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Digitalization: enabling the new phase of energy efficiency

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I. Introduction

1. Digitalization is an emerging trend revamping the energy landscape and enabling progress toward continuous energy efficiency improvements. It is argued that digitalization, from its various dimensions, shall be considered as part of policy development to ensure overall net benefit to the system and its participants.[7]

2. In its Work Plan for 2020-2021, the Group of Experts on Energy Efficiency (the Group of Experts) was therefore mandated to "explore the role of digitalization and increased use of big data and geo-spatial data in provision of energy services".[8]

3. This discussion paper is prepared with respect to this activity. It examines the role of digitalization and how it can help improve the efficiency of the overall energy system, and aims to provide a clear, concise and balanced view to policymakers and other stakeholders. It presents some sectoral opportunities along with privacy and security risks and touches upon such aspects as data ownership, hosting, and management issues that have significant potential to optimize the overall energy infrastructure. The paper also briefly highlights the potential impact that digitalization of energy system may have on the economy and society, especially in terms of jobs and skills and why reskilling and upskilling will be critical for a sustainable energy future.

4. The aim of this paper is to call on inclusion of a discussion on exploring the benefits and obstacles of digitalizing the energy system in the scope of future deliberations of the Committee on Sustainable Energy, as well as to propose considering establishment of a dedicated Task Force under the auspices of the Group of Experts, to lead the related activities.

II. Digitalization: a challenge or opportunity?

5. Energy efficiency is at the core of the energy system: achieving high level of energy efficiency must be fundamental for a broader strategy addressing the policy challenges. Recent digital innovations are offering new ways of looking at the existing energy efficiency challenges and finding exceptional ways to address them, while also providing a completely

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[7] See *Tracking SDG 7 – The Energy Progress Report 2020* available at: https://trackingsdg7.esmap.org/data/files/download-documents/tracking_sdg_7_2020-full_report_-_web_0.pdf
[8] See http://www.unece.org/fileadmin/DAM/energy/se/pdfs/CSE/comm28.2019/ECE_ENERGY_2019_8_Final.pdf (para. 14, c).

new opportunity to take up energy efficiency to the next level by improving regulatory and policy environment, data analytics and better stakeholder connectivity in all segments of the energy sector – from generation to consumption.

6. Technologies facilitating new market opportunities: digital innovations – tools, technologies and processes, such as Artificial Intelligence (AI), Blockchain, Machine Learning, Advanced Data Analytics, Internet-of-Things (IoT), Big Data, Cloud Computing, Sensors, Automation, 3D Printing, Robotics, etc. are inspiring energy suppliers, transmission and distribution companies, and demand sectors (buildings, industry, transport and other), to establish new business models allowing to generate, deliver and consume energy in a more sustainable fashion. These innovative technologies are providing new revenue-generating opportunities to businesses by changing the way how interaction happens, optimizing processes, enhancing flexibilities, and improving efficiencies.

7. Enabling better policy decisions and regulatory environment: incomplete or imperfect information may lead to flawed decisions. These frontier digital innovations have significant potential to help policymakers achieve their objectives through advancements in data, analytical capability and better connectivity. These innovations cannot only make the technology smart but can also significantly improve the way how policies are developed, coordinated and implemented by enhancing accessibility, improving accountability, and increasing transparency across the value chain. Key elements of digital integration into energy landscape are as follows:

(a) Value proposition:
   (i) Increased system efficiency;
   (ii) Innovative business models;
   (iii) Effective policymaking and implementation.

(b) Key benefits:
   (i) Data accessibility and usability;
   (ii) Automation and connectivity;
   (iii) Empowered consumers and other stakeholders.

(c) Main resources:
   (i) Digital technologies and platforms;
   (ii) Relevant expertise of different segments;
   (iii) Clear leadership and communication.

8. ‘Digitization’ versus ‘Digitalization’: before delving into technicalities of digital innovations and its applications, it is important to differentiate between ‘digitization’ and ‘digitalization’ and why both are crucial to a sustainable energy future. ‘Digitization’ refers to the process of converting physical or analogue information into a systematic digital format that can be stored as well as processed for future productivity gains. On the other hand, the term ‘digitalization’ (also referred to as digital transformation) refers to the actual process of leveraging digitization to make new or improved business or policy decisions for advancing the overall productivity, cost, safety, and sustainability. Digitalization provides the necessary infrastructure and interfaces to act intelligently and efficiently between operations and operators.

9. Side-effects of digitalization: digitalization of an energy system should not be perceived as a threat to the existing infrastructure; in fact, it is providing enormous opportunity to address the biggest challenges the energy industry is facing. At the same time, getting into it and making it a new normal from the complete infrastructure perspective is complex. It can help improve energy security, energy equity and environmental sustainability, but it comes at the cost of new system security requirements and individuals’ privacy risks along with some potential economic disruption. Relevant and robust preventive and corrective measures must be built, analysed, tested and implemented to make most of the digital transformation.

10. Consensus among stakeholders: rapid pace of digital innovations and its potential applications in the energy industry is facilitating a growing participation of new and different

types of public and commercial stakeholders. The Information & Communication Technology (ICT) companies, such as hardware manufacturers, software developers, communication enablers, and relevant service providers have increasing responsibility to improve the reliability, resilience, interoperability and efficiency of the energy system. On the other hand, ICT innovations are also opening up a completely new market and business opportunities leading to another set of new market actors, known as institutional entrepreneurs or disruptors, that work on the intersection of energy and ICT industry. These new businesses are developing ways for active participation of consumers and empowering them to become prosumers in the new energy system. Stakeholder support is a necessary condition for the success of any strategy and therefore, consensus among the traditional and new stakeholders on the future of digitalization in the energy industry will be critical. Systematic examination of landscape of different stakeholders and understanding their accountability in the future digitalized energy system will ensure the robust and effective implementation.

III. Digitalizing energy: a system level perspective

11. Impacts of energy digitalization: Information Systems (IS) are regarded as crucial enablers for driving the transformation towards more sustainable energy generation, transition and consumption, e.g., through re-engineering of business and production processes, building automation, fleet management, or teleconference systems. Beyond enhancing the efficiency of internal processes, IS-based energy monitoring and environmental management systems facilitate transparency and allow measuring the achievement of environmental targets and improve overall decision quality, as well as new sustainable business processes and end user products. However, the lifecycle of innovative digital tools, technologies and processes such as AI, IoT or Blockchain is associated with some negative environmental impacts as well. Operating computers, networks, and data centres in particular, comes along with vast amounts of electricity consumption which may result in an overall demand growth. This growth in energy demand and carbon emissions for data centre-related services and technologies must be managed by continuous improvements in both data storage and processing infrastructure and software management tools.

12. Decentralization of the energy system: digitization and digitalization are also driving the decentralization of the energy system. The ongoing cost decline of distributed energy resources (DER) and pressure to tackle the challenge of climate change leads to a dramatic shift in the global energy sector. Companies, households and communities are on track to invest considerable financial means in renewable energy generation capacity and storage. This will help to switch to local, independently-produced power by investing in a mix of large-scale renewables and distributed energy resources behind the meter such as distributed solar photovoltaics (PV), energy storage, electric mobility, combined heat and power, energy management systems, and smart appliances, such as thermostats. Along with this massive investment shift comes a plethora of device interconnections: driven by the electrification of the heating and transportation sector, billions of DER connected to internet are expected to integrate with the existing electric grids by 2030. These developments will irreversibly complicate the energy management systems on the macro and micro level, and therefore, a dynamic way of managing the energy system would be required to ensure that technologies and services are operating at optimum level and contributing towards a cleaner and more efficient energy system.

13. Establishing digital identity and coordination: tools such as energy data analytics will, however, only lead to an increase in process and energy efficiency if end-to-end digital communication enables a cost-effective coordination of billions of devices. As a result, one of the fundamental barriers to widespread DER integration still seems to be the issue of cost-effective on-boarding, vetting, and sharing key information about DER attributes, capabilities, relationships, and behaviours that allows system-wide optimization in the first place. Just as banks need to perform know-your-customer checks to verify the identity of potential customers, assess their suitability for products, and manage risks, grid operators

also need to qualify and register every asset that provides services to the electricity grid. Hence, dynamic on-boarding and dynamic status information in real-time remain the key problems: any device that wants to participate in a given electricity system has to establish first a secure digital identity to coordinate with other systems and participants.

14. Energy data sharing framework: sharing device identities is a key challenge of the 'Fourth Industrial Revolution'. Consumer-level energy data, such as PV generation data, end-use load data, electric vehicle (EV) charging data, and urban mobility data obviously might be of great value for industrial, commercial and household energy management. However, today we have no frameworks in place that allow such data to be collected, aggregated, and shared at scale. In order to reach a high number of market participants, low communication costs for data sharing, as well as simple, reliable and traceable systems to verify information are necessary. The foundation of such a digital infrastructure is the automated authentication of individual power-generating and power-consuming systems, as well as storage systems.

15. Bottom-up approach to verify credentials: in a highly fragmented real-time energy economy, billions of devices of all seizes spontaneously interact and conduct micro-transactions in real-time and they will base their generation and consumption decisions on scarcity signals. In such an environment, self-sustained infrastructures, the internet of energy and decentralization are all elements of the same emerging real-time energy economy. However, this comes with a grade of systemic complexity that cannot be met by a top-down approach. The promise of decentralized device identity registries is to massively reduce the costs for devices to participate in electricity markets by establishing self-sovereign digital identities, interacting with various already existing and future national asset registries to facilitate transactions between billions of assets, customers, grid operators, service providers, and retailers. Instead of building a central entity being in charge of verifying credentials and issuing these identities, individual devices are supposed to establish verified credentials over time through interactions with peers or various authorities in a bottom-up manner.

16. Data is more valuable than models: data streams from distribution networks continue to be poor and lacking data quality may result in improper analysis and ineffective actions. However, closed loop integration of data streams from sources referred to in para. 14, could, for instance, lead to improved load forecasting and informed planning of EV loads by coupling charging profiles with urban mobility. Modern machine learning systems, particularly ones using deep learning, are trained on huge and diverse data sets. When a deep learning model has been trained, it is not always clear whether any biases are introduced by the data sets and how it influences the decision-making. Publications discuss the models but lack detail about the features fed into those models. Publishing the model without training datasets is often meaningless, prohibiting others to reproduce research results, build upon previously accomplished work, and deploy commercially viable products based on the proven technologies. If data remains more valuable than the models, creation of frameworks/concepts/solutions that allow data to be shared while preserving consumer privacy, data integrity, and IT-security, is crucial. Meeting this challenge will require a reimagining of data ownership, data integration and persistence, and third parties' use of data.

IV. Unlocking sectoral opportunities

17. Digitalization assisting at different stages: there are four fundamental ways how digitalization can help unlock sectoral opportunities – predict, measure, monitor and improve. More specifically:

(a) Predict: one of the main challenges of renewable energy integration is to establish an optimal balance between supply and demand. This can potentially be enabled by employing advanced machine learning algorithms and other AI technologies that can help facilitate and speed up the integration by improving weather forecasts, providing reliable consumption trends, and predicting the performance of technologies, etc. By taking the predictive analysis to the next level, energy systems could be managed in a more efficient and effective way.

(b) Measure: operational efficiency of the overall energy system could be significantly improved by introducing real-time digital measurements. The energy system provides many measurable parameters that can be analysed in real time for immediate decision-making or collected and stored for analysis for future actions. For example, smart meters can be installed at homes to deliver the households' energy consumption information automatically to the energy provider and, based on that, energy supply could be optimized.

(c) Monitor: the energy sector increasingly generates data, thereby monitoring the pattern and controlling grid components accordingly can contribute to increased optimization, efficiency, and consumer choice. Digitalization can enable remote monitoring for sensitive technologies and, as a result, better ability to operate the grid more efficiently. In the area of maintenance and security, machine learning can utilize and monitor existing data from component lifetimes, failure modes and cost of outages to develop replacement and maintenance schedules.

(d) Improve: predicting, measuring and monitoring are fundamental to improving the energy system. Digitalization can increase the connectivity between technologies and its operators, and provide real time measurements, better forecasts and insights by monitoring the trend over a longer term with a large volume, or a high velocity, or a variety of data that can assist in handling complex decisions and improving the process of decision-making. Overall, digitalization can help improve the measurement, analysis, processing and forecasting of data/information which can result in higher productivity, improved safety, increased sustainability and reduced costs for consumers and companies.

18. Supply side opportunities: digitalization has significant potential to improve the productivity and reduce the cost on the supply side of the energy sector. By digitalizing the supply side, new opportunities could also emerge for a closer integration, automation and optimization between supply side and demand side. Some of the key applications are:

(a) Coal, oil and gas: these sectors operate in a highly hardware-intensive environment and have seen a comparatively low level of digital integration in the past globally as compared to other sectors. As these industries digitalize their system by incorporating sensors, process automation, remote monitoring and controls, robotics, and industrial IoT, they could gain the ability to measure and implement, in real time, remote control asset management, and predictive maintenance to improve operational efficiency of assets and reduce the overall production and maintenance cost, as can be seen increasingly, for instance, in new combined thermal-electric plants.

(b) Biomass, renewables and waste energy: the stable and uniform utilization of biomass, renewable and waste energy resources have started to get an exponential shape in recent years providing significant opportunity for efficiency improvement. Digitalization has the potential to optimize the whole process by providing a better understanding of patterns/trends, information access, connectivity, real-time information, better analytics, and engagement of stakeholders across the value chain.

(c) Power generation, transmission and distribution: the increasing utilization of renewable energy sources has the potential to decentralize energy supply and challenge the traditional business models of utility companies. Digitalization is an essential component in that opportunity to decentralise the energy system and facilitates a smooth integration of renewable energy into the existing centralized energy system. It can also offer new business opportunities for the companies to provide efficient, reliable, sustainable and customized energy solutions. AI, machine learning and deep learning can create unprecedented possibilities to collect and analyse data and assist energy suppliers in better prediction and balancing of the grid. AI can also help power system developers to create smart grid operations that detect faults and self-heal by trained machine learning algorithms. Overall, the digital transformation can significantly improve the efficiency of energy generation, transmission, and distribution of electricity and district heating/cooling. It can further provide more capabilities and choices to consumers around their energy use. It can help increase grid reliability and security and reduce the cost to generate, transmit and deliver electricity or heating/cooling to end users.

(d) Hybrid energy supply: a hybrid energy supply may become an answer to the increasing need for energy flexibility in the world of renewable energy. The supply of production processes with several competitive energy sources (e.g., PV and wind, solar thermal and biomass, PV and hydraulic, etc.) complemented by storage systems can offer the necessary flexibility to react to the fluctuating energy production of renewable energies. By changing the energy source, the power grid stability can be supported, electricity price fluctuations be exploited and converted into cost advantages, process and supply security be guaranteed, production flexibility increased, and carbon footprint reduced. The same applies for introducing demand-side flexibility, where instead of the source of energy the time and degree of consumption is adjusted to cost and availability of energy. The stability, security and reliability of such system can be achieved by utilizing the power of digital tools and technologies.

(e) The new energy producers and suppliers – 'prosumers': in a digital energy sector, traditional energy consumer can also become a producer of energy, known as 'prosumer'. Germany and the United Kingdom have, for example, feed-in tariffs (FiT) that are fixed rates a prosumer receives for the renewable energy it has not used and feeds into the grid. These kinds of incentives empower consumers to be an active participant in the new energy system, allowing a rapid growth of the share of renewable energy into the overall energy system and easing the challenge to grow the electric grid in pace with increasing electricity demand. This will only be possible at scale with intelligent and connected energy devices. These distributed generation (or microgrids) systems are also creating an opportunity for energy trading within an individual microgrid and/or between multiple microgrids to maximize the usage of renewable energy. Prosumers can also play an important role in urban generation as they can be a potential supplier to the production facility and help optimize the energy balance, either through selling surplus energy of their local generation, or their energy storage (i.e., EV batteries). On the other hand, digital technologies can also facilitate utilizing waste heat from industries and feeding it to households or using it for own production. Entire industrial parks can act as prosumers in local energy networks and help to achieve energy symbioses of production processes and local supply systems. Digitalization can enable autonomous execution of trading decisions between these multiple microgrids and can also maintain the security and privacy of information.

19. Demand side opportunities: digitalization can provide a massive opportunity to maximize the benefit in all energy consuming sectors and address the challenges of lack of data or information, which lead to poor decision-making. The three key sectors and possible applications in these are as follows:

(a) Buildings: digitalization is argued to have a potential to reduce global residential and commercial buildings' energy use by around 10% by 2040. This can be achieved by the implementation of IoT sensors, such as smart thermostats that can work automatically as well as remotely to turn on/off/adjust the heating/cooling systems to a specific temperature, smart lights, or other such smart devices that can optimize the consumption based on requirement and usage pattern. Energy usage during the construction of buildings could also be significantly reduced by applying digital tools and technologies and providing more accurate and timely information across the value chain. This is known as real-time construction management, which brings together all on-site information onto one platform, improving productivity and reducing costs.[9]

(b) Industry: digital technologies are already changing the way how industries produce, process and deliver the product. Industry is responsible for around 38% of global final energy consumption and 24% of total carbon dioxide emissions, and it is estimated that optimization enabled by digitalization could help achieve energy savings of at least 10-20%. This will be in addition to energy savings that could be achieved if the building itself were to be digitized. Technologies, such as industrial IoT, semantic technologies, additive manufacturing, augmented and virtual reality, automation and advanced analytics, industrial

[9] Relevant provisions of the Updated Framework Guidelines for Energy Efficiency Standards in Buildings, ECE/ENERGY/GE.6/2020/4, are hereby also referred to (see https://www.unece.org/fileadmin/DAM/energy/se/pdfs/geee/geee7_Sept2020/ECE_ENERGY_GE.6_2020_4e.pdf).

robots, and 3D printing could be exclusively applicable in different processes of industries that can increase the overall energy and material efficiency, reduce development time and reduce the energy cost. Furthermore, deep integration of digital technologies in manufacturing allows operational efficiency, flexibility and resilience via predictive maintenance, adjusting processes flexibly to energy source and prices and procedures to prevent or lower the often-severe impact of outages.

(c) Transport: transport sector has already been radically changed by both digitization and digitalization. These, together, will have much greater impact in all types of transport – road, rail, aviation, and maritime by collecting, storing, processing, and analysing data to improve the operations, safety, service and efficiency. IoT combined with intelligent sensors and integrated in urban infrastructures and platforms can also significantly enhance the efficiency and effectiveness of transporting goods from the point of origin to the point of consumption or optimize traffic flow, and thus creating more capacity on existing road, rail, air- and waterways infrastructure. Intelligent transport systems (ITS) could reduce energy use by 25% through less travel, modal shift, and reduction of per-km energy consumption.

20. System-wide opportunities: digital transformation of the energy system has the potential to bridge many gaps at the system level while catalysing some new opportunities through a deeper transformation of how the devices, systems and participants connect and communicate. Some of the key benefits and impacts could be:

(a) Better connectivity, trust and transparency: digitalization of the energy system can provide a better connectivity with customers, suppliers and other partners to achieve a greater outcome. While it can significantly improve trust between these various participants, it can also enable an open, transparent, competitive, more resilient and non-discriminatory energy market resulting into a wide range of benefits for the economy and society. The concept of open data across the system can also enable better decision-making for businesses and policymakers along with sparking innovations and inventions for the society.

(b) Effective supply chain management: digital technology solutions have the potential to unlock significant value for industry participants across the entire energy supply chain. The supply chain of variable renewable energy technologies needs to be robust to leverage its full potential, and big data, machine learning, and advanced data analytics can enable managing various renewable energy sources with maximum flexibility and optimization. Digitalization can streamline various processes across the entire energy value chain and significantly improve the speed as well as cost, while also providing an improved visibility and real time insights into the supply chain.

(c) New value propositions: applying digital technologies in the energy system can also provide new value proposition and business opportunities, such as automated demand response, smart battery charging and vehicle infrastructure, vehicle-to-grid services, and optimizing efforts through sector coupling, etc. These new opportunities can provide an opportunity to consumers to play an active role and gain financial benefits while also generating new revenue streams for utility companies.

(d) Reliable outcome prediction and future forecasting: digital advancements like machine learning and AI could be the foundation of a reliable energy system that comprises a larger share of DER. These technologies not only can help in predicting the outcome of unseen data, but it can also help make predictions about the future. Better forecast of demand data, weather pattern, and consumer behaviour could significantly increase grid stability and supply security as well as sustainability of the overall energy system.

V. Critical security and privacy concerns and opportunities

21. System security risks: any incident impacting the service delivery in the utility and energy sectors will have a massive and immediate negative effect on individuals, society, businesses and critical infrastructure. While most past incidents have resulted in short-term disruptions, ultimately such incidents can bring certain societies or regions to the brink of

collapse. All research indicates that the industries over the past decades have been relatively quick to adopt new transformative digitalization solutions, however, at the same time, preserving the use of a number of legacy systems (i.e., supervisory control and data acquisition, SCADA), which demonstrate increasing vulnerabilities, place more pressure on digital technology suppliers and end users. Considering the variety and uniqueness of the cyber threats in different areas of the world, many adopted systems have passed the intended support lifecycle, indicating a dire need of customized upgrading. Additionally, the growing number of 'tracking sources', such as cell site location tracking, license plate scanning, DNA databases of citizens, as well as data generated from connected vehicles and wearables, add yet another significant target for cybercriminals. All these issues leave the industries vulnerable to an abundance of modern cyber threats.

22. Individual cyber safety: an overarching focus has, over the past 4 years, been put on the individual right to maintaining security, privacy, and ownership of their Personal Identifiable Information (PII). On the surface, this collides with the industry inclination to not only analyze, correlate and derive knowledge for predictive maintenance and resource planning purposes, but also in some case to monetize the datasets collected through providing utility services. Should PII privacy be violated, the consequences to the individual can be serious and in certain cases negatively life changing. However, in most countries this concern has taken a back seat to the societal and financial consequences, when the security and safety of Critical National Infrastructure (CNI) systems and services is breached.

23. Proactive policies on cyber security are needed at regional and national level: overall, the warning signs for the industries and societies are apparent, and should lead to an effort to put stronger, more modern and reliable protections in place, to benefit all stakeholders. The potential catastrophic situation has been noticed on a global scale and several frameworks guiding how to establish an effective defense and ensure the continuity of the CNI have been proposed/put in place.

24. Cloud-based digital solution could increase cyber-attack potentials: a number of hardware- and software-based new solutions, such as IoT sensors and smart meters are integrated to a portfolio of cloud-based services, thus become the attack vectors and increases the risks and threats to the industries and the society. An attack vector is a path or means by which an attacker can gain unauthorized access to a computer or network to deliver a payload or malicious outcome. Attack vectors allow attackers to exploit system vulnerabilities, install different types of malware and launch cyber-attacks. Therefore, there is the strong need in the implementation of digital applications in homes, offices, factories and systems in general to incorporate adequate data security measures. Trust into the data security is the foundation of a rapid and widespread implementation of digital solutions.

25. Benefits of applying cloud solutions: connecting solutions to cloud services facilitate ICT development; contribute to more efficient scaling and enhance a high level of security if done right. Cloud is based on flexible sharing of resources where you only pay for what you use, which can be of great economic benefit during fluctuations in the system/service load. In addition, cloud is often operated on a very large scale, which allows for the establishment of comprehensive security solutions at data centers run by the provider.

26. Using AI to increase cyber security: due to the growing volume of digital data, the use of AI in defending against attackers hiding in the abundance of digital signals is also pivotal. AI solutions can spot abnormalities that will in most cases, not be apparent to the human eye and enable more proactive mitigation of the impact of or even fight of the attacks themselves.

27. Strengthening end user responsible practice to increase cyber security and safety: the hyper scale cloud computing providers certainly benefit from no or less shortage of skilled resources to implement and operate at the underlying service platform at the highest possible level of security and compliance. The end user (data controller) is nevertheless also responsible for implementing the 'last mile' of security in configuration and everyday usage by their employees. The tasks for the customer in protecting the integrity, confidentiality, and availability, as well as establishing resiliency through technical architecture and

organizational implementation of security measures are easily overlooked, but should in no way be considered trivial.

28. Full digital data privacy is difficult in combination with modern data analysis: maintaining the individual privacy, when introducing any type of analysis on the digital datasets remains a challenge. There are two techniques of protecting data privacy worth discussing:

(a) Simple anonymization by removing identification data and other obvious identifiers could help to secure the privacy of the data to some degrees, but not completely due to the so-called quasi-identifiers. Research into algorithms providing a higher level of privacy and guarantees against identification of individuals due to quasi- identifiers, are being conducted worldwide. Putting such research into everyday use, maintaining a high level of governance in selecting parameters and testing data validity will enable data-based prediction models to function and provide value, while preserving a higher level of privacy.

(b) Simple aggregation only displays information in groups, and is easier to implement, therefore many consider it a safeguard to protect personal information. Although aggregation may seem like a simple approach to creating safe outputs from data, it does provide false sense of security. Most research shows that intentionally or not, it might be possible to single out an individual, by applying multiple specific filters to an aggregated dataset, which means with the right analysis, aggregate information can reveal significantly personal details, too.

VI. Perceived economic disruption:

29. Changing landscape through industrial revolutions: as a first step, in 18th century, the First and Second Industrial Revolutions inevitably have moved manual production methods to machines employing mechanical manufacturing processes. In 1947, after the invention of transistor, the next step was the Third Industrial Revolution, also called as the ‘Digital Revolution’. It gave a chance to invent and bring the new consumer products and equipment to a market, that did not exist before. Therefore, it affected the economy very positively, and as a result, high skilled jobs and workplaces have been created. The economic growth gave a chance to afford these new products for consumers.

30. Navigating the ‘Fourth Industrial Revolution’: The current Industrial Revolution is a fusion of advances in frontier technologies and its entirely new capabilities for people, as well as machines. Nowadays, the growth and expansion of digitalization exploded on a very large scale, bringing positive and negative effects and potential risks. One of the potential risks focuses on ‘technological unemployment’, creation of work without a job and overall uncertainty regarding the jobs and workplaces. The world has witnessed the same uncertainty during the First Industrial Revolution – people were afraid that machines will replace them, and finally it happened but with a very positive economic effect and growth. The causal link between technological innovation and increased productivity at the macroeconomic level lead to economic growth, higher gross domestic product and the increase of the overall quality of life. On the micro-level, the observed positive effect results from the strong correlation between innovations and employment growth in firms.

30. Changing skill requirements to leverage opportunities: the same is expected with this rapid and profound digitalization – it may not only lead to the disappearance of certain jobs, but also the creation of new ones and changing skill requirements for the existing, which will significantly impact the actual working hours and will move to self-managed working time systems, and even work in a virtual environment. The use of ICT outside work hours deletes the boundaries of work and non-work hours unbalancing to work-life regime and negatively affecting employees. From opposite side, the personal ICT use at work may reflect on the individual and organizational performance. This may differ for each economical sector and worker and be company-specific. As a case, 94-98% of accounting, book-keeping, and auditing jobs are at risk and digitalization will lead to substantial loss of routine jobs in industry, but from another point of view, new types of skills will be demanded in

manufacturing related to service provision and software development, therefore the technologies affect mostly the structure of employment rather than its level. The presence of different circumstances leads to the fact that economic and policy conclusions cannot be derived for the labour market as a whole.

31. Recognizing and managing trade-offs: digitalization from a positive angle is expanding business markets and increasing the choice of consumers and the freedom of employees. From a negative angle, it may uncontrollably increase the insecurity of employees and competition between local and global companies, there may become difficult to compete for small and middle size companies, therefore the monopolization of the global market may appear. The strongest voice of employees is represented by the unions and employers' organizations, so countries with very strong unions put a lot of attention on the potential impact of digitalization on the labour market and its regulation. The expansion of new large digital platforms globally encouraged the development of sharing economy. The disruption of employment services gives new opportunities for job seekers to search and apply for work anytime and anywhere regardless of geographical location, therefore recruiters have migrated to online employment services providing digital virtual access to information and services.

32. Societal impact and scaling opportunities: ICT has already made global impact on the societies through the way we interact and the way we live. By increasing efficiency and creating new jobs, ICT also changed the way we work, especially benefitting women. The macro and micro level assessment in 156 countries of relationship between ICT, female employment and development on the macro level show that ICTs positively affects narrowing the gender gap on the labour market. Nevertheless, in developing countries, this impact is lower because of lower industrialization and digitalization and will potentially increase in future.

VII. Conclusion

33. Vital role in accelerating achievement of carbon neutrality: digitalization of the energy system brings enormous potential to accelerate our effort to achieve carbon neutrality enabled by advances in data, analytics and connectivity, and it can greatly increase the overall efficiency of the energy infrastructure and the energy use at a significantly reduced cost. It is the critical responsibility for the relevant stakeholders to recognize these opportunities and develop the appropriate strategy to get the maximum benefit of these opportunities. Government policies, guidelines and regulatory environment on digitalization of energy system can play a vital role in developing a secure, sustainable and smarter energy future.

34. Capacity building to manage challenges: apart from the capacity requirement to explore the opportunities with digitalization in the energy system, there is a critical need of skillsets to manage the perceived risks and challenges. To manage security and privacy risks, significant research, development and knowledge generating activities need to be encouraged to understand better the complexity and new vulnerabilities brought by the retention of numerous legacy systems, combined with the proliferation of digital transformational series. Private sector collaborative research also needs to be encouraged to draw upon useful case studies to further study the issues in the area of cyber security and data privacy. The development of platforms for capacity building, pilot projects development, and potential replication is a must to leverage the full potential of digital opportunities.

35. Creation of a dedicated task force: the authors encourage looking into the possibility of establishment of a dedicated ‘Task Force on Digitalization in Energy’ to carry out comprehensive work, notably a deeper analysis of opportunities as well as challenges across the whole energy system, and further developing a systematic roadmap embedding digitalization in the work of all subsidiary bodies of the Committee on Sustainable Energy. Some example opportunities to expand on are presented in Annex 1. The proposed draft Terms of Reference for such a task force are presented in Annex 2.

Annex 1

Some example opportunities for consideration and to expand on by the subsidiary bodies of the Committee on Sustainable Energy

Table 1
Example opportunities for the Group of Experts on Cleaner Electricity Systems

Area of operation	*Digital technology*	*Improvement opportunities*
Grid management and operation	Data and analytics, incl. digital electricity infrastructure and software	Reducing operations and maintenance costs
		Improving power plant and network efficiency (improved planning, improved efficiency of combustion in power plants, lower loss rates in networks, better project design throughout the overall power system)
		Enabling predictive maintenance (reducing unplanned outages and downtime –> improved resilience and reliability of supply)
		Extending operational lifetime of assets
	Remote monitoring	Equipment to be operated more efficiently and closer to its optimal conditions, and flows and bottlenecks to be better managed by grid operators
System	Distributed energy sources	Integration of variable renewable energy sources (–> energy demand matching, baseload reduction)
		Enables storing/selling surplus electricity (decentralised)
Transport	Uptake of electric (and connected) mobility	Shape energy and emissions trajectory of transport sector
	Smart charging for EV	Avoid new grid infrastructure (shifting charging periods –> requires a communication protocol)
Market	Smart demand response	Improved system flexibility
		Real-time energy pricing

Table 2
Example opportunities for the Group of Experts on Coal Mine Methane

Area of operation	*Digital technology*	*Improvement opportunities*
Mining	Space-based remote sensing observations (spatial sampling and resolution of atmospheric methane measurements by orbiting satellites)	Improved process efficiency, time optimisation

Table 3
Example opportunities for the Group of Experts on Energy Efficiency

Area of operation	*Digital technology*	*Improvement opportunities*
Industry: process controls and automation	Smart sensors and data analytics	Predict equipment failure
Industry: additive manufacturing	3D printing, industrial robots	Impact on the way products are manufactured (incl. on demand, direct production)
		Increase accuracy and reduce industrial scrap (circular economy-related)
		Reduced floor space (impact on lighting, heating, etc. – may have significant energy and resource savings under the right conditions)
		Improved characteristics of products – for machinery, may reduce resource demand, as well as fuel use
Buildings: intelligent home systems	Smart thermostats, lighting	Reduce energy use in residential and commercial buildings
	Sensors	Predict, measure, monitor and manage the energy performance of buildings in real time
		Inform about maintenance requirements, investment performance, energy saving potential, etc.
	User behaviour and AI learning algorithms	Improving responsiveness of energy services –> energy is provided when and where it is needed
Transport: big data analytics	Big data analytics and data sharing to optimise route planning	Reduce energy use (intensity) and maintenance costs
	Advanced sensing and automated decision-making capabilities	Uptake of automated, connected, electric and shared mobility (highly uncertain: changes in consumer behaviour, policy
		Intervention, technological progress and vehicle technology, etc.)
		Shape energy and emissions trajectory of transport sector

Table 4
Example opportunities for the Group of Experts on Gas

Area of operation	*Digital technology*	*Improvement opportunities*
Midstream: transportation decision-making, incl. on pipelines – mostly expanding the range of digital applications already in use	Robots and drones	Monitor/inspect transmission pipelines and remote unmanned facilities
	AI//machine learning	Analysis and processing speed of large unstructured datasets generated by the above and by seismic studies
	Digital twins	Pipeline digital twins for remaining life calculations, failure and reliability forecasts
	Wearables	Real-time monitoring of vital signs and ambient parameters

Table 5
Example opportunities for the Group of Experts on Renewable Energy

Area of operation	*Digital technology*	*Improvement opportunities*
Production and data analytics	Remote sensing, modelling and simulations	Information to determine solar and wind energy production potential, GPS and GIS tools for positioning
		Computer-aided simulations for optimised performance
		Modelling and simulations of reciprocal cross-flow of electric energy
System	Distributed energy sources	Integration of variable renewable energy sources –> Energy demand matching, baseload reduction, particularly interplay with gas
		Enables storing/selling surplus (decentralised) electricity
Market	Smart demand response	Improved system flexibility
		Real-time energy pricing

Table 5
Example opportunities for the Group of Experts on Resource Management

Area of operation	*Digital technology*	*Improvement opportunities*
Upstream, coal supply chain: reduction of production and maintenance costs, improving safety (semi- or fully-automated systems, robotic mining, remote mining, operation automations, mine modelling and simulations, use of GPS and GIS tools)	Advanced sensors	Real-time status of components of essential equipment
	Computer-aided simulations	Optimizing process configuration
	Data analytics, automation	Improve productivity while enhancing safety and environmental performance
Upstream, oil and gas: exploration/production decision-making, incl. on reservoirs (mostly expanding the range of digital applications already in use)	Miniaturised fibre optic sensors in production system	Increase overall oil and gas recovery from reservoir
	Automated drilling rigs	Inspect and repair subsea infrastructure
	Robots + drones	Monitor/inspect transmission pipelines, tanks and remote unmanned facilities
	AI	Analysis and processing speed of large unstructured datasets generated by seismic studies, i.a. for enhanced reservoir modelling and adjustment of technically recoverable resources
	Wearables	Real-time monitoring of vital signs and ambient parameters
Management of water resources (including groundwater)	Automated analysis techniques	Chemical composition with location and time information

Annex 2

Draft Terms of Reference for the Task Force on Digitalization in Energy for 2021–2022

I. Background

1. The Task Force on Digitalization in Energy is established by the Committee on Sustainable Energy at its twenty-ninth session on 22-23 September 2020. The mandate of the Digitalization in Energy Task Force is for the period of 2019-2020 with a possibility of extension.

II. Reporting

2. The Task Force on Digitalization in Energy will report to its parent body, Committee on Sustainable Energy, and to the Group of Experts on Energy Efficiency.

III. Objectives

3. The Task Force on Digitalization in Energy has the following key objectives:

A. Provide a platform for cross-industry experts

4. This platform will enable experts from the energy sector and digital innovations to come together and develop a unified voice on digitalisation in energy, which will deliver constructive critique and assessment of opportunities, challenges, risks and trade-offs of digitalising the energy system. This work will place a greater focus of the Group of Experts on this area, by involving experts from the other subsidiary bodies of the Committee on Sustainable Energy as part of the Task Force.

B. Constructive dialogue with digital mind-set

5. Digital technologies are changing the way we live, work and travel. These innovations are expanding the boundaries of information availability, data analytics, and business and policy decision-making. It holds enormous potential to make the energy system more accessible, productive, secure and sustainable, but can also imply several risks and challenges, such as security, privacy and economic disruption that need to be analysed and understood in detail for developing the pathways for digitalisation.

6. This proposed cross-industry Task Force on Digitalization in Energy will bring external experts on a range of frontier digital technologies as well as experts from the other subsidiary bodies of the Committee on Sustainable Energy. The Task Force on Digitalization in Energy aims to encourage embed digitalisation in the work of subsidiary bodies. It will critically explore the landscape of new stakeholders through a constructive dialogue to understand the interaction in the digitalised energy system and bringing consensus about the approach that should be considered for shaping the future of energy system.

C. Shaping policy agenda

7. The goal of the Task Force on Digitalization in Energy will also be aggregating and reviewing the existing national policy initiatives as well as harmonizing the information produced by other key national and international bodies, in order to better assist policymakers

and other stakeholders in ECE region to provide evidence based direction to achieve the higher levels of efficiency in the energy system.

8. The Task Force on Digitalization in Energy will also enable better linkage and collaboration between the different organizations internationally and will encourage the participation of members of the Task Force on Digitalization in Energy in the national level dialogues in different countries. A key output of the Task Force will be to bridge the gap between academic research, industrial innovations and policy needs for different countries.

9. The Task Force on Digitalization in Energy will be guided by recommendations and decisions of the Committee on Sustainable Energy and its subsidiary body Group of Experts on Energy Efficiency and will facilitate the ECE's support towards the achievement of the targets set by international agreements, such as the 2030 Agenda for Sustainable Development, in particular Sustainable Development Goal 7 on affordable, reliable, sustainable and modern energy, and the Paris Climate Agreement. These initiatives stress the importance of digitalisation to achieve high level of energy efficiency to ensure energy security, mitigate greenhouse gas emissions, and ensure access to affordable, reliable, sustainable and modern energy for all.

IV. Planned activities and outputs

10. To achieve its objectives, the Task Force on Digitalization in Energy will undertake the following activities:

(a) Development of an expert platform:

(i) Establish a network of energy digitalisation experts from the ECE member States, relevant international organizations, non-profit bodies, industry and business community, and research and academic organisations.

(ii) Actively encourage increased engagement between the organizations leading energy digitalisation activities to promote improved collaboration and developing shared objectives for the common good.

(b) Development of a resource database:

(i) Through the expert platform, a key focus will be developing a database of relevant resources i.e. reports, case studies, success stories, demonstration projects etc. from different countries.

(ii) The Task Force on Digitalization in Energy working closely with the Groups of Experts will aim to explore the role for digitalization in their work and will prepare a comprehensive list of digital technologies and relevant improvement opportunities.

(iii) The Task Force on Digitalization in Energy will ensure improved access to existing information to policymakers and other stakeholders in ECE region. The Task Force on Digitalization in Energy will also consider organising information sharing/brainstorming sessions on relevant topics of interest.

(c) Development of reports to shape future work:

(i) The Task Force on Digitalization in Energy will develop a roadmap for the next two years and beyond to explore the digitalization challenges and opportunities in the work of the Groups of Experts in this area.

(ii) The Task Force on Digitalization in Energy working closely with Groups of Experts will prioritise the work requirement and deliver at least two reports covering different topics under energy digitalization in line with the activities of the Groups of Experts.

11. All of the abovementioned activities and outputs are subject to regular consultations with the Committee on Sustainable Energy, the Group of Experts on Energy Efficiency, partner organizations, and donors, and might be subject to adaptations.

V. Funding

12. The activities of the Task Force on Digitalization in Energy are supported by in-kind contributions and extra-budgetary funds. The listed activities will be implemented depending upon the availability of funds.

VI. Timetable

13. The mandate of the Task Force on Digitalization in Energy will cover the period of 2021-2022 with a possibility of extension.

VII. Methods of work

14. The Task Force on Digitalization in Energy is expected, subject to availability of funds, to have at least two face-to-face meetings during its mandate and will have at least one online meeting every quarter to keep track of the work progress. The Task Force on Digitalization in Energy will also actively work via various means of electronic communications between meetings. Donors are invited to provide voluntary contributions to support its work.

VIII. Membership

15. The Task Force on Digitalization in Energy will be open to all ECE member States. Other United Nations Member States are also welcome to participate.

16. The Task Force on Digitalization in Energy comprises experts from the Committee on Sustainable Energy, the Group of Experts on Energy Efficiency, other ECE bodies, international organizations, non-governmental organizations, businesses and industries, business/industry associations, start-ups and institutional entrepreneurs, and research and academic bodies. Technical experts from the Group of Experts on Energy Efficiency and external experts working on the intersection of digital and energy will be in particular invited to support the work of the task force by actively contributing their expertise, collaborating with each other and participating in its meetings and activities.

16. The Task Force on Digitalization in Energy will have the Chair elected at an annual session of the Group of Experts on Energy Efficiency for the period of two years.

IX. Secretariat support

17. The secretariat will service meetings of the Task Force on Digitalization in Energy (with interpretation and translation where possible), including the preparation of meeting agendas and reports;

18. Provision of the secretariat support is dependent on the availability of additional resources as described in Section V.