IRENA
International Renewable Energy Agency

G20 TOOLKIT FOR RENEWABLE ENERGY DEPLOYMENT: COUNTRY OPTIONS FOR SUSTAINABLE GROWTH BASED ON REMAP

JUNE 2016

BACKGROUND PAPER

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 repository of policy, technology, resource and financial knowledge on renewable energy.

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Planning for accelerated renewable energy deployment

Today, the Group of Twenty (G20) has a leading role in technology development and innovation that can help to accelerate renewable energy deployment. The financing institutions within the G20 represent the bulk of the global financing system. In October 2015, under the Turkish presidency, the G20 adopted the "Toolkit of Voluntary Options for Renewable Energy Deployment". IRENA has been requested to co-ordinate the toolkit activities, in co-operation with other international organisations (G20, 2015).

One of five focus areas of the toolkit is the development of roadmaps for renewable energy deployment in the G20. IRENA's renewable energy roadmap (REmap) programme assesses renewable energy technology potentials and their costs and benefits in enabling the world to double its share of renewables by the year 2030. The second edition of the global REmap was issued in March 2016. It includes renewables roadmaps for G20 member countries. This roadmap in hand summarises the results for the G20, identifies action areas for G20 policy makers and proposes the next steps of a "REmap G20 process".

Under the Chinese presidency in 2016, the G20 Voluntary Action Plan on Renewable Energy was put forth, in which an in-depth REmap study for the G20 member countries was highlighted as part of the continued implementation of the toolkit.

The importance of G20 engagement

According to IRENA's REmap, a doubling of the renewable energy share in the global energy mix by 2030 combined with a doubling of annual improvements in energy efficiency would set the world on a path that could limit global warming well below 2 degrees Celsius (˚C) above pre-industrial levels by the end of this century, in line with what the countries have agreed in Paris at the 21st session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21). The G20 member countries will play an essential role if the world is to realise a doubling of the renewable energy share, as they account for three-quarters of the total global potential of renewables by 2030.

The modern renewable energy share of the G20 today stands at 10% (19% when traditional uses of bioenergy are included), which can increase to 15% if the member countries follow their current plans and targets. With the options identified by IRENA in consultation with the country experts, the share can reach 25% with existing technologies by 2030, and an even higher percentage of new technologies are considered in combination with energy efficiency, access and innovative renewable energy deployment strategies.

Today, renewable energy shares at the sector level vary greatly. Transport has the lowest share of renewables at 3% today. Power generation has the highest share among all sectors today, and by 2030 it will remain in that position based on both the aggregation of all country plans and if the additional potential of renewables is considered. Under REmap, renewables-based power generation will reach 45% of total generation, representing a doubling compared to today's level of about 23%. The share of renewables in end-use sectors also will grow significantly, according to REmap, but this potential is largely overlooked in countries' energy plans.

From a technology perspective, under REmap, wind and solar photovoltaics (PV) will see the largest growth in the power sector; solar thermal in the heating and cooling sector; and liquid biofuels in transport. Bioenergy will continue to be the largest source of renewables in 2030, accounting for half of total final renewable energy use.

If all REmap Options are implemented, power consumption from renewables would account for nearly half of total renewables use in the G20, with the other half stemming from direct use of renewables in the heating, cooling and transport sectors. If the renewable energy potential identified in the G20 is to be realised by 2030, G20 total installed capacity of renewable power generation would triple between now and 2030, from about 1 500 gigawatts (GW) to more than 4 500 GW. Solar PV and wind would represent the largest installed capacity, accounting for two-thirds of total renewable power capacity. In terms of generation, variable renewable energy sources will reach more than 20% in most G20 member countries. This paradigm change is not fully captured in G20 member country plans. No-regret options will need to be implemented if they do not yet exist, supported by a range of flexibility options in the medium and long term based on the power system characteristics of the countries.

Realising the potential estimated in REmap requires an investment of USD 640 billion per year, equivalent to 70% of the total global investment needed to realise all renewable energy technology options. When these investments are annualised, they translate to incremental system costs of USD 67 billion per year relative to the non-renewable energy technologies that are being substituted. However, benefits of renewables related to reduced health damage caused by air pollution and reduced carbon dioxide (CO_2) emissions outweigh these costs by between 10 and 30 times. These externalities related to human health and climate change currently are not accounted for in energy pricing.

Turning findings into action

The time required to double the renewable energy share in the global energy mix by 2030 is only 14 years. This is a very short time frame. Before the window of opportunity closes, policy makers must accelerate their efforts today and achieve significant progress within the coming years to avoid technology lock-in. To translate the potential estimated in this study into action, this roadmap identifies seven action areas for G20 policy makers:

- **Action area 1: There are important synergies between energy efficiency and renewables.** Best-available technologies in the short and medium term and novel energy technologies in the long term should be implemented to maximise energy efficiency, which also will result in higher shares of renewables. There also is a need to prioritise the implementation of renewable energy technologies – notably electrification coupled with renewable power generation – that offer both efficiency improvements and higher shares of renewables.
- **Action area 2: Introducing greater flexibility to the power system.** The power sector will continue to be the sector with the highest share of renewables in 2030, with the share of variable renewables increasing to more than 20% in most G20 member countries under REmap. This paradigm change needs to be better captured in country policy plans. Opportunities and challenges related to sector coupling and introducing greater flexibility need to be taken into account.
- **Action area 3: Deployment of more renewables in end-use sector applications.** The potential of renewables in the end-use sectors is underestimated. In particular, electrification of end-use applications coupled with renewables will be key. To a lesser extent, specific options also deserve more attention in the power sector, such as dispatchable renewables. Country plans need to account for the potential of renewables in these sectors.
- **Action area 4: Bioenergy is key in many countries but often does not receive due attention.** A significant increase in the renewable energy share in the G20 will require half of total final

renewable energy use to originate from bioenergy. As indicated in the G20 toolkit, to realise this, ensuring a sustainable and affordable supply of bioenergy feedstocks will be key. There also is a need for countries to reinforce their efforts to develop resource-efficient and cost-effective conversion technologies.

- **Action area 5: Innovation will be needed in certain areas.** A number of technology options are not covered in this roadmap, including the use of bioenergy as a feedstock for chemicals and plastic production, liquid biofuels for aviation, shipping and long-distance freight, and renewables for high-temperature steam production. These technologies require more research and development (R&D) and investment support. Innovation needs also go beyond technology to cover financing, business models and policies that can enable the higher uptake of renewables across the energy system. Policy makers need to ensure strong interaction of energy innovation between information and communication technologies (ICT), electric vehicles, agriculture and urban design.
- **Action area 6: Renewable energy costs are much lower than estimated by some, and they continue to fall.** Recent auctions across the world show that the costs of renewables are falling. Many analyses reveal significant further reduction potential of costs in the coming decades. Increased international co-operation for transfer of technologies and capacity building can play an important role in contributing to further declines in the costs of renewables in the G20.
- **Action area 7: The benefits of renewables are not adequately reflected in market prices.** The analysis shows that the benefits of renewables can significantly outweigh the costs of renewables in 2030. Today, there is a big gap between market signals and policy objectives. Policy makers need to correct for market distortions to bring them in line with the real cost of fossil fuels by accounting for externalities related to human health and climate change.

Next steps in the REmap G20 process

This roadmap shows in more detail the findings from IRENA's REmap analysis for the G20. The cornerstone of IRENA's approach is engagement with the country experts. Through collaboration with experts, IRENA has carried out initial analysis for all G20 member countries and has already prepared a number of detailed country roadmaps, including for China, Germany, Mexico and the United States. New roadmaps are being prepared for the European Union (EU), India, Indonesia, Russian Federation and South Africa.

Country plans are changing quickly, which requires continuous updating and review of the existing REmap country analysis. In line with the long-term goals of the Paris Climate Agreement adopted in December 2015, the time scope of the analysis needs to be expanded to 2050. Sustaining and expanding engagement with countries through this expert network and strengthening these teams with IRENA experts and other stakeholders from countries will be essential. This will allow countries to provide analytical feedback, and subsequently to update the results based on this feedback, which will be made available online continuously.

Based on this roadmap, which serves as a starting point for further engagement with the G20 at the country level, IRENA proposes as next steps the following "REmap G20 process" for the in-depth country study:

1) With interested member countries, form a REmap expert working group consisting of IRENA's REmap experts and national experts from the countries for deeper engagement with the country through focused group discussions, policy dialogues and technical workshops to develop a variety

of recommendations on policy and regulatory development, based on the REmap analytical results.

2) As new data come along, review and update the analysis periodically through the REmap expert working group.

3) Through the REmap expert working group, discuss implementation of results and integration into long-term energy planning and the energy development strategy.

4) Use IRENA REmap's analytical framework in the development of a decarbonisation agenda for the G20 energy sector and energy ministers, in co-ordination with other relevant ministers such as environment and natural resources.

1. Introduction: towards accelerated renewable energy deployment in the G20

Energy is critical to lasting economic growth, employment and environmental sustainability. On a global scale the energy mix is changing. The use of renewable energy has been rising in recent years, and this trend is expected to continue in the future. A range of market, technology and policy drivers that vary from country to country has caused this change. Accelerated uptake of renewable energy can save countries from the lock-in effects of greenhouse gas emission-intensive economic growth, and can contribute to an environmentally acceptable and economically sustainable development path.

The Paris Climate Agreement to limit global temperature rise to 2°C above pre-industrial levels, which was signed by world leaders in April 2016, has profound implications for future energy supply and demand. Moreover, the United Nations has for the first time included energy in its new Sustainable Development Goals (SDG 7), calling for a significant acceleration of renewable energy deployment.

Global renewable energy use has grown to account for more than 18% of global total final energy consumption (TFEC) in 2014 (IRENA, 2016a). Member countries of the G20 account for the bulk of current use, hosting 80% of existing renewable power generation capacity around the world. The G20 member countries provided 87% of renewable electricity capacity additions worldwide in 2015 (IRENA, 2016b). That year, more than half of new power generation capacity installed in G20 member countries was renewable, as was the case in 2014. The G20 therefore is crucial to the promotion of global energy market stability and economic growth, as G20 member countries have national and multinational programmes in place to accelerate renewables deployment.

Renewable energy can play a much larger role in the global economy. IRENA has assessed options for the world as a whole and for G20 member countries (19 countries and the EU)[1] specifically through its global REmap programme, an explorative approach of policy and technology options. REmap identifies the technology and sectors to realise a doubling of the share of renewables in the world's energy mix by 2030. According to the findings from the second edition of REmap, released in March 2016, the G20 member countries hold 75% of total global renewable deployment potential and a similar share of the total global investment potential for renewable energy between now and 2030. All G20 member countries can raise their modern renewable energy share, but the potentials and economics vary by country (IRENA, 2016a). The aim of this roadmap is to show the role of renewables in G20 member countries if the world is to double its share of renewable energy, and what this would imply in terms of cost and benefits to 2030. This roadmap also serves as a starting point for interested G20 member countries to take part in the review and use of these findings to support their deliberations on renewable energy.

This roadmap is structured as follows: Chapter 2 provides an overview of REmap data and methodology. Chapter 3 elaborates on the current renewable energy use status in the G20 member countries. Chapter 4 provides the outlook for the G20 if the world is to double its share of renewable energy by 2030. This roadmap concludes with chapter 5, which summarises seven action areas for G20 policy makers and also proposes the next steps of the "REmap G20 process". A detailed Annex accompanies this roadmap that shows the detailed REmap results for each country.

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[1] To date, 9 EU countries that represent two-thirds of EU's total final energy demand are participating in IRENA's REmap programme, namely Belgium, Cyprus, Denmark, Germany, France, Italy, Poland, Sweden and the United Kingdom. The results presented in this roadmap for the EU are estimated based on the scale-up of the findings of these nine countries. Once the analysis of the other 19 EU countries is added, the estimates for the EU could differ from what is shown here.

2. A transparent and inclusive analytical approach

REmap is a tool that creates options for decision makers to consider. The process is to first collect data from countries about their national plans and goals, and the next step is to produce a global baseline for renewable energy that has been compiled for the period 2010-2030. This is called the Reference Case. Subsequently, technology pathways that reap the rewards of the realistic potential of renewable energy technologies beyond the Reference Case are prepared, and these are the REmap Options. They are customised for specific countries and sectors, and aim to close an important knowledge gap for many countries by helping policy makers to a clearer understanding of the opportunities that lie before them.

The outcome of the REmap programme is not to set renewable energy targets, but the findings can inform target setting. The political feasibility and challenges to implement each option in different sectors and countries will vary depending on countries' national circumstances as well as on the level of commercialisation that technologies have reached. Targets are great starting points, but policy makers need to know more: how to get there and go beyond. A number of factors are considered in estimating REmap Options, including resource availability; access to finance; human resource needs and supply; manufacturing capacity; policy environment; the age of existing capital stock as well as the costs of technologies by 2030.

The methodology of REmap is different from other scenario studies and modelling exercises as the cornerstone of the approach is co-operation and consultation with countries. IRENA co-operates with the nominated country experts in developing the Reference Case and the REmap Options. IRENA has developed a spreadsheet tool that allows country experts to evaluate and create their own REmap analyses. These are clear and dynamic accounting frameworks to evaluate and verify Reference Case developments and REmap Options within a country. All results are displayed in a REmap-specific energy balance. The results of each G20 member country are provided in the Annex to this document.

Each REmap Option is characterised by its substitution cost, which is expressed in United States dollars (USD) per gigajoule (GJ) of final renewable energy. The substitution cost is the difference between the annualised costs of the REmap Option and a non-renewable energy technology used to produce the same amount of energy (*e.g.* electricity, heat), then divided by the total renewable energy use in final energy terms. It is based on the capital and operation and maintenance costs in 2030, and considers technological learning as well as energy price changes between now and 2030. In IRENA's REmap analysis, costs are estimated from the perspective of both business and government, accounting for the commercial focus of the former and the broad societal goals of the latter.

The business perspective provides a view on how investors would evaluate technology choice. Here, energy prices include taxes, subsidies and 40 country-specific discount rates (based on the anticipated cost of capital to private sector investors). The government perspective takes a broader societal view and includes the reduced externalities related to renewable energy. Selected externalities considered in REmap include carbon dioxide (CO_2) emissions and emissions of air pollutants, as well as their impact on human health and agricultural crops. A range of USD 17-80 per tonne of CO_2 is assumed for carbon prices and a wide range of unit external costs is assumed for air pollutants (IRENA, 2016c). Energy prices exclude taxes, subsidies and carbon pricing. A standard discount rate for investments is used: 7.5% for OECD countries and 10% for non-OECD countries. When the substitution cost is multiplied by the potential of each option (in petajoules (PJ) per year), the result is a realistic figure for the system cost associated with the increases in renewable energy deployment featured in the REmap Options.[2]

[2] A detailed explanation of the REmap methodology is provided online at www.irena.org/remap.

3. Present renewable energy deployment

The share of renewables – including electricity produced from renewables – in global TFEC[3] in 2014 was 18.4%. Fossil fuels accounted for more than 79% of energy use, and nuclear electricity accounted for about 2% (IEA, 2015). The renewable energy share in TFEC was relatively constant between 1990 and 2014, underpinned by the stable and traditional use of bioenergy in poorer countries by about 2.9 billion people, more than a third of the world's population.

By 2014, about half of renewable energy use (9.2% of TFEC) came from traditional use of bioenergy, with modern renewables providing 9.2% of TFEC, including bioenergy use in industry and in modern heating and cooling installations, liquid biofuels and all types of renewable electricity and heat. The modern renewable energy share in the G20 as a whole was slightly higher than the world average, estimated at 10%.

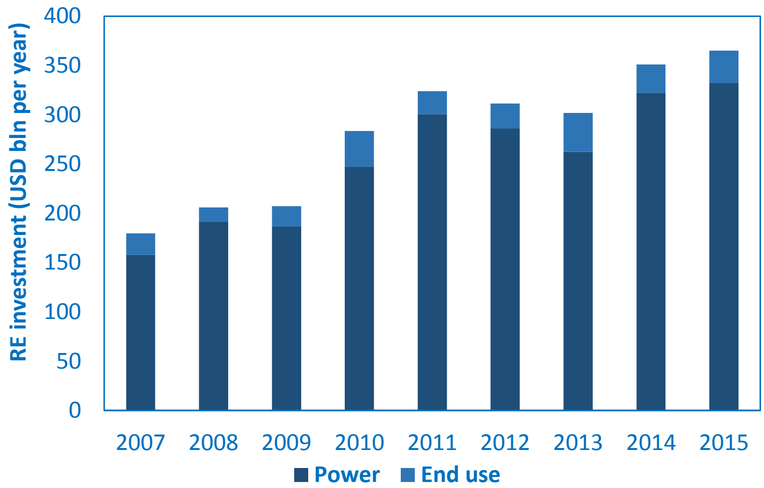
Worldwide, renewables-based power consumption accounted for 19% of total final renewable energy use in 2014, or nearly 38% of modern renewables excluding traditional use of bioenergy. To date, the power sector has experienced the majority of renewable energy capacity additions. By comparison, applications of modern renewables for heating, cooling and transport have been slower. Liquid biofuels use grew until 2010 and has been flat since then. Direct uses of renewables in end-use sectors account for 81% of the total final renewable energy use in 2014.

Today, 1.1 billion people in developing countries lack access to electricity. This is an indicator of an opportunity to meet significant demand in the future. Countries such as India, Indonesia and South Africa are likely to follow the path of rapid growth in energy use seen in China.

According to IRENA's preliminary assessment, annual investments in renewable energy capacity (including power, heating and cooling, and transport applications) increased from less than USD 50 billion in 2004 to USD 360 billion in 2015 (see Figure 1). Investments declined slightly in 2012 and 2013, but the pace of new capacity development was maintained, since a large drop in solar PV costs meant that the same growth in capacity could be accomplished with less money. Investments grew again by about 16% in 2014 and also slightly in 2015 compared to the year before (IRENA, 2016a). The G20 represents 80% of total global primary energy supply, and member countries also represent the bulk of this global renewable energy market.

[3] Energy use can be measured in different ways. One approach is to consider final energy consumption of all sectors: housing, services, industry, transport and agriculture. Electricity here is counted in terms of kilowatt-hours (kWh) consumed, not in terms of primary fuels used to generate it. This is called TFEC, the metric applied to measure renewable energy share in REmap.

Figure 1: Investments in renewable energy capacity, 2007-2015

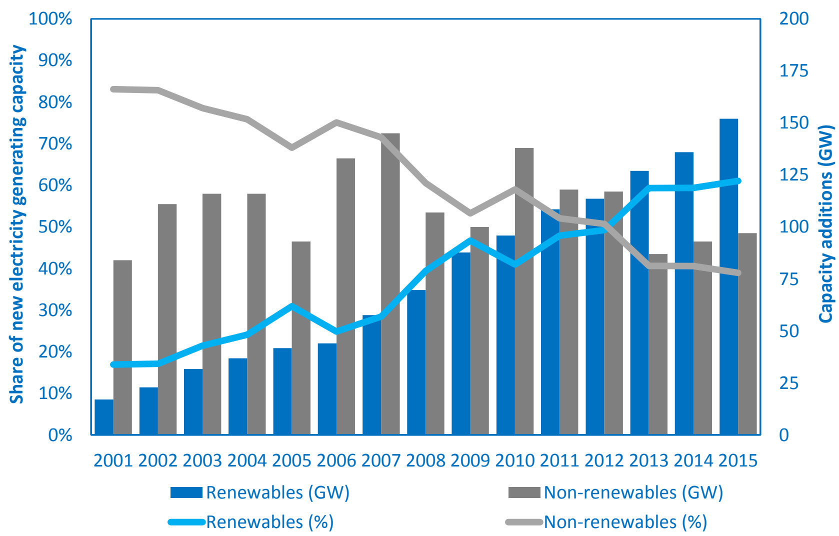


Note: includes large hydropower
Source: IRENA, 2016a

In 2015, total installed renewable electricity capacity (excluding large hydropower and pumped storage) reached 921 GW worldwide. Approximately 781 GW of this total (85% of the global total) was installed in the G20. When large hydropower and pumped storage capacity are included, total installed renewable energy capacity in the G20 member countries in 2015 was 1 516 GW, or more than 85% of the global total.

The net annual addition to renewable power generation capacity has averaged 120 GW per year worldwide since 2010 (see Figure 2). Less than 30% of this total is for large hydropower and pumped storage. The remaining 70% is accounted for by solar, wind, geothermal and bioenergy, and this share is growing. The year 2015 saw an increase in capacity of about 152 GW, of which 133 GW took place in the G20 (all values excluding the total capacity in the EU as a whole).

Figure 2: Net capacity additions for renewable and non-renewable power generation capacity, 2001-2015



Note: Bars refer to the right-hand side of the y-axis (in GW). Lines refer to the left-hand side of the y-axis (in %).
Source: Frankfurt School/UNEP Centre; BNEF, 2016; IRENA, 2016b; REN21, 2016

4. Renewable energy growth potential

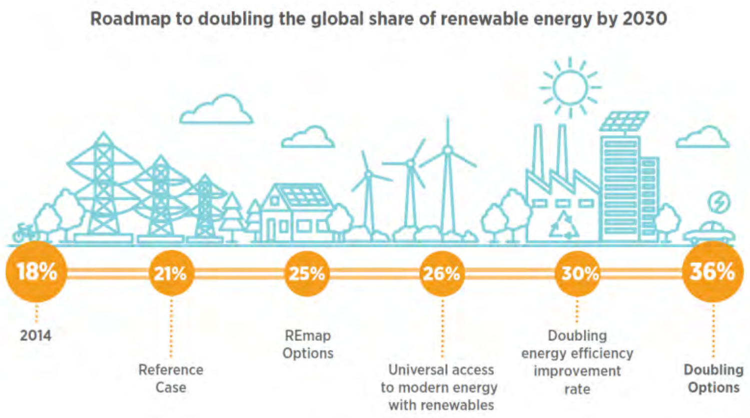
Opportunities for accelerated renewables deployment at the global and G20 country levels

The United Nations Secretary-General has called for a doubling of the renewable energy share in the global energy mix between 2010 and 2030 as one of three objectives of the Sustainable Energy for All (SE4All) initiative (UN and World Bank, 2016). This implies an increase in the renewable share to 36% in 2030, a rise of nearly 1 percentage point per year. Between 2010 and 2014, growth averaged 0.17 percentage points per year. To meet the SE4All objective, a six-fold increase in annual growth of the renewable share would be required.

According to the Reference Case, policies now in place would increase the renewable share in the global energy mix to only 21% by 2030 (or 14% when only modern renewables are considered). Starting with the 18.4% renewable share in 2014, average annual growth would amount to 0.17 percentage points, implying a continuation of the current trend, which is far short of the 1 percentage point a year required to realise a doubling. Global energy demand continues to grow – it will rise 30% by 2030 compared to the level today – and the pace of renewable deployment is only slightly higher. In the G20, growth in the demand for energy will be slightly lower, at 28%, during the same time frame.

Based on the assessment of the realistic potential of renewables with country experts, REmap suggests that it would be technically and economically feasible to significantly increase the share of renewables to 30% with existing technologies worldwide. Realising this also will require accelerated improvements in energy efficiency and universal access to modern energy with renewables, indicating the importance of interaction between energy efficiency and renewable energy technologies. Finally, the gap to reach the 36% will be closed by new renewable energy technologies combined with deep structural changes, termed "Doubling Options".

Figure 3: Roadmap to doubling the global share of renewable energy by 2030



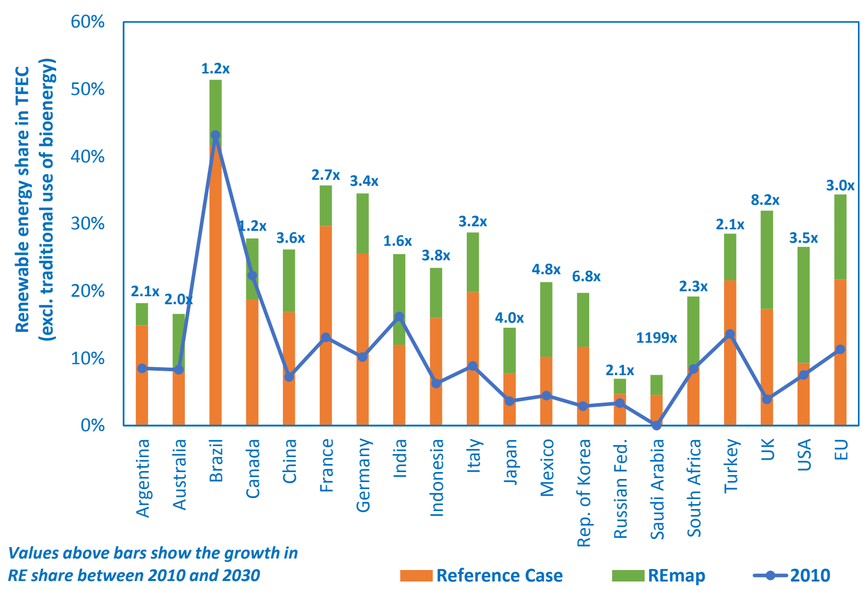
Source: IRENA, 2016a

Action area: There are important synergies between energy efficiency and renewables. Best available-technologies in the short and medium term and novel energy technologies in the long term should be implemented to maximise energy efficiency, which also will result in higher shares of renewables. There also is a need to prioritise the implementation of renewable energy technologies – notably electrification coupled with renewable power generation – that offer both efficiency improvements and higher shares of renewables.

All countries have potential to raise their renewable energy shares, but the potential varies by country and by their specific circumstances and priorities. Under REmap, for the G20 as a whole, there is a potential to increase the modern renewable energy share to 25% of TFEC. This is more than a doubling of the G20 modern renewable energy share by 2030 compared to the level in 2010 of 10%.

In 2010, the renewable energy shares of Australia, Japan, Republic of Korea, Russian Federation, the United Kingdom and the United States were all below 10%. In comparison, Brazil and India (including traditional uses of bioenergy) were at more than 40%. There is a potential to increase the renewable energy share in all G20 countries between 2010 and 2030 (see Figure 4). The renewable energy share grows by a factor of between 1.2 and 1 200 times between 2010 and 2030, depending on the starting level of renewables share and other factors that determine the REmap potential, such as resource availability, policy environment, access to finance, costs of technologies and rate of capacity stock turnover. For example, under REmap, the renewable energy share of Brazil grows by only 1.2 times, to reach 52%, as the country already has a high share of renewables in 2010. By comparison, the share grows by 1 200 times in Saudi Arabia, to reach 8% from nearly no use today.

Figure 4: Renewable energy share in total final energy consumption of G20 member countries, 2010-2030



Note: The figures show the factor growth of renewable energy share between 2010 and 2030 under REmap.
Source: IRENA, 2016a

Sector and technology-level insights

Each sector begins at a different level of renewable energy share in 2010. The power sector had the highest share of renewables in 2010, estimated at 18% globally. The transport sector had the lowest share, at 3%. According to the Reference Case, the renewable energy share of the power sector will remain the highest among all sectors by 2030, at 28%. The renewable energy share of the buildings and transport sectors will double, whereas in others, shares will remain at more or less today's levels.

REmap suggests a significant additional potential by sector. The renewable energy shares of the electricity generation and buildings sectors can increase to 44% and 35%, respectively. Although transport remains the sector with the lowest share among all, renewables in that sector increases to 11% in REmap, which represents a quadrupling over today's levels.

The comparison of the renewables' share between the Reference Case and REmap shows that the potential of renewables in end-use sectors is clearly underestimated according to country plans. Although countries increasingly are accounting for the potential in electricity generation, as indicated by the Reference Case, there is significant additional potential.

Table 1: Renewable energy share by sector in the G20, 2010-2030

	2010	Reference Case	REmap
Power	18%	28%	44%
District heat	5%	7%	21%
Buildings (modern)	11%	20%	35%
Industry	10%	11%	19%
Transport	3%	6%	11%
Total final energy consumption (modern)	10%	15%	25%

Note: Renewable energy share for buildings, industry and transport refers to direct uses of renewables only and excludes consumption of electricity and district heat from renewables.
Source: IRENA analysis

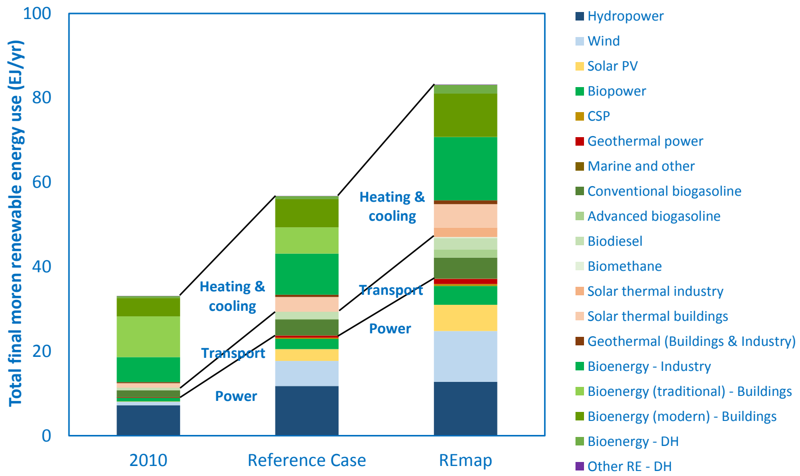
Action area: Deployment of more renewables in end-use sector applications. The potential of renewables in the end-use sectors is underestimated. In particular, electrification of end-use applications coupled with renewables will be key. To a lesser extent, specific options also deserve more attention in the power sector, such as dispatchable renewables. Country plans need to account for the potential of renewables in these sectors.

44% of the 2030 global renewable energy use potential lies in electricity generation from renewable sources. Around 56% lies in direct uses of renewables for heating and cooling and transport in end-use sectors (agriculture, industry, transport, residential and commercial).

Similar to the global share, consumption of renewables-based electricity could represent approximately 47% of total final renewable energy use in the G20 in REmap (see Figure 5). This change in the breakdown of renewable energy use by 2030 is significant compared to the share of sectors in 2010, where heating accounted for three-quarters, power for about one-fifth and transport for less than 5% of total final renewable energy use. Even in the Reference Case, the power sector accounts for more than 40% of the total. This is an outcome of the continuation of current trends where renewables use in the power sector is growing much faster than many anticipate (see Figure 6).

Likewise, REmap also shows a considerable change in the technology mix. In 2010, final renewable energy use was dominated by bioenergy, which had a share of 80% in total (including both its traditional and modern uses). This was followed by hydropower with a share of 14%. Solar, wind and geothermal all had shares below 2% of the total. In REmap, the breakdown changes considerably as a result of the significant growth in solar (both power and heating/cooling) and wind that account for 17% and 15%, respectively, of total final renewable energy use in 2030. Hydropower's share drops to 15% of the total.

Figure 5: Development of final renewable energy use potential by resource and sector in the G20, 2010-2030



Source: IRENA analysis

Bioenergy remains the single largest contributor but accounts for only half of total final renewable energy use (see Figure 6), representing a total primary biomass demand of 94 exajoules (EJ). For the G20 as a whole, bioenergy is key in nearly all countries (with exceptions of Saudi Arabia, etc.), but its potential is discussed only to a limited extent.

Compared to other renewable energy sources, bioenergy has an exceptionally complex supply chain and a wide range of applications. It begins with the availability of numerous types of feedstock, followed by numerous conversion technologies (*e.g.* biorefineries) that are available to produce biofuels for nearly all energy applications. Available feedstocks can be categorised as energy crops grown on surplus agricultural land, residues from harvesting and processing of agricultural crops, post-consumer waste such as kitchen waste and natural fibre textiles and sewage sludge, construction and demolition waste, fuel wood, and wood waste and residues. The potential of each feedstock varies across countries, but worldwide there is a potential to supply bioenergy from these feedstocks in the order of 75 EJ to 140 EJ in 2030. This supply potential is sufficient to meet the global demand as estimated in REmap. However, collection systems, in particular for residues and waste, need to be developed further, logistical infrastructure needs to be expanded greatly, and for energy crops, sustainable production pathways need to be prioritised. Sustainability concerns are focused mainly on the feedstock supply aspects.

While the global supply may be sufficient to meet demand, at the country level, a massive ramp-up implies growing trade. The cost-competitiveness of bioenergy differs first and foremost on the price of the biomass feedstock, which can be volatile. The cost-effectiveness of bioenergy solutions varies widely from application to application, depending on the price of the incumbent energy source, the conversion efficiency, and the cost and the characteristics of the application (*e.g.* high-temperature process heat). Because of the versatility of the resource in situations with limited supply potential, the optimal resource use may require consideration (IRENA, 2014). Hence the potential of bioenergy deserves more attention from policy makers across the entire supply chain, from feedstock supply and conversion technologies to end-use applications.

Action area: Bioenergy is key in many countries but often does not receive due attention. A significant increase in the renewable energy share in the G20 will require half of total final renewable energy use to originate from bioenergy. As indicated in the G20 toolkit, to realise this, ensuring a sustainable and affordable supply of bioenergy feedstocks will be key. There also is a need for countries to reinforce their efforts to develop resource- and cost-effective conversion technologies.

In the heating and cooling sector that comprises buildings, industry and district heating, bioenergy accounts for three-quarters of total final renewable energy use. It is a key technology for industrial process heat generation as it can serve various temperature levels, from hot water generation at 100 ^{o}C to high-temperature steam generation well above 400 ^{o}C. Bioenergy also is a key technology in the buildings sector to provide cooking heat in modern cook stoves and for water and space heating. Bioenergy is followed by solar thermal-based heating/cooling. Its growth expands significantly in both industrial and building applications between 2010 and 2030. The growth also is high in the Reference Case but is far below what is anticipated in REmap.

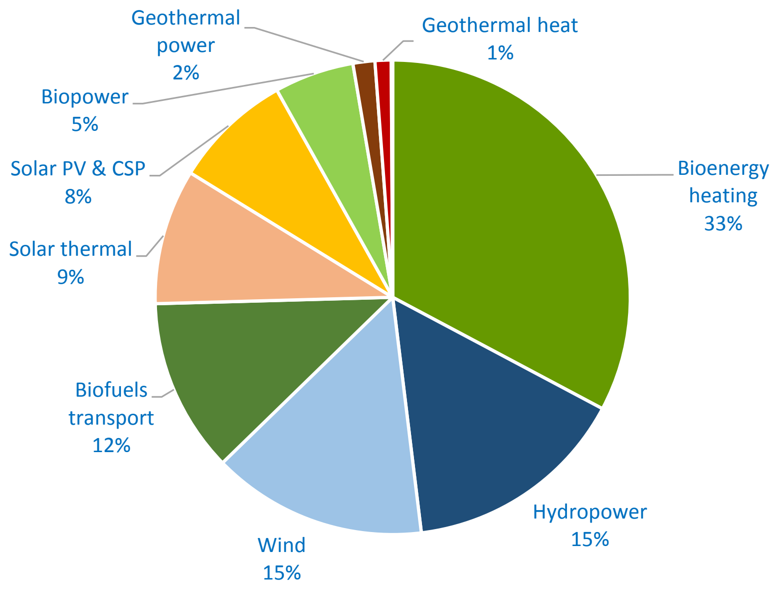
The transport sector is dominated by the use of liquid biofuels. Conventional ethanol use increases by a factor of three to a total of 293 billion litres in 2030. Advanced biofuels use increases to 91 billion litres from less than 1 billion litres today. Electric vehicles sourced with renewable power (covered under the power sector) also see a significant increase, but their contribution to the transport sector's total renewable energy use is less than 10% of the sector's total final renewable energy demand.

The power sector also sees a significant change in its renewables mix. In 2010, 80% of total renewable power generation was hydropower-based, followed by bioenergy (10%) and wind (9%). According to REmap findings, this mix shifts towards solar PV and wind at the expense of hydropower. In 2030, wind would account for one-third of total renewable power generation, the same share as hydropower, followed by solar PV, which accounts for 17%.

The electrification of end-use sectors is key, as the power that is generated will be consumed in these sectors. If the end-use sector has a high share of electricity, and if the electricity is generated by renewables, it contributes to that sector's renewable energy share. Especially in the context of cities, the electrification of transport, heating and cooling will be key. Hence, as indicated by REmap, electrification coupled with renewable power will be a key technology towards achieving higher shares of renewables. The analysis also shows that solar water heaters, solar thermal for industry, and district heating/cooling also will be important technologies in end-use sectors; however, they are to date typically overlooked in country plans. Although REmap covers a great deal of renewable energy technologies, some applications remain underestimated, such as liquid biofuels for aviation and long-distance freight transport, high-temperature industrial processes such as iron and steel production, as well as non-energy applications of fossil fuels use to produce chemicals and polymers. These areas need further technology innovation focus.

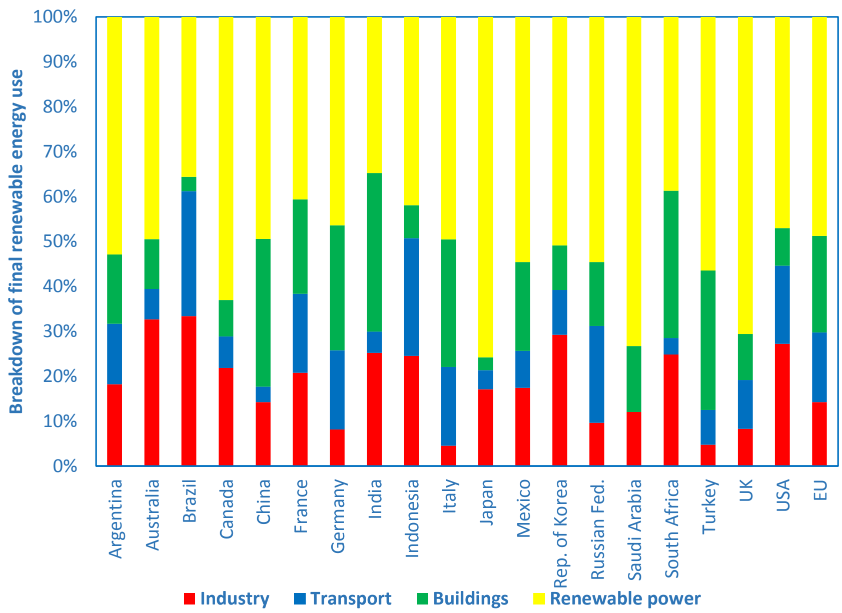
Action area: Innovation will be needed in certain areas. Numerous promising technologies will require R&D investment in order to achieve widespread adoption. These include the use of bioenergy as a feedstock for chemicals and plastic production, liquid biofuels for aviation, shipping and long-distance freight, and renewables for high-temperature steam production. These technologies require more R&D and investment support. Innovation needs also go beyond technology to cover financing, business models and policies that can enable the higher uptake of renewables across the energy system. Policy makers need to ensure strong interaction of energy innovation between ICT, electric vehicles, agriculture and urban design.

Figure 6: Breakdown of final renewable energy use potential in the G20 by resource, 2030



Source: IRENA analysis

Figure 7: Breakdown of total final renewable energy use potential in REmap in G20 member countries, 2030



Source: IRENA, 2016a

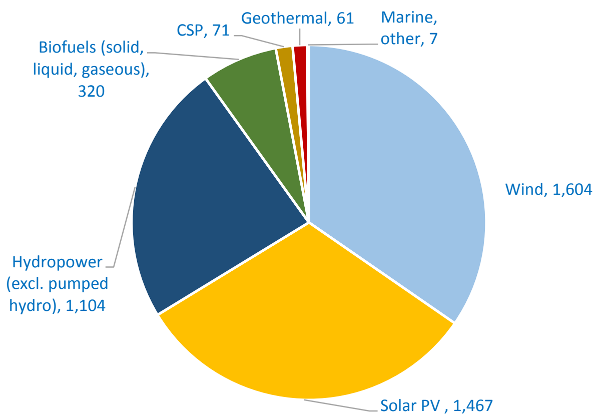
The importance of power sector transformation

Compared to today's level, REmap sees a tripling of the total installed renewable power generation capacity in the G20, from 1 512 GW in 2015 to 4 611 GW in 2030. Renewables would represent 57% of the total installed power generation capacity in the G20 in 2030. Wind and solar PV together would account for two-thirds of the total renewable energy capacity, and they would surpass the total installed hydropower capacity. Bioenergy-based power generation would rank fourth among all renewables, with a total installed capacity of 320 GW in 2030 (see Figure 8).

With the tripling of renewable power generation capacity, electricity generation from renewables would reach 12 606 terawatt-hours (TWh) per year in 2030. This is equivalent to 44% of the total electricity generation estimated in 2030 for the G20. The largest source of renewable generation would continue to be from hydropower (4 280 TWh), followed by wind (4 095 TWh) and solar PV (2 107 TWh).

At the country level, with the implementation of REmap Options, the renewable energy share in power generation will increase to more than 60% in Brazil, Canada, Germany and the United Kingdom. In countries with low shares of renewables today, such as Republic of Korea, Saudi Arabia, South Africa it will approach 20% or even more. Hence, there is a significant additional potential in the power sectors of all of the G20 member countries (see Figure 9).

Figure 8: Breakdown of total renewable power generation capacity potential in REmap in the G20, 2030



Note: in GW
Source: IRENA analysis

Many G20 member countries have the opportunity to significantly increase the share of power generation from variable renewables over the period between 2013 and 2030 (see Figure 9). Renewables also offer a solution for electrification in rural parts of some G20 member countries that do not yet have electricity access. With the significant growth potential estimated for wind and solar PV capacity in REmap, this situation would result in many G20 member countries reaching a variable renewable energy (VRE)[4] share in total power generation of more than 20% in 2030 (see Figure 10).

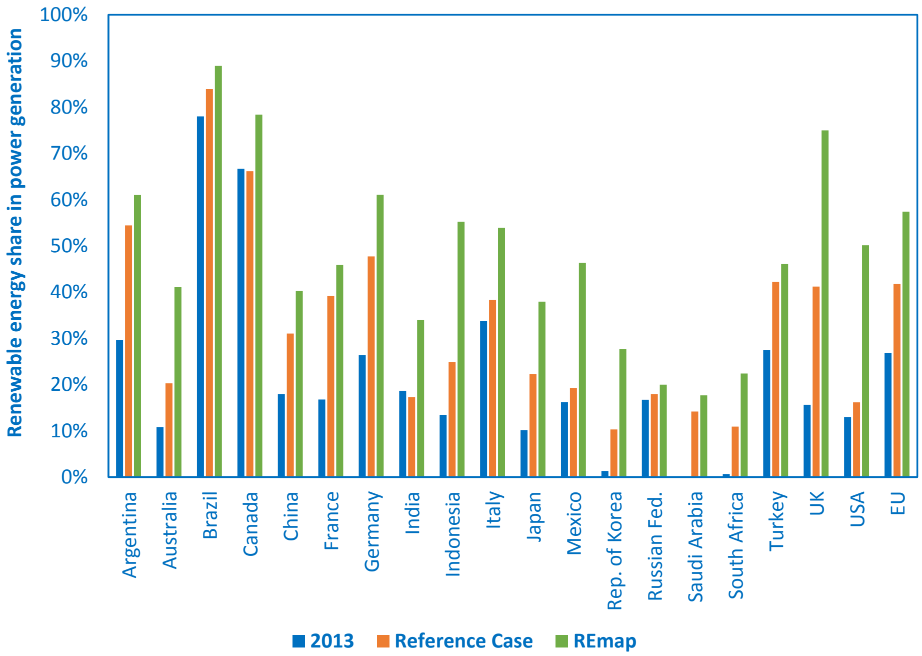
Renewables are now mainstream in the power sector, and, as the REmap analysis shows, there is significant additional potential. However, this is not yet understood in many countries, and the potential as well as the necessary planning are not captured in policy plans. Some G20 member countries already have shown that managing power grids with double-digit shares of wind and solar PV in annual electricity generation is technically feasible and can be done as long as some basic principles are adhered to. There are several no-regrets options which could result in economic benefits, improve system efficiency and ease the integration of renewables. These include real-time

[4] In this roadmap, variable renewable energy refers to electricity generated from solar PV and wind.

monitoring and control of VRE plants, VRE production forecasts and technical standards for VRE plants. These options need to be implemented if they are not yet in place (IEA, 2016a). Once peak VRE capacity exceeds demand, new solutions such as demand-side management and storage come into play, and with increasing VRE shares, a number of short-term priority improvements as well as long-term planning will be needed. These include:

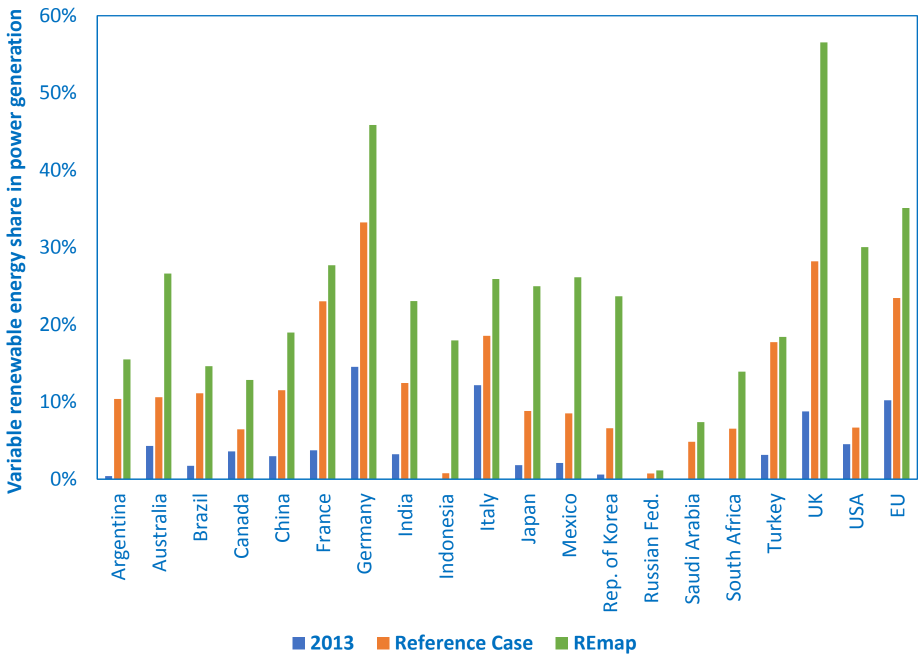
- Concentrate renewable energy development in areas of adequate grid capacity
- Make necessary grid improvements in parallel with the deployment of new renewable power
- Use modern forecasting methods to predict real-time output of VRE generation as part of the generation scheduling process
- Ensure sufficient flexible dispatchable capacity and strengthen interconnection capacity
- Innovate markets, policy frameworks and business models in parallel with the technical energy transformation

Figure 9: Renewable energy share in power generation of G20 member countries, 2013-2030



Source: IRENA, 2016a

Figure 10: Variable renewable energy share in power generation of G20 member countries, 2013-2030



Source: IRENA, 2016a

Under REmap, with the introduction of electric vehicles, heat pumps and other electricity-based heating/cooling and transport technologies, the share of electricity use in end-use sectors increases further by 2030. Electrification is an enabler as it provides complementary flexibility services to the grid where renewables-sourced power consumption raises the renewables' share in end-use sectors. This is the so-called "sector coupling" concept, and it is particularly important from the perspective of electricity-based technologies that provide support to the integration of VRE shares.

The emerging electric vehicle technology is a prime example of sector coupling. Mobile battery storage capacity in electric vehicles can contribute to achieving higher shares of renewables in the whole energy system as well as improve cost-effectiveness, reliability and local networks. Most of these electricity-based technologies also offer other forms of flexibility to the power system. They typically are more suitable for demand-side management as opposed to end-use electricity applications, such as household lighting and most industrial loads. Furthermore, electric vehicles can be coupled to the energy management systems in buildings to discharge power back to connected buildings and homes, but also they can provide a host of system services to the grid. Second-hand car batteries can be used for stationary applications to support VRE deployment, for example in off-grid systems.

However, a better understanding of the practical application and implications of these systems is required. Furthermore, continued innovation and technology development is required, such as in the areas of super-fast charging; scheduling, planning and use of charging stations; and software development for managing charging/discharging behaviour and control (IRENA, 2015).

Action area: Introducing greater flexibility to the power system. The power sector will continue to be the sector with the highest share of renewables in 2030, with the share of variable renewables increasing to more than 20% in most G20 member countries under REmap. This paradigm change needs to be better captured in country policy plans. Opportunities and challenges related to sector coupling and introducing greater flexibility need to be taken into account.

The need for systems thinking

REmap builds on a technology options assessment. This approach does not allow the assessment of developments and dynamics in the 2010-2030 period. Moreover, the possible interactions across different technologies or the developments and feedbacks in energy prices due to demand and supply changes (*e.g*. rebound effects) are not taken into account. Finally, the assessment of possible synergies and/or trade-offs between renewable energy and energy efficiency activities also are excluded (Saygin *et al.*, 2015).

However, the results of REmap have been compared with and used as input in detailed models to study the possible system effects. One of the most important impacts is the costs of renewable energy integration into the power system. The results of a comparison of REmap with the models prepared by the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency (IEA) suggests that investments in transmission and distribution networks are in the range of 10% of total system investment costs, and that energy efficiency activities are becoming an important factor to achieve very high shares of renewables in the system.

The comparison of substitution choices and the REmap cost-supply curve shows that the REmap results correspond with the sequence in which the ETSAP models choose renewable energy options to satisfy an increasing renewable energy share. The difference in results is due mainly to the political choices made by the country experts. Furthermore, the comparison concludes that the REmap tool can be used as a way to explicitly engage national experts, to scope renewable energy options and to compare results across countries. It can in particular create value when findings are supplemented with techno-economic partial equilibrium models such as those prepared by ETSAP which can provide insights into the infrastructure requirements, competition between technologies and resources, and the role of energy efficiency needed for planning purposes (Kempener *et al.*, 2015).

Another forthcoming study that pays particular attention to the European power system shows similar findings that the REmap results are robust (Collins *et al*., 2016). For this purpose, the REmap results for the 9 EU countries along with a quick scan of the remaining 19 EU countries have been made inputs to a dedicated power system model that allows detailed modelling of unit commitment and economic dispatch. The results from this comparison have shown that challenges regarding curtailment, capacity factors of combined-cycle gas turbines and wholesale market price changes will face limited impacts in a European power market operated with higher shares of variable renewables in the year 2030. However, interconnector capacity will most of the time be used to its maximum extent, and therefore planning will be key to minimise potential transmission congestion and curtailment.

Investment needs are significant and fairly well known

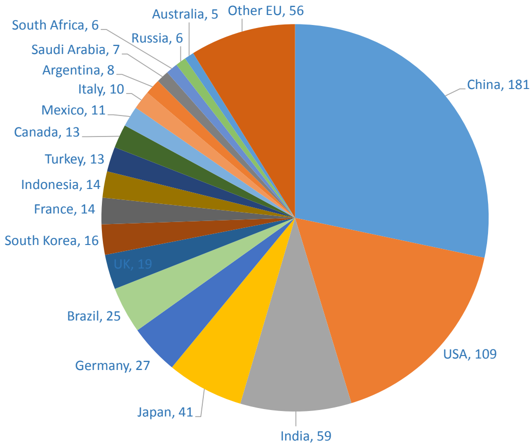
Realising a doubling of the renewables share (to 36%) will require an estimated total global investment in renewable energy technologies of approximately USD 900 billion per year between now and 2030, a tripling over today's levels. Reaching the 30% renewable energy share mark would require average annual investment of USD 770 billion per year worldwide.

The amount required in G20 member countries represents more than 80% of this total (or 70% of the total investments needed for a doubling), an average annual investment of USD 640 billion per year. As indicated in Figure 11, China, the United States, Japan, India and Brazil account for two-thirds of the total G20 investment needs between today and 2030.

Increased investments for renewables are balanced by lower investments for conventional energy. It should be noted that the investment figures listed above focus on the supply side and do not include end-use sectors (for example, electric vehicles are not included).

In addition to the renewable energy investments, there are investments required for energy efficiency measures which amount to a total of USD 470 billion per year. Together with renewables, total investments needed in the G20 reach USD 1.1 trillion per year on average between today and 2030. Under REmap, the assumption is made to maintain the same level of renewable energy capacity when energy efficiency measures are deployed. Hence, energy efficiency improvements reduce the demand for fossil fuels only. By doing so, a higher share of renewables is attained as the total deployed capacity is compared to a lower TFEC. If efficiency measures were to reduce demand for renewables as well, related investments would have been lower.

Figure 11: Average annual investment needs for renewables between now and 2030 in G20 member countries



Note: in USD billion per year
Source: IRENA, 2016a

Benefits of renewables far exceed the cost

When these investments are annualised, using a 7.5% discount rate for OECD countries and 10% for non-OECD countries, and accounting for the annual fuel, operation and maintenance costs, the renewable energy options would have an estimated incremental system cost of USD 67 billion in 2030 compared to the non-renewable energy technologies substituted. This indicator takes into account the learning effects in technologies between now and 2030 as well as the energy price developments of conventional fuels to 2030 (assuming a crude oil price of USD 105 per barrel by then, in 2010 real USD). Energy efficiency measures also incur some additional costs, but less than those of the renewable energy technologies, in the order of USD 20 billion per year.

Compared to these costs, renewables have important benefits. An important source of these benefits is fossil fuel use savings and the reduction of their external effects. In the power sector, mainly coal use is substituted, which is the most carbon-intensive fossil fuel. By comparison, in transport oil and in the heating sector, a mix of natural gas and oil is substituted. Lower use of fossil fuels means less emissions of CO_2 and air pollutants. For example, renewables would result in an 18% reduction of energy-related CO_2 emissions in 2030 compared to the Reference Case in the G20, approximately

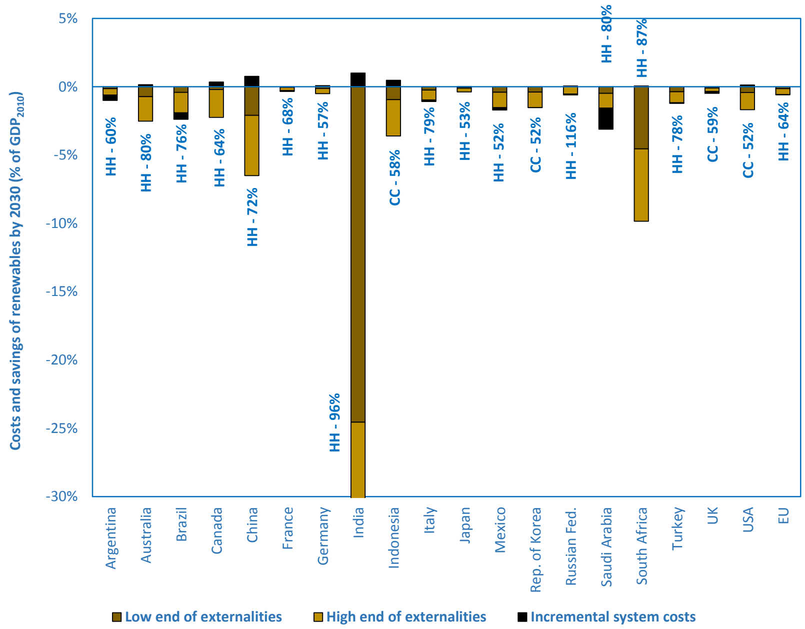
5.5 gigatonnes (Gt) of CO_2 per year. There is similar additional potential from increased energy efficiency in the order of 5 Gt of CO_2. This potential for emission reductions from both renewables and efficiency in the G20 member countries represents two-thirds of the global total.

REmap analysis has shown that when accelerated uptake of renewables according to REmap is combined with the additional potential from energy efficiency, the combination of strengthened energy efficiency and renewable energy efforts can result in a doubling of the global renewable energy share in 2030 and put the world on a path to go below the 2 °C target as agreed in the Paris Climate Agreement. The efforts to sustain renewables uptake and improve energy efficiency, however, need to continue beyond 2030 for a decarbonisation of the energy system in the next 40-60 years.

When these reduced external effects related to better human health and reduced CO_2 emissions are monetised, they result in significant savings. Estimated savings related to renewables is between USD 750 and USD 2 355 billion per year in 2030, depending on how the cost of emissions is assessed. This savings is split into benefits from climate change mitigation and reduced air pollution. Positive impacts of the avoided CO_2 emissions would result in benefits of USD 278 billion per year (range: USD 95-455) in 2030, assuming a carbon price of USD 17-80 per tonne of CO_2. Human health externalities result in much higher benefits of USD 1 220 billion per year (range: USD 655-1 900).

The relative importance of health- and climate-related externalities varies by country. Significant human health benefits dominate the savings in nearly all countries (see Figure 12). In addition to the reduced externalities from renewables, there also are savings from energy efficiency measures that add another USD 500 billion per year in 2030 savings. Combined with the total savings from renewables, this raises the total savings from externalities of air pollution to USD 1.72 trillion per year in 2030. Likewise another USD 250 billion per year in externalities can be saved related to climate change; that raises the total savings to USD 526 billion per year together with the savings of renewables.

Figure 12: Cost and savings of renewable energy options in G20 member countries, 2030



CC: Climate change, HH: human health. The share of externality that contributes most to the total is displayed below each bar.
Source: IRENA analysis

Action area: The benefits of renewables are not adequately reflected in market prices. The analysis shows that the benefits of renewables can significantly outweigh the costs of renewables in 2030. Today, there is a big gap between market signals and policy objectives. Policy makers need to correct for markets distortions to bring them in line with the real cost of fossil fuels by accounting for externalities related to human health and climate change.

The costs of renewables are much lower than the estimates found in other studies, and they continue to fall across all technologies. Even with technologies such as solar PV and wind that have seen significant cost declines over the past years, further reduction potential exists across different system components. Moreover, the benefits of renewables are not adequately reflected in market prices. However, as this study shows, the benefits of renewables can outweigh the costs of renewables significantly, if they are considered. Renewables also offer benefits other than reduced emissions of greenhouse gases and air pollutants. There are multiple socio-economic benefits such as: macroeconomic effects (*e.g*. welfare, employment); distributional effects (*e.g*. ownership, regional distribution); energy system-related effects (*e.g*. externalities) and others (*e.g*. risk reduction) (IRENA, 2016d). When these also are considered, there is a clear business case for renewables that also has important positive impacts for the economy as a whole.

The findings of this roadmap show that a significant rise in the renewable energy share of the G20 and its countries is both technically possible and economically feasible. For REmap Options that have been identified in this assessment to realise a doubling, a cut-off cost of USD 25 per GJ has been applied (see Figure 13 for an overview of all options and their costs of substitution, in USD/GJ of final renewable energy, considered for the world as a whole). This is a cost level where incremental cost typically exceeds external impact savings. The potential has been estimated in consultation with country experts.

Action area: Renewable energy costs are much lower than estimated by some, and they continue to fall. Recent auctions across the world show that the costs of renewables are falling. Many analyses reveal significant further reduction potential of costs in the coming decades. Increased international co-operation for transfer of technologies and capacity building can play an important role in contributing to further declines in the costs of renewables in the G20.

Figure 13 provides further information about the costs and benefits of the renewable energy technology options identified in the REmap analysis. The contribution of each technology to the total share of renewables in the global energy system (in %) is plotted against its cost of substitution (in USD per GJ of final renewable energy). The cost of substitution is either positive (an incremental cost compared to the non-renewable incumbent it substitutes) or negative (a saving).

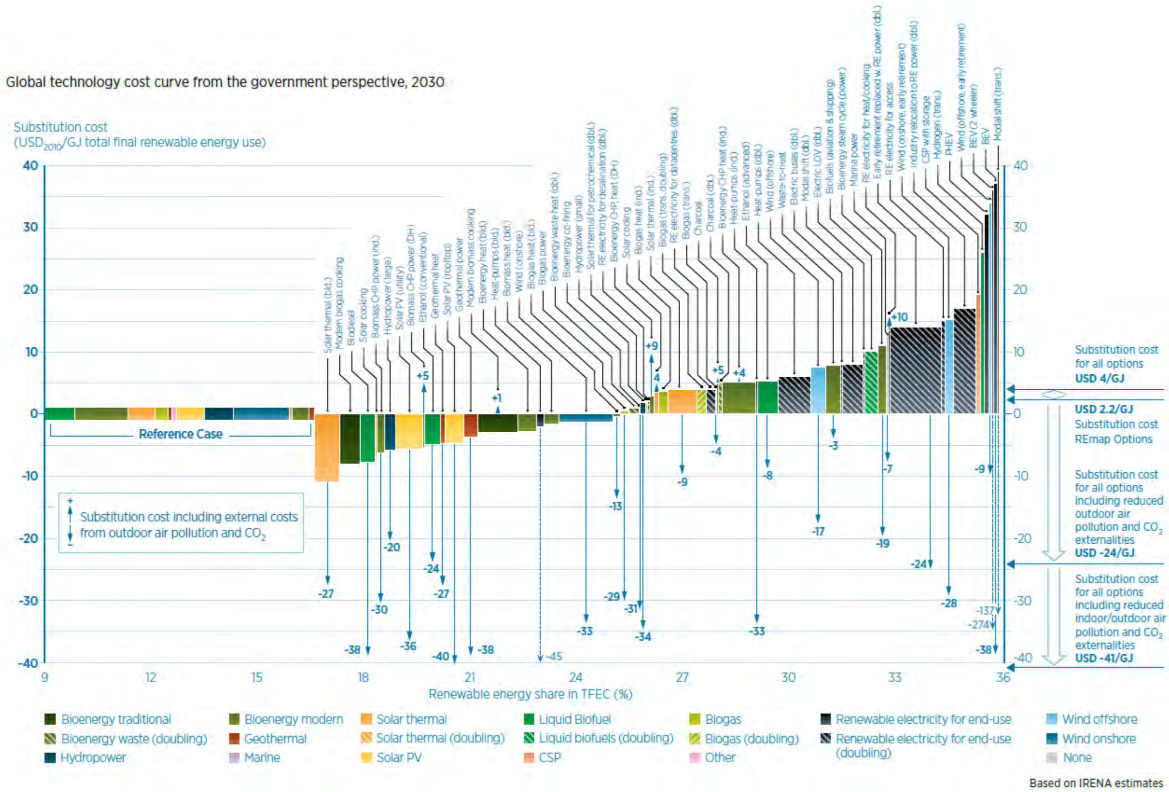
On average, the costs of substitution for realising a doubling of the share of renewable energy worldwide by 2030 is USD 4 per GJ of renewable energy (or 14 USD per megawatt-hour, MWh). Options with net cost savings represent about 40% of the total potential. Savings from these options can be as high as USD 11/GJ (USD 40/MWh). For the options that cost more, the curve has a tail with the costs of options increasing exponentially as the share of renewable energy increases. A number of technologies, notably electrification in the transport sector as well as concentrated solar power (CSP) with storage and offshore wind (against early retirement of coal-based power plants) can cost more than USD 20/GJ (USD 72/MWh). Technology options will require investment support to reach cost-competitiveness compared with non-renewable options. For the G20 as a whole, the volume of investment support in 2030 can reach up to USD 165 billion per year.

One can expect that policy makers and investors will prioritise the deployment of options that result in savings, starting from the left end of the curve until the point where costs become positive. Indeed, for solar PV (utility-scale) and onshore wind, it can be expected that the cost and capacity addition records achieved in 2015 will continue to 2030 with improving cost-competitiveness. However, in reality, cost may not be the only criteria for decision making for all other technologies. For example, the figure shows that biodiesel and conventional ethanol can result in savings in 2030. Recent market trends, however, show that investment for new capacity and uptake of liquid biofuels have slowed significantly, because of sustainability concerns, decreasing oil prices and other barriers. Solar cooking is another technology that offers savings according to Figure 13; however, it has seen only limited deployment in the world with the exception of a few countries (*e.g*. India).

The opposite also can be the case for technology options that cost more than the fossil fuel alternative they substitute. The figure puts biogas for transport or solar thermal for industrial process heating as two technologies that are not cost-competitive in 2030 (around USD 5/GJ). Today these technologies are already deployed in several parts of the world in a cost-effective way (*e.g*. biogas in Germany, solar thermal in copper mines of Chile). Hence, although the global average cost may be positive, with additional capacity deployment and technological learning, in more parts of the world, they can offer a cost-effective potential for deployment in 2030.

While this cost-supply curve provides valuable information about the costs of technologies and their relative rankings, and also identifies where further innovation is required, it should not be read only from left to right. Opportunity and barriers of each option beyond costs need to be understood better for designing new energy policy and to develop measures to overcome the related barriers.

Figure 13: Global technology cost-supply curve for REmap Options from the government perspective, 2030



Source: IRENA, 2016a

Table 2: REmap G20 summary table – the potential of renewables options

			Unit	2010	Reference Case 2030	REmap 2030	REmap + EE 2030
Energy generation and capacity	Power	**Total installed power generation capacity**	*GW*	**3 856**	**6 888**	**8 074**	**7 216**
		Renewable capacity	*GW*	934	2 783	4 611	4 611
		Hydropower (excl. pumped hydro)	*GW*	672	1 007	1 108	1 108
		Wind	*GW*	165	865	1 598	1 598
		Biofuels (solid, liquid, gaseous)	*GW*	54	189	302	302
		Solar PV	*GW*	37	666	1 466	1 466
		CSP	*GW*	1	32	71	71
		Geothermal	*GW*	6	24	57	57
		Marine, other	*GW*	0	0	9	9
		Non-renewable capacity	*GW*	2 922	4 106	3 444	2 605
		Total electricity generation	*TWh*	**16 922**	**28 049**	**28 714**	**24 973**
		Renewable generation	*TWh*	3 079	7 949	12 606	12 606
		Hydropower	*TWh*	2 438	3 911	4 318	4 318
		Wind	*TWh*	276	2 018	4 073	4 073
		Biofuels (solid, liquid, gaseous)	*TWh*	294	856	1 506	1 506
		Solar PV	*TWh*	28	934	2 111	2 111
		CSP	*TWh*	1	78	162	162
		Geothermal	*TWh*	41	150	406	406
		Marine, other	*TWh*	0	2	30	30
		Non-renewable generation	*TWh*	13 843	20 100	16 353	12 368
	District heat	**Total district heat generation**	*PJ*	**11 149**	**13 676**	**13 691**	**11 690**
		Biofuels (solid, liquid, gaseous)	*PJ*	595	936	2 720	2 720
		Other renewables	*PJ*	1	41	139	139
		Non-renewable district heat	*PJ*	10 553	12 698	10 832	8 831
Final energy use - direct uses	Buildings and industry	**Total direct uses of energy**	*PJ*	**119 372**	**153 685**	**147 485**	**125 931**
		Direct uses of renewable energy	*PJ*	21 223	26 508	33 974	33 974
		Solar thermal - buildings	*PJ*	1 041	3 353	5 562	5 562
		Solar thermal - industry	*PJ*	6	127	2 232	2 232
		Geothermal (buildings and industry)	*PJ*	240	575	895	895
		Bioenergy (traditional) - buildings	*PJ*	9 626	6 166	48	48
		Bioenergy (modern) - buildings	*PJ*	4 368	6 648	10 281	10 281
		Bioenergy - industry	*PJ*	5 941	9 640	14 955	14 955
		Non-renewable - buildings	*PJ*	34 269	37 097	30 354	24 591
		Non-renewable - industry	*PJ*	55 090	78 930	72 007	58 334
		Non-renewable - blast furnace / coke oven	*PJ*	8 789	11 149	11 149	9 032
	Transport	**Total fuel consumption**	*PJ*	**68 701**	**92 574**	**87 423**	**84 152**
		Liquid biofuels	*PJ*	2 304	5 531	9 554	9 554
		Conventional ethanol	*PJ*	1 663	3 697	4 959	4 959
		Advanced ethanol	*PJ*	0	181	1 935	1 935
		Biodiesel (conventional and advanced)	*PJ*	641	1 653	2 659	2 659
		Biomethane	*PJ*	0	10	294	294
		Non-renewable fuels	*PJ*	66 397	87 033	77 880	74 305
Total final energy consumption (electricity, DH, direct uses)			***PJ***	**249 135**	**344 168**	**335 237**	**296 622**
RE shares		RE share in electricity generation		18%	28%	44%	50%
		RE share in district heat generation		5%	7%	21%	24%
		RE share in buildings - final energy use, direct uses (modern)		11%	20%	35%	40%
		RE share in industry - final energy use, direct uses		10%	11%	19%	21%
		RE share in transport fuels		3%	6%	11%	12%
		Share of modern RE in TFEC		10%	15%	25%	29%
Financial indicators		System costs [USD bln/yr. in 2030]		*N/A*	*N/A*	67	95
		RE investment needs [USD bln/yr. (2010-2030)]		*N/A*	320	640	1 110
		Investment support for renewables [USD bln/yr. in 2030]		*N/A*	*N/A*	165	170
		Savings from reduced externalities - air pollution [USD bln/yr. in 2030]		*N/A*	*N/A*	1 220	1 720
		Savings from reduced externalities - CO_2 (USD 50/t CO_2) [USD bln/yr. in 2030]		*N/A*	*N/A*	278	526
		CO_2 emissions from energy [Mt/yr.]		23 457	30 768	25 224	20 124

Renewables as a key solution for climate change

REmap has examined the key role of renewable energy in putting the world on a path that can limit global temperature increases to 2°C above pre-industrial levels, the limit agreed unanimously by countries in 2010 to avoid unmanageable risks of climate change. REmap shows that, worldwide, a doubling of the renewable energy share by 2030, combined with significant increases in energy efficiency, can reduce energy-related total global CO_2 emissions by approximately 50% in 2030 compared to business as usual, if the world were to follow policies in place today and under consideration.

Before it became the international benchmark for climate change discussions, the 2°C target already was set as a policy goal by the EU as early as the mid-1990s, and since then it has attracted much research about its feasibility and related strategies (Vuuren *et al*., 2011, 2007).

Realising this target requires a peak in radiative forcing at approximately 3 watts per square metre (W/m^2) (~490 parts per million of CO_2-equivalent, CO_2-eq) before 2100 and then a decline to 2.6 W/m^2 by 2100. In 2014, total anthropogenic greenhouse gas emissions reached about 55 Gt of CO_2-eq worldwide. Global CO_2 emissions represented about two-thirds of this total (35.7 Gt). Fossil fuel combustion accounts for a majority of the total global CO_2 emissions (31.8 Gt). For a 50% chance to keep global warming below the 2°C target requires an emissions budget of about 1 100 Gt of CO_2 (McGlade and Ekins, 2015). This means that by between 2060 and 2080, the global energy system should be decarbonised, leaving room for a maximum of around 25 Gt of energy-related CO_2 emissions per year in 2030, in line with the findings of IRENA's REmap. If the target is to realise a maximum increase of 1.5^{o}C, then the emissions budget is much lower.

Under REmap, realising a 30% renewable energy share worldwide can reduce energy-related CO_2 emissions to 25-27 Gt, in line with the 2°C scenario. The doubling of the renewables share would reduce emissions to 20-22 Gt per year by 2030 – in other words, a halving compared to the Reference Case level of 42 Gt. By comparison, the level of energy-related CO_2 emissions that would be reached if all countries' Intended Nationally Determined Contributions (INDCs) were to be implemented is 35 Gt by 2030. The G20 would have the largest share in realising this (den Elzen *et al.*, 2016).

Table 3 shows the energy-related CO_2 emission reduction potential of renewables in each G20 country in the year 2030. In most countries, renewables can offer a potential to reduce CO_2 emissions in the order of 15%-20%. In Argentina, Russian Federation and Saudi Arabia the reduction is less, depending on the substituted fuel, the identified REmap Options and their related potential. In other countries, the reduction could be more, for example in Indonesia or the United States, explained by the low level of ambition for renewables deployment in business as usual.

In addition to IRENA's REmap programme, several other key initiatives are researching the potential of CO_2 emission reductions in major global economies. For example, the Deep Decarbonisation Pathways Project, a collaborative global research initiative convened by the Institute for Sustainable Development and International Relations (IDDRI) and the Sustainable Development Solutions Network (SDSN), seeks to understand how individual countries can transition, on a technological, socio-economic and policy "pathway", to a low-carbon economy consistent with the internationally agreed goal of limiting anthropogenic warming to less than 2°C above pre-industrial levels. As of today, the initiative covers 16 countries representing 74% of current global greenhouse gas emissions, and the countries it assesses are all G20 member countries, namely Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Republic of Korea, Russian Federation, South Africa, the United Kingdom and the United States (IDDRI, 2016). For each country, various emission development scenarios are being developed that vary depending on oil price developments, low-carbon technology uptake, etc. The results for 2015 are already available, and they are being updated continuously as new information comes out and through consultation with country experts (IDDRI and SDSN, 2015).

Table 3: Potential for energy related CO_2 emissions with renewables in G20 member countries

	2010	2030			Reduction compared to Reference Case	
		Reference Case	REmap	Doubling	REmap	Doubling
Argentina	137	263	249	233	5%	11%
Australia	375	507	429	386	15%	24%
Brazil	347	690	564	533	18%	23%
Canada	448	593	489	434	18%	27%
China	6 394	9 499	8 010	6 839	16%	28%
France	316	219	191	168	13%	23%
Germany	746	518	421	324	19%	37%
India	1 560	4 570	3 783	3 375	17%	26%
Indonesia	391	971	761	713	22%	27%
Italy	383	335	277	240	17%	28%
Japan	1 192	1 053	923	797	12%	24%
Mexico	369	619	515	490	17%	21%
Republic of Korea	504	493	378	329	23%	33%
Russian Federation	1 384	1 843	1 810	1 578	2%	14%
Saudi Arabia	360	488	465	447	5%	8%
South Africa	361	509	447	391	12%	23%
Turkey	235	316	290	256	8%	19%
UK	516	300	237	206	21%	32%
USA	5 662	5 532	3 805	3 375	31%	39%
EU	3 738	2 823	2 303	1 884	18%	33%
G20	23 457	30 768	25 224	22 061	18%	28%

Source: IRENA, 2016a

Compared to the CO_2 emissions budget, the reality is that the total CO_2 emissions that can be released from the combustion of all fossil fuel reserves worldwide is more than twice as large, estimated at 2 900 Gt of CO_2. Hard coal reserves alone represent two-thirds of the total (if non-reserve resources are included, the total of all fossil fuels is 11 000 Gt of CO_2). Realising the 2°C target would avoid the combustion of approximately 35% of all oil reserves, 50% of all natural gas reserves and 85% of all coal reserves worldwide by 2050. More than 90% of all coal reserves in the former Soviet Union, OECD Pacific and the United States would need to stay in the ground (McGlade and Ekins, 2015).

This estimate for the future corresponds with the growing focus on supply-side fossil fuel substitution measures to supplement energy efficiency. The focus is now turning towards divestments to leave the carbon in the ground. For different reasons, such as new emission regulations or market signals, countries have closed, or plan to close, coal power plants, and these trends may continue in the short term as well, as a consequence of decarbonisation. In the future, with the growing uptake of renewables, fossil fuel resources will lose their value compared to today's levels, and some companies in the world will need to adopt to this trend or otherwise may face the risk of going bankrupt.

While the energy sector is closely linked with realising the long-term climate goals, the climate agenda typically is controlled by the ministries with responsibility for environmental and natural resource issues, and not necessarily by the energy ministries. There is a strong and urgent need to develop a decarbonisation agenda for the energy sector, given its significant role, and to put more efforts into aligning the activities of both areas. IRENA's REmap programme offers the analytical framework that would be required to develop that agenda, and, through the G20, IRENA can take the lead in assisting the energy policy makers of the countries in providing valuable information about the role that renewables can play in mitigating climate change.

5. Brief overview of other low-carbon energy technologies

This report has discussed in detail the 2030 potential, cost and benefits of renewables for the G20 and for individual member countries. Renewables have the potential to provide for 36% of global energy use in 2030, and for an even higher share in the longer term, while playing a major role in realising long-term climate goals.

In this transition of our global energy system, other low-carbon technologies also may have a role to play while contributing to the supply of the remaining 64% of our global energy needs. The Fifth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) mentions that energy efficiency, nuclear, and (biomass-coupled) carbon capture and storage (CCS) will be the other key low-carbon technologies besides renewables in transforming our energy system (IPCC, 2014).

For several decades already, **energy efficiency** has been at the centre of energy and climate policy. Countries have been developing and introducing energy efficiency measures in all sectors to reduce the growing demand for energy and to create benefits for their economies and the environment. As REmap suggests, there also is now an important synergy between energy efficiency and renewables. A doubling of the share of renewables is possible only if the energy efficiency improvement rates increase significantly. Basically, a doubling of historical annual energy intensity improvement rates is required – from 1.3% in 1990-2010 to 2.6% in 2010-2030. Trends show that improvement rates are now faster than what has been achieved in the past, but there is still a gap that should be closed to realise energy efficiency's potential. Closing this gap will require the deployment of best practice technology and deployment of novel technologies for the heating and cooling sectors (buildings and industry), structural changes in the transport sector, and a focus on systems thinking to integrate the energy and material flows of our economy to make the most use out of the same resources.

If this energy efficiency potential can be achieved, together with universal access to modern energy, it can result in a doubling of the renewable energy share worldwide by 2030. According to the working paper released by IRENA and the Copenhagen Centre on Energy Efficiency (C2E2), realising this potential would require total average annual investments of approximately USD 650 billion for energy efficiency and USD 900 billion for renewables worldwide. Compared to current levels, this implies a need to grow energy efficiency investments by five times and renewables investments by about three times in the 2016-2030 period (IRENA and C2E2, 2015).

The fossil fuel that is the least carbon and air pollutant emission-intensive is **natural gas**. During the past decade, its consumption has increased significantly in most parts of the world, with a number of regions becoming trade hubs. The US shale gas boom has resulted in the expansion of that country's gas-based manufacturing industry, in particular the production of chemicals. Today 40% of all natural gas is used to provide heat for industry and buildings worldwide, with the remaining 60% being consumed for power generation. In several countries, natural gas also is used as a transport fuel.

In 2013 and 2014, natural gas markets experienced a slowdown, particularly in Asia, with the increased availability of cheap coal and the declining costs of renewables. Unlike the rest of the world, the natural gas market in the United States kept growing. Natural gas markets are impacted by various factors, including price. International gas prices are determined by regional supply and demand trends, the availability of gas by pipelines and the global market for liquefied natural gas (LNG), which has led to wide regional differences in gas prices. Oil markets also impact natural gas prices but are not the only factor. Low crude oil prices have had an impact on natural gas markets where capital-intensive upstream gas investments have slowed, in particular for LNG, which has seen large growth in the spot markets. Natural gas import dependency is another issue in a number of countries that has led to switching to other fuels.

For the short and medium term, country forecasts suggest that global natural gas demand is likely to re-accelerate, as gas is a relatively clean source for electricity generation and it faces less technical and financial risks compared to other non-renewable energy fuels. The lead time of natural gas-fuelled power plants is also quite short (around two years).

According to REmap, the share of natural gas in the total primary energy supply will increase slightly in 2030 compared to today's level, even in the case where the uptake of renewables accelerates significantly. This is explained by the fact that the fuels that typically are substituted with renewables are coal (in power generation) and oil (for heating and transport), and country plans foresee a more than 40% increase in natural gas supply. In the power sector, for example, installed natural gas-based capacity will reach around 2 000 GW by 2030 according to the Reference Case, and in REmap it will decrease to only 1 850 GW to account for 18% of total global power generation. Today's level is around 1 300 GW of natural gas generating capacity.

According to REmap country plans, **nuclear power** also is projected to grow in the same order of magnitude, to around 615 GW worldwide by 2030, from around 400 GW of installed capacity in 2015. Other projections estimate a gross installed capacity of 438-593 GW by 2025 (IEA, 2016b). With the accelerated uptake of renewables, REmap puts the installed capacity projection estimated in 2030 at 560 GW.

The advantage of nuclear power is that it can provide carbon-free baseload generation. New reactors are being added in China, Republic of Korea, Russian Federation and the United Arab Emirates. A significant share of the existing nuclear plants were built before 1990 and will need to be replaced in the 2030 time frame. An increasing number of ageing plants are being shut down because renewables push wholesale marginal prices below the operation and maintenance costs of these existing reactors.

Long construction time of new nuclear power capacity must be considered in the planning process. Experience from the construction of several plants that have been commissioned in the past decade shows that the time required for construction often takes 3-5 more years longer that what was initially planned. This raises the total time of construction to about 10 years and therefore increases the overall costs. Also, for other reasons, the costs of electricity delivered in nuclear plants are becoming more expensive. The European new reactor projects all face major problems in terms of high levelised cost of electricity (LCOE), cost overruns and significant delays. Development emphasis has now shifted to small-scale nuclear reactors of less than 100 MW. However, this means that the costs per unit of kWh delivered will be higher.

There are additional challenges associated with nuclear power. Problems such as waste treatment and storage have not been resolved in a satisfactory matter, and inherently safe reactors remain to be demonstrated. Operational safety and issues related to dealing with nuclear waste and dismantling of retiring capacity are the most common issues that have been raising concerns. Deployment of nuclear will depend on what new options will emerge (such as nuclear fusion, which is in its infancy) and on whether sufficient measures can be taken that can address public concerns about safety and also reduce investment-related risks.

Another low-carbon technology that has been long discussed is **carbon capture and storage, CCS**. The technology allows CO_2 emissions to be caught before they go into the atmosphere. The technology has been discussed for years; however, its development has lagged far behind needed levels, with most countries having stopped its development.

As of the end of 2015, total installed CCS capacity reached 28 million tonnes (Mt) of CO_2 emissions per year from about 15 large-scale projects in operation worldwide (10 of them are in the Americas).

Currently 17 projects are in the development stage (7 under construction and 10 in advanced planning) (IEA, 2016b). In 2015, there were 32 projects that were either in the planning (24) or construction (8) stage, with the majority of them being enhanced oil recovery projects (Gibson, 2015). In the next decade, total installed CCS capacity is expected to grow to more than 60 Mt of CO_2 per year, including a larger share of capture from power plants. Biomass energy with CCS (BECCS) is one of a few options that can yield a net CO_2 removal from the atmosphere. This type of option is critical for deep emission cuts beyond 2050, when emissions may have to turn negative.

CCS technology typically requires additional costs to avoid CO_2 emissions. One reason for this is that it reduces the efficiency of power plants in the order of 10%-20% compared to the level offered by the initial plant design, and it has residual emissions because the capture process also requires heat and electricity. This cost increase for power plants can be in the order of USD 2-3 cents per kWh of electricity generated. There is a significant potential to reduce these costs through technological learning, but at these rates of capacity development, it is not clear by when the technology can be cost-competitive. In particular, at today's crude oil prices, power plants combined with CCS may continue to be perceived as high-risk and not considered economically viable. For high-temperature industrial processes, such as iron and steel or cement production, where renewables have limited potential, CCS is an important technology to reduce CO_2 emissions. However, to date, no capacity has been deployed yet in these industries. Today's technology trends also are reflected in the country plans. In the REmap analysis, no CCS capacity deployment is foreseen by any country.

While the options for a low-carbon energy system are plenty, it is unlikely that CCS will play a substantial role in CO_2 reduction between now and 2030, and nuclear growth is expected to be less (and only a technology for power generation), leaving renewable energy and energy efficiency as the two main technology options to mitigate climate change.

6. Action areas for G20 policy makers and next steps for IRENA support to the G20

The findings of this roadmap show that a significant rise in the renewable energy share of the G20 is technically possible and economically feasible. All countries have the opportunity to increase their renewables share significantly between now and 2030 in accordance with their national circumstance and sustainable development priorities.

On a global scale, higher shares than those foreseen in today's policy plans would bring benefits that exceed their costs when externalities are accounted for. Even when the comparison is made based on costs without considering the savings from externalities, renewables remain the cheapest supply option, with multiple other benefits including increased employment, better energy security and other macro-economic benefits. A doubling of the global share of renewables creates an important market opportunity for the G20 as it holds 75% of total global deployment potential and around 80% of total global investment potential for renewable energy between now and 2030.

As REmap suggests, renewables will play a key role in decarbonising our energy system together with improved energy efficiency. There is a need to decarbonise the global energy system in the next 50 years in order to fulfil the Paris Climate Agreement. All countries need to contribute to this global target. What is pledged by countries in their INDCs, however, does not fully take advantage of the renewables potentials shown in REmap. This is also partly a consequence of the lack of clarity around how exactly the target set forth in the Paris Climate Agreement will be realised. There therefore is a strong need to focus on the potential of renewables in realising the climate goals.

The time required to double the renewable energy share in the global energy mix by 2030 is only 14 years. This is a very short time frame. Before the window of opportunity closes, policy makers must accelerate their efforts today and achieve significant progress within the coming years to avoid technology lock-in. In order to translate the potential estimated in this study into action, this roadmap identifies seven action areas for G20 policy makers:

- **Action area 1: There are important synergies between energy efficiency and renewables.** Best-available technologies in the short and medium term and novel energy technologies in the long term should be implemented to maximise energy efficiency, which also will result in higher shares of renewables. There also is a need to prioritise the implementation of renewable energy technologies – notably electrification coupled with renewable power generation – that offer both efficiency improvements and higher shares of renewables.

- **Action area 2: Introducing greater flexibility to the power system.** The power sector will continue to be the sector with the highest share of renewables in 2030, with the share of variable renewables increasing to more than 20% in most G20 member countries under REmap. This paradigm change needs to be better captured in country policy plans. Opportunities and challenges related to sector coupling and introducing greater flexibility need to be taken into account.

- **Action area 3: Deployment of more renewables in end-use sector applications.** The potential of renewables in the end-use sectors is underestimated. In particular, electrification of end-use applications coupled with renewables will be key. To a lesser extent, specific options also deserve more attention in the power sector, such as dispatchable renewables. Country plans need to account for the potential of renewables in these sectors.

- **Action area 4: Bioenergy is key in many countries but often does not receive due attention.** A significant increase in the renewable energy share in the G20 will require half of total final renewable energy use to originate from bioenergy. As indicated in the G20 toolkit, to realise this, ensuring a sustainable and affordable supply of bioenergy feedstocks will be key. There also is a need for countries to reinforce their efforts to develop resource-efficient and cost-effective conversion technologies.

- **Action area 5: Innovation will be needed in certain areas.** A number of technology options are not covered in this roadmap, including the use of bioenergy as a feedstock for chemicals and plastic production, liquid biofuels for aviation, shipping and long-distance freight, and renewables for high-temperature steam production. These technologies require more R&D and investment support. Innovation needs also go beyond technology to cover financing, business models and policies that can enable the higher uptake of renewables across the energy system. Policy makers need to ensure strong interaction of energy innovation between ICT, electric vehicles, agriculture and urban design.

- **Action area 6: Renewable energy costs are much lower than estimated by some, and they continue to fall.** Recent auctions across the world show that the costs of renewables are falling. Many analyses reveal significant further reduction potential of costs in the coming decades. Increased international co-operation for transfer of technologies and capacity building can play an important role in contributing to further declines in the costs of renewables in the G20.

- **Action area 7: The benefits of renewables are not adequately reflected in market prices.** The analysis shows that the benefits of renewables can significantly outweigh the costs of renewables in 2030. Today, there is a big gap between market signals and policy objectives. Policy makers need to correct for market distortions to bring them in line with the real cost of fossil fuels by accounting for externalities related to human health and climate change.

This roadmap has shown in more detail the findings from IRENA's REmap analysis for the G20. The cornerstone of IRENA's approach is engagement with the country experts. Through collaboration with experts, IRENA has carried out initial analysis for all G20 member countries and has already prepared a number of detailed country roadmaps, including for China, Germany, Mexico and the United States. New roadmaps are being prepared for the EU, India, Indonesia, Russian Federation and South Africa.

Country plans are changing quickly, which requires continuous updating and review of the existing REmap country analysis. In line with the long-term goals of the Paris Climate Agreement, the time scope of the analysis needs to be expanded to 2050. Sustaining and expanding engagement with countries through this expert network and strengthening these teams with IRENA experts and other stakeholders from countries will be essential. This will allow countries to provide analytical feedback, and subsequently to update the results, which will be made available online continuously.

Based on this roadmap, which serves as a starting point for further engagement with the G20 at the country level, IRENA proposes as next steps the following "REmap G20 process" for the in-depth country study:

1) With interested member countries, form a REmap expert working group consisting of IRENA's REmap experts and national experts from the countries for deeper engagement with the country through focused group discussions, policy dialogues and technical workshops to develop a variety of recommendations on policy and regulatory development, based on the REmap analytical results.
2) As new data come along, review and update the analysis periodically through the REmap expert working group.
3) Through the REmap expert working group, discuss implementation of results and integration into long-term energy planning and the energy development strategy.
4) Use IRENA REmap's analytical framework in the development of a decarbonisation agenda for the G20 energy sector and energy ministers, in co-ordination with other relevant ministers such as environment and natural resources.

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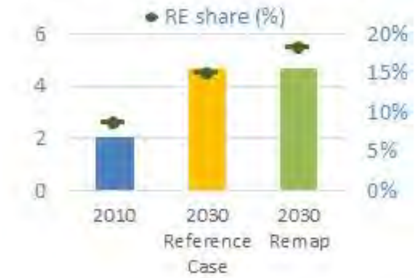
List of acronyms

°C	degree Celsius
BF	blast furnace
bln	billion
C2E2	Copenhagen Centre on Energy Efficiency
CC	climate change
CCS	carbon capture and storage
CO	coke oven
CO_2	carbon dioxide
COP21	21st session of the Conference of the Parties to the United Nations Framework Convention on Climate Change, held in Paris from 30 November to 11 December 2015
CSP	concentrated solar power
DH	district heat
EJ	exajoule
ETSAP	Energy Technology Systems Analysis Programme
EU	European Union
G20	Group of Twenty
GJ	gigajoule
Gt	gigatonne
GW	gigawatt
HH	human health
ICT	information and communications technology
IDDRI	Institute for Sustainable Development and International Relations
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
Mt	megatonne
MWh	megawatt-hour
N/A	not available/applicable
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
PJ	petajoule
PV	photovoltaic
RE	renewable energy
SDG	Sustainable Development Goal
SDSN	Sustainable Development Solutions Network
SE4All	Sustainable Energy for All
TFEC	total final energy consumption
TWh	terawatt-hour
USD	United States dollars
VRE	variable renewable energy
yr	year

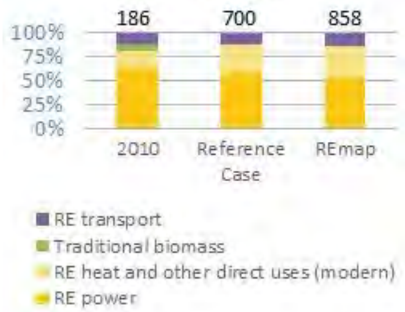
REmap Country Results - Argentina

			Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	*GW*	**29**	**60**	**62**
		Renewable capacity	*GW*	10	36	42
		Hydropower (excl. pumped hydro)	*GW*	10	23	23
		Wind	*GW*	0	6	9
		Biofuels (solid, liquid, gaseous)	*GW*	0	3	4
		Solar PV	*GW*	0	4	6
		CSP	*GW*	0	0	0
		Geothermal	*GW*	0	0	0
		Marine, other	*GW*	0	0	0
		Non-renewable capacity	*GW*	19	24	21
		Total electricity generation	*TWh*	**125**	**236**	**236**
		Renewable generation	*TWh*	36	128	144
		Hydropower	*TWh*	34	85	85
		Wind	*TWh*	0	17	26
		Biofuels (solid, liquid, gaseous)	*TWh*	2	19	22
		Solar PV	*TWh*	0	7	11
		CSP	*TWh*	0	0	0
		Geothermal	*TWh*	0	0	0
		Marine, other	*TWh*	0	0	0
		Non-renewable generation	*TWh*	89	108	92
	DH	**Total district heat generation**	*PJ*	**0**	**0**	**0**
		Biofuels (solid, liquid, gaseous)	*PJ*	0	0	0
		Other renewables	*PJ*	0	0	0
		Non-renewable DH	*PJ*	0	0	0
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	*PJ*	**836**	**2 056**	**2 067**
		Direct uses of renewable energy	*PJ*	46	215	287
		Solar thermal - Buildings	*PJ*	0	40	70
		Solar thermal - Industry	*PJ*	0	10	30
		Geothermal	*PJ*	0	0	0
		Bioenergy (traditional) - Buildings	*PJ*	13	0	0
		Bioenergy (modern) - Buildings	*PJ*	0	57	62
		Bioenergy - Industry	*PJ*	33	108	125
		Non-renewable - Buildings	*PJ*	485	1 106	1 081
		Non-renewable - Industry	*PJ*	286	629	593
		Non-renewable - BF/CO	*PJ*	19	106	106
	Transport	**Total fuel consumption**	*PJ*	**647**	**1 544**	**1 534**
		Liquid biofuels	*PJ*	23	79	115
		Conventional ethanol	*PJ*	13	29	41
		Advanced ethanol	*PJ*	0	0	0
		Biodiesel (conventional and advanced)	*PJ*	10	50	74
		Biomethane	*PJ*	0	4	5
		Non-renewable fuels	*PJ*	624	1 461	1 415
Total final energy consumption (electricity, DH, direct uses) [2]			*PJ*	**2 036**	**4 682**	**4 684**
RE shares		RE share in electricity generation		29%	54%	61%
		RE share in district heat generation		0%	0%	0%
		RE share in Buildings - final energy use, direct uses (modern)		0%	8%	11%
		RE share in Industry - final energy use, direct uses		10%	16%	21%
		RE share in Transport fuels		4%	5%	8%
		Share of modern RE in TFEC [3]		9%	15%	18%
Financial indicators		System costs [USD bln/yr. in 2030]		*N/A*	*N/A*	- 2
		RE investment needs [USD bln/yr. (2010-2030)]		*N/A*	6	7
		Investment support for renewables [USD bln/yr. in 2030]		*N/A*	*N/A*	0.4
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		*N/A*	*N/A*	1.0
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		*N/A*	*N/A*	0.7
		CO2 emissions from energy [Mt/yr.]		137	263	249

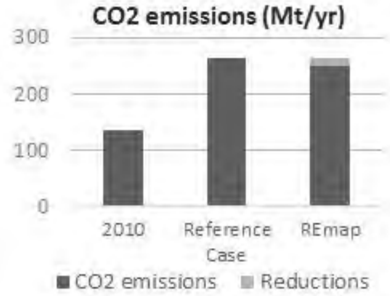
TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)



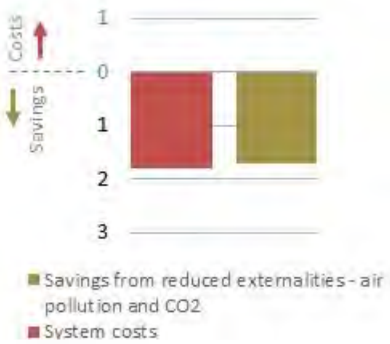
Final RE use by sector (%) and total (PJ/yr)



CO2 emissions (Mt/yr)



Costs and savings (USD bln in 2030)



References for further consultation:

- Escenarios Energéticos de Argentina, Plataforma Escenarios Energéticos Argentina 2035 (2015).

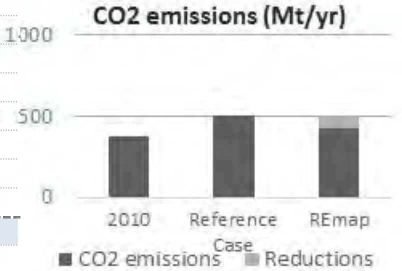
REmap Country Results - Australia

			Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	GW	**58**	**71**	**91**
		Renewable capacity	GW	12	22	52
		Hydropower (excl. pumped hydro)	GW	7	8	10
		Wind	GW	5	9	19
		Biofuels (solid, liquid, gaseous)	GW	0	1	2
		Solar PV	GW	1	4	21
		CSP	GW	0	0	0
		Geothermal	GW	0	1	1
		Marine, other	GW	0	0	0
		Non-renewable capacity	GW	45	49	39
		Total electricity generation	TWh	**262**	**317**	**334**
		Renewable generation	TWh	38	64	137
		Hydropower	TWh	17	19	27
		Wind	TWh	14	27	54
		Biofuels (solid, liquid, gaseous)	TWh	5	8	15
		Solar PV	TWh	1	7	35
		CSP	TWh	0	0	0
		Geothermal	TWh	0	4	6
		Marine, other	TWh	0	0	0
		Non-renewable generation	TWh	225	253	197
	DH	**Total district heat generation**	PJ	**0**	**0**	**0**
		Biofuels (solid, liquid, gaseous)	PJ	0	0	0
		Other renewables	PJ	0	0	0
		Non-renewable DH	PJ	0	0	0
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	PJ	**1 303**	**2 218**	**2 192**
		Direct uses of renewable energy	PJ	183	212	379
		Solar thermal - Buildings	PJ	11	12	30
		Solar thermal - Industry	PJ	0	0	35
		Geothermal	PJ	0	0	0
		Bioenergy (traditional) - Buildings	PJ	0	0	0
		Bioenergy (modern) - Buildings	PJ	54	41	66
		Bioenergy - Industry	PJ	118	159	248
		Non-renewable - Buildings	PJ	240	361	296
		Non-renewable - Industry	PJ	782	1 557	1 429
		Non-renewable - BF/CO	PJ	97	89	89
	Transport	**Total fuel consumption**	PJ	**1 466**	**1 928**	**1 821**
		Liquid biofuels	PJ	9	11	53
		Conventional ethanol	PJ	6	5	17
		Advanced ethanol	PJ	0	3	3
		Biodiesel (conventional and advanced)	PJ	3	3	33
		Biomethane	PJ	0	0	0
		Non-renewable fuels	PJ	1 457	1 917	1 768
Total final energy consumption (electricity, DH, direct uses) [2]			PJ	**3 593**	**5 236**	**5 182**
RE shares		RE share in electricity generation		14%	20%	41%
		RE share in district heat generation		0%	0%	0%
		RE share in Buildings - final energy use, direct uses (modern)		21%	13%	25%
		RE share in Industry - final energy use, direct uses		13%	9%	17%
		RE share in Transport fuels		1%	1%	3%
		Share of modern RE in TFEC [3]		8%	8%	17%
Financial indicators		System costs [USD bln/yr. in 2030]		N/A	N/A	2
		RE investment needs [USD bln/yr. (2010-2030)]		N/A	1	5
		Investment support for renewables [USD bln/yr. in 2030]		N/A	N/A	2.5
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		N/A	N/A	14.7
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		N/A	N/A	3.9
		CO2 emissions from energy [Mt/yr.]		375	507	429

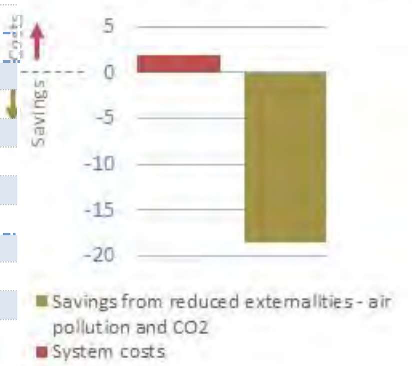
TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)

Final RE use by sector (%) and total (PJ/yr)

CO2 emissions (Mt/yr)



Costs and savings (USD bln in 2030)



References for further consultation:

- Australian Energy Projections 2014-15 to 2049-50, BREE (2014).
- "Chapter 3: THE OUTLOOK FOR GAS IN THE TRANSPORT FUEL MARKET", Transport Fuels from Australia, CSIRO

REmap Country Results - Brazil

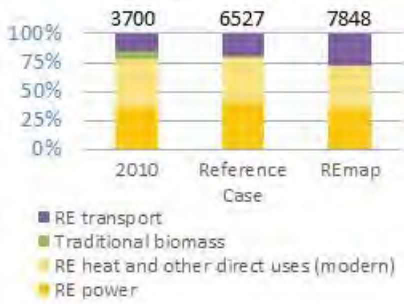
REmap – A Renewable Energy Roadmap

IRENA – International Renewable Energy Agency

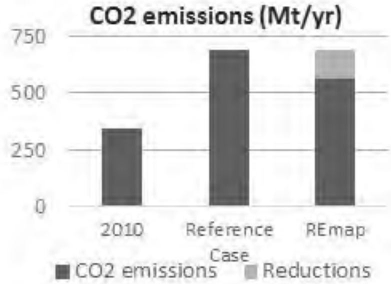
Category	Sector	Item	Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	GW	**115**	**249**	**257**
		Renewable capacity	GW	91	203	224
		Hydropower (excl. pumped hydro)	GW	82	131	134
		Wind	GW	1	36	42
		Biofuels (solid, liquid, gaseous)	GW	8	25	25
		Solar PV	GW	0	10	21
		CSP	GW	0	1	2
		Geothermal	GW	0	0	0
		Marine, other	GW	0	0	0
		Non-renewable capacity	GW	24	45	33
		Total electricity generation	TWh	**515**	**994**	**994**
		Renewable generation	TWh	437	834	884
		Hydropower	TWh	403	610	622
		Wind	TWh	2	96	116
		Biofuels (solid, liquid, gaseous)	TWh	32	111	112
		Solar PV	TWh	0	14	30
		CSP	TWh	0	2	4
		Geothermal	TWh	0	0	0
		Marine, other	TWh	0	0	0
		Non-renewable generation	TWh	78	160	110
	DH	**Total district heat generation**	PJ	**0**	**0**	**0**
		Biofuels (solid, liquid, gaseous)	PJ	0	0	0
		Other renewables	PJ	0	0	0
		Non-renewable DH	PJ	0	0	0
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	PJ	**3 442**	**5 526**	**5 485**
		Direct uses of renewable energy	PJ	1 774	2 611	2 866
		Solar thermal - Buildings	PJ	0	23	94
		Solar thermal - Industry	PJ	0	0	163
		Geothermal	PJ	0	0	10
		Bioenergy (traditional) - Buildings	PJ	225	149	0
		Bioenergy (modern) - Buildings	PJ	108	102	154
		Bioenergy - Industry	PJ	1 441	2 337	2 445
		Non-renewable - Buildings	PJ	316	432	432
		Non-renewable - Industry	PJ	1 352	2 483	2 187
		Non-renewable - BF/CO	PJ	0	0	0
	Transport	**Total fuel consumption**	PJ	**2 924**	**6 355**	**6 344**
		Liquid biofuels	PJ	589	1 228	2 187
		Conventional ethanol	PJ	389	892	1 544
		Advanced ethanol	PJ	0	6	224
		Biodiesel (conventional and advanced)	PJ	200	330	418
		Biomethane	PJ	0	0	0
		Non-renewable fuels	PJ	2 335	5 128	4 157
Total final energy consumption (electricity, DH, direct uses) [2]			PJ	**8 294**	**15 534**	**15 422**
RE shares		RE share in electricity generation		85%	84%	89%
		RE share in district heat generation		0%	0%	0%
		RE share in Buildings - final energy use, direct uses (modern)		17%	18%	37%
		RE share in Industry - final energy use, direct uses		52%	48%	54%
		RE share in Transport fuels		20%	19%	34%
		Share of modern RE in TFEC [3]		43%	42%	51%
Financial indicators		System costs [USD bln/yr. in 2030]		N/A	N/A	- 11
		RE investment needs [USD bln/yr. (2010-2030)]		N/A	17	22
		Investment support for renewables [USD bln/yr. in 2030]		N/A	N/A	3.0
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		N/A	N/A	19.5
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		N/A	N/A	6.3
		CO2 emissions from energy [Mt/yr.]		347	690	564

TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)

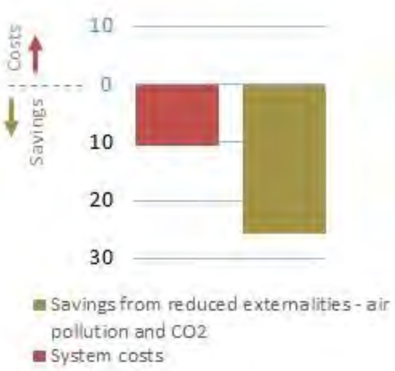
Final RE use by sector (%) and total (PJ/yr)



CO2 emissions (Mt/yr)



Costs and savings (USD bln in 2030)



References for further consultation:

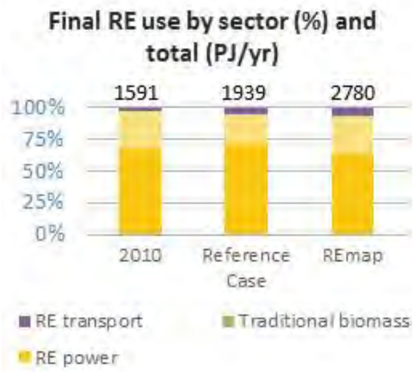
- Plano Nacional de Energia 2050, Ministério de Minas e Energia. Empresa de Pesquisa Energética (2014).
- Plano Decenal de Energia 2024, Ministério de Minas e Energia. Empresa de Pesquisa Energética (2015).

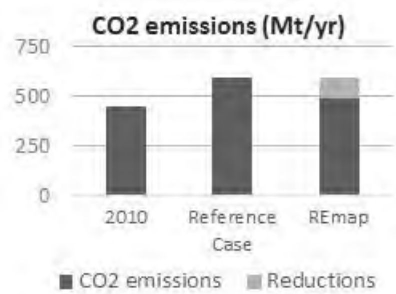
REmap
A Renewable Energy Roadmap

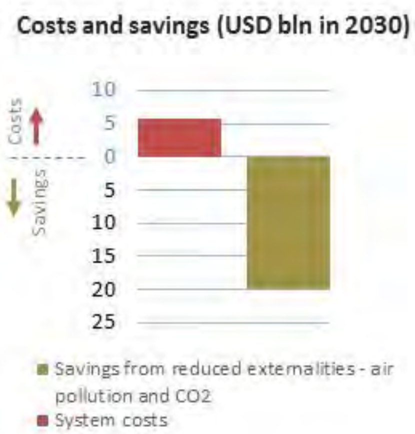
IRENA
International Renewable Energy Agency

REmap Country Results - Canada

Category	Sector	Indicator	Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	*GW*	**129**	**166**	**187**
		Renewable capacity	*GW*	81	113	147
		Hydropower (excl. pumped hydro)	*GW*	75	87	90
		Wind	*GW*	4	18	31
		Biofuels (solid, liquid, gaseous)	*GW*	2	4	12
		Solar PV	*GW*	0	5	13
		CSP	*GW*	0	0	0
		Geothermal	*GW*	0	0	1
		Marine, other	*GW*	0	0	0
		Non-renewable capacity	*GW*	48	53	40
		Total electricity generation	*TWh*	**610**	**751**	**785**
		Renewable generation	*TWh*	370	497	615
		Hydropower	*TWh*	351	432	447
		Wind	*TWh*	9	33	76
		Biofuels (solid, liquid, gaseous)	*TWh*	9	16	60
		Solar PV	*TWh*	1	16	25
		CSP	*TWh*	0	0	0
		Geothermal	*TWh*	0	0	7
		Marine, other	*TWh*	0	0	0
		Non-renewable generation	*TWh*	240	254	170
	DH	**Total district heat generation**	*PJ*	**19**	**34**	**34**
		Biofuels (solid, liquid, gaseous)	*PJ*	2	0	20
		Other renewables	*PJ*	0	0	0
		Non-renewable DH	*PJ*	17	34	14
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	*PJ*	**2 770**	**5 171**	**5 114**
		Direct uses of renewable energy	*PJ*	481	447	828
		Solar thermal - Buildings	*PJ*	0	3	8
		Solar thermal - Industry	*PJ*	0	0	15
		Geothermal	*PJ*	0	3	3
		Bioenergy (traditional) - Buildings	*PJ*	0	0	0
		Bioenergy (modern) - Buildings	*PJ*	94	145	213
		Bioenergy - Industry	*PJ*	387	296	589
		Non-renewable - Buildings	*PJ*	1 204	1 942	1 766
		Non-renewable - Industry	*PJ*	1 085	2 743	2 481
		Non-renewable - BF/CO	*PJ*	0	39	39
	Transport	**Total fuel consumption**	*PJ*	**2 449**	**2 762**	**2 331**
		Liquid biofuels	*PJ*	52	99	195
		Conventional ethanol	*PJ*	42	62	94
		Advanced ethanol	*PJ*	0	19	51
		Biodiesel (conventional and advanced)	*PJ*	9	18	50
		Biomethane	*PJ*	0	0	0
		Non-renewable fuels	*PJ*	2 398	2 663	2 135
Total final energy consumption (electricity, DH, direct uses) [2]			***PJ***	**7 152**	**10 371**	**10 003**
RE shares		RE share in electricity generation		61%	66%	78%
		RE share in district heat generation		11%	0%	59%
		RE share in Buildings - final energy use, direct uses (modern)		7%	7%	11%
		RE share in Industry - final energy use, direct uses		26%	10%	20%
		RE share in Transport fuels		2%	4%	8%
		Share of modern RE in TFEC [3]		22%	19%	28%
Financial indicators		System costs [USD bln/yr. in 2030]		*N/A*	*N/A*	6
		RE investment needs [USD bln/yr. (2010-2030)]		*N/A*	6	11
		Investment support for renewables [USD bln/yr. in 2030]		*N/A*	*N/A*	5.1
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		*N/A*	*N/A*	14.7
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		*N/A*	*N/A*	5.2
		CO2 emissions from energy [Mt/yr.]		448	593	489







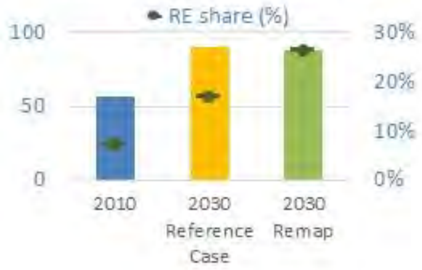
References for further consultation:

- Canada's Energy Future 2016: Energy Supply and Demand Projections to 2040, NEB (2016).
- Report on Energy Supply and Demand in Canada, Government of Canada (2016).

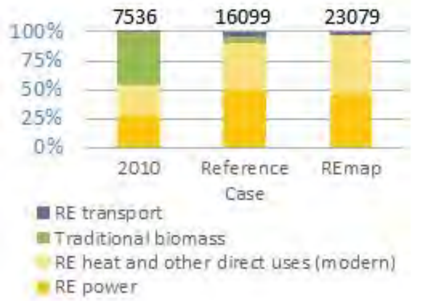
REmap Country Results - China

			Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	GW	**998**	**2 467**	**2 731**
		Renewable capacity	GW	266	1 066	1 484
		Hydropower (excl. pumped hydro)	GW	213	400	400
		Wind	GW	45	315	562
		Biofuels (solid, liquid, gaseous)	GW	6	38	67
		Solar PV	GW	2	300	422
		CSP	GW	0	12	31
		Geothermal	GW	0	1	1
		Marine, other	GW	0	0	0
		Non-renewable capacity	GW	732	1 401	1 248
		Total electricity generation	TWh	**4 234**	**9 315**	**9 466**
		Renewable generation	TWh	802	2 891	3 809
		Hydropower	TWh	722	1 600	1 600
		Wind	TWh	45	648	1 200
		Biofuels (solid, liquid, gaseous)	TWh	33	192	358
		Solar PV	TWh	1	425	595
		CSP	TWh	0	18	46
		Geothermal	TWh	1	9	9
		Marine, other	TWh	0	0	0
		Non-renewable generation	TWh	3 433	6 424	5 657
	DH	**Total district heat generation**	PJ	**2 934**	**3 530**	**3 530**
		Biofuels (solid, liquid, gaseous)	PJ	34	41	1 401
		Other renewables	PJ	0	0	0
		Non-renewable DH	PJ	2 900	3 489	2 129
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	PJ	**36 167**	**43 488**	**41 758**
		Direct uses of renewable energy	PJ	5 310	7 236	10 258
		Solar thermal - Buildings	PJ	860	2 674	3 244
		Solar thermal - Industry	PJ	0	84	1 219
		Geothermal	PJ	150	301	446
		Bioenergy (traditional) - Buildings	PJ	3 400	891	0
		Bioenergy (modern) - Buildings	PJ	793	2 407	3 632
		Bioenergy - Industry	PJ	107	879	1 717
		Non-renewable - Buildings	PJ	5 883	6 083	3 593
		Non-renewable - Industry	PJ	19 743	24 135	21 872
		Non-renewable - BF/CO	PJ	5 231	6 035	6 035
	Transport	**Total fuel consumption**	PJ	**7 226**	**17 372**	**16 409**
		Liquid biofuels	PJ	51	751	751
		Conventional ethanol	PJ	32	516	516
		Advanced ethanol	PJ	0	2	2
		Biodiesel (conventional and advanced)	PJ	18	233	233
		Biomethane	PJ	0	0	0
		Non-renewable fuels	PJ	7 175	16 622	15 658
Total final energy consumption (electricity, DH, direct uses) [2]			PJ	**57 156**	**90 172**	**88 213**
RE shares		RE share in electricity generation		19%	31%	40%
		RE share in district heat generation		1%	1%	40%
		RE share in Buildings - final energy use, direct uses (modern)		16%	44%	67%
		RE share in Industry - final energy use, direct uses		1%	4%	12%
		RE share in Transport fuels		1%	4%	5%
		Share of modern RE in TFEC [3]		7%	17%	26%
Financial indicators		System costs [USD bln/yr. in 2030]		N/A	N/A	46
		RE investment needs [USD bln/yr. (2010-2030)]		N/A	105	160
		Investment support for renewables [USD bln/yr. in 2030]		N/A	N/A	56.4
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		N/A	N/A	116.1
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		N/A	N/A	74.4
		CO2 emissions from energy [Mt/yr.]		6 394	9 499	8 010

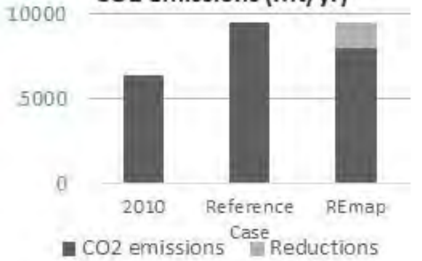
TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)



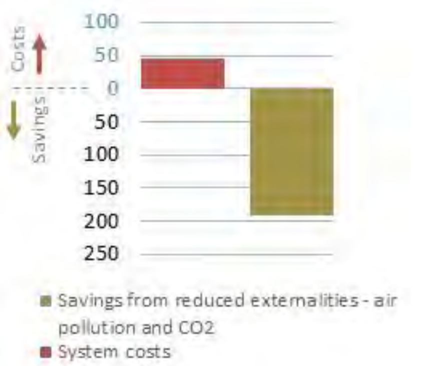
Final RE use by sector (%) and total (PJ/yr)



CO2 emissions (Mt/yr)



Costs and savings (USD bln in 2030)



References for further consultation:

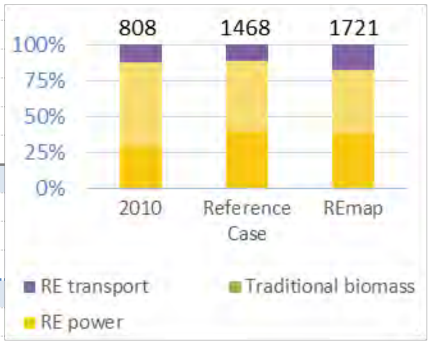
- World Energy Outlook 2012 & 2015, IEA (2012; 2015).

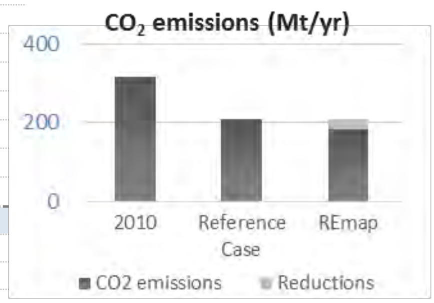
REmap Country Results – France

Section	Subsection	Indicator	Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	GW	**119**	**147**	**155**
		Renewable capacity	GW	33	83	96
		Hydropower (excl. pumped hydro)	GW	25	26	26
		Wind	GW	6	27	33
		Biofuels (solid, liquid, gaseous)	GW	1	4	5
		Solar PV	GW	1	26	31
		CSP	GW	0	0	0
		Geothermal	GW	0	0	0
		Marine, other	GW	0	0	0
		Non-renewable capacity	GW	86	63	59
		Total electricity generation	TWh	**569**	**545**	**548**
		Renewable generation	TWh	85	218	245
		Hydropower	TWh	69	75	75
		Wind	TWh	10	76	91
		Biofuels (solid, liquid, gaseous)	TWh	5	26	30
		Solar PV	TWh	1	41	49
		CSP	TWh	0	0	0
		Geothermal	TWh	0	1	0
		Marine, other	TWh	0	0	0
		Non-renewable generation	TWh	484	326	303
	DH	**Total district heat generation**	PJ	**153**	**244**	**244**
		Biofuels (solid, liquid, gaseous)	PJ	23	45	45
		Other renewables	PJ	0	5	5
		Non-renewable DH	PJ	131	193	193
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	PJ	**2 631**	**1 794**	**1 739**
		Direct uses of renewable energy	PJ	451	674	719
		Solar thermal - Buildings	PJ	2	35	65
		Solar thermal - Industry	PJ	0	0	15
		Geothermal	PJ	4	19	19
		Bioenergy (traditional) - Buildings	PJ	0	0	0
		Bioenergy (modern) - Buildings	PJ	363	278	278
		Bioenergy - Industry	PJ	82	342	342
		Non-renewable - Buildings	PJ	1 347	355	271
		Non-renewable - Industry	PJ	723	654	638
		Non-renewable - BF/CO	PJ	111	111	111
	Transport	**Total fuel consumption**	PJ	**1 808**	**1 444**	**1 445**
		Liquid biofuels	PJ	101	165	300
		Conventional ethanol	PJ	17	25	44
		Advanced ethanol	PJ	0	15	45
		Biodiesel (conventional and advanced)	PJ	85	125	211
		Biomethane	PJ	0	0	0
		Non-renewable fuels	PJ	1 707	1 279	1 145
		Total final energy consumption (electricity, DH, direct uses) [2]	PJ	**6 164**	**4 929**	**4 888**
RE shares		RE share in electricity generation		15%	40%	45%
		RE share in district heat generation		15%	21%	21%
		RE share in Buildings - final energy use, direct uses (modern)		22%	48%	57%
		RE share in Industry - final energy use, direct uses		10%	34%	36%
		RE share in Transport fuels		6%	11%	21%
		Share of modern RE in TFEC [3]		13%	30%	35%
Financial indicators		System costs [USD bln/yr. in 2030]		N/A	N/A	-2
		RE investment needs [USD bln/yr. (2010-2030)]		N/A	10	12
		Investment support for renewables [USD bln/yr. in 2030]		N/A	N/A	0.3
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		N/A	N/A	3.4
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		N/A	N/A	1.2
		CO2 emissions from energy [Mt/yr.]		316	209	184

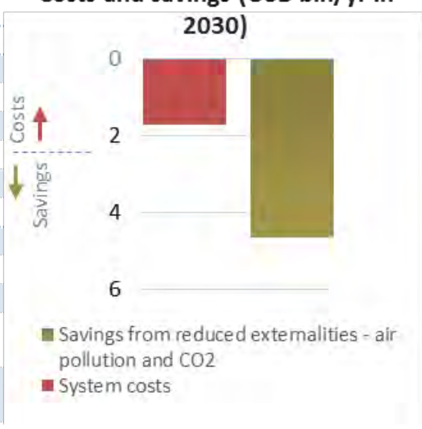
TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)

Final RE use by sector (%) and total (PJ/yr)





Costs and savings (USD bln/yr in 2030)



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- France Energy Transition Law, 2015.
- Vers un mix electrique 100% renouvelable en 2050, ADEME (2015).
- Roadmap for smart grid and electricity systems integrating renewable energy sources, ADEME (2013).

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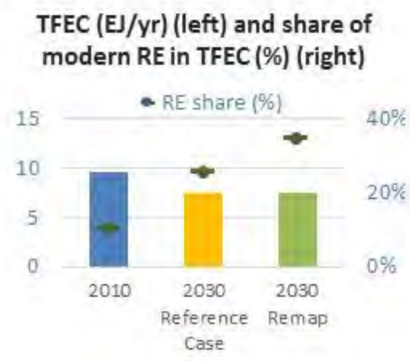
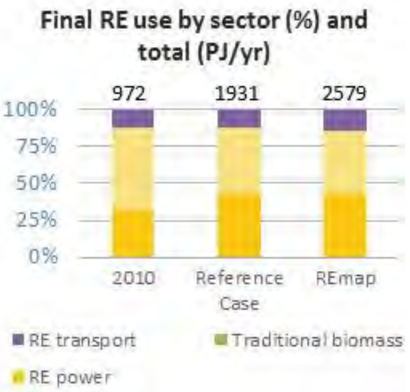
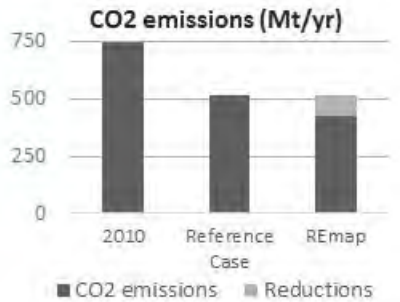
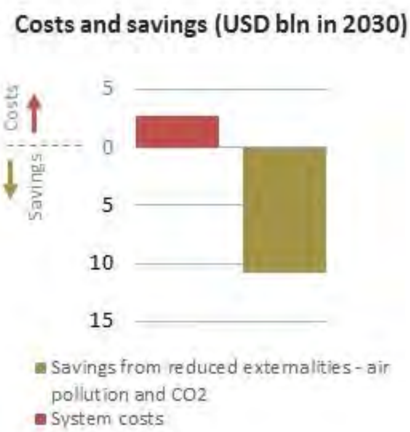
REmap Country Results – Germany

			Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	GW	**161**	**222**	**256**
		Renewable capacity	GW	63	146	189
		Hydropower (excl. pumped hydro)	GW	5	5	5
		Wind	GW	27	59	88
		Biofuels (solid, liquid, gaseous)	GW	11	20	20
		Solar PV	GW	20	62	75
		CSP	GW	0	0	0
		Geothermal	GW	0	0	1
		Marine, other	GW	0	0	0
		Non-renewable capacity	GW	98	76	66
		Total electricity generation	TWh	**629**	**599**	**620**
		Renewable generation	TWh	103	286	378
		Hydropower	TWh	21	19	23
		Wind	TWh	38	143	214
		Biofuels (solid, liquid, gaseous)	TWh	33	67	67
		Solar PV	TWh	12	56	70
		CSP	TWh	0	0	0
		Geothermal	TWh	0	1	4
		Marine, other	TWh	0	0	0
		Non-renewable generation	TWh	525	313	242
	DH	**Total district heat generation**	PJ	**555**	**578**	**620**
		Biofuels (solid, liquid, gaseous)	PJ	52	191	216
		Other renewables	PJ	0	0	84
		Non-renewable DH	PJ	504	387	320
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	PJ	**4 694**	**3 275**	**3 131**
		Direct uses of renewable energy	PJ	495	741	878
		Solar thermal - Buildings	PJ	18	106	162
		Solar thermal - Industry	PJ	0	0	25
		Geothermal	PJ	19	86	86
		Bioenergy (traditional) - Buildings	PJ	0	0	0
		Bioenergy (modern) - Buildings	PJ	318	375	431
		Bioenergy - Industry	PJ	140	174	174
		Non-renewable - Buildings	PJ	2 435	1 207	976
		Non-renewable - Industry	PJ	1 510	1 242	1 193
		Non-renewable - BF/CO	PJ	254	85	85
	Transport	**Total fuel consumption**	PJ	**2 500**	**2 137**	**2 073**
		Liquid biofuels	PJ	121	228	368
		Conventional ethanol	PJ	33	49	49
		Advanced ethanol	PJ	0	46	50
		Biodiesel (conventional and advanced)	PJ	88	133	269
		Biomethane	PJ	0	0	5
		Non-renewable fuels	PJ	2 379	1 909	1 700
Total final energy consumption (electricity, DH, direct uses) [2]			PJ	**9 565**	**7 539**	**7 459**
RE shares		RE share in electricity generation		16%	48%	61%
		RE share in district heat generation		9%	33%	48%
		RE share in Buildings - final energy use, direct uses (modern)		13%	32%	41%
		RE share in Industry - final energy use, direct uses		8%	12%	14%
		RE share in Transport fuels		5%	11%	18%
		Share of modern RE in TFEC [3]		10%	26%	35%
Financial indicators		System costs [USD bln/yr. in 2030]		N/A	N/A	3
		RE investment needs [USD bln/yr. (2010-2030)]		N/A	15	23
		Investment support for renewables [USD bln/yr. in 2030]		N/A	N/A	2.9
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		N/A	N/A	6.0
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		N/A	N/A	4.8
		CO2 emissions from energy [Mt/yr.]		746	518	421









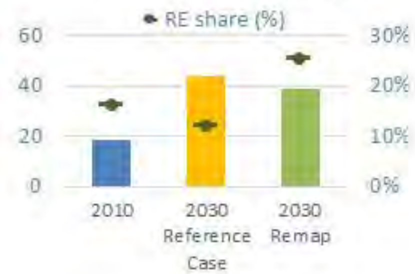
References for further consultation:

- REmap: Renewable Energy Prospects, Germany, IRENA (2015).
- Projektionsbericht 2015, BMU (2015).
- Entwicklung der Energiemaerkte – Energiereferenzprognose, BMWi (2014).

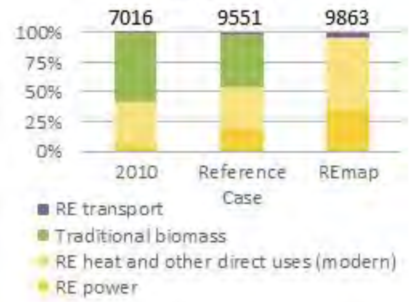
REmap Country Results – India

Category	Sector	Item	Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	GW	**174**	**663**	**854**
		Renewable capacity	GW	56	252	521
		Hydropower (excl. pumped hydro)	GW	37	48	77
		Wind	GW	14	146	194
		Biofuels (solid, liquid, gaseous)	GW	3	11	28
		Solar PV	GW	1	48	209
		CSP	GW	0	0	11
		Geothermal	GW	0	0	2
		Marine, other	GW	0	0	0
		Non-renewable capacity	GW	118	411	333
		Total electricity generation	TWh	**946**	**3 428**	**3 490**
		Renewable generation	TWh	136	592	1 186
		Hydropower	TWh	104	131	230
		Wind	TWh	21	345	458
		Biofuels (solid, liquid, gaseous)	TWh	10	35	108
		Solar PV	TWh	1	82	346
		CSP	TWh	0	0	28
		Geothermal	TWh	0	0	16
		Marine, other	TWh	0	0	0
		Non-renewable generation	TWh	810	2 835	2 304
	DH	**Total district heat generation**	PJ	**0**	**0**	**0**
		Biofuels (solid, liquid, gaseous)	PJ	0	0	0
		Other renewables	PJ	0	0	0
		Non-renewable DH	PJ	0	0	0
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	PJ	**13 055**	**27 567**	**25 256**
		Direct uses of renewable energy	PJ	6 639	7 638	5 966
		Solar thermal - Buildings	PJ	6	71	510
		Solar thermal - Industry	PJ	0	1	151
		Geothermal	PJ	9	9	19
		Bioenergy (traditional) - Buildings	PJ	4 063	4 259	0
		Bioenergy (modern) - Buildings	PJ	1 364	1 485	2 967
		Bioenergy - Industry	PJ	1 196	1 813	2 319
		Non-renewable - Buildings	PJ	1 023	4 740	4 740
		Non-renewable - Industry	PJ	5 116	14 553	13 914
		Non-renewable - BF/CO	PJ	278	636	636
	Transport	**Total fuel consumption**	PJ	**2 214**	**5 718**	**3 351**
		Liquid biofuels	PJ	8	109	468
		Conventional ethanol	PJ	7	42	108
		Advanced ethanol	PJ	0	1	37
		Biodiesel (conventional and advanced)	PJ	2	66	323
		Biomethane	PJ	0	0	0
		Non-renewable fuels	PJ	2 205	5 609	2 883
Total final energy consumption (electricity, DH, direct uses) [2]			PJ	**18 222**	**44 055**	**38 695**
RE shares		RE share in electricity generation		14%	17%	34%
		RE share in district heat generation		0%	0%	0%
		RE share in Buildings - final energy use, direct uses (modern)		21%	15%	42%
		RE share in Industry - final energy use, direct uses		19%	11%	15%
		RE share in Transport fuels		0%	2%	14%
		Share of modern RE in TFEC [3]		16%	12%	25%
Financial indicators		System costs [USD bln/yr. in 2030]		N/A	N/A	17
		RE investment needs [USD bln/yr. (2010-2030)]		N/A	25	51
		Investment support for renewables [USD bln/yr. in 2030]		N/A	N/A	22.2
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		N/A	N/A	103.2
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		N/A	N/A	39.3
		CO2 emissions from energy [Mt/yr.]		1 560	4 570	3 783

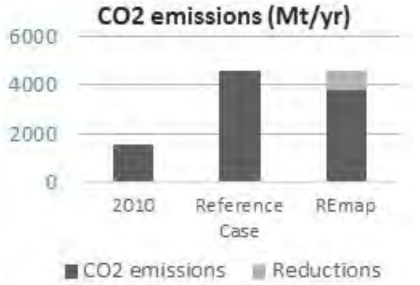
TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)



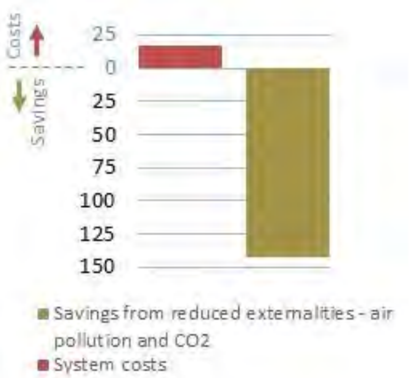
Final RE use by sector (%) and total (PJ/yr)



CO2 emissions (Mt/yr)



Costs and savings (USD bln in 2030)



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- Low Carbon Strategies for Inclusive Growth, Planning Commission of Government of India (2014).
- Report on India's Renewable Electricity Roadmap to 2030, NITI Aayog, Government of India (2015).
- Twelfth Five Year Plan (2012-2017), Planning Commission of Government of India (2013).

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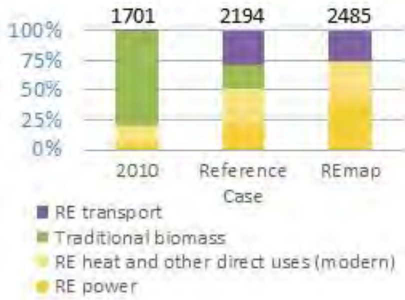
REmap Country Results – Indonesia

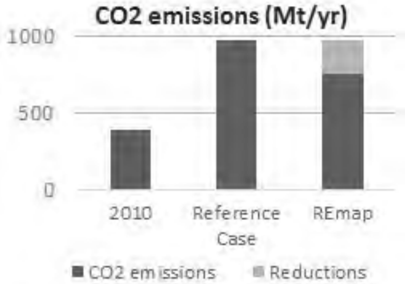
			Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	*GW*	**36**	**196**	**239**
		Renewable capacity	*GW*	7	60	129
		Hydropower (excl. pumped hydro)	*GW*	4	16	25
		Wind	*GW*	0	2	11
		Biofuels (solid, liquid, gaseous)	*GW*	2	29	29
		Solar PV	*GW*	0	4	47
		CSP	*GW*	0	0	0
		Geothermal	*GW*	1	9	14
		Marine, other	*GW*	0	0	3
		Non-renewable capacity	*GW*	29	136	110
		Total electricity generation	*TWh*	**170**	**590**	**593**
		Renewable generation	*TWh*	27	147	328
		Hydropower	*TWh*	18	37	76
		Wind	*TWh*	0	2	31
		Biofuels (solid, liquid, gaseous)	*TWh*	0	61	61
		Solar PV	*TWh*	0	2	62
		CSP	*TWh*	0	0	0
		Geothermal	*TWh*	9	45	84
		Marine, other	*TWh*	0	0	13
		Non-renewable generation	*TWh*	143	443	266
	DH	**Total district heat generation**	*PJ*	**0**	**0**	**0**
		Biofuels (solid, liquid, gaseous)	*PJ*	0	0	0
		Other renewables	*PJ*	0	0	0
		Non-renewable DH	*PJ*	0	0	0
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	*PJ*	**3 568**	**5 524**	**5 173**
		Direct uses of renewable energy	*PJ*	1 608	1 110	791
		Solar thermal - Buildings	*PJ*	0	0	0
		Solar thermal - Industry	*PJ*	0	0	20
		Geothermal	*PJ*	0	0	10
		Bioenergy (traditional) - Buildings	*PJ*	1 352	461	0
		Bioenergy (modern) - Buildings	*PJ*	0	70	182
		Bioenergy - Industry	*PJ*	255	579	579
		Non-renewable - Buildings	*PJ*	317	654	654
		Non-renewable - Industry	*PJ*	1 644	3 760	3 727
		Non-renewable - BF/CO	*PJ*	0	0	0
	Transport	**Total fuel consumption**	*PJ*	**1 492**	**3 601**	**3 577**
		Liquid biofuels	*PJ*	8	617	651
		Conventional ethanol	*PJ*	1	417	433
		Advanced ethanol	*PJ*	0	0	0
		Biodiesel (conventional and advanced)	*PJ*	7	200	218
		Biomethane	*PJ*	0	0	0
		Non-renewable fuels	*PJ*	1 483	2 985	2 925
Total final energy consumption (electricity, DH, direct uses) [2]			***PJ***	**5 590**	**11 289**	**10 923**
RE shares		RE share in electricity generation		16%	25%	55%
		RE share in district heat generation		0%	0%	0%
		RE share in Buildings - final energy use, direct uses (modern)		0%	6%	22%
		RE share in Industry - final energy use, direct uses		13%	13%	14%
		RE share in Transport fuels		1%	17%	18%
		Share of modern RE in TFEC [3]		6%	16%	23%
Financial indicators		System costs [USD bln/yr. in 2030]		*N/A*	*N/A*	4
		RE investment needs [USD bln/yr. (2010-2030)]		*N/A*	5	13
		Investment support for renewables [USD bln/yr. in 2030]		*N/A*	*N/A*	4.2
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		*N/A*	*N/A*	6.9
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		*N/A*	*N/A*	10.5
		CO2 emissions from energy [Mt/yr.]		391	971	761

TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)

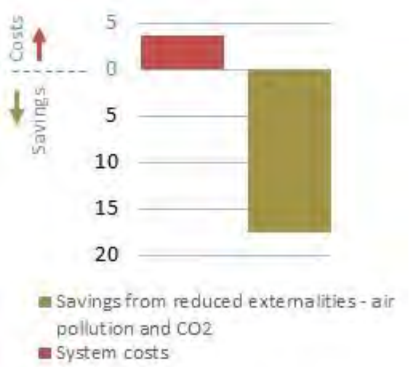
Final RE use by sector (%) and total (PJ/yr)



CO2 emissions (Mt/yr)



Costs and savings (USD bln in 2030)

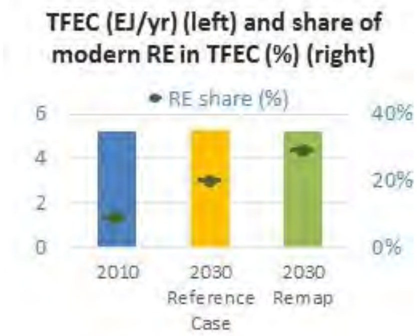


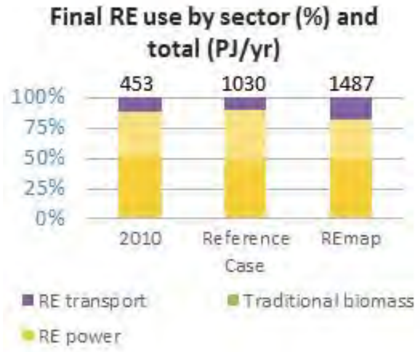
References for further consultation:

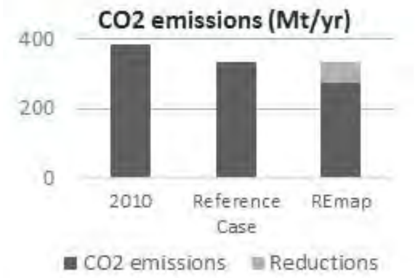
- Outlook Energi Indonesia, MEMR (2014).
- Outlook Energi Indonesia, BPPT (2015).
- Peer Review on Low Carbon Energy Policies in Indonesia (2013).

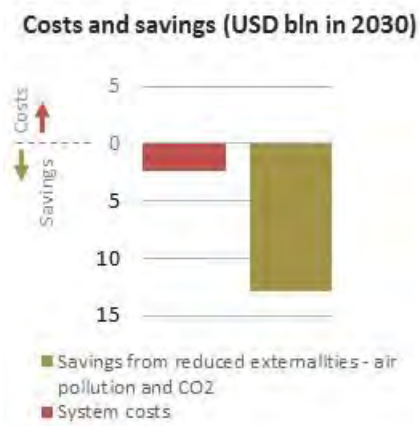
REmap Country Results – Italy

			Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	*GW*	**110**	**123**	**142**
		Renewable capacity	*GW*	26	64	90
		Hydropower (excl. pumped hydro)	*GW*	14	14	17
		Wind	*GW*	6	19	20
		Biofuels (solid, liquid, gaseous)	*GW*	2	5	7
		Solar PV	*GW*	3	25	43
		CSP	*GW*	0	1	1
		Geothermal	*GW*	1	1	2
		Marine, other	*GW*	0	0	0
		Non-renewable capacity	*GW*	84	59	52
		Total electricity generation	*TWh*	**302**	**352**	**364**
		Renewable generation	*TWh*	67	135	196
		Hydropower	*TWh*	41	39	49
		Wind	*TWh*	9	29	31
		Biofuels (solid, liquid, gaseous)	*TWh*	9	22	40
		Solar PV	*TWh*	2	37	63
		CSP	*TWh*	0	2	0
		Geothermal	*TWh*	5	7	13
		Marine, other	*TWh*	0	0	0
		Non-renewable generation	*TWh*	235	217	168
	DH	**Total district heat generation**	*PJ*	**205**	**126**	**126**
		Biofuels (solid, liquid, gaseous)	*PJ*	15	24	24
		Other renewables	*PJ*	1	1	1
		Non-renewable DH	*PJ*	189	101	101
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	*PJ*	**2 166**	**2 142**	**2 116**
		Direct uses of renewable energy	*PJ*	149	405	478
		Solar thermal - Buildings	*PJ*	5	44	90
		Solar thermal - Industry	*PJ*	0	0	20
		Geothermal	*PJ*	3	18	18
		Bioenergy (traditional) - Buildings	*PJ*	0	0	0
		Bioenergy (modern) - Buildings	*PJ*	131	304	304
		Bioenergy - Industry	*PJ*	9	39	45
		Non-renewable - Buildings	*PJ*	1 317	1 000	949
		Non-renewable - Industry	*PJ*	700	736	690
		Non-renewable - BF/CO	*PJ*	0	0	0
	Transport	**Total fuel consumption**	*PJ*	**1 703**	**1 677**	**1 590**
		Liquid biofuels	*PJ*	55	105	255
		Conventional ethanol	*PJ*	0	14	54
		Advanced ethanol	*PJ*	0	25	64
		Biodiesel (conventional and advanced)	*PJ*	54	65	136
		Biomethane	*PJ*	0	0	8
		Non-renewable fuels	*PJ*	1 648	1 572	1 327
Total final energy consumption (electricity, DH, direct uses) [2]			*PJ*	**5 200**	**5 317**	**5 246**
RE shares		RE share in electricity generation		22%	38%	54%
		RE share in district heat generation		8%	19%	19%
		RE share in Buildings - final energy use, direct uses (modern)		10%	27%	30%
		RE share in Industry - final energy use, direct uses		1%	5%	9%
		RE share in Transport fuels		3%	6%	17%
		Share of modern RE in TFEC [3]		9%	20%	29%
Financial indicators		System costs [USD bln/yr. in 2030]		*N/A*	*N/A*	- 2
		RE investment needs [USD bln/yr. (2010-2030)]		*N/A*	5	9
		Investment support for renewables [USD bln/yr. in 2030]		*N/A*	*N/A*	1.8
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		*N/A*	*N/A*	10.0
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		*N/A*	*N/A*	2.9
		CO2 emissions from energy [Mt/yr.]		383	335	277









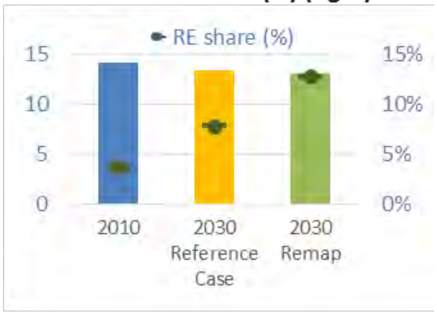
References for further consultation:

- Italy's National Energy Strategy, Italian Ministry for Economic Development (2010).
- Rapporto Energia E Ambiente, Scenari E Strategie, ENEA (2013).
- Italian National Renewable Energy Action Plan, Italian Ministry for Economic Development (2010).

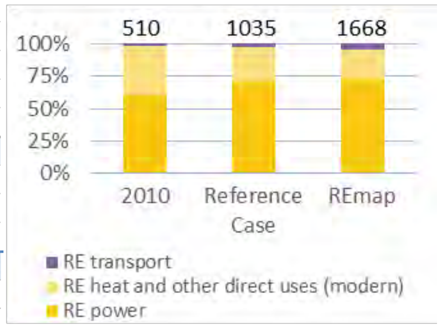
REmap Country Results – Japan

			Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	GW	**262**	**266**	**343**
		Renewable capacity	GW	31	105	207
		Hydropower (excl. pumped hydro)	GW	21	23	23
		Wind	GW	2	10	37
		Biofuels (solid, liquid, gaseous)	GW	3	7	7
		Solar PV	GW	4	64	136
		CSP	GW	0	0	0
		Geothermal	GW	1	2	2
		Marine, other	GW	0	0	2
		Non-renewable capacity	GW	231	161	136
		Total electricity generation	TWh	**1 159**	**1 057**	**1 102**
		Renewable generation	TWh	99	236	392
		Hydropower	TWh	76	88	90
		Wind	TWh	4	18	74
		Biofuels (solid, liquid, gaseous)	TWh	12	44	49
		Solar PV	TWh	4	75	165
		CSP	TWh	0	0	0
		Geothermal	TWh	3	11	11
		Marine, other	TWh	0	0	4
		Non-renewable generation	TWh	1 060	821	710
	DH	**Total district heat generation**	PJ	**21**	**20**	**20**
		Biofuels (solid, liquid, gaseous)	PJ	4	4	4
		Other renewables	PJ	0	0	0
		Non-renewable DH	PJ	17	16	16
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	PJ	**7 153**	**7 162**	**6 819**
		Direct uses of renewable energy	PJ	190	275	364
		Solar thermal - Buildings	PJ	18	21	52
		Solar thermal - Industry	PJ	0	0	50
		Geothermal	PJ	0	0	0
		Bioenergy (traditional) - Buildings	PJ	0	0	0
		Bioenergy (modern) - Buildings	PJ	0	0	0
		Bioenergy - Industry	PJ	172	254	261
		Non-renewable - Buildings	PJ	2 596	2 475	2 131
		Non-renewable - Industry	PJ	3 566	3 611	3 523
		Non-renewable - BF/CO	PJ	801	801	801
	Transport	**Total fuel consumption**	PJ	**3 363**	**2 927**	**2 818**
		Liquid biofuels	PJ	8	27	76
		Conventional ethanol	PJ	8	27	76
		Advanced ethanol	PJ	0	0	0
		Biodiesel (conventional and advanced)	PJ	0	0	0
		Biomethane	PJ	0	0	1
		Non-renewable fuels	PJ	3 355	2 900	2 741
Total final energy consumption (electricity, DH, direct uses) [2]			PJ	**14 132**	**13 381**	**13 093**
RE shares		RE share in electricity generation		9%	22%	36%
		RE share in district heat generation		20%	21%	21%
		RE share in Buildings - final energy use, direct uses (modern)		1%	1%	2%
		RE share in Industry - final energy use, direct uses		5%	7%	8%
		RE share in Transport fuels		0%	1%	3%
		Share of modern RE in TFEC [3]		4%	8%	13%
Financial indicators		System costs [USD bln/yr. in 2030]		N/A	N/A	5
		RE investment needs [USD bln/yr. (2010-2030)]		N/A	21	36
		Investment support for renewables [USD bln/yr. in 2030]		N/A	N/A	8.5
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		N/A	N/A	6.7
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		N/A	N/A	4.7
		CO2 emissions from energy [Mt/yr.]		1 192	1 053	960

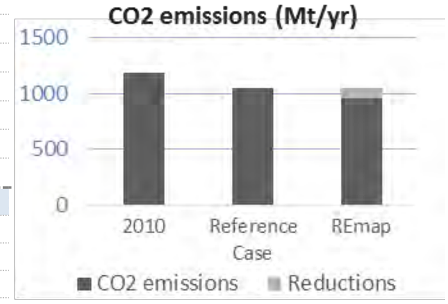
TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)



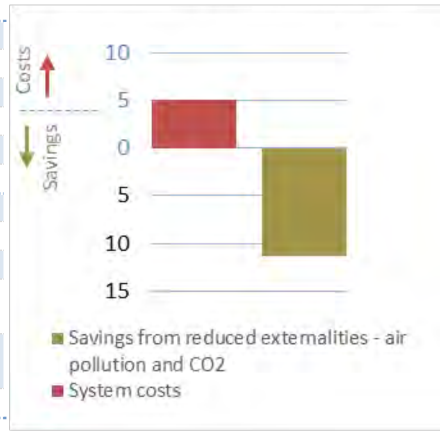
Final RE use by sector (%) and total (PJ/yr)



CO2 emissions (Mt/yr)



Costs and savings (USD bln in 2030)



References for further consultation:

- Long-term energy supply and demand outlook, METI (2015).
- Data Book on heat Pump & Thermal Storage System 2013, Heat Pump & Thermal Storage Technology Center of Japan (2013).
- FY 2013 Energy Supply and Demand Report, METI (2015).

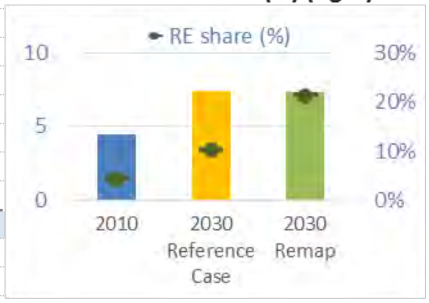
REmap
A Renewable Energy Roadmap

IRENA
International Renewable Energy Agency

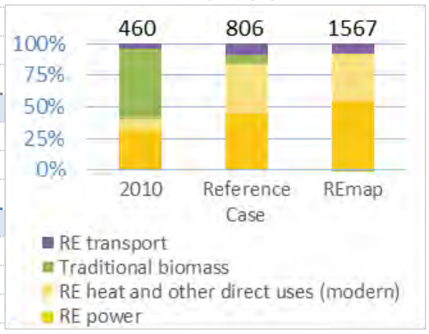
REmap Country Results – Mexico

			Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	GW	**53**	**118**	**155**
		Renewable capacity	GW	13	38	102
		Hydropower (excl. pumped hydro)	GW	12	19	24
		Wind	GW	0	11	29
		Biofuels (solid, liquid, gaseous)	GW	0	1	3
		Solar PV	GW	0	6	40
		CSP	GW	0	0	2
		Geothermal	GW	1	1	4
		Marine, other	GW	0	0	0
		Non-renewable capacity	GW	40	80	53
		Total electricity generation	TWh	**259**	**602**	**603**
		Renewable generation	TWh	48	116	280
		Hydropower	TWh	37	52	72
		Wind	TWh	1	38	92
		Biofuels (solid, liquid, gaseous)	TWh	3	4	15
		Solar PV	TWh	0	13	66
		CSP	TWh	0	0	4
		Geothermal	TWh	7	9	32
		Marine, other	TWh	0	0	0
		Non-renewable generation	TWh	211	486	324
	DH	**Total district heat generation**	PJ	**0**	**0**	**0**
		Biofuels (solid, liquid, gaseous)	PJ	0	0	0
		Other renewables	PJ	0	0	0
		Non-renewable DH	PJ	0	0	0
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	PJ	**1 491**	**2 133**	**2 109**
		Direct uses of renewable energy	PJ	302	375	583
		Solar thermal - Buildings	PJ	5	70	80
		Solar thermal - Industry	PJ	0	13	59
		Geothermal	PJ	0	0	14
		Bioenergy (traditional) - Buildings	PJ	259	51	0
		Bioenergy (modern) - Buildings	PJ	0	216	230
		Bioenergy - Industry	PJ	38	25	200
		Non-renewable - Buildings	PJ	402	590	583
		Non-renewable - Industry	PJ	788	1 168	943
		Non-renewable - BF/CO	PJ	0	0	0
	Transport	**Total fuel consumption**	PJ	**2 134**	**3 266**	**3 258**
		Liquid biofuels	PJ	17	75	128
		Conventional ethanol	PJ	17	53	70
		Advanced ethanol	PJ	0	0	17
		Biodiesel (conventional and advanced)	PJ	0	22	42
		Biomethane	PJ	0	0	0
		Non-renewable fuels	PJ	2 118	3 190	3 129
Total final energy consumption (electricity, DH, direct uses) [2]			PJ	**4 503**	**7 383**	**7 354**
RE shares		RE share in electricity generation		18%	19%	46%
		RE share in district heat generation		0%	0%	0%
		RE share in Buildings - final energy use, direct uses (modern)		1%	31%	35%
		RE share in Industry - final energy use, direct uses		5%	3%	22%
		RE share in Transport fuels		1%	2%	4%
		Share of modern RE in TFEC [3]		4%	10%	21%
Financial indicators		System costs [USD bln/yr. in 2030]		N/A	N/A	- 2
		RE investment needs [USD bln/yr. (2010-2030)]		N/A	3	10
		Investment support for renewables [USD bln/yr. in 2030]		N/A	N/A	2.2
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		N/A	N/A	2.4
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		N/A	N/A	5.2
		CO2 emissions from energy [Mt/yr.]		369	619	515

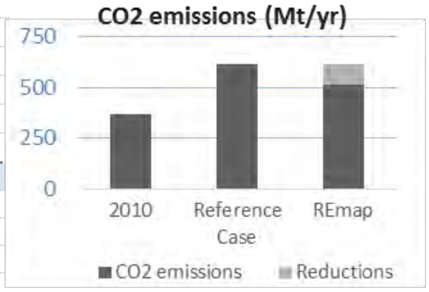
TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)



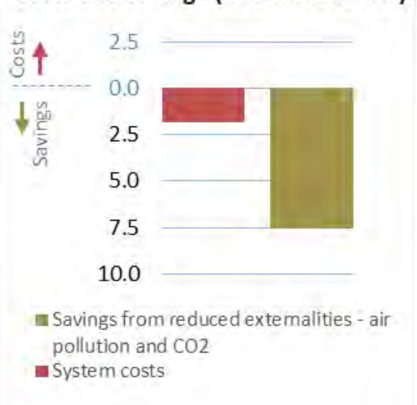
Final RE use by sector (%) and total (PJ/yr)



CO2 emissions (Mt/yr)



Costs and savings (USD bln in 2030)



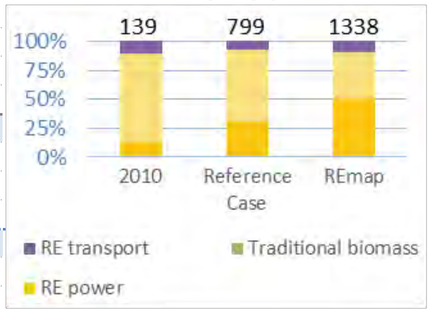
References for further consultation:
- Energy Demand and Supply Outlook 5th Edition, APEC (2014).
- Prospectiva de Energías Renovables 2012-2026 by the Mexican Energy Secretariat (SENER).

REmap Country Results – Republic of Korea

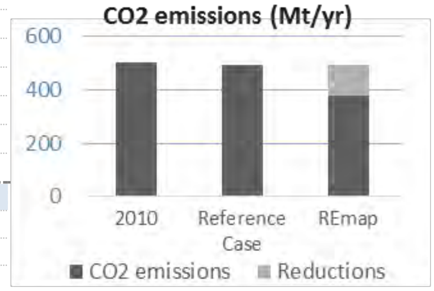
			Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	GW	**73**	**138**	**181**
		Renewable capacity	GW	7	41	101
		Hydropower (excl. pumped hydro)	GW	6	7	7
		Wind	GW	0	13	27
		Biofuels (solid, liquid, gaseous)	GW	0	5	5
		Solar PV	GW	1	17	61
		CSP	GW	0	0	0
		Geothermal	GW	0	0	0
		Marine, other	GW	0	0	1
		Non-renewable capacity	GW	67	97	79
		Total electricity generation	TWh	**480**	**738**	**748**
		Renewable generation	TWh	6	76	207
		Hydropower	TWh	4	5	5
		Wind	TWh	1	27	89
		Biofuels (solid, liquid, gaseous)	TWh	1	23	23
		Solar PV	TWh	1	20	82
		CSP	TWh	0	0	0
		Geothermal	TWh	0	0	3
		Marine, other	TWh	0	2	6
		Non-renewable generation	TWh	475	662	541
	DH	**Total district heat generation**	PJ	**172**	**305**	**305**
		Biofuels (solid, liquid, gaseous)	PJ	20	22	22
		Other renewables	PJ	0	20	20
		Non-renewable DH	PJ	152	263	263
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	PJ	**2 526**	**2 889**	**2 809**
		Direct uses of renewable energy	PJ	97	477	517
		Solar thermal - Buildings	PJ	1	57	57
		Solar thermal - Industry	PJ	0	19	38
		Geothermal	PJ	2	85	107
		Bioenergy (traditional) - Buildings	PJ	0	0	0
		Bioenergy (modern) - Buildings	PJ	3	11	11
		Bioenergy - Industry	PJ	91	306	306
		Non-renewable - Buildings	PJ	831	912	843
		Non-renewable - Industry	PJ	1 136	1 037	987
		Non-renewable - BF/CO	PJ	462	462	462
	Transport	**Total fuel consumption**	PJ	**1 539**	**1 436**	**1 409**
		Liquid biofuels	PJ	15	59	132
		Conventional ethanol	PJ	1	0	13
		Advanced ethanol	PJ	0	0	0
		Biodiesel (conventional and advanced)	PJ	14	59	119
		Biomethane	PJ	0	0	0
		Non-renewable fuels	PJ	1 524	1 378	1 277
Total final energy consumption (electricity, DH, direct uses) [2]			PJ	**5 787**	**6 910**	**6 839**
RE shares		RE share in electricity generation		1%	10%	28%
		RE share in district heat generation		11%	14%	14%
		RE share in Buildings - final energy use, direct uses (modern)		1%	13%	13%
		RE share in Industry - final energy use, direct uses		7%	25%	28%
		RE share in Transport fuels		1%	4%	9%
		Share of modern RE in TFEC [3]		3%	12%	20%
Financial indicators		System costs [USD bln/yr. in 2030]		N/A	N/A	0
		RE investment needs [USD bln/yr. (2010-2030)]		N/A	6	14
		Investment support for renewables [USD bln/yr. in 2030]		N/A	N/A	2.3
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		N/A	N/A	4.9
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		N/A	N/A	5.7
		CO2 emissions from energy [Mt/yr.]		504	493	378

TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)

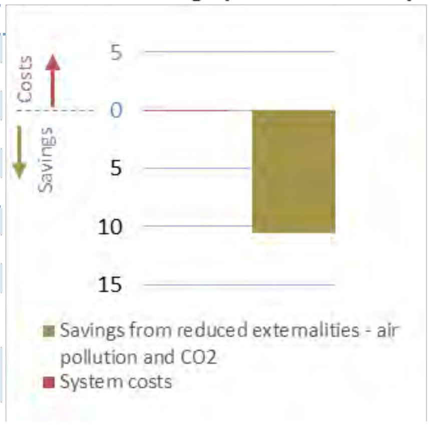
Final RE use by sector (%) and total (PJ/yr)



CO2 emissions (Mt/yr)



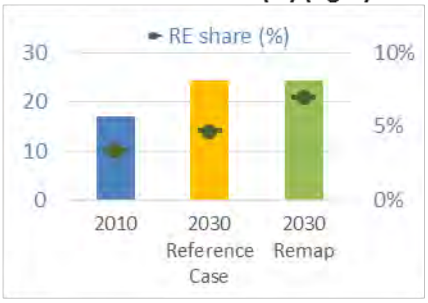
Costs and savings (USD bln in 2030)



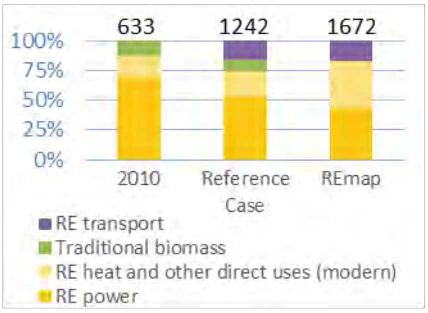
REmap Country Results – Russian Federation

Category	Sector	Item	Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	*GW*	**231**	**285**	**294**
		Renewable capacity	*GW*	47	66	76
		Hydropower (excl. pumped hydro)	*GW*	47	58	58
		Wind	*GW*	0	4	5
		Biofuels (solid, liquid, gaseous)	*GW*	0	2	7
		Solar PV	*GW*	0	2	5
		CSP	*GW*	0	0	0
		Geothermal	*GW*	0	0	1
		Marine, other	*GW*	0	0	0
		Non-renewable capacity	*GW*	183	220	218
		Total electricity generation	*TWh*	**1 036**	**1 352**	**1 379**
		Renewable generation	*TWh*	170	243	276
		Hydropower	*TWh*	166	227	227
		Wind	*TWh*	0	8	11
		Biofuels (solid, liquid, gaseous)	*TWh*	3	6	28
		Solar PV	*TWh*	0	2	5
		CSP	*TWh*	0	0	0
		Geothermal	*TWh*	1	1	6
		Marine, other	*TWh*	0	0	0
		Non-renewable generation	*TWh*	866	1 109	1 103
	DH	**Total district heat generation**	*PJ*	**5 674**	**7 305**	**7 305**
		Biofuels (solid, liquid, gaseous)	*PJ*	120	162	395
		Other renewables	*PJ*	0	0	0
		Non-renewable DH	*PJ*	5 554	7 143	6 910
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	*PJ*	**5 426**	**8 807**	**8 782**
		Direct uses of renewable energy	*PJ*	91	248	318
		Solar thermal - Buildings	*PJ*	0	0	0
		Solar thermal - Industry	*PJ*	0	0	0
		Geothermal	*PJ*	0	0	0
		Bioenergy (traditional) - Buildings	*PJ*	76	120	0
		Bioenergy (modern) - Buildings	*PJ*	0	0	190
		Bioenergy - Industry	*PJ*	15	128	128
		Non-renewable - Buildings	*PJ*	2 255	3 034	2 939
		Non-renewable - Industry	*PJ*	2 233	3 386	3 386
		Non-renewable - BF/CO	*PJ*	846	2 138	2 138
	Transport	**Total fuel consumption**	*PJ*	**3 733**	**5 401**	**5 400**
		Liquid biofuels	*PJ*	0	200	288
		Conventional ethanol	*PJ*	0	200	200
		Advanced ethanol	*PJ*	0	0	0
		Biodiesel (conventional and advanced)	*PJ*	0	0	88
		Biomethane	*PJ*	0	0	0
		Non-renewable fuels	*PJ*	3 733	5 201	5 112
Total final energy consumption (electricity, DH, direct uses) [2]			*PJ*	**16 932**	**24 336**	**24 311**
RE shares		RE share in electricity generation		16%	18%	20%
		RE share in district heat generation		2%	2%	5%
		RE share in Buildings - final energy use, direct uses (modern)		0%	0%	6%
		RE share in Industry - final energy use, direct uses		1%	4%	4%
		RE share in Transport fuels		0%	4%	5%
		Share of modern RE in TFEC [3]		3%	5%	7%
Financial indicators		System costs [USD bln/yr. in 2030]		*N/A*	*N/A*	- 1
		RE investment needs [USD bln/yr. (2010-2030)]		*N/A*	13	14
		Investment support for renewables [USD bln/yr. in 2030]		*N/A*	*N/A*	2.2
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		*N/A*	*N/A*	1.5
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		*N/A*	*N/A*	1.7
		CO2 emissions from energy [Mt/yr.]		1 384	1 843	1 810

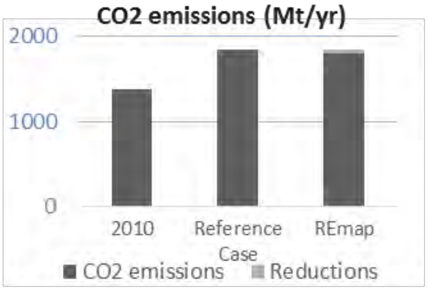
TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)



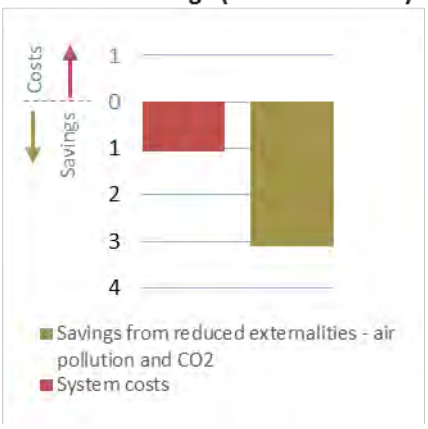
Final RE use by sector (%) and total (PJ/yr)



CO2 emissions (Mt/yr)



Costs and savings (USD bln in 2030)



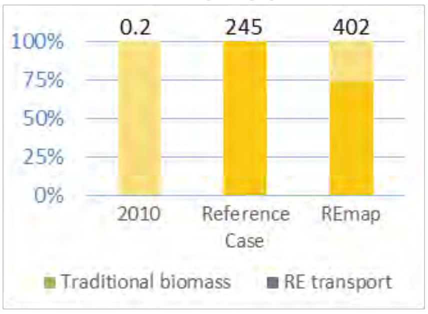
References for further consultation:
- Energy Strategy of Russia for the period up to 2035, Ministry of Energy of the Russian Federation (2010).
- Draft results of the Energy Strategy of Russia for the period up to 2030 (2016).

REmap Country Results – Saudi Arabia

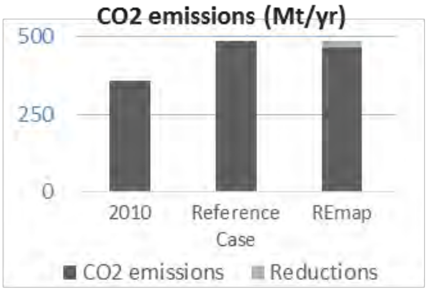
	Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity – Power sector				
Total installed power generation capacity	GW	**55**	**137**	**140**
Renewable capacity	GW	0	27	37
Hydropower (excl. pumped hydro)	GW	0	0	0
Wind	GW	0	5	5
Biofuels (solid, liquid, gaseous)	GW	0	2	2
Solar PV	GW	0	8	16
CSP	GW	0	13	14
Geothermal	GW	0	1	1
Marine, other	GW	0	0	0
Non-renewable capacity	GW	55	110	104
Total electricity generation	TWh	**240**	**601**	**601**
Renewable generation	TWh	0	85	106
Hydropower	TWh	0	0	0
Wind	TWh	0	15	16
Biofuels (solid, liquid, gaseous)	TWh	0	11	12
Solar PV	TWh	0	14	28
CSP	TWh	0	42	46
Geothermal	TWh	0	4	4
Marine, other	TWh	0	0	0
Non-renewable generation	TWh	240	516	495
Energy generation and capacity – DH				
Total district heat generation	PJ	**0**	**0**	**0**
Biofuels (solid, liquid, gaseous)	PJ	0	0	0
Other renewables	PJ	0	0	0
Non-renewable DH	PJ	0	0	0
Final energy use - direct uses [1] – Buildings and Industry				
Total direct uses of energy	PJ	**824**	**1 020**	**1 073**
Direct uses of renewable energy	PJ	0	0	107
Solar thermal - Buildings	PJ	0	0	59
Solar thermal - Industry	PJ	0	0	38
Geothermal	PJ	0	0	10
Bioenergy (traditional) - Buildings	PJ	0	0	0
Bioenergy (modern) - Buildings	PJ	0	0	0
Bioenergy - Industry	PJ	0	0	0
Non-renewable - Buildings	PJ	63	69	69
Non-renewable - Industry	PJ	761	951	897
Non-renewable - BF/CO	PJ	0	0	0
Final energy use - direct uses [1] – Transport				
Total fuel consumption	PJ	**1 476**	**2 629**	**2 594**
Liquid biofuels	PJ	0	0	0
Conventional ethanol	PJ	0	0	0
Advanced ethanol	PJ	0	0	0
Biodiesel (conventional and advanced)	PJ	0	0	0
Biomethane	PJ	0	0	0
Non-renewable fuels	PJ	1 476	2 629	2 594
Total final energy consumption (electricity, DH, direct uses) [2]	**PJ**	**2 990**	**5 376**	**5 332**
RE shares				
RE share in electricity generation		0%	14%	18%
RE share in district heat generation		0%	0%	0%
RE share in Buildings - final energy use, direct uses (modern)		0%	0%	46%
RE share in Industry - final energy use, direct uses		0%	0%	5%
RE share in Transport fuels		0%	0%	0%
Share of modern RE in TFEC [3]		0%	5%	8%
Financial indicators				
System costs [USD bln/yr. in 2030]		N/A	N/A	- 8
RE investment needs [USD bln/yr. (2010-2030)]		N/A	4	6
Investment support for renewables [USD bln/yr. in 2030]		N/A	N/A	0.3
Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		N/A	N/A	4.3
Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		N/A	N/A	1.1
CO2 emissions from energy [Mt/yr.]		360	488	465

TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)

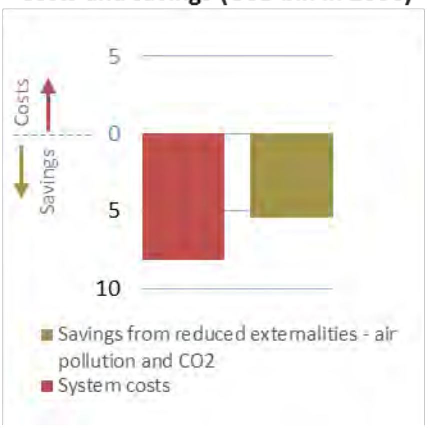
Final RE use by sector (%) and total (PJ/yr)



CO2 emissions (Mt/yr)



Costs and savings (USD bln in 2030)



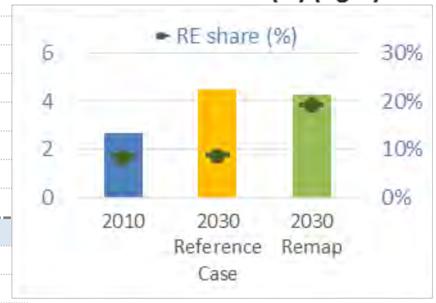
References for further consultation:

- Saudi Arabia's Renewable Energy Strategy and Solar Energy Deployment Roadmap, KACARE (2013).
- Geothermal Development Roadmap for the Kingdom of Saudi Arabia, Hashem (2012).
- Prospects of Renewable Energy to Promoto Zero-Energy Residential Buildings in the KSA, Alrashed and Asif

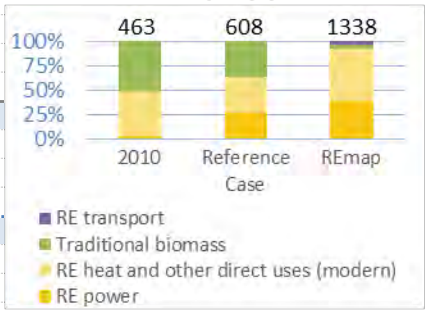
REmap Country Results – South Africa

Section	Sector	Indicator	Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	GW	**37**	**75**	**92**
		Renewable capacity	GW	1	19	43
		Hydropower (excl. pumped hydro)	GW	1	1	1
		Wind	GW	0	4	8
		Biofuels (solid, liquid, gaseous)	GW	0	1	3
		Solar PV	GW	0	10	25
		CSP	GW	0	3	5
		Geothermal	GW	0	0	0
		Marine, other	GW	0	0	0
		Non-renewable capacity	GW	36	57	50
		Total electricity generation	TWh	**259**	**438**	**440**
		Renewable generation	TWh	4	48	98
		Hydropower	TWh	4	4	4
		Wind	TWh	0	11	22
		Biofuels (solid, liquid, gaseous)	TWh	0	5	16
		Solar PV	TWh	0	17	39
		CSP	TWh	0	11	18
		Geothermal	TWh	0	0	0
		Marine, other	TWh	0	0	0
		Non-renewable generation	TWh	255	390	341
	DH	**Total district heat generation**	PJ	**0**	**0**	**0**
		Biofuels (solid, liquid, gaseous)	PJ	0	0	0
		Other renewables	PJ	0	0	0
		Non-renewable DH	PJ	0	0	0
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	PJ	**1 189**	**1 427**	**1 277**
		Direct uses of renewable energy	PJ	451	445	487
		Solar thermal - Buildings	PJ	3	4	75
		Solar thermal - Industry	PJ	0	0	26
		Geothermal (Buildings and Industry)	PJ	0	0	0
		Bioenergy (traditional) - Buildings	PJ	237	219	33
		Bioenergy (modern) - Buildings	PJ	133	123	170
		Bioenergy - Industry	PJ	78	99	184
		Non-renewable - Buildings	PJ	175	153	70
		Non-renewable - Industry	PJ	587	829	720
		Non-renewable - BF/CO	PJ	- 24	0	0
	Transport	**Total fuel consumption**	PJ	**740**	**1 524**	**1 497**
		Liquid biofuels	PJ	0	0	31
		Conventional ethanol	PJ	0	0	16
		Advanced ethanol	PJ	0	0	0
		Biodiesel (conventional and advanced)	PJ	0	0	15
		Biomethane	PJ	0	0	0
		Non-renewable fuels	PJ	740	1 524	1 466
Total finale energy consumption (electricity, DH, direct uses) [2]			PJ	**2 682**	**4 490**	**4 239**
RE shares		RE share in electricity generation		2%	11%	22%
		RE share in district heat generation		N/A	N/A	N/A
		RE share in Buildings - final energy use, direct uses (modern)		25%	25%	70%
		RE share in Industry - final energy use, direct uses		12%	11%	23%
		RE share in Transport fuels		0%	0%	2%
		Share of modern RE in TFEC [3]		8%	9%	19%
Financial indicators		System costs [USD bln/yr. in 2030]		N/A	N/A	0
		RE investment needs [USD bln/yr. (2010-2030)]		N/A	2	5
		Investment support for renewables [USD bln/yr. in 2030]		N/A	N/A	3.5
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		N/A	N/A	16.6
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		N/A	N/A	3.1
		CO2 emissions from energy [Mt/yr.]		361	509	447

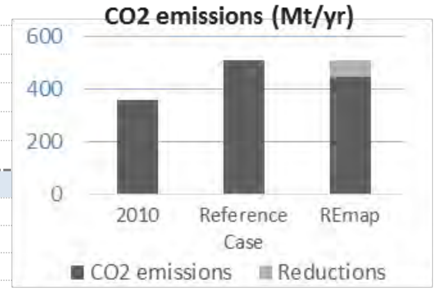
TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)



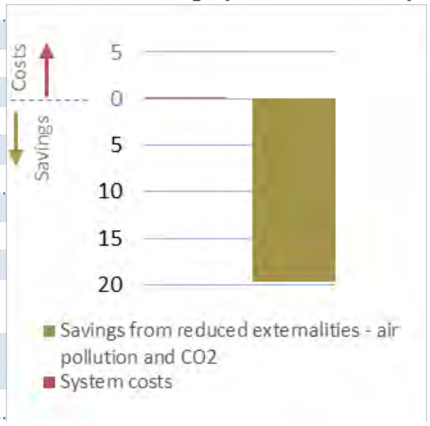
Final RE use by sector (%) and total (PJ/yr)



CO2 emissions (Mt/yr)



Costs and savings (USD bln in 2030)



References for further consultation:

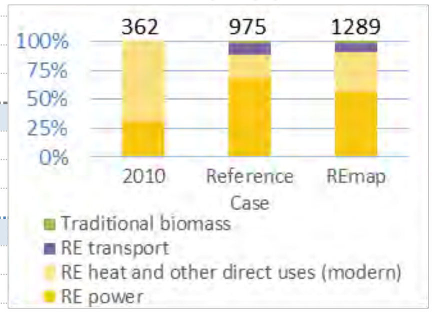
- Draft 2012 on Integrated Energy Planning (2012).
- IRP 2010-2030, update report, DOE (2013).

REmap Country Results – Turkey

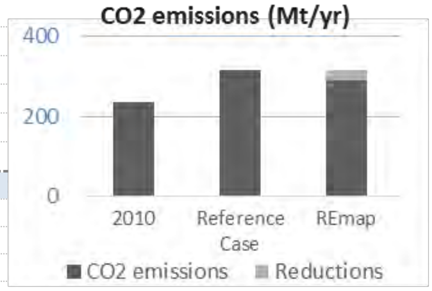
			Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	*GW*	**45**	**144**	**146**
		Renewable capacity	*GW*	16	89	95
		Hydropower (excl. pumped hydro)	*GW*	15	44	44
		Wind	*GW*	1	33	33
		Biofuels (solid, liquid, gaseous)	*GW*	0	1	4
		Solar PV	*GW*	0	9	11
		CSP	*GW*	0	0	0
		Geothermal	*GW*	0	1	3
		Marine, other	*GW*	0	0	0
		Non-renewable capacity	*GW*	29	55	51
		Total electricity generation	*TWh*	**187**	**543**	**544**
		Renewable generation	*TWh*	38	229	251
		Hydropower	*TWh*	36	119	119
		Wind	*TWh*	1	82	82
		Biofuels (solid, liquid, gaseous)	*TWh*	0	7	18
		Solar PV	*TWh*	0	14	18
		CSP	*TWh*	0	0	0
		Geothermal	*TWh*	0	8	13
		Marine, other	*TWh*	0	0	0
		Non-renewable generation	*TWh*	149	313	293
	DH	**Total district heat generation**	*PJ*	**0**	**0**	**0**
		Biofuels (solid, liquid, gaseous)	*PJ*	0	0	0
		Other renewables	*PJ*	0	0	0
		Non-renewable DH	*PJ*	0	0	0
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	*PJ*	**1 456**	**1 598**	**1 630**
		Direct uses of renewable energy	*PJ*	252	210	461
		Solar thermal - Buildings	*PJ*	13	37	54
		Solar thermal - Industry	*PJ*	5	0	23
		Geothermal	*PJ*	40	24	102
		Bioenergy (traditional) - Buildings	*PJ*	0	16	16
		Bioenergy (modern) - Buildings	*PJ*	192	124	244
		Bioenergy - Industry	*PJ*	2	8	23
		Non-renewable - Buildings	*PJ*	620	712	548
		Non-renewable - Industry	*PJ*	488	573	518
		Non-renewable - BF/CO	*PJ*	96	103	103
	Transport	**Total fuel consumption**	*PJ*	**623**	**1 220**	**1 205**
		Liquid biofuels	*PJ*	0	100	100
		Conventional ethanol	*PJ*	0	9	9
		Advanced ethanol	*PJ*	0	0	0
		Biodiesel (conventional and advanced)	*PJ*	0	91	91
		Biomethane	*PJ*	0	0	0
		Non-renewable fuels	*PJ*	623	1 120	1 105
Total final energy consumption (electricity, DH, direct uses) [2]			*PJ*	**2 663**	**4 441**	**4 463**
RE shares		RE share in electricity generation		20%	42%	46%
		RE share in district heat generation		0%	0%	0%
		RE share in Buildings - final energy use, direct uses (modern)		28%	20%	41%
		RE share in Industry - final energy use, direct uses		2%	1%	11%
		RE share in Transport fuels		0%	8%	8%
		Share of modern RE in TFEC [3]		14%	22%	29%
Financial indicators		System costs [USD bln/yr. in 2030]		*N/A*	*N/A*	0
		RE investment needs [USD bln/yr. (2010-2030)]		*N/A*	10	12
		Investment support for renewables [USD bln/yr. in 2030]		*N/A*	*N/A*	1.4
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		*N/A*	*N/A*	4.3
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		*N/A*	*N/A*	1.3
		CO2 emissions from energy [Mt/yr.]		235	316	290

TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)

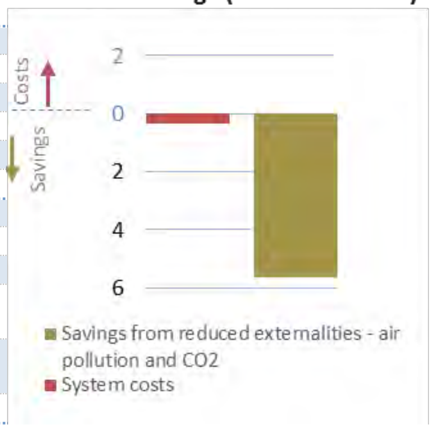
Final RE use by sector (%) and total (PJ/yr)



CO2 emissions (Mt/yr)



Costs and savings (USD bln in 2030)



References for further consultation:

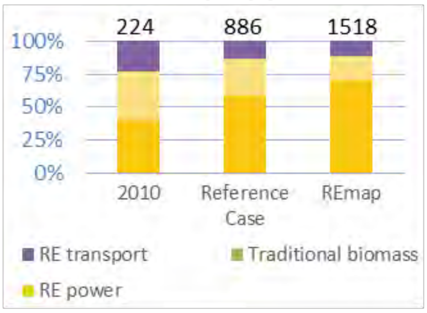
- National Renewable Energy Action Plan for Turkey, Ministry of Energy and Natural Resources (2014).

REmap Country Results – United Kingdom

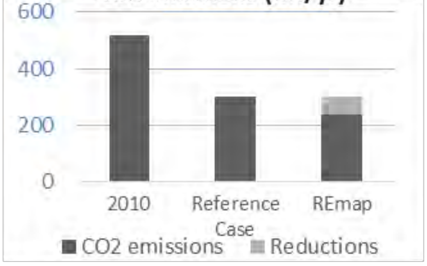
Category	Sector	Item	Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	GW	**91**	**109**	**141**
		Renewable capacity	GW	9	50	98
		Hydropower (excl. pumped hydro)	GW	2	2	4
		Wind	GW	5	27	60
		Biofuels (solid, liquid, gaseous)	GW	2	6	6
		Solar PV	GW	0	16	24
		CSP	GW	0	0	0
		Geothermal	GW	0	0	3
		Marine, other	GW	0	0	1
		Non-renewable capacity	GW	82	58	43
		Total electricity generation	TWh	**366**	**346**	**397**
		Renewable generation	TWh	28	142	298
		Hydropower	TWh	5	6	14
		Wind	TWh	11	82	195
		Biofuels (solid, liquid, gaseous)	TWh	12	39	39
		Solar PV	TWh	0	15	25
		CSP	TWh	0	0	0
		Geothermal	TWh	0	0	19
		Marine, other	TWh	0	0	4
		Non-renewable generation	TWh	338	203	99
	DH	**Total district heat generation**	PJ	**231**	**165**	**165**
		Biofuels (solid, liquid, gaseous)	PJ	8	25	48
		Other renewables	PJ	0	0	0
		Non-renewable DH	PJ	224	140	117
Final energy use - direct uses [1]	Buildings and Industry	**Total direct uses of energy**	PJ	**2 976**	**2 418**	**1 881**
		Direct uses of renewable energy	PJ	82	246	281
		Solar thermal - Buildings	PJ	0	0	23
		Solar thermal - Industry	PJ	0	0	3
		Geothermal	PJ	0	0	0
		Bioenergy (traditional) - Buildings	PJ	0	0	0
		Bioenergy (modern) - Buildings	PJ	61	133	133
		Bioenergy - Industry	PJ	20	114	122
		Non-renewable - Buildings	PJ	2 059	1 593	1 034
		Non-renewable - Industry	PJ	726	480	467
		Non-renewable - BF/CO	PJ	110	99	99
	Transport	**Total fuel consumption**	PJ	**1 753**	**1 605**	**1 514**
		Liquid biofuels	PJ	52	119	165
		Conventional ethanol	PJ	17	90	100
		Advanced ethanol	PJ	0	1	36
		Biodiesel (conventional and advanced)	PJ	34	29	29
		Biomethane	PJ	0	0	0
		Non-renewable fuels	PJ	1 701	1 485	1 349
Total final energy consumption (electricity, DH, direct uses) [2]			PJ	**5 936**	**5 330**	**4 871**
RE shares		RE share in electricity generation		8%	41%	75%
		RE share in district heat generation		3%	15%	29%
		RE share in Buildings - final energy use, direct uses (modern)		3%	8%	13%
		RE share in Industry - final energy use, direct uses		3%	19%	21%
		RE share in Transport fuels		3%	7%	11%
		Share of modern RE in TFEC [3]		4%	17%	32%
Financial indicators		System costs [USD bln/yr. in 2030]		N/A	N/A	- 3
		RE investment needs [USD bln/yr. (2010-2030)]		N/A	7	16
		Investment support for renewables [USD bln/yr. in 2030]		N/A	N/A	1.6
		Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		N/A	N/A	2.0
		Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		N/A	N/A	3.2
		CO2 emissions from energy [Mt/yr.]		516	300	237

TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)

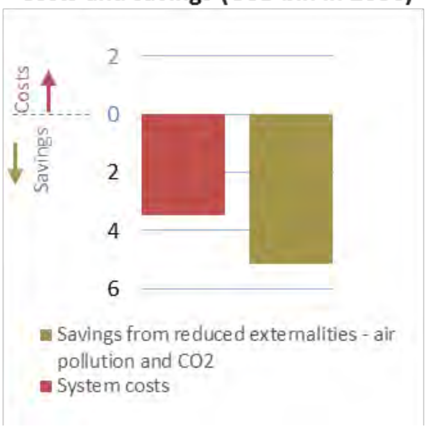
Final RE use by sector (%) and total (PJ/yr)



CO2 emissions (Mt/yr)



Costs and savings (USD bln in 2030)



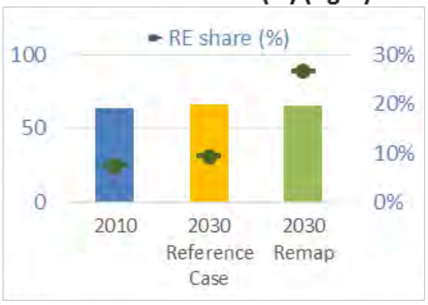
References for further consultation:

- 2015 energy and emissions projections: projections of greenhouse gas emissions and energy demand from 2015 to 2035, DECC (2015).
- Delivering UK Energy Investment, DECC (2014).
- UK Renewable Energy Roadmap Update 2013, DECC (2013).

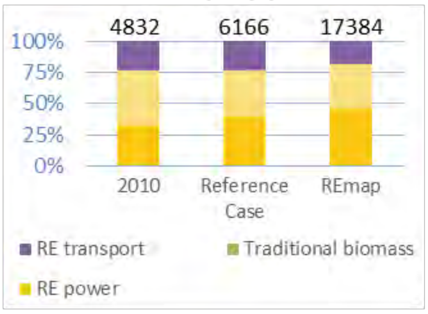
REmap Country Results – United States

	Unit	2010	Reference Case 2030	REmap 2030
Energy generation and capacity – Power sector				
Total installed power generation capacity	*GW*	**983**	**1 106**	**1 435**
Renewable capacity	*GW*	133	227	792
Hydropower (excl. pumped hydro)	*GW*	78	80	115
Wind	*GW*	39	87	343
Biofuels (solid, liquid, gaseous)	*GW*	10	13	66
Solar PV	*GW*	2	37	237
CSP	*GW*	1	2	6
Geothermal	*GW*	2	7	25
Marine, other	*GW*	0	0	0
Non-renewable capacity	*GW*	850	880	643
Total electricity generation	*TWh*	**4 129**	**4 679**	**4 887**
Renewable generation	*TWh*	470	756	2 450
Hydropower	*TWh*	260	295	429
Wind	*TWh*	96	245	1 099
Biofuels (solid, liquid, gaseous)	*TWh*	95	94	348
Solar PV	*TWh*	4	68	368
CSP	*TWh*	1	3	16
Geothermal	*TWh*	15	52	189
Marine, other	*TWh*	0	0	0
Non-renewable generation	*TWh*	3 659	3 923	2 437
Energy generation and capacity – DH				
Total district heat generation	*PJ*	**455**	**516**	**516**
Biofuels (solid, liquid, gaseous)	*PJ*	91	154	154
Other renewables	*PJ*	0	0	0
Non-renewable DH	*PJ*	363	363	363
Final energy use - direct uses [1] – Buildings and Industry				
Total direct uses of energy	*PJ*	**23 098**	**24 802**	**23 763**
Direct uses of renewable energy	*PJ*	2 114	2 228	6 065
Solar thermal - Buildings	*PJ*	96	113	692
Solar thermal - Industry	*PJ*	0	0	241
Geothermal	*PJ*	11	29	59
Bioenergy (traditional) - Buildings	*PJ*	0	0	0
Bioenergy (modern) - Buildings	*PJ*	550	501	704
Bioenergy - Industry	*PJ*	1 456	1 585	4 370
Non-renewable - Buildings	*PJ*	9 556	8 789	6 644
Non-renewable - Industry	*PJ*	11 090	13 481	10 750
Non-renewable - BF/CO	*PJ*	339	304	304
Final energy use - direct uses [1] – Transport				
Total fuel consumption	*PJ*	**27 264**	**26 196**	**25 462**
Liquid biofuels	*PJ*	1 125	1 422	2 965
Conventional ethanol	*PJ*	1 060	1 227	1 465
Advanced ethanol	*PJ*	0	44	1 350
Biodiesel (conventional and advanced)	*PJ*	65	150	150
Biomethane	*PJ*	0	0	261
Non-renewable fuels	*PJ*	26 139	24 775	22 236
Total final energy consumption (electricity, DH, direct uses) [2]	*PJ*	**64 150**	**66 370**	**65 462**
RE shares				
RE share in electricity generation		11%	16%	50%
RE share in district heat generation		20%	30%	30%
RE share in Buildings - final energy use, direct uses (modern)		6%	7%	18%
RE share in Industry - final energy use, direct uses		12%	11%	30%
RE share in Transport fuels		4%	5%	12%
Share of modern RE in TFEC[3]		8%	9%	27%
Financial indicators				
System costs [USD bln/yr. in 2030]		*N/A*	*N/A*	20
RE investment needs [USD bln/yr. (2010-2030)]		*N/A*	13	96
Investment support for renewables [USD bln/yr. in 2030]		*N/A*	*N/A*	41.5
Savings from reduced externalities - air pollution (average) [USD bln/yr. in 2030]		*N/A*	*N/A*	73.3
Savings from reduced externalities - CO_2 (USD 50/tonne CO2) [USD bln/yr. in 2030]		*N/A*	*N/A*	86.3
CO2 emissions from energy [Mt/yr.]		5 662	5 532	3 805

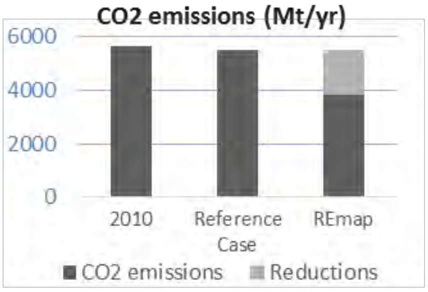
TFEC (EJ/yr) (left) and share of modern RE in TFEC (%) (right)



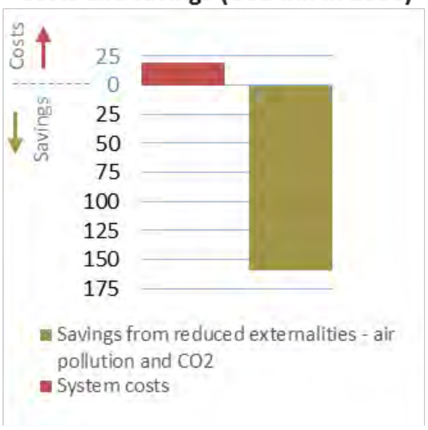
Final RE use by sector (%) and total (PJ/yr)



CO2 emissions (Mt/yr)



Costs and savings (USD bln in 2030)



References for further consultation:

- Annual Energy Outlook 2015, US Energy Information Agency (2015).
- Clean Power Plan, US Environmental Protection Agency (2015).
- Transportation Energy Futures, National Renewable Energy Laboratory (2014).
- Renewable Electricity Futures Study, National Renewable Energy Laboratory (2012).

NOTES:

[1] Final energy use/consumption from direct uses excludes electricity and district heat consumption.

[2] TFEC is the energy delivered to consumers, whether as electricity, heat or fuels that can be used directly as a source of energy. This consumption is usually sub-divided into that used in: transport; industry; residential, commercial and public buildings; and agriculture; and it excludes non-energy uses of fuels.

[3] Modern renewable energy (RE) excludes traditional uses of bioenergy (in countries that use traditional bioenergy); the share of modern RE in TFEC is equal to total modern RE consumption in end-use sectors (including consumption of renewable electricity and district heat and direct uses of renewables), divided by TFEC.

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