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Unlocking energy efficiency potential through digitalization

Improving Efficiency of Buildings through Digitalization – Policy Recommendations from the Task Force on Digitalization in Energy

Note by the secretariat

Summary

The building sector globally represents over one-third of total final energy consumption. Despite significant increase of energy efficiency in buildings over the last decades, a potential for further improvement remains. Many technologies and solutions to achieve higher energy performance of residential, commercial, and industrial buildings at any stages of their lifecycle (construction, occupancy, or retrofitting) exist, and many of these are enabled by digitalization. Unlocking the energy efficiency potential of buildings through digitalization, however, in many cases requires advancement of relevant policies.

This evidence-based document, developed by the Task Force on Digitalization in Energy, elaborates on the role that application of digital technologies could play to increase energy efficiency in buildings. It aims to raise awareness of policymakers and stakeholders of related benefits, risks, uncertainties, and trade-offs, and contains key recommendations for further consideration by the Group of Experts on Energy Efficiency and the Committee on Sustainable Energy.

I. Introduction

1. Digitalization is often recognized as a priority area of innovation in the energy sector. One of the largest opportunity areas for digitalization is in buildings, where it is argued to have the potential to reduce energy use by as much as 10 per cent globally by 2040 if applied throughout buildings value chain and life cycle. Such an ambition is also premised on certain elements being in place, including:

(a) A customer-centric energy economy. This implies having energy systems that customers not only feel ownership of, but also that help consumers understand their role. Digitalization accelerates the transition of all sectors and systems towards a more customer-centric environment;

(b) A vision towards accelerating achievement of carbon neutrality. The reduction of carbon emissions is a global challenge that is both cross-sectoral and has societal relevance. Energy efficiency is an action priority for national energy transitions for many countries which have led to the adoption of plans to improve the performance of appliances, buildings, and distribution grids. Grid-interactive efficient buildings (GEBs) are excellent exemplars of how the coordination of sensors (comprising Internet of Things, IoT), smart devices, and grid signals can work together to drive energy efficiency in the global building stock;

(c) A newly up-skilled generation of workforce to expand global capacity. The digital transformation will have both advantages and disadvantages for the existing workforce, requiring policy responses in industry, education, training, and re-skilling. Issues of cybersecurity, data protection, and personal privacy are some of the key areas in which specialist, and at times, cross-disciplinary skills are needed for a successful digital transformation. Specifically, talent pool should be broadened in the areas of science, technology, engineering, and mathematics (STEM), and importantly, skills at intersection of different disciplines such as technology and public policy are also highly critical.

2. Within the context of these activities, this discussion paper examines the role of digitalization in buildings and addresses issues that have significant potential to optimize building operations and the overall energy infrastructure while aiming to provide a clear, concise, and balanced view on the matter to policymakers and stakeholders.

3. This paper presents digitalization opportunities and benefits of using big data and advanced analytics to optimize buildings' energy use over a lifetime, discusses issues of consumers' privacy and cybersecurity, elaborates on the role of data centers and their implications to the broader environmental matters, and highlights the increasingly important issue of human capital.

4. Finally, this paper aims to call on the subsidiary bodies of the Committee on Sustainable Energy and other relevant bodies or organizations to join efforts in exploring the benefits and obstacles of digitalization of energy system.

II. Big Data in buildings

5. Globally, there is an ever-increasing growth in data from the building sector, due largely to the huge increase of IoT in buildings and the gathering of information from sources such as control systems, sensors, meters, and wearable devices. There is a significant growth of these devices in the building sector are predicted. Sensor and control technologies are anticipated to save roughly 10% of total energy consumption from the buildings sector by 2050. The data collected through these devices will help provide an increased knowledge of building stock and take proper action towards attainment of many Sustainable Development Goals. Crucially, greater knowledge of buildings' energy use can lead to more accurate policy decisions and implementations.

A. Synergy between energy-related Big Data and Artificial Intelligence techniques

6. Big Data is a huge volume of data gathered from various sources; this data is growing at an exponential rate. Big Data is centred around: (1) Volume (quantity of data), (2) Velocity (generation speed), (3) Variety (numerous types of data), (4) Variability (how much this constantly changes), (5) Veracity (trustworthiness or the accuracy of data), (6) Visualization (how accessible and readable the data is), and (7) Value (being the main purpose of gathering data in the first place, data must be of value).

7. Data analytics is the autonomous or semi-autonomous systematic computational analysis of data or statistics, with four main types: (1) descriptive, (2) diagnostic, (3) predictive, and (4) prescriptive analytics. Data analytics employs the use of highly sophisticated techniques for automated processing and knowledge discovery in order to provide greater insights into the data gathered and, eventually, the state/process described through that data. It also goes further in helping provide predictions that succour reduce energy consumption of buildings and increase the thermal comfort of their occupants.

8. Given the soaring increase of Big Data, the traditional methods of analysing data would take centuries to trawl through. A more advanced approach to this is artificial intelligence (AI). There is a very strong symbiotic relationship between Big Data and AI: the value of Big Data cannot be exploited without AI and AI needs access to a huge volume of data to increase the accuracy of its outputs.

9. AI is an interdisciplinary field of science: AI leverages computers and machines to mimic the decision-making capabilities that typically require human intelligence. The advancement in processing power, cheaper data storage, and availability of massive amount of data has led to unprecedented algorithmic advancements in the field of AI. Machine learning is a branch of AI that allows systems to automatically learn and improve from experience and new data without being explicitly programmed. It consists of a well-known technique Machine Learning (ML), which is typically used on building data to make use of the data gathered. On the other hand, ML is a set of algorithms that are designed to allow the software to "learn" from previous iterations. ML can be majorly divided into three different types: (1) Supervised Learning, (2) Unsupervised Learning, and (3) Reinforcement Learning.[1] Deep learning is a subset of ML inspired from human brain in which artificial neural networks learns from vast amount of data. The algorithms in ML can be widely divided into classical machine learning and deep learning.

B. Legislation, regulation, and standards within the energy context of digitalization in buildings

10. Innovating regulations is critical and requires decisive and, above all, swift action. In this context, the energy consumption of buildings plays an important role; as in other sectors, increasing digitalization can and will provide purposeful support. However, to ensure that digitalization can provide rapid support here – and thus help reduce energy consumption of buildings – technological developments must be accompanied and innovation fostered by regulatory measures. While digitalization can facilitate making buildings more sustainable throughout their entire life cycle (design, construction, operation and maintenance, and

[1] Supervised Learning in short is the provision of training data that the algorithm's uses during the learning process to verify it is functioning properly and producing the right results. Supervised Learning is divided into two main types, regression and classification. Unsupervised Learning works without the benefit of having training data to compare its result to, this is due to the fact that data is typically imperfect and doesn't always have a well formatted structure to make the algorithms job easier to do.
Unsupervised Learning uses clustering, dimensionality reduction and density estimation to trawl through vast quantities of data to provide some meaningful results to aid decision support.
Reinforcement Learning focuses on how certain intelligent agents should perform or act in response to other actions that have taken place, to maximise the notion of a cumulative reward in the process. It is a behaviour-based technique with positive and negative reinforcement.

demolition), standards need to be defined, and legislation as well as regulation need to support approaches to bring digitalization in buildings into practice.

11. More often these are 'least-costs' financial objectives that are pursued during building life cycle, therefore promotion of end-users' interests through application of adequate energy efficiency solutions is required from the legal and regulatory side. As an example, the Energy Efficiency Directive 2012/27/EU [2] encompasses an overview of the national building stock based on statistical sampling; deals with request of current information on final customers' consumption, including, where applicable, load profiles, customer segmentation and geographical location of customers; facilitates implementation of intelligent metering systems and roll out of smart meters, and; focuses to provide information on historical consumption including cumulative data for at least three previous years, detailed data according to the time of use for any day, week, month and year, and these data have to be available to the final customer via the internet or the meter interface.

12. Other examples show that during the pre-construction phase, 3D scanning (e.g., Geographic Information Systems (GIS) positioning of a building) enables to optimize buildings for solar heat gains depending on the climatic zone, as well as to optimize project management and logistics to save resources. During operation and maintenance of a building, digitalization may enable an "active" energy system: among other, this includes active and fully automated control of electricity and heat demand and the switch from self-consumption to grid supply. Buildings can make a significant contribution to balancing the fluctuating supply of renewable energy sources. In this context, e.g., applications of AI may help to predict individual needs, and hence, enable a predictive operation and increase overall energy security along with ensuring integration of renewable energy sources.

13. However, the development and implementation of such digital solutions requires not only regulatory support, but also technical standards. It is important to interconnect corresponding information systems and technologies internally, while they must have a specific interface to the external environment. Hence, corresponding systems should be technically open and not proprietary so that interfaces to operational information systems can be easily developed.

14. It is therefore increasingly important to use modern instruments of innovation policy. In concrete terms, the question is how science and research can cooperate more closely with the building and energy industries in order to quickly and purposefully test digital innovations in the broadest sense and, in particular, to learn from them quickly and to implement applications rapidly. For necessary investments in climate-neutral buildings and digital technologies, investors also urgently need investment security. Due to the importance for society, the development of non-proprietary, scalable, and expandable concepts is a sovereign, political task that should be addressed with priority.

III. Mapping digital technologies and opportunities

A. Digital technologies in materials, products, structures, and in engineering systems

15. The buildings' construction sector (including both pre-construction and construction phases) is changing significantly and will arguably continue to do so in the future. The reasons for this can be clustered into several categories, as follows:

(a) Increased demand and regulation supporting a lower environmental impact (while governments increase energy efficiency and introduce more strict emissions targets, clients are more concerned on the environmental impact of construction and operation phases of their buildings);

(b) Changes in building demand preferences, especially in post-COVID-19 period (clients, both individuals and businesses, demand more complex buildings, designed to be

[2] Available from the EUR-Lex website (www.eur-lex.europa.eu)

connected, as consumers' focus changes from the product itself to the usage of its features; ultimately, COVID-19 determined numerous changes in the labour market and will alter the demand for individual buildings in the coming years);

(c) Increased technological potential (new technologies, including sensors and complex hardware-software integrated solutions, create new possibilities to be adopted during the construction phase and in the operation of buildings);

(d) New professional skills (companies in the construction sector recruit trained professionals, who possess skills in digital processes).

16. In this context, digital technologies and processes will define the materials, products, structures, as well as the engineering systems involved in the overall building life cycle: from pre-construction of building, through construction and operation and maintenance, and towards its demolition.

17. A critical component of this transformation is given by an up to 6D building information modelling (BIM), where 3D is the shared information model, 4D is construction sequencing, 5D is cost, and 6D is projects' lifecycle information (including assessments of energy efficiency). This process provides buildings' developers the tools and data for highly efficient planning and design operations, construction, and operating activities. Moreover, inspection and maintenance are addressed in the extended BIM ecosystem, by providing long-term schedules and asset management tools. BIM processes can be used both on new-build constructions, as well as refurbished ones, for this reason being also considered a vector for innovation and sustainable growth.

18. Additionally, an increasingly adopted tool used both in pre-construction and construction, as well as in the operation and maintenance phases, is represented by digital twins – a virtual clone-representation of a physical asset, which represents its real-time digital counterpart, throughout the entire life-cycle. The technology provides data and information, while unlocking numerous tools for buildings developers and operators, by helping the creation of more effective asset designs, supporting the project execution phase or by assisting operation and maintenance. While implementation of digital twin technologies even from pre-construction phase proves beneficial, retrospective models can also be developed, provided that real-time data for a built asset is available, which increases the need for deploying sensors in buildings.

19. Digital technologies and processes will also influence the building materials and products sector. For instance, although 3D printing in constructions is still a niche, it has a solid potential for significant changes. Among the advantages of 3D printing are a highly-efficient use of construction materials (almost no waste result from the building process), and higher operation efficiency and operational expenditure (OPEX) reduction (3D printers can work continuously, thus constructions can be completed faster, while also reducing some costs associated to labour). Reduction of OPEX by digital technologies in buildings can be achieved also during maintenance and operation phase. For example, national-level legislation and regulation on the mandatory energy audits in several European countries led to the development of software that utilises Big Data to identify and assess prospective energy efficiency options. Energy performance labelling is also done through digital means and specifically developed software.

B. Digital technologies for buildings

20. For tackling the challenge of an increasing share of renewable energy sources, e.g., the short-term balancing of energy supply and demand, it is necessary to activate the potential of smart buildings. That means to integrate millions of decentralized consumption and generation units and devices within buildings into an energy system as active market players. Vertical integration ranges from electric vehicles, heat pumps, and electrolysers for system services to the participation of decentralized units such as photovoltaic (PV) home storage in local, regional, or national electricity trading markets. Digital technologies can be leveraged to improve buildings' efficiency in several phases of the building life cycle by facilitating the development of distributed energy resources, such as household solar PV panels and storage,

by creating better incentives and making it easier for producers to store and sell surplus electricity and heat to the grid.

21. With respect to system-wide resource optimization, tools like Advanced Distribution Management Systems (ADMs), Distributed Energy Resource Management Systems (DERMS), and microgrid controllers are argued to be proved solutions with significant prospects. As a result, one of the fundamental barriers to integration of distributed energy resources (DER) still seems to be the issue of vetting and sharing key information about DER attributes, capabilities, relationships, and behaviours that allow 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 various products, and manage risks, grid operators need to qualify and register every asset that provides services to the electricity grid. Dynamic onboarding and dynamic status information in real-time remain the key problems: any device that wants to participate in a given electricity market has to establish first a secure digital identity to coordinate with other systems and participants.

22. It is necessary that units within buildings as well as their associated rights are verified electronically in real time to ensure transaction cost minimization and secure and dynamic interaction. Digital personal and machine identities thus become an important linchpin in the context of energy-efficient and smart buildings. The goal of energy economy including smart buildings is for decentralized units to be able to switch sovereignly and dynamically between self-consumption, system services and trading markets: the more participants and the more frequent the interactions are (i.e., the larger and more liquid the markets), the more efficient, cost-effective, and environmentally-sound the energy system is.

23. Decentralized units will contribute to a higher utilization of the electricity grids by providing system services. The flexibility potentials of buildings in low voltage grids must therefore be raised and further developed through real-time capable and resilient digitization concepts in the sense of reactive grid management. Overall, the integration of devices "behind" the existing metering systems requires a flexible and learning regulatory framework, as does their approval for the competitive electricity trading markets. The key step in this context are digital identities, allowing each decentralized unit to interact with energy grid and participate in energy market.

C. Smart energy production and share by prosumers

24. Smart grids have been generally defined as energy networks that can automatically monitor energy flows and adjust to changes in energy supply and demand accordingly. The digital technology that allows for two-way communication between the utility and its digitalized customers, and the sensing along the transmission and distribution lines is what makes the grid smart. Incorporating advanced controls, such energy systems can quickly react and adapt to changes in energy supply and demand, while maintaining a steady balance between the two. Therefore, it provides operational flexibility and dynamic response to load requirements.

25. Smart generation, often with DER, are mostly located in buildings or their vicinity and being small in scale are easy to permit and locate near load thus reducing the required infrastructure. DER typically refers to small, geographically dispersed generation resources, such as solar, wind, or combined heat and power, installed and operated on the distribution system at voltage levels below the typical bulk electric system levels operated at 100 kV and above.

26. Active energy consumers in buildings, often referred to as 'prosumers', produce and consume electric and thermal energy thus blurring the lines between the two roles. The shift from consumers to prosumers is made possible, in part, due to the rise of new connected technologies and the steady increase of more locally controlled resources such as solar, wind and electric vehicles with bi-directional charging connected onto electric grids. Various types of prosumers exist from residential prosumers who produce electricity or thermal energy at home, to citizen-led energy associations, to commercial prosumers whose main business activity is not electricity or thermal energy production, and to public institutions like schools or hospitals. As their diffusion is still ongoing, DER currently tend to distribute unevenly

across prosumers/buildings, which may temporally limit the exploitation of their full potential.

27. Smart buildings could act as connected microgrids easily playing a role in demand management and other activities by, e.g., isolating themselves from the grid during peak periods, blackouts, or cyber-attacks. Such smart buildings, if acting in a coordinated manner with the grid operator, would also then play a role in making the grid smarter and more resilient. Energy-intensive commercial and industrial buildings can also be demand side response (DSR) participants. They can increase or decrease their power consumption based on the grid requirement and provide immediate support in rebalancing the grid and prevent blackouts and other severe faults. Storage technologies are also critical for larger uptake of renewables in building sector as it can optimize energy cost while maintain comfort by enabling load shifting. Vehicle-to-grid technology (V2G) has also a massive potential to help manage the grid during peak hours and buildings could play a critical role in electric vehicles charging services and facilitating vehicle-grid integration.

28. Integration of smart generation, smart grid, storage, electric vehicles technologies, consumers and prosumers, and other technologies as well as stakeholders will transform the overall electricity and thermal energy system and challenge the traditional business model of the energy utilities. It will, however, come with new system security requirements and individual privacy risks. It then will be important that this transformation integrates relevant and robust preventive and corrective measures, including cyber security, as part of its fundamental principles in design, engineering, and operations.

IV. Security and privacy issues

29. Security in the operations of buildings plays a critical role not only on a physical level, but also on a digital level. This means that security is not only important for those who live or work in the buildings, but also for those who own the buildings, who run the systems connected to these buildings, and who process and use the data generated by these systems. Important concepts for security from a digital point of view are data security (including cybersecurity, information security, and data privacy).

30. Data security consists of cybersecurity and information security. Data privacy is one aspect of the latter. Cybersecurity is also known as ‘IT-security’ and concerns protecting computers, servers, mobile devices, etc. from malicious attacks, that is, from being hacked. Cybersecurity is essential for data security, as malicious attacks can i.a. aim at penetrating a system to gain unauthorized access to data. In general, data security concerns protecting data from unauthorized access, malicious attacks, and exploitation. Another aspect of data security is information security, which concerns protecting people and companies against the unauthorized use of information (confidentiality), making sure that information is available when required (availability), and ensuring that information is correct (integrity). Both data and information security are prerequisites for yet another important aspect of the digital age: data privacy.

31. Data privacy concerns the individual’s right to control how personal information is collected and used. For example, in Europe, laws concerning data privacy are captured in the General Data Protection Regulation (GDPR);[3] in the United States, including in particular in California, it is the California Consumer Privacy Act (CCPA).[4] Both regulations aim at making digital experiences more secure, by requiring companies to, e.g., specify what data is processed, to define the purpose of data processing and to allow customers to opt-out.

A. Privacy and security preserving techniques

32. An important question is how, in the context of buildings, cybersecurity, data security, information security and data privacy can be taken into account, so that the risk of data

[3] Available from the EUR-Lex website (www.eur-lex.europa.eu)
[4] Available from the California Legislative Information website (www.leginfo.legislature.ca.gov)

breaches and misuse of data is minimized. One important factor for companies to achieve this is to implement security by design. This means that security is already considered when designing the building and its information and communications technologies (ICT) systems. For example, when residents plan to send internet signals through electricity cables, each apartment should have its own circuit or other security measures, so that signals cannot be accessed from other apartments.

33. Continuous security testing should be part of the development process of ICT systems for buildings. This way, security issues can be resolved sooner and potentially quicker. Also, learning from such issues helps to create more secure systems in the future. This can include code reviews and automated penetration tests. A penetration test is a simulated attack on a computer system to be able to evaluate the security of this system. Such penetration tests should be performed at the latest just before using the system.

34. One important factor for companies to achieve minimized risk of data breaches and misuse of data in the context of information security is to implement specific policies containing regulations on, e.g., passwords, physical access to buildings, encryption, social media usage, backups, and data privacy. When such policies are defined, audits should be performed to ensure they are implemented. Such audits can, for example, be done in the context of the Information Security Management (ISO-27001) certification.[5]

B. Security and data leak implications

35. The importance of cybersecurity and data security in the context of buildings becomes clear when looking at possible implications when they are not taken into account. Not considering data security may allow attackers, for example, to obtain energy usage data thus enabling investigation of when residents are away from home and planning of a subsequent physical attack.

36. This scenario can happen when cybersecurity is neglected, for example, when hackers obtain access to energy data through a security breach in the application that controls energy supplies. It can also happen when information security is neglected, for example, when employees get unauthorized access to this application. It can also happen when data privacy is neglected, for example, when this data is captured and processed although residents did not give permission to gather this data. These examples show that implications reach much further than the digital world and may cause physical harm, too. In fact, in an extreme event, it may threaten energy security at large: when attackers would be able to massively increase the energy usage of each building, energy system may fail (so-called Denial-of-Service attack).

V. Role of data centres and implications

37. Data centres are the key element of the overall digital infrastructure and there is an increasing need of data centres for data processing and storage to support smart technologies rollout in the buildings sector. A data centre is a dedicated building or a separated room, which houses the technology for data processing, data storage, and data communication of one or more organizations. This space is exclusively used for the placement of information technology (IT) hardware and the necessary power and cooling infrastructure. Data centres operate based on two main types of assets: (1) the physical infrastructure, i.e. building and equipment, and (2) the service offerings, i.e. storage, management and maintenance, and security of data. The digitalized economy is built upon data and internet connectivity. Data centres are a fundamental part of digital infrastructure supporting data growth generated by many activities across the public and private sectors.

38. Data centres are very energy-intensive buildings that require 10 to 100 times more electricity per floor space area than other commercial building types. It is estimated that data centres account for about 1 to 1.5 per cent of the total energy use worldwide, corresponding

[5] Available from the International Organization for Standardization website (www.iso.org)

to approximately 200 TWh of electricity. Comparing to the volume of data increased in the last decade, energy consumption of data centres worldwide increased modestly due to the application of energy efficiency measures. Whereas energy use increased by 6 per cent in the period 2010 to 2018, the number of computing instances in data centres increased by 550 per cent. On the other hand, in terms of emissions, data centres contribute around 0.3 per cent to overall carbon emissions, whereas ICT ecosystem as a whole reportedly accounts for more than 2 per cent of global emissions. Exemplarily, this puts carbon footprint of ICT on a par with emissions from fuel consumption by aviation industry.

39. Apart from the high energy demand and sustainability concerns, data centres are also a resource for generating surplus heat. Waste heat produced by the data centres' operations can be captured and utilized in district heating networks or by nearby customers and thus increase energy savings and improve efficiency of the overall system. The development of new modern energy supply technologies comes to the synergy of district heating and cooling, electricity, renewable and waste energy integrated smart energy system, which also requires an 'energy smart' or 'digitalized buildings' as end-users. These would be able to decide which kind of energy is available on the market and to select to use it. By these means the consumers will consume most economically attractive energy, while overall district energy grid might become better balanced.

40. Most adopted metric for assessing data centre sustainability performance is the power usage effectiveness (PUE), which measures the ratio between the power used by the IT equipment and the power delivered to the data centre. There are a number newly developed metrics, which look beyond the energy use and examine the carbon aspect and water resource used for data centre operations, namely carbon usage effectiveness (CUE) and water usage effectiveness (WUE) respectively. These metrics focus on energy efficiency and renewable energy, including not only IT system but also energy source for cooling and power. However, these measures and metrics mainly focus on the energy side, but ignore any damages caused by data centres to ecosystems, human health, and natural resources. Additionally, most of the assessment are designed for monitoring data centre operations, but overlook potential environmental impact stemming from construction, transport, and end-of-life of different components of data centres.

41. During the operation stage, data centre energy efficiency potentials primarily exist in IT equipment, cooling system, and power delivery system. Such energy efficiency solutions include consolidation of servers, replacing chips and servers to gain operational efficiency, utilizing heat from servers for district heating, using air and water-based free cooling, shifting to hyperscale systems, cooling servers with isolating materials, and drawing on AI for regulating data centre's cooling system. Besides energy efficiency solutions, hyperscale data centre operators also investigate the potential decarbonization contribution from renewable energy supplies to power data centre operations through PV or wind turbines. A critical factor needs to be brought into attention when looking to increase use of renewables for data centre power supply, which is the location selection of a data centre. Key factors to be considered are, for instance, the renewable energy content of the energy supply, the stability of the power grid, and the average annual ambient temperature.

42. Worth noting that the environmental impacts deriving from the pre- and post-operation stages of the data centre are as significant as the impacts stemming from the operations. For example, the equipment in data centres require materials extraction, manufacturing, and disposal of large amount of metals. These processes can lead to material shortage and potential metal pollution that may in turn cause damage to ecosystems and human health. If improving energy efficiency through hardware replacement in a frequent way remains the focus, energy saving and decrease of carbon emissions during the operation stage may be achieved; in the longer term, however, this will lead to increased material consumption and related pollution. To avoid burden shifting from one stage of data centre life cycle to another, either improvement of materials efficiency during equipment manufacturing or enhancement of material reuse and recycling at the end-of-life of the equipment should be considered.

43. Finally, to ensure data centre energy use is monitored effectively and efficiently through its entire life cycle stages, much higher public data and modelling competencies are

required. To develop and evaluate evidence-based policies, national policymakers should appoint robust data collection and open data repository systems.

VI. Improving human capital

44. Energy efficiency is one of the key vectors in both achieving climate targets and generating economic recovery. This is labour-intensive sector that entails significant job opportunities. Energy efficiency jobs grow at a rapid rate, and additional job opportunities requiring ICT skills for improving energy efficiency in buildings (including, but not limited to) will arguably emerge. The refurbishment or development of new buildings will call for ICT specialists to operate BIM processes. ICT skills are also needed when deploying, securely operating, and maintaining digital technologies in buildings (e.g. sensors, IoT, energy management, AI, predictive maintenance, etc.). Additionally, an important share of these new jobs will require specialized ICT skill sets (e.g. cybersecurity, big data analysis, coding, etc.), which are indispensable for specialists to design and implement appropriate and secure systems. Furthermore, big data collected from buildings will also need be processed, assessed, and interpreted, to be able to understand the needs of customers and design new products and services. This will create new markets and will continue to generate additional work demand.

45. A prolonged market gap in availability and requirement of digital skills for the buildings industry is visible. While many factors contribute to this, the main is identified as the typical inertia of adopting digital processes and technologies in the energy sector. Moreover, the change in consumers' behaviour and lifestyle and energy consumptions, partly caused by the COVID-19 pandemic, as well as concentrated efforts to invest in energy efficiency measures due to pressing environmental challenges will determine an even higher demand for digital talent in the energy sector.

46. While investing in capacity-building of existing workforce is critical, developing the future-ready workforce also cannot be denied. Collective capacity-building activities on ICT technologies are required for reskilling the existing workforce and formal ICT education in primary, secondary, and tertiary education are required to train the future workforce. Increase in the learning opportunities at multiple levels will contribute to the local retention of ICT talent, which can be eventually acquired by the building energy efficiency solution providers and a broader energy sector. To achieve that, public-private partnership on skill building may be needed, as private entities could provide forecasts on the workforce, understanding on skills needed, and training sessions and contributions to the curriculum.

VII. Conclusions and Policy Recommendations

47. Taking the above into account, the Task Force on Digitalization on Energy[6] considers appropriate to set forward the following key conclusions and policy recommendations:

(a) Closer collaboration and consensus building. Building sector is highly complex, with many stakeholders and different values and priorities. A closer collaboration will be key to leverage the full potential of digital technologies in creating sustainable buildings. Information sharing and consensus building between building energy professionals and digital specialists is critical to enable the progress towards the adoption of sustainable practices in buildings;

(b) Strong role of technical standards and mandate for implementation process. Technical standards have far-reaching environmental, economic, and social consequences. Digital technologies to be integrated into buildings at any stage of their life cycle (pre-construction, construction, operation and maintenance, and demolition) must be accompanied by stringent technical standards and a strong mandate for its implementation to ensure its efficacy and efficiency in the long-term. The technical standards of digital technologies incorporated into buildings will also help alter the balance between the interest

[6] See: https://unece.org/sustainable-energyenergy-efficiency/digitalization-energy

of competing businesses and priorities of national governments. It is also important to note that not just product technical standards, but also how the product communicates with other devices in the building, and the standards behind that, are also important;

(c) Supportive and protective regulation. ICT technologies are evolving at a very fast pace. Supportive regulations are required to enable the digital investments into the building sector and rapid implementation of ICT technologies. These digital technologies also come with lot of volatilities and uncertainties and clear legal and regulatory measures will be required at the local, national, and international level to protect individuals, organizations, as well as the overall infrastructure of the building sector;

(d) Facilitate science and research. The role of building sector is critical for ambition of a low- or zero-carbon economy. National innovation policies need to consider building sector innovation on priority and facilitate science and research to cooperate more closely with building and energy industries as well as ICT professionals operating in that space. Piloting digital innovations and its rapid iterative testing, through regulatory sandboxes or pilot projects, is fundamental for the scalable implementation and therefore supportive innovation polices could be a game changer for sustainable buildings;

(e) Security and privacy considerations. With customer-centric digital innovation, the traditional business model of utilities is at risk and, as a result, utilities are exploring and testing a range of business models to tackle the building energy sector challenges and meeting customer demands. However, the new way of doing businesses and a greater interaction of multiple stakeholders into the system comes with new security issues and privacy risks. Robust preventive and corrective measures must be planned through national polices and regulations to avoid any extreme event and endangering individuals, organizations, or infrastructure;

(f) Sustainability of data centres. While integrating digital technologies into the building sector, ensuring the efficiency and sustainability of data centres cannot be compromised. Strategies and policies on consolidation of servers, improving their operational efficiency, utilizing waste heat for district heating, renewable energy based cooling systems, intelligent cooling control system, and increasing use of renewable energy for power supply are needed to be considered to avoid any rebound effects. Robust energy and emissions data collection from data centres and its public availability is also critical and will help develop relevant national strategies;

(g) National digital talent strategy. There is a significant shortage of digital literacy and skill sets, and full advantage of digital technologies cannot be harnessed until a national digital talent strategy, which considers both training of future workforce and re-training of the existing workforce, is developed. The scope of developing digital talent with the potential in the building sector in mind must be focused on improving sustainability of buildings, increasing new job opportunities, and minimizing risks and unintended consequences due to a higher integration of digital technologies;

(h) Open, accessible, high quality data. A solid data foundation can help to improve the understanding of decision processes in the building sector (construction, operation, maintenance and deconstruction), increase transparency (e.g. of resource demand, energy consumption, efficiency standards among others), and allow for the use of new methods (AI/ML) to, eventually, inform policymakers and industry leaders taking the most impactful decisions towards the decarbonisation of the building sector.