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Review of the implementation of the 2030 Agenda for Sustainable Development in Asia and the Pacific and issues pertinent to the subsidiary structure of the Commission: energy

Employing digitally driven innovation in the energy sector to support the achievement of Sustainable Development Goal 7

Note by the secretariat

Summary

Energy systems across Asia and the Pacific are undergoing fast transformations. Driven by renewable energy and net-zero emissions targets and declining technology costs, and enabled by digital innovation, the way in which energy is produced, distributed and consumed is changing rapidly. Innovations across the energy sector value chain are creating new dynamics that will drive decarbonization and sustainable development. However, although innovations will present opportunities, they will also create challenges that, in order to be addressed, will require policymakers to find new solutions, in particular by leveraging digitalization.

In the present document, the secretariat explores how digitally driven innovation is reshaping the energy sector in the Asia-Pacific region and how that transformation can help address some of the most urgent priorities contained in the 2030 Agenda for Sustainable Development. The Asia-Pacific region's potential as a hub for the development of many cutting-edge energy sector technologies is also highlighted. Furthermore, the secretariat provides recommendations for policy options aimed at leveraging digitalization to accelerate the achievement of the 2030 Agenda and the Paris Agreement, consistent with national policy objectives, including net-zero emissions targets where relevant.

The Economic and Social Commission for Asia and the Pacific may wish to take note of the document and provide guidance on the future work of the secretariat in that regard.

I. Introduction

1. Power systems across Asia and the Pacific are undergoing fast transformations, driven by renewable energy and net-zero emissions targets and declining technology costs and enabled by digital innovation. The energy transition is creating new dynamics that will drive decarbonization of the power system and shift energy consumption patterns and sustainable

* ESCAP/80/1.

development. However, they will also create challenges for power system operators and policymakers that, in order to be addressed, will require new solutions, in particular by leveraging digitalization.

2. Digitalization within power systems is not new. Power utilities have long utilized sensors and supervisory control and data acquisition systems to securely and efficiently operate transmission systems that extend across hundreds or thousands of kilometres, often across multiple jurisdictions. However, there have been notable advancements in recent years that are changing the entire power system value chain, including by affecting how electricity is generated and consumed and enabling power to be transmitted over long distances to lower-voltage distribution networks.

3. For example, sensors, advanced data analytics and the Internet of things are enabling predictive maintenance to be conducted and helping to prevent power outages, thereby improving power system security. Developments in automated switching, digitalized control, monitoring and communication capabilities are enhancing grid flexibility, allowing for the secure and cost-effective integration of higher shares of variable renewable energy. Consumers benefit from the digitalization of the power sector using smart meters that can provide real-time data on electricity consumption and behind-the-meter generation and storage, transforming households and businesses into "prosumers" that can both draw from and contribute to the grid.

4. The Asia-Pacific region is the hub for the development of many cutting-edge power sector technologies and is well placed to both benefit from and drive a digitalized energy transition. The application of innovations in a regional setting can help countries meet the rapidly increasing demand for electricity while simultaneously pursuing decarbonization goals. Countries, in other words, do not need to choose between decarbonization and economic growth. Rather, decarbonization combined with digitalization can become a driver of economic growth and social development. This is especially true when one considers the opportunity to leverage digitalization to enable cross-border power system integration, which will allow countries to tap into the abundant, low-cost renewable resources that are often located far from demand centres. Cooperation on the energy transition is critical to accelerating the achievement of the Sustainable Development Goals in Asia and the Pacific.

5. In the present document, the secretariat explores how digitally driven innovation is reshaping the energy sector in the Asia-Pacific region. It also examines how that transformation can help address some of the most urgent priorities contained in the 2030 Agenda for Sustainable Development.

II. Role of digitally driven innovation in accelerating the energy transition for the achievement of the Sustainable Development Goals

6. Access to clean, affordable and reliable energy enables sustainable development. At the same time, the energy sector is by far the single largest source of greenhouse gas and particulate emissions in the region, contributing to climate change and air pollution.

7. The energy sector has a far-reaching impact on and interlinkages with multiple Sustainable Development Goals, including with regard to poverty reduction, food security, health, quality education, economic growth, sustainable cities and climate action. As a result, in accelerating the achievement of the Goals, a critical role will be played by digitally driven

innovation in the energy sector, with the aim of reducing environmental externalities, enhancing energy efficiency and improving access to clean and affordable energy services.

8. A key challenge in the Asia-Pacific region is the need to rapidly and significantly increase the share of renewables in the energy mix. Countries in the region have made remarkable progress in achieving many of the targets of Goal 7 (Affordable and clean energy), in particular in enhancing energy access and reducing energy intensity. The region also leads the world in the deployment of renewable energy technologies. For example, it accounts for 58.9 per cent of the global solar photovoltaic market in terms of cumulative capacity, with China, India and Japan among the top five countries globally. In addition, developing countries in the region, including Viet Nam, have rapidly increased their solar photovoltaic capacities. However, despite that progress, fossil fuels still account for over 85 per cent of the region's energy consumption and the gap between investments in renewables and projected growth in energy demand remains considerable.[1]

9. The successful achievement of the objectives set out in the 2030 Agenda for Sustainable Development and the Paris Agreement requires the rapid transformation of energy systems around the globe towards high shares of renewable energy. As countries in the Asia-Pacific region announce ambitious pledges and actions to phase out fossil fuels and enact policies in line with achieving net-zero emissions by 2050, renewable energy will come to play a dominant role across all sectors. That imperative was again echoed by the Conference of the Parties to the United Nations Framework Convention on Climate Change at its recently concluded twenty-eighth meeting, during which it committed itself to work to triple renewable capacity by 2030.

10. The pace of efforts to improve energy intensity in the Asia-Pacific region, however, is falling short of the global target. While a few countries have successfully implemented energy efficiency measures across sectors, many have faced difficulties in achieving scale, especially least developed countries. Moreover, in least developed countries, improvements in access to energy are occurring at a slower pace than in other countries. In fact, they are actually falling behind what is needed to achieve structural transformation. Progress in least developed countries has been hindered by the fact that, in 2021, they received only 11 per cent of all international financial flows directed to developing countries in the Asia-Pacific region to support the development of clean energy. While that was an improvement in relative terms from the 5.5 per cent of financial flows they had received in 2020, in absolute terms financial flows have been declining since 2017.[2] The delivery of finance from all sources and the mobilization of resources has to accelerate to meet the needs related to energy access and energy transition. In terms of support, promoting effective and least-cost transitions for least developed countries will require an increase in international cooperation, including cross-border cooperation and

[1] See https://asiapacificenergy.org/apef/index.html#main/lang/en/graph/5/type/1/sort/0/time/[min,max]/indicator/[1295-M:834]/geo/[ASPA]/legend/1/inspect/0. See also Renewable Energy Policy Network for the 21st Century, "*Renewables 2022 Global Status Report*: Asia factsheet", available at www.ren21.net/wp-content/uploads/2019/05/GSR2022_Fact_Sheet_Asia.pdf.

[2] Economic and Social Commission for Asia and the Pacific (ESCAP), "Indicators by theme: financing – international support to clean energy and renewable energy", SDG Gateway Data Explorer. Available at https://dataexplorer.unescap.org/ (accessed on 10 January 2024).

the collection and publication of data to aid in development and investment decisions.

11. In that context, digitalization will play an important role in shaping future outcomes for policymaking and investment decisions across all countries. Digital solutions can be used to offer cost-effective approaches to automating standardized and accessible information for stakeholders. Small island developing States in particular may benefit from off-grid services, since their remote location may make the cost of extending the main grid prohibitive.

12. Data can be a driver of more transparent financial flows within businesses, further leading to effective investment decisions. The availability of data can provide investors with greater clarity, allowing them to make informed decisions when allocating capital to projects, thereby presenting more opportunities for financial aggregation. That is particularly relevant for projects located in small island developing States and least developed countries, where the risks are greater than in developed economies. Innovations in infrastructure and services, including Internet of things-enabled technologies (e.g. smart meters), as well as blockchain and pay-as-you-go business models, have helped to further reduce costs, improve reliability and expand the range of electricity services provided.[3] In 2021, a $30 million investment was made in an innovative, artificial intelligence-enabled energy financing platform.[4] The platform is used to collect essential information, including consumer repayment data, in order to standardize credit risk assessments, inform due diligence processes and enhance portfolio and impact monitoring.

13. Least developed countries and small island developing States face significant barriers to attracting finance as they have a weak presence in capital markets, since they lack credit ratings, suffer from high political volatility and experience difficulties in generating investment returns, thus posing many risks for investors. However, previous innovations in digital financing combined with emerging technology in digital twins will help reduce the risk and provide incentives for investors to increase financing to least developed countries and small island developing States. Digital twin technology can help improve capital allocation processes, screen and manage risk and improve asset values. One of the key components of digital twin technology is that it is capable of generating what-if scenarios, allowing companies and banks in different sectors to experiment with operational settings to discover the best working configuration or outcome.

III. Regional trends and tools of digitally driven innovation in the energy sector in the Asia-Pacific region

14. Digitally driven innovation in the energy sector has supported efficiency gains throughout the years. More recently, technological advancements and deployment in the region have accelerated as a result of sector coupling. As a result, there have been greater opportunities for developing countries to leapfrog by using digital innovation for clean energy

[3] International Renewable Energy Agency and Climate Policy Initiative, *Global Landscape of Renewable Energy Finance 2023* (Abu Dhabi, International Renewable Energy Agency, 2023).

[4] United Nations Development Programme, *Linking Global Finance to Small-Scale Clean Energy*: *Financial Aggregation for Distributed Renewable Energy in Developing Countries* (New York, 2022).

solutions. Some of the notable trends in the Asia-Pacific region and the digital technology tools supporting them are discussed in the table below.

Key milestones in the development and use of digital technologies in electric power systems

Time period	*Milestones*
1970–1979	• The development of supervisory control and data acquisition systems enables remote monitoring and control of power system components
1980–1989	• The introduction of microprocessor-based digital relays improves the accuracy and reliability of power system measurements and monitoring • The development of phasor measurement units enables real-time monitoring and analysis of power system dynamics
1990–1999	• The introduction of digital protective relays replaces traditional electromechanical relays, leading to better accuracy, faster response times and more advanced fault detection and diagnosis
2000–2009	• The use of digital communications technologies and wireless networks facilitates the integration of distributed energy resources, such as solar panels and wind turbines, into the power grid • The development of synchrophasors enables the measurement and visualization of power system dynamics in real time, leading to improved situational awareness and enhanced stability • The adoption of smart grid technologies enables the integration of advanced sensors, communications networks and automation systems, leading to greater efficiency, reliability and sustainability of the power grid
2010–2019	• The advent of big data analytics, machine learning and artificial intelligence enables advanced data processing and predictive modelling, leading to improved forecasting, fault detection and outage management • The development of cloud computing platforms enables the processing and storage of large amounts of data generated by the power system, leading to improved data analytics and decision-making • The introduction of virtual power plants enables the aggregation and management of distributed energy resources, leading to more efficient and flexible energy management

Time period	*Milestones*
Since 2020	• The use of digital twins, which are virtual replicas of physical assets, in the power system has the potential to improve asset management, maintenance and planning, leading to improved reliability and cost-effectiveness • The development of blockchain technology and distributed ledger systems has the potential to revolutionize the way energy transactions are managed, enabling secure and efficient peer-to-peer energy trading and billing • The deployment of fifth-generation (5G) wireless system networks has the potential to enable the integration of more advanced communications and automation systems in the power grid, leading to greater efficiency, reliability and sustainability

Source: Erdal Irmak, Ersan Kabalci and Yasin Kabalci, "Digital transformation of microgrids: a review of design, operation, optimization, and cybersecurity", *Energies*, vol. 16, No. 12 (June 2023).

A. Key regional characteristics of present and future digital trends in the energy sector in support of the Sustainable Development Goals

1. Distributed generation systems

15. Digitalization is enabling the use of distributed energy resource management systems (decentralized or distributed generation systems) based on variable renewable energy resources, which in turn provide localized, sustainable and reliable power, thereby enhancing energy security and resilience. By integrating sensors, real-time monitoring, data analytics and control systems, grids can be more responsive to fluctuations in demand, changing weather conditions and variable supplies of power coming from a diverse set of technologies. In other words, the grid can be managed efficiently despite the increased challenges posed by the integration of variable renewable energy, namely intermittency and supply/demand mismatches. Distributed energy resource management systems, Internet-of-things devices, big data analytics, artificial intelligence and other digital technologies have also contributed significantly to the control and management of microgrids in remote locations by helping to optimize their operation, including with regard to load balancing, energy storage management and demand response.[5] The market for distributed energy resources in the Asia-Pacific region has been growing rapidly. That pace is projected to continue, led not only by solar photovoltaics, but also by analytics and forecasting software and virtual power plants.

16. Distributed energy resource management systems are particularly relevant in the context of small island developing States, whose remote location and small population act as barriers to investment in adequate power transmission lines. In addition, the situation of small island developing States is aggravated by other disadvantages and challenges in infrastructure development. They are susceptible to disruptions in the supply of fossil fuel

[5] Erdal Irmak, Ersan Kabalci and Yasin Kabalci, "Digital transformation of microgrids: a review of design, operation, optimization, and cybersecurity", *Energies*, vol. 16, No. 12 (June 2023).

shipments, and the increasing frequency of extreme weather events threatens to make such disruptions more common. It is therefore imperative for small island developing States to design tailor-made electric power systems and develop local renewable energy resources. Recent extreme weather events that disabled the grid in Hawaii, United States of America, and Puerto Rico present valuable lessons for sustainable development. The integration of distributed energy resources, such as rooftop solar panels, battery energy storage and network-enabled appliances, is enabling the use of decentralized and highly connected power systems with extensive data exchange and digital solutions. Traditionally, power systems have tended to be centralized, with communication flowing mostly from central power plants to system operators. In the future, as new business models emerge, and as more parts of the system become flexible and are able to support the variability introduced to the system by renewable energy, communication will become multidirectional.

2. End-user electrification

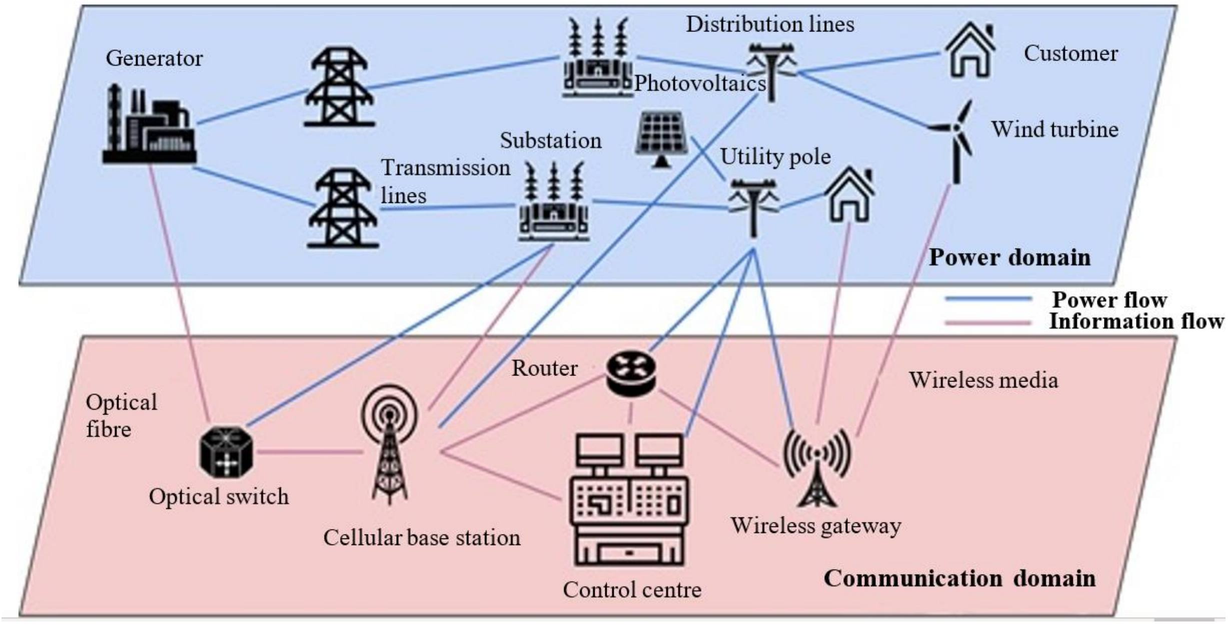
17. Digitally driven innovation in various sectors, advancements in grid expansion and distributed energy resource management technologies have significantly increased the demand for electricity over the years and will continue to drive demand in the Asia-Pacific region. By 2025, more than 70 per cent of growth in demand for electricity is projected to come from China and India, as well as South-East Asia.[6] While electrification can increase energy demand, it also provides opportunities to improve energy efficiency across sectors. For example, the electrification of transport is the single greatest driver of electric power demand. At the residential scale, the adoption of electric vehicles and micromobility solutions is estimated to increase daily home energy demand by between 50 and 100 per cent. At the same time, electrified vehicles can serve as demand-side resources that provide grid-balancing services through two-sided electricity markets and automatic feedback control systems. Linking the energy, transport, and information and communications technology (ICT) sectors enables the greater use of variable renewable energy. The electrification of end uses also means significant potential for demand growth, which leads in turn to increased revenues that utilities can use to help finance upgrades to the electric power system, including capital-intensive investments (such as transformers and substations, as well as distribution and transmission lines), and improve the economic case for the development of cross-border power lines.

3. Integrated infrastructure planning and development

18. Digitalization offers the traditional advantages of resource optimization; efficient land use; and cost savings realized by co-locating infrastructure, such as power lines, ICT cables and transport networks. In addition, digitalization is helping to enhance the benefits of the integrated planning of infrastructure. One good example is the development of smart grid technology, which is leading to greater interdependencies between power grid resilience and communication networks (see figure I).

[6] International Energy Agency, *Electricity Market Report 2023* (Paris, 2023).

Figure I
Interdependent relationship between power and communication domains



Source: Xin Liu and others, “Electronic power grid resilience with interdependencies between power and communication networks: a review”, *IET Smart Grid*, vol. 3, No. 2 (April 2020), pp. 182–193.

19. Transport access is also essential when expanding an electric power system, which increases the need for more sector coupling, for which digitalization will be a key driver. The siting of new electric power transmission and distribution lines is often tied to road networks. Overhead and underground lines are typically built along roadways to support regular maintenance and access, and the required rights of way are often planned in concert with their proximity to major highways or other corridors.

20. It is important to recognize that in less developed regions, low demand may stall grid investments. Under these circumstances, a sustainable energy transformation plan that prioritizes transport electrification would make investments in grid infrastructure more likely. Furthermore, electrified transport requires charging stations to be distributed widely, including in remote areas along major transport arteries. In other words, the expansion of transport and energy infrastructures will have to move in lockstep.

4. Cross-border power grid integration and trade

21. International energy connectivity is required to improve access to the region’s most affordable clean energy resources. For many decades, hydropower facilities in the region have provided a dispatchable and renewable energy resource that is cheaper than fossil fuel-based power generation. More recently, variable renewable energy resources, such as solar and wind generators, have become the most cost-effective options for electric power generation. Power system connectivity will play a key role in mitigating climate change by reducing greenhouse gas emissions through the deployment and integration of renewable energy resources. For example, in the Asia-Pacific region, many landlocked developing countries have ample hydroelectric resources or the potential to develop them. Hydroelectricity can be a key supplier of flexible power generation and support the integration of other renewable energy sources. To illustrate, through the exchange of power

across borders, hydropower generated in the Lao People's Democratic Republic could balance the generation from solar photovoltaics in neighbouring Thailand. Similarly, hydropower in Nepal could make it easier for India to meet its ambitious targets for solar and wind power.

22. Connectivity along the grid also can serve as an engine for national and regional economic development. It can reduce the so-called levelized cost (the value of the total lifetime cost of the generation equipment divided by the value of the total electricity generated over the lifetime of the equipment), reduce the need for additional electric power generation capacity and connect previously unserved communities to the grid. For example, the development and cross-border trade of the vast renewable energy resources of the Gobi Desert would raise export revenue in Mongolia, create jobs and help decarbonize the domestic energy sector. When a sparsely populated country rich in solar, wind and hydro resources serves cities in a neighbouring country, both countries benefit. The exporter creates jobs in the power sector and generates revenue, while the importer gets access to low-cost energy that can make industries more competitive. This cost-reducing effect is especially important in the manufacturing of consumer goods and energy products, such as hydrogen.

23. Cross-border connectivity can also help enable access to modern energy resources. While the Asia-Pacific region has made significant progress towards achieving universal energy access, large gaps remain. For some least developed countries and landlocked developing countries, the fastest way to connect hard-to-reach communities is to tap into the electricity resources from a neighbouring country by means of cross-border energy trade. In Cambodia, for example, 17.5 per cent of the population lacks access to electricity. In the Lao People's Democratic Republic, as a result of the fragmented internal transmission system, it is easier and cheaper in some contexts to connect to the system in, and import power from, neighbouring Thailand.

B. Digital technology tools for energy transition in the Asia-Pacific region

24. The use of blockchain technology enables the encryption of data for peer-to-peer energy trading platforms, which in turn enhances the security, transparency and traceability of data. The blockchain also makes it possible to securely record energy ownership data for trading and minimizes information asymmetry between producers and consumers so that trading can occur in a transparent manner that supports real-time decision-making. The capacity of blockchain to monetize excess renewable energy (e.g. solar electricity) could usher in a transition to a production-by-consumer model and attract additional investments in solar energy. There are many examples of the application of blockchain technology in the region. For example, a building development in Thailand is among the world's largest blockchain-based peer-to-peer solar power projects. Similarly, in Bangladesh, a blockchain-based peer-to-peer energy trading network was developed for rural households to improve access to sustainable, reliable and affordable electricity. In Singapore, a blockchain platform registers solar energy production by small producers using renewable energy certificates, which can be purchased by businesses to offset their carbon emissions. In Malaysia, blockchain applications are being piloted, both for peer-to-peer solar energy trading and for the trading of carbon certificates, and investments are being leveraged for energy efficiency and renewable energy projects.

25. Smart grid technology integrates sensors and data-sharing into grid technologies to enable greater situational awareness and responsiveness. Smart

meters in houses and businesses, and sensors along transmission and distribution lines, can constantly monitor demand and supply, while small-sized devices (synchrophasors) measure the flow of electricity through the grid in real time, allowing operators to foresee and avoid, or identify and manage, disruptions. On the consumer side, smart appliances can communicate with the grid and, for example, shift electricity use to off-peak times, easing the burden on the grid while also saving consumers money. However, countries must have procedures and institutions in place that effectively collect and integrate the smart grid data into system operations, in order for benefits to be realized. The Government of the Republic of Korea recently launched its third basic plan on smart grids, focusing on power system flexibility, digitalization and increasing the engagement of consumers. One of the key initiatives under the plan is to enhance grid flexibility by integrating electric vehicle charging stations into the grid and storing surplus power in the form of heat and hydrogen.

26. Related to smart grids is the deployment of smart meters or advanced meters and demand response programmes. Smart meters provide real-time data on electricity consumption, allowing consumers to monitor and manage their energy usage more effectively. They also enable power utility companies to remotely read meters, reducing the need for manual meter reading. The use of smart meters mixed with the deployment of distribution automation systems will further enhance grid reliability and efficiency by employing sensors, communication networks and control systems to monitor and manage the distribution network in real time. Distribution automation helps utilities respond quickly to outages and optimize grid operations. Through smart meters and communication infrastructure, consumers can receive signals and pricing information to adjust their energy use, while demand response programmes help balance supply and demand, reducing grid stress and avoiding blackouts.

27. Virtual power plants and digital twin technologies are also becoming an important part of distributed energy resource management systems. Virtual power plants aggregate distributed energy resources to balance the supply and demand of electricity to and from the grid or to store electrical energy in a connected energy storage system. The use of decentralized renewable energy generation and grid-scale storage has the added benefit of reducing the effects of natural disasters on energy availability, which is an important consideration in the disaster-prone Asia-Pacific region.

28. Cross-border transmission over very long distances, which was previously considered economically and technically unviable, has now become a real possibility with the development of high- and ultra-high-voltage direct current technology. The Asia-Pacific region is the hub of cutting-edge high-voltage direct current technology and related platforms based on the Internet of things, which are being used to regulate and protect high-voltage direct current grids. Both physical cross-border transmission infrastructure, such as high-voltage direct current transmission systems, and non-physical infrastructure supporting the trading of electricity depend heavily on digitalization. As high-voltage direct current cables are used for transmitting large amounts of power over long distances, digitalization ensures the efficient operation and remote monitoring of these links. In addition, digitalization provides the tools necessary for analysing the large volumes of data generated by the high-voltage direct current equipment for grid optimization, and it is also used for management purposes. Furthermore, digitalization is required for the efficient cross-border trading of electricity, as it facilitates, for example, the use of trading platforms, the timely exchange of market data and the clearing and settlement of payments.

IV. Creating an enabling environment for the development and deployment of digitally driven innovation in the energy sector

A. Mobilizing investments in grid digitalization

29. A key component of the digitalization and modernization of the grid lies in improvements to grid efficiency and operations, in particular maintaining the stability, security and reliability of the transmission and distribution network. Better digital analytics and data intelligence help utility managers improve the management of their grid assets; enterprise software and integrated billing platforms help improve financial performance and reduce costs; and the digitalization of specific grid elements enables the remote monitoring, automation and precision of grid management.

30. Many of the power utilities in countries within Asia and the Pacific operate as nationalized, State-owned (either partly or wholly) utility companies. In these contexts, the drivers for the digital transformation of utilities are primarily political (citizens demanding cheaper electricity, cleaner electricity and more efficiently run State-owned utilities) and financial (a desire to improve cost savings and revenue growth).

31. Industrialization and urbanization are the two key drivers of power system digitalization in the Asia-Pacific region. Approximately 75 per cent of electricity in the region is delivered to industrial and commercial customers, while the remaining 25 per cent is delivered to residential customers. But industrialization and urbanization do not necessarily lead to a more efficient use of energy.[7] Smart grid investments, meanwhile, can help improve the efficiency of demand and power system operations. However, they are relatively expensive compared with traditional grid investments and therefore tend to require higher levels of demand in order to make economic sense.

32. While some research suggests that smart grid deployment can lower overall costs,[8] evidence is still limited, and digital technology providers have little incentive to focus on deploying high-cost smart grid technologies in least developed countries. Policy measures and interventions may be required, for example, providing economic incentives for smart grid investments. At the same time, Governments could consider investing in domestic innovation and technology facilities that incentivize home-grown smart grid technologies and combine research and resources through increased South-South and triangular cooperation.

33. With renewable energy deployment primarily concentrated in developed economies, the full benefits of the energy transition are not yet being reaped by least developed countries, landlocked developing countries and small island developing States. Ultimately, the digitalization of the power

[7] Pengfei Sheng, Yaping He and Xiaohui Guo, "The impact of urbanization on energy consumption and efficiency", *Energy and Environment*, vol. 28, No.7 (November 2017), pp. 673–686 and Perry Sadorsky, "The effect of urbanization and industrialization on energy use in emerging economies: implications for sustainable development", *American Journal of Economics and Sociology*, vol. 73, No. 2 (April 2014).

[8] Rad Stanev, Nikolay Nikolaev and Yulian Rangelov, "Interconnected laboratories for stability studies of the future power system", paper prepared for the Eleventh Electrical Engineering Faculty Conference, Varna, Bulgaria, September 2019.

sector must complement and support efforts to enable an inclusive and just energy transition.

B. Implementing regulatory policies and incentives to increase consumer and private sector engagement

34. The development and deployment of digital innovations in the energy sector have been heavily driven by the private sector. At the same time, providing incentives to increase private sector engagement can result in greater and faster development and penetration of these technologies (see box), which can contribute to leapfrogging in the energy transition pathways of developing countries.

Regulatory sandboxing in Australia

The Australian Energy Regulator implemented a regulatory sandbox framework under the Energy Innovation Toolkit to support energy innovators and start-ups to navigate the complex regulatory frameworks and test new products and services for the delivery of different energy options to consumers. The Toolkit has three components, including an innovation enquiry service that provides innovators with guidance on how to deliver new technologies or business models under the current regulatory scheme; a time-bound trial waiver on specified law and rules; and a trial process that allows for a temporary change in existing rules or the introduction of a new rule to enable a trial of technologies and business models.

Source: See www.aer.gov.au/about/strategic-initiatives/regulatory-sandboxing-energy-innovation-toolkit.

35. Other incentives could be in the form of tax schemes to promote behavioural shifts in consumers and businesses towards cleaner energy, supported by digital technologies and platforms. For example, feed-in tariff schemes implemented by a number of States members of the Economic and Social Commission for Asia and the Pacific provide incentives for homeowners and businesses to install rooftop solar panels. These tariffs ensure that the surplus electricity generated from distributed energy resources, such as rooftop solar photovoltaic systems, can be sold back to the grid at favourable rates, making solar investments financially attractive. To implement these schemes, however, clear and standardized rules for connecting distributed energy resources to the grid are a prerequisite. These standards help maintain grid stability and reliability while accommodating a growing number of distributed energy resource installations. In addition, the establishment of a peer-to-peer trading platform may require government support related to regulation and oversight.

36. The digitalization of energy is an area that is still growing and one in which key technologies bring both opportunities and challenges. While the implementation of such digital technologies is a key component of both the decarbonization imperative and the decentralization of the sector, timely and effective policies and regulations are required. Although digitalization offers greater efficiency and flexibility, there are also risks, such as those related to cybersecurity, that are just as critical and should be given equal consideration.

37. As countries work towards meeting energy and emissions targets, regulatory enforcement becomes critical to ensure progress. Digitalization helps ensure compliance with regulatory requirements and reporting. Automated and real-time monitoring and reporting capabilities help ensure adherence to regulatory requirements and also make it possible to provide

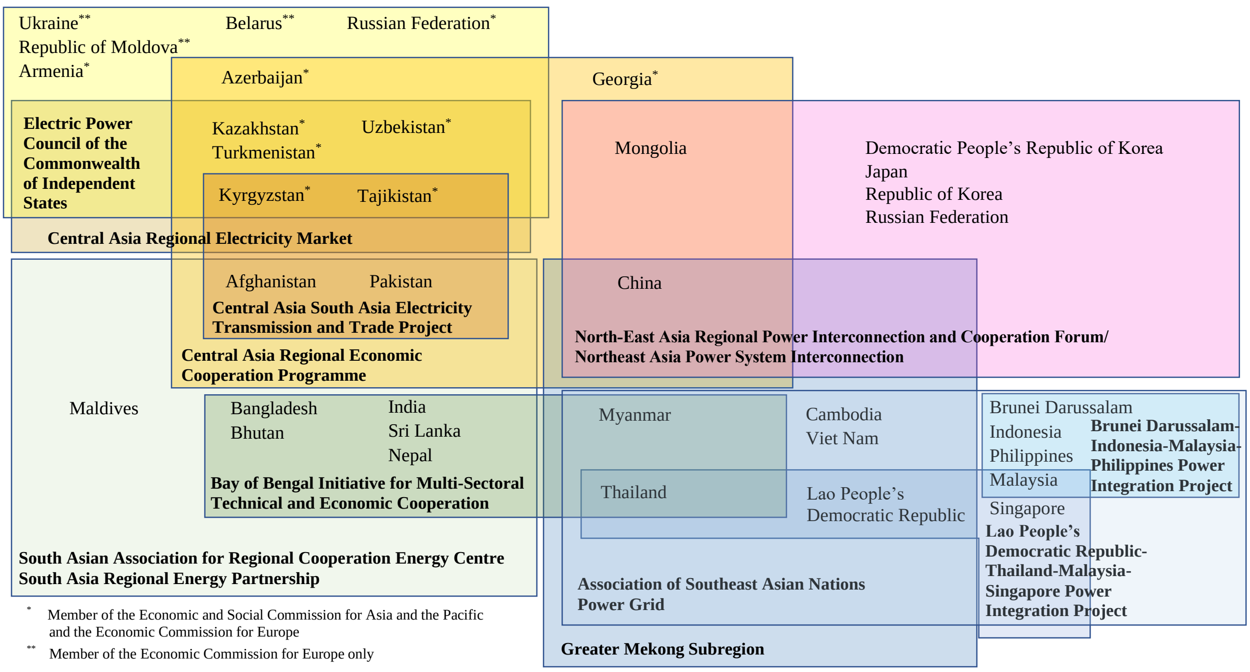
accurate and up-to-date information to regulatory bodies. In addition, data analytics tools contribute to proactive compliance management by identifying patterns, trends and potential issues, thereby enabling organizations to address challenges before they escalate. Remote inspections and monitoring, enabled by digital technologies, allow for efficient compliance checks without the need to be physically present, contributing to reduced costs and increased operational efficiency.

C. Strengthening regional cooperation in digitally driven innovation in the energy sector aimed at achieving the Sustainable Development Goals

38. With the notable exception of North-East Asia, the Asia-Pacific region has several energy- and electricity-related cooperation mechanisms (see figure II). The proliferation of coordination mechanisms – which may or may not be similar to the classic structuring of intergovernmental organizations – suggests that countries are acknowledging their potential role in achieving power connectivity and trade. However, it is also noted that most institutions still approach the preliminary efforts of regional integration using analysis and experience sharing, while institutions that implement processes and detailed market designs are still largely lacking in the Asia-Pacific region. In addition, the traditional power sector is shifting to a more decentralized energy system through the use of digital innovation and new technologies, allowing customers to access renewable energy sources and providing a two-way exchange of both data and energy. Instead of a linear flow of energy from one large-scale producer to the customer, the system operates in a more circular manner, which illustrates the importance of greater stakeholder engagement at every step of the value chain, as well as of the development of digital innovation to foster such platforms to encourage such engagement.

Figure II

Existing power system connectivity and energy cooperation initiatives in Asia and the Pacific



39. Many studies have shown that the increased interconnectivity of power systems offers a number of potential benefits. These include economic and financial benefits, such as lower costs; security benefits, including increased reliability and resilience; technical and operational benefits; and social and environmental benefits. Cross-border trade can help to meet growing demand, enhance energy access and help address power shortages, thereby improving energy security while potentially reducing costs. In certain cases, improving low electrification rates can be achieved more easily or in a more cost-effective manner by importing electricity from a neighbouring country's distribution grid rather than constructing distribution lines to the national power grid.

40. Countries in Asia and the Pacific face multiple challenges to implementing cross-border power connectivity and trade. The analysis of successful initiatives, both from within and outside the region, suggests that regional markets require a regional institutional support mechanism of some sort. Institutions are the key to developing common policies, regulations and standards; a sense of trust and commitment; and power system operations. Moreover, institutional frameworks – even loosely defined ones – have clear roles to play in supporting power system integration. Energy-related institutions can support: (a) the harmonization of regulations or the establishment of common regulatory frameworks; (b) data-sharing initiatives; (c) capacity-building; (d) the assessment of renewable energy potential; (e) the development of common technical standards, codes and guidelines in the areas of planning and design; and (f) the operation and maintenance of cross-border power systems. Knowledge-sharing will help all members of the Commission; improve efficiency and system operations; and support the implementation of the interconnection process. Sharing relevant sectoral information and data, as well as best practices and lessons learned, in particular with regard to new technologies, can support integration efforts by increasing awareness and addressing knowledge gaps.

41. Unlocking the potential of power interconnectivity in all Asia-Pacific subregions by building on existing regional cooperation mechanisms can accelerate the achievement of the Sustainable Development Goals in the region. Not only will cross-border power grid integration create new pockets of economic growth and dynamism, it will help to narrow the vast and growing development gap in the region by spurring much-needed investments in infrastructure and digital technologies for power transmission and trade.

42. Investments have become concentrated in specific technologies and uses and in a small number of countries or regions. In 2020, solar photovoltaics attracted the largest share (43 per cent) of the total investment in renewables, followed by onshore wind (35 per cent) and offshore wind (12 per cent). Based on preliminary figures, this concentration seems to have continued through the end of 2022. To best support the energy transition, more funds need to flow to less mature technologies, as well as to sectors beyond electricity, such as heating, cooling and system integration. More importantly, more than 50 per cent of the world's population, mostly residing in developing and emerging countries, received only 15 per cent of global investments in 2022. For the energy transition to have a positive impact, Governments and development partners need to play a more active role in ensuring equitable financial flows. There needs to be a greater emphasis placed on lending to developing countries that are looking to deploy renewables. In addition, the need for public financing to play a much stronger role, beyond mitigating investment risks, needs to be highlighted. Recognizing the limited public funds available in the developing world, it is vital to strengthen international

collaboration, including through a substantial increase in financial flows from the global North to the global South.

V. Issues for consideration by the Commission

43. In the present document, the secretariat has examined several priority areas for Governments to consider in harnessing the role of digitally driven innovation in the energy sector to support the achievement of the Sustainable Development Goals.

44. Digitally driven innovation in the energy sector presents both opportunities and challenges for the Asia-Pacific region. While digital technologies are providing the means and motivation for accelerating the energy transition, they are also contributing to the digital divide between countries in the region, especially in terms of investment flows to support the development and deployment of new technologies. To address this imbalance, concerted efforts are needed to strengthen regional cooperation through the use of existing, and the creation of new, cooperation platforms so that energy transition targets can be achieved by all member States. In addition, Governments should actively implement policies that incentivize digitally driven innovation in the energy sector and should also implement regulatory frameworks to ensure secure, transparent and standardized rules for emerging technologies.

45. The Commission may wish to take note of the present document and provide guidance on the future work of the secretariat in that regard.