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The role of science, technology and innovation in increasing substantially the share of renewable energy by 2030

Report of the Secretary-General

Executive summary

This report focuses on how science, technology and innovation can help increase the share of renewable energy in the global energy mix. It reviews the latest trends in the use of renewable energy technologies, identifies the barriers and drivers of their deployment and provides an overview of emerging technologies. The report also discusses some of the key issues in the use of renewable energy, including market and policy design, technical challenges in integrating renewables in the electricity grid, off-grid and mini-grid applications, and the use of renewables in households. The report emphasizes that countries will have different national renewable pathways, depending on contextual factors and priorities. It argues that policy mixes are necessary to support renewable energy deployment. It concludes by underscoring the key role of international cooperation in knowledge sharing, policy learning, capacity-building and technology development, and in improving the interconnection of grid infrastructures.

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Introduction

1. At its twentieth session in May 2017, held in Geneva, Switzerland, the Commission on Science and Technology for Development selected "The role of science, technology and innovation in increasing substantially the share of renewable energy by 2030" as one of its priority themes for the 2017–2018 intersessional period.

2. The secretariat of the Commission convened an intersessional panel from 6 to 8 November 2017 in Geneva, to contribute to a better understanding of this theme and to assist the Commission in its deliberations at its twenty-first session. This report is based on the issues paper prepared by the Commission secretariat,[1] the findings of the panel, country case studies contributed by Commission members, relevant literature and other sources.

3. This report identifies, analyses and presents for discussion key issues concerning the role of science, technology and innovation in increasing substantially the share of renewable energy in the global energy mix by 2030, particularly in developing countries. The report highlights Member States' contributions on good practices and lessons for applying science, technology and innovation to increase the deployment of renewable energy technologies. Chapter I introduces challenges and recent global trends in renewable energy deployment, technological and non-technological barriers and drivers of deployment, and emerging technologies. Chapter II presents key issues related to innovation and deployment of renewable energy technologies. Chapter III highlights how policymakers can harness science, technology and innovation to increase the share of renewable energy. Chapter IV presents findings and suggestions for consideration by Member States and other relevant stakeholders.

I. Background and context

A. Clean energy as a cross-cutting issue for sustainable development

4. It is estimated that 1.1 billion people in the world today have no access to electricity. This is 14 per cent of the world's population. Some 85 per cent of those without access to electricity live in rural areas, mainly in Africa. Furthermore, 2.8 billion people do not have access to clean forms of energy for cooking.[2] Using traditional biomass and inefficient technologies has serious health, social and environmental consequences. Increasing access to clean forms of energy makes a critical contribution to achieving the 2030 Agenda for Sustainable Development and the Sustainable Development Goals, agreed in September 2015. Goal 7 aims primarily to ensure universal access to affordable, reliable, sustainable and modern energy services by 2030. Within this, there is a target "to increase substantially the share of renewable energy in the global energy mix" by 2030.

5. Achieving universal energy access and increasing renewable energy is likely to have largely positive impacts on other aspects of sustainable development and other Goals.[3] The reduction of poverty (Goal 1) requires, among other things, the development of modern infrastructures. Renewable energy can play an important role in the development of such infrastructures. In addition, it is critical for productive capacities and the creation of income generation opportunities, as highlighted by recent UNCTAD research.[4] Renewable energy can also contribute to good health and well-being (Goal 3) by reducing the health risks

[1] The issues paper and all presentations and contributions to the intersessional panel cited in this report are available at http://unctad.org/en/pages/MeetingDetails.aspx?meetingid=1562.

[2] International Energy Agency (IEA), 2017a, *World Energy Outlook 2017* (Organization for Economic Cooperation and Development (OECD), Paris).

[3] International Council for Science, 2017, A guide to SDG [Sustainable Development Goal] interactions: From science to implementation.

[4] UNCTAD, 2017, *The Least Developed Countries Report 2017: Transformational Energy Access* (United Nations publication, Sales No. E.17.II.D.6, New York and Geneva).

associated with pollution by replacing the use of fossil fuels for cooking and lighting in homes, for example. It is also relevant for gender equality (Goal 5). By replacing traditional forms of energy such as wood fuel, modern forms of renewable energy can reduce the time spent gathering wood by women and girls.[5] Lighting through renewable energy systems can also provide greater time flexibility for domestic activities, especially for women.[6] Furthermore, there are clear synergies with industry, innovation and infrastructure (Goal 9), as well as climate action (Goal 13). Many national innovation policies and international initiatives include a focus on renewable energy technologies, and the expansion of renewable energy is part of most national strategies to mitigate the greenhouse gases that cause climate change.

B. Global trends in renewable energy deployment

6. Recent efforts to increase the use of renewable energy sources have been driven by the following interrelated needs: to improve energy security and diversify energy sources, encourage sustainable economic development and protect the climate and the environment from the impacts of fossil fuel use.[7] These motivations led to a step change in the development and deployment of a range of renewable energy technologies. In addition, policy interventions contributed to dramatic costs reductions of some renewable electricity technologies and the rapid deployment of these technologies.

7. The source of renewable energy can be solar power, wind power, geothermal power, hydropower and biomass. Accordingly, technologies are diverse and can be differentiated by their nature – variable or dispatchable, centralized or distributed, direct or indirect and traditional or modern.[8] Some renewable energy sources and technologies, such as traditional biomass that involves the direct – and often inefficient – combustion of wood and charcoal, are not considered “clean”. Renewable energy can play an important role across the entire energy system. It can be used for electricity generation, transport, heating and cooling or cooking. Renewable energy sources have been used for as long as energy systems have existed and predated the use of fossil fuels.

8. In absolute terms, the contribution of renewable energy to the world’s total primary energy supply has increased significantly in the last decades – from 1,121 million tons in 1990 to 1,823 million tons in 2015. However, its share thereof increased to a smaller extent, from 12.8 per cent in 1990 to 13.4 per cent in 2015.[9]

9. According to IEA,[10] renewable energy accounted for 14 per cent of global primary energy demand in 2016 (9 per cent, if traditional forms of solid bioenergy are excluded). The power sector is the principal user of renewable energy, representing almost 60 per cent of its use. Twenty-four per cent of electricity now comes from renewables worldwide: 16 per cent, from hydropower; 5 per cent, from wind, geothermal, solar and tidal power combined; and 2 per cent, from bioenergy and waste. Renewables supply 9 per cent of heat demand in industry and buildings, while the proportion in transport is much smaller, at 3 per cent. Most of the latter is biofuels.

10. Regional figures on the use of renewable energy show significant variation between different countries. This is because the use of renewable energy largely depends on contextual factors such as geographical and environmental conditions, socioeconomic and development priorities, cultural and institutional conditions, and policy and regulatory frameworks. In OECD countries, the share of renewable energy in the total primary energy supply was 9.6 per cent in 2015. In comparison, the share of renewables was 40 per cent in

[5] S Oparaocha and S Dutta, 2011, Gender and energy for sustainable development, *Current Opinion in Environmental Sustainability*, 3(4):265–271.
[6] M Millinger, T Mårlind, and EO Ahlgren, 2012, Evaluation of Indian rural solar electrification: A case study in Chhattisgarh, *Energy for Sustainable Development* 16(4):486–492.
[7] IEA, 2011, *Renewable Energy: Policy Considerations for Deploying Renewables* (OECD/IEA, Paris).
[8] IEA, 2016, *World Energy Outlook 2016* (OECD/IEA, Paris).
[9] OECD, 2018, OECD Data, Renewable energy, available at https://data.oecd.org/energy/renewable-energy.htm (accessed 7 March 2018).
[10] IEA, 2017a.

Brazil, 8 per cent in China and 25 per cent in India. The use of renewable energy in developing countries is often dominated by traditional forms of bioenergy. The share of renewables in total primary energy supply varies considerably – from 28 per cent in Viet Nam, to 53 per cent in Costa Rica and 81 per cent in Kenya.[11]

C. Technological and non-technological barriers and drivers in renewable energy deployment

11. In recent years, there has been fast progress in the deployment of some renewable energy technologies. The range of factors that have promoted or inhibited renewables development and deployment are both technological and non-technological in their nature and include costs and affordability, financing, technical maturity, integration into electricity systems, environmental sustainability and skills.

12. Until recently, the costs of renewable technologies have usually been higher than those of fossil fuels. The gap has now started to close, especially for solar photovoltaics and wind energy, driven by cost reductions and deployment incentives implemented in an increasing number of countries. For example, between 2008 and 2015, the average costs of solar photovoltaic energy decreased by almost 80 per cent, while those of land-based wind energy declined by 35 per cent.[12] On the other hand, the current costs of off-grid and mini-grid solutions often make these technologies unaffordable for rural communities in many developing countries.

13. Cost reductions and decades of policy support in a number of countries have created a favourable investment climate for some renewable energy technologies. Investment in renewable energy has almost doubled since 2007 – from $154 billion to $305 billion (2015). In 2015, global investment in renewable energy was mostly due to solar photovoltaic and wind energy, which accounted for around 90 per cent.[13] However, finance has been a significant barrier to deployment in many countries and has required policy intervention to provide greater certainty for investors. It remains a major challenge in many developing countries.

14. Solar power, hydropower and wind power are now considered well-established technologies. However, some technologies, such as geothermal energy or bioenergy, are not yet ready to be widely deployed and require significant development and demonstration before reaching adequate levels of reliability and cost-effectiveness. South Africa, for example, has a demonstration project that is examining the commercial viability of growing algae and converting it into energy products.[14] Furthermore, renewable technologies sometimes present new challenges – such as bottlenecks in network infrastructure and limits to the ability to absorb variable renewables – to electricity systems and markets.

15. Non-technological barriers include concerns about environmental sustainability that have led to controversy about the use of some renewable energy sources. There are pertinent questions, for example, about the following issues: the use of first-generation biofuels with respect to life-cycle emissions and implications for land use; the impacts of large hydropower plants on regional ecosystems; the lack of appropriate skills and capabilities to install, operate and maintain renewable energy technologies; and the lack of awareness of renewable energy solutions. In addition, the deployment of renewable energy technologies and the design of policies to encourage this require new skills and capabilities.

[11] IEA, 2017b, *Renewables Information 2017* (OECD/IEA, Paris).

[12] IEA, 2016, *Next-Generation Wind and Solar Power: From Cost to Value* (OECD/IEA, Paris).

[13] International Renewable Energy Agency, 2017a, *Rethinking Energy 2017: Accelerating the Global Energy Transformation* (Abu Dhabi).

[14] Contribution from the Government of South Africa, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T1_RenewableEnergy_con10_SouthAfrica_en.pdf (accessed 6 March 2018).

D. New and emerging renewable energy technologies

16. There remains significant scope for innovation that can further improve and reduce costs of renewable energy technologies. This can include material science in solar photovoltaic cells, the integration of electric vehicles into the power grid and enabling digital technologies into the energy systems.

17. While silicon-based solar photovoltaic energy is likely to remain dominant, a promising variety of third-generation thin film cells based on Earth-abundant materials[15] is emerging in material science. Perovskite solar cells, for example, have excellent light-absorbing capacities and lower manufacturing costs – photoelectric efficiencies improved from 10 per cent to over 20 per cent between 2012 and 2015. However, perovskites are still in the early stages of research and development, with uncertainty regarding long-term stability and feasibility for large-scale deployment.[16] Third-generation solar photovoltaic cells are aiming for combinations of high-power conversion efficiency, lower cost and usage of materials, and lower manufacturing complexity and costs. Achieving all three objectives remains elusive, but with greater efforts into research and development, solar photovoltaic technology can achieve an even larger scale of deployment.

18. Another emerging area in renewable energy deployment is integration into smart infrastructures, such as vehicle-to-grid integration. On average, personal vehicles are on the road for about one hour a day, while the rest of the day, they are stationary – in parking lots or garages, near buildings with electrical power.[17] There is a growing interest in developing vehicle-to-grid systems that provide a bi-directional electricity flow between a vehicle and the power grid. There is a possibility of using electric vehicles as storage devices, with the potential of selling electricity back to the grid during peak demand while the vehicles are not being used. Numerous benefits can include new business models that can incentivize owners with additional revenues, scaling application of electric vehicles beyond individual use and integration into smart infrastructure and cities. One of the motivations for using electric vehicles is the increasing trend of countries to phase out petrol and diesel vehicles. For example, India plans to do so by 2030; China, France and the United Kingdom of Great Britain and Northern Ireland, by 2040.[18] Several other countries have different target dates for the phase-out.[19]

19. As renewable energy technologies increasingly rely on digital technologies, a key future research area is the digitalization of energy systems that become more connected, intelligent, predictable and sustainable. Transport infrastructure and electric vehicles are being increasingly used as leverage for automated, connected, electric and shared mobility. Smart power grids can match and integrate intermittent sources of electricity such as solar and wind power with transport systems on a wide scale, owing to the cross-sectoral nature of mobility. Potential benefits include greater energy efficiency and optimized energy consumption. However, automated, connected, electric and shared mobility is dependent on consumer acceptance, policy measures and technological progress.[20]

[15] For example, copper zinc tin sulphide, perovskite solar cells, nanomaterials such as organic solar photovoltaic cells and quantum dot solar cells.

[16] Massachusetts Institute of Technology, 2015, *The Future of Solar Energy*, Energy Initiative.

[17] BK Sovacool, J Axsen and W Kempton, 2017, The future promise of vehicle-to-grid (V2G) integration: A sociotechnical review and research agenda, *Annual Review of Environmental Resources*, 42(1):377–406.

[18] World Economic Forum, 2017, Countries are announcing plans to phase out petrol and diesel cars. Is yours on the list? 26 September.

[19] IEA, 2017c, *Global EV Outlook 2017: Two Million and Counting* (OECD/IEA, Paris).

[20] IEA, 2017d, *Digitalization and Energy* (OECD/IEA, Paris).

20. Digital technologies are also relevant for buildings, which account for more than 50 per cent of electricity demand. Energy in buildings is generally used for heating, cooling and lighting. Digital technologies are contributing to improved energy response through real-time data by using sensors, which can be managed and monitored through smart devices. Predictive user behaviour, which utilizes learning algorithms, is another emerging technology that can effectively balance energy loads between consumer demand and utility supply. However, the potential impact of greater connectivity of energy systems is still uncertain because of perceived consumer reservations on data privacy, cybersecurity and implications for employment due to automation.

II. Key issues in the innovation and deployment of renewable energy technologies

21. The following section focuses on issues in the innovation and deployment of renewables. These issues are not isolated, but rather interrelated. The deployment of renewable energy technologies involves an innovation system, comprising technological and non-technological contextual factors, and this requires a mix of policies as nations identify the most appropriate renewables deployment pathway to their conditions.

A. Renewable energy market and policy design

22. Technological innovation can be accelerated by both international competition and cooperation. An important aspect of policymaking is to recognize the value of both, and the benefits of encouraging them as appropriate in different circumstances. International interactions within the innovation chain of a renewable technology can allow economic specialization – in manufacturing for example – resulting in efficiency benefits for all countries involved. It might also enable countries without a fully developed innovation chain to begin activities further along the chain. However, the internationalization of the innovation system can also create tensions, given that competition is a key feature of international trade, and the success of a sector in one country can spell demise for the same sector in another country.

23. For some countries, the near-term priorities may be to provide energy access to improve people’s health, well-being and opportunities for income-generating employment. The benefits of providing this access as soon as possible may present compelling reasons for accessing international innovation supply chains to use already developed technology and intellectual property, so that technologies can be rolled out quickly, rather than waiting several years for the innovation chain to be built up domestically.

24. On the other hand, a longer-term perspective might consider the economic and industrial strategy of a country over decadal time frames. Such a perspective might also consider that building up more elements of the innovation supply chain domestically could in the longer term generate greater benefits for the economy as a whole, through employment creation and associated macroeconomic stimulus. The example of the development of solar photovoltaic energy markets in box 1 shows that innovation in renewables is highly international, with drivers in one country having the potential to produce a significant impact on others.

Box 1

Market designs in developing solar photovoltaic markets: Case studies

When China started developing its solar photovoltaic industry, it did not own any designs. It focused on labour-intensive downstream manufacturing, rather than domestic research and development. During the 2000s, the country's approach to photovoltaics was production based and export driven, aiming at markets that provided strong incentives for the use of photovoltaics. It supported the manufacturing of photovoltaics through innovation funds, regional investment support policies and loans. More recently, China has begun to manufacture and deploy solar photovoltaic systems on very large scales.

Germany had a different approach. Its investment in the research and development of solar photovoltaic energy began in the 1970s, involving research institutes, universities and industry. Such investment was supported by federal and regional funding. From the 1990s, Germany also acted to create a domestic market for the technology, initially for rooftop installations and then later, larger-scale installations, for example. It introduced feed-in tariffs to further support market creation. In large part due to the activity of Chinese manufacturing, a rapid fall in the global cost of photovoltaic modules took place. Germany responded by reforming its feed-in policy. This has led to a sharp decline in the production and installation of photovoltaic cells.

Sources: S Jacobsson and V Lauber, 2006, The politics and policy of energy system transformation: Explaining the German diffusion of renewable energy technology, *Energy Policy*, 34:256–276; AL Polo and R Haas, 2014, An international overview of promotion policies for grid-connected photovoltaic systems, *Progress in Photovoltaics*, 22:248–273; HJJ Yu, N Popiolek and P Geoffron, 2016, Solar photovoltaic energy policy and globalization: A multi-perspective approach with case studies of Germany, Japan, and China, *Progress in Photovoltaics*, 24:458–476.

25. The policy instrument most frequently used to promote renewable energy has been the feed-in tariff, which guarantees a fixed price per unit of electricity sold over an agreed period. This is an attractive form of price support for renewables, which are typically dominated by high capital costs. Feed-in tariffs have contributed to swift cost reductions of renewables, particularly onshore wind and solar photovoltaic energy. Bulgaria, Germany, Hungary, Japan, Kenya, Portugal, Turkey and the United Kingdom are among those countries that have used feed-in tariff-based approaches.[21] However, the risk of the feed-in tariff is that Governments could lock themselves into subsidising renewables for a long time, which would have an adverse impact on the economy.[22]

26. In this context, tendering or auction-based approaches are increasingly used as policy instruments to identify the price for renewable energy contracts and deliver substantial cost reductions in renewable energy. In many countries, a transition from government-administered feed-in tariffs to auction systems has taken place during the past few years. Chile and Mexico have achieved low prices for solar photovoltaic energy through auctions, while Germany, Japan, Portugal and the United Kingdom have revised their allocation of contracts or tariffs to be delivered on an auction basis. It is expected that almost 50 per cent of all renewable electricity capacity additions will be driven by auctions in the next five years, compared with 20 per cent in 2016.[23]

27. Governments tend to play a crucial role in the innovation and deployment process, for example, by funding research and development, creating demand through deployment incentives, reforming energy markets and setting standards, and implementing other measures to strengthen investor confidence. Mexico, for example, has created and invested in six energy innovation centres focusing on geothermal, solar and wind power; bioenergy;

[21] Contributions from the Governments of Bulgaria, Germany, Hungary, Japan, Kenya, Portugal, Turkey, and the United Kingdom, available at http://unctad.org/en/pages/MeetingDetails.aspx?meetingid=1562 (accessed 6 March 2018).

[22] F Zhang, 2013, How fit are feed-in tariff policies? Evidence from the European wind market, Policy Research Working Paper 6376.

[23] IEA, 2017e, *Renewables 2017: Analysis and Forecasts to 2022* (OECD/ IEA, France).

ocean energy; and smart grids.[24] Furthermore, government incentive systems and procurement policies can also encourage the use of local technology and equipment, such as in the Islamic Republic of Iran.[25] In general, Governments can play an important role in providing a legal and regulatory structure, which ensures that private sector activities are being directed in a way that is beneficial for society and provides clarity and confidence to players in the private sector.

28. Financing is an important factor in the deployment of renewable energy technologies. Box 2 describes the different roles that public, private and institutional investors can play in financing renewable energy.

Box 2
Landscape of financing renewable energy deployment

Public finance institutions: Renewable energy has often had to rely on public finance institutions, particularly in early stage project development. Examples include international financial institutions such as multilateral development banks and development finance institutions (the latter are usually bilateral development agencies). Public finance instruments are often in the form of grants, subsidies and guarantees to facilitate renewable energy projects that are too risky for private sector support.

Private investors, including new capital market instruments such as green bonds: Green bonds are gaining prominence as innovative mechanisms attracting finance for renewable energy projects in emerging economies. Green bonds are any type of bond instrument to fund projects that have a positive environmental and climate impact. They can be used to raise large-scale long-term financing from non-bank sources and at relatively low cost.

Institutional investors, including pension funds: Institutional investors are a major potential source of capital for renewables. Institutional investors such as pension funds from developed economies show increasing interest in investing in developing countries.

Sources: International Renewable Energy Agency, 2016, *Unlocking Renewable Energy Investment: The Role of Risk Mitigation and Structured Finance* (Abu Dhabi); and 2017a.

B. Technical challenges of integrating renewable energy to electricity grids

29. As more renewable energy is deployed, the technical and economic aspects of integrating larger shares of renewables into electricity grids becomes increasingly challenging. There is a major emphasis on innovation in enabling technologies that can help integrate variable renewables into electricity systems, including storage; smarter electricity systems that include the widespread integration of digital and so-called exponential technologies such as artificial intelligence; and technologies to increase the flexibility of energy demand.

30. Storage is a key enabling technology. Yet storage technologies vary significantly in terms of output, rates of charge and discharge, and the length of time they can store energy. Current battery technologies are unlikely to be sufficient to deliver large-scale seasonal storage so that solar electricity can be stored in summer to heat buildings in winter. Therefore, there is a need for advances in other types of heat or energy storage that can operate over longer timescales. Likewise, a range of storage technologies are being developed, with applications ranging from small-scale applications to grid-scale applications, and from rapid-discharge applications to interseasonal storage applications.

[24] Contribution from the Government of Mexico, available at http://unctad.org/meetings/en/Presentation/cstd2017_p07_Mexico_en.pdf (accessed 6 March 2018).

[25] Contribution from the Islamic Republic of Iran, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T1_RenewableEnergy_con05_Iran_en.pdf (accessed 6 March 2018).

31. The mix of variable and dispatchable renewable energy depends on a country's availability of resources and consumption patterns. In Portugal, for example, hydropower and wind power play a significant role in the country's power mix. On average, renewables provide more than 60 per cent of its electricity mix over a year – in 2017, there were six consecutive full days during which renewables provided 100 per cent of the country's electricity.[26]

32. Renewable energy is site specific, and solar- or wind-rich areas can be distant from where the demand is located. Therefore, infrastructure development is important for electricity systems. Such infrastructures are noteworthy investments, and once in place, have a considerable limiting and directing influence on the evolution of the supply and demand balance in a power system. The future of the power grid infrastructure therefore becomes a major issue in countries that have historically invested in a power grid based around the locations of supply and demand in a largely fossil-fuel-based system, but whose plans to transition to a renewables-intensive system means that the location of power generation will substantially change (see box 3).

33. Infrastructure development is also important when related to the different types of renewables, such as centralized versus distributed renewables. Centralized electricity systems are grid bases that require extensive transmission and distribution infrastructures. Conversely, decentralized systems are smaller in scale (for example, mini grids or standalone systems) and have shown to be more appropriate for remote, harder-to-reach rural areas. For example, solar home systems are highly decentralized, while large-scale hydropower technologies are used in some of the largest power plants in the world. These factors in turn influence the scale of renewables that are deployed from bottom-up off-grid applications (for example, solar home systems) to larger grid-scale power plants (for example, hydropower plants, concentrated solar power plants or geothermal plants).

Box 3

Adapting grid infrastructure to renewable energy deployment: Case studies

In Germany, the electricity transmission network is facing a challenge: there is significant wind power potential in the north of the country, but the major demand centres are in the south. This means that deploying wind power in the windiest northern regions will entail a huge power flow from north to south during times of high wind and high demand. As a result, the country's energy transition (*Energiewende*) also includes plans to upgrade the grid infrastructure. However, this is not without its challenges, as public acceptance is more amenable to underground cables for the electricity superhighways, resulting in increased costs.

In Japan, part of the Fukushima innovation coast framework is to expand power lines to gain access to wind-rich areas.

The United States of America is also making efforts to modernize its grid. The Department of Energy has developed a grid modernization initiative, with activities focusing on the integration of energy efficiency, renewable power and sustainable transportation technologies into the electrical power system. Technologies and techniques required for successful grid integration include the following: improved renewable power forecasting; energy storage technologies; advanced power electronics; grid-responsive building technologies; vehicle-to-grid technologies; and new grid sensing, control and operations approaches.

Sources: Contributions from the Governments of Germany, Japan and the United States, available at http://unctad.org/en/pages/MeetingDetails.aspx?meetingid=1562.

[26] Contribution from the Government of Portugal, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T1_RenewableEnergy_con09_Portugal_en.pdf (accessed 6 March 2018).

C. The role of renewable energy in extending access to electricity

34. Some 1.1 billion people still require access to electricity. A range of evidence suggests that extending electricity access contributes to various improvements in overall socioeconomic development.[27]

35. Rapid technological progress in renewables and cost reductions represent an opportunity for electrification in rural areas – especially in developing countries – through off-grid and mini-grid solutions. According to recent research by UNCTAD, energy access plans and related income-generation opportunities should be fully integrated into a country's overall development strategies through an energy-transformation nexus.[28] In this perspective, supply and demand for energy are tackled holistically and are a means of fostering economic diversification and job creation.

36. Historically, most of the interventions that extend electricity access by renewables have been through grid extension, less so through off-grid technologies. Grid-based solutions typically involve the upfront investments in infrastructure being paid for by the Government or utility company and spread through customer bills. As such, the upfront cost to any individual customer willing and able to connect is relatively low – a small connection charge followed by running costs. However, this kind of top-down approach can take time to reach the whole of society. In such situations, it is possible that off-grid renewables may be able to provide access to electricity to communities faster than grid electrification can manage. IEA[29] has suggested that off-grid solutions, particularly solar photovoltaic technology, are likely to be the most cost-effective solutions for universal electrification in sub-Saharan Africa.

37. Another important consideration in increasing energy access by using renewable energy is affordability. Low-income communities may be unable to pay in advance for the investments required, and investors may be equally unwilling to invest in uncertain returns due to the low density of demand users. New business models can make this viable and conducive to development, for example by using microfinance or pay-as-you-go arrangements to spread these costs. Solar Sister, a non-governmental organization that provides support for women in establishing solar microbusinesses, have effectively used the pay-as-you go model. In some cases, payments for new renewable energy technologies can be structured so they are similar to the costs of the energy sources they are replacing, for example, kerosene.

38. Private sector investors are not always interested in developing off-grid applications in remote areas. One approach to address this issue could be clustering and bundling of projects to achieve scale. Measures to overcome barriers to private sector-led investment in small-scale renewable energy projects may include setting up a robust governance structure with clear regulatory and enabling policy environments, standardized licensing procedures, off-grid tariffs and addressing upfront costs through low-interest credit and microfinancing (box 4).

[27] IEA, 2017f, *Energy Access Outlook 2017: From Poverty to Prosperity* (OECD/IEA, Paris).
[28] UNCTAD, 2017.
[29] IEA, 2017f.

Box 4
Rural electrification in Uganda: Case study

Lessons learned from the rural electrification strategy of Uganda revealed the need for government leadership in financing, building initial infrastructure capacities and promoting electrification-related economic development. Thereafter, it becomes feasible for private investors and commercial financing to take over.

The key risk factor inhibiting the rapid expansion of rural electrification in Uganda was commercial risk. New approaches were needed to build demand and rapidly accumulate customers. Cooperatives and the peer-interest principle proved to be useful concepts.

In addition, the previous set of rural electrification providers were struggling because they were too small. Rural service territories must be sufficiently large to generate revenue levels as needed to meet service providers' financial cost requirements.

Another lesson learned was that planning and management for the renewable energy sector should be centralized, and programme implementation simplified. The best way forward was to centralize authority in the lead entity responsible for the renewable energy sector and ensure that electrification was carried out in harmony with the broader scope of national economic and social development planning. It was also important to adequately coordinate the rural aspect of the nation's electricity infrastructure development with the other power sector functions and entities.

Source: Contribution from the Government of Uganda, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T1_RenewableEnergy_con12_Uganda_en.pdf (accessed 6 March 2018).

D. Using renewable energy in the household sector for cooking

39. Traditional biomass represents 49 per cent of the total renewable energy consumption in the world.[30] Some 2.8 billion people still cook and heat their homes using open fires and simple stoves that burn traditional biomass (wood, animal dung and crop waste) and coal. This has grave health, environmental and social consequences.[31]

40. Sustainable Development Goal 7 is not only about increasing the share of renewable energy from the energy mix, but also about the elimination of traditional, dirty biomass – a pressing issue in many developing countries. Therefore, there is an urgent need to deploy alternatives to the traditional use of bioenergy for cooking and other energy services.

41. There are two approaches to address the issue: to promote more efficient and sustainable use of biomass (for example, by producing and distributing bio-methane from biodegradable waste and syngas from lignocellulosic biomass available locally)[32] or to encourage households to switch to modern cooking fuels and technologies. It has proved difficult to make progress in improving access to clean cooking because of affordability (solid biomass is often free, while improved cookstoves and alternative fuels are not) and cultural resistance (preference for taste of food prepared in traditional ways).[33] Evidence has shown that policies and programmes to address this challenge must be embedded in the social and cultural contexts of the communities they involve and take account of their current energy practices, needs and expectations, and potential for productive uses. The engagement of women in this process is particularly crucial, as they frequently have the main responsibility for household energy-related practices such as fuel

[30] International Renewable Energy Agency, 2017a.
[31] World Health Organization, 2016, Household air pollution and health, Fact Sheet No. 296.
[32] Contribution from the Government of Pakistan, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T1_RenewableEnergy_con08_Pakistan_en.pdf (accessed 7 March 2018).
[33] IEA, 2017f.

gathering and cooking. Women can also be effective trainers and communicators in managing and maintaining new local energy systems.

42. While increasing access to clean cooking facilities may overlap with increasing the deployment of renewable energy, the two objectives are not necessarily aligned in all cases. However, as shown in box 5, some solutions are consistent with the increased deployment of renewable energy.

Box 5
Cooking with renewable energy in Bangladesh: Case study

With support from SNV Netherlands Development Organization and KfW Bank, the National Domestic Biogas and Manure Programme in Bangladesh has installed over 46,000 small-scale biogas systems using animal waste in rural areas. The programme has been supporting the expansion of biogas technology in rural areas, with the ultimate goal of establishing a sustainable and commercial biogas sector in Bangladesh. The biogas produced through these plants is used for cooking and lighting in rural households, but slurry, a by-product of biogas plants, can be also used as an organic fertilizer. The programme is being implemented through a network of 45 partner organizations, including private companies, non-governmental organizations and microfinance institutes. The programme saves 44,300 tons of firewood and reduces the use of 1,400 tons of kerosene every year.

Source: Infrastructure Development Company Ltd, 2014, Biogas and biofertilizer, available at http://www.idcol.org/home/dbiogas (accessed 7 March 2018).

III. Key policy considerations

A. Countries have different national renewable energy pathways

43. A country's renewable energy pathway is an important consideration, because once in place, several mechanisms, such as economies of scale, sunk investments, learning effects, user practices and lifestyles can result in "lock-in" for years, if not decades. This lock-in effect can make pathways difficult to change. Renewable energy pathways and related income-generation opportunities should have a central place in national development strategies because of their strategic importance.

44. Renewable energy innovation systems must be seen within country and regional contexts, and, therefore, their deployment depends on various contextual factors. These include geographical and environmental conditions, macroeconomic conditions, socioeconomic and development priorities, cultural and institutional conditions, and policy and regulatory frameworks. Accordingly, countries have largely varying shares of renewables in their energy mix. For example, the share of renewable energy from total primary energy supply is 22 per cent in Colombia, mostly from hydropower, which is an important renewable energy source for electricity in Latin America. In Ethiopia, the share is almost 93 per cent, mostly from biomass. The share of renewables is 36 per cent in the Philippines, from a combination of geothermal energy, solar energy, wind energy and biomass.[34]

[34] IEA, 2017b.

45. Policymakers should balance aims and priorities for renewable energy deployment. Expansion of renewables can contribute to local or national goals, such as invigorating industrial, manufacturing and commercial sectors associated with the production and deployment of renewables, creating jobs as a result. Expanding renewable energy can also help increase income-generating opportunities for communities whose access to energy has been limited or intermittent. It can be an important contributor to gender equality by reducing time spent by women and girls gathering fuel, by increasing access to education, or by improving health through the reduction of indoor pollution. Furthermore, renewable energy can play a role in improving the productivity of agriculture, for example by enabling pumped irrigation.

46. As such, there is not one optimal pathway for the deployment of renewables, but rather a range of possible pathways. Thus, a pathway for such deployment is not a one-size-fits-all exercise but is dependent on a clear understanding of contextual factors and priorities.

B. Policy mixes are necessary to support renewable energy deployment

47. Science, technology and innovation policies should take an innovation-system approach that includes national, regional and sectoral innovation systems to support renewable energy. The systemic nature of renewables innovation requires the creation of a clear market demand for renewables and a mix of supporting policies to stimulate research and development, build local skills, coordinate players and infrastructure, align regulations and incentives, and mobilize funding.

48. Renewable energy innovation can vary in scope and scale. Some incremental innovations can lead to improvements in existing technologies, such as scaling up the size of offshore wind turbines. In the meantime, radical innovations yield new inventions and/or methods of production, such as the development of smarter, more flexible electricity systems that can help integrate variable renewable technologies in greater proportions or at a lower cost than was previously thought possible. Incremental and radical innovations are both relevant to renewable energy technologies, and policies can encourage both.

49. Applying policy mixes requires a complex system of interventions, players and processes co-evolving over a long time. Comprehensive policy mixes should include complementary types of instruments such as feed-in tariffs, international standards, demand-side measures such as public procurement, and incentives such as mission innovation programmes and bottom-up funding mechanisms, depending on country-specific challenges, priorities and different levels of technology maturity.

50. It is important to build capabilities in order to increase awareness of renewable energy technologies and to develop skills to install and maintain them. In rural energy applications, the effectiveness of training and capacity-building can be enhanced by considering social and economic factors, including gender issues. Recent research by UNCTAD underscores the importance of building local innovative capabilities, including the ability to develop and design technologies that are adapted to local needs.[35] Science, technology and innovation, and policy measures that can support local innovative capabilities may include supporting universities and research centres that focus on renewable energy technologies or providing incentives for firms for research, development and demonstration.

51. Furthermore, to maximize the effectiveness of policy mixes, appropriate policy processes and governance mechanisms are needed. These include coordination, coherence, policy learning and collaboration.

[35] E/CN.16/2010/4.

C. International and regional cooperation have a key role to play

52. Because of the international nature of renewable energy supply chains, international cooperation has an essential role to play in increasing the deployment of renewables. International cooperation can bring together different players of a supply chain or help them benefit from shared natural resources and shared infrastructure. As well as forming markets to which private players can respond in a competitive environment, Governments should be aware of where their role as a broker can improve the functioning of supply chains or enable an efficient accessing of naturally shared assets – be they natural, infrastructure or knowledge assets.

53. Interregional cooperation is especially important in mitigating different renewable energy potential due to geographical differences between neighbouring countries. Some regions have a particularly high potential for renewables, that if harnessed, could exceed the demands of the country in which they are located. Furthermore, offsetting diurnal and seasonal timing of renewable outputs of different regions can mean that the renewable outputs of such regions could effectively complement each other, if they were linked up into an integrated cross-national network. There are several initiatives and plans in this area, for example, the Nordic Grid Development Plan, which is considering new interregional transmission lines that could deliver energy surplus in one region to consumption centres.[36] Another example is the Africa Clean Energy Corridor initiative by the International Renewable Energy Agency that aims to accelerate the development of renewable energy, including cross-border trade of renewable power in the power pools of eastern and southern Africa.[37]

54. Cooperation may also include technology transfer.[38] China, for example, is facilitating wind farm development in Argentina and Pakistan,[39] while India is supporting the transfer of renewable energy technology and skills in Mozambique (box 6). The main challenge is to design policies and cooperation mechanisms that facilitate technology transfer between firms, especially in countries with emerging renewables sectors. However, technology transfer should not replace, but rather complement, domestic capacity-building efforts.[40]

55. As shown in box 6, international cooperation, including North–South and South–South cooperation, can extend to many areas: policy learning and capacity-building, technology development, improvement of the interconnection of grid infrastructures across borders, development of manufacturing capacity or contribution through funding. One notable example of the latter is a solar photovoltaic energy plant in Cobija, Plurinational State of Bolivia, that was financed almost half-half by the Bolivian National Electricity Company and Denmark.[41] The plant generates enough solar power to cover approximately half of the energy demand of Cobija during daytime hours, saves an important amount of diesel and reduces emissions.

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[36] Stattnet, Fingrid, Energinet and Svenska Kraftnat, 2017, Nordic Grid Development Plan 2017, available at http://www.statnett.no/Global/Dokumenter/Nyheter%20-%20vedlegg/Nyheter%202017/Nordic%20Grid%20Deleopment%20Plan%202017.pdf (accessed 6 March 2018).

[37] Southern African Development Community, 2016, *Renewable Energy and Energy Efficiency Strategy and Action Plan*: *REESAP 2016–2030* (Gaborone).

[38] DG Ockwell J Watson, G MacKerron, P Pal and F Yamin, 2008, Key policy considerations for facilitating low carbon technology transfer to developing countries, *Energy Policy*, 36(11): 4104–4115.

[39] J Gosens and Y Lu, 2013, From lagging to leading? Technological innovation systems in emerging economies and the case of Chinese wind power, *Energy Policy*, 60(C):234–250.

[40] E/CN.16/2010/4.

[41] Contribution from the Government of the Plurinational State of Bolivia, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T1_RenewableEnergy_con01_Bolivia_es.pdf (accessed 7 March 2018).

Box 6

International science, technology and innovation cooperation in renewable energy: Case studies

The Southern African Solar Thermal Training and Demonstration Initiative, or SOLTRAIN, started in 2009 with funding from the Austrian Development Agency and the Fund for International Development of the Organization of the Petroleum Exporting Countries. Since 2009, it has raised awareness and built competencies in Lesotho, Namibia, Mozambique, South Africa and Zimbabwe. During its first two phases (2009–2016), 187 small- to large-scale solar heating systems were installed, and 2,150 people trained. In the third phase, particular emphasis will be placed on demonstration projects in organizations that support women and other marginalized groups.

A solar panel factory has been set up in Mozambique with joint investment by the Governments of Mozambique and India. Mozambican technicians are being trained, including in India. The factory currently employs 33 people. Though this is a small-scale operation, it offers an interesting example of how technology and skills transfer can benefit countries by producing and deploying renewables quickly. Despite the lack of research and development background in the country, the example also illustrates how new skills and employment in the manufacturing stage of the supply chain can be developed.

Mission Innovation is a global initiative of 22 countries and the European Union that aims to accelerate global clean energy innovation in order to make clean energy widely affordable. There are seven priority innovation challenges that focus on collaborative research, development and demonstration. Several of these challenges focus on renewable energy or related innovations, including smart grids, off-grid electricity access, sustainable biofuels, new technologies to convert sunlight into energy and clean energy materials.

The Global Alliance for Clean Cookstoves is a public–private partnership that has an instrumental role in supporting the research, design and rolling out of programmes for improved cookstoves, including cookstoves using biofuel and solar energy. It emphasizes the need to develop markets by raising consumer awareness and ensuring availability and affordability. The organization brings together more than 1,600 partners worldwide, representing the private sector, Governments, non-governmental organizations, philanthropists and donors, and academia.

Sources: Contributions from the Governments of Austria, Canada and the United Kingdom, available at http://unctad.org/en/pages/MeetingDetails.aspx?meetingid=1562 (accessed 7 March 2018); Global Alliance for Clean Cookstoves, 2016, Clean Cooking: Key to Achieving Global Development and Climate Goals; Southern African Development Community, 2016.

56. International organizations and bodies such as the Commission on Science and Technology for Development can play an important role in supporting these forms of cooperation. They can provide a platform whereby countries can share lessons and best practices in the deployment of renewable energy. Moreover, they can facilitate the identification of mechanisms for improving renewable energy capabilities in developing countries. These include capabilities to develop and implement supportive policy mixes; the development of flexible plans and regulations for the energy sector that incorporate incentives for renewable energy; and measures to improve capabilities to absorb, maintain and adapt renewable energy technologies to the local context.

IV. Suggestions for consideration by Member States and the Commission on Science and Technology for Development at its twenty-first session

57. The achievement of the Sustainable Development Goals is highly dependent on increasing access to clean energy services. Increasing renewable energy deployment has a substantial implication on income generation and other development outcomes such as gender equality, health and climate change. As shown in this report, countries have different renewable energy pathways, depending on local contexts, including geographical patterns, cultural and institutional conditions, and policy and regulatory frameworks. Owing to their strategic importance for sustainable development, renewable energy policies should be incorporated in national development strategies. Furthermore, the report finds that policy mixes and a systematic approach to innovation are necessary to increase the share of renewable energy in the global energy mix. This would include measures targeting both the demand for and supply of renewables, as well as a mix of supporting policies to stimulate research and development, build skills locally, ensure affordability and create a supporting regulatory environment. Finally, international cooperation, including North–South and South–South cooperation, has a major role to play in increasing substantially the share of renewable energy in the global energy mix by 2030. International cooperation can facilitate not only knowledge sharing, policy learning, capacity-building, and technology development, but it can also contribute significantly to developing interconnected grid infrastructures.

58. Member States may wish to consider the following suggestions:

(a) Increase national support for research and development activities in renewable energy technologies and enabling technologies, and bring together government, academia, the private sector and civil society to take part in these activities, from basic research to implementation;

(b) Adopt policy mixes that allow for flexibility to support renewable energy innovation and deployment, and improve policy coordination and policy coherence with sectoral policies such as science, technology and innovation policies;

(c) Ensure the coherence of renewable energy policies with a country's broader national development agenda;

(d) Enable the contribution of grid and off-grid approaches by creating a supporting regulatory environment and tariff structure;

(e) Consider policies on renewable energy technologies to increase income-generation opportunities and contribute not only to household use, but also to the industrial, commercial and agricultural sectors;

(f) Support new business and financing models to ensure the affordability of renewable energy technologies by spreading upfront costs;

(g) Recognize and consider the social and cultural contexts of local communities, especially women, and support innovation, scaling and deployment of technologies in household-related energy services;

(h) Promote North–South, South–South and triangular partnerships on renewable energy technologies and investigate collaborative research and development mechanisms that might be effective in facilitating technology transfer;

(i) Build domestic innovative capabilities, including skills for installing, maintaining and repairing renewable energy technologies, and engage with local communities, including women, in training and maintenance of these systems.

59. The international community may wish to consider the following suggestions:

(a) Facilitate international and regional joint research activities on renewable energy, including in forecasting trends, and apply holistic approaches to examine the relationship between water, food, energy and the environment;

(b) Encourage international science, technology and innovation collaboration in renewable energy;

(c) Improve the interconnection of grid infrastructures for renewables across borders.

60. The Commission is encouraged to take the following steps:

(a) Support multi-stakeholder collaboration in policy learning, capacity-building and technology development;

(b) Improve coordination among stakeholders and enable partnerships in renewable energy that harness the specific expertise and interest of stakeholders;

(c) Encourage the sharing of lessons between countries and regions, while recognizing that policies and policy mixes cannot be simply transplanted from one context to another;

(d) Identify mechanisms for improving capabilities in developing countries for renewable energy, including capabilities to develop policies, flexible plans and regulations, and measures to improve capabilities to absorb, maintain and adapt renewable energy technologies to the local context.