UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

Building Resilient Energy Systems:

Actions for Achieving Greater Energy Security, Affordability and Net-zero in the UNECE Region

UNECE

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Abbreviations and Acronyms

Acronym	Expansion
AMM	Abandoned mine methane
CCUS	Carbon capture, use and storage
CMM	Coal mine methane
CBM	Coalbed methane
HELE	High-efficiency low emission
HVAC	Heating, ventilation and air-conditioningv
MSME	Micro, small and medium enterprises
NDC	Nationally determined contributions
SMR	Small modular reactors
UNECE	United Nations Economic Commission for Europe
UNFC	United Nations Framework Classification for Resources
UNFCCC	UN Framework Convention on Climate Change
UNRMS	United Nations Resource Management System

Introduction

Across the United Nations Economic Commission for Europe (ECE) region, member States are facing unprecedented challenges due to the COVID-19 pandemic, geopolitical crises in the region, supply chain disruptions, and climate change impacts. These challenges have exposed the vulnerability of the UNECE energy systems and highlighted the urgent need to build more resilient energy systems. Member States are now re-examining energy with a goal to identify, enhance and implement strategies to meet their immediate energy and economic needs without jeopardizing achievement of their longer-term 2030 Agenda for Sustainable Development (2030 Agenda) and the Paris agreement goals.

When taking a comprehensive approach to building resilient energy systems, it is important that the UNECE member States take the following steps: (1) Set or acknowledge goals and priorities, including near term and long-term energy, economic and environmental objectives; (2) Identify, compare, analyse and prioritize options to meet the short and long term goals comprehensively, examining the trade-offs and synergies; (3) Design, finance and implement policies, projects and programs for the short and long term using appropriate and clearly defined mechanisms, such as regulations, legislation and incentives; (4) Evaluate the impacts relative to the goals over time, and adapt as needed; and (5) Collaborate and share best practices with peers, particularly those in the UNECE region.

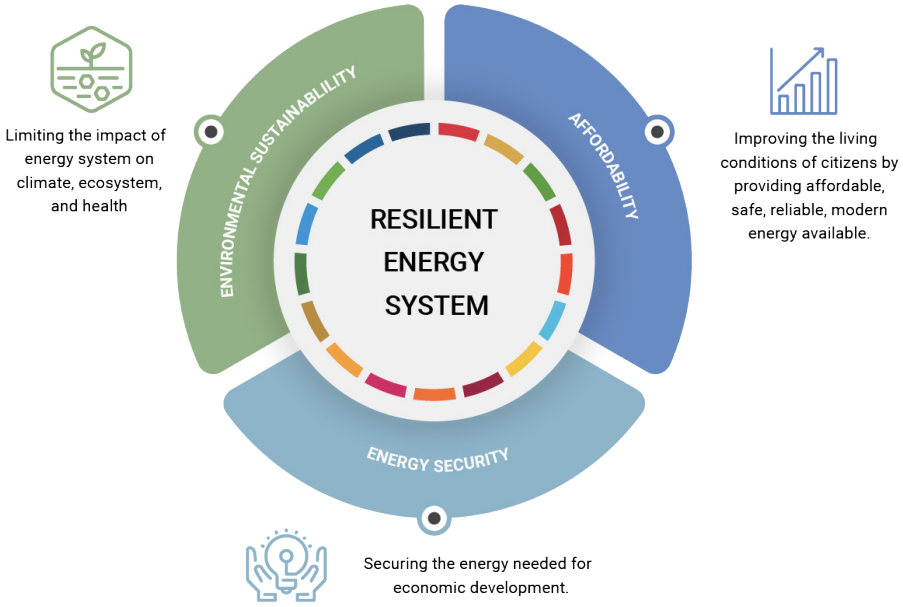
In September 2022, at the thirty-first session of the Committee on Sustainable Energy, member States agreed to prioritize and implement special activities related to energy resilience across the UNECE region, providing an UNECE Platform on Resilient Energy Systems for inclusive dialogue. The Platform serves to coordinate, compile, promote and provide information, guidance, training and/or technical assistance to support member States as they build resilient energy systems. The expert groups under the Committee, including the Groups of Experts on Cleaner Electricity Systems, on Coal Mine Methane and Just Transition, on Energy Efficiency, on Gas, on Renewable Energy, and the Expert Group on Resource Management, have identified a number of recommendations for member States to consider supporting the second set of activities listed above. The recommendations, delivered in the support of the Platform and described below, can help member States meet their short- and long-term energy, economic and environmental goals and build resilient energy systems.

Defining a Resilient Energy System

A resilient energy system is one where energy makes an optimal contribution to a country's social, economic, and environmental development, and that is able to withstand and recover quickly from any unanticipated shocks and reflects potential impacts of climate change on energy resources in its planning and operations. Sustainable energy is based on three pillars: i) energy security, ii) quality of life and iii) environmental sustainability.[1] Each of the pillars contributes to attaining sustainable energy. Still, none of them independently fully describes Sustainable Energy, a golden thread that underpins the delivery of the 2030 Agenda and the Paris Agreement. Premised on this, the definition of a resilient energy system is based on all three pillars:

FIGURE 1

A resilient energy system



- **Energy security - Securing the energy needed for economic development.** There are significant social, economic, environmental and technological factors which come into play in this area. Some countries might define energy security as energy independence, whereas others see energy security in a regional context, focusing on interconnectivity and trade.
- **Quality of life - Providing affordable energy available to all at all times.** A resilient energy system improves the living conditions of citizens by providing access to safe, sustainable, reliable, modern and affordable energy for all. This objective includes physical access to electricity networks and stand-alone grids, and the quality and affordability of access to the broader concept of energy services. It is important to consider costs and the need to ensure uninterrupted availability of energy services, including electricity, heating, cooling, and transport when assessing the resiliency of a system.

1 For the purposes of this document, the definitions from the UNECE project on Pathways to Sustainable Energy are used; UNECE, January 2020, Pathways to Sustainable Energy - Accelerating Energy Transition in the UNECE Region

- **Environmental sustainability - Limiting the impact of the energy system on climate, ecosystems and health.** Energy emissions contribute 75% of total anthropogenic greenhouse gas emissions[2,3], so the energy sector needs to reduce its carbon footprint to support climate change mitigation efforts across the energy supply chain. Energy and associated resource consumption should be used more efficiently by all sectors and end-users, and should consider circularity aspects that reduce energy demand and accelerate energy transition. Beyond climate change concerns, this pillar also includes other nexus topics such as water scarcity in the energy sector, transport emissions, and air pollution caused by energy generation and consumption.

Finding a balance between the three pillars is a complex social, political, economic, and technological challenge. The UNECE Platform on Resilient Energy Systems, through resources like this paper, provides a significant value for member States as it helps them to identify options and better understand the possible trade-offs and synergies between delivering on (i) energy security, (ii) quality of life and (iii) environmental sustainability. While there are no easy answers, there is an urgent need to find a balance between those competing yet interrelated interests.

BOX 1 Key recommendations for building resilient energy systems

According to the experts under the Committee on Sustainable Energy, to build more resilient energy systems, policymakers should prioritize the following five solutions that improve systemic efficiency, optimize resources use, and reduce associated carbon footprint:

1. Prioritize and maximize the implementation of energy efficiency solutions. Increase energy efficiency and enhance systemic efficiencies across industry, buildings and transport sectors, as well as across energy generation, transmission, distribution systems. This will improve the ability of energy systems to absorb shocks and recover quickly.

2. Digitalize the energy systems and capitalize on opportunities arising from improved digital literacy and the availability of digital solutions throughout the energy transition process and across all layers of the energy systems. This can reduce end-use energy demand and improve energy system resiliency..

3. Accelerate fuel switching from carbon-intensive to low- and zero-carbon solutions. Countries should undertake efforts aimed at using available fuels strategically to maintain stability in their economy and ensure energy security while replacing carbon-intensive fuels over time with other low- and zero-carbon technology options.

4. Manage resources effectively, sustainably and with circularity considerations by implementing the United Nations Framework Classification for Resources (UNFC) and the United Nations Resource Management System (UNRMS) which are tailored to improve resource management and project planning. Integrating circular carbon considerations into decision-making is critical as transformation of the energy system towards a cleaner one will require increased circularity of materials and resources, including both the repairability and recyclability-by-design of goods.

5. Accelerate the deployment of low- and zero-carbon technology to decarbonize the energy system over time. Invest in scaling of renewable energy deployment and replace carbon intensive fuels with other low- and zero-carbon technology options where technically and economically feasible. Take steps to reduce the carbon footprint of remaining hydrocarbon-based fuels through carbon capture utilization and storage (CCUS) deployment. Encourage increased cooperation and develop non-discriminatory regulatory frameworks, technologies and financing mechanisms for region-wide investments in all low- and zero-carbon technologies.

These recommendations are expanded upon in the rest of this document, with a focus on energy demand options by sector, energy supply options across the different fuels and technologies, and cross-cutting options for decisionmakers to build more resilient energy systems.

2 IEA, 2021, Greenhouse Gas Emissions from Energy: Overview, https://www.iea.org/reports/greenhouse-gas-emissions-from-energy-overview

3 Our World Data, Hannah Ritchie, Max Roser and Pablo Rosado (2020), "CO_2 and Greenhouse Gas Emissions", https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

BOX 2 Key considerations for policymakers

As policymakers look across the options included and assess what will be best for their circumstances, it will be important to:

1. Recognize that there is not a one-size-fits-all approach. Countries have their unique national circumstances and development aspirations when building more resilient energy systems - endowment of natural resources, technological base, pursued socio-economic model, cultural heritage, as well as institutional, legal and regulatory structure. These should all be considered and evaluated as part of the planning process.

2. Consider long term goals as they design policies today. While some of the strategies member States may choose, such as energy efficiency, are clearly supportive of long-term sustainability or environmental goals, others, such as a short-term increase in the use of fossil fuels, pose risks. It is important for member States, therefore, to identify and implement an optimal set of near-, mid- and long-term strategies that will help them build resilient energy systems that protect them from future shocks and achieve energy security, economic and environmental goals in the near and long term.

3. Address behavioural barriers to unlock the full potential of innovative low- and zero-carbon technologies and digitalization. Although the technologies and capabilities are in place to achieve more resilient energy systems, this process remains sporadic and slow. Consider psychological aspects and harness organizational and behavioural optimization potentials related to demand side energy systemm behaviours.[4]

4. Build a workforce to deliver on a just energy transition and address the skills and labour shortage. Invest in the next generation of qualified experts, such as through capacity building initiatives and workforce development programmes, so that a workforce will be available to further develop, advise on, deploy and maintain clean energy and energy efficiency technologies and services.

5. Integrate resiliency concerns into existing and related planning efforts, when possible. Policymakers should integrate resiliency options into existing strategies and plans, such as national energy or economic recovery strategies, plans for modernizing energy system infrastructure and/or nationally determined contributions (NDCs) under the UN Framework Convention on Climate Change (UNFCCC), to leverage, complement, and enhance other efforts while avoiding the creation of redundancies.

6. Consider climate change impacts on supply and demand. For example, increased temperatures will lead to increased demand for cooling while water scarcity, flooding, extreme weather, and rising sea levels impose a threat to the resilience of energy generation and transmission across the UNECE region. Policymakers should consider contingency plans to boost energy system resilience.

Immediate Cross-cutting Actions for Policymakers

Attaining resilient energy systems for the UNECE region that are energy secure, affordable and environmentally friendly would require the deployment of low- and zero-carbon technologies. For the region to succeed in this endeavour, the experts find that it will be necessary to: i) raise awareness and develop campaigns to inform all the stakeholders why the current energy system is fragile, and what is necessary to develop a resilient energy system and how this can be achieved; ii) develop a clear regulatory framework and energy system design to allow all technologies to be deployed and integrated into such an energy system effectively, and iii) develop financing mechanisms and unlock both private and public funding. These are actions policymakers can directly support with the actions listed below.

Raise awareness to design and develop resilient carbon neutral energy systems

- **Establish the language which resonates with all the stakeholders**, taking into account the current crises and the resulting repercussions felt by stakeholders.
- **Inform stakeholders about best practices** on efficient energy consumption and energy savings. Most of these solutions require low or now investments and bring vast benefits.
- **Familiarize the stakeholders with all benefits and risks** associated with other low- and zero-carbon technologies and solutions.
- **Create enabling environment** to lose fear, remove mental roadblocks, gain confidence to successfully implement the proposed solutions, and take individual action towards achieving the set goals.
- **Identify and apply the approaches** that have proven to boost stakeholders' competence and awareness levels and thus led to widespread and decentralized uptake of the suggested technical and non-technical solutions and measures.

Create regulatory frameworks to enable resilient carbon neutral energy systems

- **Develop and implement clear, technically non-discriminatory regulatory frameworks** for all zero- and low-carbon technologies required to deliver resilient energy systems in the region.
- **Promote a nexus approach to managing the natural resource base** in the region with firm linkages to food, water and energy security, and the preservation of nature.[5]
- **Put consistent planning, policies and market frameworks** across the region necessary to provide favourable investment signals and attract private finance for high capital cost projects.
- **Review interconnection infrastructure across the region.** Network design is technically highly complex. Introduction of any changes to the existing structure should be carefully studied and well understood.
- **Separate interconnections to isolate system disturbances** and prevent them from cascading.
- **Ensure (cyber-) security by design** across all levels of the energy system to enable energy system responsiveness and resiliency through digitalization solutions.

5 UNECE (2021) Natural Resource Nexuses in the ECE region https://unece.org/info/Sustainable-Energy/UNFC-and-Sustainable-Resource-Management/pub/355180

- **Ensure circularity-by-design** to increase energy security, availability of secondary raw materials and enhance the resiliency against shocks.
- **Consider energy system integration.** The energy system's coordinated planning and operating (across multiple energy carriers, infrastructures, and consumption sectors) could promote efficiencies and enhance resource diversity and sharing.
- **Study practical ways to ensure affordability of energy** in the UNECE region by examining current regulations and tariffs, and identifying ways to enhance the cost effectiveness of energy production and delivery to end user.

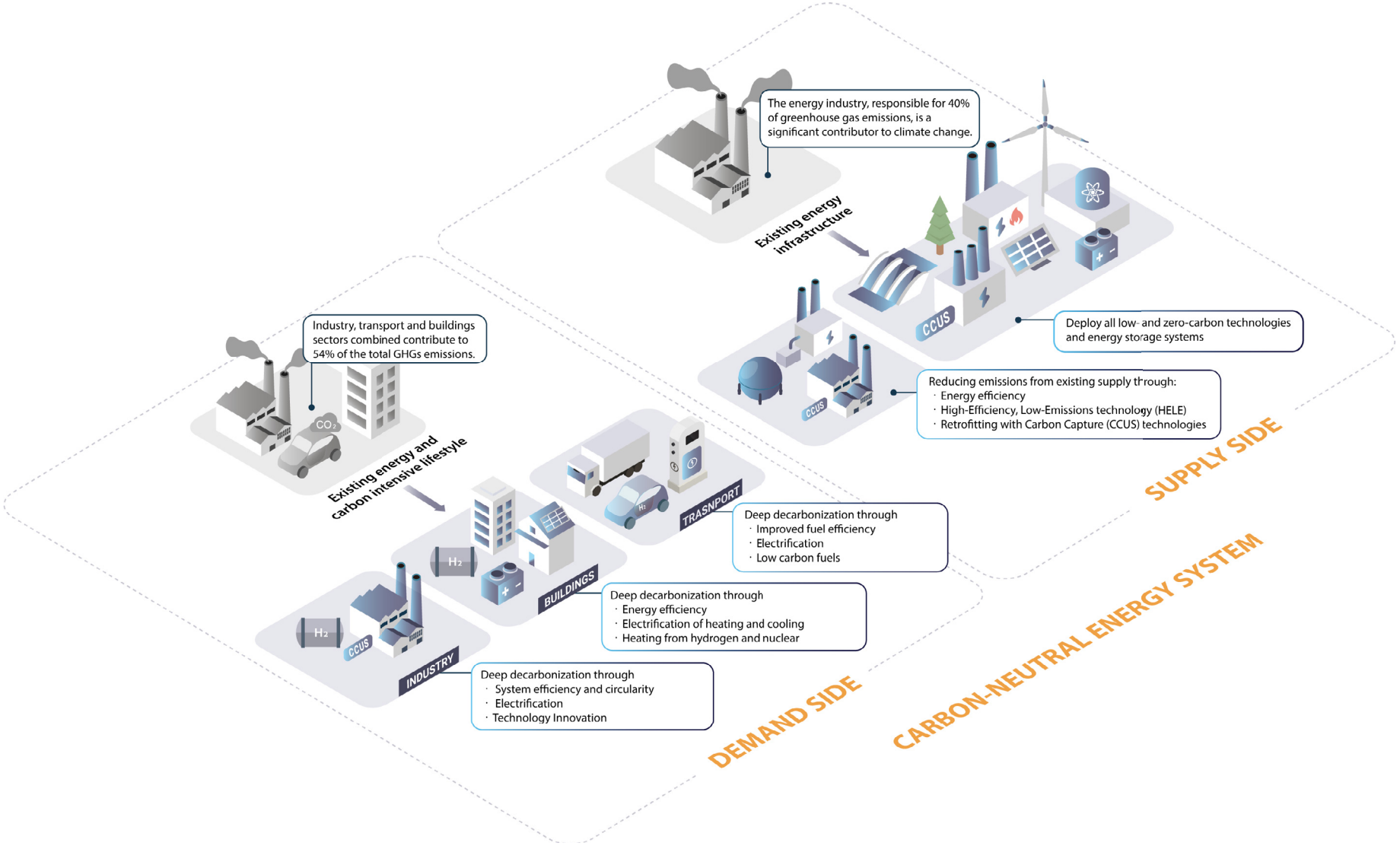
Finance deployment of resilient and carbon neutral energy systems

- **Establish the cooperation with the global financial community** on developing an investment framework that facilitates the development and deployment of all low- and zero-carbon technologies (including those focused on CCUS, capture and use or conversion of methane released during fossil fuel extraction, low-carbon and renewable hydrogen production, nuclear power (for those countries that support it), and renewable energy).
- **Support development projects** with an appropriate risk-sharing structure and facilitate access to low-cost financing to accelerate the deployment of new innovative technologies.
- **Develop climate and sustainable finance classifications** based on scientific and technology-neutral methodologies and support the transition to a low-carbon economy.
- **Encourage the international financing institutions to recognize and provide access** to the necessary financing for CCUS, coal mine methane, coal bed methane and abandoned mine methane projects, low-carbon and renewable hydrogen production pathways, and new generation nuclear projects in countries that support nuclear power.
- **Evaluate current approaches to carbon pricing and energy subsidies** in the UNECE region and beyond to identify improvements and best practices that could be applied in the UNECE region, ensuring pricing incorporates externalities and that the market sends the appropriate signals to consumers and investors.
- **Encourage the decision-makers and the end-users to make the investment decision.** In many instances, energy and decarbonization-related aspects of the project exceed the core area of work and experience of (financial) decision-makers, thus leading them to an over proportional perception of risk that effectively prevents investments even though the financial means are available.

For the remainder of the document, detailed options and technical solutions experts recommended for energy demand by sector and energy supply by fuel are presented. Policymakers should consider designing, implementing and/or adopting policies, standards, legislation, incentives and/or voluntary capacity building programmes to support them as appropriate.

FIGURE 2

Transformed Energy System Vision



Detailed Solutions for Designing Resilient Energy Systems: Energy Demand by Sector

There are three main categories of activities policymakers should focus on when it comes to building resilience on the demand side of the energy system: energy efficiency, digitalization and fuel switching in the buildings, industrial and transport sectors.

- **Energy efficiency** is one of the most critical determinants of a secure and resilient energy system, and it needs integrated thinking and governance. Energy efficiency can reduce consumption, contribute to load profile management, and reduce infrastructure investment while also bringing social and environmental benefits. Solutions that improve energy efficiencies on both the demand and the supply side need to be explored and extensively deployed. Vast opportunities remain untouched, although their challenges often are less technical and more of a systematic or adoption-related nature. This would require effective awareness-raising campaigns to increase stakeholder awareness about easy to implement measures at low or no cost that deliver short-term high impact results on energy consumption.
- **System-wide digitalization** has the potential to bridge many gaps at the system level while catalyzing new opportunities through a more profound change in how the devices, systems, and actors communicate. Digital technologies can unlock massive potential with demand-side flexibility, which could be a key instrument for balancing the grid and reducing the carbon footprint of energy systems in a cost-effective manner. Machine learning and artificial intelligence can optimize energy use, identify inefficiencies and anomalies, and enable automatic switching between different energy sources, depending on price and availability.[6] Digital tools enable real-time resource-use optimisation pathways as well as individual decarbonisation roadmaps.[7,8,9]
- **Fuel switching from carbon-intensive to low- and zero-carbon technologies** requires a demand-side pull. For example, the local generation of clean energy, such as roof top solar power generation, or on-side use of otherwise lost resources, such as waste heat, could significantly decrease the load on the energy systems as well as reduce exposure to price and supply shocks, and increase the self-sufficiency and resiliency against costly and harmful outages.

6 UNECE, "Digitalization: enabling the new phase of energy efficiency" (GEEE-7/2020/INF.3), Available at: https://unece.org/documents/2020/12/informal-documents/digitalization-enabling-new-phase-energy-efficiency

7 UNECE, "A pathway to reducing the greenhouse gas footprint in manufacturing: determinants for an economic assessment of industrial decarbonization measures", ECE/ENERGY/GE.6/2021/3. Available at: https://unece.org/sed/documents/2021/07/working-documents/pathway-reducing-greenhouse-gas-footprint-manufacturing

8 UNECE, "Digitalization: Accelerating the Electricity System Transformation", ECE/ENERGY/GE.5/2022/4, ECE/ENERGY/GE.6/2022/4. Available at: https://unece.org/sed/documents/2021/06/working-documents/improving-efficiency-buildings-through-digitalization

9 UNECE, "A pathway to reducing the greenhouse gas footprint in manufacturing: determinants for an economic assessment of industrial decarbonization measures", ECE/ENERGY/GE.6/2021/3. Available at https://unece.org/sed/documents/2021/07/working-documents/pathway-reducing-greenhouse-gas-footprint-manufacturing

Buildings Sector

In order to improve energy efficiency, build resilient energy systems and support decarbonization in the building sector, according to the experts, policymakers should consider designing, implementing and/or adopting policies, standards, legislation, incentives and/or voluntary capacity building programmes that:

- **Improve the energy efficiency in the buildings sector** through deployment of digital technologies in design and manufacturing of materials, products, structures, and engineering systems; decarbonization of the buildings sector supply chains; technical advancement of materials and construction techniques; retrofitting and insulation of the existing buildings; and by ensuring, through enforcement mechanisms, that new buildings comply with sustainable and energy efficient standards.[10, 11]
- **Scale-up net-zero buildings sector energy consumption programmes** by developing distributed renewable energy generation on roofs and by enhancing prosumers' role. Apply smart appliances, smart meters and artificial intelligence solutions coupled with data analytics, feedback loops, and data protection to predict individual needs, ensure more efficient integration of renewable energy sources and enhance coordination across the transmission and distribution systems.
- **Modernize Heating, Ventilation, and Air Conditioning** (HVAC) systems and ensure their efficient operation. Deploying heat pumps and heat recovery systems could attain significant emissions reduction and increase energy savings across the domestic, commercial and industrial domains. Incentives should be provided to modernize traditional HVAC systems to become digitally enabled higher efficiency units.
- **Embrace low-carbon district heating (and cooling) solutions using** renewable energy, waste heat (e.g. waste heat from data centres, industrial estates, refineries and others can be utilized to heat homes or businesses, with numerous examples already employed in Europe), nuclear power (in countries that support this technology), hydrogen, and, in cases where emission reduction technologies are utilized on both supply and use, fossil fuels (e.g. coal or natural gas with methane emission reductions in the fuel supply segment and carbon capture on the post combustion segment of the value chain) .
- **Introduce the "Energy and Resource as a Service" model** that moves away from the current commodity and product-based models towards the subscription-based models that are outcome-focused. Under this model, an energy provider commits to deliver to a recipient an agreed service, such as certain indoor temperature or brightness, rather than delivering energy that it is priced per specific unit (e.g., kWh). This model incentivises the provider to have an interest in efficiency improvements as these directly translate into energy savings and greater profits. This approach is crucial in progressing toward a circular economy and it increases the resource efficiency and cuts carbon footprints.

10 UNECE, "Framework Guidelines for Energy Efficiency Standards in Buildings" (ECE/ENERGY/GE.6/2020/4), available at: https://unece.org/documents/2020/12/updated-framework-guidelines-energy-efficiency-standards-buildings

11 UNECE, "Improving Efficiency of Buildings through Digitalization – Policy Recommendations from the Task Force on Digitalization in Energy" (ECE/ENERGY/GE.6/2021/5). Available at: https://unece.org/sed/documents/2021/06/working-documents/improving-efficiency-buildings-through-digitalization

Industrial Sector

In order to improve energy efficiency, build resilient energy systems and support decarbonization in the industrial sector, according to the experts, policymakers should consider designing, implementing and/or adopting policies, standards, legislation, incentives and/or voluntary capacity building programmes that:

- **Track energy use and emissions**, in the context of energy and resource consumption as well as carbon and methane emission footprints, and keep track of energy use across all different forms of energy, ideally by automatic energy data metering. [12]
- **Apply digital approaches**, such as smart meters, anomaly and leakage detection sensors, advanced load management and energy flexibility techniques based on energy and resource consumption data.
- **Adopt market-ready technologies** with high energy saving potentials for industry[13] as well as the range of non-technical measures that help save energy in the short-run and identify saving potentials. Full adoption of the market-ready technologies has the technical potential to reduce industrial energy demand by approximately 30% [ibid].
- **Deploy innovative low-and zero-carbon solutions.** Some industries, such as steel, cement and chemicals production, cannot easily reduce use of fossil fuels. Innovative technologies, such as carbon capture, use and storage (CCUS) or low-carbon and renewable hydrogen, have the potential to decarbonize these hard-to-abate sectors.
- **Improve recyclability and repairability of products** to achieve full circularity by applying 'designed for net-zero' models. This would reduce the carbon footprint and ease pressure on securing sufficient supply of raw materials and interim products. Apply the principles and requirements of the United Nations Resource Management System (UNRMS).[14]
- **Put mechanisms in place and inform** micro, small and medium-sized enterprises (MSMEs), which often lack inhouse expertise and capacity, about the potential to increase their energy resilience and reduce their energy-related costs. Empower them to take action through local/regional advisory programmes, guided business to business collaboration networks and multi-language online training and material repositories.[15, 16, 17]

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12 UNECE, "Framing the ambition of carbon neutrality", GEEE-7/2020/INF.2

13 BMWK, "Marktverfügbare Innovationen mit hoher Relevanz für die Energieeffizienz in der Industrie". Available at: https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/marktverfuegbare-innovationen-mit-hoher-relevanz-fuer-energieeffizienz-in-der-industrie.pdf

14 UNECE, 2022, Draft United Nations Resource Management System: Principles and Requirements https://unece.org/sites/default/files/2022-04/ECE_ENERGY_GE.3_2022_6.pdf

15 INNOVEAS, "Trainings for Small and Medium sized Enterprises", Available at: https://innoveas.eu/

16 SME Climate Hub, Available at: https://smeclimatehub.org/

17 GIP Green Industry Platform, Available at: https://www.greenindustryplatform.org/

Transport Sector

In order to improve energy efficiency, build resilient energy systems and support decarbonization in the transport sector, according to the experts, policymakers should consider designing, implementing and/or adopting policies, standards, legislation, incentives and/or voluntary capacity building programmes that:

- **Electrify the transport sector** through enabling policies that reduce oil demand and lower carbon emissions across the sector. Develop compatible charging, metering and billing infrastructure. This must be done in conjunction with decarbonization of the electricity grid or it could increase emissions.
- **Apply digital means** to avoid congestions, improve traffic and parking management systems, increase capacity of low-carbon transportation systems and further ease multi-modal transport and ticketing.
- **Raise awareness of energy saving measures** in the transport sector, such as adjusting tyre pressure, avoiding loads, reducing engine idling, and adjusting speed to cut the carbon footprint and improve the cost per mile driven.
- **Develop alternative low-carbon solutions**, such as low-carbon and renewable hydrogen, battery-storage, synthetic fuels, and direct air capture. These solutions are key to decarbonizing hard-to-abate segments of the transport sector, such as long-haul road transport, aviation and maritime, etc.

Detailed Solutions for Designing Resilient Energy Systems:

Energy Supply by Fuel and Storage

Renewable Energy

Renewable energy technologies have a key role to play in building resilient energy systems to achieve the goals of the 2030 Agenda for Sustainable Development and meet the commitments of the Paris Agreement. The countries of Eastern and South-East Europe, Central Asia, the Caucasus and the Russian Federation have seen an unprecedented growth in renewable electricity since 2018 yet the transport and heating and cooling sectors have not seen such increases. Public and private investment in renewables across the seventeen focus countries remains modest compared to global growth trends. Countries of the region need significant investment in renewables.[18] In order to scale deployment of renewable energy, according to the experts, policymakers should consider designing, implementing and/or adopting policies, standards, legislation, incentives and/or voluntary capacity building programmes that:

- **Accelerate the deployment of renewable energy technologies** (such as solar and wind). The policymakers should take advantage of the economic and environmental benefits of renewable energy technologies, including effective re-powering schemes and robust end-of-life scenarios to re-use scarce materials.
- **Adopt UNFC and UNRMS as socially and environmentally focused standards** to comprehensively assess the renewable energy resource potential and integrate its development with other energy sectors, such as natural gas or mining of critical raw materials. This should promote a nexus approach between water, food and energy security while managing the natural resource base in the region.
- **Encourage distributed renewable energy generation projects** to minimize power transmission and distribution needs and reduce grid losses. Micro-wind, hydro, geothermal and solar schemes could be an option in places where the environment is unsuitable for larger-scale installations. The development of flexible power and heat generation allows for a balance of variable generation profiles.
- **Deploy decentralized smaller scale solar photovoltaic and solar thermal installations** on public, commercial, and private roofs to significantly accelerate the transformation of the energy system. If combined with various types of smart storage, it could create a buffer storage capacity, removing an additional part of the burden from the transmission infrastructure, and ease the pressure on scarce resources. This would also help shield consumers from outages and price shocks.
- **Explore to what extent coal, in addition to natural gas, can be an effective short-term supplement** to intermittent solar and wind resources to deliver continuous electricity supplies in times of an uncertain gas supply. If some fossil fuels are deemed effective in the short term, it is important that those sources of electricity production upgrade their technology to the greatest extent possible to increase the efficiency of their generation while minimizing their environmental footprint.
- **Employ demand-side flexibility and virtual storage** provided by large energy consumers, as well as a variety of storage types (electric, mechanic, thermal, chemical), in the medium to long-term, to decrease the need for fossil-based electricity or thermal generation in this role unless it can be made net-zero compatible by other means (i.e. carbon capture and storage, either directly or via direct air carbon dioxide removal).
- **Develop an effective dispatch of variable generation** which could be a viable alternative to integrating renewable-based energy with highly flexible balancing resources and could be done while taking steps to improve the flexibility of the balance of the system to minimize renewable curtailments.

18 UNECE Renewable Energy Status Report 2022, https://www.ren21.net/wp-content/uploads/2019/05/REN21_UNECE2022_FullReport.pdf

- **Scale renewable energy deployment through an integrated energy system approach.** Such approach connects electricity, heating and cooling systems. For example, wind- or solar-based electricity surplus would heat thermal storage tanks for district heating and supply heat to end-customers, along with waste heat from industry.
- **Scale hydropower project development** as it brings benefits associated with storage and operating flexibility for intermittent renewable energy integration. It is important to evaluate the existing hydropower infrastructure in terms of its capacity for expansion and an assessment of the opportunities for developing new reservoir-based generation plants across the region. It is critical to take the risks associated with climate change and extended draughts into considerations when designing projects.
- **Develop pumped hydro storage** as a potential vehicle for providing large scale electricity storage capacity to balance renewables. Depleted oil fields and abandoned mines may potentially be suitable and less intrusive locations worth exploring for pump hydro, other energy storage schemes, and district energy installations.
- **Enhance the transmission systems** to integrate increasing renewable energy and electrolyzers capacity into the grid network. Implement mechanisms to ensure that surplus renewable energy the grid cannot absorb is stored and not wasted, and further extend interconnections between regional, national, and pan-regional grids to enable the transfer of surplus energy to areas with surplus demand and to increase the overall grid resilience.

Bioenergy

Bioenergy is renewable energy which can be created using biomass, derived from biological material directly or indirectly produced by photosynthesis. It can serve as a sustainable energy resource for member States yet before investing heavily in bioenergy, it is critical that policymakers consider its potential impacts on food security and on the environment, including water depletion and pollution, soil degradation, nutrient depletion, and the loss of wild and agricultural biodiversity. A nexus, integrated and holistic approach is needed to scale-up bioenergy production in the right way.

In order to scale up deployment of biofuels from biomass and waste, according to the experts, policymakers should consider designing, implementing and/or adopting policies, standards, legislation, incentives and/or voluntary capacity building programmes that:

- **Deploy biofuels such as corn ethanol or biogas** to decarbonize the transport sector in those cases where it is difficult to electrify. However, it is important to consider land use economics, potential environment impacts, and trade-offs with food security, especially if fertilizer production is also to be affected by natural gas costs.
- **Develop projects for combined heat and power generation** that use biomass and waste, potentially with carbon capture, use and storage (CCUS) in the long term, to increase energy security, diversify supply and facilitate the circularity of the economies in municipalities and regions
- **Unlock the full potential of biomass and waste** in the energy system through the deployment of biofuels. Biomass and waste are well-positioned as feedstock for biogas and upgraded biomethane production. Utilization of waste heat enhances the security of energy supply as waste is predominantly locally sourced. Biofuels can be injected into the gas grid and utilized for multiple uses that range from combined heat & power (CHP) to heavy-duty transportation.

Natural Gas

Until the full potential of low-carbon and renewable gases is unlocked and capitalized on, natural gas is likely to remain an important fuel enabling and driving energy transition. In order to address the short-term need for gas and long-term methane emissions management, climate change and sustainability goals, according to the experts, policymakers should consider designing, implementing and/or adopting policies, standards, legislation, incentives and/or voluntary capacity building programmes that:

- **Secure domestic oil and gas production in the short-term** from operational assets to meet the demand if the existing renewable energy capacity cannot meet it. This includes increasing production at the diminishing oil and gas reservoirs in the North Sea in the Western Europe. Those reservoirs, where compatible, can receive fluids for energy storage now and become repositories for carbon dioxide as oil and gas are withdrawn, providing a mechanism for both energy and long-term carbon storage.
- **Rethink European short-term oil and gas production options**, including reinitiating the debate on fracking exploration sites where geologically unharmful (i.e., outwit seismic active areas), for the short term in countries that support this technology, to enhance their energy security.
- **Expand the Liquified Natural Gas (LNG) import and export capacity** across the region. Developing the LNG capacity and increasing the LNG fleet will be necessary to meet the expected demand for natural gas across the region without or with insufficient access to pipelines and gas storage. Additional LNG capacity will also need the expansion of interconnections to overcome supply chain bottlenecks and unlock the total potential of the existing gas infrastructure. Investing into gas infrastructure today will not be a stranded-asset as in the long-term it could be used for ammonia or hydrogen import-export routes, as well as for CO_2 import-exports.
- **Explore possibilities for exploiting coal mine methane, abandoned mine methane, and coalbed methane** for power generation and potentially developing synthetic gas. Coal to synthetic gas for use as fuel or as chemical feedstock is a proven but expensive technology that requires the deployment of emission reduction technologies to achieve net-zero emissions (as does natural gas, but to a different extent).
- **Reduce fugitive emissions from natural gas production and transmission** to the lowest possible levels, following the best practice already demonstrated in leading countries in the UNECE region. Doing this will increase the amounts of gas available to use as well as reduce methane emissions, with their high global warming potential.
- **Deploy CCUS technologies to limit the carbon footprint of fossil fuel infrastructure** and produce low-carbon gases, such as hydrogen from natural gas, biomass, or coal, with CCUS. Captured CO_2 might be shipped and stored into depleting oil and gas reservoirs through enhanced oil (and possibly gas) recovery processes, used as industrial gases, or converted into stone.

Coal

Coal remains a widely used source of power generation across the UNECE region. Uncontrolled emissions from fossil-based generation are incompatible with the set environmental goals. While coal, natural gas, and other fossil fuel use may be identified as a short-term solution to deliver energy security, nations must accelerate efforts toward the phasedown of unabated coal power..

Experts recommend that policymakers consider designing, implementing and/or adopting policies, standards, legislation, incentives and/or voluntary capacity building programmes that:

- **Accelerate deployment of CCUS and high-efficiency low emission (HELE)** retrofit technologies on the existing coal-based generation infrastructure, especially in the countries across the UNECE region where there are no other viable and quickly deployable other low- and zero-carbon alternatives.

- **Ensure the effective management of fugitive methane emissions from coal mines**, including after mine closures. The capital and operating costs of projects to reduce methane emissions at coal mines are less than the costs of CCUS projects on a per tonne of CO_2e basis.
- **Put in place regulatory and financial frameworks to facilitate** the development of coal mine methane (CMM), coalbed methane (CBM), abandoned mine methane (AMM), and CCUS projects. Unblocking investments in the sector and providing funds for the deployment of the above-mentioned solutions would help to reduce the carbon footprint across the whole coal supply chain.

Nuclear power

For countries that support nuclear, nuclear power generation can be a low-carbon source of energy and heat. In countries that decide to deploy nuclear power, it can play an important role in decarbonizing the energy system. According to the experts, policymakers interesting in increasing deployment of nuclear power reactors should consider designing, implementing and/or adopting policies, standards, legislation, incentives and/or programmes that:

- **Extend the operational lifetime of existing nuclear power reactors** that are structurally safe to improve regional energy security. UNECE countries that deploy nuclear power might want to reconsider the existing plans for the closure of their nuclear power stations to delay that process until the capacity of other zero- and low-carbon technologies is sufficient to fully cover the energy demand.
- **Accelerate the development and deployment of advanced nuclear technologies**, including small modular reactors (SMRs), to produce high-temperature heat and hydrogen. New nuclear power stations should be considered as long as they are safe and feasible (compliant). SMRs are safer, cheaper, and more efficient than conventional reactors. They could be deployed at scale to satisfy the energy needs in places where renewable energy sources alone cannot meet the demand.

Hydrogen

Hydrogen that is already used as a chemical feedstock could also be used as an energy carrier and storage medium. Scaling of projects across the whole hydrogen value chain are needed to enable a hydrogen ecosystem and unlock the potential of hydrogen to decarbonize hard-to-abate sectors, such as long-haul transport or production of steel and chemicals.

In order to scale deployment of hydrogen, according to the experts, policymakers should consider designing, implementing and/or adopting policies, standards, legislation, incentives and/or programmes that:

- **Scale all low-carbon and renewable hydrogen production pathways** (fossil fuels with CCUS, pyrolysis of methane captured at coal mines, biomass with CCUS, or electrolysis from renewable energy or nuclear power, in countries that support it) to ramp up a regional hydrogen ecosystem.
- **Develop a clear regulatory framework and support mechanisms** to scale up low-carbon and renewable hydrogen projects from short- to mid-term.
- **Build on the existing natural gas infrastructure.** This would provide numerous operational and economic advantages, as most of it could be repurposed cost-effectively for transporting hydrogen instead of natural gas. Such adaptation would cost only a small fraction of the expenses that would otherwise be necessary for building a new hydrogen pipeline network.
- **Prepare the demand side** to assess where and how a switch from natural gas or other forms of energy is feasible, encourage the development and deployment of, i.e., gas fired combined heat and power installations that are hydrogen ready and upgrade-kits for existing installations; further develop platforms where end-users, notably industry, can test and explore how their operations could be switched to hydrogen.

Detailed Solutions for Designing Resilient Energy Systems:

Technology Innovation in Energy Demand and Supply

Resilient energy systems in the UNECE region will require continuous investments into research and development of all low- and zero-carbon technologies and sector-wide digitalization until the next generation of zero-carbon technologies is developed and ready to be commercialized. The countries should work together to exchange knowledge and experience to accelerate the development of all low- and zero-carbon technologies.

Specifically, in order to scale deployment of hydrogen, according to the experts, policymakers should consider designing, implementing and/or adopting policies, standards, legislation, incentives and/or programmes that:

- **Develop advance storage technologies** (e.g., batteries) with extended lifetime capacity and rapid discharge rates. This would enable a faster and deeper integration of renewable energy capacity into the energy system.
- **Promote the availability of social and environmental reference data** for primary and secondary (recycled) critical raw materials based on UNFC and UNRMS. This is required for effective planning and project development as well as informed decision making.
- **Advance efficiencies across all supply-side technologies** and support further development of all innovative solutions, such as CCUS, next generation of nuclear power (SMRs) (in those countries that support it) and low-carbon and renewable hydrogen.
- **Deploy digital controls and load management systems** focusing on security and strong controls around remote access and routable connectivity.
- **Improve cyber security** of the supply chain of critical components, such as protective relays, transformers, and the operating technology software. Comply with supply risk management standards[19] that require the development of at least one documented supply chain cyber security risk management plan.
- **Digitalize the electricity grid** based on opportunities associated with a broader energy system digitalization. Development of digital technologies, controls and digitally enabled load management systems should continue with a focus on system-level security and consumers' privacy aspects[20].
- **Encourage 'open energy data'.** This is crucial to scale research and development, demonstration of new technologies, innovation of business models and policy solutions to support flexibility and efficiency services[21].
- **Embrace CCUS in all its forms**, be it direct air capture of carbon at source, or as part of hydrogen production. Research collaboration across the CCUS technologies portfolio should be encouraged. Countries leading in practical deployment should make their legal, regulatory and technical experience as fully available to others as possible.

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20 UNECE, "Digitalizing electricity systems" (ECE/ENERGY/GE.6/2022/4– ECE/ENERGY/GE.5/2022/4), Available at: https://unece.org/sed/documents/2022/07/session-documents/digitalization-accelerating-electricity-system

21 UNECE, "Policy discussion - Challenges of big data and analytics-driven demand-side management" (GEEE-9/2022/INF.3), Available at: https://unece.org/sed/documents/2022/07/informal-documents/policy-discussion-challenges-big-data-and-analytics-driven

Conclusion

This paper presented five high-level actions that can improve systemic efficiency, optimize resources use, and reduce the associated carbon footprint and help build resilient energy systems. According to the experts under the UNECE Committee on Sustainable Energy, policy makers should prioritize these five actions as discussed in section 4 above:

1. **Maximize the implementation of energy efficiency solutions immediately.**
2. **Digitalize the energy systems.**
3. **Accelerate fuel switching.**
4. **Manage resources effectively, sustainably and with circularity considerations.**
5. **Accelerate the deployment of low- and zero-carbon technology to decarbonize the energy system over time.**

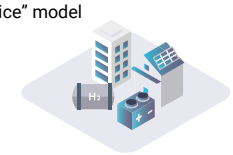
The paper further presented key cross-cutting considerations, immediate actions policymakers can take, and specific options policymakers can consider, including energy demand options by sector, energy supply options across the different fuels and technologies, and technical innovations across energy supply and demand that can help policymakers to build more resilient energy systems.

When taking a comprehensive approach to building resilient energy systems, the strategies and considerations presented can help member States identify which options might meet their immediate energy and economic needs based on their unique national circumstances and development aspirations without jeopardizing achievement of their longer-term 2030 Agenda and the Paris agreement goals.

The UNECE Expert Community and the Committee on Sustainable Energy have launched the UNECE Platform on Resilient Energy Systems. The Platform is aimed to further coordinate, compile, promote and provide information, guidance, training and/or technical assistance to support member States as they work to prioritize, design, finance and implement options to build resilient energy systems.

Annex I - A Framework for Resilient Energy Systems

Energy Efficiency
System-Wide Digitalisation
Fuel Switching-Options

DEMAND SIDE	STORAGE AND TRANSMISSION SIDE	SUPPLY SIDE
Buildings • Decarbonize building supply chain • Modernize heating, cooling and energy distribution • Apply smart meters • Optimise resource and energy use with artificial intelligence • Integrate local generation with clean energy • Introduce "Energy and Resource as a Service" model 	**Grid Network** • Develop controls, and digitally enabled load management systems • Integrate with decentralized system • Increase routable connectivity	**Renewable Energy** • Accelerate deployment • Adopt socially and environmentally focused standards • Explore support from coal and gas • Scale up hydropower projects • Deploy decentralised smaller scale installations
Industry • Adopt smart meters • Deploy all low- and zero-carbon solutions • Track energy use • Achieve full circularity of products • Apply principles from the UN resource management systems 	**Energy Storage** • Develop effective dispatch of variable generation • Expand transmission system and integrate electrolyzers capacity into the grid • Extend battery duration capacity • Develop pumped hydro storage • Develop hydrogen as a chemical feedstock and an energy carrier • Depleted reservoir can be used for energy storage	**Biofuel & Waste** • Deploy corn ethanol or biogas • Develop biomass projects with carbon capture utilization and storage • Unlock biomass and waste as feedstock for biogas **Natural Gas** • Integrate with CCUS for reducing emission and enhanced gas recovery • Secure liquefied natural gas import • Develop synthetic gas • Reduce fugitive emissions **Coal** • Deploy carbon capture utilization and storage and high-efficiency low emission technologies • Manage fugitive emissions • Implement rigid regulatory and financial frame-works for current projects amid phasedown
Transport • Electrify the transport system • Develop alternative low carbon fuel 	**Geological Storage** • Develop deep saline aquifers for geological CO_2 storage • Depleted oil and gas fields used for geological CO_2 storage • Develop geological storage for hydrogen • Share practical deployment experience • Collaborative research on subsurface resource consumption	**Nuclear** • Extend operational lifetime • Deploy advance nuclear technologies for nuclear reactors **Hydrogen** •Scale up renewable hydrogen • Develop regulatory framework and support mechanisms • Expand on existing natural gas infrastructure

REGIONAL INNOVATION-RELATED
Advance efficiencies
Develop digital controls and load management systems
Innovative low- and zero-carbon technology solutions, including hydrogen, CCUS, small modular reactors
Encourage open energy data, social, and environmental reference data
Improve cyber security

Building Resilient Energy Systems:
Actions for Achieving Greater Energy Security, Affordability and Net-zero in the UNECE Region

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