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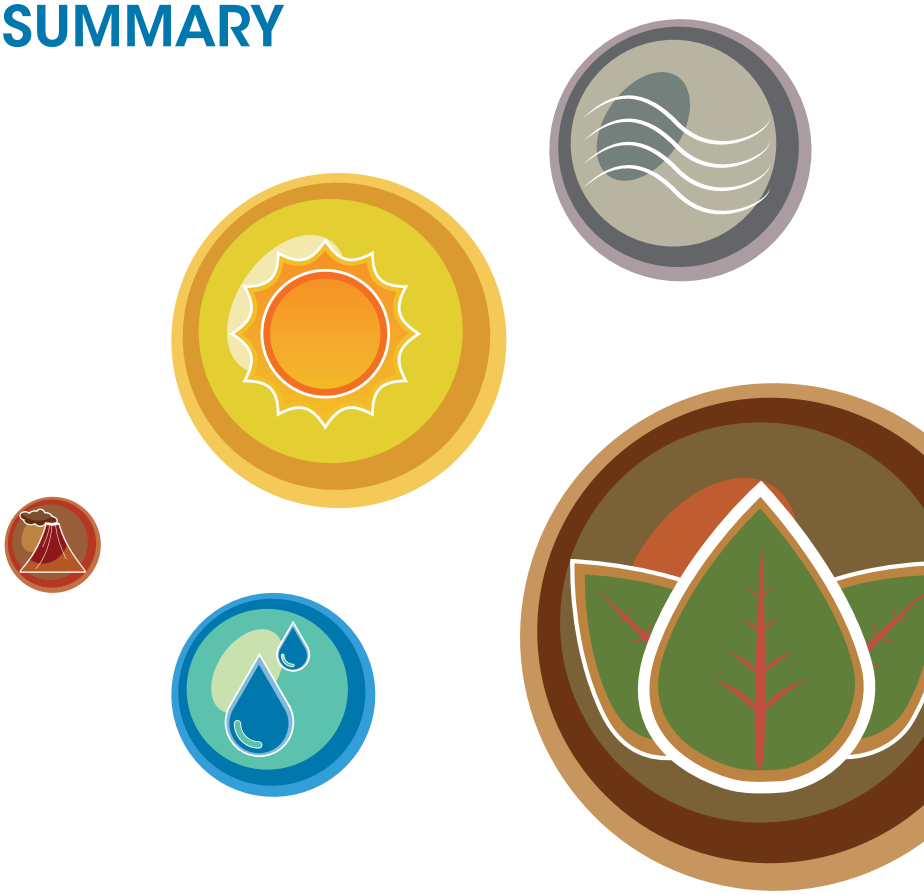
IRENA
International Renewable Energy Agency

REmap 2030
A Renewable Energy Roadmap

EXECUTIVE SUMMARY



RENEWABLE ENERGY PROSPECTS:

MEXICO

May 2015

About IRENA

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

About SENER

The Mexican Energy Secretariat (SENER) is the institution in charge of driving the country's energy policy, within the national constitutional framework, to ensure an economically viable competitive supply of, sufficient, high quality, and environmentally sustainable energy. With the vision, to achieve a country with universal access to modern energy services at competitive prices, provided securely by public and private companies of the highest world standards, and with the extensive promotion Energy Efficiency and Renewable Energy.

The full country report for Mexico, the REmap 2030 global report and summary of findings and other supporting material are available at www.irena.org/remap

For further information or to provide feedback, please contact the REmap team at remap@irena.org

REmap reports are available for download from www.irena.org/publications

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HIGHLIGHTS

- Mexico has a large and diverse renewable energy resource base. Given the right mix of policies, Mexico has the potential to attract large-scale investment in renewables that can help diversify its energy supply. Increased renewable energy use would also set Mexico on a pathway toward significantly reducing its greenhouse gas (GHG) emissions. However, development has been limited so far.
- Under current plans, the share of modern renewable energy in total final energy consumption (TFEC) is forecast to increase from 4.4% in 2010 (base year of this analysis) to 10% in 2030. According to REmap 2030, Mexico has the potential to increase this share to 21% by 2030. This implies a threefold growth in total renewable energy use in absolute terms from 0.5 exajoules (EJ) to 1.5 EJ in 2010-30.
- By 2030, Mexico could generate up to 46% of its electricity each year, or 280 terawatt-hours (TWh), from renewable sources. This compares with 18% using business-as-usual developments (116 TWh/year). To achieve a 46% share of renewables in electricity generation, the country is likely to see the greatest deployment in wind (30 gigawatts (GW)) and solar photovoltaic (PV) (30 GW). Together these could account for 26% of total power generation in 2030. Small and large hydropower (26 GW) could contribute 12% of total power generation, with geothermal energy supplying 5% (4.5 GW) and biomass 2.5% (4 GW).
- If renewables uptake were accelerated, all traditional uses of biomass for cooking or heating in the buildings sector would be replaced by modern forms of renewable energy. Total biomass consumption in all end-use sectors for heating or as transport fuels could reach 685 petajoules (PJ) by 2030. This represents more than one third of total renewable energy use. Total installed capacity of solar thermal applications for heating/cooling in buildings and industry would amount to 33 GW, making up almost one tenth of the country's renewable energy consumption.
- Renewables can be an important driver for diversifying Mexico's energy supply. Renewable energy has the potential to reduce Mexico's total coal demand by 62%, natural gas by 21% and oil by 6% compared to business as usual to 2030. As a result, total natural gas demand would grow by 115% in 2010-2030 compared to 175% under business as usual.
- Accelerating Mexico's uptake of renewable energy could result in savings of 7.2 US dollars (USD) per megawatt-hour (MWh) compared to the equivalent new capacity with conventional generation. This saving would equate to 9% of the production cost of natural gas-fired power generation in 2030.
- The result of this higher renewable energy uptake is an annual net savings of USD 1.6 billion in Mexico's total energy system cost by 2030. Meanwhile, if the benefits resulting from lower harm to health and reduced carbon dioxide (CO_2) emissions are taken into account, savings could amount to USD 4.6 billion and 11.6 billion respectively each year.
- To achieve such gains, policy changes in the power market are needed. Planning is essential for transmission, expansion and grid integration to accommodate the full range of renewable power technologies.
- New policies are also needed to promote the uptake of renewable energy for heat and fuel applications in the buildings, industry and transport sectors.

Building a renewable energy market

Mexico accounts for one fifth of all energy use in Latin America, and demand is growing fast. Business-as-usual growth will result in an increase of installed power generation capacity from 64 GW in 2013 to 118 GW in 2030. Mexico is the world's tenth largest oil and natural gas producer. However, natural gas and coal imports are growing, and its dependence on natural gas for power generation has become a major concern. To address these and other challenges, Mexico enacted a series of energy reforms in December 2013. These opened up the energy sector to new players and new ideas, and are set to gradually remove subsidies for oil products and electricity tariffs over the coming years.

In order to fulfil its international GHG reduction pledges, Mexico has also set a clean energy power generation target for 2050. The aim is to reach a share of as much as 40% in power generation from zero or low-emission energy types by 2035, and 50% by 2050. This includes renewables as well as nuclear and fossil fuels with carbon capture and storage. Renewable energy also offers great potential for fostering social and economic development in Mexico's relatively remote and poorer regions. Mexico is taking measures to provide modern energy to nearly three million people in rural areas who lack access to electricity, and to reduce the use of traditional biomass in cooking.

These trends have boosted the case for renewable energy deployment. Mexico has a large and diverse renewable energy resource base. However, development has been limited, so that significant opportunities remain. With the right mix of policies, Mexico can attract large-scale investment in renewables.

REmap 2030: Mexico's renewable energy potential

The International Renewable Energy Agency (IRENA) has developed a global renewable energy roadmap called REmap 2030. This shows how the share of renewables in the global energy mix can be doubled by 2030, both realistically and cost-effectively. This is in line with one of the key objectives of the Sustainable Energy for All (SE4All) initiative led by the United Nations (UN). REmap 2030 is the result of a collaborative process between IRENA, national experts within each of the 26 countries covered by the analysis to date and other stakeholders.

This study is the joint work of IRENA and the Mexican Ministry of Energy (SENER). It identifies the country's possible development path to increase the use of renewables across its entire energy system by 2030. This is one of the first country reports to be released in the REmap 2030 series as part of the IRENA roadmap for doubling the global share of renewables.

Mexico is only just beginning to draw on its large renewable energy potential. As of 2013, total renewable energy capacity in the power sector was 14.2 GW out of 64 GW total system capacity. This share was composed mainly of hydropower (18% of total installed capacity), followed by wind and geothermal (with a combined total of around 4%).

Meanwhile, the renewable energy share in the industry and transport sectors in 2010 (the base year of this analysis) was 5% and

0.8%, respectively. This was largely derived from the combustion of bagasse by-products for industrial process heat generation based on bioenergy, as well as from liquid biofuels. Although the renewables share was higher in the building sector, more than a quarter of that was attributable to the traditional use of biomass (firewood and forestry residues). This is often not sustainably sourced and is not considered a modern form of renewable energy for the purpose of this analysis.

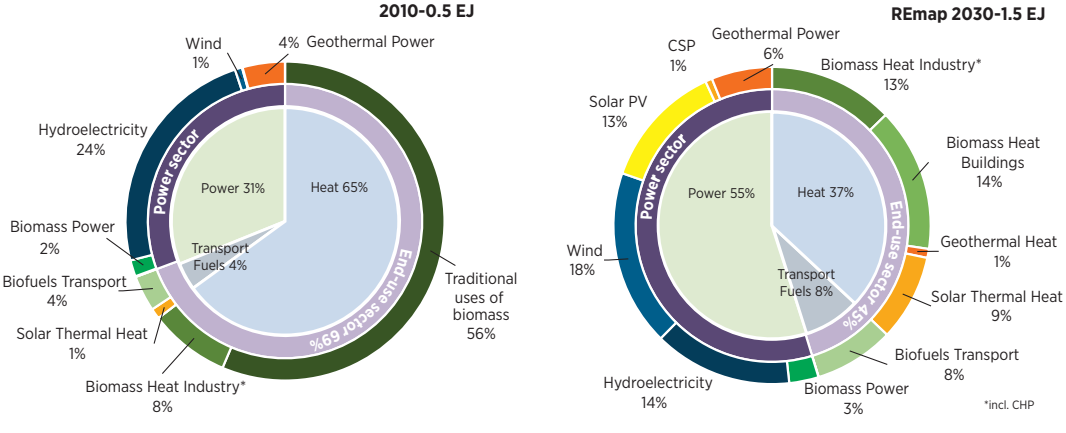
According to SENER and Asia-Pacific Economic Cooperation (APEC) predictions, Mexico's share of modernised renewable energy will only reach 10% of TFEC by 2030 under business as usual. This amounts to more than twice the proportion of 4.4% in 2010. Considered in the light of a 64% growth expected in TFEC, this means a substantial renewable energy scale-up with a significant acceleration compared to historic trends. Even so, the REmap analysis shows far more is possible.

REmap 2030 estimates a portfolio of technology options to accelerate renewable energy deployment across Mexico's entire energy system that could raise the 2030 share to 21%. This implies a threefold increase in total renewable energy use in the same period.

Renewable power generation: wind and solar take the lead

Based on REmap 2030, more than half of Mexico's total renewable energy use would be in the electricity sector. Mexico has the potential to generate 280 TWh of renewable power by 2030, representing a sixfold increase over today's level of 48 TWh. Achieving this would require a diversified mix of wind, solar, hydro, geothermal and biomass power technologies.

Wind and solar PV combined would account for nearly 60% of Mexico's renewable power generation, and 26% of total generation in



Total renewable energy use can triple between 2010 and 2030

Note: Exajoules (EJ) in figures refer to renewable energy use in total final energy consumption.

2030. Reaching this level of deployment requires policies that take into account Mexico's major land area, in which demand and supply are often far apart. The country has the potential for significant power generation from biomass and geothermal sources, which are also some of the least expensive power supply options.

Wind power represents a major opportunity across both the north and the south of Mexico, with the potential to produce 92 TWh of electricity per year by 2030. Nearly all of this would be derived from onshore wind. In the context of the country's total installed wind power capacity of 1.7 GW in 2013, a total of 30 GW in 2030 would require an average annual installation rate of 1.7 GW.

Solar PV could contribute 30 GW of power capacity, generating 66 TWh of electricity per year in 2030. This would require an average annual installation rate of 1.5 GW. A quarter of the total installed capacity in 2030 would be in the form of distributed PV and mini-grid applications for street lighting, agricultural water pumping and mobile phone towers (7 GW). An additional 1.5 GW would come from concentrated solar power (CSP).

Bioenergy for power generation would amount to around 4 GW of capacity. Approximately 1 GW of this would come from biomass co-firing in coal plants and 1.8 GW from combined heat and power (CHP) in the manufacturing industry.

Mexico already has the world's fifth largest **geothermal power** installed capacity after the US, the Philippines, Indonesia and New Zealand, and could utilise its high-temperature reservoir potential to reach 4.5 GW in 2030.

Under current plans, Mexico would reach 17 GW of **large hydropower** capacity by 2030. According to REmap, a further 6.5 GW could be installed. **Small hydropower** capacity is already forecast to reach 1.8 GW, equivalent to an annual addition of 90 megawatts (MW) in 2015-30, or about ten small hydropower plants per year. Total installed hydropower capacity would reach 26 GW under REmap 2030.

System integration and expansion of transmission capacity will be essential to ensure the smooth integration of renewables. This is particularly true given the 26% share of variable renewable energy estimated in the accelerated case in REmap 2030. Additional transmission capacity must be planned to exploit wind and solar PV capacity in the northern and western parts of Mexico, which are distant from population centres and industrial activity. The first step will be to fulfil plans to connect Baja California and Baja California Sur to the main grid, both of which have significant resources of solar and wind. It will also be important to plan for rooftop distributed generation. Mexico covers a large area and has many scattered communities. This means mini-grid and rural electrification will play a crucial role, particularly in helping diminish the challenge of grid integration and transmission capacity expansion.

Using renewables to meet transport, buildings and industry energy needs

The other half of total renewable energy use in REmap 2030 would come from non-electricity needs in the transport, buildings and industry end-use sectors.

Modern renewables for heating, cooling and cooking in buildings and industry offer the greatest growth potential, although their use is limited today. Renewable energy use for heating is currently dominated by traditional biomass use, with a small share of bagasse combustion used for industrial process heat and power generation. Solar water heating for buildings is also limited, but there is great potential to replace liquefied petroleum gas (LPG) in this market segment as LPG subsidies are phased out.

REmap 2030 estimates that solar thermal capacity for heating and cooling could reach 33 GW. This includes 13 GW of heating in the manufacturing industry, which represent 6% of heat demand. The buildings sector would account for 20 GW of solar water heaters, contributing 25% of water heating demand. About 5 TWh of power today is used in the residential sector for space cooling, and this is estimated to rise to about 20 TWh/year in REmap 2030. To help meet this need, buildings provide an estimated 4 GW of solar cooling potential. This would reduce total power demand for cooling in the household sector by 5% in REmap 2030. Industry offers the potential for 7 GW of solar thermal use for low-temperature process heat applications (textiles, food production and some chemical processes). There is also potential for more than 2 GW for medium-temperature process heat applications using concentrated solar thermal systems (mainly in chemicals production). Some niche applications already exist in Mexico today in the food sector.

Under current plans, traditional biomass used for cooking will account for 17% of total biomass use in buildings in 2030. REmap estimates traditional uses of biomass will be replaced by modern and efficient cook stoves that use wood for cooking.

Under current policies, only limited growth for renewable energy is forecast for Mexico's transport sector. This is due to rise from 0.8% in 2010 to 2.4% by 2030. In REmap 2030 this could climb to 4.2% in 2030 with the introduction of about six billion litres of liquid biofuels. This would constitute an important step in raising the renewables share in the transport sector, which accounts for nearly half of Mexico's total energy demand today. Dedicated policies based on renewables are needed, both to increase biofuels uptake and to promote mass transportation and electric transport.

In REmap 2030, total use of primary biomass would reach 810 PJ/year, mostly for heating in industry and buildings. This volume is as much as 10% of Mexico's total primary energy supply in 2010.

Cost and benefits of REmap 2030

Increasing the renewable energy share to 21% of Mexico's total final energy mix would result in financial savings. The cost and benefits of renewables are presented in the REmap analysis from both business and government perspectives. The former is based on the national cost of capital and commodity prices that include local taxes or subsidies. The international or government perspective is based on standard international commodity prices and a fixed 10% discount rate.

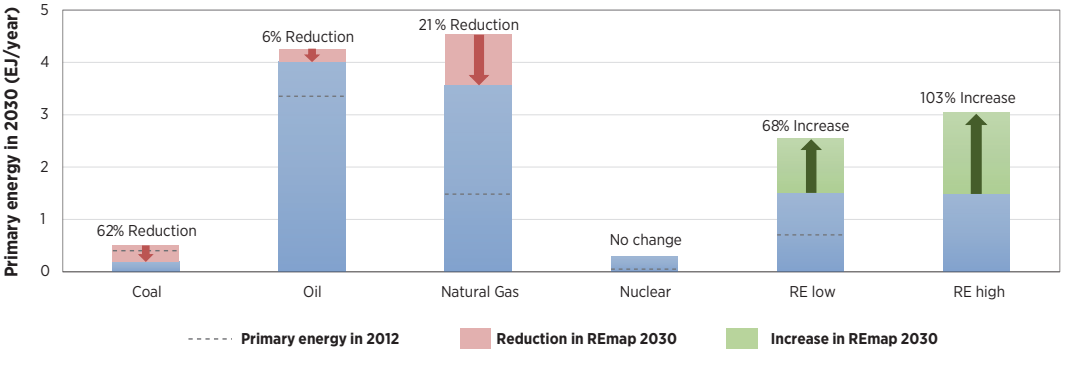
The results from REmap 2030 show that more than half of all renewable energy technology options could be deployed with cost savings

when compared to conventional technology options. From the business perspective, this translates into savings of USD 0.4/MWh (USD 0.1 per gigajoule (GJ)). From a government perspective, this results in savings of USD 7.2/MWh (USD 2/GJ). These estimates are based on 2030 capital cost projections for energy technologies and assume an increase of 50% in fossil fuel prices between 2010 and 2030. These cost savings, however, do not account for infrastructure (*e.g.,* additional generation or transmission capacity) and enabling technology costs (*e.g.,* grid integration).

Savings related to socio-economic benefits arise from increasing the share of renewables as estimated in this study. When accounting for externalities resulting from reduced health effects and CO_2 emissions, total savings could be USD 4.6 billion-11.6 billion in 2030. The health savings are estimated based on the unit external costs of sulphur dioxide (SO_2), mono-nitrogen oxides (NO_x) and particulate matter ($PM_{2.5}$) emissions. These cause outdoor air pollution from fossil fuel combustion in power generation, heating and transport, as well as through traditional biomass use resulting in indoor pollution in Mexico. In addition, a price range was assumed of USD 20-80 per tonne of CO_2, with the same range applied to all other countries in the REmap study.

The replacement of conventional technologies by renewable energy in REmap 2030 cuts fossil fuel demand by almost 1.5 EJ by 2030 compared to business as usual. Lower fossil fuel demand leads to an estimated reduction of 102 megatonnes (Mt) per year of CO_2 emitted by 2030. This amounts to a 17% reduction compared to the business-as-usual case in 2030. Three quarters of that total mitigation potential comes from the power sector.

Implementing all the options indicated by REmap would more than halve Mexico's total coal demand by 2030 compared to 2010 levels. REmap Options also represent an opportunity to reduce total demand for natural gas



Tripling total renewable energy use by 2030 would reduce Mexico's natural gas demand 21% compared to business as usual

by 21% compared to current policies for 2030. Savings in oil products are lower – about a 6% reduction. Two thirds of these savings are located in the manufacturing sector.

Policies to accelerate renewable energy

Recent progress in renewable energy uptake indicates that the country has begun to deploy its high renewable energy potential. But further policies are still needed to ensure progress. These recommendations can be categorised into five core areas in which action can be taken to achieve higher renewable energy shares.

Planning transition pathways: planning for renewable power generation capacity needs to go hand in hand with planning for related infrastructure. There is a need for clear and adequate market operation rules and codes for grid connection and access. These need to guarantee renewable power capacity development. The major low-cost renewable energy potential in the end-use sectors needs to be more fully extracted through targeted renewable energy policies. There is a need to accelerate the uptake of solar water heating and biomass-fired CHP capacity, and new policies will be essential to make use of biofuels in Mexico's transport sector.

Creating an enabling business environment: improving cost-effectiveness starts with reducing risks for investors in renewable energy, as well as deploying new capacity. Suitable policy frameworks are needed to implement effective economic, financial and fiscal incentives to accelerate investments. Furthermore, the market needs mechanisms to account for externalities. Continuing the discussion around fossil fuel and renewable subsidies for transport and electricity will also be important.

Ensuring smooth integration of renewables into the system: the integration of a major proportion of different renewable energy technologies is accompanied by three main challenges:

- building and paying for enabling grid infrastructure to address variability
- planning for the most effective use of solar rooftops in buildings
- securing bioenergy supplies, and replacing the use of traditional biomass

Creating and managing knowledge: improving information on renewable energy among policy makers, manufacturers, project developers/installers and users is essential. Applying appropriate system models to create knowledge of Mexico's power system will provide insight into how higher shares of variable renewable power generation can be accommodated in terms of transmission, demand-side resources and grid operation.

Unleashing innovation: technology innovation will play a key role in realizing Mexico's renewable energy potential. Mexican Energy Innovation Centres have started to make important contributions. Expanding these further could help the sector to break down barriers related to the costs and availability of technologies that have so far seen only limited growth. A number of issues are under examination in these and other similar centres. They include, for instance, construction, testing and certification of medium-scale and grid-friendly wind turbine concepts, industrial solar thermal innovations, and solar-powered cooling systems.

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