United Nations ECE/ENERGY/2019/1

Economic and Social Council

Distr.: General
16 July 2019

Original: English

Economic Commission for Europe

Committee on Sustainable Energy

Twenty-eighth session
Geneva, 25-27 September 2019
Item 3(a) of the provisional agenda
High-level segment: Accelerating and deepening the transition to sustainable energy systems: Pathways to Sustainable Energy: Presentation of results and recommendations

Pathways to Sustainable Energy: Accelerating Energy Transition in the Economic Commission for Europe

Note by the secretariat

I. Introduction

1. Energy underpins the development of economies and most of the goals and targets of the 2030 Agenda on Sustainable Development (2030 Agenda). The energy sector plays a critical role in finding solutions for both sustainable development and climate change mitigation. Since the universal agreement on the seventeen Sustainable Development Goals (SDGs) including the goal on sustainable energy SDG 7 in 2015, countries have commenced with the implementation of the 2030 Agenda. However, at this stage, there is a gap between the agreed energy and climate targets and the strategies and systems that are being put in place today to achieve them. Accelerated and more ambitious strategies and policies will be needed to fill the persistent gaps to achieve the 2030 Agenda, and in particular, energy will need to play an increasing role across various SDGs. If gaps are not addressed urgently, more drastic and expensive action will be required to avoid extreme and, potentially, unrecoverable adaptation measures.

2. Currently, there are many different interpretations of what is “sustainable energy”. Countries in the region of the United Nations Economic Commission for Europe (ECE) have not yet agreed on a collective pathway to achieve energy for sustainable development. For the ECE region there is an important opportunity to explore the implications of different sustainable energy pathways and to work together on developing and deploying policies and measures to attain the 2030 Agenda. This is why the Committee on Sustainable Energy (the Committee) initiated this flagship project “Pathways to Sustainable Energy” (the project).

3. The objective of the project is the development of strategies and actions to ensure the attainment of sustainable energy in the ECE region[1]. The project’s goal is to strengthen the knowledge and capacities of countries to develop, implement and track national sustainable energy policies aligned with their commitments on climate change and sustainable development, and to understand the objectives and actions of other countries. The project

[1] See also ECE/ENERGY/2016/7, ECE/ENERGY/2018/1, CSE-27 2018_INF.11, and CSE-27/2017/INF.8

aims to contribute concretely to climate change mitigation and sustainable development. To achieve this goal, the project set forth three milestones:

(a) development of sustainable energy policy and technology options to 2050 supported by modelling and experts' insights;

(b) development of a concept for an early-warning system to monitor and forecast if achievement of sustainable energy objectives is on track; and

(c) facilitation of a high-level political dialogue.

4. Policy dialogues among ECE member States improve the understanding of countries on how best to coordinate their efforts to achieve energy for sustainable development. The twenty-eighth session of the Committee is an opportunity to hold such a high-level dialogue among countries and to consult with member States on next steps after the completion of Phase I.

5. This document seeks to inform the Committee about potential policy pathways in the ECE region based on modelling results and insights from experts (see chapter V and VI). It invites the Committee to provide inputs to shape the project's Phase II approach, including through additional analysis of sub-regional, policy or technology deep dives (see chapter VII). Additional funding will be required for all future stages of this project.

II. Policy Recommendations

6. Policy recommendations have been developed based on modelling results, insights from subregional[2] workshops and multistakeholder consultations. Based on the recommendations from the Open-ended informal consultation of the Committee on 16 May 2019, the following policy recommendations are grouped by near-term and long-term priority policy recommendations to provide policy makers with a better sense of priority setting. The former have been identified as low-hanging fruit opportunities for which an immediate action across the whole ECE region (and beyond) would be necessary if achieving 2ºC is the target. The latter, on the other hand, are associated with complex social and financial implications that need to be carefully examined across all sectors for implementation into countries' strategic national energy action plans.

A. Near-term priority policy recommendations

1. Pursue energy efficiency as the first fuel with energy conservation and energy efficiency as core elements of the future energy system

(a) Pursue energy efficiency and productivity improvements in the production, transmission, distribution and consumption of energy prior to investing in new production and supply infrastructure to reduce the need to new carbon intensive energy production;

(b) Develop progressive energy efficiency retrofit schemes for residential sector and introduce stringent building standards. Deploy initiatives that promote high performance buildings[3] for new and existing buildings urgently;

(c) Initiate national programmes to improve the energy efficiency of the energy and carbon intensive industries;

(d) Introduce minimum energy performance standards for energy using equipment;

[2] For the modelling, the ECE region is divided into seven subregions: North America, Western Europe, Eastern Europe, Russian Federation, Central Asia, the Caucasus and BMU (Belarus, Moldova and Ukraine). Two subregional workshops were held - on BMU and on the Caucasus.

[3] UNECE High Performance Buildings Initiative https://www.unece.org/fileadmin/DAM/energy/se/pdfs/geee/Booklet_HPBI_June19/HPBI_Brochure.pdf

(e) Develop progressive mobility solutions to reduce the carbon intensity of transport. Promote new technologies to reduce all types of travel, increase the use of shared commuter transport and bicycle schemes. Discourage the use of private vehicles by cost increases such as, pollution charging in urban areas, increasing parking costs, and car taxes based on carbon footprint.

2. Reduce the environmental footprint of energy. The 2ºC target and net zero commitments can only be achieved with reduced carbon emissions and negative carbon technologies to bridge the gap until innovative low or zero-carbon energy technologies are invented and deployed

(a) Encourage informed decision making by establishing clear sustainability criteria for energy investments. Develop and disseminate investment guidelines for low-carbon technologies (high efficiency and low emission (HELE) and carbon capture usage and storage (CCUS)) and modernize the current energy infrastructure to accelerate the transition to renewable energy or other carbon neutral solutions;

(b) Develop and disseminate guidelines on best practice for CCUS. Given the near-term importance of CCUS and CCS accelerate the deployment of these technologies for tackling climate change and providing energy security;

(c) Deploy and disseminate best practice guidance on methane management (monitoring and remediation) in extractive industries;

(d) Deploy a full-fledged United Nations Resource Management System (UNRMS) to assist countries in managing their endowments of national resources in line with the 2030 Agenda.

3. Prepare the energy system for the transformation to significant levels of renewable energy and to monitor ongoing process, highlighting barriers to the transformation

(a) Discourage the use of high carbon energy with environmental taxes. A price on carbon, which incentivizes emissions reductions from carbon-intensive value chains, is vital to signal the willingness to promote the economics of lower carbon energy solutions and to catalyse the transition;

(b) Develop an ECE overview of the policy readiness of countries for the energy transition. Improvements in the legal and regulatory frameworks are necessary to enable further transformation of the energy system (e.g. through accelerated phasing out of subsidies). Legal frameworks for transition require long lead times and have to be implemented in parallel with technology developments. Related frameworks need to be transparent, include all technologies which contribute to the implementation of the Agenda 2030 and the Paris Climate Agreement, and support the emergence of new business models;

(c) Facilitate cooperation to encourage accelerated use of Information & Communication Technologies (ICT) (e.g. smart grids, smart cities, internet of things, 5G technology for advanced and smart consumption metering as well as grid asset management and protection, lowering or eliminating tariffs on cross-border transmission of energy) to improve demand-side participation in energy markets, to improve efficiencies and to enable greater penetration of intermittent renewable energy;

(d) Accelerate the energy transition in low-income countries through capacity building, direct investment and best practices exchange. Low-income countries may be low emitters of CO_2 emissions today but in light of their growing populations sizes and their development needs, facilitating the shift to renewable energy today will prevent an increase in CO_2 emissions in the future;

(e) Facilitate cooperation to set national targets and develop action plans towards sustainable energy. Regional and national early warning systems need to be developed to help forecast progress and indicate optimal pathways to achieve sustainable energy.

B. Long-term policy recommendations

1. Position the transition to sustainable energy as a shared challenge requiring continuous action and effective, accountable and inclusive institutions at all levels. Promote mutually beneficial economic-interdependence to accelerate attainment of the 2030 Agenda through integrative, nexus solutions beyond the energy space. Advocate efficient integration of energy markets over energy independence to ensure energy security

(a) Advocate an interconnected system in which supply, demand, conversion, transport and transmission interact freely and flexibly;

(b) Facilitate technological and regional cross-border cooperation to strengthen best practice exchanges. Introduce and scale up low-carbon technologies engagement in joint investments;

(c) Identify sub-regional opportunities for joint energy system planning to strengthen national and regional grids, improve energy security and provide integrated planning of resources (such as water, energy and agriculture);

(d) Facilitate the conditions that would allow industry to deploy its best capabilities (competence plus capacity) in ways that the capital market can finance. There is need to promote dynamic and integrative public private partnerships and to clarify to investors what criteria can be used to assess the sustainability of an investment.

2. Accelerate energy transition towards a sustainable system. Modernizing and optimizing fossil-based infrastructure and integrating it with new renewable infrastructure is essential to achieve sustainable development. This is a long-term undertaking and must embrace all pillars of sustainable development seeking to leave nobody behind and maintaining social cohesion. All technologies, that support the Agenda 2030 and the Paris Climate Agreement, will have a role to play in the modernization of the energy system in the ECE region

(a) Address the social and economic impacts of phasing out obsolete and aging fossil-based infrastructure and recognize the crucial role that this infrastructure has for the livelihoods of many and economic development. Mitigating the negative social dimension is key to a *just* energy transition;

(b) Coordinate efforts to ensure a technology neutral, level playing field of fiscal policies that allow investment in CCS/CCUS/HELE technologies and negative carbon technologies and position them in parity with other carbon neutral electricity generation technologies (such as natural gas, nuclear energy, renewable energy). Persist with efforts to phase out subsidies;

(c) Address challenge of integrating fluctuating renewable energy into power and heating grids. Demand-side flexibility can also facilitate in the integration of variable renewable generation. International standards are required to optimize flexible power systems that rely on the interplay of fossil fuels and renewable energy. Storage systems can play an important role in grid resilience and stability and are of vital importance to balance the intermittency of the wind and solar PV;

(d) Facilitate regional discussions on the regulatory frameworks for big data, smart grids and a systematic approach support energy transition and create opportunities for new entrants. Effective research and development can drive integration of innovative technologies while adjusting policy frameworks to accommodate “disruptive” technologies;

(e) Appropriate skill set for the implementation of digital economy and provision of maintenance services of the renewable energy infrastructure across the region is of vital importance to be developed to provide the baseload and support an accelerated energy transition towards a sustainable system.

3. Promotion of a low-carbon circular economy is a Herculean task that requires significant State intervention and international cooperation. Sustainable resource management practices that embrace circular economy principles and that integrate the full spectrum of the 2030 Agenda's goals and targets need to be implemented

(a) Monitor developments of energy storage technologies that need to be promoted to support fluctuating renewable energy systems. Heat storage in molten salts, phase change materials and other forms of thermal mass, power-to-energy as well as other forms of chemical energy storage also need to be investigated;

(b) Facilitate policy discussions for the commercialization of renewable gases (such as hydrogen and biomethane) as essential elements for advancing in the decarbonization through sector coupling and sectoral integration;

(c) Facilitate policy discussions for waste-to-energy technologies, especially providing visibility for new, sustainable technologies as options for member States;

(d) Facilitate policies and standards to limit emissions of natural gas if it is to provide the baseload requirements for introducing renewable energy sources into the grid sustainably;

(e) Promote the need to improve quality of life through better air quality in cities and polluted areas. This benefit should be included in the cost benefit analysis of energy transition investments;

(f) Explore additional policy options to use concentrated sources and atmospheric CO_2 within a circular economy as a feedstock for petrochemical and inorganic materials, since large-scale removal of CO_2 from the atmosphere will be required to meet the 2°C target.

4. Facilitate and encourage new business models using sustainable principles and promote technological innovation in sustainable energy. This requires market designs that reward sustainable businesses. New business models will necessarily be developed on lower carbon applications, increasing energy efficiency and more control by customers. Technology integration into the energy system is a prerequisite for energy transition and modernization of the energy system

(a) Coordinate discussions on the design of markets that promote innovative, sustainable and flexible business models and create necessary regulatory frameworks that foster technological innovation and energy transition in the region. Such discussion should apply to any low- or zero-carbon, sustainable technology and business model that can be cost effective at the appropriate scale and replicated to make it widely available;

(b) Encourage business models that prioritize improvements in energy productivity of industrial processes and buildings performance;

(c) Promote alternative business models that are moving away from energy as commodity (push model/customer communication as a one-dimensional bill) to energy as service, where customer partners with (or even replaces) the provider;

(d) Develop and implement alternative low-carbon approaches in cities to meet the increasing energy demand to compensate increasing urbanization in the entire region. This includes transport, buildings, and services. Urbanization planning has to be based on optimized energy usage while giving credit to enhancing quality of life, decreasing air pollution and improving transport systems;

(e) Increase significantly investments flows into renewable energy in the Caucasus, Central Asia, Russian Federation, and South Eastern and Eastern Europe, given that renewable energy potential (power, heat, transport) in these subregions remains untapped. This should be done in partnership between the United Nations, international development banks and local stakeholders;

(f) Integrate "just transition" approach into all restructuring activities to involve all societal stakeholders to develop new business models based on the Three Pillars of Sustainable Energy (see chapter IV) – *Energy Security, Energy and Quality of Life and*

Energy and Environment - that can support regional restructuring and avoid desertification of regions upon loss of economic activity.

III. Strategic Options

7. Countries can choose from various strategic approaches to achieve sustainable energy and meet their international climate commitments (see Table 1). Countries choices are influenced by a wide range of factors.

(a) *Commitments to addressing climate change.* It will be challenging for countries to deliver on the full slate of objectives to which they have committed through the National Determined Commitments (NDCs) and they may have to make important trade-offs. This will also be affected by the public perception of sustainability and climate change relative to the other major issues in their lives;

(b) *Role that energy plays in national economies and the sensitivity of governments to modify that role.* The social and economic fabric of many countries or regions within countries are based on activities linked to fossil energy, and deep transformation will have enormous consequences, hence the need to address the social dimension of the transition from the beginning;

(c) *Assuring energy security*. Some countries and subregions promote energy independence, while others strive for efficient integration of energy markets. Most countries focus on national level actions, whereas global and regional solutions would be more effective if there were a culture of trust and reliability in energy transactions;

(d) *Timeframe within which countries might take transformational action*. Urgent and unprecedented changes are needed, but the promise of Paris was matched by recognition that countries will choose their own tempo for change;

(e) *Action by change agents that shape investments and modify behaviours*. New business models that advocate new market design and structure, flexible network access, adapted fiscal and monetary policies as well as competition. Changes in consumer behaviour driven by millennials' green generation push;

(f) *Technology choices for sustainable energy*. The ability to implement a portfolio of technologies that deliver energy for sustainable development by integrating three axes of economics, environment, and society. A country needs the appropriate expertise and financial strength to operate and integrate technology into its system;

(g) *Availability of energy related sources*. Countries will have access to sovereign resources (fossil, wind, solar, hydro-electric, carbon storage potential) which will influence its preferred transition pathway. Institutional investors have an increasing role to shape countries' choices;

(h) *Relative significance within the existing and future energy infrastructure*. Countries host regional energy infrastructure (distribution grids) partly based on their geographical location linking energy supply and demand.

Table 1
Strategic approaches to achieve sustainable energy[4]

Energy Champions	Countries turn to domestic or global energy champions to finance and manage needed investments while deploying an array of policy measures aligned (e.g, standards or fiscal incentives)
Policy Stretch	Countries consider that intensification of investment in energy efficiency and renewable energy and new entrants in both supply and demand sides accelerate the transformation to a low carbon energy system while meeting the demands of growing economies and populations
Deep Transformation	Countries undertake to transform energy fundamentally. The transformations cover pricing, tariffs, market design, market actors and enabling new categories of demand and supply side players

8. The modelling conducted during the Phase I of the project indicates that the first two options are not likely to meet NDCs or limit global warming to 2°C without extensive carbon capture and that time to act is running out. The longer this situation continues, the more likely that the only policy option to avoid uncontrollable climate change is the third one.

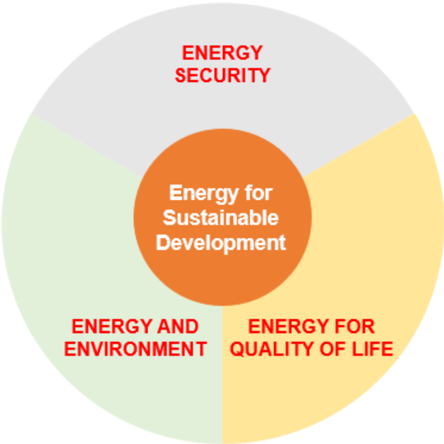
IV. Defining Sustainable Energy

9. One conundrum is particularly relevant for the ECE region, namely that there is not yet a universally accepted definition of "sustainable energy", nor that countries have agreed on a pathway to achieve energy for sustainable development. There is now an important opportunity to explore the implications of the coexistence of different sustainable energy pathways and to work with member States on policies and measures for attaining the 2030 Agenda.

10. The project defines "Sustainable Energy" through three pillars that embrace the SDGs: i) Energy Security, ii) Energy and Quality of Life, and iii) Energy and Environment. Relevant SDGs align with these pillars (see Figure 1). This visualization highlights the inter-connection among the different facets of sustainable energy and trade-offs that countries face.

[4] For more information see "Strategic Options for Countries", https://www.unece.org/energywelcome/committee-on-sustainable-energy/committee-on-sustainable-energy/meetings-and-events/committee-on-sustainable-energy/committee-on-sustainable-energy/2019/open-ended-consultation-of-the-committee-on-sustainable-energy/docs.html

Figure I
Energy for Sustainable Development



11. The following policy objectives were assigned to each of the pillars:

(a) **Energy Security – 'Securing the energy needed for economic development'**. The Energy Security pillar deals with economic aspects of energy security from a national perspective. It includes accessibility to energy supplies including import, export, and transit considerations. Some countries define energy security as energy independence, whereas others see energy security in a regional context, with a focus on inter-connectivity and trade. In addition, there is considerable social, economic, environmental and technological uncertainty. To cope with this situation, countries need to embrace greater creativity in developing policy, ensure that they are alert to changes and adaptive in the response and build resilience into their policies to cope with the inevitable surprises;

(b) **Energy for Quality of Life - 'Provision of affordable energy that is available to all at all times'.** The Energy for Quality of Life pillar seeks to improve living conditions by providing access to clean, reliable and affordable energy for all. This includes not only physical access to modern energy and electricity services, but also investigates the quality and affordability of access. Price developments for energy services including electricity, heating, cooling, and transport are important measures. In relation to bio-energy and its nexus-related considerations, such as competition for resources for food production, food prices can give an indicator to the sustainability of energy as well as food systems. An issue is that, apart from affordability, the benefits of clean energy on Quality of Life cannot be not quantified in this modelling approach, and it is difficult to balance the true costs of clean energy with all the social benefits;

(c) **Energy and Environment - 'Limit the impact of energy system on climate, ecosystems and health'**. The third pillar of "Energy and Environment" represents the trade-offs between meeting the increasing demand for energy supply, providing a healthy environment with clean air, and protecting the environment from climate change. Energy emissions contribute 60% of total greenhouse gas emissions so the energy sector needs to improve its carbon footprint across the energy supply chain and support climate change mitigation efforts. Beyond climate change and air pollution measures, the Energy and Environmental pillar also includes further nexus topics such as the use of water in energy sector transport emissions and air pollution caused by energy generation and consumption. In all scenarios, CO2 emissions is the dominant environmental constraint.

V. Modelling Approach

12. Three distinctive scenarios were developed by two modelling institutions: the International Institute for Applied System analysis (IIASA) and the Pacific North West National Laboratory (PNNL). In addition to three policy scenarios, a range of technology options were tested within the model. It was decided to explore in more detail technology

cost assumptions variations for renewable energy (wind, solar PV and geothermal), CCS and nuclear[5].

(a) Reference scenario is based on socio-economic pathway (SSP2)[6] Middle of the Road Development assumptions without dedicated sustainable energy or climate policies (hereinafter – REF);

(b) A scenario with regional CO_2 constraints, consistent with country-level NDCs and current sustainability policies, based on the assumption that the policies have been implemented by 2030 with "continued ambition" through 2100 (hereinafter – NDC);

(c) Techno-economic scenario, where regional CO_2 constraints, consistent with NDC through 2030, are assumed to continue reduction (hereinafter – P2C) and thus allows to stay below 2°C.

13. In addition to these three policy scenarios, a range of technology options were tested within the model. It was decided to explore in more detail technology cost assumptions variations for renewable energy (wind, solar PV, CSP, geothermal), CCS, and nuclear. The intention is to demonstrate how variations in technology costs can impact the deployment of a selected technology under the three policy scenarios.

14. The three scenarios and variations within the technology costs can be clustered within the two axes for the scenario space. These two axes were identified during stakeholder workshops in 2016 and define the most important and uncertain variables influencing the future of sustainable energy. The two meta drivers are "Degree of Innovation" and "International cooperation". Innovation was interpreted as all types of innovation including technology and business models. International cooperation focuses on how countries cooperate to achieve shared targets, such as the 2030 Agenda and the Paris Climate Agreement.

VI. Key Insights from the ECE Region

15. The sustainable energy subprogramme works to assist ECE member States in improving access to affordable and clean energy for all and to help reduce greenhouse gas emissions and the carbon footprint of the energy sector. It is overseen by the Committee, an intergovernmental body in the United Nations development system. The objective is to make concrete, measurable progress towards the 2030 Agenda by ensuring that energy makes an enduring contribution, including reducing energy systems' CO_2 intensity and meeting quality of life aspirations.

16. The work of the subprogramme falls under three broad and critical areas: (a) reconciling the reality of fossil fuels' enduring share of the energy mix with the need to address climate change; (b) enhancing integration of energy markets in the region; and (c) facilitating the transition to a sustainable energy system. The subprogramme focusses on issues related to energy security, energy efficiency, cleaner electricity systems, renewable energy, coal mine methane, natural gas and resource management, and the inputs by the expert community into this project have to be seen in this light.

17. The key insights propose a reaction of the modelling results and results from the multistakeholder approach by the six expert groups and link with the three pillars of Sustainable Energy as defined above. As such, the key insights provide an interpretation of the modelling results, rather than a presentation of the analytical results themselves within the governance structure and the regional context of the ECE.

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[5] For more information see documents: ECE/ENERGY/2018/1, CSE-27 2018_INF.11, and CSE-27/2017/INF.8 and visit project website https://www.unece.org/energywelcome/committee-on-sustainable-energy/committee-on-sustainable-energy/meetings-and-events/committee-on-sustainable-energy/pathways-to-se/2019/pathways-to-sustainable-energy-consultation-workshop/docs.html

[6] The SSPs include qualitative narratives and quantitative elements. See detailed description of SSPs: Riahi K. et al (2017): The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. In: Global Environmental Change 42 (2017) 153–168.

18. **The region is falling short on its sustainable energy objectives. There is an urgent need to accelerate the transformation to avoid tipping the climate into a dangerous state**. According to data, current NDC mitigation commitments are insufficient to achieve a 2ºC target. More determined action is needed before 2030:

(a) In REF scenario, a temperature increase of 4.2°C is expected by 2100. Cumulative ECE emissions are expected to amount to 1,250 Gt CO_2 (2020 – 2100). Under this scenario the impacts of climate change are expected to be very severe and will probably trigger unrecoverable changes in the climate system;

(b) In NDC scenario, a temperature increase of 3.0°C is anticipated by 2100. Cumulative ECE emissions are expected to be 18% (225 Gt CO_2) lower compared to REF scenario (2020 - 2100). Under this scenario the impacts of climate change are expected to be severe and may trigger unrecoverable changes in the climate system;

(c) In P2C scenario, a temperature increase of 2.1°C is expected by 2100. Under this scenario, emissions are expected to peak by 2020. To meet the target, negative emissions are mandatory post 2070. Under this scenario, climate change would be limited to, for example, more extreme weather patterns, major damage to coral reefs, major movements in agriculture.

19. With regional carbon markets, emissions of regions with non-binding NDCs do not deviate from REF (no policy) levels through 2030, as carbon prices are zero. A global carbon market with a single carbon tax in all regions redistributes emissions mitigation and relative carbon prices compared to NDC regional markets. Carbon prices are lower in a global market for regions with stringent NDCs. Regions with non-binding NDCs have higher carbon process under a global carbon market.

20. **Energy demand in the ECE region decreases in the P2C scenario by 2050, whereas it increases in the REF scenario.** Based on data, in the P2C scenario total energy demand is expected to decrease by 25% compared to the REF scenario due to efficiency and intensity improvements in transport and industry sectors, technology and structural changes as well as lifestyle changes. The ECE region is comprised of high- and low-income countries, countries that are energy rich and energy poor and countries that are in economic transition. In total, the region's 56 countries represented 39% of the world's primary energy consumption (as of 2015) to produce 41% of world GDP. **The region produced 40% of the world's primary energy resources and emitted 39% of global CO_2 from fossil fuel combustion.** When averaged across the entire region, the share of fossil fuels in total primary energy supply is 80% (equal to the global 81%); when evaluated across the subregions, the least share is in Western Europe at 71%, and the greatest is in Central Asia at 94%. Even under a climate change scenario that meets a 2°C target, in the ECE region fossil fuels are expected to account for 56% of the regional energy mix by 2050.

21. **Energy security is achieved by ensuring that energy supply, transformation, transport and demand make significant contributions to countries' social, economic, and environmental development.** Countries that consider that energy supply can be assured through energy independence are prepared to pay a premium for it. Other countries consider that energy security can be achieved through diversification of technology choices, suppliers, transit routes, and consumers. Most countries focus on national level actions whereas a priori it would appear that global and regional solutions would be more effective if there were a culture of trust and reliability in energy transactions. The regional business models require a foundation of institutionalized investment and transaction frameworks. Ensuring energy security as part of the ongoing deep transformation creates an imperative to mobilize needed investment in the energy system of the future that is rational and pragmatic socially, environmentally, and economically.

22. The current state of **the ECE primary energy supply and power generation mix imply that technological change is crucial to accelerate energy transition and achieve sustainable energy.** The region is over dependent on fossil fuels and higher CO_2 emission fuels. The electricity generation portfolio is anticipated to experience significant structural changes based on the ECE scenarios. Market expansion across all scenarios for all technologies is anticipated except for coal and oil. According to data, P2C scenario implies higher degree of diversification with fast up-take of low carbon emitting technologies. Across

scenarios, demand for electricity increases and is met largely by natural gas (in P2C scenario with CCS). Increase in demand in NDC and P2C scenarios is driven by increased electric mobility. Coal appears to follow a long-term phase out trajectory in the REF scenario, but it is quickly replaced in NDC and P2C by expansion of natural gas and renewable energy. Compared to REF and NDC scenario, P2C depicts a fundamental realignment of generation structure with a large share of gas with CCS, fast expansion of offshore wind and solar PV, and a steady expansion of nuclear power.

23. **All technologies that contribute to implementation of the Agenda 2030 and the Paris Climate Agreement will have a role to play in the modernization of the energy system in the ECE region**. This chapter investigates pathways to sustainable energy based on: a) Reducing the Environmental Footprint of the Energy Sector, b) Deep Transformation of the Energy System and c) Sustainable Resource Management.

A. Reducing the Environmental Footprint of the Energy Sector

24. **Ensuring secure, affordable and sustainable energy requires a diverse energy mix, of which coal will remain a part**. Based on REF scenario, coal is anticipated to retain its role in the primary energy mix through to 2030. As countries implement their climate change pledges, the role of coal in power generation is expected to decline steadily in all scenarios. Traditional coal-fired power generation plants are being shut-down or upgraded. This trend is anticipated to accelerate in P2C scenario. Phasing out coal must be managed with appropriate action to mitigate adverse effects and minimize negative socio-economic implications for communities that heavily depend on coal. **Investments in cleaner coal technologies are crucial if the role of coal is to be maintained in energy mix in the mid-term. Deploying HELE coal-fired power plants is a key first step along a pathway to near-zero emissions from coal with CCUS.** Coal-fired power plants have undergone modernization over the past decade experiencing improvements in operational efficiencies and emission control system performances. Although traditional power grids were not designed to adapt to rapidly changing supply side schemes, system operators around the world have learned how to use various flexible resources that complement growing shares of variable renewable energy. **Increasing the flexibility of coal power plants' operations could allow for a faster deployment of renewable energy sources, thereby reducing the carbon intensity of electricity generation.**

25. **GHG emissions associated with coal mining need to be treated carefully. Some coal mines are very gassy and emit a lot of methane. Methane has severe impact on environment and climate change that needs to be addressed.** The emissions do not cease at the time of mine closure. Methane escapes abandoned mines through natural and mining related fractures and other conduits. In active and closed mining areas and cities capture and use of methane translates directly into better air quality and thus also better quality of life. Methane emissions should not be forgotten while addressing the problems of air quality. Managing methane emissions throughout the whole value chain – from well to burner tip – is essential.

26. Based on NDC and P2C scenarios, natural gas is expected to increasingly gain traction in the primary energy mix and is anticipated to play a continuing role beyond 2050. **Due to its lower carbon content compared to other fossil-fuels, natural gas moderately contributes to reducing carbon intensity and pollution effects resulting from energy related activities.** The lifecycle GHG emissions of gas-fired power generation are 40% lower compared to oil-fired and 50% lower compared to coal-fired. Switching from coal to natural gas in electricity generation can reduce the carbon intensity of fossil energy and improve air quality in many urban areas, in particularly in developing countries, given their rapid rate of urbanization.

27. In spite of the low CO_2 emissions, abundancy and cost-effectiveness of natural gas, **methane emissions associated with natural gas need to be managed carefully across the value chain**. Methane is a potent greenhouse gas. **Conducting methane emissions mapping exercises in terms of detection, quantification and mitigation of methane emissions along the gas value chain is necessary to better plan emissions management**.

B. Deep Transformation of the Energy System

28. The future energy system must be designed with efficiency as its core value

(a) **Industrial Energy Efficiency**: Energy efficiency in the industry sector already has been proven. It brings financial benefits to the companies, not just by the value of the energy saved, but also of increased productivity due to process optimization. The main challenge for improvement of industrial energy efficiency is addressing the issue of highly energy intensive processes in some industrial sectors (e.g. cement, steel, chemicals, etc.). This could be addressed with fostering innovation, and targeted R&D that would drive the industry to better efficiency improvements;

(b) **Building Energy Efficiency**: Buildings are central to meeting the sustainability challenge. In the developed world, buildings consume over 70% of the electric power generated and 40% of primary energy and are responsible for 40% of CO2 emissions from the energy services they require. The ECE's High Performance Buildings Initiative (HPBI) encourages member States to disseminate and deploy its Framework Guidelines for Energy Efficiency Standards in Buildings worldwide. HPBI is aimed at radical reduction of the global carbon footprint of buildings and dramatic improvement in the health and quality of life provided by buildings;

(c) **Transport Energy Efficiency**: Compulsory fuel economy standards played a pivotal role in boosting the efficiency of road vehicles. Carbon taxes have only a limited impact on the cost of mobility. Change in customer preferences coupled with the speed of innovation and commercialization of new technologies, such as electric vehicles, biofuels and hydrogen, are expected to drive decarbonization of transport. Most of the transport in urban areas is consisted of commuter transportation for short distances. This should be addressed with proper planning of city infrastructure and transport efficiency. Large freight transport remains a challenge due to the volume and complexity of the transportation system.

29. **There is potential to enhance the interplay between renewable energy and gas in electricity generation in the ECE region.** Based on REF scenario in 2030, natural gas is expected to account for 40% and renewable energy for 26% of the total electricity generation mix. In P2C scenario, the share of natural gas is anticipated to increase to 41% and renewable energy to 36%. The flexibility and low capital and operational expenditures make gas a viable source to provide the baseload requirements for introducing renewable energy into the grid sustainably. Gas supply chain is responsive to changes in demand thanks to gas storage, liquified natural gas (LNG) and operational flexibility of gas pipelines. However, **much of the ECE region seeks increasingly to develop flexible systems that would limit the requirement for gas to fulfil such a role**. Where gas is necessary as a transition fuel in a sustainable system, emissions must be managed carefully. Decarbonization projects such as power-to-gas, energy storage and renewable, decarbonized and low-carbon gases (e.g. green/blue hydrogen and biomethane) will decrease the environmental impact and carbon footprint of the energy sector. Power-to-gas technologies use electricity that cannot be used directly or stored in batteries but can be instead stored as gas within the gas system at minimum costs. Other flexibility options involve demand side management incentivising customers (private, commercial and industrial) to manage or decrease energy consumption.

30. **Renewable energy is playing a key role in the transformation of the energy system. In recent years, the competitiveness of renewable power generation options has been substantially increasing**. In 2016, the installed electricity capacity of renewable energy sources in the ECE region amounted to about 869 GW (388 GW from large hydro power plants), accounting for almost half of the renewable electricity capacity installed worldwide. Increasing installed capacity of renewable energy technologies in many ECE countries has driven the reduction in capital costs and increased confidence in lifecycle costs, improving their economic viability. However, it must be noted that the role of renewable energy in the energy mix across the ECE region remains imbalanced. Whilst Europe and North America account for 23% and 16% of the total renewable generation capacity, the Caucasus, Central Asia and Russian Federation collectively account for only 4%. Renewable energy potential (power, heat, transport) remains untapped in many ECE countries, particularly in the

Caucasus, Central Asia, the Russian Federation, and South East and Eastern Europe which represent only a fraction (0.2%) of the global investments in renewable energy in 2015[7].

31. **A modernized energy system increasing relies on renewable resources and digitalization plays a key role in supporting the uptake of renewable energy. Fostering, therefore, development and deployment of solutions that increase the system flexibility required to integrate higher shares of renewable energy is the key. The '3D energy transition' to a decarbonized, decentralized and digitalized energy system is underway**. Innovation and technological developments are steering the direction of the transition. The energy system as we know it is in flux. As electricity becomes a vehicle for achieving deep transformation of the energy system, the incumbent energy utility companies that rely on the traditional large centralized generation systems and passive consumers need to modernize to protect their market share. Grid operators are confronted with new market entrants and community. New business models will necessarily be developed on lower carbon applications, increasing energy efficiency and more control by customers under the assumptions in this modelling exercise. Platforms of trusted innovative technologies are expected to create the foundation for the further development of such a system. Technology integration into the energy system, therefore, is a prerequisite for energy transition and modernization of the energy system. Ongoing innovation and digitalization of the energy system is creating a new generation of consumers. Modern customers value to be in control. The so-called prosumers value to produce as well as consume energy. As the cost curve for renewable energy is coming down and more reliable storage solutions (e.g. batteries) are being developed, consumers move to a central position.

C. Sustainable Resource Management

32. **Renewable energy technologies could address some of the trade-offs between water, energy and food production, bringing substantial benefits in all three sectors**. They can moderate competition by providing energy services using less resource-intensive processes and technologies compared to conventional energy, for example in transboundary river basins in South East Europe, the Caucasus and Central Asia. In most of these basins, the riparian countries have active hydropower development, but also have the potential to exploit other renewable sources such as solar, wind and geothermal energy. The distributed nature of many renewable energy technologies means that they can offer integrated solutions for expanding sustainable energy while enhancing security of supply across the three sectors. The energy-water-food nexus approach aims to support more sustainable renewable energy deployment by building synergies, increasing efficiency, reducing trade-offs and improving governance among sectors.

33. **Low-carbon futures will have implications on countries' resource base and availability, costs and prices of critical raw materials and rare earth minerals**. **Sourcing these essential materials and minerals will be a challenge and are shifting geopolitical relationships.** Massive amounts of critical raw materials will be required (e.g. for batteries and renewable energy technologies, such as lithium, cobalt and nickel) to aliment the energy revolution. Limited access, availability and rising costs could be a limiting factor due to induced import dependency bottlenecks with large amounts of materials supplied by a very limited number of countries. Alternative technologies, innovation, acceptable international standards and adoption of circular economy practices can reduce material demand and costs and increase resource security.

34. **Sustainable resource management practices that embrace circular economy principles and that integrate the full spectrum of the 2030 Agenda should be on the forefront of countries' strategies.** Over 80 elements in the periodic table are required for energy production today. Rate of recycling and reuse varies from 1 to over 80%. Over 15 elements of the periodic table have achieved more that 50% recycling rates. Systems-thinking approach would be required in which the whole life-cycle of resource production and

[7] UNECE, Renewable Energy Status Report, 2017 https://www.unece.org/fileadmin/DAM/energy/se/pp/renew/Renewable_energy_report_2017_web.pdf

consumption should be considered both from producers and consumers' side. Apart from price and quality, end-users are becoming more aware about environmental and social issues. Knowledge will be crucial for resources management and strengthening the circular economy. There is a need for a comprehensive raw materials management system, such as the United Nations Resource Management System (UNRMS) assessing resources for the circular economy.

35. **Energy poverty in the ECE region still needs to be tackled**. **Carbon neutrality has consequences for countries. The more urgent this becomes the more expensive it is**. Across scenarios, energy and environment indicators in the ECE region improve until 2050, except for the increasing energy expenditure per GDP. In REF scenario, the indicators only improve slightly and the ECE as the region switches to a net energy exporter by 2050. In P2C scenario, the energy system transformation becomes apparent by 2050 - all indicators strongly improve except cost indicators.

36. **A predictable environment with forward looking policies is a precondition for investments in energy innovation and is also essential for both economic growth and environmental protection.**

(a) In REF scenario, in the period from 2020-2050 cumulative investments of USD 23.5 trillion would be required, of which 50% of the total is anticipated to be spent on extraction of fossil fuels**.** Electricity generation investments are expected to be dominated by lowest carbon emitting hydro power and wind plants followed by nuclear power and solar;

(b) In NDC scenario, during the same period, anticipated investments are slightly higher (by USD 800 billion) to the REF scenario, caused by a different investment portfolio. Energy efficiency and intensity reduction measures are steadily introduced. Investments in wind and solar are expected to dominate power generation;

(c) In P2C scenario, investments are expected to rise by 24% to USD 29.2 trillion compared to REF scenario. Whilst the upstream fossil fuel investments are anticipated to absorb 28% of investments, investments in energy efficiency will account for 25% of the total**.** Generation commands almost twice as much capital investment as in REF scenario, of which renewable energy accounts for 60% of generation investment. It is important to note, that the difference between the P2C and REF scenario is about USD 6 trillion, or USD 200 billion annually. To put it into context, according to an OECD study, in 2015 premature deaths caused by air pollution imposed a cost of USD 1.8 trillion on OECD countries[8]. This implies that additional investments required to meet the 2ºC target are negligible compared to health care and social cost of air pollution and stresses ones more the nexus context of the project;

(d) Investments in transmission infrastructure are a prerequisite in the Caucasus, Central Asia, East and South East European countries and the Russian Federation for increasing the uptake of renewable energy technologies;

(e) Public private partnership (PPP) schemes and public based investments are useful to empower consumers and local community to be active participants in the transformation of the energy system. Distributed renewable energy can offer reliable and clean energy to both grid connected and non-grid connected communities.

VII. Planning phase II (2019-2021)

37. The Committee has always stressed the need for continued dialogue about pathways to sustainable energy. As such, the project is only the starting point for more in-depth policy and technology analysis in the ECE region, and that with a view to developing

[8] OECD, The Rising Cost of Ambient Air Pollution thus far in the 21st Century: Results from the BRIICS and the OECD Countries, 2017, https://www.oecd-ilibrary.org/docserver/d1b2b844-en.pdf?expires=1562931679&id=id&accname=ocid57015274&checksum=85C593638BA8AB5F354F95C4083EC303

recommendations for ECE countries on the different options that are available to achieve a desired future.

A. Capacity development – Application and use of the model

38. Countries and their stakeholders could be supported in developing skills on the model application and usage of modelling results to allows the analysis and assessment of policy options based on national circumstances, and the implementation of recommendations and policy pathways locally and regionally.

B. Regional and/or subregional deep dives

39. Stakeholder dialogues have called for the importance of the subregional component both for the development of the scenarios and the interpretation of the results of the project, for examples the trade-offs and just transition policy recommendations are very different according to national and regional circumstances. Additional sub-regional deep dives could provide a deeper assessment of scenarios and their consequences in selected sub-regions, for example, Central Asia, with a focus on the energy-water-food-nexus challenges or scenarios on how to achieve energy security (energy self-sufficiency versus intraregional cooperation and trade). Another example could be the assessment and consequences of a combined European Union and Eurasian Economic Union market and the consequences for sustainable energy developments in the region. Additional modelling work could focus on the country-level disintegration of selected sub-regions (e.g. Central Asia, Caucasus, etc.) to provide deeper analysis of countries' roles and opportunities in a sub-regional context. More country-specific scenarios and policy options could derive from this analysis. The approach could include partnering with other United Nations Regional Commissions. Additional areas comprise inter/intra-regional trade, regional cooperation and market integration; role of external influencers to the ECE region (e.g. China, Belt and Road Initiative, others).

C. Technological deep dives

40. Additional analysis of existing scenarios in form of deep dives, with the possibility of a variety of topics depending on countries' identified needs have been proposed. Suggested technology deep dives comprise the cost of stranded assets (investment requirements in modernizing energy infrastructure); disruptive technologies (hydrogen, power-to-gas (PtG) and power- to-liquid (PtL); renewable energy system integration including the role of gas; the role of nuclear energy in attaining sustainable energy; time for diffusion and development of new technologies; resource availability for new technologies and the energy revolution; digitalization and energy, including blockchain; energy productivity and energy efficiency; waste to energy; biomass; infrastructure and infrastructure resilience; impacts of investing in clean fossil structures on the system; the impact of methane management on the energy system.

D. Infrastructure deep dives

41. It would be worth considering further analysis on the mainstreaming of energy and carbon implications of wider infrastructure developments (e.g. airports expansions, new road versus new rail) and to analyse if infrastructure investments will bring positive social, environmental and economic benefits to attain the 2030 Agenda. ECE is part of the Coalition for Green Development on the Belt and Road, an international platform with a mandate to share the environmental policies and experiences among beneficiary countries and promote wider cooperation. Conducting such analysis would connect the project with ongoing work of the Coalition, which is supported by many ECE member States.

E. Nexus areas

42. Nexus areas worth exploring comprise affordability of energy and energy poverty; health (incl. air, food and water); risks associated with energy transition such as access to critical raw materials, scale up and implementation; resource management; circular economy and critical raw materials in the energy transition; as well as decision making in uncertainty and complex systems and modernization of energy infrastructure and the implications of the phase out of coal.

F. Implementation of policy pathways

43. Supporting the implementation of adaptive, cross-cutting and holistic policies in a subregional or national context are the focus here. This can closely be connected to tracking initiatives of the 2030 Agenda implementation. Countries could be supported by identifying suitable policy pathways, and subsequently, receive support in the implementation of the chosen approach. This could further be linked to the tracking of SDG targets, such as SDG 7, 9, 11, 13, or 17.

VIII. Conclusions

44. At its twenty-eight session, the Committee will be invited to:

(a) take note of the results of the first phase of the project "Pathways to Sustainable Energy", summarized in this document ECE/ENERGY/2019/1;

(b) endorse the policy recommendations (Chapter II of this document);

(c) request EXCOM to submit this document to the next Economic Commission for Europe session for discussion and in parallel inform its parent body ECOSOC of the project results, in particular with regards to the region's energy base, strategic options to attain sustainable energy and linkages to the 2030 Agenda;

(d) note the conclusions on where the region is headed, endorse steps to accelerate progress towards attaining the energy-related SDGs based on different strategic options and make recommendations for the future work of the sustainable energy subprogramme, including an effective and streamlined role of the subsidiary bodies;

(e) request the secretariat to continue the implementation of the "Pathways to Sustainable Energy" project until completion and present the final report at its next session;

(f) request its subsidiary bodies to further refine the findings, recommendations and key insights and present the results at its next session;

(g) request to reach out to ECE's sister regional commissions for a more global outreach of the key findings in a cooperative manner and requested the secretariat to take steps for a potential joint undertaking to implement the policy recommendations;

(h) request the organisation of a high-level political dialogue with countries provided a host-country and supporting funds can be found;

(i) request the secretariat to draft a project proposal for Phase II of the "Pathways to Sustainable Energy" project to be discussed with potential donors;

(j) take note that the end date of the project is 31 October 2019 if no additional funds are made available.