IRENA
International Renewable Energy Agency

REmap 2030

A Renewable Energy Roadmap

Summary of findings

June 2014

This report was first published in January 2014 as the first release of findings from REmap 2030. Some of the contents and data are updated in the current edition, (particularly on pages 25-28, including in Figure 7, and on pages 38-39, including in Table 3).

About IRENA

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

The full REmap 2030 report, this summary of findings and other supporting material are available for download through www.irena.org/remap

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

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REmap 2030

A Renewable Energy Roadmap

Foreword

In 2011, the United Nations Secretary-General launched the Sustainable Energy for All (SE4ALL) initiative with three interlinked objectives to be achieved by 2030: ensure universal access to modern energy services; double the global rate of improvement in energy efficiency; and double the share of renewable energy in the global energy mix. IRENA joined this global effort and took the lead as the SE4ALL Hub for Renewable Energy. REmap 2030 is IRENA's solution for how we can work together to double the share of renewable energy in the global energy mix. This report is a summary of the first-ever global roadmap to meet this challenge.

REmap 2030 is both a call to action and a remarkable piece of good news. The good news is that the technology already exists to achieve that aspirational goal by 2030, and even to surpass it. Strikingly, taking external costs into account, the transition to renewables can be cost-neutral.

The call to action is this: unless countries take the necessary measures now, we will miss the goal by a considerable margin. If we continue with business as usual, under the policies currently in place, the world will increase the share of renewable energy from 18 percent today to only 21 percent, instead of a potential 36 percent or more.

REmap 2030 represents an unprecedented international effort that brings together the work of 82 national experts from 42 countries, who collaborated through a year-long programme of global webinars, regional meetings, and national workshops involving technology experts, industry bodies and policy makers. Its findings are clear. Compared to energy systems based on fossil fuel, renewable energy offers broader participation, is better for our health, creates more jobs and provides an effective route to reducing carbon emission – a goal that becomes increasingly urgent by the day. Many renewable energy technologies already provide the most cost-effective option for delivery of energy services, with innovation and increasing deployment continuing to drive costs down.

But amid these advances, there are still misconceptions on the positive impact that renewable energy has to offer in a global drive for a sustainable and inclusive growth. Policy makers are insufficiently aware of the challenges and opportunities that lie before them, and national electorates cannot easily obtain objective and transparent information. REmap 2030 aims to contribute to remedying these shortfalls.

Of course, there is no-one-size-fits-all solution. Every country is different, and each will need to take a different path. REmap 2030 is an invitation to countries to forge the renewable energy future most appropriate to their circumstances, informed by the most comprehensive and transparent data available. It is also a living document. This summary will be supplemented by a more comprehensive report, followed by a series of country and issue-specific studies. This updated summary supplements the release of a more comprehensive report, to be followed by a series of country and issue-specific studies.

But at its heart, REmap 2030 offers a simple choice. Take the necessary action now and build a healthy, prosperous and environmentally sustainable future through renewable energy, or carry on as usual and see our hopes for a future built on a sustainable energy system recede a long way into the future. To me, this is no choice at all. Renewable energy is not an option. It is a necessity. REmap offers a pathway to make it happen.

Adnan Z. Amin
Director-General
International Renewable Energy Agency

Message from Sustainable Energy for All

When the United Nations Secretary-General launched the Sustainable Energy for All initiative in 2011, he sent a message to the world: to achieve sustainable, equitable progress, we have to change the way we power our societies. Along with ensuring universal access to modern energy services and improving energy efficiency, we need to double the share of renewable energy in the global energy mix by 2030.

Achieving sustainable energy for all requires an investment in our collective future, which must be fully integrated in the post-2015 development agenda. In 2014, the Intergovernmental Panel on Climate Change has added new urgency to the Secretary-General's call. As the panel's report clearly shows, a global shift to clean energy, with energy efficiency and renewable energy at the center, offers us the best option for the protection of the world's climate.

The launch of REmap 2030, therefore, could not be more timely. The first global roadmap of its kind, based on an unprecedented analysis of the 26 most important energy markets, it shows not only what we must do, but how we can do it. At its heart lies a remarkable finding: not only is it possible to double the global share of renewable energy by 2030, but it is possible to do so more cheaply than the alternatives. In other words, one of the key solutions to the greatest challenge of our era – climate change – is also the most cost-effective option.

REmap 2030 also shows how the other major objectives of Sustainable Energy for All – ensuring universal access to modern energy services and doubling the global rate of improvement in energy efficiency – are furthered by this push toward renewable energy. It provides a pathway for hundreds of millions of people currently left off the grid to benefit from clean, healthful, locally produced power, and it demonstrates the powerful symbiotic relationship between renewable energy and energy efficiency, in which progress in one fosters progress in the other.

Our challenge is to ensure that these messages find the widest possible audience. REmap 2030 needs to be seen not only by international policy makers and climate scientists, but also by financiers and entrepreneurs, industry leaders and venture capitalists. Its message is clear: the world stands poised at the dawn of a new industrial revolution – one that can be powered by clean, healthful energy sources that will never run out. Let us grasp this opportunity with enthusiasm to build a better world.

Kandeh Yumkella
Special Representative of the
Secretary-General of the United Nations
and CEO, Sustainable Energy for All

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Australia: Helen Bennett, Shari Lapthorne, Arif Sayed, Tim Sill, Veronica Westacott; **Belgium**: Reinhilde Bouckaert, Els van de Velde; **Canada**: Michael Paunescu, Nadja Schauer; **China**: Dong Ming Ren, Kaare Sandholt; **Denmark**: Therese Kofoed Jensen, Hans Jørgen Koch, Jakob Stenby Lundsager, Trine Tougaard; **Ecuador**: Jorge Burbano, Daniel Ortega, Alfredo Samaniego, Luis Villafuerte; **European Commission**: Thierry Bertouille, Tom Howes, Oyvind Vessia; **France**: Cécile Gracy, Remy Lauranson; **Germany**: Alexander Haack, Rainer Hinrichs-Rahlwes, David Jacobs, Niklas Martin, Tobias Nagler, Thomas Pregger, Martin Schoepe, Gerhard Stryi-Hipp, Sven Teske, Ellen von Zitzewitz; **India**: D.K. Khare; **Indonesia**: Herman Darnel Ibrahim; **Italy**: Maria Gaeta, Luca Miraglia, Estella Pancaldi, Riccardo Toxiri, Jan Okko Ziegler; **Japan**: Junichi Fujino, Mirei Isaka, Yoshihiro Kaga, Kenji Kimura, Yuki Kudoh, Daisuke Kunii, Hiranao Matsubara, Toshiaki Nagata, Mika Ohbayashi, Tetsuro Oi, Yoshiaki Shibata, Manabu Utagawa, Tatsuya Wakeyama, Yoh Yasuda; **Malaysia**: Wei-nee Chen, Gladys Mak, Lim Shean Pin; **Mexico**: Margott Galvan, Eduardo Iglesias Rodríguez, Ricardo Saldana; **Morocco**: Karim Choukri; **The Netherlands**: Rick Bosman, Marc Londo, Karina Veum; **Nigeria**: Eli Jidere Bala; **Russia**: Evgeniy Nadezhdin; **Saudi Arabia**: Thamer AlMahoudi, Ibrahim Babelli, Ahmed Al Sadhan, Otman Al Saleh, Hussain Shibli, Maqbool Moos; **South Africa**: Andre Otto; **South Korea**: Jiwoon Ahn, Yong-Kyung Chung, Sangjun Lee, Yungsoo Shin, Jin Yong Soh, S.K.Gavin Yu; **Tonga**: 'Inoke F. Vala; **Turkey**: Selahattin Çimen, Mustafa Erkeç, Sebahattin Öz, Yusuf Yazar; **Ukraine**: Oleksandr Grytsyk, Igor Kovalov, Mykola Pashkevych; **United Arab Emirates**: Ayu Abdullah, Steve Griffiths, Dane McQueen, Sgouris Sgouridis; **United Kingdom**: Nick Clements, Jonathan Radcliffe, Rachel Solomon Williams; **United States**: Doug Arent, Carla Frisch, Michael Mills, Timothy Williamson; **Uruguay**: Pablo Caldeiro, Magdalena Preve.

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- IRENA REmap workshop, Malta, 5 September 2012
- IRENA REmap workshop, Abu Dhabi, 14 November 2012
- Singapore International Energy Week, 31 October 2013
- IRENA REmap workshop, Abu Dhabi, 12/13 November 2013
- United Nations Framework Convention on Climate Change, 19th Conference of Parties (COP-19) side event, Warsaw, 22 November 2013

Sole responsibility for the analysis, findings and conclusions lies with IRENA.

Contents

Tables

Figures

1. REmap 2030: An Overview

The global renewable energy share can reach and exceed 30% by 2030*. The technologies are already available today to achieve this objective. Energy efficiency and improved energy access can advance the share of renewables in the global energy mix to as much as 36%. Going further will require thinking "outside the box", with early retirement of conventional energy facilities, technology breakthroughs and consumer-driven societal change. The report summarised here, prepared by the International Renewable Energy Agency (IRENA) through broad consultations and engagement around the world, provides a global roadmap for doubling the share of renewables in the energy mix.*

- **REmap 2030** indicates a pathway for doubling the share of sustainable renewable energy in the world's total final energy consumption (TFEC).[1] The policies that are currently in place and under consideration – termed the **Reference Case** in this study – would take the world only from the current 18% renewables share to a 21% share in 2030. This study identifies additional **REmap Options**. Doubling the rate of energy efficiency improvements and providing universal access to modern energy services via renewables would raise the renewable energy share to as much as 36%.[2]

- To continue the transition beyond doubling the share of renewable energy, intensified research, development and deployment (RD&D) policies are needed, along with standards, quality control, technology co-operation and project development capacity. These technology options are presented under **RE+**.

- Biomass currently makes up 75% of the total renewable energy consumption, with traditional biomass use accounting for more than 50% of all renewables. Not all traditional biomass used today is sustainable, however. As the use of traditional biomass decreases, **the share of modern renewables will more than triple**. As energy demand continues to grow, this requires **a quadrupling of modern renewables in absolute terms**. Technology costs have fallen significantly and will continue to decline through technology innovation, competition and growing markets, and regulatory streamlining.[3]

- On a country level, the Reference Case for renewable energy deployment in 2030 ranges from 1% to 43%, with a 21% weighted average for the 26 REmap countries (including traditional biomass use). With REmap Options fully implemented, the range would be from 6% to 66%, with a 27% weighted average (excluding traditional biomass use). The average increases to 30% for the world as a whole.

- The level of renewable energy ambition tends to correlate with the energy price level. The macroeconomic perspective and business economics diverge in many countries.

The compelling economic case for the renewable energy transition is even stronger when we include socio-economic benefits*, such as climate change mitigation, health impact and job creation. A high share based on a range of renewables provides flexibility, increases independence and makes the overall energy supply more reliable and affordable.*

- IRENA's analysis suggests that the **average substitution cost** for doubling the share of sustainable renewables is USD 2.5 per gigajoule (GJ)[4] of final renewable energy use in 2030.[5] In comparison, at a price of USD 100 per barrel, a GJ of crude oil costs around USD 17. The average substitution cost by country ranges from USD -12 to USD 14 per GJ.

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1 TFEC includes the total combustible and non-combustible energy use from all energy carriers as fuel (for the transport sector) and to generate heat (for industry and building sectors) as well as electricity and district heat. It excludes non-energy use, which is the use of energy carriers as feedstocks to produce chemicals and polymers. This report uses this indicator to measure the renewable energy share, consistent with the Global Tracking Framework report (World Bank *et al.*, 2013a).

2 Using a different metric, such as primary energy, would yield more than a doubling for the same amount of renewables.

3 Renewable energy share in TFEC is estimated as the sum of all renewable energy use by all energy sources (*e.g.*, biomass, solar thermal) and the share of district heat and electricity consumption originating from renewable energy divided by the TFEC. It can be estimated for the total of all end-use sectors of a country or for each sector separately.

4 1 gigajoule (GJ) = 0.0238 tonnes of oil equivalent (toe) = 0.0341 tonnes of coal equivalent (tce) = 0.238 gigacalories (Gcal) = 278 kilowatt-hour (kWh) = 0.175 barrel of oil equivalent (BoE) = 0.947 million British thermal units (MBtu).

5 Substitution cost represents the difference between the annualised costs of the REmap Option and a conventional energy technology used to produce the same amount of energy divided by the total renewable energy use in final energy terms.

- Worldwide incremental energy system costs amount to an average of USD 133 billion annually until 2030, while average incremental investment needs are around USD 265 billion annually to 2030. Renewable subsidies rise to USD 315 billion in 2030 with the REmap Options fully deployed, but in some countries, subsidies peak before 2030. In comparison, global subsidies for fossil fuels amounted to USD 544 billion in 2012. Fossil-fuel subsidies will fall when the share of renewable energy rises.

- Average health benefits due to the mitigation of air pollution from fossil-fuel use are in the range of USD 1.9-4.6 per GJ, while carbon dioxide (CO_2) mitigation benefits are in the range of USD 3-12 per GJ. The total of cost and benefits results in net savings of at least USD 123 billion, and as high as USD 738 billion by 2030. **Compared to the Reference Case, renewable energy can yield 8.6 gigatonnes (Gt) of CO_2 reductions in 2030**, on par with the potential reduction due to energy efficiency. Renewable energy and energy efficiency offer, jointly, the prospect of significant CO_2 reductions, in line with a maximum 2-degree Celsius global temperature rise.

- Options will result in the creation of 900 000 jobs on average to 2030, compared to the Reference Case, generated directly by core activities without taking into account the intermediate inputs necessary to manufacture renewable energy equipment or construct and operate facilities.

Renewables growth needs to take place across all four sectors of energy use: buildings, transport, industry and electricity. *Global electricity consumption will continue to grow faster than total final energy consumption; to around 25% of the TFEC in 2030.*

Renewable electricity uptake and direct replacement of fossil-fuel use in the three end-use sectors (buildings, transport and industry) are needed *in order to reach a doubling of the renewable energy share. If the REmap Options are deployed, the total share of modern renewable energy in 2030 would reach 44% in power, 38% in buildings, 26% in industry and 17% in transport. Around 40% of the total renewable energy potential in 2030 is in power generation, with 60% in the other three, end-use sectors.*

- Governments underestimate the change that is coming. Solar photovoltaics (PV) is a good example: total governmental projections yield less than 500 gigawatts (GW) of solar PV in 2030 whereas REmap 2030 demonstrated that a combination of current market trends coupled with enabling policies can result in 1 250 GW.

- If the REmap Options are deployed, coal use will be affected most, with a decline of up to 26%; gas and oil use would decline by 15%, compared to the Reference Case. A higher share of renewable energy in the energy-supply mix would change the balance and impact international trade flows. **Total renewables consumption would exceed the consumption of each of the three fossil fuels in primary energy terms.**

- Biomass dominates the renewable energy portfolio. Greater focus on ensuring sustainability is necessary to accelerate the use of biomass, especially in the end-use sectors. In addition, innovative solutions for electrification should be explored.[6]

Markets and policy makers both play crucial roles. *Markets provide affordable solutions, but a sustainable future requires policy guidance. Policies must enable investments and stimulate market growth and transformation, with a focus not only on short-term gains, but also on long-term impact. Effective policies must take into account system and infrastructure issues, such as biomass supply and demand, electricity generation capacity and the transformative value of smart grids. Market forces play a key role in finding efficient solutions and scaling up best practices.*

- Five key areas for national action have been identified: transition pathways for renewable energy; enabling businesses and knowledge; renewable energy integration; technology innovation; and enablers. Targeted policies are needed to accelerate the progress in these areas.

- There is a need to focus on overall system design rather than the cheapest source of renewable energy. Governments must ensure the development of enabling infrastructure, including power grids and storage, to integrate high shares of variable renewables.

- Pre-commercial research needs to be conducted in emerging technology areas. Notably, new renewable energy solutions are needed for end-use sectors.

[6] Electrification means that services provided by end-use sectors which are currently based on fuel-based technologies (*e.g.*, gasoline running passenger vehicles, coal-based industrial production processes) are being substituted with their electricity-based counterparts (*e.g.*, electric vehicles, electrolysis for chemical production processes). This raises the share of electricity use in the TFEC of the end-use sectors since less fuel is used whilst more electricity is consumed.

International co-operation will enable a surge in the adoption and use of renewable energy worldwide. *Economies of scale, increased trading of renewable electricity and biomass commodities, faster technology learning and the sharing of experience are all indispensable to go beyond a 36% renewables share – and are achievable only when countries work together.*

Renewables potential varies by country, and therefore specific areas and groupings for co-operation need to be considered. *Areas of focus include:*

- Scaling up international markets, for economies of scale and accelerated technology learning.
- An enhanced knowledge base, including better data on biomass use, renewable energy resource potential, and comparative technology costs.
- More detailed assessment of the nexus between access, efficiency and renewable energy share, as well as energy, water and land use.
- Promotion of the role of sustainable biomass products and renewable electricity as internationally traded energy carriers.
- Intensified sharing of experiences and best policy and planning practice for renewable energy.

2. Actions for Accelerated Renewables Deployment

Meeting the objective of doubling the share of renewable energy by 2030 requires action by public and private sectors. Numerous barriers exist today, and action is needed to overcome them. The REmap analysis has identified priority areas for action. Most action will be national, but in many regions more international co-operation can help to accelerate an energy transition. Actions and policies will need to be tailored to account for the specific needs of regions, sectors and technologies and involve multiple stakeholders (World Bank *et al.*, 2013b). The priority areas for action are the following:

1. Planning realistic but ambitious transition pathways

- Assess the base-year situation and Reference Case trends for renewable energy for 2030.
- Develop a national roadmap to meet objectives. Monitor progress and re-evaluate targets and framework effectiveness and efficiency regularly.
- Streamline planning processes and ensure their consistency and inclusiveness on different levels, including municipal, national and regional planning.
- Ensure human and institutional capacity to develop and sustain the transition.

2. Creating an enabling business environment

- Establish a set of credible and predictable policy frameworks for the power sector and the three end-use sectors (buildings, transport and industry) that can be maintained over longer periods.
- Reduce risk for investors in order to reduce the cost of capital.
- Ensure a level playing field for commercial renewables and other energy options where cost and benefits are valued appropriately.
- Promote international technology markets, *e.g.*, through standards and certification.

3. Managing knowledge of technology options and their deployment

- Build a strong, publicly accessible knowledge base on renewable energy technology costs and potentials and options.
- Establish and strengthen programmes to increase awareness and strengthen the capacity of manufacturers, installers and users.

4. Ensuring smooth integration into the existing infrastructure

- Build enabling infrastructure such as transmission grids and interconnectors.
- Facilitate sustainable biomass supply to enable bioenergy growth.
- Consider nexus issues in the development of renewable energy strategies, notably renewables-efficiency-access, energy-water-land use, as well as energy and industrial development.

5. Unleashing innovation

- Ensure appropriate support mechanisms for emerging renewables depending on their development status and perspective.
- Review high energy-using applications and develop programmes to fill the technology gap.

3. Institutional Framework and Country Dialogue

Sustainable Energy for All (SE4ALL)

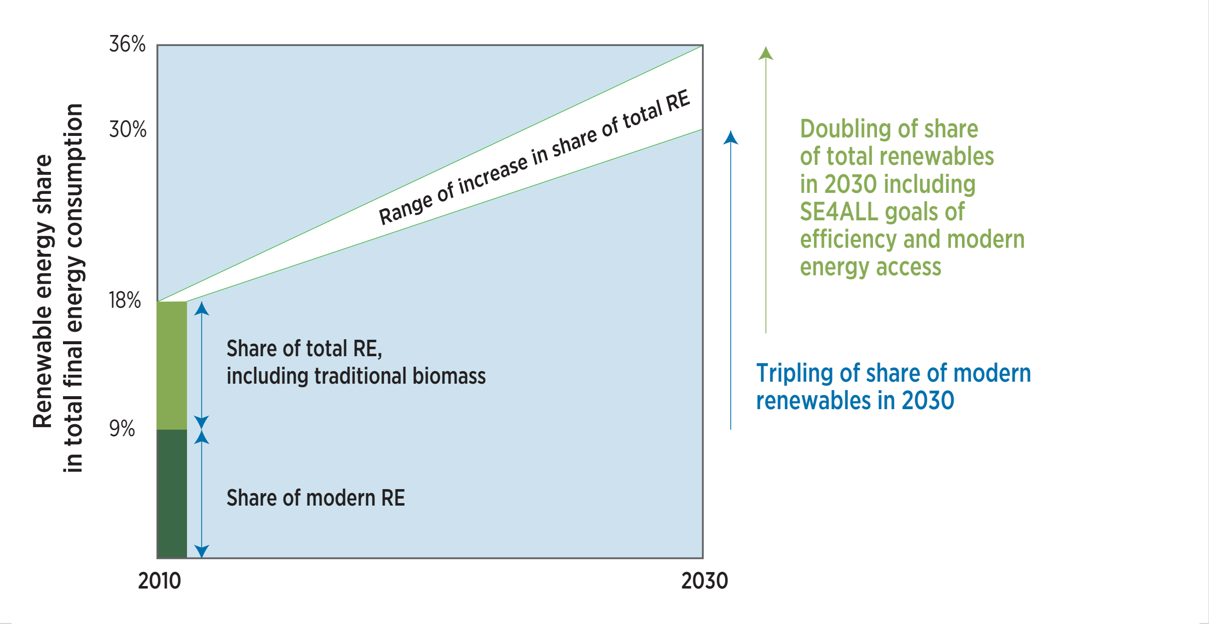
In 2012, the United Nations General Assembly declared 2014 to 2024 to be the Decade of Sustainable Energy for All, underscoring the importance of energy issues for sustainable development and for the elaboration of the post-2015 development agenda (UN GA, 2012).

In the same year, the United Nations Secretary-General set up a High-Level Group on Sustainable Energy for All (SE4ALL) to develop a global action agenda based on three interconnected objectives: 1) ensuring universal access to modern energy services, 2) doubling the rate of improvement of energy efficiency, and 3) doubling the share of renewable energy in the global energy mix (SE4ALL, 2012). IRENA is the renewable energy hub for SE4ALL.

IRENA was established in April 2011 as the intergovernmental agency for the deployment of renewable energy. As of the end of 2013, the Agency had 122 Members and more than 45 countries in the process of accession. The Members asked the Agency to explore how an aspirational target of doubling the global renewable energy share could be put into practice (IRENA, 2012a). IRENA developed REmap 2030 to explore the feasibility of the third objective – including the interconnectivity between renewable energy and energy efficiency strategies – in more detail.

In January 2013, IRENA published the working paper Doubling the Global Share of Renewable Energy: A Roadmap to 2030 (IRENA, 2013a). This publication, based on an analysis of global energy scenarios for 2030, showed that a doubling of renewable energy is achievable and requires action in all regions. It also revealed a significant gap between the global renewable energy share in 2030 based on existing national renewable energy plans and the doubling objective of the SE4ALL initiative. Bridging this gap will require major progress in improving energy efficiency and achieving universal energy access.

Figure 1. Doubling the share of renewables by 2030



Doubling the share of renewable energy implies a tripling of the share of modern renewables.

Note: The world currently gets 18% of its energy from renewables, but only 9% is modern renewables, and the other 9% is traditional biomass, of which only part is sustainable. On the path towards a doubling of sustainable renewable energy, modern renewables therefore need to replace traditional biomass almost entirely. As a result, the share of modern renewables more than triples from 9% in 2010, to 30% or more by 2030.

RE = renewable energy; TFEC = total final energy consumption

Figure 1 shows the share of renewable energy in 2010 as a share of TFEC. Nine percent of TFEC is modern renewable energy, and up to another 9% is traditional biomass, resulting in a total renewable energy share of 18% in 2010. The International Energy Agency defines traditional biomass as: "…the use of wood, charcoal, agricultural residues and animal dung for cooking and heating in the residential sector. It tends to have very low conversion efficiency (10% to 20%) and often relies on unsustainable biomass supply" (IEA, 2012a). The estimate of traditional biomass use in 2010 follows the IEA definition, which assumes that all biomass use in the building sectors outside countries of the Organisation for Economic Co-operation and Development (OECD) is traditional, unless a REmap country provided a more detailed breakdown which allowed for more comprehensive reporting (IRENA, 2014a).

Although the IEA collects data on biomass use in the building sector and proposes a methodology for breaking down the reported data by modern and traditional forms, the total volumes reported are subject to great uncertainty. There are numerous reasons for this. The actual volumes used in some non-OECD countries are often not measured but are instead estimated based on simplified approaches, such as the extrapolation of historical data based on GDP growth. Furthermore, because the definition of traditional biomass use is broad, the total volume changes depending on the definition and method of estimation, resulting in inconsistencies across years. Consequently, there is a broad range of uncertainty.

REmap 2030 is not just another roadmap. Rather, it engages policy makers to improve the underlying data and pursue those projections.

On the path towards a doubling of renewable energy, modern renewables need to replace traditional biomass nearly entirely. As a result, the share of modern renewables more than triples from 9% in 2010 to 30% by 2030.

IRENA discussed the development of a more detailed IRENA roadmap for its Members at the 3rd meeting of the IRENA Council in July 2012 (IRENA, 2012b) and organised two consultation workshops with IRENA Members in September and November 2012. Representatives from 18 countries attended. The main feedback was that an IRENA roadmap would help streamline IRENA's internal and external activities and should be based on a transparent process for country engagement and peer review so that country experts can learn from each other's inputs (IRENA, 2012c,d). REmap 2030 is an evolving document (IRENA, 2012e).

A full roadmap report which provides detailed results of the analysis and additional information related to the objective of doubling the share of modern renewable energy will be released in the first quarter of 2014 (IRENA, 2014a). Both this roadmap summary and the full report are based on the 26 REmap country analyses prepared by the IRENA Secretariat in dialogue with national experts. These country analyses will be made available in the coming months and are living documents that will be updated regularly.

The foundations for the REmap 2030 process – along with the results of the global analysis – were presented at the third meeting of the Assembly and in the REmap working paper in 2013. The proposed way forward was an iterative three-step process built around and reliant upon full Member engagement with three elements:

- Pathways for a doubling of the global renewable energy share;
- Technology options to meet the objective; and
- Opportunities for international co-operation to realise this vision

Methodology and assumptions

An analytical approach was chosen based on an assessment of the gap between national renewable energy plans, 2030 projections and the doubling objective, as well as of the large number of sector-regional analyses to identify, evaluate and prioritise region-specific and inter-regional sectoral actions. IRENA worked with the World Bank, IEA and other parties to establish the SE4ALL references for renewable energy. The Global Tracking Report was published in the second quarter of 2013 (World Bank *et al*., 2013a).

As a starting point, the analysis in 2013 was to focus on economic aspects and prerequisites for a transition. To ensure a transparent, inclusive and open process, IRENA invited all of its Members to identify and nominate national REmap focal points and experts to support REmap 2030. The experts provided their overall energy supply and demand projections up to 2030, including renewable energy policies and targets that were in place or under consideration. Furthermore, the experts provided insights and expertise on the technical, economic and political feasibility of different pathways for renewable energy deployment in the electricity and end-use sectors in this period, and how these different sectors and renewable energy technologies interact. These submissions are not the official views of participating governments, but are perspectives contributed by credible research institutes nominated by the country.

The following 26 countries, which account for 75% of projected global total final energy consumption in 2030, were analysed in detail:

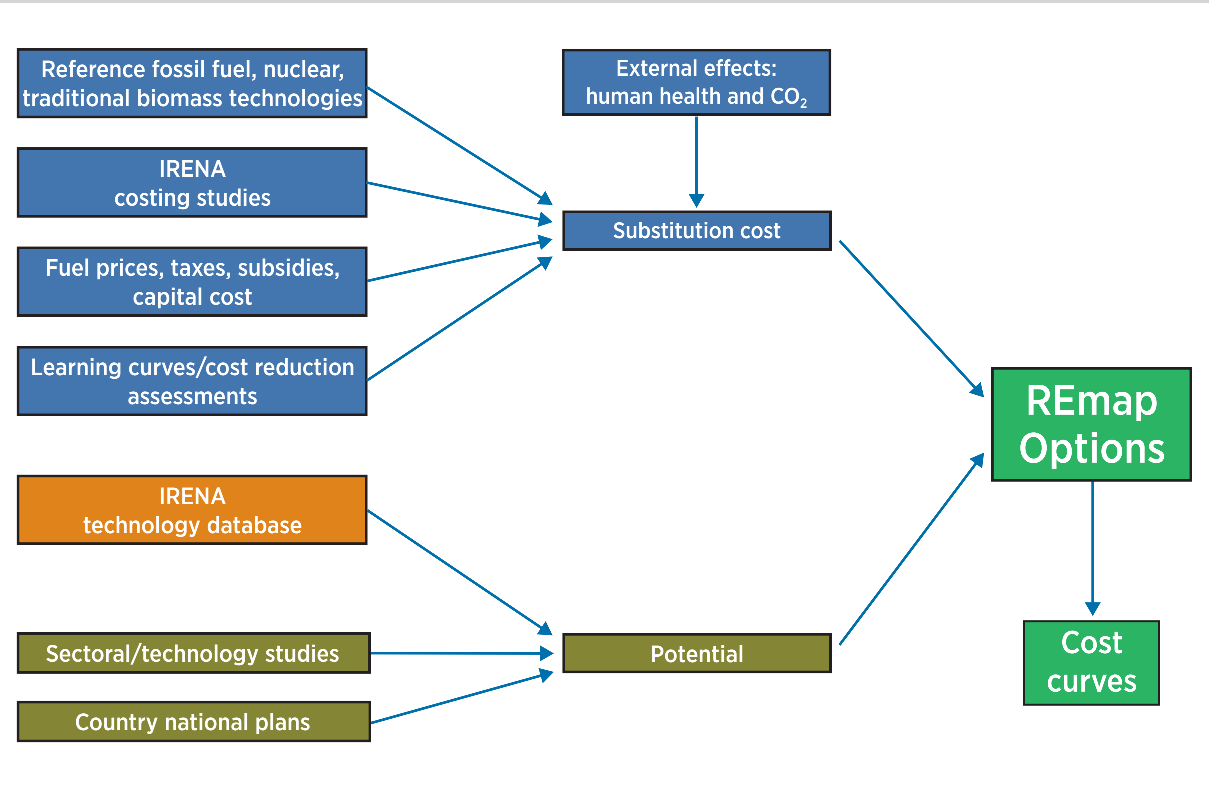
> Australia, Brazil, Canada, China, Denmark, Ecuador, France, Germany, India, Indonesia, Italy, Japan, Malaysia, Mexico, Morocco, Nigeria, Russia, Saudi Arabia, South Africa, South Korea, Tonga, Turkey, Ukraine, the United Arab Emirates, the United Kingdom and the United States.

Figure 2 shows the methodological steps of the REmap analysis. The countries first provided their current national plans, which were collated to produce the business-as-usual **Reference Cases**, including their targets for renewables. Then, the additional technology options were investigated. These additional technologies are defined as **REmap Options** – essentially illustrating what a doubling of the share of renewables would look like. The choice for the Options approach instead of a scenarios approach is deliberate: REmap 2030 is an exploratory study, not a target-setting exercise, and countries can make informed choices as to how to use the identified options.

The REmap Options are the central part of the analysis as they define potentials for additional renewable energy technologies. They do not represent a theoretical or technical potential, but the "realistic" potential estimate for each country by taking into account factors such as that country's resource availability, capacity stock turnover (and average age), planning procedures (*e.g.*, years required to implement a project) and environmental considerations. Each technology option is also characterised by its costs.

Based on the REmap Options country cost curves were developed, which were then combined in **global cost curves** to provide two perspectives: governmental and business. In the government perspective, international costs exclude energy taxes and subsidies, and a standard 10% discount rate was used. This approach allows for a comparison across countries and for a country cost-benefit analysis. For the business perspective, the process was repeated to include national prices (including, for example, energy taxes, subsidies and the cost of capital) in order to generate a localised cost

Figure 2. Characterisation of the REmap Options



26 REmap countries cover 74% of the projected global TFEC in 2030.

curve including taxes, subsidies and the cost of capital for individual countries.

In collecting data from 26 countries, IRENA had to harmonise the Reference Case projections to ensure consistency across countries (*e.g.*, the system boundaries of end-use sectors, time horizon of national plans, etc.); since this study is the first attempt to collect such data. For REmap 2030, IRENA's experts therefore first cross-checked the zero-order drafts of country analyses to improve comparability, as different country plans are based on different assumptions and system boundaries.

Other inconsistencies were found when identifying the REmap Options. A few countries provided projections or data, but for most of them IRENA worked together with the country experts to collect data. The variables required for this assessment include such country-specific parameters as capital stock age profile, resource availability, and the local capital cost and availability of technologies. Finally, energy price data was taken in part from countries and in part from third-party sources.

Although the analysis is based on 26 REmap countries, results are presented and conclusions are drawn also for the world as a whole. The total of the Reference Case and the REmap Options, according to the 26 REmap country analyses, is defined as **REmap 2030**; where results refer to the global situation, this is made clear.

IRENA developed a **REmap tool** to include the data in an energy balance sheet and a list of key technology options, including their expected contributions by 2030. The costing data from IRENA's costing publications and IRENA/IEA-ETSAP technology briefs were used to populate the tool for validation by the national experts and update if necessary (IRENA, 2013d,e,f). The tool includes the cost (capital, operation and maintenance) and technical performance (reference capacity of installation, capacity factor and conversion efficiency) of renewable and conventional (fossil fuel, nuclear and traditional biomass) technologies for each sector analysed, namely industry, buildings, transport, power and district heat. The tool also includes the international and national energy prices and discount rates.

The collected information was crucial to validate and improve estimates from the existing literature and also served as a useful resource for countries developing, reviewing or updating their own renewable energy plans. Separate guidelines on the methodology (IRENA, 2013g) and the costing calculations (IRENA, 2013h) were prepared, as well as a detailed manual for the tool (IRENA, 2013i). The REmap tool allows experts to choose additional renewable energy options, assess their impacts on the country's renewable energy share and evaluate their position within the country's cost supply curve. Furthermore, the tool allows for a consistent analysis and comparison of results among countries. Finally, energy systems engineering model analysis supplements the REmap tool.

In addition to REmap Options, there are also **RE+ Options**, which are based on IRENA studies, technology databases and other literature. They investigate which flanking measures (in particular, efficiency and modal shifts) will take the share of renewables even higher. The analysis shows that the REmap Options are not a technical limit; more renewable energy is possible. It is important for policy makers to pave the way for further progress and new technologies in the long term.

Dialogue with countries and next steps in REmap analysis

The REmap 2030 work received support from a network of 82 national experts from 42 countries. The REmap analysis benefited from extensive and transparent co-operation between IRENA and country experts that helped shape the analysis. Global webinars were organised on 13 June, 6 September and 24 September, 2013, to inform all national REmap experts on the REmap tool and the preliminary results and to collect feedback on the content and next steps (IRENA, 2013j,k).

Conference calls and country visits were organised to discuss the results. Major review workshops for national REmap and industry experts took place on 12-13 November in Abu Dhabi and 29 November in Brussels (IRENA, 2013l; IRENA and IEA-RETD, 2013). Separate regional outreach events were organised in Manila and Singapore (IRENA, 2013m,n). The final draft was presented and discussed with IRENA Members at the sixth meeting of the Council on 10-11 December 2013 in Abu Dhabi.

IRENA also elicited input from a network of external experts. Modelling workshops were organised with the IEA Energy Technology Systems Analysis Programme (IRENA and IEA-ETSAP, 2013) and the International Energy Workshop (IRENA, 2013o), the former resulting in a collaborative effort to compare country results. Furthermore, IRENA and IEA-RETD initiated a new collaborative project called "Factor 2" to analyse energy system evolutions towards a doubling of the renewable energy share by 2030. A REmap 2030 session was organised at the International Research Network for Low Carbon Societies (LCS-RNet). A separate working paper on REmap 2030 was prepared for businesses and discussed during a REmap session at the World Business Council for Sustainable Development (IRENA, 2013p). Furthermore, REmap was presented at the meeting of the UNFCCC Ad-hoc Group on the Durban Platform for Enhanced Action in April 2013 and at the 77th General Meeting of the International Electrotechnical Committee in October. A special session on the benefits of a doubling of renewables for greenhouse gas mitigation was organised at the UNFCCC COP19 in Warsaw, Poland (IRENA, 2013q).

As outlined by IRENA Members in the consultation workshops, an important part of REmap 2030 is the deployment of renewable energy in end-use sectors. As such, IRENA integrated its two technology roadmap activities on manufacturing and cities into REmap 2030. For the manufacturing sector, IRENA launched its first technology roadmap, Doubling the Global Share of Renewable Energy by 2030: The Crucial Role of the Global Manufacturing Industry (IRENA, 2014b).

The roadmap provides an overview of the techno-economic potential of renewable energy by technology, region and subsector. It also proposes seven areas of action where policy makers and industry can work together to accelerate the deployment of renewables. For cities, IRENA is in the final stages of preparing a similar roadmap. City workshop proceedings are available online (IRENA, 2013r).

As a background document to its technology roadmaps on electricity storage and renewable energy integration, IRENA published a guidebook for decision makers, Smart Grid and Renewables: A Guide for Effective Deployment (IRENA, 2013s). It provides an easy-to-read overview of all smart grid technologies available to support renewable energy integration into the grid, thereby positioning IRENA as an authoritative source of information on grid solutions.

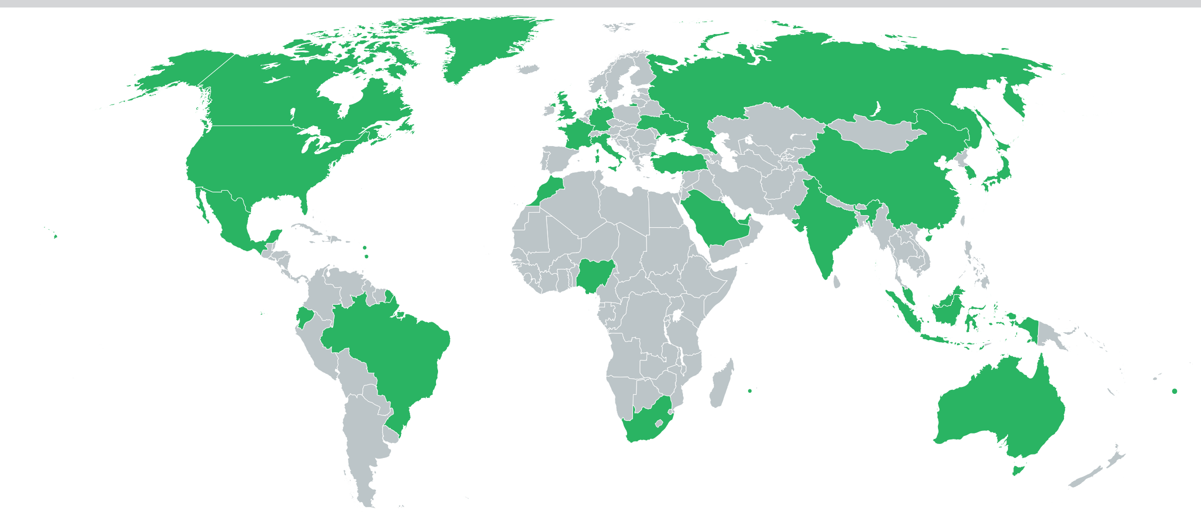
REmap 2030 is a living document. IRENA will extend the scope and detail of the analysis in the course of 2014 and 2015. IRENA will continue to engage with the countries and other key stakeholders to ensure that REmap 2030 presents a global perspective on the opportunities and challenges ahead. Country engagement remains a crucial element to the roadmap. The full report (IRENA, 2014a) discusses next steps in the REmap analysis and opportunities for international co-operation. IRENA is inviting its members and other interested parties to join REmap action teams for follow-up action.

In further rounds of REmap 2030, IRENA will work with the current countries and new disciplines to improve the underlying data. With each round of improvements, the results will become more accurate – as will, more importantly, the recommendations for policy makers. This is why IRENA believes that it is not only the specific projections for particular technologies that are important in this study, but also the unique interaction with Member countries.

REmap 2030 is thus not only another roadmap. Rather, its main purpose is to engage policy makers towards improving – and ultimately pursuing – their own energy plans.

The level and scope of REmap and IRENA's ability to engage with countries benefited greatly from the voluntary contributions provided by Germany and Japan. These contributions provided the means for in-depth analysis that would not have been possible otherwise. The biomass analysis has benefited from a secondment from the Japan International Research Center for Agricultural Sciences. Other in-kind contributions were provided by governments that made their experts available for country analysis and REmap review.

Figure 3. The 26 REmap countries



4. Pathways for Doubling the Global Renewable Energy Share

The pathways for doubling the global share of renewables are illustrated in Figure 4 and present results for the REmap Options, the goals of SE4ALL and the RE+. At present, renewables make up 18% of the global TFEC, of which nine percentage points is modern renewables and nine percentage points is traditional biomass, whose global use is hard to quantify.

Figure 4 shows the status quo in 2010 (far-left, grey bars), where the light grey-shaded area of the bars represents the share of traditional biomass. Under the Reference Case (light green bar), renewable energy use grows slowly, increasing its share from 18% of TFEC in 2010 to only 21% in 2030. However, IRENA's analysis found that markets are already growing faster than governments anticipate and that more can be achieved at lower cost than governments have estimated.

With policy action to ensure the uptake of the REmap Options (dark green bar), the renewable energy share could increase much further – to around 27% in the 26 REmap countries – and the REmap Options also entail a shift from traditional biomass, with its associated health and environmental consequences, to modern biomass. This represents an almost tripling of the share of modern renewable energy from 9% in 2010 to nearly 27% in REmap 2030. This tripling comes at a cost of USD 2.5 per GJ in 2030. Moreover, this transition saves money once the external costs of fossil fuels, which are not priced today, are taken into account.

The REmap Options do not assume that all traditional biomass use is phased out. Achieving the SE4ALL goal of modern energy access (see first blue bar in Figure 4) will require additional policy efforts. At present, more than a third of the world's population still relies on wood and animal waste as a source of energy, especially for cooking. The resulting indoor air pollution (smoke) poses considerable health risks. A shift to clean cookstoves fired with modern biomass would provide a better cooking service, reduce energy consumption and drastically reduce negative health impacts. Likewise, 1 billion people may still lack access to electricity in 2030; this additional access to electricity, partly in the form of small, distributed generators of renewable power (such as minigrids and solar home systems), would push the share of renewables in the TFEC to 30%.[7]

In 2010, 9% of total final energy consumption was traditional biomass, and 9% was modern renewables. Only 3.6% was renewable electricity, dominated by hydropower.

Important synergies exist between access, efficiency and renewables.

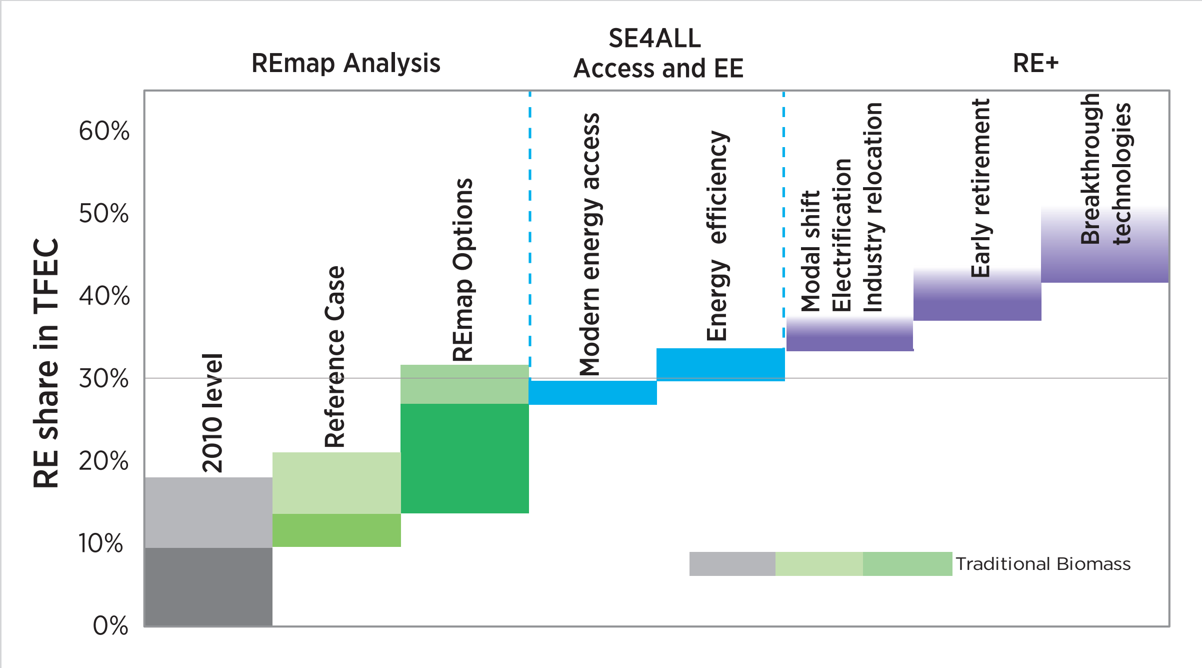
The second blue bar is the impact of SE4ALL's energy efficiency objective on the renewable energy share in 2030. With greater energy efficiency, the same amount of renewable energy covers a larger share of demand and would raise the share of renewables. Efficiency gains and the first bar of RE+ could bring the share of renewables up to 36%.

RE+ (the three purple bars) represents technologies and steps that can take the share of renewables even further; the REmap Options, in combination with SE4ALL's other two aspirational objectives, is not the limit. RE+ includes modal shifts in transport, electrification and technologies not yet ready for the market today ("Breakthrough"), but also other actions that are hard to monetise.

"Modal shift" means a switching of modes, such as when people shift from cars to, say, buses, trains and (electric) bicycles. "Electrification" generally covers the transition towards the use of electricity-based technologies in all sectors, with prominent examples including electric stoves and heat from electricity using heat pumps. Note that these actions often take place because of convenience and irrespective of cost: for example, North Americans are already talking about how electric vehicles (EVs) will help solve local pollution problems, China is by far the world's largest market for electric

[7] Substituting modern biomass for traditional biomass reduces biomass consumption by around a factor of two for the same energy service, so this reduces the share of renewables in energy consumption, while also increasing its share of energy services provided.

Figure 4. The stepping stones towards a doubling of renewable energy



The world can double its share of renewable energy in total final ene gy consumption by 2030.

Note: The shaded areas indicate traditional biomass. The Reference Case represents the renewable energy share by 2030 based on the policies in place in the 26 REmap countries. The REmap Options show the additional growth by 2030 based almost entirely on modern renewables, with traditional biomass being reduced to less than 2% of the TFEC. The blue bars represent the SE4ALL objectives of modern energy access and energy efficiency (EE), which bring the share of renewables up to around 34% by 2030. The purple bars, RE+, represent other fields of action that can be pursued to take the share of renewables even further.

RE = renewable energy; TFEC = total final energy consumption

bicycles, and Europe continues to expand its already well-developed public transport networks. Finally, "industry relocation" means that new industrial facilities will be built where renewable energy is abundant and inexpensive, just as old industry was placed where conventional energy was readily available. As industry increasingly follows sources of renewable energy, renewables can be integrated more easily into overall supply.

Up to now, industry has relocated mainly to countries with considerable inexpensive hydropower, with a prominent recent example being new aluminium production facilities in Iceland. But increasingly, firms may relocate to follow inexpensive wind and solar power.

The second purple bar indicates the potential impact of "early retirement" on the renewable energy share. Renewables growth is normally limited by energy demand growth and capital stock replacement rates. Early retirement of conventional energy equipment in industry, buildings and the power sector can open up additional opportunities for renewables growth. This process is already materialising in some European countries (*e.g.*, Germany and Italy) where the recent fast growth of wind and PV power is resulting in a certain level of over-capacity, which reduces the annual operating time of gas- and coal-fired plants. Lower operating time or early closure affects the companies that operate the existing plants and comes at an additional cost. Conventional facilities have generally been designed for a service life of 40 years or longer, and they become increasingly profitable the longer they stay in operation without having to be modernised. The challenge for policy makers is to encourage the early retirement of conventional facilities that inhibit the further growth of renewables, since once a conventional plant has repaid its financing, it remains profitable even though it is inefficient and polluting.

Early retirement of existing plants can accelerate the deployment of renewable energy in final energy consumption.

Finally, the third purple bar represents the impact of a wide range of fledgling technologies which are promising, but not certain to be competitive on a grand scale by 2030. In ocean power, for example, a number of technology options are currently being pursued, from wave energy collectors to underwater turbines. Here, it is important for policy makers to remember that although 2030 is the time frame for this discussion, it does not mark an endpoint for renewables. If we are to continue the transition to renewable energy after 2030, we need to not only ramp up wind power, solar, biomass and geothermal today, but also pave the way for additional options to become competitive further into the future.

REmap Options by sector

Energy is generally consumed to provide energy services; in some cases, energy is transformed into a different energy carrier before consumption (*e.g.*, wind energy is captured by blades to provide mechanical energy that is used to produce electricity). Energy services differ by sector, but heat is predominant in industry and transport (used in the internal combustion engine to provide motive power) today and in buildings in the industrialised countries. To provide policy makers with guidance for specific sectors, however, REmap 2030 investigates the three end-use sectors of industry, buildings and transport and their energy service demands, as well as which renewable technologies or fuels can meet the energy service demands of these sectors, with the power sector overlaid across each of the three sectors as a high-value energy carrier (see Table 1).

The share of renewables by end-use sector (industry, buildings, transport) in Table 1 is estimated based on two indicators. The first adds up total renewable energy use from all energy carriers (biomass, solar thermal, etc.) and divides this sum by the sector's TFEC excluding total district heat and electricity consumption. It therefore excludes the contribution of renewable energy for district heat and electricity use in end-use sectors. The second indicator includes that contribution. The renewable energy shares of power and district heat generation are provided separately.

Table 1 shows that the Reference Case increases the renewable energy share in end-use sectors only minimally in the period between 2010 and 2030 (for sector TFEC including electricity and district heat) – with transport rising three percentage points and buildings rising six percentage points. For all end-use sectors, the increase is only five percentage points (from 9% to 14%). These developments are insufficient to double the global renewable energy share. The only exception is the transport sector, whose renewable energy share doubles from 3% in 2010 to 6% in 2030, including electricity use. If all REmap Options are implemented, the global renewable energy share increases to 27% by 2030 – a tripling of the modern renewable energy

Buildings offer large potential for renewable energy transformation.

share. The renewable energy share increases at a similar magnitude in buildings and even more (by a factor of five at least) in the transport sector. The increase is approximately 2.4-fold in the industry and power sectors.

Table 1 reveals that there is only a major difference in industry, where the share of renewables including electricity and district heat is 26% – or seven percentage points higher in REmap 2030 compared to the case where renewable electricity and district heat are excluded (19%). In contrast, despite all of the talk about electrification of the transport sector, electricity is projected to add only two percentage points to the share of renewables in transport in REmap 2030, compared to no addition in 2010. The high efficiency of EVs is one reason for the modest contribution in TFEC terms, approximately 10% of the car fleet would be electric.

A comparison of the Reference Case and REmap Options for 2030 reveals another salient finding: the largest percentage increase in the share of renewable energy occurs in buildings, where renewables increased by nearly 24 percentage points. Furthermore, in relative terms, the greatest difference between 2010 and REmap 2030 is in the transport sector, where the share of renewables in fuels rises five-fold, largely because advanced biofuels are expected to become increasingly competitive.

Different countries use different accounting methods to estimate the share of renewables in their total energy mix. For example, European Union (EU) countries and Ukraine estimate their renewable energy share based on gross final energy consumption. In comparison, Indonesia uses the total primary energy supply (for instance, crude oil and lumps of coal before these are converted into the gasoline and electricity – the "final energy" – that reaches consumers). As useful as this distinction is in revealing system losses for energy sources that use fuel (fossil, nuclear and biomass), it is problematic when comparing these energy sources to wind and solar – which have no fuel, and hence no losses between primary and final energy. When calculating the consumption of finite resources, a focus on primary energy consumption makes sense: we count what we take from nature. But what if want to compare the share of coal power to wind power? A coal plant has an efficiency of 33%, so its primary energy value (lumps of coal) is three times greater than its final energy value

Table 1. Breakdown of global renewable energy share by sector and total

	Renewable share of:	as % of:	2010	2030 Reference	REmap 2030	RE use REmap 2030 (EJ/yr)
Industry	Heat[1]	Heat consumption	8%	9%	19%	25
	Heat & Electricity & DH[2]	Sector TFEC	11%	15%	26%	51
Buildings (excluding traditional biomass)	Heat[1]	Heat consumption	12%	16%	35%	25
	Heat & Electricity & DH[2]	Sector TFEC	14%	20%	38%	50
Transport	Fuels[1]	Fuel TFEC	3%	5%	15%	16
	Fuels & Electricity[2]	Sector TFEC	3%	6%	17%	18
Power[3]		Generation	18%	26%	44%	62
District heat (DH)[3]		Generation	4%	14%	27%	5
Total (as % of TFEC)	Modern renewable energy (excl. traditional biomass) (see Figure 6 for the cost-supply curve, which plots the development of the modern RE share)		9%	14%	27%	119
	Modern + Access		18%	21%	30%	132
	Modern + Access + EE (assumes the implementation of all the 3 SE4ALL objectives)				34%	
	Modern + Access + EE + "RE+"				>36%	

The greatest progress will be made in industry, buildings and transport, not in the power sector.

1 *Represents total combustible and non-combustible renewable energy use from all energy carriers to generate heat (for industry and building sectors) divided by the sector's TFEC, excluding electricity and district heat. For the transport sector, it represents total renewable energy fuel use divided by the sector's TFEC, excluding electricity.*

2 *Represents total combustible and non-combustible renewable energy use from all energy carriers to generate heat (for industry and building sectors), and total electricity and district heat consumption generated from renewable energy divided by the sector's TFEC. For the transport sector, it represents total renewable energy fuel use and total electricity consumption generated from renewable energy divided by the sector's TFEC.*

3 *Represents total electricity generated from renewable energy sources divided by total electricity production, or total district heat generated from renewable energy sources divided by total district heat production. The absolute values (in EJ) for the power and district heat sectors refer to the total generation, but not to consumption. Therefore they should not be added on top of the total renewable heat and fuel use in the end-use sectors to estimate the total renewable energy share in the TFEC.*

EE = energy efficiency; DH = district heating; RE = renewable energy; TFEC = total final energy consumption

(electricity); as a result, a focus on primary energy greatly overstates coal's contribution.

The growth in the renewable energy share (including traditional biomass) of the 26 REmap countries shows a doubling when the share is expressed based on TFEC. When the growth is expressed in terms of primary energy[8] based on either of the commonly applied accounting methodologies (*i.e.*, physical energy content and the substitution methods) the growth would be 20%-30% higher.

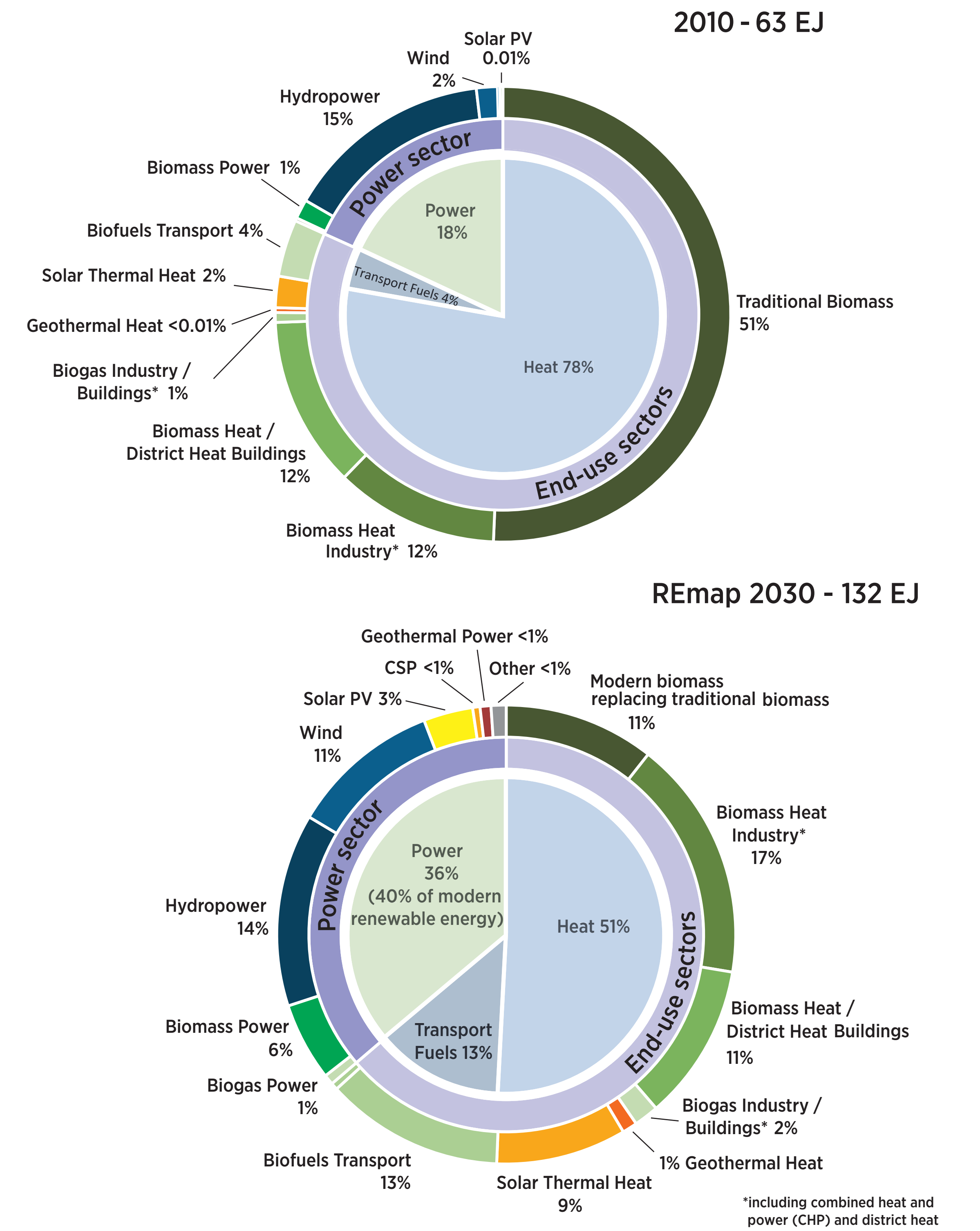
REmap Options by source

Figure 5 shows the share of different renewable energy sources in total final energy consumption globally (not just for the 26 REmap countries) for 2010, as well as for 2030 with the additional growth from the REmap Options included. The largest source of renewable energy clearly will continue to be bioenergy, which can be used not only to generate power, but also to provide heat and motor fuels. The various forms of solid, liquid and gaseous biomass make up 61% of renewable energy use in REmap 2030. But, as mentioned earlier, the main shift within biomass will be from traditional to modern technologies and fuels.

Today, hydropower makes up the largest share of renewable electricity, but by 2030, REmap Options will increase both the absolute amount and share of wind power consumption significantly, as wind power deployment exceeds that of hydropower to 2030. Solar PV will make up a sizable share of power generation as well. Solar thermal heat will provide nearly ten times

8 Based on either of the commonly applied accounting methodologies, namely physical energy content or the substitution method.

Figure 5. Breakdown of global renewable energy use in 2010 and in REmap 2030, by technology and sector



Global renewable energy use will grow by 110% in absolute terms. To double the share of renewables, the world needs to focus largely on end-use sectors, not just electricity; biomass will continue to be the largest source of renewable energy in 2030.

Note: REmap 2030 (lower) estimates total renewable energy use shares of 36% for power and 64% for the end-use sectors, including traditional biomass use. When traditional biomass is excluded, the shares of power and the end-use sectors are 40% and 60%, respectively.

more energy compared to the industrial and building sectors today if all REmap Options are deployed.

Finally, it is worth noting that the power sector makes up only just over a third of the share of renewables in TFEC, with the other nearly two-thirds coming from heat and fuels use in the three end-use sectors.

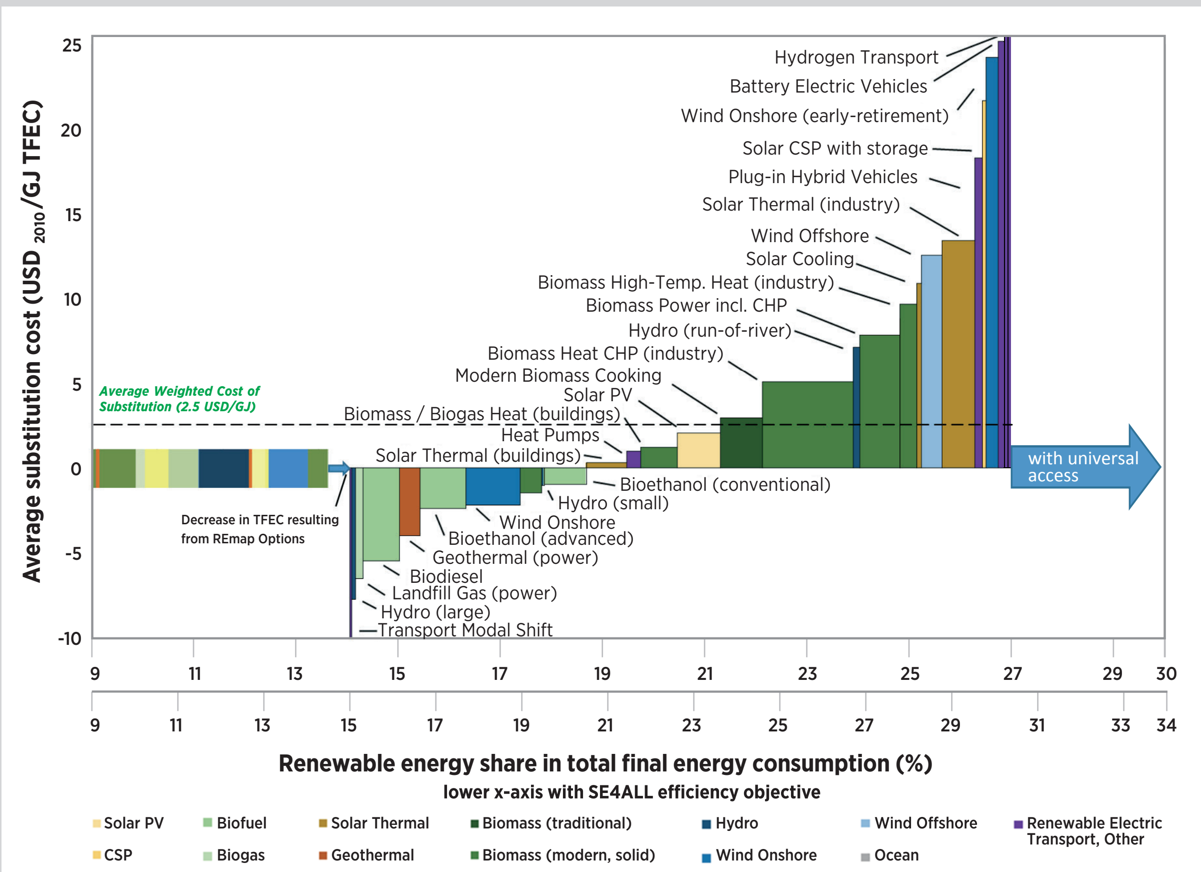
The substitution costs of the REmap Options

Once the REmap Options were identified, cost curves were created to determine the substitution cost per option. Figure 6 shows the global cost curve for the 26 REmap countries, calculated from the perspective of governments and analysed at a standardised 10% discount rate, without fossil fuel taxes and subsidies. This approach produces a better cost estimate for society than the business perspective, which includes national taxes and subsidies that amount to redistributions of national output. The options are aggregated and shown individually based on the average cost of substitution.

The figure highlights the three main categories of possible technology deployment, as envisaged in REmap 2030 analysis:

1. The horizontal bar to the far left shows the growth of modern renewables in the Reference Case, which rises from around 9% in 2010 to around 14% in 2030, as in Figure 4. The cost impact was not determined for the Reference Case, as this growth is assumed to take place in any case. Some traditional use of biomass is already substituted in the Reference Case, which results in a lower TFEC, thereby increasing the renewable energy share. In Figure 6, the green areas in the Reference Case indicate biomass, which accounts for about half of the uptake. The other half consists of power-

Figure 6. Technology cost curve for 26 REmap countries based on the perspective of governments in 2030



The average cost of doubling the modern renewable energy share is negligible, at USD 2.5 per GJ; doubling will require all options to be pursued.

Note: The horizontal bar from 9% to 14% represents the Reference Case developments. The cost-supply curve shows the REmap Options in the 26 REmap countries reaching 27% as represented by the green bars in Figure 4 (upper x-axis). SE4ALL's energy efficiency objective takes the share of renewable energy further (lower x-axis).

CHP = combined heat and power; CSP = concentrated solar power; RE = renewable energy; TFEC = total final energy consumption sector options: hydro and wind, followed by solar. Solar heating applications complete the renewables uptake.

2. The REmap Options raise the share of modern renewable energy from around 14% to around 27% (upper x-axis) and range from negative cost options (savings) to more costly options. The trends visible in Figure 6 would produce savings of as much as USD 10 per GJ, while the most costly options reach USD 25 per GJ. These estimates are based on substitution costs for renewable technologies, rather than the final cost of energy services, which can also be influenced by other factors. Consequently, savings occur wherever a renewable alternative is less expensive than the existing conventional one. Likewise, a positive cost figure indicates additional costs because of substitution, not just the cost of that particular renewable energy source.

Health and environment consequences must be taken into account in policy.

3. The figure also shows the contribution of the other two SE4ALL objectives to the renewable energy share in TFEC. Subsequently, with implementation of the modern energy access objective, the renewable energy share reaches 30% (the blue arrow on far right). Implementing the energy efficiency objective takes the renewable energy share to 34% (the lower x-axis).

The area between the curve and x-axis is a measure of the total annualised cost in 2030. Cost savings offset most of the cost increases. Net annualised costs divided by total final renewable energy use yields an average cost of substitution for the total of REmap Options of approximately USD 2.5 per GJ. This outcome suggests that the share of renewables can be doubled with only limited additional costs.

The net incremental system cost between 2010 and 2030 is USD 133 billion per year worldwide, just 3% more than in the Reference Case. However, adding in the value of reduced CO_2 emissions, even assuming moderate costs for these emissions, means that the REmap Options do not cost 3%, but reduce total system costs. To 2030, renewables are at least as important as energy efficiency in CO_2 reduction potential terms, and their importance will only grow after 2030.

The full report (IRENA, 2014a) provides both this cost curve from a government perspective as well as the cost curves from a business perspective (which includes taxes and the effects of energy markets).

This curve displays the aggregated potential of selected REmap Options. REmap Options are the realistic potential of renewable energy technologies beyond national plans of the countries, taking into account resource availability, capital age of stock, planning procedures, etc. Further technology portfolios can be generated based on the different understanding of the parameters that constitute REmap Options.

Decision makers will be tempted to pick low-cost options, from the left end of the curve, and to skip high-cost options on the right side; but the figure gives a global perspective, and not all options are available everywhere. Therefore, the cost curve should not be misinterpreted as a series of steps from left to right, in order of costs that can be chosen or not chosen in isolation; rather, there are interactions, and all of these options need to be exercised together to achieve this level of costs and the indicated renewable energy shares. For instance, some options produce savings or improvements in efficiency that help reduce the costs of more expensive options below those that would exist otherwise.

The position on the cost curve can also change, depending on taxes, subsidies and external effects. Macroeconomic effects can change the ranking as well. The focus on the cheapest individual options will not result in the least expensive overall transition; achieving that requires a holistic approach, and only when all of these options are pursed simultaneously can the share of renewables in TFEC be doubled by 2030 at the costs presented.

Furthermore, current plans need to take account of the effect of technological learning; what seems costly now may not be by mid-century, particularly if already-emerging technologies are promoted. Another reason to consider costlier options is to accelerate technology learning. Governments may want to invest in technologies that are costly now in order to "buy down" the unit investment cost through technology improvements and economies of scale.

To the right of the cost curve, some technology options have higher costs. This does not, however, mean that the potential for low-cost REmap options is exhausted, or that only the potential of technologies with high costs remains for implementation. Rather, it points to two important findings about the ambition level across countries:

1. Certain countries with very high renewable resource potential either have few policies in place to utilise that potential at low cost, or leave deployment to the market only (*e.g.*, Russia);

2. other countries that already have a high renewable energy share appear content with it and see less need to proceed further (*e.g.*, Brazil).

Technical potential is much higher than the deployment indicated by the width of individual technologies according to Figure 6. This is valid for all technologies, and more renewable energy can be deployed than the REmap Options shown. With further utilisation of technical potential, the global share of renewable energy can be expanded, and the contribution of individual technologies to global renewable energy use can change. Further deployment will depend on the political will of countries and on innovation with existing and mature technologies.

This cost curve represents the global average; costs of specific options and their orders in the cost curve will differ from one country to another, based on local costs and renewable resource quality. Another key insight is that a focus on the cheapest individual options will not result in the least expensive overall transition. Achieving that requires a holistic approach, due to the complex interactions within and between energy systems.

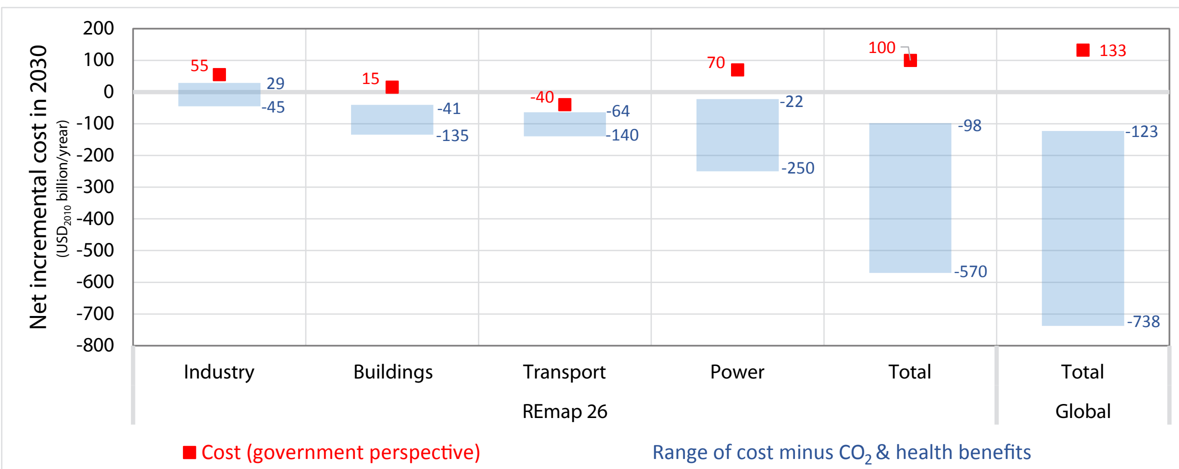
Based on identical datasets used in the REmap analysis, IEA-ETSAP teams modelled how renewable energy and energy efficiency activities evolve as countries increase their renewable energy share. The results of the analysis showed that investments in transmission and distribution networks are limited and represent around 10% of the total energy system investment costs. The results also confirmed the power generation mix by 2030 when the renewable energy share reaches 36% of TFEC in the countries analysed. With regard to developments in energy efficiency and renewable energy, the results showed that energy efficiency becomes the most dominant driver for achieving renewable energy shares beyond 34%.

Results of other analyses show that universal electricity access and a transition to modern cooking equipment are both possible by 2030 with limited investments (Pachauri, *et al.*, 2013)

Substitution costs including externalities

Figure 7 compares the net incremental costs of REmap Options in 2030 from a government perspective, by sector and for the total energy system as a whole, in the 26 REmap countries and for the world. The figure also shows the reduction in net incremental costs

Figure 7. Net incremental costs and benefi s by sector in 2030, based on the perspective of governments



Compared to average annual costs of USD 133 billion, the savings from other benefi s are far greater with renewable energy scale-up. With these externalities taken into account, the shift to renewable energy produces yearly savings of at least USD 123 billion, and as high as USD 738 billion.

Note: The first five bars from the left refer to the 26 REmap countries, with respect to industry, buildings, transport, power and the total of all sectors. The bar on the far right refers to the total to total of all sectors globally.

if reduced external costs related to human health and CO_2 emissions achieved in REmap Options are accounted for.

Externalities, such as health and environmental considerations, far outweigh the cost of scaling up renewable energy worldwide. As the figure shows, factoring in such externalities reduces the net incremental system cost of from USD 133 billion per year in the Reference Case to considerably less than zero. The result would be savings between USD 123 billion and USD 738 billion per year with REmap Options implemented, with the extent of the savings varying widely by sector.

With the doubling of the global renewable energy share and the simultaneous substitution of fossil fuels, human health problems related to fossil-fuel emissions would be mitigated to a considerable degree, effectively at no cost. Net incremental costs in the power-generation sector and the building sector (meaning energy end-use in commercial or residential buildings) show the largest changes when externalities are included. Air pollution related to the combustion of traditional biomass in open fires is a major source of health problems. When improved human health from modern energy access is accounted for, together with CO_2 emission reductions, net incremental costs in the building sector could be reduced by as much as USD 150 billion per year. Similarly, the substitution of emission-intensive coal for power generation results in savings of as much as USD 320 billion per year in the power sector. The analysis underlines the need for governments to include externalities when formulating new policies, in order to fully appreciate the overall savings to be made from proper the implementation of all REmap Options.

Employment benefits of REmap Options

The employment benefits of the REmap options have also been analysed. An approach based on employment factors (further elaborated in IRENA, 2013t) has been followed. Compared to the Reference Case, the deployment of REmap Options will result in 16 million cumulative additional direct jobs in the energy sector from now to 2030, which means that on average 900 000 additional jobs will exist in the sector for the whole period. These jobs account for the job gains in

Strategies are needed for financing small-scale renewable energy projects.

Table 2. Employment effects of REmap Options

	Additional Direct Jobs (million)[1]	
	Cumulative (2013-2030)[2]	Annual Average (2013-2030)
Renewable Energy Sector Only	60	3.5
Conventional Energy Sector Only	-44	-2.6
Energy Sector (Renewable and Conventional)	16	0.9

Deployment of REmap Options will result in an average net increase of 900 000 jobs and 16 million job-years.

Note: Direct jobs refers to employment which is generated directly by core activities without taking into account the intermediate inputs necessary to manufacture renewable energy equipment or construct and operate facilities; e.g., the jobs in steel or plastic industry are not included but those in solar PV manufacturing and installation industry are.

1 Difference between the Reference Case and REmap 2030 employment.

2 Cumulative jobs are calculated by multiplying the additional jobs with the years of employment.

the renewable energy sector and corresponding job losses in the conventional energy sector. The job gains in the renewable energy sector in the same period will equal 60 million cumulative direct jobs, or an average of 3.5 million jobs annually (see Table 2).

Country-specific REmap Options

The global doubling of the share of modern renewable energy does not mean a doubling in every country. Figure 8 shows that in 2010 the 26 REmap countries start off at different levels – ranging from 0% in Saudi Arabia and the United Arab Emirates, to more than 20% in Denmark, Canada and Nigeria, to more than 40% in Brazil.

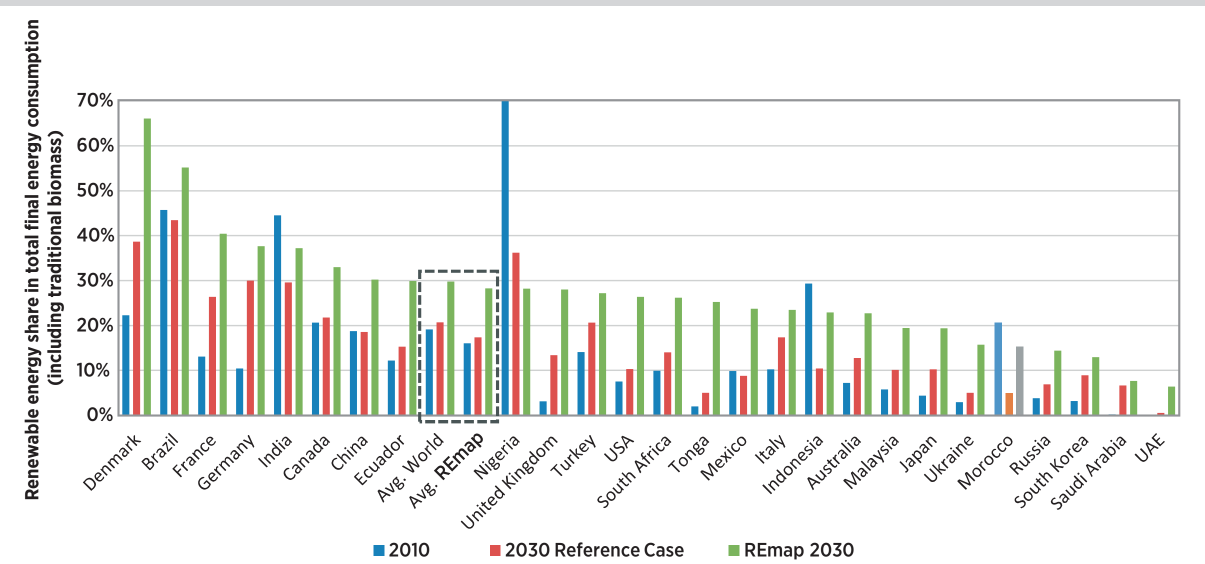
Most countries display an upwards progression of renewable energy share from 2010 to the Reference Case in 2030, with the largest share of renewables found in REmap 2030. EU countries show strong growth in both the Reference Case and REmap 2030. EU Member States all have renewable energy targets for 2020 as defined by their national renewable energy action plans (NREAP), and were discussing targets for 2030 at the end of 2013. Some have targets for 2030, such as Denmark and Germany, which take their renewable energy share in their respective 2030 Reference Case higher.

Brazil, Canada, China, Denmark, Ecuador, France and Germany could reach renewable energy shares of 30% or more.

Nigeria shows different trends. Because it now uses so much biomass (including solid biomass in industry), the country expects its share of renewables to shrink dramatically as industry switches mainly to natural gas, and as the use of traditional biomass in households for cooking is replaced by the more efficient use of modern biomass.

Except for Nigeria, as the bars for the average show in Figure 8, the share of renewables is much greater in 2030 under REmap 2030 than it would be in the Reference Case.

Figure 8. Current and projected share of renewable energy in total final energy consumption by country, 2010-2030

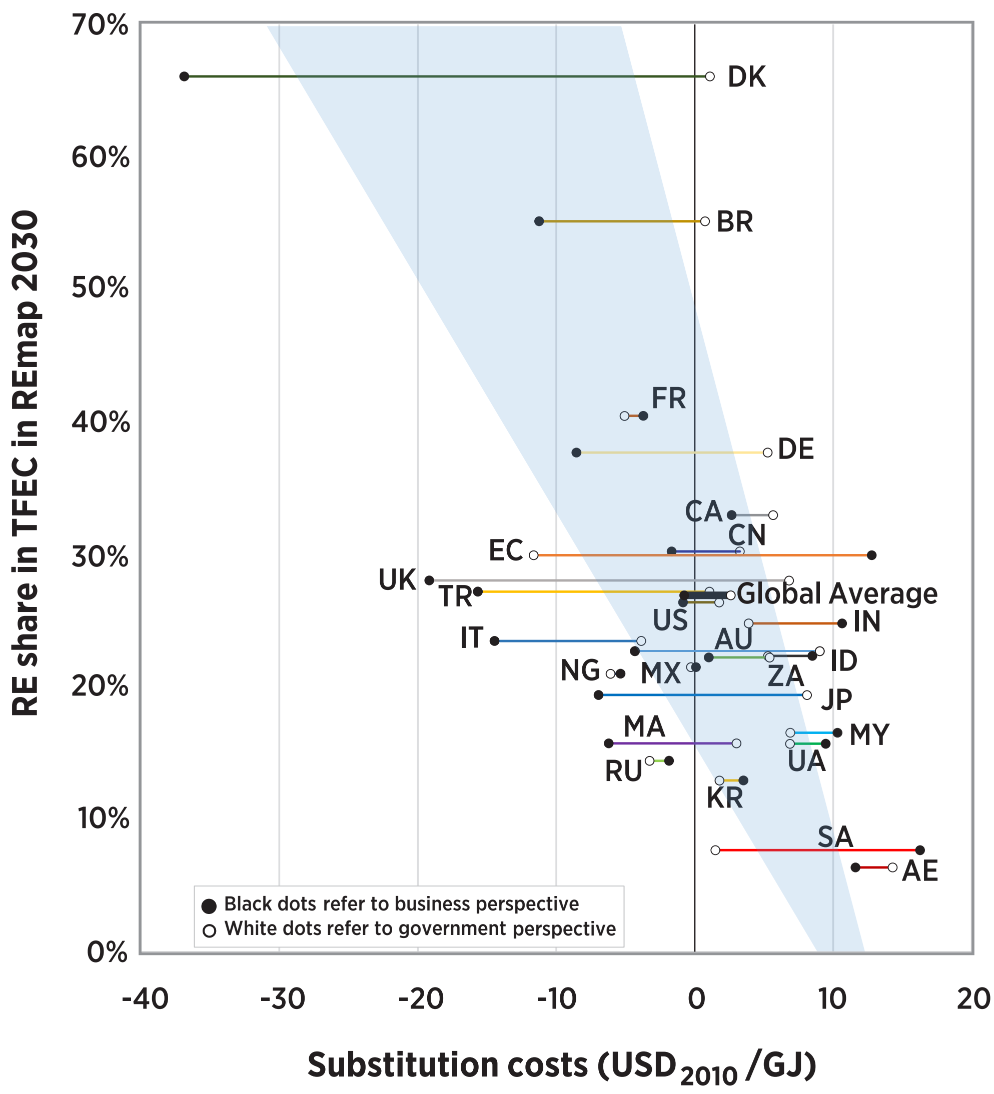


A doubling of the share of renewables worldwide does not mean a doubling in every country

Note: The renewable energy shares for the 2030 Reference Case for France and the UK were assessed based on their 2020 renewable energy commitments according to their national renewable energy action plans (NREAP). No further deployment of renewable energy was included in their analysis of the Reference Case between 2020 and 2030, however any improvements in energy efficiency were taken into account.

RE = renewable energy; TFEC = total final energy consumption

Figure 9. Relation between country renewables potentials and substitution costs



The cost of transition decreases per unit of energy as the target share of renewables increases (the blue shaded area)

Note: Economic incentives increase to the left and decrease to the right. The global average refers to the total of the 26 REmap countries as shown in Figure 7, and the other bars show the breakdown of this total by country.

Countries: Australia (AU); Brazil (BR); Canada (CA); China (CN); Denmark (DK); Ecuador (EC); France (FR); Germany (DE); India (IN); Indonesia (ID); Italy (IT); Japan (JP); Malaysia (MY); Mexico (MX); Morocco (MA); Nigeria (NG); Russia (RU); Saudi Arabia (SA); South Africa (ZA); South Korea (KR); Turkey (TR); United Arab Emirates (AE); United Kingdom (UK); United States (US); Ukraine (UA)

RE = renewable energy; TFEC = total final energy consumption

Country-level average substitution costs of REmap Options

Figure 9 shows the average substitution costs for each of the 26 REmap countries under the REmap Options by 2030, both from a government perspective (no taxes and subsidies) and from a business perspective (local taxation and subsidies included). In Figure 6, we saw the cost curve for different types of technologies; here, we see what the overall cost looks like for particular countries. National taxation and subsidies have been removed in the government perspective (white dots) but are included in the business perspective (black dots). Each country line represents the difference in the

World energy markets are heavily affected by taxes and subsidies.

substitution cost between the government and business perspectives with the REmap Options.

Note that the x-axis starts on the left at low costs and moves into high costs to the right. The positions of the countries show a general relationship: countries with weak economic incentives (positive substitution costs) tend to have low renewable energy shares, whereas those with strong economic incentives (negative substitution costs) tend to have high renewable energy shares. The countries on the left can raise their renewable energy share at negative costs (*i.e.*, higher savings) of substitution.

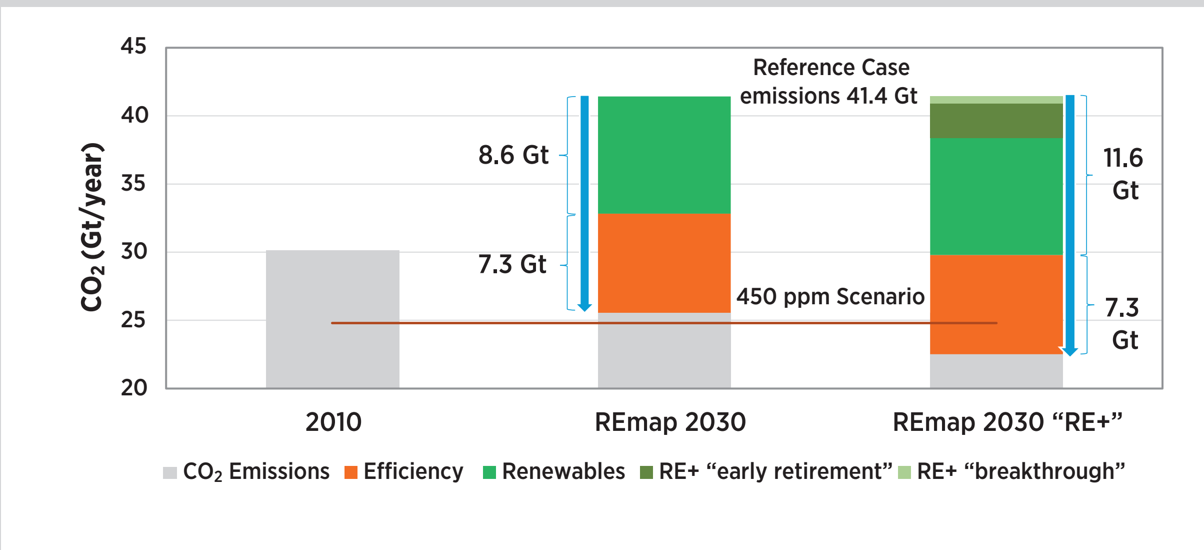
Countries that subsidise energy (bottom right) raise their renewable energy share from a low level, but only to a limited extent – and often at positive substitution costs. In many cases (Malaysia, Saudi Arabia, Indonesia, etc.), these countries have higher substitution costs from the business perspective than from the government's view – a reversal of the situation in Denmark, Brazil and Germany. Denmark and Brazil are two outliers in terms of the share of renewable energy in REmap 2030.

The substitution costs in the business perspective are higher than in the government perspective for those countries with high energy subsidies because the national prices of fossil fuels are lower than the international market prices in these countries. Saudi Arabia, and Indonesia are examples of these countries. Although Russia heavily subsidises its natural gas, the difference in its prices is minor because a mix of nuclear and diesel generators is being substituted, resulting in negative costs in both perspectives. South Korea subsidises its electricity retail prices and is therefore positioned next to energy subsidising countries. For countries with high national energy prices, such as Denmark or Japan, substitution costs with a government perspective are much higher; here, energy pricing policies create a market which could favour the further deployment of renewable energy.

Carbon dioxide emission reductions in REmap Options

Global emissions from energy consumption surpassed 30 Gt of CO_2 in 2010. In 2013, the concentration of CO_2 in the atmosphere exceeded 400 parts per million (ppm), far above the fluctuations of between 180 ppm and 300 ppm that have been experienced over the past 650 000 years. Annual CO_2 emissions continue to grow and could easily reach more than 41 Gt by 2030.

Figure 10. Carbon dioxide emissions under REmap 2030



Renewable energy can provide half of the CO_2 emission reductions needed in 2030 from the energy sector.

Note: Only emissions resulting from fossil fuel combustion are shown. CO_2 emission savings from energy efficiency are based on its share in total emissions in the IEA's World Energy Outlook (WEO) 2012 (IEA, 2012b). IRENA applies this share to the total Reference Case emissions of 41.4 Gt of CO_2 to estimate approximately 7.3 Gt of CO_2 emission savings related to energy efficiency in REmap 2030.

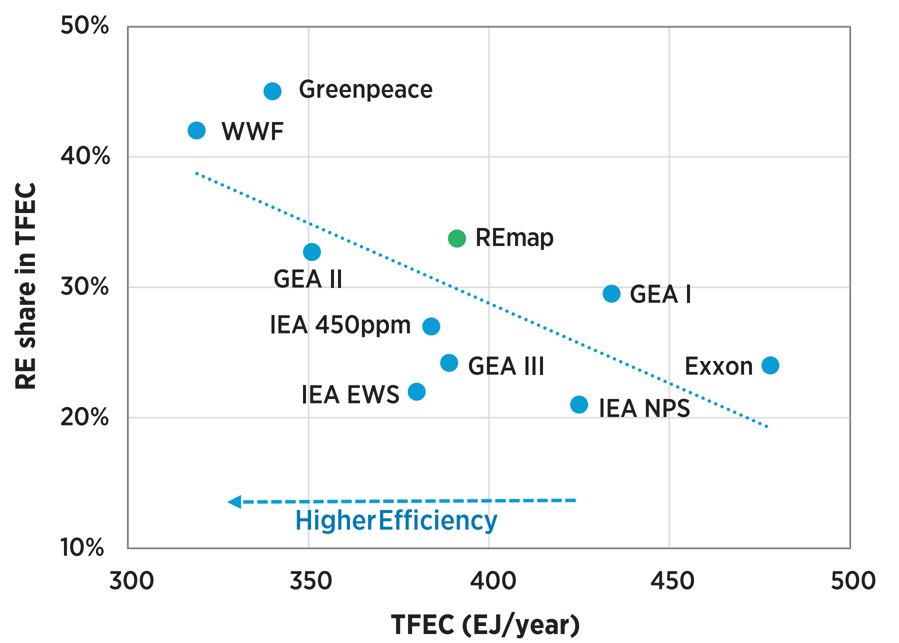
Climate scientists believe that emissions from energy consumption need to go down, not up. The line in Figure 10 shows that annual CO_2 emissions from fossil fuel combustion would need to drop below 25 Gt by 2030 to keep the concentration in the atmosphere from surpassing 450 ppm of CO_2, the level at which scientists believe that global warming can be kept within an increase of two degrees Celsius to avoid the most catastrophic consequences.

Numerous options are available for reducing CO_2 emissions, such as efficiency improvements, renewables, nuclear power and carbon capture and storage (CCS). IRENA examined the implications for CO_2 emissions after estimating the REmap Options and RE+ and found that the potential of renewables was substantial, resulting in a reduction in Reference Case emissions of approximately 21% (8.6 Gt versus 41.4 Gt of CO_2). REmap Options together with energy efficiency could reduce total Reference Case CO_2 emissions nearly to the level required for the 450 ppm scenario (by an additional 7.3 Gt of CO_2). When the RE+ options of early retirement and breakthrough technologies are added in (an additional 3 Gt of CO_2 emissions), annual CO_2 emissions could be reduced to around 22.5 Gt.

Figure 11 shows the relation between the renewable energy share and TFEC in 2030 from several scenario studies. The same amount of renewables use yields a different renewable energy share depending on the TFEC. The lower the TFEC, the higher the renewable energy share, and vice versa. Higher energy efficiency reduces TFEC. Thus, an integrated renewables and energy efficiency strategy will boost the share of renewables. But while this global result is valid for rapidly growing economies, energy efficiency could reduce the need for power sector capacity additions – and therefore, the opportunity to introduce renewables – in economies with stagnant or slowly growing energy demand but relatively young capital stock (such as some European countries and China). The two measures reinforce each other, but policies need to arrive at an optimum deployment mix to ensure that climate change is mitigated effectively.

Renewables and efficiency alone can keep the global concentration of CO_2 in the atmosphere below 450 ppm.

Figure 11. Scenario projections for renewable energy share in total final ene gy consumption, 2030



The less energy we consume, the greater the renewable energy share can be.

Note: Projections for the share of renewable energy in TFEC in 2030 (IRENA, 2013a) are based on IPCC (2011); WWF/Ecofys/OMA (2011); BP (2012); ExxonMobil (2012); GEA (2012); Greenpeace/EREC/GWEC (2012); IEA (2012b). EWS is the "Efficient World Scenario" and NPS is the "New Policies Scenario" of IEA (2012b). The sum of REmap Options would be placed in the middle of the field in terms of the expected level of energy consumption by 2030 (at around 390 EJ per year) but towards the top of the field in terms of the share of renewable energy.

5. Technology Options to Meet the Objective

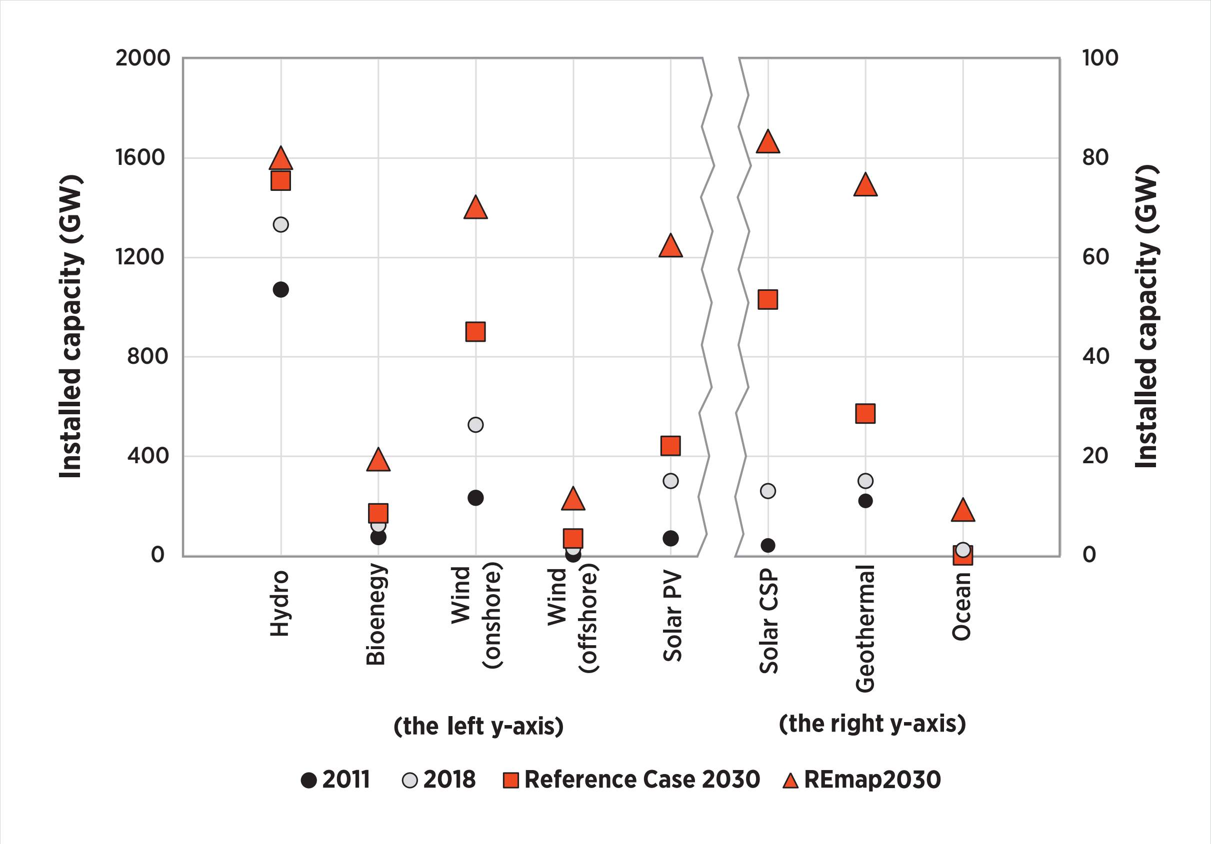
Figure 12 shows the renewable energy capacities by 2030 for the power technologies when all of the REmap Options are realised. In the case of solar PV, the discrepancy between the Reference Case and the additional REmap Options is especially great, growing more than twice as fast by 2030.

On a smaller scale (see right y-axis), concentrated solar power (CSP) and geothermal also will have roughly twice the volume expected in the Reference Case, and a significant amount of ocean power capacity will also have been installed.

In contrast, the difference between the Reference Case and REmap 2030 is minor for hydropower. To facilitate the comparison, the figure provides the projected installed capacities for 2018 given in the IEA's Medium-term renewable energy market report (IEA, 2013a).

Renewables substitute a large share of the fossil fuel use in the power sector. Renewables primarily offset coal consumption for power generation in absolute terms, as shown in Figure 13. The reduction in coal consumption (57 EJ) is greater than the offset of natural gas and oil products combined. The changes in demand for oil and natural gas will have an impact on energy-producing countries. In comparison, total renewable energy use (also in primary energy terms) will increase by 90-150% in REmap 2030 depending on which accounting method is applied to measure primary energy. If REmap Options are implemented in addition to the Reference Case,

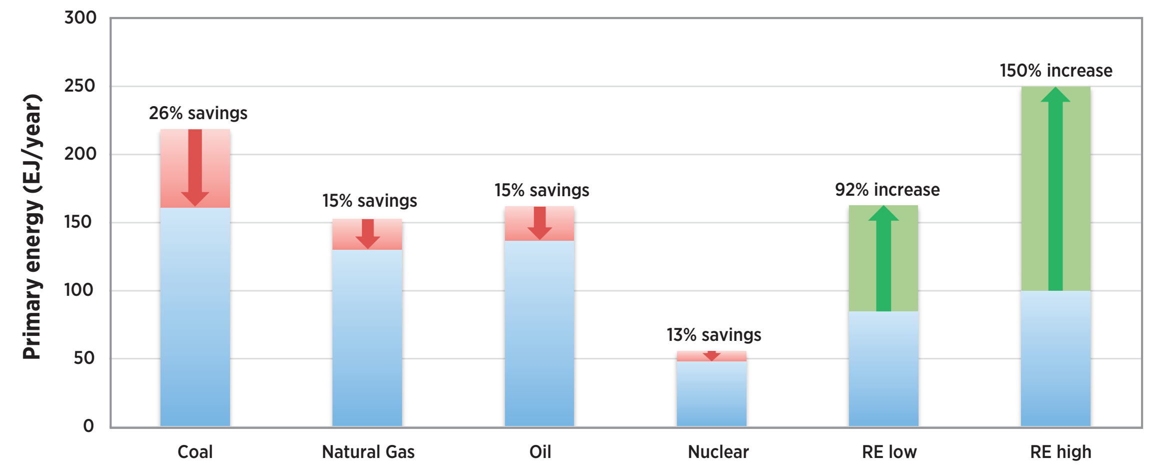
Figure 12. Growth projections for specific enewable electricity technologies



The potential of renewable power growth is signifi antly underestimated in governmental projections.

Note: Pumped hydro is excluded because it is considered energy storage. Figures for 2018 are based on the IEA mid-term energy market report (IEA, 2013a).

Figure 13. How renewables offset fossil fuels



Renewables will mainly substitute coal by 2030 to become the largest source of primary energy.

Note: Figure shows the future level of fossil fuel use in the Reference Case and the savings (in red) when the REmap Options are pursued; savings from the doubling of energy efficiency are excluded.

renewable energy could be the most important energy carrier worldwide by 2030.

Global fossil fuel use will grow by approximately 39% between 2010 and 2030 according to the Reference Case. In comparison, the resulting growth in REmap 2030 fossil fuel consumption due to the implementation of all REmap Options is only 12%. Coal growth would be flat and oil and natural gas would increase by 10% and 35%, respectively. The REmap Options will reduce coal consumption by more than the total reductions of both natural gas and oil.

REmap Options will offset more coal consumption by 2030 than natural gas and oil combined.

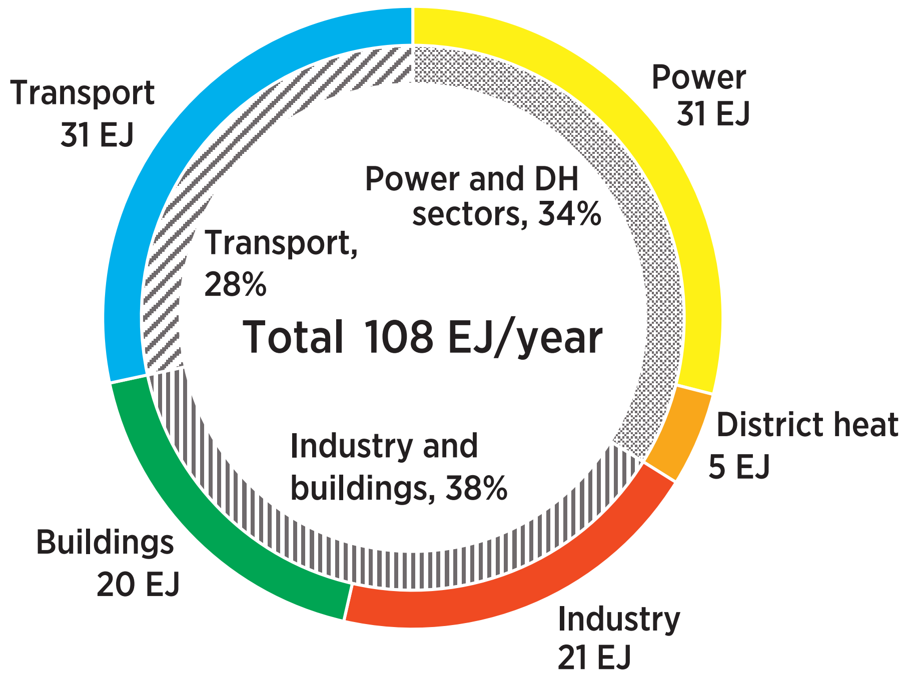
Replacing oil and natural gas with renewables is fairly straightforward in the power sector and for heating, but the challenge is greater in the transport sector. Biofuel will grow significantly, but electrification will not always be an option (such as in shipping and aviation). Moreover, as mentioned earlier, the share of electricity in transport does not rise much even if EVs make up 10% of the global fleet, because electric mobility is so efficient. In its analysis of REmap Options from the government perspective, IRENA expects advanced biofuels to become competitive with petroleum before 2030; however, this assumes a price increase for oil of 50% a barrel by that year compared to 2010.

Figure 14 shows how biomass consumption is spread across the three end-use sectors of industry, transport and buildings, as well as the power and district heat sector, by 2030, when the additional REmap Options are implemented (in primary energy terms). It is assumed that the biofuels are produced from solid biomass with a conversion efficiency of 50%; hence, 1 GJ of biofuel (in final energy terms) requires 2 GJ of solid biomass (in primary energy terms). IRENA finds that demand for solid biomass will grow at an annual rate of 1.9% to 2030, far higher than projected in the Reference Case and in the historical increase of 1.3% per year between 1990 and 2010.

The growth is far greater for liquid biofuels, which in the Reference Case increase by a factor of only 2.7 from 2010 to 2030, compared to six-fold growth in REmap 2030. From 2000 to 2010, annual liquid biofuels growth averaged 19%, although it flattened at the end of the decade, in part because of the EU's hesitation to increase its mandate for liquid biofuels. IRENA believes, however, that advanced biofuels will become competitive well before 2030 (IRENA, 2013e).

Figure 15 shows the supply potential for primary biomass in EJ along with the price by type/region. IRENA estimates that up to 30% of the total global biomass supply potential of 105-150 EJ is exportable

Figure 14. Global primary bioenergy demand by sector with REmap Options, 2030



Biomass is versatile and can be used to provide power, transport and heat.

surplus, meaning that biomass is largely a resource to be consumed locally. Traded biomass products will be mainly liquid biofuels, pellets and chips. Note also that global biomass demand is expected to increase to 108 EJ in 2030 with implementation of the additional REmap Options, close to the lower end of the total supply potential. These are very ambitious potentials for biomass, indicating that concerns about its sustainability will gain further importance as the limits of biomass supply are reached. This outcome also points to the importance of innovation and the development of new technologies. With the commercialisation of more efficient and emerging renewable energy technologies, the portfolio can be widened and dependence on biomass can be reduced.

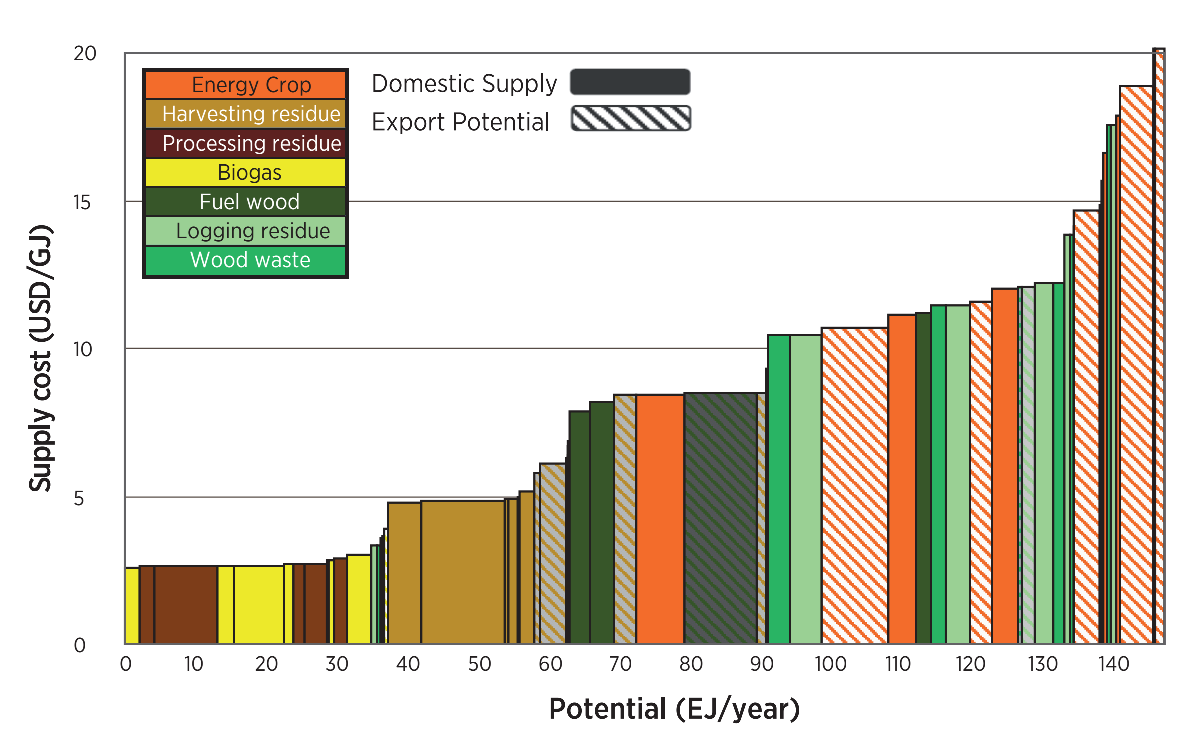
The average supply cost of primary biomass is estimated at USD 8.3 USD per GJ worldwide, but domestic supply costs generally range from USD 2 to 18 per GJ.

Supply costs are lowest for agricultural residues and biogas from food waste and animal manure, and highest for energy crops.

IRENA's biomass supply estimate for 2030 compares well with World Bioenergy Association (WBA) estimates (Kopetz, 2013), which suggest that up to 153 EJ of biomass can be supplied by 2035, with more than 80% of this originating from forest products (wood fuel, residues and waste) (70 EJ) and agricultural residue and waste (62 EJ). The remaining 12% is energy crops (18 EJ). IRENA's estimates for agricultural residues and food waste are similar, at 39-66 EJ, although its estimates for forestry products are lower, at 25-42 EJ. In comparison, IRENA estimates a higher potential for energy crops of about 31-37 EJ, explained mainly by the difference in land availability assumed.

If biomass is sourced sustainably, it can contribute substantially to CO_2 emission reductions. This is because biogenic CO_2, resulting from the combustion of biomass, is assumed to be sequestered by growing biomass in the next season; hence, it could be carbon neutral. When

Figure 15. Global supply curve for primary biomass, 2030



The most affordable biomass comes from residue and waste, which also makes up roughly half of the potential

Note: Supply estimates represent the higher end of the supply potential. Striped bars indicate export potential.

life-cycle stages of bioenergy other than combustion are considered (*e.g.*, harvesting and recovery), however, bioenergy may have higher GHG emissions compared to fossil fuels, and also when emissions related to direct and indirect land use change are accounted for. Strategies to ensure the sustainability of biomass include improving agricultural yields, managing the land and other resources sustainably, and increasing the use of agricultural and forest residues while not exceeding the limits posed by, for example, soil organic matter.

Roadmap for doubling the global renewable energy share

Who needs to do what by when? Change is needed in physical terms (for example, in GW capacity and tonnes of fuel) but also in terms of policy frameworks (for example, in energy pricing, market structure and planning). This section explores the physical changes that need to happen between today and 2030 and puts the change into perspective with the developments of the past decade.

The options for 2030 can be broken down into four main strategic categories:

1. Renewables for power generation (representing around 40% of modern renewable energy use in REmap 2030), including one-third hydro, one-third wind, one-tenth solar, and the remainder other renewable energy sources.
2. Renewables for end-use sectors (representing around 60% of modern renewable energy use), with buildings accounting for 38%, industry for 38% and transport for 24%. This includes:
   - Modern biomass for thermal applications (representing around 25% of renewable energy use), excluding the replacement of traditional biomass.
   - Access to modern energy through renewables, notably the replacement of traditional biomass with modern cooking stoves and modern biomass fuels (representing around 20% of the renewable energy potential).
   - Solar thermal solutions for hot water and space heating and for industrial process heat (representing around 5% of renewable energy use).

3. Other energy policies, including:
   - Electrification as a strategy to enable more renewable energy power use (representing around 2-3% of renewable energy use).
   - A doubling of energy efficiency improvement rates (makes a 15% difference for the renewable energy share in 2030).
   - Energy efficiency improvement rates and structural change, such as modal shifts.

4. Enabling infrastructure measures and technologies, such as grid and storage infrastructure, recharging stations, biomass supply and logistics.

The share of modern renewable energy could increase by at least 50% by 2020 if action starts today.

As REmap 2030 illustrates, with additional REmap Options, modern renewable energy use worldwide could increase by at least 50% between today and 2020, and could nearly quadruple in the 2010-2030 period in absolute terms, doubling the global renewable energy share. According to REmap 2030, about one-third of the additional modern renewable energy potential – on top of the Reference Case – exists in the power sector, and the remaining two-thirds in the three end-use sectors of industry, buildings and transport.

Investments for renewable energy capacity need to start today if all additional REmap Options are to be implemented by 2030.

Table 3 provides an overview of REmap 2030 based on three groups of indicators. The first group is physical indicators. Biomass is found to be a key resource. Total biomass use grows from around 50 EJ to 108 EJ per year – a more than doubling, or a growth rate of 4% per year, significantly faster than the growth during the last two decades of around 35%, or 1.5% per year. The 58 EJ of additional biomass to be used by 2030 equals around 4 billion tonnes, or a queue of trucks that would circle the world 25 times. Up to half of the supply potential would originate from Asia and Europe (including Russia). It is critical that the biomass supply is sustainable, including through reduced life-cycle greenhouse gas emissions.

Modern solid biomass use would increase by four times, and liquid biomass use would increase by six times, between 2010 and 2030. About 63% of the total demand for biomass liquids is estimated to be for conventional biofuels, with the remaining 37% being for advanced biofuels. Cane ethanol accounts for the bulk of conventional biofuel growth – equivalent to five-fold growth in cane for biofuel production. The production of liquid biofuels from cane could be located in regions where cheap feedstocks are available, such as Africa and Latin America. Asia, Europe and North America could concentrate on supplying agricultural and forestry residues for various applications.

If additional REmap Options are implemented, the largest liquid biofuel users could be in Brazil, China, India, Indonesia and the United States. These five countries could more than double their biofuels demand beyond their national plans by 2030 and make up at least half of the total global biofuel market in REmap 2030.

Achieving the goal of modern energy access requires the substitution of traditional biomass for cooking and space heating. If all REmap Options are implemented, the installed capacity of advanced cooking technologies would increase more than four-fold, particularly between today and 2020, mainly in Africa and parts of Asia. A core part of the transition is the provision of more than 1 billion clean cookstoves.

In the next seven years (from 2014 to 2020), all renewable power sector technologies will need to grow substantially in order to implement all additional REmap Options by 2030. Different technologies would grow at different rates, however, with wind and solar PV increasing at least five- and twelve-fold, adding about 70 and 60 GW, respectively, of new wind and PV capacity on average each year between today and 2030.

Today, four countries (Germany, Italy, China and the United States) account for approximately 60% of total installed solar PV (around 100 GW) and wind (around 300 GW) capacities worldwide. According to additional REmap Options, all other countries would invest in new capacity along with their national plans and beyond. In REmap 2030, India, Japan, Mexico and the United Kingdom could reach a total installed wind capacity of at least 300 GW, nearly 20% of the global potential. Similarly, China, India, Indonesia, Japan, South Africa and the United States would together add another 500 GW of PV capacity by 2030.

Early planning requirements for grid and systems in the power sector will be crucial as the share of

Advanced biofuels will cover 37% of demand for bioenergy liquids by 2030.

Table 3. REmap 2030: An Overview

	Units	2000	2012	REmap 2020	REmap 2030	Reference case 2030	REmap / Reference (%)	CAGR: 2000-2012 (%/y)	CAGR: 2012-2030 (%/year)	Indicators for REmap 2030
Technology indicators										
Hydropower (excl. pumped storage)	(GW_e)	689	1 004	1 350	1 600	1 508	6	3.2	2.6	
Pumped hydro	(GW_e)		150	225	325	306	6	N/A	4.4	
Wind onshore	(GW_e)	17	283	600	1 404	900	56	26.4	9.3	300 000 of 5 MW_e plants
Wind offshore	(GW_e)		6	50	231	68	242	N/A	22.5	
Solar PV	(GW_e)	8	100	400	1 250	441	184	23.5	15.1	12.5 million of 100 kW_e plants
CSP	(GW_e)	0	3	15	83	52	62	7.6	21.5	830 of 100 MW_e plants
Biomass power	(GW_e)	35	83	139	390	170	129	6.7	8.9	
Geothermal	(GW_e)	8	11	25	67	26	162	3.1	10.6	
Ocean	(GW_e)	-	1	3	9	2	519	-	17.3	
Biomass, traditional	(EJ/yr)	28	27	20	12	29	-58	-0.0	-4.3	
Biomass, advanced for cooking	(EJ/yr)		1	4	4	2	88	10.4	8.4	270 million 5 kW_{th} cookstoves
Biomass heat from cogen for ind/DH	(EJ/yr)	1	3	4	14	6	129	10.2	9.8	
Biomass pellets for heating	(EJ/yr)	0.1	1	2	3	2	49	48.6	5.8	16 million 20 kW_{th} household boilers
Biomass chips logs etc. for heating buildings	(EJ/yr)		5	5	6	4	49	6.4	1.0	31 million 20 kW_{th} household boilers
Biomass boilers industry incl. biogas	(EJ/yr)	4	4	5	7	7	0	-1.0	3.4	0.7 million 1 MW_{th} industrial boilers
Biofuels transport	(billion litres/yr)	18	105	214	650	287	127	15.9	10.7	15% of global transport fuel use
Biomass use, total	(EJ/yr)	43	51	61	108	79	37	1.4	4.3	20% of total primary energy supply
Solar thermal area (2005 data)	(million m^2)	157	446	1 162	4 029	1 532	163	11.3	13.0	
Share in buildings	(%)	100	99	91	67	97	-31	-	10.5	
Share in industry	(%)	-	1	9	33	3	968	-	41.8	
Geothermal heat	(EJ/yr)	0.2	0.5	0.7	1.2	0.6	86	9.6	4.3	
Heat pump	(GW_{th})	N/A	50	177	474	300	58	N/A	13.3	
Number of heat pumps	(mln)	N/A	4	15	40	25	58	N/A	13.3	
Battery storage	(GW_e)	N/A	2.0	25	150	73	105	N/A	27.1	5% of total variable renewables capacity
EV, PHEV	(mln)	N/A	0.2	25	160	69	133	N/A	45.8	10% of the total passenger car fleet
Financial indicators										
Net incremental system cost	(billion USD/yr)				133	0.9%	of 2011 gross fixed capital formation (15.5 trillion)			
Net incremental investment needs	(billion USD/yr)				265	1.7%				
Subsidy need	(billion USD/yr)		101		315	58%	of 2012 fossil fuel subsidies (of 544 billion)			
Fossil fuel subsidies	(billion USD/yr)		544							
Regional indicators (based on REmap 2030)										
Global - Modern RE (excl. Trad. Biomass)	(%)		9		27	14				
Global – Modern + Access	(%)				30					
Global – Modern + Access + EE	(%)				34					
Global – Modern + Access + EE + "RE+"	(%)				>36					

Note: Transition indicators for technology deployment, investment and regional deployment, and renewable energy shares provided in the policy indicators refer to REmap 2030, thereby excluding the full implementation of SE4ALL objectives of doubling the energy efficiency improvements and modern energy access.

variable renewables approaches 20% in REmap 2030. The United States, Indonesia and Japan are the main countries which will contribute to the global deployment of geothermal power technology. For CSP, the main countries are Saudi Arabia, the UAE and India.

Six countries (Brazil, China, India, Indonesia, Russia and the United States) account for half of global potential and 75% of the estimated scale-up through REmap Options in 26 countries.

There are currently some 200 000 EVs worldwide, and an expansion to 160 million EVs would represent approximately 10% of the global passenger car fleet. Infrastructure needs to be developed in parallel to accommodate this shift in vehicle type. The contribution of six countries (the United States, China, Japan, the United Kingdom, Germany and Canada) is crucial, as they would account for at least 60% of the EV market in REmap 2030.

The United States, China, Indonesia, India, Brazil and Russia would account for over half of the total global renewable energy use in REmap 2030. These six countries – representing different regions, policy frameworks, development levels, and shares of renewables today – indicate that opportunities for renewable energy exist in very different resource, political and economic environments. As this roadmap shows, realising the full technology potential requires the contribution of all countries – from industrialised to developing and emerging economies.

The second group of indicators in Table 3 is investment flows with all REmap Options realised. Net incremental investment needs (above the Reference Case) for doubling the renewable energy share by 2030 amount to USD 265 billion per year worldwide. More than 60% is in the power sector, with 10% in the industry sector and the remaining 30% in the building sector (the transport sector requires no additional investments). When the net fuel cost savings are also accounted for (USD 130 billion per year), the net incremental system costs worldwide are estimated at USD 133 billion per year. These incremental costs are relatively modest, as the average cost of substitution in the REmap Options is USD 2.5 per GJ.

The subsidy triples to USD 315 billion worldwide in 2030. This is a market correction for the fact that CO_2 and health costs of fossil fuels are not priced. Subsidies per unit of modern renewable energy continue to fall during this period due to technology learning and rising fossil fuel costs.[10] The largest subsidy needs are for the power sector (two-thirds of the total), with solar PV and wind accounting for more than 65% of the sector's total. The transport sector's subsidy needs are largely for electrification and advanced biofuels. In comparison, global subsidies for fossil fuels amounted to USD 544 billion in 2012 (IEA, 2013b).

Lastly, Table 3 shows indicators for policies measured, based on the growth in renewable energy shares. The Reference Case takes the global modern renewables share from 9% to 14%, an increase of approximately five percentage points. When all REmap Options are implemented, the additional increase is 13 percentage points, to 27%. This roadmap suggests that policy ambition needs to increase so that the global renewable energy share can be doubled.

All countries – big and small – must contribute in order to double the global renewable energy share by 2030.

[9] The incremental system costs are added to the Reference Case system costs. They do not consider a drop in fossil fuel prices because of lower demand. If fossil fuel prices would drop by 10% due to 15-26% demand reduction, the savings amount to USD 450 billion per year, which exceeds the system costs increase by more than a factor four.

[10] The subsidy needs in 2030 represent an upper estimate. For example, if one tonne of CO_2 is priced around USD 35 in 2030, the subsidy needs would drop from USD 315 per year to zero.

6. National Action and International Cooperation

REmap analysis clearly underlines the necessity for national actions and international cooperation to support the transition to a doubling of the share of renewables in the global energy mix by 2030. This chapter discusses the opportunities at the national and international levels, ranging from policy options to potential areas for greater cooperation. The chapter also highlights the role that IRENA can play, as the recognised hub for renewable energy, to further facilitate the transition.

A framework for national renewable energy technology development and deployment

Governments play an instrumental role in supporting the development and deployment of renewable energy technologies. As renewables evolve, they require a specific mix of targeted incentives at each stage, from basic science and research and development to commercial deployment. Figure 16 illustrates the relationship between different stages of technological development and the policy objectives needed to support renewable energy uptake, with a focus on three main areas: competency building, knowledge creation and diffusion, and deployment.

Within the three areas outlined in Figure 16, a range of enabling policy actions and instruments should be implemented. Doubling the share of renewable energy by 2030 will require a context-specific mix of policy interventions, including innovation, deployment and other complementary policies, to ensure the fulfilment of the REmap Options that have been identified.

Renewable energy deployment policies, in particular, have been instrumental in stimulating market development. Such policies can be categorised broadly into: 1) fiscal incentives (tax credits, grants, rebates, etc.); 2) public financing (guarantees, low-interest loans, etc.); and 3) regulations (quotas, feed-in tariffs, auction mechanisms, etc.). Various deployment policies have been adopted globally at the regional, national and state/provincial levels. Although renewable energy policies have focused mainly on the electricity sector, there is a trend towards greater adoption of policies for the heating/cooling and transportation sectors (Mitchell *et al.*, 2011). Adoption of policies across all end-use sectors will be crucial not only for the realisation of REmap Options, but also to bring about the necessary step-change beyond the electricity sector.

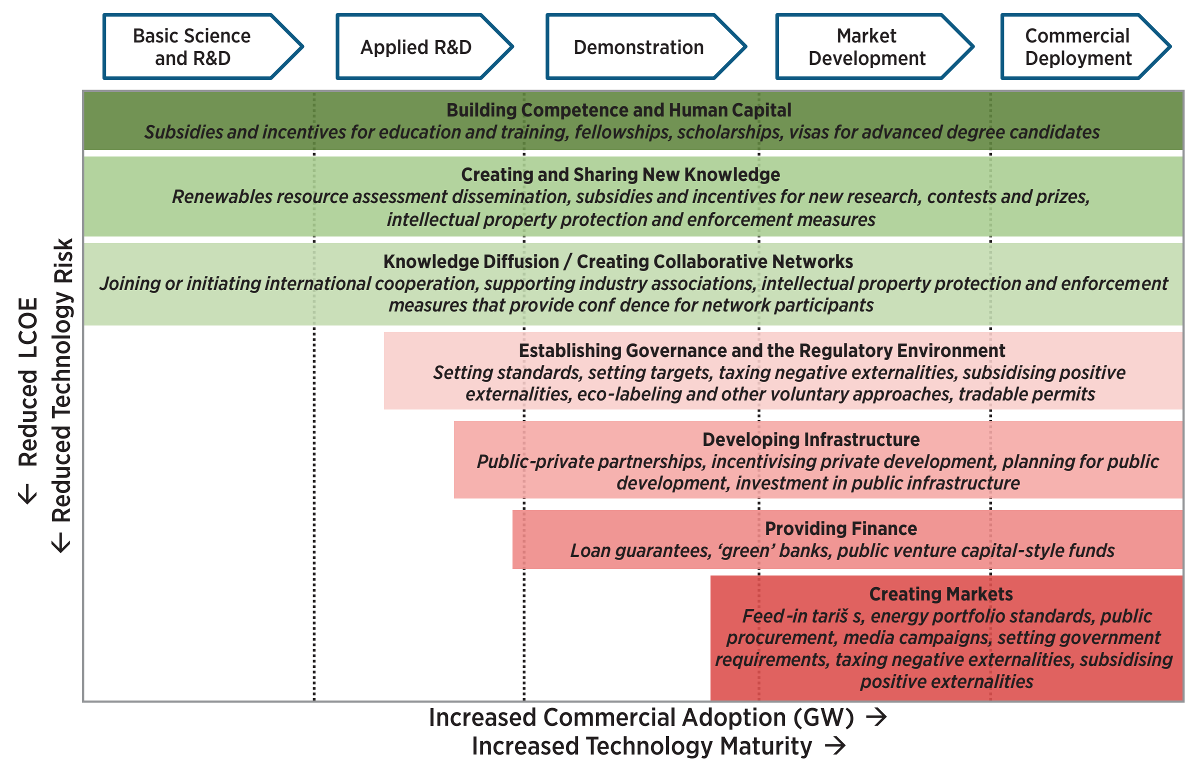
The success of REmap Options will also depend on a broad range of complementary policies, including trade and investment, research and development, and education. In this context, adequate measures and planning will be required. For instance, the deployment of REmap Options will result in an additional 3.5 million jobs per year in the renewable energy sector on average for the period of 2013 to 2030 (Chapter 4). These jobs will need to be filled with a suitably skilled and trained labour force, requiring an appropriate policy environment to meet the employment needs of a growing renewable energy sector (IRENA, 2013t).

Establishing the right mix of policies also has the potential to generate new economic activities and maximise value creation. These will depend on existing industrial capacities, regional and global market developments and the current competitiveness of each market. Governments can support value creation through a variety of measures, including programmes to strengthen technology transfer through cluster development, implementation of local content requirements, and product development through public and private cooperation in the field of research and innovation (IRENA and CEM, 2014). IRENA's econValue project analyses value creation from renewable energy deployment and provides recommendations for policy design options to optimise such benefits.

Planning realistic but ambitious transition pathways

The implementation of policies to support the growth of renewable energy deployment can benefit from an overarching long-term strategy based on credible and attainable targets. The full background report for this roadmap (IRENA, 2014a) provides a detailed overview of existing targets by year and by sector for each of the 26 REmap countries. A long-term strategy that is adequately supported by an appropriate policy framework can play an important role in attracting investments into the renewable energy sector. There is also a need for periodic review and adaptation of policies as markets and technologies evolve, so that

Figure 16. Guide for policies in the technology life cycle



Note: Obtained from IRENA, 2013u.

LCOE = levelised cost of electricity;

support schemes remain effective and efficient, while sufficient certainty is maintained in the investment environment (IRENA, 2012f) .

For now, attention is focused mainly on the power sector; meanwhile, the building and industrial sectors receive limited attention. As the results of this roadmap show, however, a considerable share of total renewable energy use could be in those end-use sectors if all REmap Options were implemented. There is a need to strengthen efforts in the end-use sectors.

Renewables are growing faster in the market than in government plans. There is a need to increase investments, notably in end-use sectors.

Finally, renewable energy policies do not stand on their own. The analysis has shown the importance of simultaneously improving energy access and energy efficiency in order to attain the objective for renewables. At the same time, renewable energy expansion needs to take place in a sustainable way, so deployment has to be undertaken in a holistic manner that takes into account the overall context, including the use of land and water. This added complexity must be dealt with by governments.

Creating an enabling business environment

As policy makers continue their efforts to build an environment that facilitates renewable energy deployment, access to finance becomes increasingly important. Yet this has often proven an obstacle in promoting renewables. Although public and multilateral funding is necessary and often available, the bulk of financing required to adequately scale up renewables will have to come from the private sector.

Recent trends show increased attention being directed to the more efficient use of scarce development funds, such as risk guarantees, mezzanine capital and revolving funds, along with a shift to project preparation and the development of project pipelines. As banks and private sector institutions focus on project development, governments need to put greater attention on establishing well-rounded, predictable and comprehensive renewable energy policy frameworks that foster actual, successful deployment. The creation and strengthening of such policy frameworks will ensure that market forces follow.

The risk profile of renewable energy projects is, in many cases, different from that of conventional energy projects. A better understanding of risks, real and perceived, is necessary in order to effectively mitigate their impact. In turn, mitigating risks for investors, for example through guarantee schemes and insurances, will accelerate the deployment of renewables. Among these risk mitigation measures, lowering transaction costs, raising standards and implementing quality control mechanisms have been successful. More uniform international application of such measures will increase competition, increase market size and strengthen national deployment efforts.

REmap analysis has also revealed that planning and permitting practices vary widely among countries. Streamlining such practices frequently offers the prospect of significantly accelerated renewable energy uptake, as inconsistency or obstacles in this area are a source of project development risk and potential cost overruns.

Another important element to create an enabling environment for the deployment of renewables is to ensure a level playing field with conventional counterparts. Yet in many countries, this is not the case, and as REmap analysis shows, the cost and benefits of renewable energy are not valued adequately in current market frameworks. This is also partly because inaccurate information and misconceptions about renewable energy technologies have influenced public opinion (IRENA, 2013v).

Ensuring smooth integration into the existing infrastructure

Renewable energy technologies are part of wider supply chains or systems. Electricity transmission grids, sustainable biomass supply chains and recharging networks for electric vehicles are all examples. Governments play an important role in facilitating the roll-out of such infrastructure, which often exceeds the capacities of individual private sector players.

At the same time, major existing energy infrastructure will need to be modified to accommodate the different characteristics of renewable energy. Capital stock, age profiles and demand projections must be taken into account, so as to avoid overcapacity and ease the transition while serving the needs of consumers at an acceptable price.

The integration of large amounts of variable renewables into the power sector calls for particular attention. Best-case experiences must be applied more widely, and the full range of available strategies must be carefully considered to deal with the integration of renewables into the power system.

Unleashing innovation

As REmap analysis has revealed, certain energy applications are highly important yet have and low renewable energy potential at the present time. For example, primary iron and steel making and shipping lack obvious renewable energy solutions at scale. To achieve a more complete transition to renewables, there is a need to find specific, effective renewable solutions for these sectors. In many cases this will require thinking "outside the box" to look for alternatives that create co-benefits, such as new types of productive use, enhanced performance and increased comfort (IRENA, 2013u). Renewable energy opportunities also exist in other areas not considered here, like biomass feedstock for plastics and fibres (IRENA, 2013f, 2014b). Around 5% of all fossil fuels currently goes into such non-energy uses. Innovation includes not just inventing and deploying new machines, but also new forms of financing or enabling policy frameworks. Micro-credits or crowd financing are examples of such innovation in such fields, which can be essential to accelerate renewables deployment.

Managing knowledge of technology options and their deployment

While there has never been a more important time to invest in renewable energy technologies, reliable information about them remains scarce. The debate on renewables is all too often fuelled by misconceptions and inaccurate data, and greater efforts are needed to improve the knowledge base. IRENA initiatives like the work aiming to build and consolidated public support for renewables, and the Renewable Costing Alliance, which compiles information on real-life project costs, are intended to strengthen this effort. Through the Global Renewable Energy Atlas, which provides resource-assessment data and is contributing to the development of methodology for accurate statistics gathering and analysis, IRENA is assisting in making authoritative data and information widely available (for both modern renewables and traditional biomass).

Societal acceptance and global awareness of renewable energy options will create increased focus and pressure on outside actors to push for the systematic integration of renewables. Societal and political will, nurtured by international co-operation and facilitation, can create an environment in which the mistakes and successes of all contribute to building a stronger, cleaner future for all. IRENA has proposed a multi-stakeholder global coalition for a concerted and innovative effort to develop clear messaging to improve social acceptance of renewable energy.

International cooperation for deployment at scale

As national policy makers work to ensure that the right policies and financing are in place, that markets are stimulated and accessible, and that technological innovation is nurtured, countries are increasingly exploring new modalities of international cooperation to find sustainable energy solutions to meet their growing energy needs without negatively affecting the climate system. This cooperation is critical to attain the goals of REmap 2030.

REmap 2030 analysis shows that development and deployment of renewable energy technologies cannot be contained within national borders. The deployment of renewable energy technologies in one country will have an impact – through energy prices, technology learning, externalities and finance flows, for example – on the deployment of renewables elsewhere. At the same time, renewable energy technologies are products in themselves; they use resources, components and manufacturing capabilities contributed by multiple countries.

International co-operation is therefore vital to advance the deployment of renewables and ensure that countries meet their energy needs while reaping the benefits of sustainable solutions that renewable energy provides. While this co-operation may take many forms, priority must be placed on those areas where the impact of such co-operation would be the greatest.

Deployment at a scale that would both affect the cost of technologies and stimulate private investment requires cross-border and regional co-operation. Despite the existence of funds invested in renewables, there is a significant lack of investment in cross-border and regional initiatives. For example, development banks invested a total of USD 60 billion in renewable energy in 2012 – more than half of their total investments in clean energy – but the bulk of this came from regional or national banks investing in national projects. Less than USD 10 billion represented North-South or South-South investments in renewables (BNEF, 2013).

Yet, given natural resource restrictions and the global interdependencies of investments, international co-operation to maximise renewable energy potential at regional levels is not just desirable, but absolutely essential. IRENA is supporting regional initiatives in Africa, Central America, Central and South Asia, Southeast Europe and the Middle East and North Africa to create regional Clean Energy Corridors, intended to utilise the potential of abundant renewable energy sources to meet growing energy needs and increase access to modern energy services. Regional co-ordination of policy initiatives, along with ensuring that trade in both resources and experience grows along with renewable energy markets, can help to attain the necessary economies of scale.

Electricity grid interconnectors exemplify the benefits of international co-operation, with both exporting and importing countries benefiting from increased renewable energy use. IRENA analysis (IRENA, 2013w,x) highlights the importance of interconnectors in the African context to spread the benefits of large renewable-resource potential in different regions of the continent. Trade in renewable power could account for 15-20% of the power supply in West Africa and Southern Africa, the analysis shows. Electricity exports from the Grand Inga project in the Democratic Republic of the Congo alone could reduce average regional power generation costs in the Southern African power pool by nearly 10% in 2030.

Bioenergy trade is also important. Based on the REmap analysis, international bioenergy trade could account for 20-35% of total bioenergy demand in 2030. The economic value of global biomass trade flows would be in the range of USD 100-400 billion. This trade poses a significant business opportunity, but it requires a widely applied, uniform framework to ensure sustainability and the development of the necessary logistical infrastructure.

Spurring global co-operation and exchange of best practices

For countries at an early stage of development and/or deployment of particular renewable energy options, international co-operation provides an opportunity to learn from the experience already acquired and assessments already taking place in other countries. At the same time, governments with a track record in certain renewable energy options can use this experience to support the development of new markets in other countries. Governments can assist each other in relieving some of the national barriers that impede renewable energy deployment.

There is a significant lack of investment in cross-border and regional initiatives.

International co-operation can play a key role in strengthening national renewable energy plans, both in the REmap countries and beyond. Specific areas of co-operation include best-practice analysis and documentation of conducive and credible policy frameworks, including streamlined planning frameworks, targets and deployment policies. Sharing input from research institutions and other international knowledge hubs in the creation of national renewable energy plans can be of help.

IRENA as the SE4ALL renewable energy hub

As the only global intergovernmental organisation dedicated solely to renewable energy, IRENA is uniquely positioned to advance the aspirational goal of doubling the share of renewables in the global energy mix (Roehrkasten and Westphal, 2013). The SE4ALL initiative launched in early 2012 represents an opportunity to influence the global debate and promote renewable energy to a new range of stakeholders, as well as to share IRENA's agenda and priorities through the SE4ALL network. IRENA has been entrusted with the role of SE4ALL's Hub for Renewable Energy.

IRENA will engage with those who have made specific commitments to renewable energy, both within the initiative and in the context of different SE4ALL High Impact Opportunities (HIO), on issues related to its own programmes, such as studies on islands, cities, off-grid lighting and the water-energy-land nexus. Close co-operation with other SE4ALL hubs, as well as with the Global Facilitation Team, will be central to this role. IRENA will work closely with regional banks to ensure synergies and complementarity of effort with IRENA's activities in each region. A formal framework of co-operation will be established with the World Bank, an SE4ALL Knowledge Hub, to leverage respective strengths in the area of renewables. In partnership with the SE4ALL Energy Efficiency Hub in Denmark, IRENA will promote the necessary and inseparable link between renewables and energy efficiency.

Another important area of future work, which this roadmap exercise has highlighted, is to pursue a more detailed assessment of the potential of sustainable biomass.

In the course of 2014-2015, IRENA will create REmap Action Teams, bringing together interested countries and other stakeholders to work together under the REmap 2030 umbrella on specific issues, such as transportation, joint strategies for renewables and energy efficiency, and other areas that could have a transformative impact on the deployment of renewables. IRENA will also expand the range and scope of its technological, geographic and topical work to provide a sound knowledge base for efforts to provide sustainable energy for all.

Another way IRENA will expand its work is to engage in deeper analysis for the 26 countries encompassed by REmap studies to date, as well as to broaden the scope of countries included in this global roadmap exercise.

In doing so, it is hoped, we can advance IRENA's mandate – adopted by founding members in 2009 and embraced by over 160 participating countries to date – to promote the widespread and increased adoption and sustainable use of all forms of renewable energy to ensure a sustainable energy future for future generations.

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List of Abbreviations

CAGR	compound annual growth rate
CHP	combined heat and power
CO_2	carbon dioxide
COP	Conference of the Parties
CSP	concentrated solar power
DH	district heat
EE	energy efficiency
EJ	exajoule
EU	European Union
EV	electric vehicle
GEA	Global Energy Assessment
GJ	gigajoule
Gt	gigatonne
GW	gigawatt
HIO	high impact opportunities
IEA	International Energy Agency
MW	megawatt
NREAP	National Renewable Energy Action Plan
OECD	Organisation for Economic Co-operation and Development
PHEV	plug-in hybrid electric vehicles
PJ	petajoule
ppm	parts per million
TFEC	total final energy consumption
TWh	terawatt-hour
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USD	U.S. dollars
WBA	World Bioenergy Association
WEO	The International Energy Agency's World Energy Outlook report
WWF	World Wide Fund for Nature

Glossary

Exajoule	One quintillion (10^{18}) joules.
Final energy	Energy in the form it reaches consumers (such as electricity from a wall socket).
Gigajoule	One billion (10^{9}) joules.
Gigatonne	One billion (10^{9}) tonnes.
Gigawatt	One billion (10^{9}) watts.
Joule	A unit of measurement for energy, equivalent to one watt of power for one second.
Megawatt	One million (10^{6}) watts.
Petajoule	One quadrillion (10^{15}) joules.
Primary energy	A source of energy before any conversion has taken place, such as crude oil and lumps of coal.
Reference Case	In this study, the business-as-usual case under current policies and governmental plans.
REmap 2030	The name of this study and the collective outcome of the Reference Case and REmap Options.
REmap Options	The additional growth of renewables on top of the Reference Case.
RE+ Options	The additional growth potential on top of REmap 2030.
SE4ALL	Sustainable Energy for All, the UN Secretary General's initiative for global access to sustainable energy.
Terawatt-hour	One trillion (10^{12}) watt-hours.

Country Findings

Australia: Renewable energy can comprise more than one-fifth of the country's TFEC by 2030, with a mix of solar PV (half rooftops, half utility), onshore wind and biomass (half biofuels, half heat applications). Uptake of renewables in the power sector is progressing faster than planned, particularly in rooftop PV. Renewable energy policy is under revision with the change of government in September 2013. Important policy initiatives also exist on the state level.

Brazil: Today, Brazil has the highest renewable energy share among the large economies. According to national plans, the country's renewable energy share will remain at the current level of 40% of TFEC, but with REmap Options it can go beyond 50%. Brazil would account for one-fifth of the global liquid biofuels demand, and its power generation would be almost 100% renewables. Very-low-cost wind has been added in recent years through a successful auctioning scheme.

Canada: Canada has abundant renewable energy resources, and renewables can account for one-third of Canada's TFEC by 2030. Biomass-fired industrial CHP plants can double the sector's renewable energy share, and a wide portfolio of renewable energy technologies would account for three-quarters of the country's total power generation. Important policy initiatives exist on the state level.

China: China would account for 20% of total global renewable energy use if all REmap Options worldwide were implemented, and for a similar magnitude of the total installed capacity of the different renewable energy technologies. China's engagement is critical in order to meet the doubling of the global renewable energy share objective. Objectives for solar PV and wind capacity additions have been raised recently to 10 GW and 15 GW per year, respectively. Air pollution is a major driver, along with industrial development policy and rising oil import dependency.

Denmark: Denmark represents the best practice in renewable energy deployment, in terms of both its policy environment and target setting. The country aims to reach a 100% renewables share by 2050 with renewable electricity combined with district heating, liquid fuels and gas, and complemented by extensive energy savings. Over the shorter term, the conversion of coal CHP to biomass CHP is a unique feature of the Danish transition.

Ecuador: Already, renewable energy accounts for more than 70% of Ecuador's power generation. The sector's renewable share could near 85%, mainly with additional hydropower and other renewable energy technologies. With a higher share of electricity use in the end-use sectors, the country's share of renewable energy in TFEC could be raised further.

France: France already has an ambitious goal for 2020: to reach a 23% share of renewables in its gross final energy consumption. This means building 840 PJ of renewable capacity in both the heating and power sectors. France is also the second-largest producer of bioethanol and biodiesel in Europe. Looking further ahead, after a national debate on energy transition, the French government is preparing a new long-term energy bill, to be adopted by the end of 2014. The precise trajectories and scenarios will be determined afterwards, also taking into account the future, post-2020 European energy and climate framework.

Germany: Germany's Energiewende ("Energy Transition") initiative has a long term target of achieving an ambitious share of 60% renewable energy in final energy consumption by 2050. The country plans to achieve this target with aggressive renewable energy deployment in the power and district heat sectors, including novel uses of solar thermal and heat pumps in district heat generation. Along with Denmark, it will be one of the major countries to deploy offshore wind capacity.

India: India is one of the main countries that relies heavily on traditional biomass and where a transition to modern energy services has yet to be achieved. It is also a big net importer of fossil fuels, and all end-use sectors could take up renewables. In industry, some biomass-fired technologies are already deployed (*e.g.*, gasification) and could be used more widely along with other medium- and high-temperature process heat technologies such as CSP. Solar PV, CSP and biogas power are being rolled out to meet rapidly rising electricity demand, with remarkably low costs being achieved in some projects.

Indonesia: Because of Indonesia's large size and hundreds of islands, a significant share of the country still lacks access to modern energy, including electricity. Electricity demand is projected to grow more than five-fold between now and 2030. Important efforts exist to electrify remote communities and islands using renewables. Expansion of geothermal power is being pursued, but additional efforts are needed to meet

REmap 2030 - Summary 50

targets. Uptake of solar PV is just starting. Indonesia is already the largest producer of palm oil worldwide, and biomass offers opportunities for all sectors of the country, provided that it is sustainably sourced. Abatement of high energy subsidies is a policy priority.

Italy: Already in 2011, Italy surpassed its EU binding target of 26% renewable energy in final energy consumption within the power sector and in 2012 the renewable energy share was 27.1%. On June 2013, for two hours, the cost of energy in the Italian Energy Market has reached the quote of ZERO in the whole territory of the country. Renewable energies covered entirely the energy demand all over Italy, cutting down the cost of energy until the quote of zero was reached. The country is developing a number of innovative smart grid solutions to support even higher shares of variable renewables into the power sector.

Japan: Given uncertain nuclear plant prospects and high gas prices, Japan has put in place an ambitious renewable energy policy. This policy is delivering. In addition, as of July 2013 more than 4 GW of new renewable power was in operation. In order to accelerate growth, Japan will continue to steadily implement this policy, together with efforts for deregulations and grid enhancements.

Malaysia: The government is already pushing for increased use of renewable energy through targets and by establishing an organisational structure to facilitate the targeted growth. To a large extent, these targets can be fulfilled by the large biomass resource of the country. A feed-in tariff scheme has been put in place, but high energy subsidies present an obstacle for renewable energy uptake.

Mexico: The country's energy policy was fundamentally re-designed at the end of 2013, and a progressive policy has been put in place to accelerate renewable energy growth in the power sector.

Morocco: Morocco is one of the most energy import-dependent countries in the region. To reduce this dependency and benefit from socio-economic aspects of renewables, the country has ambitious plans for the year 2020 to use CSP, solar PV and wind technologies. Future export of renewable power to Europe could be hindered by transmission capacity limitations.

Nigeria: Nigeria today meets nearly 65% of its energy demand from traditional biomass. It is one of the most challenging countries in terms of meeting the objective of modern energy access, in particular because energy demand is growing very fast. The developments and experiences which are being achieved in Nigeria will be important examples for the greater Africa region, in terms of both modern energy services and the uptake of renewable energy.

Russia: Russia has a wide range of renewable energy resources, such as biomass and geothermal, but the country's tremendous land area creates difficulties in deploying these potentials. Coal and natural gas use in Russia's large district heat sector could be substituted with biomass, and additional sectors could benefit from the large biomass resources available, raising the country's renewable energy share further. The country's first renewable energy power auction was held in 2013, and exports of biomass commodities such as pellets are growing. Important initiatives are taking place on a regional level that supplement national efforts.

Saudi Arabia: the Kingdom's dynamic economic and population growth have spurred the local demand for electrical power. Historically, the Kingdom has satisfied local power and desalinated water demands through the use of its plentiful, but non-renewable, hydrocarbon resources. The Kingdom has begun an ambitious all-encompassing approach towards a sustainable energy mix that emphasizes education, research, global collaboration, local integration, commercialisation and social benefit. This ambitious strategy positions the Kingdom to not only implement the world's largest renewable energy projects but to also export the resulting expertise and developed technologies globally.

South Africa: Although South Africa is a major coal producer and consumer, the power supply crunch in recent years has served as a wake-up call, and the country has rolled out an ambitious renewable energy policy. This includes wind and solar power investments, as well as hydro imports. In combination with solar thermal for water heating and different forms of biomass and waste (including landfill gas), these measures have the potential to nearly triple the renewable energy share by 2030.

South Korea: South Korea imports 96% of its energy, and industry is a key player in the country's economy, accounting for 61% of total energy consumption. To enhance energy security and reduce GHG emissions, South Korea has not only been increasing deployment of renewable energy, but also developing renewable energy industry as a new economic growth engine. As a result, the Korean manufacturing sector is producing innovative renewable energy technologies and is planning to become one of the largest exporters of green technologies in the world. Korea will be releasing a new national renewable energy plan in 2014.

Tonga: The Tonga Energy Road Map (TERM) is a proven framework for energy transition. In other Pacific islands, the recent price slide of solar PV has resulted in a pipeline of new projects, and grid stability and electricity storage have come to the forefront as renewable energy integration issues.

Turkey: The country aims to raise its solar, wind, biomass and geothermal capacity and also to deploy its technical hydro potentials in its power sector to ensure energy security. A considerable share of its building stock will be renewed within the next two decades, which creates a large potential for integrating renewables; in general, however, new renewable energy policies are required to increase renewables use in end-use sectors.

Ukraine: Ukraine is dependent on natural gas imports, and its energy intensity is higher than in most other economically developed countries. The country could be an interesting illustration of how SE4ALL objectives for both energy efficiency and renewables can be met, as potentials for both are large. For renewables in particular, biomass, solar thermal and wind offer potentials for both end-use and power and district heat sectors.

United Arab Emirates: The UAE foresees abundant RE potentials of mainly solar and can considerably increase the renewable energy share in its energy mix. For example CSP can be used to generate industrial process heat (including in petroleum refining) and for power generation. The UAE is a leader through funding, development and operation of projects globally, using MASDAR and Abu Dhabi Fund for Development (ADFD). The UAE hosts the IRENA headquarters.

United Kingdom: The United Kingdom has some of the best wind and marine energy resources in the world and is promoting the deployment of these technologies through a range of innovative policies. Biomass is imported on a significant scale and used for co-combustion, with Drax being the largest plant of this type in the world. The United Kingdom has clear plans to support future biomass deployment. The United Kingdom is well placed to meet EU renewable energy targets, and has a robust package of financial support and other policy measures in place to help ensure its achievement.

United States: The United States has tremendous renewable energy potentials, but these vary greatly by region given the size of the country. It has one of the largest geothermal and wind resources and also is developing novel forms of hydro that have low environmental impact. The United States is also a test-bed for transport sector technologies, such as hydrogen, battery electric and hybrid systems, and has innovative projects for advanced biofuels. Policies at the state level, rather than the federal level, are driving renewables deployment, and some states are world leaders in renewable energy deployment.

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REmap 2030

The world can double the share of renewables in its energy use by 2030. REmap 2030, a renewable energy roadmap, is the first study of global renewable energy potential to be based on data from official governmental sources. Prepared by the International Renewable Energy Agency (IRENA) in consultation with governments and other stakeholders worldwide, the roadmap encompasses 26 countries representing three-quarters of current energy demand. In determining the potential to scale up renewables, the study not only focuses on technologies, but also on the availability of financing, political will, skills, and the role of planning.

The study finds that doubling of the share of renewable energy in total final energy consumption by 2030 would be nearly cost-neutral. When external costs that can be avoided by replacing conventional energy are taken into account, this ambitious transition even results in cost savings.

Nor is the proposed doubling an absolute limit; the world can increase the share of renewables much further, but policymakers need to make preparations for this long-term transition today. This has to start by providing investors in the sector with clear guidelines for the transition to a future driven by renewable energy.

This REmap 2030 summary presents the main findings and charts, while directing readers to the REmap 2030 web portal (**www.irena.org/remap**), which presents extensive background documents. The study will continue to be updated in the years to come, as new countries join the process and as the data for all REmap countries becomes available.

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