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Attaining carbon neutrality

The role of Information and Communications Technology in enabling high-performance buildings and smart, sustainable cities

Note by the Secretariat

I. Introduction

1. This document opens a discussion at the Group of Experts on Cleaner Electricity Systems and then at the Committee on Sustainable Energy about the implications of advances in the information technology space that is and will be influencing attainment of "energy for sustainable development" by enabling or augmenting capacities for:

(a) Monitoring;

(b) Communicating;

(c) Managing and analyzing data;

(d) Coordinating real-time responses;

(e) Predicting;

(f) Managing systems holistically;

(g) Optimizing cross-sectoral interconnections ;

(h) Managing long-term responses;

(i) Informing complex investment decisions.

2. Key issues for the Group of Experts and thence the Committee are the roles the United Nations Economic Commission for Europe (ECE) should play in accelerating technology uptake or protecting against possible risks by developing and deploying normative instruments such as best practices or standards.

3. A number of expressions describe the spectrum of technologies that are involved in the unfolding megatrend related to information management:

(a) **Digitization** is the process of converting information into digital format to facilitate efficient data gathering, processing, transmission, sharing, storage, and access;

(b) **Digitalization** is the use of digital technology and digitized data to modernise how work is done, transform how stakeholders interact, and enable new business models;

(c) **information and communications technology (ICT)** includes any communication or data management device such as cameras/monitors, microphones, Bluetooth, radio/television, cell phones, computer and network hardware, data storage and management, satellite systems, and associated services and applications. These devices and their applications are changing fundamentally how people, organizations, and even objects interact;

(d) **Smart (city, highways, grid, house, everything)** technology that began with monitoring, analysis, and reporting but now embraces automation;

(e) **Internet of things**: the interconnection via the Internet of devices embedded in everyday objects, enabling them to send or receive data.

Evolving Communications Technology

In terms of communications technology, the digital world is stepping forward to its fifth generation, or 5G. First generation communication technology, introduced in the 1980s, comprised wireless cellular technology based on analogue telecommunications standards. The second generation of mobile networks were digital and allowed multiple users on a single channel. The third generation of wireless mobile telecommunications upgraded for 2.5G and 2.5G GPRS networks for faster data transfer. The fourth generation evolved to use internet protocols for voice data and allows access to broadband level speeds when away from a Wi-Fi network. The 5G network is designed to connect virtually everyone and everything including machines, objects, and devices with higher speeds and more reliability, capacity, and availability.

4. Across its broadest expressions, information technology is evolving rapidly. Artificial intelligence, geospatial data management, automation, and other advances are driving an accelerating technological evolution. Devices in homes, cities, networks, transportation systems, and so forth are becoming ubiquitous, interconnected and smart. Robotics are becoming smarter and mobile (including drones). Advancing technology will enhance system-wide resilience as discovery, correction/adaptation and healing are automated. Conversely, resilience will be tested by newly empowered, disruptive hackers as cyber-security threats.

5. The advances in technology will affect society beyond mere economic and technical efficiency. The impact will be observed at many levels – individual, household, community, urban, regional, national, international – and will reverberate across those many levels. As has been witnessed during the coronavirus pandemic, coordination and connectivity is changing the organisation of daily routines, including work, school, and other activities. The implications of the changes have not played out fully. One’s “tribe” or community is defined increasingly by virtual networks and less by geography, with positive implications for gender and social equality, poverty, work, and the like. The impacts are not all positive, unfortunately, as increased connectivity can lead to invasions of privacy or be characterised by self-segregation into network ghettos of like-minded, malevolent individuals. If the negative risks can be managed, improved performance, efficiency, and transparency are expected to empower new user experiences and to create and connect new industries.

6. In the energy sector the capacity to integrate new actors and new business models will be augmented substantially, including for example intermittent renewables, distributed

generation, and newly empowered consumers and alternative service providers. Embracing automation of price discovery and price response will engender price elasticity in electricity demand. The advances will accelerate changes in business models and players as barriers to entry and exit are lifted and as enormous amounts of actionable information is made available.

7. This document provides a thumbnail overview of ICT in homes, transport, and cities, describes the opportunities, issues, and gaps in ICT for attainment of energy for sustainable development, and sets the stage for a discussion of the role for the ECE in the area.

II. Applications

A. High Performance, Smart buildings

8. Home automation or domotics is building automation for a home, called a smart home or smart house.[1] A home automation system will monitor and control lighting, climate, entertainment systems, and appliances. It may also include home security such as access control and alarm systems. When connected with the Internet, home devices individually and collectively are an important constituent of the internet of things. A home automation system typically connects controlled devices to a central hub or "gateway". Control of the system is accessed either through terminals, tablet or desktop computers, a mobile phone application, or a Web interface that may also be accessible off-site through the Internet. Controls can be automated, with system operations managed considering either internal environment feedback on temperature, humidity, air quality, and the like or external environment information such as environmental quality or market prices. While there are many competing vendors, there are very few worldwide accepted industry standards and the smart home space is heavily fragmented.

9. Building owners and managers can use data analytics, high-tech sensors and the latest technology to monitor and track the internal environment of their buildings and the performance of their systems. Algorithms and machine learning techniques predict issues such as mould growth, allowing preventative intervention before repair costs or health issues escalate. For remote building managers, the technology vastly reduces the amount of property visits, cutting down on carbon emissions, while helping to identify and support vulnerable occupants who may be struggling with fuel poverty. Sensors in properties can be supported with energy efficiency advice, guidance, and programmable controls. The digital evolution can be expected to accelerate as businesses and local and national governments turn increasingly to technological solutions to deal with the long-term health and economic consequences of pandemics such as COVID-19.

10. Real-time remote monitoring of housing provides evidence that energy efficiency projects result in quantifiable benefits to buildings' conditions and both health benefits and financial savings for their occupants. Both affordability and health are improved. Benefits of information technology go well beyond direct cost-savings and include:

(a) Having real-time accurate visibility of building conditions allows for predictive and proactive maintenance interventions by building managers. Proactive actions are typically five times less costly than reactive ones;

(b) Instant access to information means reduced administration, improved communication and fewer, more focused property visits;

(c) Providing access to data means that insurance companies and financial institutions will have more faith in building managers, which can lead to reduced premia;

(d) Working collaboratively, data can inform customers' future home design and system and material procurement;

[1] https://en.wikipedia.org/wiki/Home_automation

(e) Early warning of potential issues means healthier buildings and tenants, which translates further into higher property valuations.

11. Having the right level of heating and ventilation with effective filtering in buildings reduces the risk of disease transmission and the risks of allergies. Viruses spread more easily indoors, and poor ventilation and overcrowding increases the density and build-up of infectious viral particles in a room. Lower temperatures due to inadequate heating or poor insulation are considered to reduce the immunities to viruses. The most significant health gains can be achieved through prevention by using data to understand how to improve the quality of life for occupants. The information gathered can inform owners as to what aspects of their properties are the best performing, such as the most efficient types of boilers or what building types may need to get upgraded first with insulation. Poor environmental conditions cost money and cause health issues: hot dry countries with poor air conditioning can witness virus spread because of low humidity, whereas occupants in wet, mild countries are more prone to respiratory problems.

B. Smart cities[2][3]

12. A smart sustainable city is an innovative city that uses ICTs and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects. It is an urban area that uses different types of electronic internet-connected sensors to collect data to manage assets, resources and services efficiently. As a consequence, operations across the city are improved. Data collected from habitants, devices, buildings and assets are then processed and analyzed to monitor and manage traffic and transportation systems, power plants, utilities, water supply networks, waste, crime detection, information systems, schools, libraries, hospitals, and other community services. ICT is used to enhance quality, performance and interactivity of urban services, to reduce costs and resource consumption and to increase contact between citizens and government. Smart city applications are developed to manage urban flows and allow for real-time responses. A smart city may therefore be more resilient to emerging challenges.

C. Smart grids (electric and gas[4])

13. A smart grid is, in essence, an updated power grid that not only transmits electricity between producers, transmission/distribution networks, and consumers, but also exchanges information between them and eventually with third parties. The principal functional characteristics of a smart grid are:

- Self-healing from power disturbance events
- Enabling active participation by consumers in demand response
- Operating resiliently against physical and cyber attack
- Providing power quality for 21st century needs
- Accommodating all generation and storage options
- Enabling new products, services, and markets
- Optimizing assets and operating efficiently.

14. A smart grid uses digital technology to improve reliability, resiliency, flexibility, and efficiency (both economic and energy) of the electric delivery system. Smart grids depend on the availability of telecommunication capability. Whether focussed upon local, regional or national objectives, most smart grid applications rely on the availability of

[2] http://www.unece.org/housing/sustainablesmartcities.html
[3] https://en.wikipedia.org/wiki/Smart_city
[4] See document ECE/ENERGY/GE.5/2011/2

telecommunications for interconnection of a generating unit, network sensor or smart meter into the power utilities operational processes.

15. Smartening electricity systems can be carried out at a city, national or regional scale, and can also be brought to the level of mini- or micro-grids. Smart grids can be a significant tool used to optimise electricity systems by monitoring and managing electricity flows from generation to demand. The demands of climate change and the 21st century information based society however requires development of a smart grid that can deliver real time monitoring and control.

16. A smart grid is an array of existing and emerging technologies that allows a more decentralized and efficient way of operating the industry, including:

- ***Advanced Metering***. Meters on the bulk system or at customers' locations that can provide hourly price and user information to the system operator, the customer, or directly to devices and appliances
- ***Visualization Technology***. Monitoring devices for system operators (advanced SCADA systems, Phasor Measurement Units, other real-time sensors, communication devices, and cyber-security protections)
- ***Advanced Transmission Technology***. Controllable high voltage direct current lines and other advanced transmission elements that improve the operation of the transmission system
- ***Distributed Generation and Storage Technology***. Under the broadest reading of the term "Smart Grid", certain distributed generation and power storage technologies are included.

17. From a starting point of an existing grid, or a construction of new networks (or extensions of networks), the deployment of smart grid technologies is not a goal in itself – but rather an enabler to the provision of secure, reliable, clean, economic electricity required by end users.

18. As smart grid solutions deploy across the power delivery value chain, there is growth in the points of interconnection with other information networks. As a result the potential threat of cyber-attack to these critical power management systems will build exponentially. It is therefore critical that policies and standards ensure that cyber security is mandated as a central and essential element of smart grid design and operation. A number of international energy organizations address smart grids and standards for smart grid standards.

19. Smart gas meters improve the monitoring of gas use and demand. Smart gas grids go farther by maximizing a gas network's ability to integrate decentralized production of renewable gases and therefore accelerates decarbonization of end-uses (heat, cooking, industrial processes and mobility). It allows connection between complementary energy systems (especially with the power network), and thus increases the development of renewables and the flexibility potential of the whole energy system.

20. A smart gas grid is a digitized gas network that integrates innovative, low cost and smart sensors based on nanotechnology. Data are collected and communicated via a radio network and are processed with data analytics and artificial intelligence. These innovations allow for dynamic monitoring of the network, including local balancing. A smart gas grid has four defined missions:

- Incorporate new information and communication technology
- Improve the efficiency of the gas grid (monitoring performance of systems and components)
- Integrate with electricity, heating, water and telecommunications networks
- Increase the share of "green" gas in the network.

21. With smart gas grids, gas distribution networks become a tool for achieving circular economy objectives as recovered waste is used as a feedstock for the production of green gases that are then injected into the network. Smart gas grids also optimize energy costs at local level through the flexibility that it offers to the electricity grid. In addition, it helps

accommodate intermittently available renewable energy sources such as wind and solar energy in the energy mix, thus facilitating the achievement of greenhouse gas reduction targets.

22. A key component of a smart gas grid is smart pipes, which are based on three key concepts:

- Remote ***surveillance*** of installations detects any malfunctions and ensures the highest quality service possible.
- Remote ***sensing*** helps improve flow reconstruction by combining data from the various meters and sensors at key points in the network. Added benefits include improved response in emergency situations, optimized investments and optimized stocks.
- Remote ***control*** of certain installations – already in place for biomethane injection stations – will help maximize the injection of renewable gases and allow better balancing between supply and demand.

D. Intelligent Transport Systems[5]

23. ICT relating to road transport use often is referred to as Intelligent Transport Systems (ITS). These include a wide range of organisational and technology-based systems that are designed to facilitate the realisation of efficient, seamless transport systems with optimised traffic flows. An ITS is an advanced application that provides innovative services relating to different modes of transport and traffic management and enable users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks.

24. The deployment of ITS provides for the better usage of both existing road networks and available energy while also helping to curb accidents and improve the efficiency of transport as a whole. Intelligent Transport Systems provide state-of-the-art customised devices that can relay real-time information to road users and law enforcement agencies, while also facilitating remote access to pre-paid accounts and electronic payments. Technologies that allow authorities and operators to achieve managed transport networks and more sustainable land mobility generally come under the umbrella of ITS. In-vehicle and roadside ITS include all technologies that improve vehicle and infrastructure safety, enabling smooth and comfortable transportation by making use of specific vehicle functions and interacting with roadside infrastructure and sometimes other vehicles.

III. Opportunities/Issues/Gaps

25. The information management megatrend presents a broad spectrum of opportunities and risks for the energy sector. The opportunities include efficient monitoring of performance and gathering of data throughout value chains and across sectors, complete reporting and sharing of results, short-term operational improvements and responses in real time, and longer-term monitoring of relevant indicators with strategic responses to emerging trends and shaping of infrastructure investment. With improvements in the “intelligence” of systems, the monitoring function leads not only to reactivity, but also to prediction. For example, a smart meter in a home may detect increasing frequency of voltage surges or frequency excursions thereby signalling a need to intervention on a system or a circuit before a major failure occurs. Importantly, there appears to be a growing though not yet realised opportunity to connect the information technology that is penetrating homes, cities, transportation, and energy systems to achieve superior outcomes.

26. Deep transformation of the energy system can mean many things, including smart everything (grids, cities, homes, equipment, the internet of things), enabling decentralisation and distribution generation business models, and enabling customer participation and thereby

[5] http://www.unece.org/fileadmin/DAM/trans/publications/Intelligent_Transport_Systems_for_Sustainable_Mobility.PDF

raising the price elasticity of electricity demand. Wide deployment of information technology and digitalisation of economic sectors represents enormous opportunities if done right and can improve the resilience of the future energy system to external factors (e.g., hacks or other disruptions).

27. Digitalization lies at the heart of ongoing changes in modern society regarding how we live, travel, and do business. In modern economies, without a digital infrastructure there would be no energy production, distribution or use. Questions of security, dependency, privacy and disruption are arising as industrial players and utilities invest in digitalization in a major way. There is little information on the value digital technology provides to the energy industry.

28. Improving energy efficiency in buildings is the single largest opportunity to save resources and address climate change, it also makes good business sense to develop improved building envelopes, insulation, more efficient heating and cooling systems and the like. The transition to sustainable energy consumption requires action on different scales, from installation of equipment in individual buildings to development of infrastructure on district, city and regional levels. Some energy solutions are complementary (e.g., a building can be equipped with different types of energy efficient equipment from lighting to HVAC systems), while other solutions are alternative (e.g., a building can be heated by an individual heating system or connected to a district heating network). In practice, implementation of energy efficiency and renewable energy solutions involves a multitude of stakeholders, from energy consumers and installers to utilities, energy program administrators and government authorities. In this context, effective coordination between the stakeholders based on high quality data is an important success factor. Opportunities lie in the area of smart appliances, smart houses, smart buildings, smart cities, and smart grids, and challenges include the emergence of new business models, managing data, marrying new and old, and technology lock-in. There are clear risks in terms of resilience and cyber-security and, in the early stages, achieving economies of scale.

29. Many countries and cities have started to use big and geo-spatial data for the successful implementation of sustainable energy projects, e.g. for estimating renewable energy potential at a country level, developing city energy infrastructure plans or the identification of energy saving potentials for individual energy consumers. In many countries, multiple demonstration projects showcase modern technology for energy efficient renovation. However, many high technology buildings do not sustain their performance over time as there is poor understanding of the required technical expertise. Further, it is increasingly difficult to achieve consensus among residents on needed investments. This human factor presents a huge challenge in organising renovation of residential multi-apartment buildings in addition to the technological, managerial and financial challenges.

A. Renewables: Digital innovation is essential to improve the integration of renewables

(a) Digitalization blurs the distinction between generation and consumption through smart demand response, increased system flexibility, improved integration of variable renewables, and better management of distributed renewables;

(b) Machine learning improves real-time weather forecasting of VRE generation and siting of wind and solar facilities;

(c) Advanced sensors in wind turbines can extend the lifetime of assets.

B. Access to electricity: It is expected that 650 million people will still be unconnected in 2030

(a) Digitalization can make payments more flexible and enabling remote asset control will be essential, thereby enhancing the contribution of off-grid solutions. Geospatial analyses can underpin policy decisions;

(b) 54% of the population without access would be best served by decentralized renewables (based on a geospatial analysis of grid extension, mini-grids and off-grid systems to determine the least-cost solutions for universal access to electricity).

C. Energy efficiency: Digitalization is central to improve end-use energy efficiency

(a) Transport is becoming smarter and more connected, improving safety and efficiency. Digitalization of trucks and logistics could reduce energy use by 20-25%, for example through platooning, route optimisation, and data sharing across the supply chain. In platooning, connectivity and automation allows a convoy of trucks to safely travel close together to reduce drag and improve fuel efficiency;

(b) In buildings, digitalization could cut energy use by about 10% by using real-time data to improve operational efficiency. Smart thermostats can anticipate the behaviour of occupants (based on past experience) and use real-time weather forecasts to better predict heating and cooling needs. Digital energy services could also allow consumers to become more active participants in the energy system. Currently there are approximately 1 billion households, where 11 billion connected appliances could provide 185 GW of flexibility, totalling about 270 USD billion in avoided electricity infrastructure investment.

D. Digitalisation and Industrial Processes:

(a) Industrial production is undergoing a fundamental transformation in which the physical world of industrial production is merging with the digital world of information technology, the creation of a digitized and interconnected industrial production, also known as cyber-physical systems. The world is just beginning to understand the possibilities;

(b) New state-of-the-art technologies offer increased deployment of renewable energy in manufacturing, reduced carbon emissions, optimized energy-use, heightened productivity and cost savings at an unprecedented scale. Digitalisation of industrial processes will enable self-organisation for both effectiveness and cost-efficiency and will offer greater opportunities for harmonization of industrial processes with operation of the power system;

(c) Increased access to ICT and affordable access to the Internet in least developed countries also will improve the ability to produce customized products cost-effectively due to a higher degree of flexibility;

(d) Another opportunity will be to develop new business models based on data generated during production and use (including customer feedback) through to end of product life (e.g. recycling);

(e) Big Data capabilities could support sustainability, for instance by helping produce relevant statistics that enable better informed decision making as much on economic, environmental or societal issues;

(f) Challenges that will require attention are the adaptation of the work environment and changes in the types of jobs with consequences for society;

(g) Digitalisation offers two distinct opportunities – transformation through retrofitting and leap-frogging by developing countries.

E. Digitalisation and the Developing World

(a) While the developed world is progressing towards digitalisation of existing systems, the reality in the developing world is quite different. Often consumers do not have access to reliable energy services. While there may be a physical connection, the utility offering energy services does not meet necessary standards for reliability;

(b) Half of utilities in the developing world are not solvent and suffer from insufficient cash flow to fund operations. Even if end-users are credit worthy, the utility is not;

(c) Digitalisation offers solutions, but in a very different way from the proposition in the developed countries. For example, digitalisation of billing and payments would facilitate the economic transaction by connecting end-users to the up-stream billing. If the digital system is connected through the substations to the end-users, it will be possible to put in place basic protocols;

(d) A good example of the challenges is found in smart meters – the hardware may be relatively inexpensive, but the software and maintenance are often very costly. The total package then moves out of reach of most consumers in developing countries.

30. There is a need to understand the range of opportunities that wide deployment of information technology represents and the need for an effective deployment strategy. Digitalisation, geosurveys, and resource identification are key areas of opportunity for the renewables industry, and the financing ecosystem for renewables is clearly improving.

31. There is a need to think carefully about how energy services are provided. The discussion always is about electricity, and yet often energy services are provided through access to combustible fuels. Digitalisation will have a positive effect here as well. From the perspective of labor, the transition to smartness may present a risk, and the social implications of a digitalisation strategy need to be understood.

32. Energy access is not equivalent to provision of energy services, and there is a need to reinvent energy as a service industry rather than the commodity industry it has always been. Digitalisation will be an important driver of this trend. As the world moves towards digitalisation, should there be concerns about “fail-safe” approaches (e.g., the risks of hacks or natural climatic events)? What happens to digital strategies in the case of blackouts? Also, will critical rare earths be available in sufficient quantities to support a robust digital strategy?

33. The process of digitalisation brings a number of opportunities to the fore, including sectoral cross-over and sectoral convergence, for example smart grids and electric vehicles. Architects, building contractors, and engineers are perfecting building envelopes – getting the materials and design right and then ensuring perfect construction techniques to reduce building energy requirements to levels that can be met by low- or no-carbon energy sources. Systems professionals deliver heating, ventilation, and air conditioning as well as the range of plug-in loads. Energy suppliers are essential to ensure the no- or low-carbon solutions needed to meet the systems’ needs. The energy can be provided on-site through a distributed energy services model – imagine roof-top solar or on-site storage – or through some sort of network connection. A fourth community delivers on ICT – the information and communications technology that connects a building to its built environment. ICT connects all the parts and allows for system-wide optimization that enables full participation by both consumers and intermittent energy resources. Until now, each of the four communities have been operating as stand-alone contributors. Getting them to act together enables an integrated approach, unlocking the potential of buildings to make the ambitious vision of the 2030 Agenda a reality.

34. In the financial and contracting sector, improvements in ICT can shift risk profiles by improving information quality and transparency, enhancing predictive capabilities, enabling new entrants and new business models, empowering both distributed generation and consumer participation, and increasing price elasticities by automating price discovery and price response (notably in the power sector, thereby flattening price excursions and moderating “fat tails[6]”). All of these outcomes will influence financing and contracting. The

[6] The statistical term ‘fat tails’ refers to probability distributions with relatively high probability of extreme outcomes with an influence on expected future risk.

unfolding trend in block chain technology[7] and its technological support provide additional tools for addressing real-time physical and price exposures.

35. An area of significant opportunity is in wide-area system integration and improvements in generation and consumption efficiencies with benefits for affordability and environmental performance. The improvements include better heat rates, integration of renewables, provision of and valuation of balancing services and grid management, and real-time demand-side participation in energy markets.

36. The coronavirus pandemic has revealed enormous potential for improved sharing of knowledge and experience through on-line platforms. This potential remains underdeveloped as stakeholders try to imitate in a virtual setting what they have experienced in physical settings, whereas improvements in ICT capacities, speeds, and applications are setting the stage for new mechanisms for interactions on teaching, capacity building, knowledge sharing, and negotiation.

IV. Conclusions

37. ICT continues to evolve and the rate of change continues to accelerate. The world remains at the starting gate of its information technology revolution. In its broadest conception, information technology embraces the systems that monitor and collect data, that transmits, stores, shares, and analyses data, and that responds to the fully-vetted information. New business models are emerging and old business models are failing. For the energy system information technology represents an important opportunity to improve significantly total system performance and to reduce waste and resource requirements. In light of these developments, it is recommended that the ECE Committee on Sustainable Energy, through a cross-sectoral task force under the Group of Experts on Cleaner Electricity Systems:

- Monitor and report regularly on developments, opportunities, and challenges
- Share lessons on information technology deployment experiences and opportunities among member States
- Highlight the cross-sectoral opportunities for collaboration across ECE sectoral committees and with other organisations active in these areas
- Discuss the need for and optimal timing of norms and standards for information technology across the full spectrum of applications.

[7] Blockchain technology is a distributed, replicated and shared ledger for managing and recording transactions across multiple participants. Transactions are no longer stored in a central database, but among market participants.