G20 Deployment of Renewable Energy

Summary

The Group of Twenty (G20) Energy Sustainability Working Group (ESWG) has requested the International Renewable Energy Agency (IRENA), in close cooperation with the International Energy Agency (IEA) as well as with the Energy Charter, the Global Bioenergy Partnership (GBEP), the International Energy Forum (IEF), the Organization for Economic Cooperation and Development (OECD), the Organization of the Petroleum Exporting Countries (OPEC), and the World Bank (WB) as well as other regional organizations, to develop a report, which may result in a G20 toolkit of options on renewable energy deployment. It focuses on the following subjects, which are divided into chapters:

Fossil fuel price fluctuations and their impact on renewable energy deployment - The recent steep fall in oil prices has prompted questions about the competitiveness of renewables. This chapter explains why the recent drop in oil prices is expected to have a limited impact on renewable energy deployment. It considers what these changes mean for the electricity, heat and transport sub-sectors.

Options for renewable energy deployment in G20 – The role of renewable energy is expected to grow in the future. IRENA's REmap 2030 programme explorative approach characterizes country and sector specific options for renewable energy deployment considering technical and economic factors. IRENA has found that renewable energy's share in the global energy mix can double between 2010 and 2030. The G20 countries hold 75% of total global deployment potential and a similar share of the total global investment potential for renewable energy between now and 2030. The interested G20 countries can take part in review and use of these findings to support their deliberations on renewable energy.

Innovation needed for accelerated renewable energy deployment - A better understanding of the reasons why technology costs vary in G20 countries may result in significant cost savings. The G20 may consider possible national approaches and options for innovation based on research and development, enabling an infrastructure accelerated renewable energy deployment and a bridging of the gap between technology development and deployment. That learning process would be improved by the increased sharing of relevant information between interested G20 countries, for example in the area of technology and systems integration cost.

Accelerating renewable energy deployment: risk mitigation mechanisms – Financial risk mitigation instruments and approaches can help address some of the risks that prevent renewable energy investments from being viable and sustainable. Innovative financing structures, such as loan and power purchase agreement (PPA) guarantees or mezzanine finance can reduce the cost of financing. The interested G20 countries may consider the design of a renewable energy-specific risk mitigation mechanism addressing the risks and barriers to renewable energy investments in emerging markets.

Sharing national practices and experiences in policy design - Sharing best practices in policy design can help the G20 countries in building their own policy frameworks to facilitate investment. The IEA-IRENA policy database, IRENA and IEA's in-depth assessments of enabling mechanisms and OECD policy guidelines may inform the dialogue. International cooperation efforts to promote favourable investment climate and removal of regulatory barriers – including for example activities under the IEA, OECD, the United Nations Conference on Trade and Development (UNCTAD) - can strengthen market confidence in the renewable energy sector.

Based on the findings in this report and in line with points 7 and 8 of the G20 Principles on Energy Collaboration, four main options have been identified for **G20 consideration:**

1. Identify and quantify concrete renewable-energy technology options for interested G20 countries and suggest cooperation opportunities to facilitate their deployment.
2. Strengthen renewable energy innovation (grid integration, modern bioenergy deployment, technology cost information).
3. Promote renewable energy investment using financial risk mitigation instruments, and support developing countries through a renewable energy specific risk mitigation mechanism.
4. Share national best practices and experiences in policy design that can facilitate renewable energy investment.

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1. Introduction

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

Energy Sustainability is one of the key themes for the Group of Twenty (G20) under the Turkish presidency[1]. In November 2014, the G20 leaders adopted nine principles for energy collaboration. Three are closely connected to renewable energy as one of the clean energy technologies:

- Ensure universal access to affordable and reliable energy (1);
- Support sustainable growth and development consistent with our activities and commitments to mitigate climate change, including by promoting cost-effective energy efficiency, renewables and clean energy (7);
- Encourage and facilitate the design, development, demonstration and widespread deployment of innovative energy technologies, including clean energy technologies (8).

The G20 *Energy Sustainability Working Group* (ESWG) has requested the International Renewable Energy Agency (IRENA), in close cooperation with the International Energy Agency (IEA) as well as with the Energy Charter, the Global Bioenergy Partnership (GBEP), the International Energy Forum (IEF), the Organization for Economic Cooperation and Development (OECD), the Organization of the Petroleum Exporting Countries (OPEC), and the World Bank (WB) as well as other regional organizations, to develop a toolkit of options to accelerate renewable energy deployment. The analysis does not necessarily imply an endorsement of the content presented within this paper by all organizations and/or G20 countries.

There is no one-size-fits-all solution for embracing renewables. A toolbox is needed that countries can draw on to develop their own customized renewable energy policies in accordance to national circumstance and sustainable development priorities. The development and promotion of such a toolbox by the G20 could lead to a wider deployment of best practices in policy design, innovations that broaden the renewable resource base and technical deployment potential, and reduce the cost of financing for renewables projects.

Global renewable energy use has grown to account for more than 18% of total global final energy consumption (TFEC)[2], and IRENA's global renewable energy roadmap (REmap) suggests a roadmap how this share could be doubled by 2030. G20 member countries account for the bulk of current use, hosting 80% of existing renewable power generation capacity around the world. The G20 countries provided 82% of renewable capacity additions worldwide in 2013. In 2014, more than half of new power generation capacity installed in G20 countries was renewable. The G20 is therefore crucial to the promotion of global energy market stability and economic growth, as G20 countries have national and

[1] The 2015 G20 agenda is built on three pillars: (i) Strengthening the Global Recovery and Lifting the Potential; (ii) Enhancing Resilience; (iii) Buttressing Sustainability. Energy sustainability is covered under the third pillar of the agenda (G20, 2014).

[2] The World Bank (2015), Global Tracking Framework 2015. May 2015. The World Bank, Washington, DC.

multinational programmes in place to accelerate renewables deployment. An important opportunity exists to strengthen engagement within the G20 framework.

The goal of this paper is develop a toolkit of options to reduce the cost of renewables and accelerate their deployment through the joint initiatives of interested G20 countries in specific areas, also taking into account the recent fall of oil prices. G20 collaborates with other international (*e.g.* International Monetary Fund) and regional organizations (*e.g.* Association of Southeast Asian Nations, African Union) as well as other stakeholders. Through these joint initiatives, G20 plays a strategic role to contribute to global policy issues.

Chapter 2 discusses the fossil fuel price fluctuations and their impact on renewable energy. Chapter 3 quantifies the potential, cost and benefits of renewable energy technology options for the year 2030. The findings from this chapter point to three areas where more focus on innovation need is needed. These areas are discussed in three separate chapters: variable renewable energy integration in the power sector (Chapter 4), sustainable biomass (Chapter 5), and costs of renewables (Chapter 6). Chapter 7 shows how risk mitigation can contribute to accelerating investments in renewable energy. The role of best practices in policy design in facilitating renewable energy investment is discussed in Chapter 8. This paper provide four options for G20 consideration in Chapter 9.

2. Fossil fuel price fluctuations and their impact on renewable energy deployment

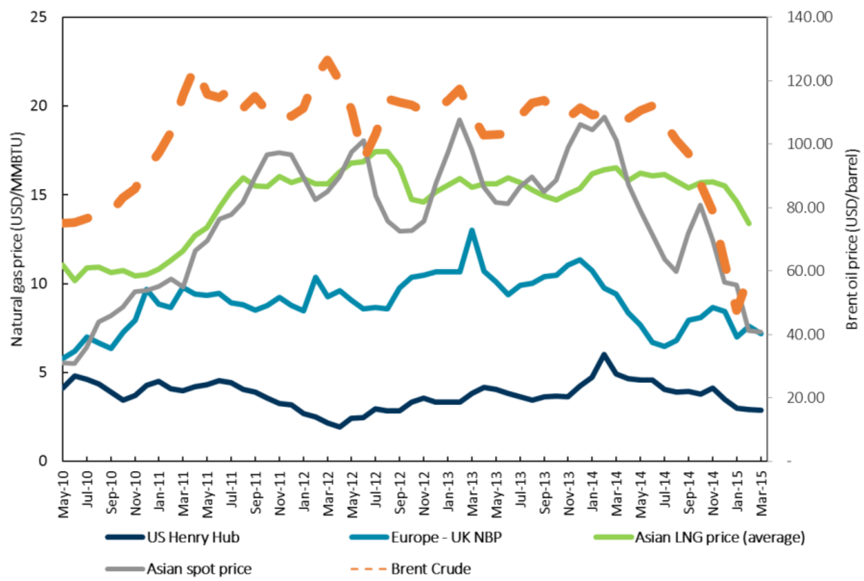
The recent steep fall in oil prices has prompted questions about the competitiveness of renewables. This chapter discusses what the changes in fossil fuel prices would mean for renewables use in the electricity, heat and transport sub-sectors.

Commodity prices are fundamentally volatile. The price of crude oil has fallen sharply since June 2014. As of February 2015 oil prices were half what they averaged from 2011 to 2014, and such declines and subsequent rebounds are a basic trait of commodities. Such a drop is not unprecedented -- corrections of that magnitude have been seen in the market at roughly ten-year intervals since the 1970s. Analysis from the IEA (IEA, 2015a) and OPEC (2015) suggests that the recent fall is a consequence of high levels of supply (particularly from non-OPEC producers) and lower growth in demand, as the pace of economic expansion in China has slowed and the global economy is becoming less fuel intensive.

International gas prices are affected by a number of factors including regional supply and demand trends, the availability of gas by pipelines and the global market for LNG, which has led to wide regional differences in gas prices. Oil markets are among the multiple factors determining gas prices. Gas prices in some regions have also fallen sharply during 2014/15 due largely to changes in the supply/demand balance. Figure 1 illustrates the changing pattern of regional gas prices along with oil price trends, showing that the gas price reductions in Asia preceded the oil price fall.

The link between oil and coal prices is weak. Crude costs are a factor for coal miners but the commodity has its own supply and demand factors that are the main contributor to pricing. Coal prices are currently at historically low levels because of diverse and ample supplies as well as slowing growth in demand, particularly in China.

Figure 1: Recent gas price trends in the US, European and Asian markets



Source: IEA Analysis

Direct price competition between fossil fuels and renewables depends on fuel type and market segment. For example, the specific impacts of crude prices on renewables will differ from sector to sector because renewables options compete with different fossil fuels across them. Worldwide only less than 5% of electricity is produced from oil. Its share is high mainly in some Middle East, Latin-American and Sub-Saharan Africa countries, as well as Indonesia, Pakistan, and many islands. Direct competition with renewable electricity is therefore limited.

In transport sector, cheap oil will not affect deployment of biofuels on the short-term since their use is predominantly mandated, such as in Brazil, Europe and the United States (US), but it will affect economics. The long-term outlook for liquid biofuels would therefore be negatively affected by a prolonged period of low oil prices.

The use of renewables in the electricity sector is dependent on its end-use as replacement for existing sources of electricity, or as an electrification solution. In the case of the former, the falling cost of technologies has already made renewables competitive. This is the subject of analysis in this paper. But, deployment of renewables as an electrification solution for those consumers who do not have access to the grid, the challenge is deeper. Due to intermittent and variable nature of this source, the consumer needs back-up either through a battery or grid based supply as a stand by. In such cases, the cost of renewables goes up and becomes un-competitive.Renewable energy projects can help to diversify any investment portfolio, especially in the light of the enhanced competitiveness of renewables caused by falling cost for technologies such as solar and wind power generation. Investors and policy makers must factor in future competitiveness into their strategies today and the hedging value of renewables with very low operating costs by comparison with price-volatile fossil fuels. In the short-term, renewables growth in a number of markets will be protected by policy measures, such as renewable-electricity production targets or quotas and blending quotas for biofuels. Over a longer time horizon the prospects for renewables solutions will largely depend on their economic competitiveness compared with fossil fuel options, and on the extent to which countries are willing to continue policy support if there is a long period of low fossil fuel prices.

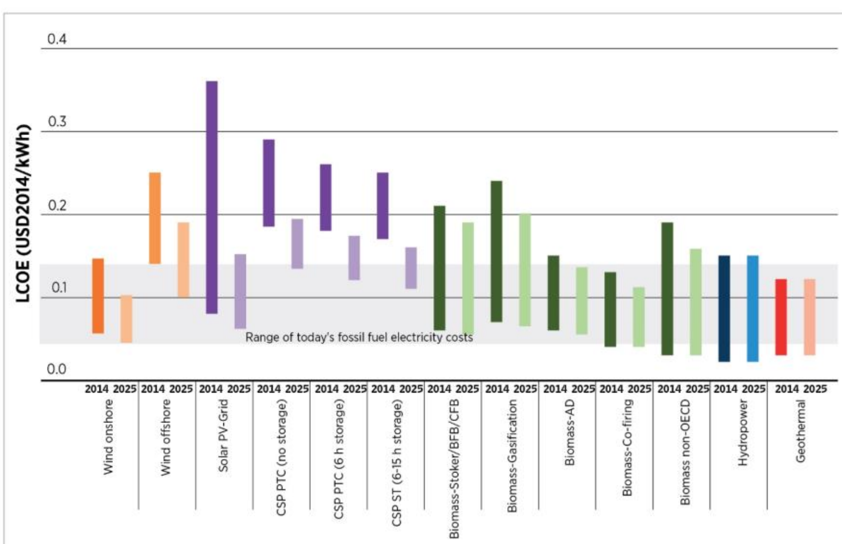
2.1. Renewable electricity

Around 40% of global electricity production is based on coal. 22% is from renewables (including hydropower), another 22% is from natural gas and 11% from nuclear. Some 4% of global electricity production is generated using oil. Coal and gas are more significant direct competitors for renewables generation.

Recent analysis by IRENA and IEA shows that renewables generation can be increasingly competitive with new fossil fuel generation where conditions are favourable (Figure 2). Renewables electricity production costs have been falling rapidly in recent years (especially for wind and solar photovoltaic, or PV). This has been driven by falling technology cost as well as rising investor confidence, which has reduced the financing costs for renewables. Within G20 countries, some recently commissioned wind power generation projects have contract prices below 50 US Dollars per megawatt-hour (USD/MWh) and some commissioned solar PV projects have been contracted below 70 USD/MWh. Even lower prices have been observed for some future projects that will come online in 2016/17 outside G20.

At these low generation prices renewables can compete on a full cost basis with new gas or oil generation at all but the lowest current fuel prices. It should be remembered that generation costs for renewables are determined over the project lifetime by the initial costs of capital and costs of financing since no fuels are used (biomass-based power generation being an exception). The capital costs for wind and solar PV are likely to continue to decline in the future. The costs of gas and oil generation are largely determined by the fuel costs. Market will be the main driver for oil and gas price developments. Renewables would remain cost-competitive compared to oil and gas prices that would remain close to or below today's levels not just in the short term, but over the next 20-25 years, the economic lifetime of these plants. If the costs of storage solutions were accounted for as part of electrification, cost-competitiveness of renewables for power generation would be less cost-competitive.

Figure 2: Cost-effectiveness of renewable energy solutions



Source: IRENA (2015a)
Note: Options are evaluated at a weighted average capital cost of between 7.5% and 10%.

Governments wishing to develop renewables as a low cost generation source should therefore continue to put in place policies that create market conditions that ensure long-term, stable revenue streams for investors, in order to reduce the cost of financing, and also foster competition and innovation.

2.2. Renewable heat

Around 20% of global oil supply and 40% of gas is used to provide heat for industry and buildings (IEA, 2014b). Coal is used to generate heat in energy-intensive industries such as steel, cement, and ceramics production.

Oil used for heating purposes has dropped in price alongside crude oil, with specific costs depending on the type of fuel (heavy fuel oil for industrial use, light fuel oil for commercial and household use), location, and taxation regimes.

Renewable sources of heat - bioenergy, solar and geothermal – are alternatives to fossil fuels. The opportunities and costs for producing renewable heat are location specific and depend on the quantity and quality of the resource. Options such as biomass heating and solar heating can be cost competitive with other energy sources, under the right conditions when capital costs are factored in.

In addition to costs, there are also non-economic barriers to deployment of renewables for heating which need to be tackled by policy and regulations that are based on national circumstances and priorities. There are also technical barriers (*e.g.* access to geothermal resources, limited space availability of space for solar heating, technical issues related to the use of biomass in large-scale blast furnaces for iron production). But the share of modern renewables in the heating market is still low. Renewable heat policies are often not given as much attention as those for electricity: about 50 countries have renewable-heat policies in place whereas more than 120 have established them for electricity.

2.3. Biofuels in the transport sector

Biofuels currently provide some 4% of road transport fuel needs. Of that total 80% is bioethanol, with production and use concentrated in Brazil and the US. Other countries which consume biofuels are mainly the OECD countries and several non-OECD ones where there is abundance of sugarcane cultivation and oil palm oil plantation. In most parts of the world, availability of agricultural land is limited and there is pressure on land resources for production of food crops or oil seeds to meet the growing demand for food. This limits the scope for biofuels in most developing countries.

In general, falling oil prices could undermine the economics of conventional biofuels. However, falling oil prices can also lead to reduced agricultural production costs to the extent that fuel and fertilizer prices drop. Production costs are controlled by short-term feedstock dynamics as well as investment in new plants and feedstock supply chains. In recent years feedstock costs have fallen as dramatically as oil prices have, because of good harvests in key regions. Low oil prices also reduce costs for fertiliser, harvesting, and transport.

However, these cost reductions have not been enough to compensate for the drop of fossil fuel prices in the US, where currently corn ethanol is not competitive with gasoline. In addition, long-term supply growth will depend on continued investment in biofuels plants and feedstock supply. Such growth may be difficult in Brazil, for example, where the ethanol industry has struggled financially in the face of thin production margins and rising costs for labour and land. On the other hand, some countries are taking advantage from low oil prices to phase out fossil fuel subsidies (e.g. Indonesia) or increase taxes on gasoline (*e.g.* in Brazil), thereby increasing the attractiveness of biofuel alternatives.

The development and production of advanced biofuels (produced from lignocellulosic biomass, waste, residues) which in the longer term are necessary to reduce the overall GHG footprint of the transport sector, has progressed in the last few years thanks to a number of commercial plants beginning operation and demonstrating in the process that production at scale is feasible. The output from these first plants is not yet financially competitive with fossil-based transport fuels, or with conventional biofuels and there are still a number of technical challenges to be resolved, however there is evidence that with more of these plants in existence, costs could be reduced through expertise and efficiency gains. In developing countries, the technology for crops relevant for advanced biofuel production (rice and wheat straws, and cotton-based biomass) has received limited R&D focus. Global progress will depend on a supportive policy framework which allows the next generation of plants to be built and operated. Policy support could come from creating quota for such fuels (Italy has recently announced a 1.2% advanced biofuels blending requirement, set to increase to 2% by 2022) and providing loan guarantees. However a prolonged period of low oil prices could reduce the impetus for reform, delay positive measures and lead to the abandoning of projects.

2.4. Conclusions

Renewables are increasingly competitive. Overall, the stability and predictability of policy and market frameworks are key factors influencing for investment in renewables. Fossil fuel prices and GHG emission policies depending on countries national circumstances would to large extent determine the optimum balance between renewable and fossil fuel energy sources in future. There is no need for immediate action, but it is important to ensure market signals are aligned with policy priorities and investment decisions today take into account fossil fuel price volatility. There is also a need to undertake a deeper analysis with regard to the adoption of renewable energy technologies as a solution to electrification of nearly 1.1 billion people that has today no access to electricity. The cost-competitiveness of substituting conventional electricity generation technologies with renewables is somewhat different than the supply of electricity to the un-electrified people in view of the cost of back-up power.

3. Options for renewable energy deployment in G20

Renewable energy can play a much larger role in the global economy. IRENA has assessed options for world as a whole and for G20 member countries through its REmap 2030 programme, an explorative approach of policy and technology options. The G20 countries hold 75% of total global deployment potential and a similar share of the total global investment potential for renewable energy between now and 2030. All G20 member countries can raise their modern renewable energy share, but the potentials and economics vary by country. The interested G20 countries can take part in review and use of these findings to support their deliberations on renewable energy.

3.1. The growth in renewable energy deployment

In TFEC[3], the global share of renewables – including electricity produced from renewables – was 18.1% in 2012. Fossil fuels accounted for more than 79% of energy use, nuclear electricity accounted for 2.2%[4]. Development of the renewable energy share in TFEC was relatively constant between 1990 and 2012 underpinned by the stable and traditional use of biomass in poorer countries by about 2.9 billion people, more than a third of the world's population.

By 2012, about half of renewable energy use (9.7% of TFEC) came from traditional use of biomass, with modern renewables providing 8.4% of TFEC, including biomass use in industry and in modern heating and cooling installations, liquid biofuels, and all types of renewable electricity and heat. Renewable power generation accounted for 22% of total renewable energy use in 2013, or nearly 45% of modern renewables excluding traditional use of biomass. To date, power generation sector has experienced majority of the renewable energy capacity additions. By comparison, applications of modern renewables for heating and cooling were slower. Liquid biofuels use has grown until 2010 and since then it is following a flat trend.

Between 1 billion and 1.3 billion people in developing countries lack access to electricity. This is an indicator of an opportunity to meet significant demand in the future. Countries such as India, Indonesia and South Africa are likely to follow the path of rapid growth in energy use seen in China.

Investments in renewable energy increased from less than USD 50 billion in 2004 to USD 214 billion in 2013. Investments declined in 2012 and 2013, but the pace of new capacity development was maintained, since a large drop in solar PV costs meant that the same growth in capacity could be accomplished with less money. Investments grew again by 21% in 2014 to USD 270 billion (

[3] Energy use can be measured in different ways. One approach is to consider final energy consumption of all sectors: housing, services, industry, transport and agriculture. Electricity here is counted in terms of kilowatt-hours (kWh) consumed, not in terms of primary fuels used to generate it. This is called the total final energy consumption, the metric applied to measure renewable energy share in IRENA's REmap 2030.

[4] International Energy Agency (IEA) (2015), Energy Balances of non-OECD countries. OECD/IEA, Paris.

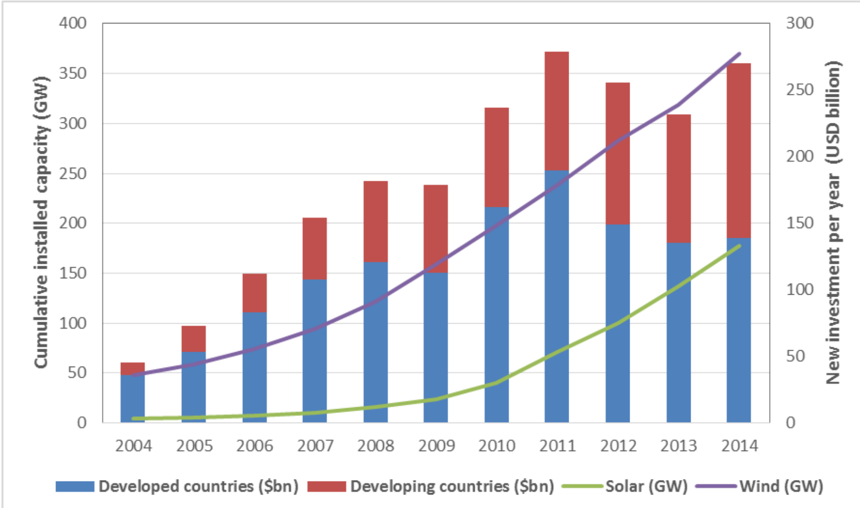
Figure 3).

The G20 represents 80% of the total global primary energy supply, and member countries also represent the bulk of the global renewable energy market.

In 2013, total installed renewable electricity capacity (excluding large hydro and pumped storage) has reached 685 GW worldwide. 560 GW of this total (more than 80% of the global total), was installed in the G20. When large hydro and pumped storage capacity are also included, total installed renewable energy capacity in the G20 countries was 1,264 GW in 2013 that is again more than 80% of the total global.

The net annual renewable power generation capacity addition has averaged 115 GW per year worldwide since 2010. Less than 30% of this total is for large hydro and pumped storage. The remaining 70% is accounted for by solar, wind, geothermal and biomass, and this share is growing. 2013 has seen an increase in capacity of about 111 GW of which 91.4 GW took place in the G20.

Figure 3: Growth of investments and installed capacity in renewable energy



Source: IRENA analysis

3.2. The outlook for renewable energy

If the global policy environment for renewables today remains constant, a rise in the global share of renewable energy in TFEC to 21% is expected by 2030.

The United Nations (UN) Secretary General has called for a doubling of the renewable energy share in the global energy mix between 2010 and 2030 as one of three objectives of the SE4All initiative. This implies an increase from 18% in 2010 to 36% in 2030, a rise of nearly 1 percentage point per year. Between 2010 and 2012, growth averaged 0.15% points per year. To meet the SE4All objective, a six-fold increase in the annual growth of renewables share would be required.

Together with experts from its member countries, IRENA has assessed the realistic potential for renewable energy technology options that can double the share of renewables in the global energy mix by 2030 compared to the 2010 level. This analysis is called REmap 2030. The first volume of this study that includes the detailed results of the countries participated in REmap 2030 was released in June 2014[5].

REmap suggest that it would be technically and economically feasible to increase the share of renewables to 36% in the global TFEC by 2030. This doubling requires the scaling up of renewables development and deployment as well as measures that enhance energy efficiency and broaden energy access.

All countries have potential to raise their renewable energy shares, but the potential varies by country and their specific circumstances and, priorities. The analysis suggests that within a G20 context, the potential renewable energy share by 2030 in REmap countries ranges from 9% in Saudi Arabia to 56% in Brazil (Figure 4). In 2010 the renewable energy shares of Australia, Japan, Russia, South Korea, the UK and the US were all below 10%. In comparison, Brazil and India were at more than 40%.

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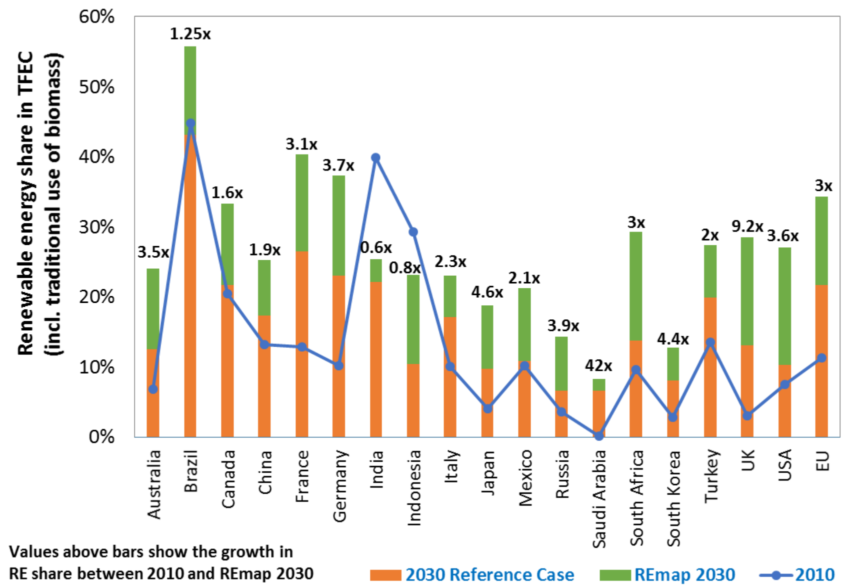
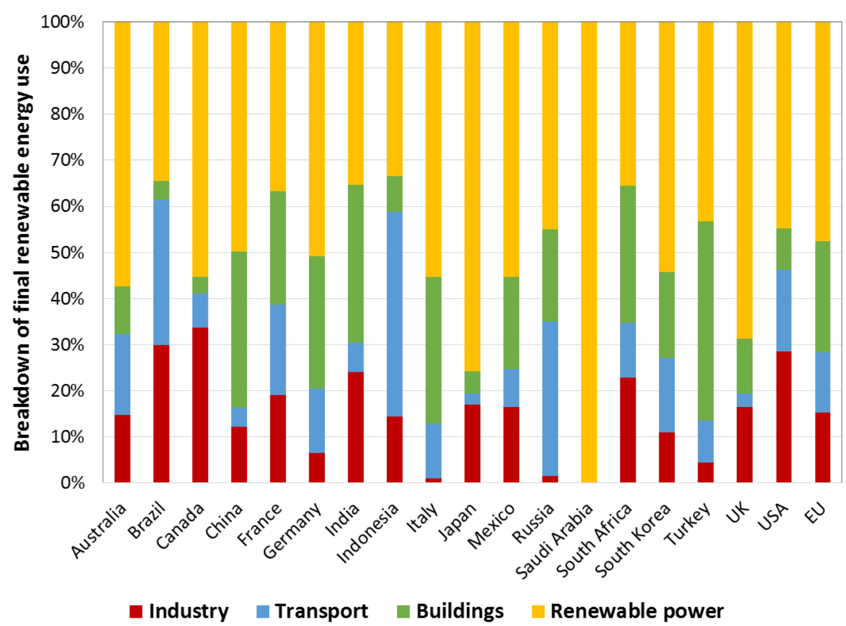
[5] Subsequently REmap country reports for China, Mexico and United States have been released. Similar reports for Germany, India, Turkey and South Africa are in preparation and reports for other G20 countries are under discussion. In cooperation with OLADE an analysis for the Latin America and Caribbean region is being prepared.

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



Source: IRENA analysis

Figure 5: Breakdown of total final renewable energy use potential in REmap 2030 in G20 countries

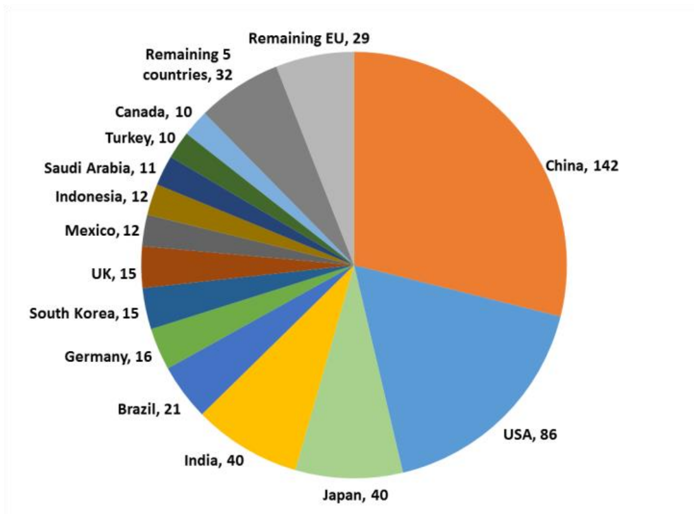


Source: IRENA analysis

Renewables have a potential for all energy use applications in varying potential. Around 40% of the 2030 global renewable energy use potential lies in power consumption from renewable sources. Around 60% lies in end-use sectors (agriculture, industry, transport, residential and commercial). In end-use sectors, it is critical to combine renewable energy with energy efficiency measures. Similar to the global share, consumption of renewable power could represent at least 45% of the total final renewable energy use in G20 countries according to REmap 2030's analysis (yellow bars in Figure 5).[6]

A doubling of the renewables share needs an estimated total global investment in renewable energy technologies of USD 650 billion per year between 2010 and 2030. The total required in G20 countries represents 80% of this total, an annual investment of USD 490 billion (Figure 6), China, the US, Japan, India and Brazil accounting for two-thirds of this total.

Figure 6: Average annual investment needs for renewables between 2010 and 2030 in G20 countries (USD billion/year)

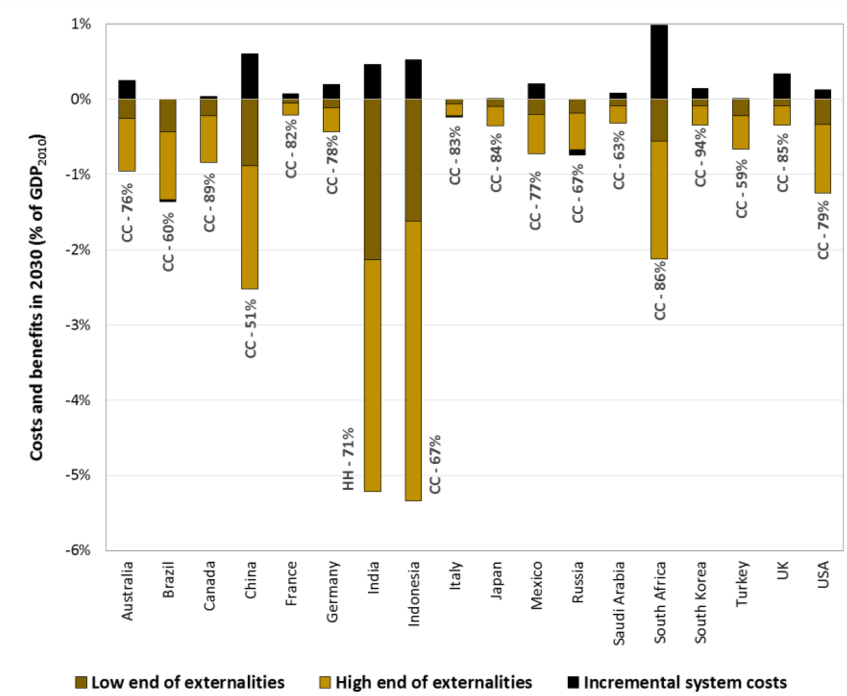


Source: IRENA analysis

When these investments are annualized, using a 10% discount rate and accounting for the annual fuel, operation and maintenance costs, the renewable energy options would cost USD 115 billion in 2030 compared to the conventional technologies substituted. This indicator takes into account the learning effects in technologies between 2010 and 2030 as well as the energy prices of conventional fuels in 2030 based on either own country projections or IEA's World Energy Outlook. However, when cost savings from reduced external effects related to better human health and reduced carbon dioxide (CO_2) emissions are accounted for, renewables result in net savings of between USD 485 and USD 655 billion per year in 2030, depending on how these externalities are assessed. Positive impacts of the avoided CO_2 emissions would result in benefits of USD 115-455 billion per year in 2030. The impacts of human health externalities results in additional benefits of USD 145-315 billion per year. The relative importance of health- and climate-related externalities varies by country. Significant human health benefits dominate the savings in the cases of China and India, while climate benefits dominate elsewhere (see Figure 7).

[6] IEA climate friendly scenarios show that renewables could even meet 50% of global electricity generation by 2040 (IEA 2015c)

Figure 7: Cost and benefits of renewable energy options in G20 countries, 2030



Note: Results for Argentina and the EU are not displayed.
CC: Climate change, HH: human health. The share of externality that contributes most to the total is displayed below each bar.
Source: IRENA (2014a)

Significant growth potential in wind and solar PV capacity is estimated in REmap 2030 that would take the variable renewable energy (VRE) share of total power generation in most G20 countries to more than 20% in 2030. Biomass provides an alternative to the use of conventional fuels in all applications, power and heat generation as well as transport fuel. Assuming that land and water use, biodiversity and food security and other considerations are addressed, biomass would represent 60% of the total renewable energy use in 2030, equal to a doubling of the quantity used in 2010 by G20 members.

3.3. Conclusions

All G20 countries have the opportunity to increase their renewable energy shares significantly between now and 2030 in accordance to their national circumstance and sustainable development priorities. On a global scale higher shares than those foreseen in today's policy plans would bring benefits that could exceed their cost when externalities are accounted for. The G20 countries hold 75% of total global deployment potential and around 70% of total global investment potential for renewable energy between now and 2030. The investment potential amounts to USD 450 billion per year, on average, in that time period. This is an important market opportunity.

4. Innovation needed for accelerated renewables deployment: Managing the integration of variable renewable electricity generation

For more than a century, utilities have been asked to provide reliable, viable, secure and affordable electricity to homes and businesses. Technologies, standards, and more importantly business models have been optimised to do just that: match demand by bringing electricity from centralised power stations to the consumers while minimising operational expenditure. Renewables are changing this century-old model.

This new paradigm requires both a different mindset as well as innovation, not just in components and devices, but also at the system level, in regulation, and institutions to develop a new market design that matches the integration of renewables with energy security and economic concerns, including affordable energy prices for consumers. In this context the integration of “variable sources” such as wind and solar PV into the electricity grid is a particularly important one, given their rapid growth and key role in future low carbon energy systems.

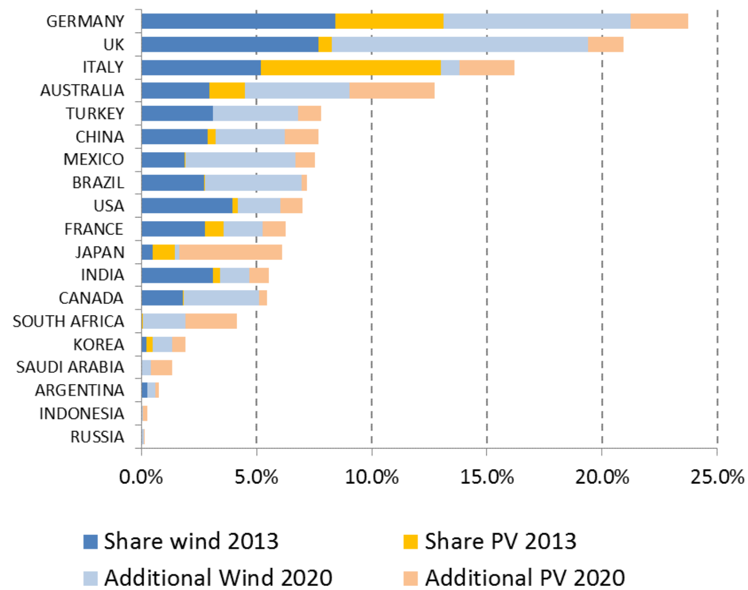
Specific needs vary with the characteristics of the particular electricity system in a country, such as the extent to which other sources of generation are flexible, the strength of the transmission and distribution system, the availability of storage and variations in demand and its interconnections and dependency on energy market developments in adjacent and wider regional markets, which may also have cost implications. Advancing such capacity would be partly dependent on the ability to attract private capital from domestic and foreign resources. Hence, the growth of renewables will take place as their level of integration increases hand in hand.

4.1. Power sector

Some G20 countries have already shown that managing power grids with double digit shares of wind and solar PV in annual electricity generation already is business as usual, and can be managed as long as some basic principles are adhered to. These include avoiding concentrations of generation in areas where grid infrastructure is weak; making necessary grid improvements in parallel with the deployment of the new renewables generation; and using modern forecasting methods to predict real-time output of VRE generation as part of the generation scheduling process. There are several no-regrets options which could result in economic benefits to improve system efficiency as well as ease the integration of renewables. The interested G20 countries can prepare an overview of such measures and develop guidelines for their beneficial deployment.

Many G20 countries have the opportunity to significantly increase the share of power generation from variable renewables over the period between 2014 and 2030. Renewables offer also a solution for electrification in rural parts of some G20 countries that do not yet have electricity access. Results are based on current market projections up to 2020 (IRENA, 2014a). This situation would result in many G20 countries reaching a situation similar to Spain, Italy, and Germany today that have more than 15% share of VRE. In the short-term (up to 2020), Germany and the UK are expected to reach the 20% threshold (IEA, 2014c).

Figure 8: Current and 2020 share of VRE in annual generation for G20 countries



Sources: 2013 and 2020 based on IEA statistics and Medium Term Forecasts.

4.2. Integrating higher shares of VRE – system transformation

Analysing a set of case studies[7], the IEA Grid Integration of Variable Renewables (GIVAR) project (IEA 2014) has found that from a purely technical perspective and based on current level of system flexibility, grids can handle increased VRE penetration levels at rates up to 40% of annual generation. Further analysis in the same study showed that this share could be increased further (reaching levels above 50% in some systems), if a small amount of VRE curtailment is accepted. There is no technical limit to the amount of VRE that can be accommodated if there is sufficient investment to make the system sufficiently resilient and flexible.

However, mobilising system flexibility to its technical maximum can be considerably more expensive than least-cost system operation. Measures must and can be taken to develop a more flexible system able to cope with higher levels of variable generation as cost competitively as possible. This can be achieved with a transformation strategy of the electricity system that can be broken down into three main areas:

- improved system and market operation;
- encouraging system-friendly VRE deployment;
- and investment in additional flexible resources.

Tackling the first two areas is a priority wherever and whenever VRE are deployed. The approach towards the third area differs depending on system context.

[7] The IEA GIVAR case study regions are: Brazil, Electric Reliability Council of Texas (Texas, United States), Iberia (Portugal and Spain), Italy, North West Europe (Denmark, Finland, France, Germany, Ireland, Norway, Sweden and the UK), Japan East (Hokkaido, Tohoku and Tokyo), and India.

Analysis of both IEA (IEA, 2014a) and IRENA (IRENA, 2013a; 2015c) highlight the need to consider flexibility options both on supply and demand and underline the importance and cost-effectiveness of investments in smart grid technologies demand side management and as well as adjusted or new operational procedures to allow a much more flexible generation and use of electricity.

Many G20 members of the OECD have stable power systems that are characterised by stagnant electricity demand and little or no need to replace ageing generation and grid infrastructure. They face different challenges and opportunities compared to dynamic systems in emerging G20 economies where demand grows and investments are needed in additional capacity. In stable systems, integration of higher VRE shares is possible by increasing flexibility via improved operations. The challenge is that the rapid addition of new VRE generation and a more flexible operating pattern can put existing generators under economic stress.

Emerging G20 economies can leap-frog economies with stable demand in their power system design and operation, but only if investment strategies prioritise flexibility. For example, new grids can be planned and deployed in line with VRE targets, avoiding the need for later retrofits. This raises the importance of investment strategies and planning tools that take into account VRE in longer-term system planning.

Despite the differences in timing, in both types of systems additional flexibility is required at some point in order to boost VRE generation. Ambitious renewable penetration targets in the power sector need to be discussed with system operators to ensure that they can handle the transition. The lack of established best practices on energy planning with a high share of renewables hinders countries' abilities to establish credible long-term energy plans that guide policy.[8] A global platform for an open discussion among system operators and policy makers as the IEF provides for, would reduce uncertainty and boost confidence to address these future changes.

4.3. Conclusions

Number of G20 countries have built reliable power systems to fuel their economies and they will be the main drivers of the power sector in the next decade. Changes in the G20 countries show that a power sector transformation is already ongoing and will continue for decades. However, G20 countries are now also faced with the largest evolution in the power sector.

G20 countries may consider planning best practices and options for power-sector planning for the rest of the world, including the full suite of flexibility options. Electricity-sector design for high shares of renewable electricity may need to go beyond technical integration by providing well-designed market, policy and regulatory frameworks.

As more countries are expected to reach higher levels of renewable-energy penetration in the next decade, research and development will need to continue on the combined potential of demand side management, smart-grid technologies and electricity storage to bridge the gap between technology development and deployment.

[8] For example questions have been raised whether or not some of these concerns over day-to-day demand and supply balancing need to be reflected in long-term policy making, and more specifically in the tools that support long-term decision-making, topic of IRENA's Addressing Variable Renewables in Long-term Energy Planning (AVRIL) programme.

5. Innovation needed for accelerated renewable energy deployment: The importance of bioenergy

Bioenergy is a versatile energy source. Bioenergy is energy derived from biofuels, which are fuels produced directly or indirectly from biomass, and these are the only type of renewable resources that can be stored with ease. Biofuels come in liquid, gaseous and solid forms.

Biomass accounts for around three quarters of final renewable energy consumption worldwide today, dominated by use for cooking and heating in developing countries, a practice ongoing for centuries. In primary energy terms, biomass accounts for around 13% of total energy supply.

Biomass is potentially one important source of modern renewable energy and modern biomass use is on the rise. Availability and types of biomass vary largely across countries.

Sustainability of bioenergy is a topic of general interest, and some best practices are beginning to emerge that may help guide the process. The Global Bioenergy Partnership (GBEP), which brought together 50 countries and 26 international organizations, has developed a set of 24 sustainability indicators for bioenergy. These indicators do not represent a standard, but are a monitoring tool that can provide an assessment of the sustainability of bioenergy projects[9]. The application of these indicators is gradually spreading around the world.

Modern biomass prospects depend on sustainable feedstock availability, which in turn depends on a host of factors that are not well understood today at a global level. Bioenergy is different from other forms of renewable energy because feedstock availability today is not a good measure of its future availability, and because allocating feedstock for the energy sector could in some cases imply a diversion of agricultural land away from producing food crops in places where food security is not assured, as well as a conflict with the necessary preservation of biodiversity and natural ecosystems (forests, grasslands, wetlands, etc.). Hence the question how much feedstock is available today and in the future, and at what price, is critical for the long-term development of bioenergy. This needs to be addressed given the role of biomass in a low-cost energy sector transformation.

6. Innovation needed for accelerated renewable energy deployment: Renewable power generation costs -

The competiveness of renewable power generation technologies has continued to improve over time. Biomass for power, hydropower, and geothermal have provided electricity competitively for many years where good, low-cost resources exist. But the cost reductions and technology improvements witnessed for solar PV and onshore wind as deployment has accelerated mean that these technologies are also increasingly competitive.

In 2013 and 2014, onshore wind and solar PV are now providing electricity at comparable generation costs with fossil fuel-fired power generation (Figure 8**Error! Reference source not found.**), even in the absence of financial support to facilitate market entry. Where the resource is good and market and

[9] These indicators address all types of biofuels (*e.g.* ethanol, biodiesel, biogas) for electricity, heat and transport. The indicators can be applied in a country or circumstance, however the methodologies developed by GBEP to measure the 24 sustainability indicators may need to be adjusted according to local conditions.

regulatory conditions are appropriate renewables-based power-generation technologies are now increasingly competing head-to-head with fossil fuels around the world. Further significant cost reductions are expected for wind and solar generation.[10]

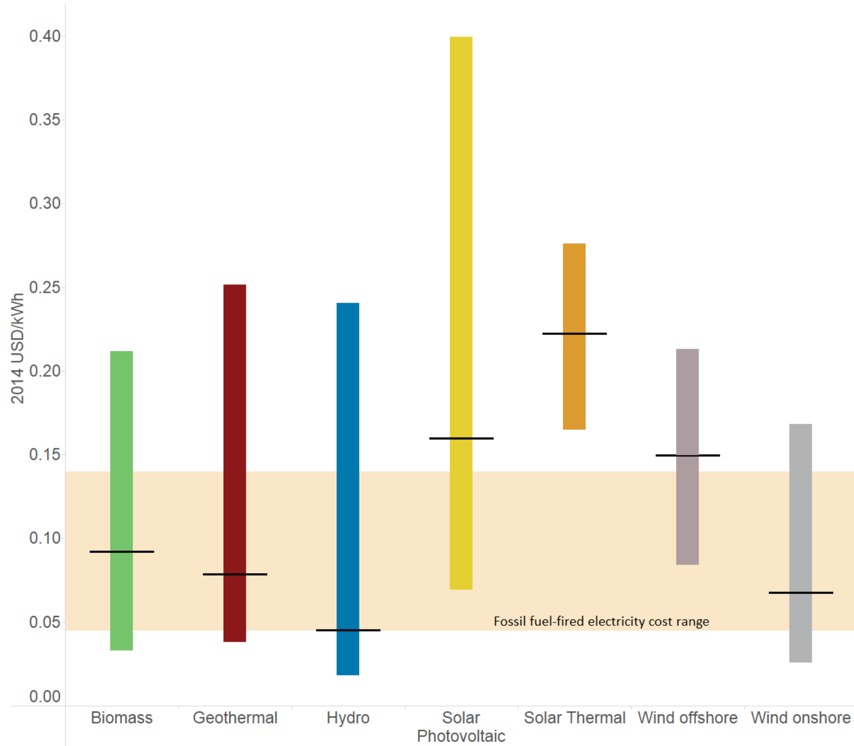
The variation in the levelised costs of electricity (LCOE) for renewables can be explained by three main factors: the differences in the quality of the renewable resource at the project site; in total installed project costs, and in financing costs. These last two factors are often heavily influenced by the market maturity (both globally and locally) and the policy framework in place.

Some of the differences in the observed costs for renewable power generation technologies are due to structural factors (e.g. local labour rates and commodity prices), but in other cases exist for reasons that policy-makers can directly influence. Some of these non-structural reasons for significant cost differences include:

- Small target markets that do not support economies of scale or competition in the supply chain or sufficient density and proximity of project developers (especially for distributed PV);
- Onerous regulatory and administrative procedures related to project development, permitting, grid connection, market integration and other areas;
- Energy market structures that penalise, hinder or do not encourage renewable deployment, in particular if they prohibit long-term contracts;
- Uncertainty over grid-connection policies or offtake agreements, including counter-party risks;
- A lack of integrated support policies to address all the non-financial barriers to renewables deployment;
- Exaggerated perceptions of project technology- and policy-related risks that inflate financing costs, sometimes as a result of a lack of understanding of renewables by local financing institutions;
- Uncertainty about the long-term support policies for the deployment of renewables or previous policy reversals;
- Inefficient or perverse support policies (e.g. FiT tariffs that are not adjusted frequently enough, some tax incentives that are "captured" by developers and are not passed on to consumers);
- International trade and investment barriers that hinder trade in renewable energy technologies and cross-border infrastructure investments and constrain the transfer of technology.

[10] The story of increased competitiveness, however, remains a nuanced one due to the wide cost ranges between individual technologies in different countries or regions due to the variation in project details, resource quality and type of renewable energy used.

Figure 9: Levelised cost of electricity ranges and regional weighted averages for projects deployed in 2014 by technology in the G20



Note: Data based on individual project data in the IRENA Renewable Cost Database. With weighted average values by region. Assumes a real cost of capital of between 7.5% and 10%.

The cost reductions in a region from moving towards the most competitive cost structure are potentially very large. Two contrasting examples are useful in illustrating this point. In China and India, average installed costs for onshore wind projects were around USD 1,310 and USD 1,370 respectively per kilowatt (kW) in 2013 and 2014. In Europe and North America the average were around USD 2,000 and USD 1,710/kW, respectively. Although this difference is partly explained by the technologies used, labour and other input costs, such as for cement and steel, there remains opportunities for costs to converge.

Wide ranges for utility-scale costs for solar PV plants across countries are more pronounced. The most competitive cost structures for utility-scale PV saw total installed costs of around USD 1,300/kW in 2014, whether they were in Europe, North America or China. Yet country averages in many regions were significantly higher. A better understanding of how to close this gap could lead to dramatic declines in the average installed costs of solar PV around the world.

For hydropower, geothermal and biomass there is relatively little potential to reduce average costs to the lowest cost structure level, as the underlying resource quality, and cost in the case of biomass, largely determines what the lowest costs are. Offshore wind and solar thermal are somewhat special examples, as they are in the infancy of their deployment and markets are very thin, cost reductions will occur as deployment rises.

However, for onshore wind and solar PV projects commissioned in 2014, where wide cost discrepancies exist, there are also large potential cost reductions (**Error! Reference source not found.**). Differences in LCOE maybe even larger than these project data imply, as the LCOE assumes a single weighted average cost of capital to highlight, just the variation in resource and installed costs. In reality, variations in financing costs by project can be large and could widen this range – or reduce it. For onshore wind projects commissioned in 2014, the weighted average LCOE of the two most expensive regions is between 61% and 65% higher than for the cheapest region (Asia). However, North America is only 7% higher than the cheapest region, with four other regions having weighted average LCOEs between 28% and 37% higher compared to Asia.

The variation for solar PV projects commissioned in 2014 is much wider. The weighted average LCOE of the least competitive region compared to the most competitive region is 162% more expensive. Once again, North America has the closest weighted average LCOE to the most competitive region, as its excellent solar resource offsets the higher costs of building. The four other regions for which IRENA has quality data have weighted average LCOEs for solar PV that are between 44% and 78% higher than the weighted average of the most competitive region (IRENA, 2015a).

There remains a significant difference between the weighted average LCOE of commissioned projects in a region and the most competitive projects. It is also worth noting that with solar PV deployment, in particular, concentrated in a few countries regional weighted averages for LCOE's may be driven by just a handful of projects. This can lead to significant confusion about what average cost structures are like as small projects that were initiated two to five years ago, sometimes inefficiently procured projects, come online at the same time as projects for 2017 are announced with very different cost structures. For instance in the Middle East, current deployment of solar PV is minimal and the recent projects that have been commissioned have relatively high costs, yet efficient procurement processes in the United Arab Emirates and Jordan have seen PPA prices for projects that will come online in 2017 in the USD 59 to USD 77/MWh range.

7. Accelerating renewable energy deployment: risk mitigation mechanisms

Risk mitigation instruments and approaches can help address some of the risks that prevent renewable energy investments from being viable. The interested G20 countries could consider designing a renewable energy specific risk mitigation mechanism. Risk mitigation mechanisms should be seen in the context of policy and regulatory efforts to reduce risks and uncertainty first. This requires effective actions by host governments to create enabling regulatory and market frameworks for renewable energy investments.

Even though renewable energy generation costs have decreased dramatically and renewable energy is increasingly cost-competitive, global investment levels are still almost USD 400 billion short from the USD 650 billion per year required between 2010 and 2030 to double the share of renewables. In many regions there are risks and barriers impeding renewable energy investment. Rather than supporting and subsidizing energy prices directly, effective approaches would use policies and public funding to address risks and barriers instead. Risk mitigation instruments such as loan guarantees, off-taker risk guarantees and mezzanine finance schemes could be efficient ways to use public sector finance to prompt private sector investments in the field of renewables.

Power generation based on renewable energy is typically highly capital intensive compared with conventional electricity investments, while operating costs are low. Investment costs of renewable energy have decreased rapidly over the past years but the cost of capital remains high in many markets, even in those with fundamentally good potential.

Institutional and other investors are strongly interested in entering the renewable energy sector and have taken an increasingly active role in recent years. Given the record low interest rates in the financial markets, it is challenging for them to balance their investment allocations. At the same time, more investors are looking to renewable energy as an attractive diversification opportunity that provides stable long-term cash flow.

However, the real and perceived risks related to renewable energy are currently impeding investments even if cash flow profiles are attractive to investors. Therefore, even as renewable energy is becoming cost-competitive, mitigating the risks of renewable energy to bring down the cost of capital, which can form a large part of renewables based power generation costs, will continue to be part of an effective deployment strategy.

Renewable energy investments basically face similar risks and barriers as conventional energy investments. However, various factors have led to an exaggerated perception of them, in particular:

- The sector is still relatively new to investors and many technologies still lack long-term track record;
- The level of standardisation of renewable energy technologies, methodologies and contracts is still low compared with that of conventional energy; and
- Regulatory frameworks for renewable energy are not yet well established in many countries.

Furthermore an increasing share of global renewable energy investments – reaching almost 50% in 2014 – are made in the developing world, where the perceived risks and barriers tend to be higher.

The fundamental **risks** can be classified as follows:

- **Host government related risks** include political risks related to unlawful interference by the host government and losses caused by political instability. Regulatory and policy risks in turn include changes in permitting procedures, subsidy or pricing mechanisms and taxation.
- **Risks related to financial markets** include currency risk and interest rate risk. Currency risk is specifically challenging in developing countries with smaller and weaker currencies, but is also relevant in developed countries. These risks are difficult to manage in the long term, posing a challenge for renewable energy investments requiring stability for at least 15-20 years. Liquidity risk can also emerge from the high barriers to buying and selling renewable energy based assets.
- **Energy market and counterparty risks** include the fluctuations in price or volume (or quality) of the inputs and outputs of a project, and risks related to the intentional or unintentional breach of agreements by contractual counterparties. The most important counterparty risk is usually related to the off-taker: whether the buyer of the energy will be able and willing to fulfil its obligations in a PPA.
- **Project level risks** include both the technology and organisations involved with its operation, as well as a failure to properly maintain facilities.

The main **barriers** to renewable energy investment are the following:

- **Lack of experience and expertise** among the relevant stakeholders, including project sponsors and developers, investors and financiers, and regulators and authorities.
- **Lack of regulatory capacity and clarity** in permitting processes and other regulations. These regulations are often disadvantageous for renewable energy projects as they are tailored to the needs of conventional energy sources and not to the needs of renewable energy sources.
- **Typically higher transaction costs** in relative terms, including project development costs and financial and ownership arrangements, for renewable energy projects. These are caused by the issues mentioned above, but also by the typically smaller size of renewable energy investments as well as the lack of standardisation of methodologies, technologies and agreements.

Based on surveys and IRENA's analyses and expert meetings, the following conclusions can be highlighted:

1. Political and regulatory risks often impede investments that would otherwise be economically and financially sound. They require attention in all countries but especially in developing countries, where perceived political risk is higher. In small- and medium-scale renewable energy projects investors are often unable to use the existing political risk mitigation instruments provided by export credit agencies or multilateral financing institutions. These risk mitigation instruments tend to be complex, expensive, or are better suited to larger investments, whereas many renewable investments are relatively small. An additional challenge is providing the collateral demanded by banks in order to secure financing. Dedicated risk mitigation instruments with simplified application processes and a higher margin for transaction costs will be needed, including guarantee schemes specifically tailored for small- and medium-sized enterprises (SMEs) as widely used both in OECD and non-OECD countries (OECD, 2012), but not yet specifically targeted at renewable energy projects.

2. In developing countries, financially weak off-takers (often national power utilities) can create a prohibitive investment barrier. Host countries may not be financially strong enough to back the off-takers, thus a guarantee from the host government may not be sufficient to mitigate the risk. In such situations a PPA guarantee could be issued by an international institution to make these investments bankable[11]. For instance, wind and solar PV projects would not need any other credit enhancement besides a PPA guarantee, as the technologies are proven, operation and maintenance could be arranged by technology providers, and the profitability of the projects would in many cases be sufficient to secure the debt.

3. In both developing and developed markets a common challenge to scaling up renewable energy investments is that newer technologies have an insufficient track record and especially smaller and newer technology suppliers often have weak financials. Companies offering such technologies may be unable to provide the industry-standard completion and performance guarantees that project owners and financiers ask for, and are thus excluded from the bidding processes. The same challenge arises if proven technologies try entering new markets. In these situations a high perceived risk by local financiers may exist, which could be mitigated by loan guarantees bridging the period until the local financial market is comfortable to finance such projects. Partial loan guarantees could be provided to cover the performance risks of a new technology and accelerate its commercialisation, or to speed up the penetration of proven technologies in new markets.

[11] Such solutions have been proposed for example by finance professionals in high level expert meetings on RE finance and risk mitigation organized by IRENA.

The public sector should be conservative in guaranteeing risks, in particular avoiding covering all of them, in order to avoid setting false incentives and distorting the market. Therefore, partial risk coverage should be given priority and guarantees should be designed and priced in a reasonable manner. Alternatively, instead of using guarantee instruments, risks could also be mitigated through mezzanine financing. Guarantee and mezzanine schemes can enable governments to deploy scarce public funds efficiently to mobilise larger pools of private capital. In many cases, blending public financing, be it direct (*e.g.* mezzanine finance) or indirect (*e.g.* guarantees or letters of credit), with private funding could be an efficient way to finance projects.

In order to address the aforementioned barriers, such instruments should be supplemented by technical assistance facilities[12]. Also bundling of projects can reduce both perceived risks and transaction costs, and should be considered as an option when addressing the risks of small- and medium-sized projects.

Developing a risk mitigation facility could address multiple risks by incorporating one or more of the approaches described above. This approach could be universal and applied across a variety of developed and developing countries, and across various technologies, with adjustments to the design according to specific circumstances and needs.

In a first phase the G20 may wish to consider targeting countries in the Southern and Eastern African power pools through the Africa Clean Energy Corridor (ACEC) initiative facilitated by IRENA. As part of the initiative IRENA is creating a virtual marketplace for renewable energy to provide visibility and transparency to the project development and financing processes and facilitate private sector engagement. The marketplace will be launched in the second half of 2015 and would be strongly enhanced by a risk mitigation facility. The financing required for such a facility is relatively small compared with the potential of total investment mobilised. However, when the financing needs for other parts of the world, which are also facing large electrification challenges are taken into account, a large deficit looms. It may also be noted that there is a large capital requirement for this source of electricity in developed countries as well, which dims the chance of fund transfer from these countries to developing countries.

Several potential sources of risk mitigation funding exist. One example to highlight is climate finance, notably the Green Climate Fund (GCF). Countries have already pledged contributions totalling over USD 10 billion to the GCF, and the GCF Board has decided that half of this amount would be used for climate change mitigation, with renewable energy and energy efficiency playing a prominent role.

Financial risk mitigation instruments promote investment and financing for renewable. Risk mitigation mechanisms dedicated to renewable energy could use public funding to efficiently catalyse private financing. This needs to build on action by host governments to create enabling environments for renewables investments. Interested G20 countries, to take part in accelerating global renewable energy deployment, may promote such risk mitigation instruments mainly in developing countries by designing and launching a renewable energy specific risk mitigation mechanism based on IRENA's research and experience in close cooperation with other international financial institutions.

[12] Good examples are the GET FiT Premium Payment Mechanism applied in Uganda, which utilises competitive selection process to select projects, and the Energy Efficiency Guarantee and Technical Assistance Fund of the Inter-American Development Bank, which is funded by it and the Nordic Development Fund, and finances small-scale projects in Latin America (http://www.ndf.fi/).

8. Best practice in policy design

Renewable energy deployment is accelerating, with the reality of a sustainable energy system based on renewables beginning to emerge. Energy security, environmental concerns, job creation and new economic activity have been strong drivers for renewables development. As of today, nearly 6.5 million people are employed in the renewable energy sector (excluding large hydro) globally, out of which at least 5.8 million are in the G20.

This is being spurred on by a range of market, technology and policy drivers that vary from country to country. G20 countries play a key role in this regard, as these few examples show:

- **Brazil** aims to reach a share of 42.5% renewables in total energy supply by 2023.
- **China**, which has rapidly become the largest market for several renewable energy technologies, has a set of ambitious targets for each technology to bring clean energy to 20% of its energy mix by 2030.
- In the **European Union**, legally binding national targets are in place to reach 20% renewable energy in gross final energy consumption by 2020. For 2030, an EU-wide target of 27% (without national targets) has been agreed.
- **Japan** has set targets to realise a 22-24% share of renewables in total power generation by 2030.
- **India** has scaled-up up its renewable energy targets to 100 GW solar and 60 GW of wind by 2022.
- **Mexico** aims for a power generation share from low-emissions energy sources, including renewables, nuclear and fossil fuels with carbon capture and storage, of as much as 40% by 2035.
- **Russia** has set targets to realise a 4.5% share of renewable power generation by 2020.
- **Turkey** aims to reach a renewable energy share of 30% in its power generation mix by 2023.

In order to reach their targets, a number of G20 countries have adopted different policy mechanisms to promote the deployment of renewable energy and maximize the socio-economic benefits. These mechanisms have been mostly included in the IEA-IRENA Policies and measures database. While individual policies and measures are important, analysis shows that an overall stable and predictable enabling policy and regulatory framework is essential and should include at least four key elements [13]:

- A long-term policy framework showing government commitment towards the market, and credible short, medium and long term targets, backed up by action plan designed to remove barriers. Long-term commitment will also require that governments align policies to minimise competitive barriers for investors domestically and internationally.
- Smart remuneration arrangements that provide long term predictable revenue streams and include built in flexibility to allow for adaptation as costs reduce so as to minimise policy costs.
- Actions to tackle non-economic barriers including streamlining planning and permitting, developing the necessary skills base and providing public information.
- Measures to enable technical and market integration once deployment grows.

[13] This is particularly true for the Initiation and Take-off Phases, where effective policy principles can be distilled from this experience which provide a basis for formulating country specific policies (IEA, 2011a, 2015, IRENA 2013, 2014a, etc.)

Accelerating renewable energy deployment in the energy system can only happen by addressing the three major sectors (power, heat and transport) and therefore, policies need to be designed to support renewables deployment across sectors. A brief overview of the sectoral policy-related aspects is provided in the following section.

8.1. Power sector

Many of the G20 countries are early adopters of renewable energy policy, and they can provide lessons learnt and best practices, focusing on policy adaptation and the need for the appropriate policy mix.

Policy adaptation. As market conditions evolve, renewable energy policies need to adapt in order to overcome arising barriers and ensure their efficiency and effectiveness. For example, policy instruments in some countries of the G20 are evolving to integrate variable renewable power in the grid and to account for rapidly falling renewable generation costs.

- **Grid integration.** As the share of renewable energy increases, countries need to ensure that adequate physical infrastructure, as well as enabling regulations are in place to allow integration of increasing variable generation. For example, **India** is investing in the reinforcement of existing grid infrastructure as well as the development of dedicated green energy corridors for the evacuation of power from renewable resource-rich regions to the load centres. These efforts are being complemented with regulatory measures to improve forecasting and scheduling of renewable energy generation[14]. In **China**, the 12th Five Year Plan (FYP) included the investment in an ultra-high transmission corridor to increase the integration of renewable energy resources. Moreover, the 12th FYP includes the development of smart grids to effectively manage the supply and demand of power through the national distribution network[15].
- **Falling technology costs.** With technology costs falling, some governments have adapted by introducing a gradual reduction in the direct financial support they provide to renewables. The planned, predictable and clearly communicated approach ensures the stability of the market. This was the case with the degression mechanisms adopted in France, Germany and the United Kingdom[16] and the implementation of caps on the price of Renewable Energy Certificates (REC) traded in Australia.

In a changing environment where renewable electricity generation is becoming more competitive, market and regulatory mechanisms have a key role to play in providing a long-term predictable income stream for investors. A predictable income stream can be provided, for example, by feed-in tariffs (FIT's) or through long-term power purchase agreements following a tender or auction process.

Subsidy schemes such as FITs have been widely used in a number of G20 countries and elsewhere to stimulate large-scale deployment which has in turn contributed to global cost reductions. FITs are attractive for many different types of investors and for a wide range of projects, including small scale (e.g. distributed solar PV). The main issue with FIT's is the need to establish tariffs in a manner that provides sufficient incentive for investors while not over-rewarding them. The solution increasingly adopted by some jurisdictions in the G20 is to switch from FITs to auctions, which use competition as a means to reduce prices and encourage technical and financial innovation. For example, in 2004, **Brazil**

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[14] IRENA, 2014. Adapting Renewable Energy Policies To Dynamic Market Conditions
[15] IRENA, 2014. Renewable Energy Prospects: China, REmap 2030 analysis.
[16] IRENA, 2014. Adapting Renewable Energy Policies To Dynamic Market Conditions

implemented renewable energy auctions after the 2002 FITs' scheme in order to allow for the discovery of the real price of renewable energy, yielding more efficient tariffs[17]. In 2014, the **EC** released the Guidelines to Member States requiring them to implement a pilot bidding process for parts of the renewable energy capacity in 2015 and 2016. Starting 2017, aid will only be granted based on a competitive bidding procedure[18].

Policy mix. As renewable energy markets become more sophisticated, policy-making increasingly combines complementary characteristics of different support mechanisms. For instance, some **US** utilities in the states of Oregon and Wisconsin use FIT schemes as the basic mechanisms for contracting renewable energy to meet their purchase obligations. Auctions have also been used as procurement schemes for meeting renewable purchase obligations, such as in New York.

Some G20 jurisdictions have applied both FITs and auctions simultaneously. For example, in order to minimize administrative costs, **France** applies a FIT for solar PV projects of capacity less than 100 kW, and auctions for any larger capacity. In **Italy**, capacity caps are set for each technology, and project developers must participate in a descending auction in order to gain access to the existent FIT. The bids that offer the highest tariff reduction of the pre-established FIT win the right to access them.

At the same time, other G20 countries have moved from auctions to FITs, such as **China** for wind energy. China implemented a series of auctions for wind from 2005 to 2009 that spurred competition, drove price reductions and the successful development of the domestic wind industry, with leading global manufacturers setting up production facilities.

Local content requirement (LCR) policies combined with auctions and FITs were also introduced in **Brazil**, **Canada**, **India** and **South Africa** to support the development of a nascent industry. Their experience shows that the success of building a local industry lies in the implementation of a mix of cross-cutting policy instruments, tailored to country-specific conditions, and aiming at encouraging investment and technology transfer, strengthening firm-level capabilities, promoting education and training as well as research and innovation. **Turkey**, for example, has introduced LCRs tied to the FIT as well as policies aimed at strengthening firm-level capabilities. It should be noted, however, that LCR policies can be controversial in light of international trade rules and have prompted five World Trade Organization (WTO) disputes since 2010 (OECD, 2015 forthcoming).

8.2. Heating sector

Renewable heat can in many circumstances provide a cost-effective contribution to energy security, sustainability of the energy supply, economic development and energy access. Around 47 countries have introduced targets that apply to the heating/cooling sectors. Several technology options exist that tap into diverse resources, such as biomass, solar and geothermal, to cater to different grades of heating demand[19]. Solar thermal technology, for instance, can fulfill a substantial amount of heat demand in buildings, industrial and agricultural food processing. Furthermore, renewable heating can be supported

[17] IRENA, 2013. Renewable Energy Auctions in Developing Countries

[18] IRENA. 2015, forthcoming, Renewable Energy Auctions Design and Best Practices

[19] IEA-ETSAP and IRENA, 2015. Solar Heat for Industrial Processes; IEA-ETSAP and IRENA, 2015. Solar Heating and Cooling for Residential Applications.

by local manufacturing, as showcased in **India** with solar process heat technologies, thus providing a mutually reinforcing strategy to support a healthy national industry[20].

To support renewable energy for heating, a broad range of policies have been adopted in G20 countries. A number of studies have looked at the current policy experience in the heating sector (*e.g.* IEA 2014c, IEA RETD, 2010, IEA RETD 2015). These typically include capital grants and rebates (*e.g.* in **Germany**, **China**), grants and feed-in tariffs (*e.g.* in the **UK**), tax reductions/exemptions (*e.g.* in the **US**), soft loans or guarantees (*e.g.* in India and in the US) and CO_2 taxes or carbon trading schemes (*e.g.* in **the UK, Denmark**, **Sweden**)[21]. It is possible to distil some general principles from existing experience, taking lessons where appropriate from work on analysis of renewables policies more generally:

- Policy should be guided by a systematic analysis of the specific opportunities and technologies as well as the deployment barriers inhibiting the uptake of the technologies.
- Governments should adopt a sector-specific approach– distinguishing among industry, the commercial and buildings sector, rather than a "one-size-fits-all" policy.
- Incentives should encourage progressive cost reduction and be reviewed regularly. So far capital grants have been used extensively to encourage the deployment of renewable heat, although in some cases (*e.g.* the **UK**) the equivalent of a FIT has been introduced providing revenue support.
- Competitive bidding processes can help to reduce the cost of support policies and procurement.
- Governments can play an important role in mitigating non-economic barriers and risks to investments by simplifying and clarifying regulatory frameworks, developing quality assurance and skills-training schemes and developing information programmes.
- For the buildings sector, measures to encourage renewable heating and cooling, such as building codes and standards, should be integrated, and carefully coordinated, with energy efficiency and GHG emission reduction initiatives.
- In industry, concerns about profitability and the availability of investment funds are likely to be the major concern. Promotion of energy service companies (or ESCOs) and support for performance guarantees can play important roles in stimulating the market.
- Market design should allow for long term purchase agreements of renewable power and heat, which provide visibility to investors while allowing customers to hedge against price-volatile fossil fuels.

8.3. Transport sector

Energy use in the transport sector is growing rapidly. The use of biofuels may play an important role, particularly when other low GHG options are very limited – particularly long-haul and heavy transport[22]. Biofuels also offer an energy diversity benefit in many economies have to rely on imported final oil products (*e.g.* Indonesia).

The use of biofuels or other renewable sources must be an integral part of the overall transport energy strategy, complementing efforts on energy efficiency. The strategy must be based on a careful

[20] IEA-ETSAP and IRENA, 2015. Solar Heat for Industrial Processes.

[21] OECD/IEA, 2014. Heating without Global Warming: Market development and policy considerations for renewable heat.

[22] Heating without Global Warming – Market Developments and Policy Considerations for Renewable Heat, IEA 2014

assessment of nationally available biomass resources and the potential to produce crops for energy purposes, bearing in mind the wider implications for food security and land use policy. Such an approach is equally important where there is an apparent opportunity to produce biofuels for exports. Guidance on such assessments is available from the IEA, IRENA and the FAO[23].

Biofuels mandates have proved an effective way of stimulating demand for biofuels, but they have to be linked to realistic penalties for non-compliance and designed so that they are progressively introduced at a pace compatible with the development of the supply side and infrastructure. The strategy needs to take into account the likely blending constraints imposed by infrastructure and the nature of the vehicle fleet, or take steps to evolve the fleet to be able to accommodate higher levels (*e.g.* by promoting the uptake of flex-fuel vehicles, as has been successfully accomplished in Brazil).

Liquid biofuels are not entirely GHG emission free. This is particularly the case for conventional biofuels that are produced from food crops. New biofuels options ("advanced biofuels") can be produced with much lower GHG emissions. However, the encouragement of their development and deployment poses some particular policy challenges. Good progress has been made in the **US** and **EU** in the last few years, with a number of commercial plants beginning operation and demonstrating that production at scale is feasible. However, further progress will depend on a supportive policy framework which allows the next generation of plants to be built and operated, perhaps by providing loan guarantees and by creating quota for such fuels (See section on impact of low oil prices on RE).

Countries are also continuing to explore additional options such as increasing the number of vehicles fuelled with biomethane, renewable hydrogen, or electricity from renewable sources. In **China**, for example, the government offers subsidies and tax incentives to promote the deployment of alternative-energy vehicles. It has set a target for 5 million alternative energy vehicles by 2020. More broadly, there is general agreement that achieving a complete energy sector transformation will require effective policy action in the transportation sector.

8.4. Conclusions

In conclusion, policies that stimulate the deployment of RE and aim at building a domestic industry need to ensure a stable environment to encourage investments. These policies increasingly combine complementary characteristics as RE markets become more sophisticated. At the same time, these policies need to adapt to changing market conditions such as falling technology costs, and to overcome arising challenges such as the integration of variable renewable energy into the grid. Policy choices aimed at developing a domestic industry need to be part of a holistic policy mix that is tailored to countries' particular strengths and weaknesses. Within their national strategies, countries need to account for renewable energy integration across the three end-use sectors and devise context-specific policies that can enable a sustainable growth of the sector and maximize associated socio-economic benefits.

The joint IEA-IRENA database for renewable energy policies contains the most authoritative overview of policy frameworks worldwide. This database can be used as a basis to explore trends and best practice in policy design. IRENA has recently analysed policy measures to adapt dynamic market conditions including rapidly changing cost, best practice in the design of auctions, target setting and other aspects

[23] IEA, IRENA and FAO: How To Guide for Bioenergy (A guide to preparing a national bioenergy roadmap). Forthcoming, 2015.

related to the design of policy instruments. The OECD has issued high level Policy Guidance for Investment in Clean Energy Infrastructure which includes sound investment policy principles, investment promotion and facilitation coherence and comprehensiveness, energy market design/competition policy, financial market policy for capital access and public governance policy. The G20 countries may wish to use or build on this existing information and analysis as a basis to explore further best practices in the design of policy instruments in order to accelerate the deployment of renewables.

9. Four options for G20 consideration

1. Identify and quantify concrete renewable-energy technology options for G20 members and suggest cooperation opportunities to facilitate their deployment.

There is no "one fits all" solution for renewable energy deployment. IRENA's global REmap analysis and IEA scenarios provide toolboxes that can be used to analyse options. Such analysis should be considered within broader energy-planning frameworks and guided by resource availability, economics, sustainable development, and national circumstances.

2. Strengthen renewable energy innovation.

An exchange on best practices of technology and policy between G20 members is recommended to encourage innovation for enabling power-sector transformation, encompassing both grids and electricity storage. Although member countries are at different stages of renewables deployment, shares of variable renewables in power generation will rise across member states. The systems integration of high shares of variable renewables will soon become a topic of importance for all members. A better understanding is needed of the potential role of technology options such as enabling (smart) grid infrastructure, including interconnectors, affordable electricity storage and opportunities for demand side management, to cope with natural variations in renewable electricity supply together with variations in demand. An exchange of best practices within the G20 framework can add value to the designing of electricity markets, which should be a top priority for member states.

A better understanding of sustainable bioenergy prospects is needed for applications such as liquid transportation fuels and for heating. Understanding of biomass feedstock should also be improved.

Finally, a voluntary sharing of information regarding technology costs across countries may be considered in order to learn what opportunities exist today to lower the cost of technologies across G20 members.

3. Promote renewable energy investment in developing countries through risk mitigation, and explore new risk mitigation instruments.

The G20 may consider smart and efficient funding mechanisms to promote investment and financing of renewable energy in developing countries. Several G20 countries and their public financing institutions have introduced risk-mitigation instruments and have gained practical experience in this field. Therefore, these G20 countries are in a good position to support the design and launch of a renewable energy-specific risk mitigation mechanism to support scale-up of investment in developing countries.

4. Share best practices in policy design that facilitates renewable energy investment.

Important opportunities exist to share best practices in policy design that may facilitate investments in renewable energy. The IEA-IRENA policy database, IRENA assessments of enabling mechanisms and OECD policy guidelines can inform the dialogue. Countries can access the IEA-IRENA database without having to agree to implement any specific policies. They remain free to choose an approach based on their capabilities and circumstances.

Following discussion of the analysis in the September 2015 ESWG meeting and building on guidance of the delegates these areas could be elaborated into a G20 toolkit of options on renewable energy deployment.

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List of Abbreviations

ACEC	Africa Clean Energy Corridor
AECM	European Association of Mutual Guarantee Societies
bbl	Barrel
CC	climate change
CCGT	combined cycle gas turbine
CCS	carbon capture and storage
CO_2	carbon dioxide
CSP	concentrating solar power
DEWA	Dubai Electricity and Water Authority
EJ	Exajoule
ERCOT	Electric Reliability Council of Texas
ESWG	Energy Sustainability Working Group
ETBE	ethyl tert-butyl ether
EU	European Union
FAO	United Nations Food and Agriculture Organization
FIT	feed-in-tariff
FYP	Five Year Plan
G20	Group of Twenty
GBEP	Global Bioenergy Partnership
GCF	Green Climate Fund
GFEC	gross final energy consumption
GHG	greenhouse gas
GIVAR	Grid Integration of Variable Renewables
GJ	Gigajoule
Gt	Gigatonne
GW	Gigawatt
HH	human health
IEA	International Energy Agency
IEF	International Energy Forum
IRENA	International Renewable Energy Agency
kW	Kilowatt
kWh	kilowatt-hours
LAC	Latin America and the Caribbean
LCOE	levelised cost of electricity
LCR	local content requirements
LNG	liquefied natural gas
MBTU	million British thermal unit
Mt	megatonne
MTBE	methyl tert-butyl ether
MW	megawatt
MWh	megawatt-hour
NREAP	National Renewable Energy Action Plan
OCGT	open cycle gas turbine

OECD	Organization for Economic Cooperation and Development
OLADE	Latin American Energy Organization
OPEC	Organization of the Petroleum Exporting Countries
PPA	power purchase agreement
PROINFA	Programme of Incentives for Alternative Electricity Sources
PTC	production tax credit
PV	photovoltaic
REC	renewable energy certificates
RED	renewable energy directive
REFIT	Renewable Energy Feed-in Tariff
SE4ALL	Sustainable Energy for All
SIDS	Small Island Developing States
SME	small and medium-sized enterprise
TFEC	Total final energy consumption
UK	United Kingdom
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
US	United States
USD	US Dollars
VRE	variable renewable energy
WB	The World Bank