transmission expansion plans are based on the scenario from 2012. If REmap options were to be realised, it may be necessary to update these expansion plans.

Figure 36: Local net load for South region



Note: Curtailment of VRE power can occur due to several reasons (including technical, and regulatory factors). These reasons could co-exist at the same time (e.g. a limit due to network congestion, another due to instantaneous penetration, the existence of long-term contracts).

In the assessment of these technical challenges, only two reasons for VRE curtailment were considered. The first is due to the maximum instantaneous penetration level of non-synchronous generation, which is related to the stability of the gird, and the presence of fast frequency balance technologies. The second, is the presence of congestions at the transmission electrical network. There are technical solutions to both these limiting factors (e.g. state-of-the-art operating practices, strict and forward-looking grid codes, incentivising thermal plants to work as must-run or back-up power plants, and electrical network expansion). The optimal solution is system specific requires in-depth analysis and dedicated studies.

4.2 End-use sectors

In the Reference Case, much renewable energy is deployed in the power sector although direct uses of renewables for heating, cooling and cooking also present interesting opportunities to replace non-renewable energy carriers. The biggest challenge is to make policy makers and users aware of the renewables potential in end-use sectors and to implement appropriate solutions and policies that realise this potential.

The rest of this section describes the main opportunities and key action areas for the successful deployment of renewables in end-use applications.

Industry

Industry in the Dominican Republic is dominated by industrial processes based on low-temperature steam, mainly in the food and beverage industry. Industry is also populated by a large number of micro and

Table 14: REmap findings on direct uses of renewables in industry, 2030

	REmap findings	Action areas
Bioenergy	• Bioenergy (including renewable waste) can provide industrial process heat at all temperatures and scales but is not a straightforward option. In the case of the Dominican Republic, bioenergy can be easily integrated to the production processes of food, chemicals, and other small and medium scale industries that require low to medium process heat temperatures. In that respect, CHP can be a favourable option to produce also on-site electricity to meet auxiliary and motor drive needs. Its use in other sectors mean there is competing demand for this limited resource. Sufficient onsite storage is required as biomass feedstocks are seasonal, as is the case of bagasse.	→ Feedstock storage to ensure continuous daytime and harvest-time supply
Bioenergy	• The sugar cane production yield is around 40 tonnes per hectare, which is half the global best practice achieved in Brazil today. Improvements in agricultural yields can make a significant contribution to feedstock availability, both considering the direct use of the feedstock (*e.g.* to produce conventional ethanol) or its residues (*e.g.* taking advantage of the higher amount of bagasse after sugar cane production).	→ Increase sugar cane agricultural yield
Solar heat	• As in many other countries, industry solar thermal energy use is not part of the national energy plans for 2030. REmap estimates that solar thermal energy can provide around 10%-15% of the low- (< 200°C) and medium-temperature (200°C-450°C) process heat use in 2030. This equates to a total installed capacity of 85 MW supplying around 16 ktoe (0.7 PJ) of heat with conventional and CST installations. • Given the continuous demand for heat, the design of the installations will need to include appropriate storage capacity. Hybrid solutions with fossil fuels can be another option. • Many industrial processes require large amounts of heat, and many plants have limited space. This might create a problem for installing collectors covering a wide area. An alternative is to install them on the roof. Existing buildings would not usually accommodate this but it is a consideration for new buildings design and construction. Alternatively, CST is an option to optimise the use of available space as well as to raise process heat temperatures. REmap considers a 46 MW option for CST. Organised industry regions can create symbiosis between different plants within them, and this can to some extent resolve the space problem.	→ National awareness on the opportunities for renewables in industry → Energy planning and strategy that includes solar thermal energy → Optimise techno-economic design that that includes the need for thermal storage → Deploy CST in enterprises with limited space and for higher-temperature process heat

small enterprises (OMG, n.d.), creating significant opportunities for deployment of renewables.

Energy costs are a substantial part of the industry sector's overall expenditure. This is an issue in particular for small businesses with low operating budgets beyond the energy-intensive sectors. There is major potential for solar thermal and bioenergy systems in small-scale plants and less energy-intensive industries like food and beverages, textile or some chemical installations. Most enterprises in the Dominican Republic fall under these categories. A share of the energy used for heat generation in many of the low-temperature processes in REmap is therefore easily supplied by solar and bioenergy.

Table 15: REmap findings on direct uses of renewables in transport, 2030

	REmap findings	Action areas
Liquid biofuels	• Around 100 000 hectares of appropriate land are available for sustainable sugar cane harvesting and could be dedicated to liquid biofuel production (*i.e.* without affecting sugar cane for food production). This represents less than 30% of the total arable land for sugar cane production. Given that enough land is available, ethanol uptake is a potential consideration and could supply a significant share of transport energy demand. Current national plans do not yet take this into account. • In REmap, conventional ethanol use in road transport reaches 173 million litres in 2030. Assuming that production yields remain at today's levels, this would imply cultivating around 50 000 hectares of land for sugar cane production – equivalent to half the suitable land available for this purpose. A market for both biofuels demand and supply should be created to incentivise production.	→ National awareness of renewables opportunities in transport → Energy planning and strategy that considers the biofuels use → Reactivation of sugar cane land not cultivated for sugar production → Liquid biofuel blending mandates
	• Bagasse remaining after industrial processes provides a significant opportunity for advanced biofuel production for the benefit both of local businesses and technology development. REmap estimates that at least 19 million litres of advanced ethanol could be produced per year from bagasse.	→ Accelerate production and research and development for advanced liquid biofuels
Electric mobility	• With growing urbanisation and demand for mobility, a large market for electric mobility could open up, especially in major cities such as Santo Domingo, Santiago de los Caballeros, La Romana. National energy projections do not include electric mobility estimates for road transport. REmap proposes electric mobility penetration amounting to 2% of road vehicle energy demand in terms of distance. This represents 9.6 billion passenger-kilometres. • Battery electric and plug-in-hybrid electric car estimates in REmap would replace cars fuelled by petrol. This would amount to around 4% and 10% of total vehicle stock in 2030 respectively (220 000 vehicles). • There is an opportunity for the early introduction of two- and three-wheelers in major urban areas and beyond. This is motivated in particular by short distances, which means less need to recharge than for four-wheeled electric vehicles. This is also an attractive tourism option. REmap considers 375 000 two- and three-wheelers on the road in 2030. • REmap suggests that battery electric buses used for urban public transportation could form a fleet of 1 100 out of 19 000 units in 2030.	→ Long-term energy planning and strategy taking into consideration a major role for electric mobility → Promote electric vehicles by simultaneously incentivising vehicle sales and investment in charging stations

Transport

In transport, biofuels are the key technology for raising the sector's renewable energy share. The right policies are needed to incentivise demand and create a market while ensuring affordable and sustainable feedstock supply to meet this growing demand. The sustainable

Table 16: REmap findings on direct uses of renewables in buildings, 2030

	REmap findings	Action areas
Solar water heating	• Solar energy use in the Dominican Republic's residential sector today covers around 12% of energy demand for water heating. In the Reference Case this would increase to 17% in 2030. Given that solar water heaters are already cost-effective their actual potential is largely overlooked. • Water heating accounts for one-fifth of energy demand in the commercial, public and service sectors. This stays stable in the period to 2030. The Reference Case includes 10% of this demand supplied with solar water heaters in 2030 but there is potential to exceed this proportion. REmap proposes to replace LPG meeting 35% of energy demand for hot water in 2030. This would imply deploying around 775 000 m^2 of solar water heater capacity. • The economic development expectations in the Dominican Republic are reflected in building stock expansion. To fulfil the additional potential for residential solar water heating in REmap in 2030, it suffices to install solar water heaters in 35% of new households constructed in 2017-2030. This is three times current levels. • Solar water heating is particularly competitive in middle- and high-income households given that they desire more hot water than low-income households. They also find this more affordable. By contrast, low-income households may need financial support to adopt this technology.	→ Raise governmental and public awareness of renewables opportunities in buildings → Include direct use of renewables in energy projections and planning → Urban planning → Building codes → Educate and raise awareness among end-users → Optimal use of buildings space → Government support → Facilitation of financing schemes
Solar space cooling	• Solar space cooling has been overlooked in energy projections in most countries across the world yet some technologies could already offer competitive alternatives to electricity use for air conditioning. Cooling energy demand represents 25% of energy use in urban households and more than 45% in commercial buildings. • The Reference Case ignores renewable cooling. Under REmap, 20% of cooling demand in buildings would be supplied by solar thermal cooling installations. These would cover around 500 000 m^2. • REmap estimates that 6% of cooling demand is equivalent to more than 200 000 PV rooftop installations.	→ Raise governmental and public awareness of renewables opportunities → Energy planning and strategies → Optimal use of available buildings space
Modern bioenergy cooking	• Tourism is growing in the Dominican Republic so there is an opportunity to develop waste-to-energy technologies for different applications. REmap proposes a minor option to make use of organic waste arising from the hospitality sector to produce biogas in anaerobic digesters. • REmap considers the integration of 100 biogas systems in hotels (80-100 cubic meters – m^3 – size). It is assumed that the biogas produced is used for cooking but it could also be used for other purposes *e.g.* for water heating. A business case exists for such applications. However, limited experience of the technology means the hospitality sector needs to improve its understanding of the opportunity and benefits of biogas.	→ Raise governmental and public awareness of renewables opportunities → Energy planning and strategies → Building codes and design

potential of energy crops (such as sugar cane) is limited so the appropriate pathways need to be moulded to avoid interfering with land and water use for food and feed production.

The alternative to biofuels is electric mobility sourced with renewable power. This requires a policy effort for both electric vehicle deployment and modal shift, thereby changing consumer behaviour as well as investing in infrastructure. Electric two- and three-wheelers present an early opportunity for major urban areas in the Dominican Republic and beyond. This is because distances are short, and the need to recharge is lower than for four-wheeled electric vehicles.

Buildings

Although energy plans currently include some renewables development, the vast potential of direct renewables use in buildings is not fully integrated in the long-term vision. This omission could become a major issue considering that most renewable technologies that can be used for heating, cooling or cooking are more sustainable and cost-effective than non-renewable alternatives.

The following table summarises the main findings on renewables development relating to REmap estimates in the buildings sector.

The major potential for renewables use in direct applications in buildings could both decrease consumer energy bills and increase the renewables share in the energy mix.

Key action areas for renewable energy use in end-use sectors

To ensure renewables are successfully integrated in the years ahead, a number of obstacles need to be overcome. They include high initial investment costs for renewable installations, fossil fuel subsidies, high interest rates, limited access to financing for equipment purchase, lack of end-user confidence in the technology and few experienced installers. Law 57-07 already incentivises renewable technologies in end-use sectors, in buildings through exemptions on import duties for solar thermal components or collectors, for example, but further efforts are needed.

Based on the findings of each of the sectors described above and considering the additional potential identified in REmap, the key areas for government and policy maker attention are explained in further detail below. Some of them are relevant for more than one end-use sector, while others are sector-specific. This will provide a platform for the major adoption of direct uses of renewables.

Cross-sectoral

- **More ambitious representation of renewable technology options in end-use sector energy planning**. It is necessary to include realistic but ambitious estimates in the projections of renewable energy use in all end-use sectors. This means the strategies accompanying energy plans can be shaped with the aim of achieving a higher share of renewables. The establishment of targets is a possible complementary measure.

- **Improve public education and awareness of the economics and direct uses of renewable technologies.** Many end-users and local industry stakeholders currently have limited awareness of the benefits and economics of renewables. Yet the building sector is the largest energy user after transport and numerous benefits could arise from renewables use. These include energy bill savings and reduced air pollution in urban settlements. To harness the renewable potential by 2030, the Dominican Republic should consider promoting further educational and training initiatives. This would improve the understanding of renewables opportunities particularly of solar and biomass technologies for household, commercial and industrial applications.

- **Reactivate sugar cane production land and increase agricultural yields.** Some years ago, sugar cane was cultivated on around 350 000 hectares of Dominican Republic land (Instituto Interamericano de Cooperación para la Agricultura, 2007). However, sugar cane production has declined significantly so today only around 100 000 hectares of land are used for this purpose. Given the vast experience of the sugar industry, the unused arable land presents an opportunity to decrease dependency on imported transport fuels and boost activity in the sector.

Improvements in agricultural yields can make a significant contribution to feedstock availability, both considering the direct use of the feedstock (*e.g.* to produce conventional ethanol) or its residues (*e.g.* taking advantage of the higher amount of bagasse after sugar cane production). The low sugar cane production yields also offer a major opportunity for improvement. However, this needs to be realised sustainably without resulting in increased water stress, excessive fertiliser application etc.

- **Include urban planning and promote renewable energy at the municipal level to adopt it more rapidly through local action.** As population and economic growth accelerate urbanisation, city demand for clean, reliable and affordable energy will increase exponentially. Significant urban planning efforts are therefore key to integrating more renewables in heating and cooling and also electric mobility. Local governments, at state or municipality level, can play an important role here by encouraging, enabling and regulating the increased uptake of renewable energy. Even cities that do not directly control power generation have options to drive clean energy use, *e.g.* supporting low-carbon transportation solutions including the implementation of charging stations (IRENA, 2016f). As managers of local infrastructure, cities and local governments can develop solutions that integrate renewable energy (IRENA, 2016a) and can set an example by integrating renewable technologies into public buildings. All this needs to be held together by sound national policy and planning with common goals and enforcement mechanisms.

- **Build a solid industry along the entire renewable technology value chain with high expertise and quality assurance to help develop successful renewable markets**. Manufacturers, system designers, distributors and installers need to have enough expertise and quality compliance in the use, installation and maintenance of renewable technologies. This too will enable direct renewables to thrive. Government can support this by defining standards, certification and control mechanisms, which will ensure that renewable installations are fully functional and reach their optimal efficiency. This is needed to retain the interest and trust of end-users in these technologies and sustain market development. Barbados is a success story in the development of direct uses of renewables, particularly in solar thermal applications. By 2009, almost half the island's homes had water heating systems (Energy Transition Initiative, 2015; UN Environment Programme, n.d.). Some key measures included programmes to improve local skills of solar water heating technicians and financial incentives such as low-interest loans aimed at manufacturers.

Industry

- **Sufficient feedstock storage to ensure continuous daytime and harvest-time supply.** Bioenergy (including renewable waste) can provide industrial process heat at all temperatures and scales but is not a straightforward option. Its use in other sectors means there is competing demand for this limited resource, and supply logistics can be difficult. Sufficient onsite storage is required, and in many cases customised solutions are needed. This is particularly important because most industry plants have a continuous need for energy to produce heat. By contrast, biomass feedstocks are seasonal. Bagasse, one of the main residues exploited in the Dominican Republic, is one example.

Transport

- **Develop electric vehicle infrastructure.** It is important to develop the necessary infrastructure to enable the uptake of electric vehicles and to account for the role of electric mobility coupled with electricity generation based on renewables in energy system planning. Charging points need to be readily accessible to make electric vehicles an attractive option. On the other hand, charging stations will not be an attractive investment until more electric vehicles create the necessary demand for infrastructure (IRENA, 2016a). Infrastructure development plays a significant role in raising the number of early adopters and could be one way to achieve a breakthrough.

Increasing home, public, and workplace charging options is crucial. In addition to charging point expansion, charging needs to be rapid (IRENA, 2016a). However, this is likely to be a minor concern in the Dominican Republic because vehicles cover fairly short distances, making this an opportunity for electric vehicle deployment.

- **Open up an avenue for advanced biofuels.** Given the opportunity to use excess bagasse from industrial applications, the Dominican Republic could develop expertise in advanced biofuels production. This will be critical in the long term because there are limits to the production of land-intensive conventional biofuels. Bioenergy waste streams arising from industrial applications should also be utilised for advanced liquid biofuels production. However, this means developing technology and creating finance resources for advanced biofuels capacity, which up until now has been subject to only limited commercial development.

Buildings

- **Embed codes and standards that integrate renewable technologies in buildings construction or renovation and make them part of urban development.** The Dominican Republic is a country with growing population and energy demand. It is thus in a good position to integrate renewables in the residential and commercial segments since it is easier to build for renewable energy use than to retrofit (IRENA, 2016a). Renewables can ride on this growth if measures are introduced to stimulate their use in the construction and renovation of buildings. Examples include command and control mechanisms such as building codes and technology standards or incentives such as lower interest loans or end-user fiscal incentives. When promoting renewables in buildings, the whole range of technology options should be considered. Examples include different arrangements and types of solar thermal collectors for heating and cooling, anaerobic digesters producing methane for cooking or water heating and PV panels for electricity production.

- **Optimise the use of building space available for renewable installations.** One factor to take into account when different renewable technologies are proposed is the optimal use of rooftop and other available spaces to install different technologies. This is essential, especially in cities rising vertically such as Santo Domingo. Maximising buildings-integrated PV at the same time is another possibility.

Figure 37: Rooftop area covered by renewable energy technology in REmap in 2030

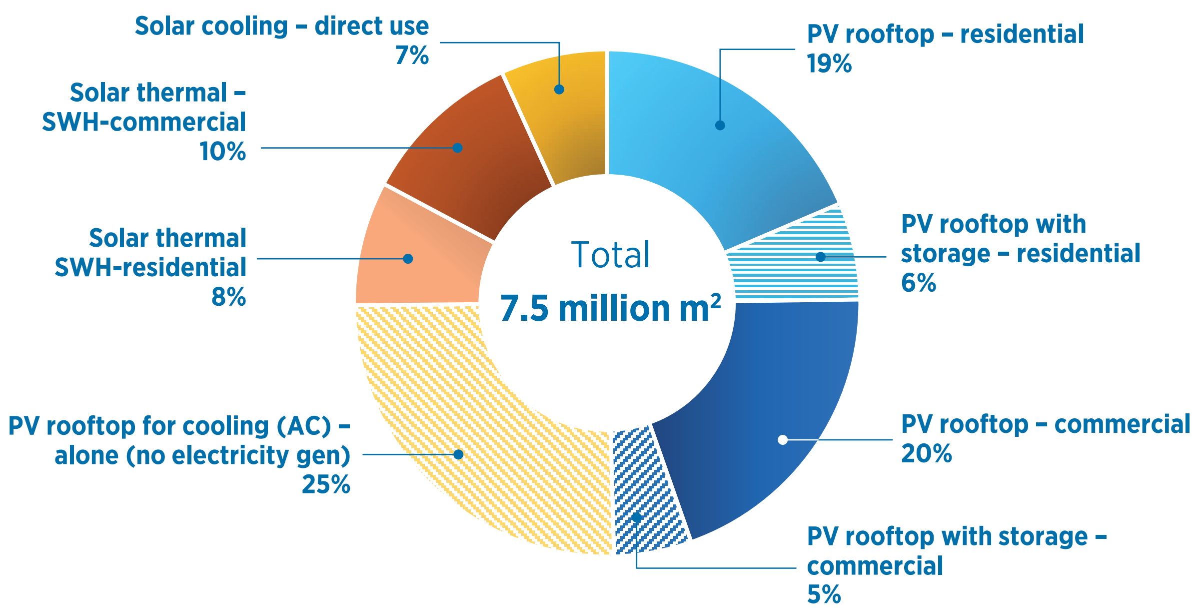


Figure 38 shows rooftop area distribution by renewable technology segment as estimated in REmap by 2300. Most rooftop space will be taken up by PV rooftop applications. Even with all this potential installed, only 5% of total available rooftop in the Dominican Republic in 2030 would be covered by a renewable energy installation.

- **Provide accessible financial options for households to purchase renewable energy technologies.** The widespread use of modern renewables requires new programmes making modern renewable technologies (solar water heaters, efficient cook stoves, solar cooling, PV installations etc.) more affordable to low-income households. This could be complemented by other types of economic or fiscal support. In remote areas, this will also be a key to modern and universal energy access. These can take the form of government initiatives but also presents opportunities for other stakeholders, including the private sector. Many schemes could be designed to fund and/or support households in acquiring renewable energy technology.

4.3 Bioenergy market development

A breakdown of primary energy use in the Dominican Republic is shown in Figure 38. The Reference Case sees a total annual demand of 42 PJ bioenergy in 2030. Buildings, power generation and industry each account for approximately a third of total demand in the country.

There are changes to the sector mix of total demand in REmap. Following the decline in traditional use of bioenergy, the buildings share of total demand falls below 10%, which in absolute terms halves total demand. The share of transport and power generation in total bioenergy demand increases significantly; demand for power generation doubles and for transport increases by over 500% compared to the Reference Case.

According to IRENA estimates, annual primary bioenergy supply could amount to 38-84 PJ. More than three-quarters of this total derives from agricultural residues and waste. Potential for energy crops and forestry products is rather limited.

Industry and power generation will be the main source of demand for agricultural harvesting and processing residues. Biogas and municipal solid waste will be used to a great extent by the power generation sector (landfill gas) and for cooking in buildings. This is also where forestry products (*e.g.* charcoal) for modern cook stoves will be used. To a great extent, the transport sector will rely on sugar cane for conventional ethanol production. A small share of demand will be met by bagasse, a harvesting residue, for advanced ethanol production. Finally, feedstocks for minor biodiesel production will be imported.

There is a potential to meet demand according to the high end of the supply (according to IRENA estimates shown in Table 7) with limited reliance on imports. However, mobilising feedstock supply will not be easy. Markets for bioenergy will need to be created to realise

Figure 38: Breakdown of primary bioenergy use in Dominican Republic, 2030

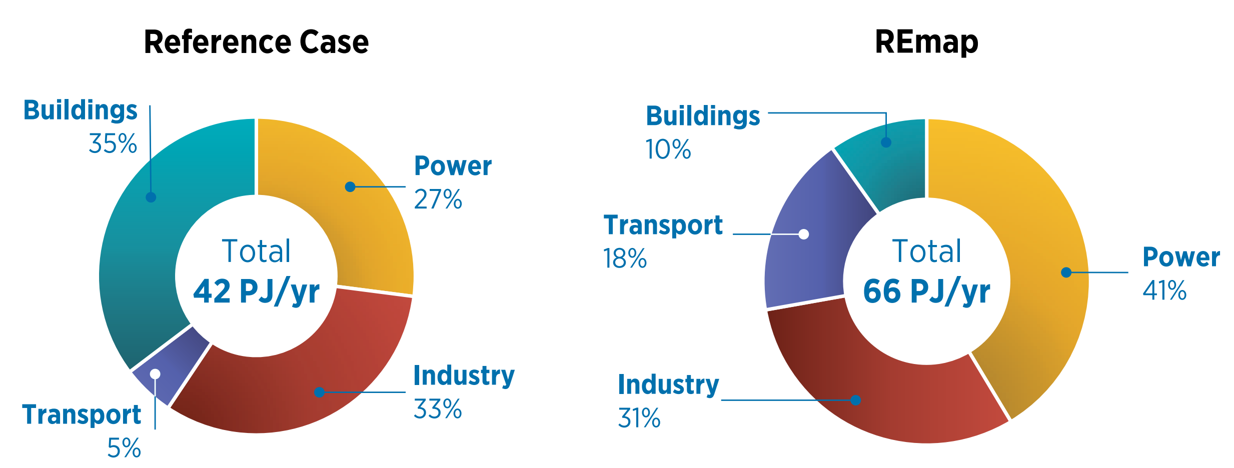
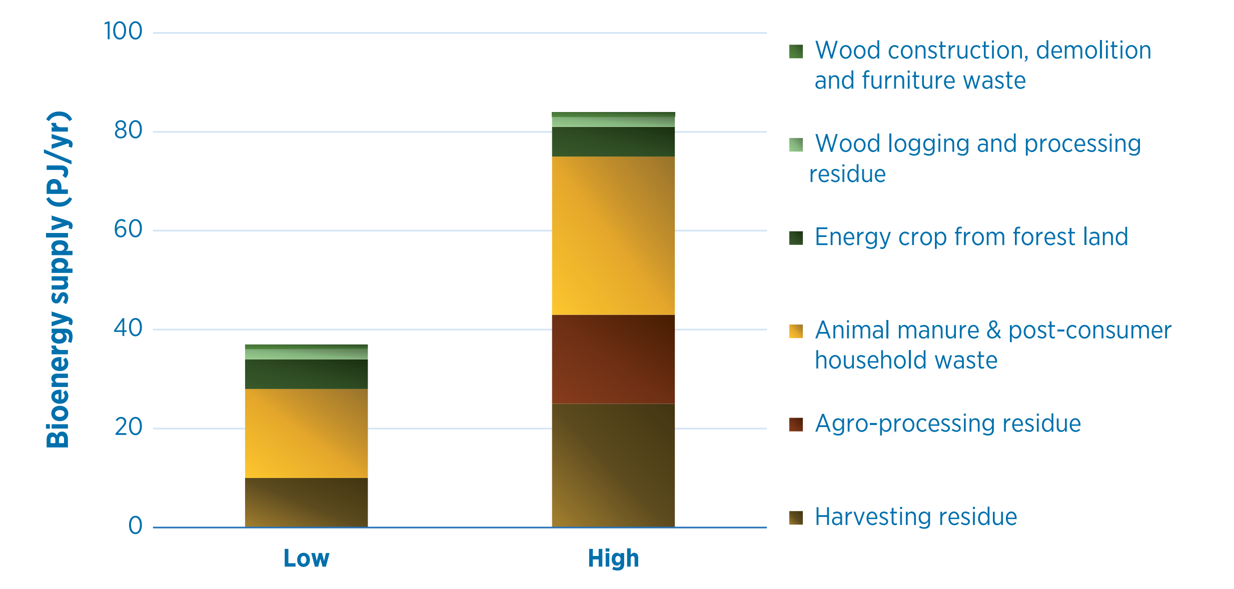


Figure 39: Bioenergy supply potential in Dominican Republic for primary biomass, 2030



this potential, implying a dual policy effort in supply on the one hand and demand on the other.

Three main challenges need to be overcome in relation to demand:

1) **Traditional uses of bioenergy:** in the Reference Case, demand is already very close to the low end of the supply range (as shown in Table 7) so that it can technically be met with local resources. However, the outcome is alarming when demand and supply are compared at the feedstock level. Buildings require 14 PJ of bioenergy in total of which 10 PJ is traditional uses of bioenergy for cooking. Total volume of forestry product supply is 3 PJ – significantly lower than the bioenergy demand for cooking. This points to potential deforestation in a country with already limited forest resources. Furthermore, traditional uses of bioenergy often result in indoor air pollution, a major cause of premature death.

Under REmap Options, demand for bioenergy in buildings declines significantly, and the traditional uses of bioenergy are replaced either by its modern forms or LPG. Modern forms of bioenergy include charcoal and biogas. According to REmap estimates, production for charcoal needs to more than double compared today's level. Biogas digesters are not used at present and need to be introduced into rural areas.

Substituting traditional uses of bioenergy by modern forms of energy makes a significant impact on sustainability when their hidden costs (*e.g.* collection time) are also considered. In addition, it reduces household air pollution.

Hence improvements are needed in the efficiency of conversion technologies and appliances currently used with traditional bioenergy as well as in charcoal production for clean cook stoves and cooking.

2) **Liquid biofuel use in transport sector:** transport is the other major challenge. IRENA's estimate is conservative in terms of the supply potential of energy crops (sugar cane) amounting to around 6 PJ. This represents around 40 000 hectares of land use per year (based on average ethanol yield of 3 460 litres per hectare). As observed in Section 4.2, 100 000 hectares of land could be used for sugar cane production without disturbing food/feed production. Assuming this land is used, total conventional ethanol supply is doubled – and it is the main technology for increasing the renewables share in transportation. Bagasse used to make advanced biofuels increases the renewables share in the sector. To date, advanced biofuels production in the region is low, as in the rest of the world. The production costs of these fuels are much higher than their conventional equivalents.

A small market for liquid biofuel use already exists in the transport sector. A market needs to be created through blending mandates and/or volumetric targets by taking into account the projected growth in the sector's demand for total energy. Law 57-07 in chapter V on the special regime of biofuels, already lays down the first foundations for incentives for biofuels production and for blending non-renewable fuels with liquid biofuels to 2020. Since the legal framework is already in place, CNE should next gradually introduce blending mandates to encourage the formation of the market. Depending on how markets evolve, incentives could be expanded beyond 2020.

Up until now, there has been limited production of advanced biofuels, and its increase requires more than blending targets. Research and development support and technology innovation will be key to accelerating deployment of the most cost-effective routes of production. The sustainability aspects of biofuels need to be taken into consideration when creating the market. This will mean not just meeting a target but also deploying the most resource-effective pathways with the least intensive GHG emissions.

3) **Creating a market for industrial heating and power generation**: industrial heating and power generation are the two largest markets after transport for bioenergy in the Dominican Republic. Bioenergy is a readily available alternative to fossil fuels to generate process heat at various temperature levels. The main issues in the industry sector include the need for continuous bioenergy supply to run processes, and space to store feedstocks. However, low-temperature and some medium-temperature processes can also be supplied with energy from non-bioenergy renewables. Examples include solar thermal, geothermal or heat pumps if a resource is available.

The Dominican Republic already benefits from rich solar, wind and geothermal resources to supply renewable electricity. Given limited bioenergy availability and competition from other sectors, bioenergy is not the first choice. However, bioenergy combusted to generate both heat and electricity in CHP plants can be viable. Power plants fired by bioenergy are dispatchable like their fossil fuel counterparts and can contribute to baseload power generation.

As a first step, demand needs to be created by setting targets that can make use of the synergies from bioenergy for medium- and high-temperature process heat, dispatchable power and transport fuels. This means accounting for feedstock seasonality and prioritising the development of the most resource-effective, least emission-intensive and most cost-effective bioenergy pathways across all end-use sectors.

The main supply-side challenges relate to mobilising a continuous supply of affordable and sustainable bioenergy feedstocks. A significant share of bioenergy supply in the country will originate from agricultural residues and waste. These feedstocks are sustainable but typically not collected and currently have no market. A collection and recovery system should be developed while maintaining sustainability criteria. Sugar cane yields should be improved to reach levels in advanced countries. The Dominican Republic surface area is small, and import dependency will be limited. Nevertheless, a strong logistics system will be required to distribute feedstocks across the country to conversion plants and end-users.

Agriculture is one of the main economic activities in the Dominican Republic so experience and channels exist. These can be developed on the basis of the existing market for energy crops. For instance, some sugar mills also cultivate and trade other energy crops used to feed process heat in industry on land not suited to sugar cane production. This may be a minor activity today but could be easily expanded.

To ensure supply, it will be necessary to harvest farm residues along with post-consumer waste and create a supply market and logistics system across the country. This must be affordable as well as stable when local harvests fluctuate.

5 RENEWABLES COSTS AND SAVINGS IN REMAP DOMINICAN REPUBLIC

5.1 Investment needs

Total annual average investment needed in renewable energy technology deployment in 2016-2030 (*i.e.* capital investment in renewable capacity for power generation and end-use sectors) amounts to USD 695 million (see Table 15). USD 245 million is required each year to fulfil the Reference Case, and an extra USD 450 million per year would be needed to implement the REmap Options.[38]

Most of the additional investment[39] is needed for the power sector (USD 344 million per year) as shown in Table 15, especially wind (USD 155 million per year, shown in Figure 40). Bioenergy technologies (including the capacity to produce liquid biofuels and biomethane for transport) also require an extra USD 105 million each year beyond the Reference Case. Bioenergy for heating technologies in industry (process heat) and buildings (mainly for cooking) will require additional investments of USD 56 million per year on average. Investment in solar heating and cooling systems will require a total annual average of USD 34 million.

5.2 Costs of renewables in the Dominican Republic

Table 16 provides an overview of substitution costs by sector for 2030 based on the business and government perspectives. National prices are based on a discount rate of 12% and take into account energy tax and subsidies in energy prices in the Dominican Republic. International prices are based on a discount rate of 10% and exclude tax and subsidies in energy prices.

In both the business and government perspective, most of the industry and buildings options are cost-effective (except modern uses of solid biomass and SWAC in the business perspective). In the power sector 90% of the renewable energy supplied with REmap Options is cost-effective. This is a result of the country's high dependency on expensive oil product imports.[38] All power sector REmap Options substitute oil products and coal but even when PV or wind technologies are compared with natural gas generation, they are still cost-competitive.[40]

Table 17: Average annual investment needs for renewable energy capacity by sector, 2016-2030

	Reference Case		REmap Options		REmap
	USD million per year		USD million per year		USD million per year
By sector	**245**	**+**	**450**	**=**	**695**
Power	213	+	344	=	557
Industry – heating and cooling	28	+	60	=	88
Buildings – heating and cooling	2	+	34	=	37
Transport	1	+	12	=	13

38 These costs exclude infrastructure (*e.g.* additional generation or transmission capacity in the power sector or electric vehicle charging stations) and enabling technology costs (*e.g.* grid integration).

39 Additional investment needs represent the difference between investments needed in the REmap case and the Reference Case.

40 The estimated levelised cost of energy (LCOE) in this study for 2030 is USD 0.075-0.09/kWh for onshore wind, USD 0.055-0.08/kWh for utility-scale PV and USD 0.14-0.18/kWh for natural gas power generation.

Table 18: Average substitution costs of REmap Options by sector, 2030

	Business perspective	Government perspective
	USD/GJ	USD/GJ
Industry	-20.8	-21.7
Buildings	-9.0	-13.3
Transport	-17	13.7
Power	-20.3	-30.5
Average – all sectors	**-17.7**	**-20.5**

Using the small amounts of bioenergy and waste from industrial processes to generate process heat as well as solar process heat is a cost-effective option.

In the government perspective, the average cost of substituting the selected technology options in each sector is lower than in the business case. This is explained by the exclusion of taxes and subsidies from energy prices.

Figure 41 and Figure 42 rank the costs of each REmap Option and show its contributions to the increased share of renewable energy. Table 17 shows the substitution costs of REmap Options in 2030 for the Dominican Republic (the same information as plotted in the two figures). The option cost ranges from USD -72/GJ to as high as USD +103/GJ in the government perspective. The business perspective starts off with options costing as low as USD -110/GJ and ends with options as expensive as USD +42/GJ. In both cases, over 80% of the energy from these options is cost-competitive and therefore incurs a negative substitution cost.

Most of the bioenergy technologies in the business perspective experience low substitution costs and would generate savings when compared to the petroleum product alternative. Onshore wind, cogeneration with bagasse, landfill gas generation and decentralised PV incur the lowest substitution cost for on-grid power generation. Solar heaters and coolers in industry and buildings are cost-competitive. This is explained by their low capital costs and the expensive petroleum products or electricity used as an alternative. In the transport sector, battery electric two- or three-wheelers and public buses are the cheapest REmap Option in the business perspective. This is due to the substitution of costly conventional fuels. Conventional biofuels

Figure 40: Average annual investment needs for renewable energy technologies, 2016-2030

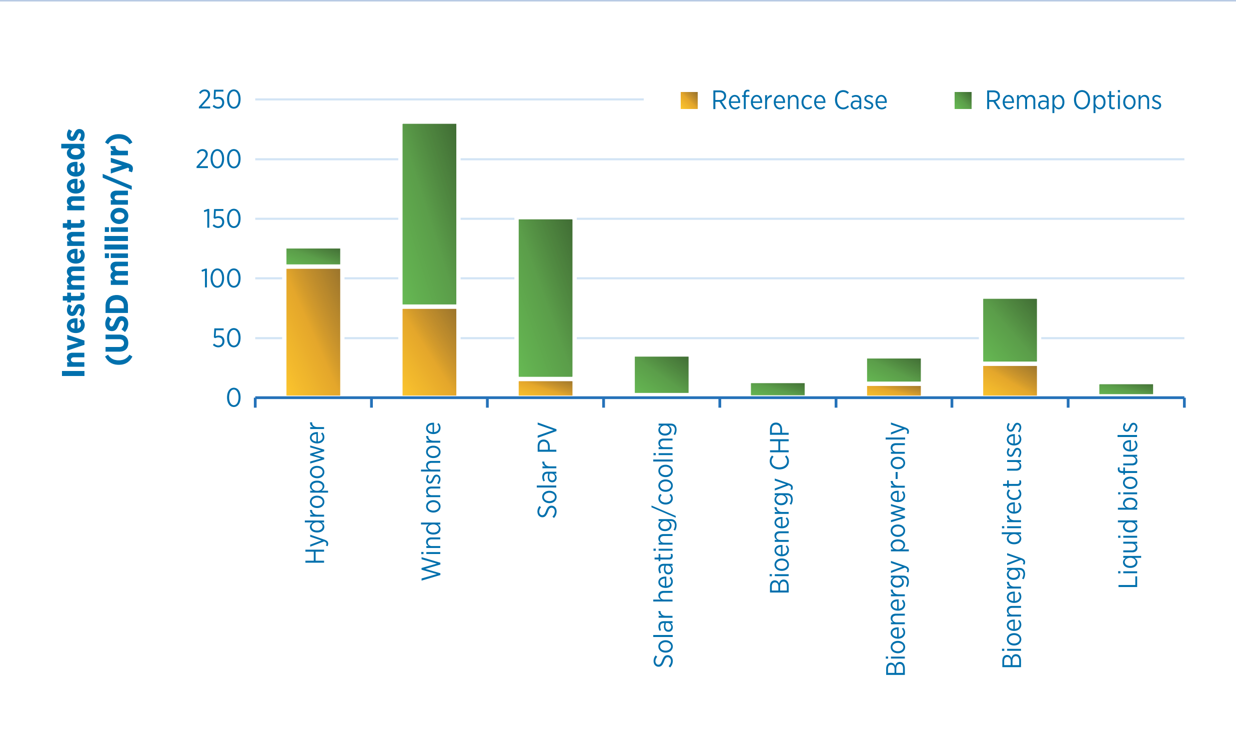
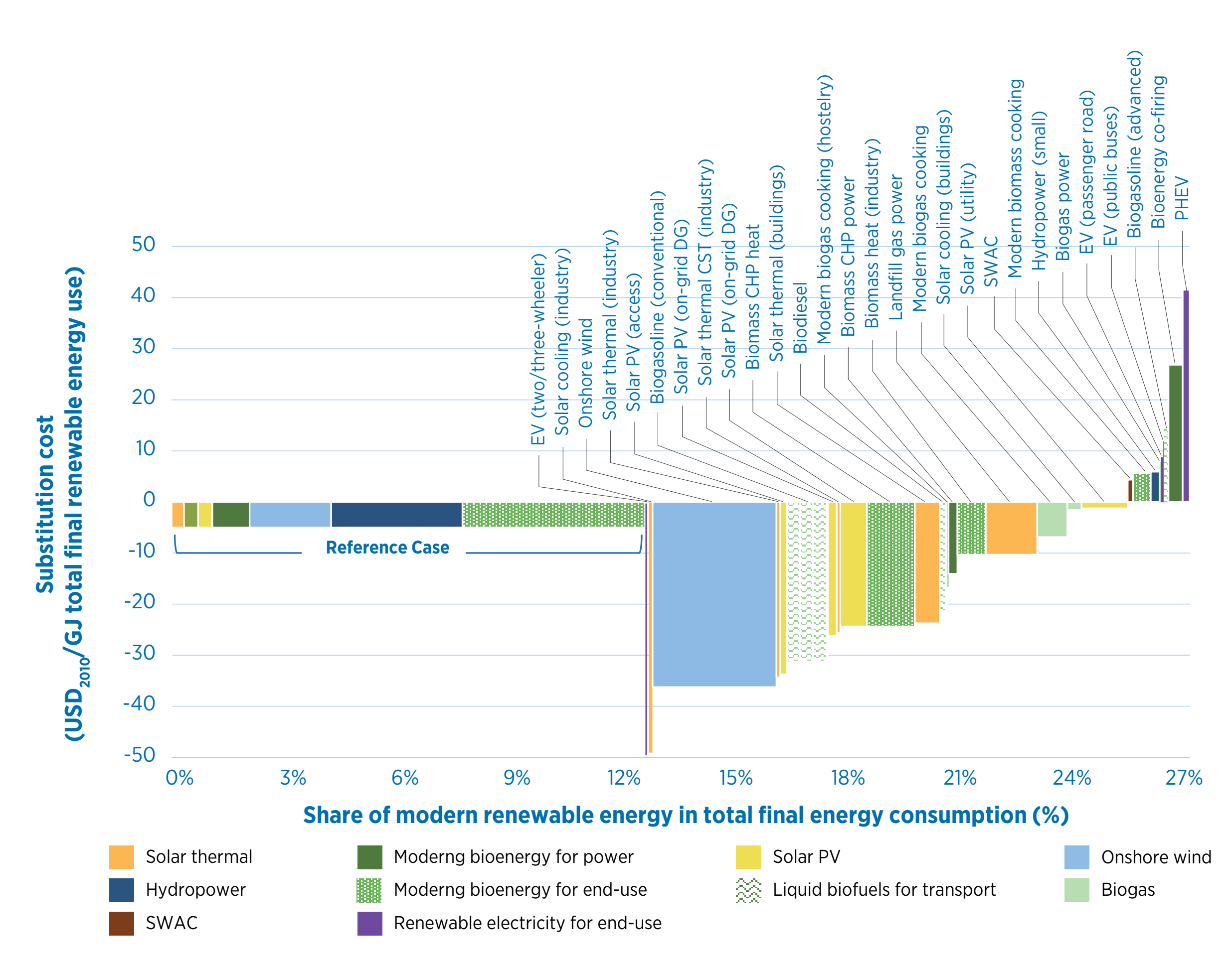


Figure 41: Renewable energy cost-supply curve by renewable energy resource, business perspective, 2030



follow and would also generate savings when replacing conventional gasoline or diesel.

5.3 Benefits of REmap Options

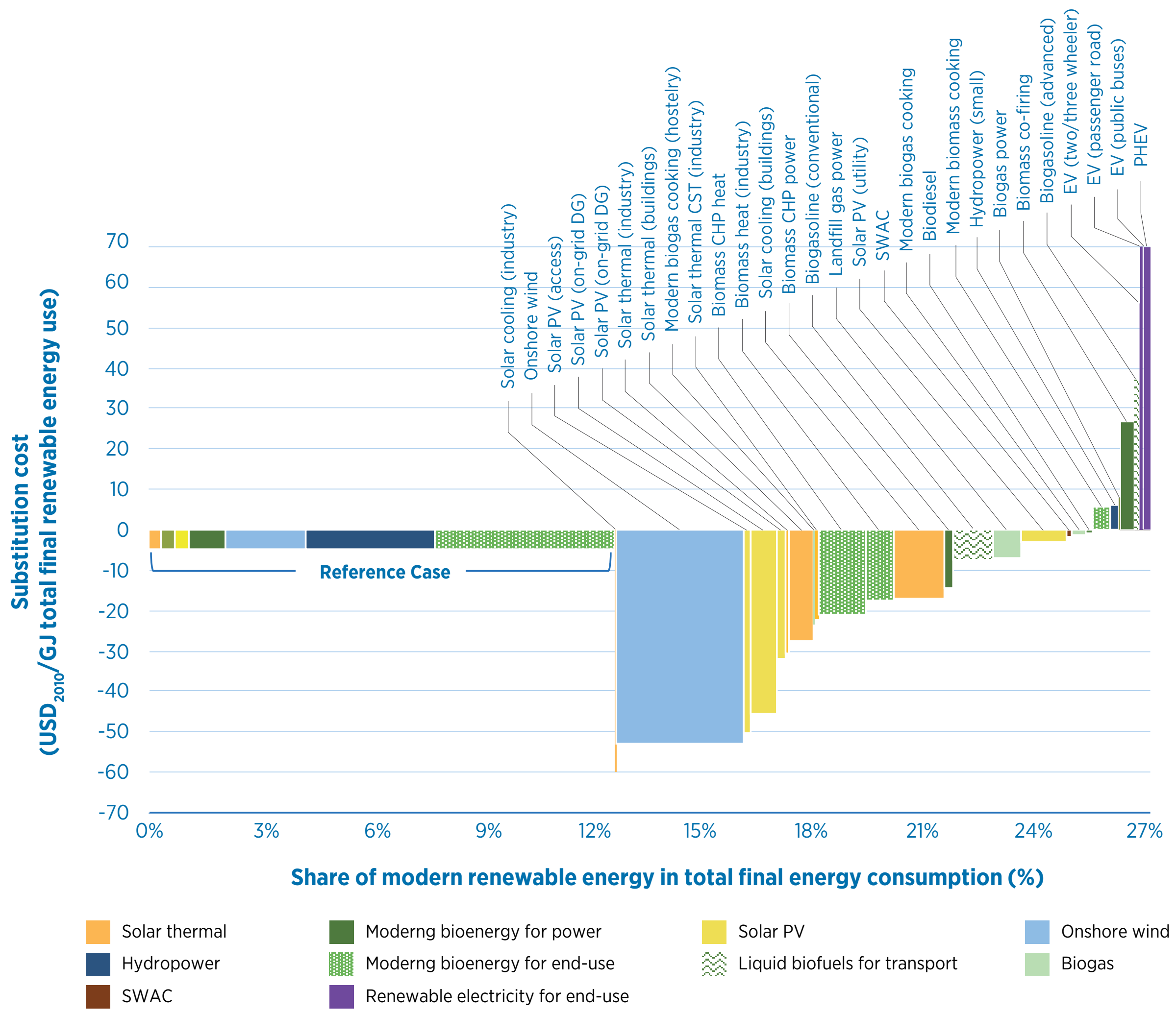
Figure 43 shows primary energy supply trends in 2010-2030 in the Dominican Republic under the Reference Case and REmap. REmap Options would cut fossil fuel demand by 21% compared to the fossil fuel consumption in the Reference Case. The savings range from 19% for oil products to 34% for coal.

Total oil demand in REmap would be close to 2010 levels. By comparison, coal rises 230% in Remap in 2010-2030 (compared to 400% rise in the Reference Case over the same period). Likewise, total renewable energy supply in REmap grows about 240% over the same period (compared to 65% in the Reference Case).

The bottom-up CO_2 emissions estimate of sectors covered in this analysis amounts to 20 million Mt CO_2 per year in 2010 (or 2 tonnes CO_2 per capita per year).[41] In the Reference Case, total energy related CO_2 emissions in the Dominican Republic increase to 35 million tonnes in 2030 (or 2.9 tonnes CO_2 per capita). This is an alarming result, given that GHG emission reduction targets in the country's INDC is 25% by 2030, compared with 3.6 tonnes CO_2 equivalent per capita in 2010. This implies that total GHG emissions in 2030 should be at a level of 2.7 tonnes CO_2 equivalent per capita (for all sectors including energy). Therefore, energy related CO_2 emissions alone are already above the total GHG objective under the Reference Case developments.

41 For this same year, total energy related GHG emissions amount to 2.5 tonnes CO_2 per capita.

Figure 42: Renewable energy cost-supply curve by renewable energy resource, government perspective, 2030



If all REmap Options identified in this study are put in place, total CO_2 emissions reduce to 27 million tonnes (or 2.3 tonnes CO_2 per capita). This is 23% lower than the Reference Case in 2030 (or an annual absolute volume of 8 million tonnes CO_2), as shown in Figure 44. These reductions would be an important step in meeting GHG emission reduction targets in the country's INDC.

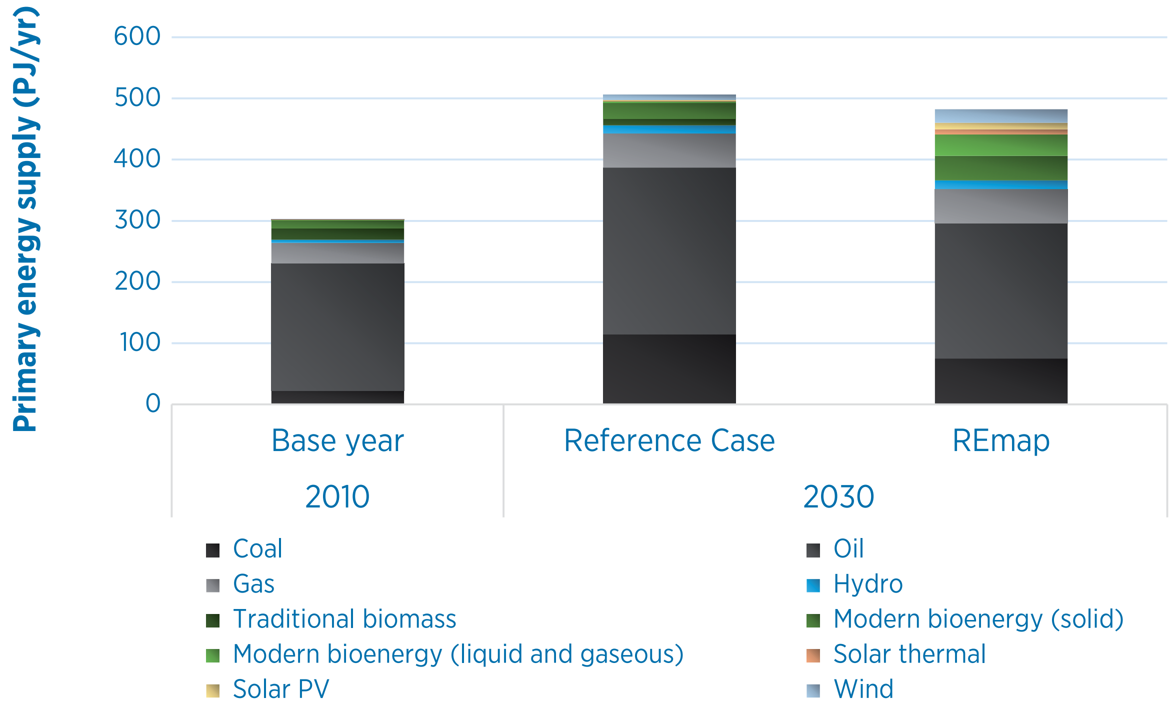
The power sector accounts for around 70% of that total mitigation potential. Meeting these emission reduction targets and making greater reductions means accelerating renewables deployment and energy efficiency measures to reach the emissions target reduction by 2030.

Table 17 shows a number of financial indicators for the Dominican Republic. The package of REmap Options for industry, buildings and power sectors would already result in annual savings of USD 1 billion in 2030 from the substitution of non-renewable technologies and fuels. The power sector shows the greatest potential for cost reductions with this particular energy mix. The transport sector REmap Options would be implemented for less than USD 190 million per year.

Reduced externalities from avoided CO_2 and air pollutant emissions estimated in this roadmap[42] also yield savings. Externalities related to air pollution (impacts on human health and agriculture) result on savings of USD 0.9-3.5 billion per year. Furthermore, at an assumed

42 The five air pollutants assessed include ammonia, mono-nitrogen oxides, particulate matter, sulphur dioxide and volatile organic compounds.

Figure 43: Total primary energy supply in Dominican Republic, 2010-2030



carbon price of USD 17-80 per tonne, related externalities could save USD 0.2-0.8 billion each year.

When accounting for the savings derived from the substitution of non-renewable technologies and reduced externalities, total annual savings could amount to USD 2.1 billion-5.3 billion per year[43].

If the REmap Options are analysed individually, some result in savings and others incur additional costs. REmap Options incurring additional costs require economic support, which amounts to less than USD 120 million per year in 2030. This represents around 2% of the total potential savings in REmap.

Since the savings largely offset the costs, policy makers should also consider innovative measures which could help balance the potential of renewables offering savings in some technologies and sectors. This would support the implementation of the REmap Options incurring some extra costs when compared to the non-renewable substitute.

In addition, the REmap mix estimated for the Dominican Republic cuts fossil fuel imports. Simply introducing REmap Options substituting oil and coal products decreases annual fuel input by about 91 PJ (2 170 ktoe) and save up to USD 1.6 billion a year in fuel costs. About three-quarters of these savings correspond to electricity generation fuel savings.

43 The costs of renewables have been compared with the non-renewable energy technologies assuming a relatively high growth in crude oil prices to 2030. This and the assessment of externalities has been carried out on the basis of standard parameters which may overestimate the savings in the island context.

Figure 44: Energy-related CO_2 emissions, 2010-2030

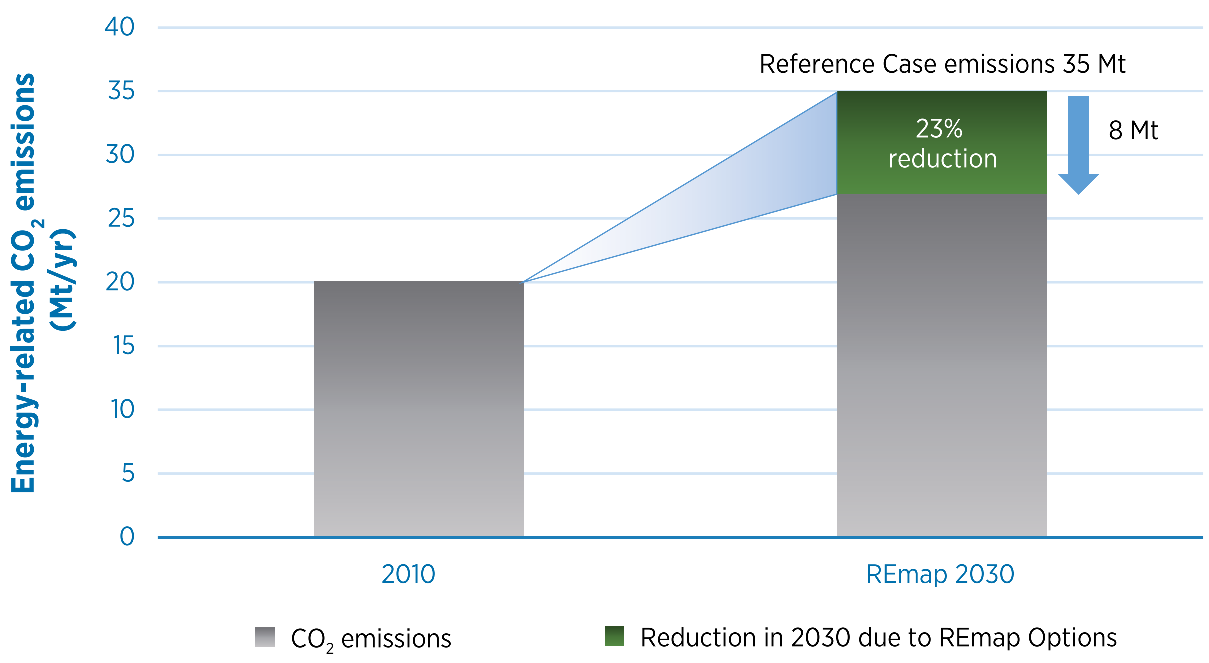


Table 19: Financial indicators for renewable energy use in Dominican Republic, government perspective

Annual energy system costs and savings, 2030 (Remap vs. Reference Case) (USD billion per year in 2030)	
System costs from REmap Options	**-1.0**
Industry	-0.2
Buildings	-0.1
Transport	0.2
Power	-0.9
Savings from reduced externalities	**1.1 to 4.3**
Reduced externalities from outdoor air pollution	0.6 to 2.7
Reduced externalities from indoor air pollution (traditional biomass)	0.3 to 0.8
Reduced externalities from climate change	0.2 to 0.8
System costs from Remap Options and reduced externalities	**-2.1 to -5.3**
Incremental subsidy needs	**0.15**

6 SUGGESTIONS FOR ACCELERATING RENEWABLE ENERGY UPTAKE

This roadmap has shown that the Dominican Republic has the potential to raise its renewable energy share to 27% by 2030. This would result in an annual consumption of 87 PJ (2 080 ktoe) of final renewable energy. About half this potential is in the power sector and the other half in the direct use of renewables in end-use sectors, namely heating, cooling and transport.

If the potential of technologies in REmap are implemented, the renewable energy share in the power sector reaches 44%. This is significantly higher than the 25% target in Law 57-07. In heating sectors, the renewable energy share can reach 43% and 41% for buildings and industry respectively. In transport, it could work out as high as 5.1%. Existing energy plans and targets in the Dominican Republic do not account for this potential, especially in end-use sectors.

In terms of technology mix, bioenergy has considerable potential to account for about half the total final energy mix because it can replace fossil fuels in different applications across the energy system. Most importantly, onshore wind and solar PV show exponential growth between now and 2030 with total installed generation capacities reaching 2.3 GW and 1.7 GW respectively. Their combined output would represent 25% of total electricity generation by 2030 meaning VRE would represent a considerable share of the country's total power output.

Realising the renewable energy share estimated in this roadmap would require an average annual investment of USD 695 million between now and 2030. When these investments are annualised, and the annual operation, maintenance and fuel costs accounted for, renewables actually result in savings compared to the costs of non-renewable energy technologies that they substitute. This energy mix yields a number of important benefits in 2030. CO_2 emissions relating to energy could be reduced by up to 23% compared to the baseline level in the same year. This means only the accelerated deployment of renewables suggested by REmap provides the important step the Dominican Republic needs to fulfil its INDC. Moreover, renewables would improve the environment and reduce externalities related to the human health impacts of fossil fuel by USD 1.1-4.3 billion per year by 2030. Finally, the country's fossil energy bill can be cut by USD 1.6 billion per year.

Fulfilling this potential raises a number of challenges. In this roadmap, challenges specific to the power sector and end-use sectors are separately identified.

In the power sector, the challenges fall mainly into institutional, economic and technical. Technical challenges include generation adequacy and flexibility, adequate electric grid development, management of variability, limited predictability of variable renewable power and management of instantaneous penetration levels for variable renewable power.

End-use challenges can be broadly categorised around limited consideration in planning and limited awareness of the major potential offered by renewable energy technologies. For bioenergy, it will be important to create markets and ensure affordable and reliable supply while maintaining sustainability.

As far as the Dominican Republic policy landscape is concerned, these are the high-level suggestions for dealing with the specific challenges described above:

- In light of the vision in REmap, establish clear and consistent renewable energy targets. Ensure they are consistent with other national energy strategies and a stable institutional and regulatory framework with the right financial incentives to attract renewables investments.

- Ensure enough dispatchable generation is available to provide the firm capacity and flexibility required by the power system. Design appropriate incentives for this purpose supported by updated generation expansion plans with intermediate targets.

- Align transmission planning with renewable energy targets and assess the cost and benefits of grid expansion and other local balancing measures to efficiently manage possible grid congestion.

- Define measures in line with planning for renewable energy deployment and transmission capacity to guarantee economic levels of curtailment. Explore the feasibility of flexibility measures to manage it efficiently.

- Devise and introduce appropriate incentives and market mechanisms to promote a flexible power system able to handle the new operational conditions imposed by the expected high share of variable renewables.

- Define codes and standards for buildings construction and renovation that take account of renewables such as solar water heating and cooling. Integrate renewables into energy and urban planning to accelerate their uptake by ensuring cost-effective energy supply to the population.

- Plan and develop a strategy for renewables use in industry by paying particular attention to the technical/economic design, operational hours and temperatures of industrial processes.

- Create a market for liquid biofuels in transport and promote electric mobility in congested urban areas and touristic parts of the country. This market also needs to make use of synergies with the power sector and plan for related infrastructure and financing needs.

- Set targets for bioenergy use in applications lacking any other renewable energy alternative and where bioenergy creates added value to the system. Promote the uses of its most resource-efficient and cost-effective pathways to ensure sustainability.

This roadmap provides a detailed overview of the realistic potential of renewables in the Dominican Republic by 2030. Fulfilling the REmap Options by 2030 will require significant effort to plan the intermediate targets and measures to achieve them, particularly in the power sector. The findings of this roadmap thus need to be complemented by detailed technical and economic studies on operating and planning the interconnected systems containing a high share of VRE.

IRENA looks forward to further supporting the energy transition in the Dominican Republic, particularly by conducting any studies necessary. This research will be needed to prepare for the integration of the large share of solar and wind energy identified in this analysis, as well as the possible impacts of REmap Options on the power market. All this is inscribed in the context of the work the Agency carries out for SIDS.

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ANNEXES

ANNEX 1: SUMMARY OF RESULTS

		Unit	2010	2014	Reference Case 2030	REmap 2030
TFEC	Total final energy consumption - TFEC	PJ	221	275	321	328
	Total renewable energy consumption (incl. electricity and direct uses; incl. traditional biomass)	PJ	37	38	52	87
	Total renewable energy consumption (incl. electricity and direct uses; excl. traditional biomass)	PJ	19	21	41	87
Renewable energy share	Share of renewable energy in final energy consumption of direct uses (excl. electricity; incl. traditional biomass)	%	18%	14%	12%	17%
	Share of modern renewable energy in final energy consumption of direct uses (excl. electricity; excl. traditional biomass)	%	7%	6%	8%	17%
	Share of total renewable energy use (incl. traditional biomass) in TFEC	%	17%	14%	16%	27%
	Share of modern renewable energy use (excl. traditional biomass) in TFEC	%	8%	8%	13%	27%

ANNEX 2: COMMODITY PRICE PROJECTIONS

Commodity price projections were taken from the following:

- Commodity prices as a first point for determining price projections were based on a number of sources. These include data provided by local experts and CNE and the Latin American Energy Organisation (OLADE) database on energy prices and IRENA assessments from other countries in the region.
- Biomass prices provided by IRENA bioenergy supply and cost assessment.

Commodity	Unit	2030 average government prices excluding taxes and subsidies
Crude oil	(USD/GJ)	19.05
Steam coal	(USD/GJ)	4.32
Electricity buildings (household/commercial)	(USD/kWh)	0.27
Electricity industry	(USD/kWh)	0.36
LPG household	(USD/GJ)	34.25
Oil products industry (fuel oil, diesel)	(USD/GJ)	29.17
Oil products electricity generation (fuel oil, diesel)	(USD/GJ)	27.49
Diesel for transport	(USD/GJ)	23.99
Gasoline for transport	(USD/GJ)	29.13
Biodiesel for transport	(USD/GJ)	23.00
Conventional biogasoline for transport	(USD/GJ)	21.00
Advanced biogasoline for transport	(USD/GJ)	66.00
Primary bionergy (surplus forest and non-forest land)	(USD/GJ)	17.32
Biomass from surplus forest land	(USD/GJ)	17.32
Biomass from surplus forest land	(USD/GJ)	17.32
Bioenergy residue – agro-processing	(USD/GJ)	1.29
Bioenergy residue – crop harvesting	(USD/GJ)	8.91
Bionergy residue – animal manure & post-consumer household waste	(USD/GJ)	3.19
Traditional biomass	(USD/GJ)	1.00
Municipal waste	(USD/GJ)	1.16

ANNEX 3: TECHNOLOGY COST AND PERFORMANCE IN THE DOMINICAN POWER SECTOR IN 2030

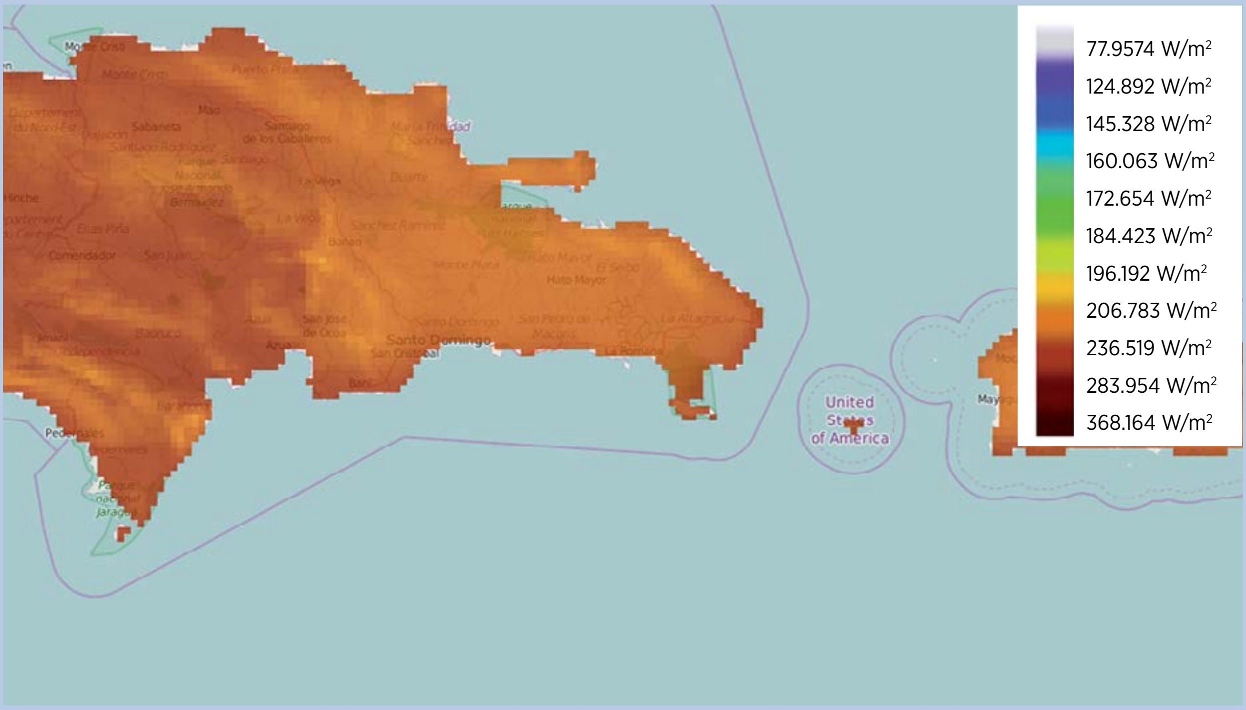
Average Capital costs for power generation technologies are largely IRENA assessments but include localised capacity factors based on the Reference Case projections for energy production.[44]

Technology/units	Overnight capital cost	Operation and maintenance costs	Capacity factor	Conversion efficiency[44]
	USD/kW	USD/kW per year	%	%
Hydropower (small)	2 500	50	35	100
Hydropower (large)	1 500	30	35	100
Onshore wind	1 500	60	30	100
Solar PV (residential/commercial)	1 400	14	18	100
Solar PV (residential/commercial) with battery storage	1 700	60	18	100
Solar PV off-grid with battery storage	1 650	60	25	100
Solar PV (utility)	1 000	10	20	100
Biomass co-firing (retrofit)	500	13	70	38
Biomass anaerobic digester	3 300	83	70	35
Landfill gas internal combustion engine	1 800	45	70	32
Coal	1 300	52	80	30
Oil products	1 100	17	39	42
Diesel (gen-set)	1 500	38	40	42

44 The table provides the conversion efficiencies used when estimating primary energy. Primary energy is, for instance, crude oil and lumps of coal before conversion into the gasoline and electricity – the "final energy" – that reaches consumers. Different organisations use different ways to estimate primary energy. In the REmap analysis, the Physical Energy Content method is used. This method, employed by the IEA and Statistical Office of the European Union (EUROSTAT), renewable electricity (*e.g.,* wind, solar PV and hydropower) and biofuels are counted in primary energy as they appear in the form of secondary energy (i.e., using a 100% efficiency to convert them into primary energy equivalents), while geothermal, CSP electricity and nuclear electricity are counted using average process efficiencies (*e.g.*, 10-33%) to convert them into primary energy equivalents.

ANNEX 4: RESOURCE MAPS FROM IRENA'S GLOBAL ATLAS

Solar resource map, average annual GHI



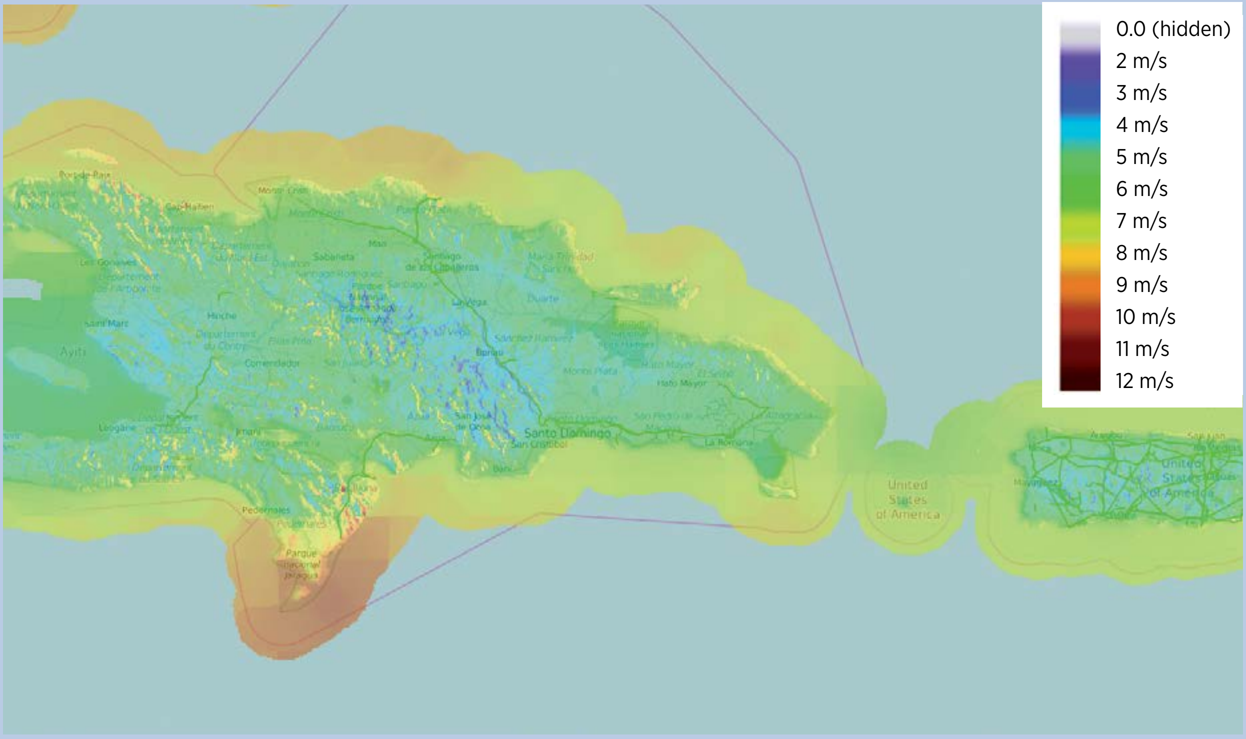
W – watts

Source: IRENA Global Atlas (irena.masdar.ac.ae/), map data: Vaisala, 2016, base map layer: 2015 Global power lines OpenStreetMap (www.openstreetmap.org)

The maps shows Vaisala's Global Solar Dataset 3 km with units in W/m² per day. Vaisala's Global Solar Dataset provides average annual GHI at a 3 km spatial resolution. Average values are based on more than ten years of hourly GHI data. They are derived from actual, half-hourly, high-resolution visible satellite imagery observations via the broadband visible wavelength channel at a 2 arc minute resolution. Vaisala processed this information using a combination of in-house research and algorithms published in peer-reviewed scientific literature.

Further details for the Dominican Republic resource or other maps can be found in the IRENA Global Atlas site: *http://irena.masdar.ac.ae/*

Wind resource map, wind speed mean at 100 metres height



Source: IRENA Global Atlas (irena.masdar.ac.ae/), map data: Technical University of Denmark (DTU), 2015, base map layer: 2015 Global power lines OpenStreetMap (www.openstreetmap.org)

DTU Global Wind Atlas: onshore and 30 km offshore wind climate dataset accounting for high resolution terrain effects. The Global Wind Atlas provides a high resolution wind climatology at 50, 100 and 200 metre hub heights above the surface for the whole world (onshore and 30 km offshore). These layers have been produced using microscale modelling in the Wind Atlas Analysis and Application Program (WAsP). They capture small-scale spatial variability of wind speeds due to high-resolution orography (terrain elevation), surface roughness and surface roughness change effects. The layers shared through the IRENA Global Atlas are served at a 1 km spatial resolution.

Further details for the Dominican Republic resource or other maps can be found in the IRENA Global Atlas site: *http://irena.masdar.ac.ae/*

ANNEX 5: EXISTING POWER GENERATION PLANTS AND TRANSMISSION INFRASCTRUCTURE FROM CNE MAPS

Existing power generation plants and transmission infrastructure (as of August 2016)

Source: CNE maps (2016e) – (Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community)

For further details and other features of the energy maps please visit the CNE maps website: *http://mapas.cne.gob.do/*

ANNEX 6: GENERAL ASSUMPTIONS ON INDICATORS FOR DOMINICAN REPUBLIC

	Units	Latest available data	2030	2030 assumption details
Population	million	10.4 (2013)	11.9	Extrapolation based on historical growth trends
Passenger cars per 1 000 people	units	94 (2013)	127	Extrapolation based on historical growth trends
Public transport bus stock	units	14 192 (2010)	18 890	Extrapolation based on historical population growth
Number of households	million	2.67 (2010)	3.48	Based on CNE (2014a) population assumptions for energy projections
Available rooftop area – residential	km^2	134.5 (2013)	173.0	Extrapolation based on historical growth
Available rooftop area – commercial	km^2	20.7 (2013)	25.8	Extrapolation based on historical growth

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