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Digitalization: Accelerating the Electricity System Transformation. Joint Paper by the Task Force on Digitalization in Energy of the Group of Experts on Energy Efficiency and the Group of Experts on Cleaner Electricity Systems

Summary

Digital solutions enable advances in connectivity, data, and analytics, and can greatly increase overall efficiency of energy system and facilitate achievement of Sustainable Development Goals. Digital innovations offer new ways of addressing challenges in the overall energy delivery process, in addition to energy efficiency specifically, and of finding exceptional ways to address them.

The present document was prepared pursuant to the Work Plans for 2022-2023 of the Group of Experts on Energy Efficiency (ECE/ENERGY/2021/10) and of the Group of Experts on Cleaner Electricity Systems (ECE/ENERGY/2021/8) that mandate these Groups of Experts to jointly explore opportunities and side-effects of digitalizing electricity systems, with a focus on system efficiency, innovative business models, and effective policymaking. This work was conducted under the dedicated Task Force on Digitalization in Energy (hosted by the Group of Experts on Energy Efficiency), which serves as an umbrella for the subsidiary bodies of the Committee on Sustainable Energy to conduct relevant research and assess sectoral opportunities and challenges.

The document discusses opportunities and benefits of digitalizing electricity systems, maps stakeholders involved, and outlines challenges for consideration by public authorities, private sector actors, and end-users. It concludes with recommendations on policies to accelerate electricity systems transformation through digitalization, to achieve higher levels of efficiency while ensuring security and sustainability. The document also contains results of a survey launched to acquire expert-level insights on challenges and opportunities of digitalizing energy systems across geographies.

1.0 Supply-side Considerations of Digitalizing Electricity Systems

The global share of electricity for final energy consumption increased from 15 per cent in 2000 to 20 per cent today. By 2040, it is expected to grow to 24 per cent if countries stay on their present course, and it may reach 31 per cent if countries embrace efficient electrification of a range of energy uses[1,2]. Digital technologies, as a means to coordinate, analyse and interpret increasing quantities of energy system data, user preferences, and system requirements, may facilitate the complex system-level optimization of decentralized energy,

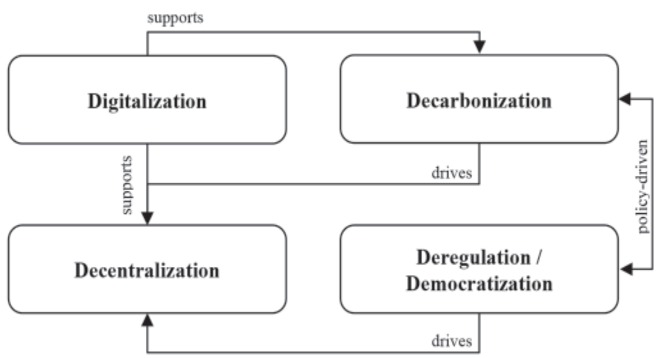

Figure 1: 4D framework in the energy sector

and will be at the core of multi-sector electrification. In electrified energy systems, digitalization will ensure overall net benefits to the system and its participants and will enable progress toward continuous energy efficiency improvements.

Digitalization increasingly becomes an essential, integral part of energy policies. Its role for the energy sector can be summarized using a "4D framework" (Figure 1): digitalization, decentralization, deregulation/democratization, and decarbonization.

Reduction of carbon footprint of the energy sector and environmental impacts resulting from the production, transport, and use of energy, is pursued in part through policies that foster decentralized generation based on renewable energy sources as well as deregulation and unbundling efforts. This often results in a spatial and temporal decoupling of energy supply and generation sources. Digital technologies, as a means to coordinate, analyse and interpret increasing quantities of energy system data, user preferences and system requirements, may facilitate the complex system-level optimization of a decentralized energy sector. For example, data and its effective use will be critical in further enhancing forecasting of variable energy resources (e.g., wind, solar). New technology solutions can also help optimize the storage of these energy resources to help ensure energy delivery during extreme weather events like heat waves and wildfires, among others. By increasing automation and transparency of processes and resource use, digitalization can support the reduction of the carbon footprint of the energy sector by identifying and addressing inefficiencies.

Tapping the full potential of digitalization in the energy sector requires a robust, fully developed information and communications technology (ICT) backbone, as well as widely available access to mobile and fixed network infrastructure. Open challenges related to electricity and resource demand from digitalization, as well as data privacy, cyber security or complexity of automated decisions, remain largely unsolved and require immediate and sustainable solutions[3,4]. Further, digitalization requires the application of robust cyber security controls within the planning stages to ensure a high level of cyber security, and reduction of potential vulnerabilities.

2.0 Stakeholders Involved in Digitalizing Electricity Systems

Digitalization of electricity systems is a complex process with multiple interdependencies across international, governmental, private, and civil sector actors. In general, stakeholders involved in digitalization of electricity systems fall into four larger groups:

(a) International governmental organizations, local and national governments, as well as international organizations;
(b) National and international non-governmental organizations (NGO) fostering social inclusion, digital upskilling, transparency and anti-corruption, or accountability of market participants;
(c) All types of electricity companies and companies of the digital economy, from local to international;
(d) Consumers and prosumers or energy communities (including local).[5,6]

An overview of the different stakeholders, their main interest in influencing digitalization as well as showcases that serve as practical examples of the aforementioned systematization is shown in Table 1.

Mentioned stakeholder groups typically perform influence both vertically and horizontally, to other peer organizations within the same stakeholder layer (horizontal) or beyond (vertical). Recognizing policymaking as a complex process that goes beyond simple schematic representations, vertical and horizontal influences can be performed simultaneously and weaken or reinforce each other, especially as in a multilateral world.

3.0 Opportunities and Benefits of Digitalizing the Electricity System

Digital technologies offer an array of opportunities to benefit electricity consumers, prosumers, energy suppliers, grid managers and the system as a whole, including improved efficiency, cost savings and better reliability, improved energy system resilience and energy security. Furthermore, they support the accelerated transition to clean energy resources. Connected devices via Internet of Things (IoT), together with the possibilities of data science techniques such as with Artificial Intelligence (AI) and Machine Learning (ML), blockchain, and other technologies, can unlock larger demand response resources, offer new and innovative grid flexibility solutions to handle increased variability and uncertainty, improve energy efficiency, and facilitate the integration of higher shares of variable renewables in a cost-effective, reliable, resilient, and secure manner[8].

Efficiency of the overall electricity system could be significantly improved by introducing real-time measurements coming from a more digitalized grid, presenting opportunities for enhanced grid operations. Specifically:

(a) Decision-making based on real-time data rather than static models. This includes using the real-time data for enhanced operator decision-making, situational awareness, asset management, and reliability study analytics;

Table 1: Stakeholders of the digitalization process, with relevance for the energy sector

Stakeholder	Main interests	Showcase[7]
International organizations, governmental organizations	Fairness, equality, and equity of digital solutions available around the world; consumer and business protection; articulation, consideration, and protection of common interests of members; alignment of national frameworks to the common international viewpoint (including standardization and interoperability); consensus- building.	Internet Governance Forum (IGF), a multi-stakeholder forum with annual meetings on regulation of the Internet.
National and regional governments	Protecting overarching national or regional interests; national security; consumer and business protection; alignment of international frameworks to national viewpoint.	A countrywide Energy Digitalization Strategy that sets out a vision and suite of policies to digitalize the energy system, are in place in the United Kingdom of Great Britain and Northern Ireland, developed by the Government and the energy regulator.
International, national and regional NGO	Articulation, consideration, and protection of group interests; consensus-building.	Algorithm Watch, a Swiss/German non- profit research and advocacy organization, watches, unpacks and analyses automated decision-making systems and their impact on society.
Electricity companies	Maintaining profitability and revenue generation; reliability; quality of service and consumer satisfaction; regulatory compliance.	Iberdrola, a Spanish energy company, uses MeteoFlow system to predict production of the company's renewable facilities by analysing meteorological variations using Big Data analytics techniques.
Digital economy companies	Profitability and revenue generation; product development; reliability; quality of service and consumer satisfaction; regulatory compliance.	Google, a major owner of data centres, plans to decarbonize its electricity supply by 2030 by operating twenty- four-seven on carbon-free, inexpensive energy.

(b) Grid optimization and aggregation made possible through even smarter real-time load balancing and network controls, enabled by connected devices and advanced monitoring capability, on one hand, and dynamic grid tariffs, on the other, will allow for dispatch of most economic and sustainable sources to meet demand at any time[9];

(c) Grid flexibility giving the ability to manage a highly variable and uncertain grid through better access to possible resources (particularly on the demand side). Leveraging flexible capabilities of electric vehicles (EV) and of the Internet connectivity of many electric and electronic assets in the field that could provide grid relief during times of heightened reliability risk (stressed conditions);

(d) Remote monitoring:

(i) Of the grid assets – provides network operators better knowledge of the status of assets, both in real-time and throughout the life cycle, optimizing operations. The enhanced level of information brings operations closer to optimal conditions and network capabilities, improving energy flow management, lowering loss rates, etc. Ultimately, this leads to more persistently reliable operation of the grid;

(ii) Of both grid and technological assets – coupled with remote maintenance and operation, leads to better knowledge of the entire chain, better understanding of the cause of an outage and quicker intervention resulting in shorter restoration time. The availability and sharing of data, could also lead to better visibility and awareness of the grid and surrounding grids, allowing grid operators to take better actions to avoid cascading effects. This also has the potential to reduce future investments by using the current assets to their technical limits (reducing the margins).

(e) Energy suppliers will be able to receive the latest use information from customers, while customers will receive up-to-the-minute pricing signals and tariffs. This can lead to real-time energy pricing. Local energy markets can be easily created, increasing local consumption of locally produced energy, reducing grid reliance while enabling more choices for an individual, and encouraging higher individual investment in distributed energy resources (DER), including storage[10]. This will also lead to the prosumer mindset where an informed and capable customer can make decisions on participation in grid services and support through connectivity and analytics.

As DER and other non-traditional resources continue to replace traditional industry generation resources, the fuel mix and operational characteristics of the system will change. DER will necessitate changes to how the system is planned and operated, requiring increased visibility into the distribution system, and enhanced coordination across the transmission-distribution interface.

The changing energy landscape is marked by the challenging integration of variable renewable energy sources and an increasing DER share in the energy mix. Both necessitate changes to how the system is planned and operated, treating DER as a flexibility resource. It will also require changes to the tools and models used. Digital innovations can help ensure the modelling and study tools are accurate and valid in the face of these uncertainties.

The impact on the bulk power system (BPS)[11] of DER from a transmission planning and system analysis perspective can be summarized by two key aspects[12]:

(a) Modelling: representing aggregate DER in BPS reliability studies, advancing industry capabilities and expertise with representing DER, developing robust and reasonable data sets for power flow and dynamic simulations;

(b) Studies: improving study techniques, models, and methods to ensure the most stressed operating conditions are chosen for BPS reliability studies, identifying key operating conditions and sensitivities to perform, improving software tools and study capabilities, including AI/ML tools to develop algorithms to account for weather and other environmental conditions, and integrate other data input for improved results and more optimal role of energy assets in a wider system.

With more flexibility in network planning and design, digitalization will enable more "non-wired solutions" – non-traditional transmission and distribution solutions, such as DER, energy efficiency, and demand response along with grid software and controls that defer or replace the need for specific equipment upgrades (e.g., lines, transformers) by reducing load at a substation or circuit level[13].

The digital grid serves and fosters a wider and deeper ecosystem-built environment – comprised smart buildings, smart charging of EV, vehicle-to-grid services, prosumers, grid edge analytics, etc.

In addition to more optimal grid operations and planning, the availability of more dynamic data set from digitalization of the grid, it will be key to build a more flexible and resilient electricity grid. The additional benefits of such data availability and analytics can be considered in two broad categories:

(a) Assets, tools and technology benefits – The operational and commercial benefits for grid operation, asset management, and commodity supply, including:

(i) Enterprise asset management. The physical infrastructure of an electricity company is built on the importance of preserving and protecting its assets. Digitalizing these physical assets enables monitoring and control in such a way that drives efficiencies and optimization in performance and management and creates flexibility to boost resilience. Utilities need to move away from traditional asset management strategies and towards developing comprehensive digital strategies with robust data governance and cybersecurity at their core. Virtual power plants as well as higher competition of energy suppliers are some of the market transformations. Availability of more dynamic data, combined with advanced analytics, will enable more optimal assets management leading to predictive maintenance, as opposed to traditional systematic and conditional maintenance, and to asset sustainment based on real wear of assets, as opposed to systematic replacement;

(ii) Forecasts for demand and meteorological data. The new reality for electric utilities and grid operators (including their efforts towards energy transition, changing demand patterns due to remote working arrangements and to more extreme natural events, etc.) has disrupted utilities' demand forecasts making accurate electricity use more difficult to predict. Now more than ever, smart investments in distributed and remote managed assets (e.g., smart meters) are necessary to deliver value and efficiency. Research in forecasting including the use of AI and Big Data will also be key;

(iii) Exploration of new technology options. Microgrids and control systems, advanced analytics tools and techniques, as well as cloud computing, AI and blockchain solutions are some of the technology investments that Big Data is driving grid operators and energy enterprises to consider in their future planning[14].

(b) Customer benefits – Many of today's energy customers are digital natives and expect innovation from their energy provider, including a tailored touchpoint plan, current use information and options for integrating the in-home smart devices[15]. Utilizing the benefits of Big Data, electricity companies and energy suppliers can gain insights into consumer behaviour to improve customer service and gain accurate insights into customer demands, while protecting data privacy. Energy providers can work more strategically and intelligently to enhance results and drive revenues. Opportunities include two broad categories:

(i) Reduced or eliminated costs. This relates to:
- generation capacity reaction to change in (peak) demand
- transmission and distribution capacity reaction to the change in (peak) demand
- grid adaptation to environmental conditions like extreme natural events
- energy costs related to the change in energy in each time period (off-peak, peak, and high-load hour); clearly, avoided energy costs vary by region and are based on current energy market data
- external costs of greenhouse gas emissions related to the change in energy use in each time period (off-peak, peak, and critical peak), where applicable
- easier and less subject to error metering and invoicing with the use of smart meters.

(ii) Customer engagement strategies (including broader choices related to energy use). Achievement of targets of energy system transformation towards the one embracing a cleaner energy mix should be a customer-centric process. The energy service provider needs to consider the role of the customer that is no longer a passive consumer of energy but as an energy citizen (engaging in energy-related discourse and making conscious decisions related to energy or its certain service) and to build programmes around these new roles:
- EV and energy efficiency programmes – As countries mandate the use of carbon-neutral technologies, and reduction and eventual elimination of fossil- based products, the consumer uptake on incentives for low-carbon and energy- efficient programmes will need to be managed through targeted education campaigns and customer outreach. This is facilitated with the use of machine learning techniques and analytics for customer segmentation, load signal disaggregation, voice responses and customer help applications in addition to relevant infrastructure investment and incentives combined with increased cost of fossil use, for instance via carbon tax. Digitalization can provide deep and lasting impact to the electricity industry, especially with customer-oriented activities. Energy efficiency and energy savings programmes can be designed, deployed, and examined for their empirical impact in a short period of time, especially in comparison with new generation capacities, which can take years to build and commission
- Outage detection and diagnostics – Giving customers the benefit of early warning and accurate estimated restoration times increases customer trust and improves the utility's storm readiness and responsiveness. Improving the access to large data sets increases responsiveness and reliability for all public safety stakeholders. Customers can also support the grid by adapting their behaviour or providing flexibility through local DER. DER programmes would enhance the capability to leverage microgrids or intelligent segmentation/islanding to mitigate or eliminate the impact of outages
- Dynamic pricing programmes – Grid operators have immediate access to their customer and prosumer base and an opportunity for wide-scale deployment of dynamic pricing deployment and tracking as well as integration with emergency load management programmes. This is especially helpful for those customers who are in an energy-burdened area. Grid operators and energy suppliers can incorporate energy savings programmes for critical customers whilst reducing their own operation risk.

In the context of social and economic benefits of digitalization, besides the fact that it will be a contributor to a cleaner electricity system, it is argued that:

(a) Digital transformation could unlock 1.3 trillion US dollars of value for the electricity sector if it embraces digitalization[16];

(b) The percentage of electricity industry profits that are at stake from digital transformation (through value addition and migration) over the next decade is estimated at 45 per cent[17];

(c) In addition to the economic benefits, digitalization will enable customers to play a more active role in the energy market and thus reshape the dynamic of electricity markets, contributing to environmental and social goals;

(d) Digitalizing the electricity system will create a healthy stream of diverse jobs – it will transform existing jobs and create new ones. A new set of skills will be needed to maintain and manage the assets, operate the network and perform the related analytics.

4.0 Challenges of Digitalizing Electricity Systems

While digitalization of the electricity systems comes with numerous opportunities and benefits, the transition also poses considerable challenges, which ought to be considered by the public authorities in charge of incentivizing a higher adoption rate, by private sector actors responsible with deploying and operating them, and by customers.

To manage potential economic, social, or environmental issues derived from adopting digital technologies in the electricity systems, it is important to understand the acceptable pace of the transformation, while also considering the starting point of different electricity systems. Many utility companies are using outdated hardware and software, including data management systems using different software architectures. However, as data integration between different energy system hardware and software is often limited or non-existent, legacy systems are largely isolated from new platforms. At the same time, the investments in digitalization are mainly directed toward new systems and technologies, rather than upgrading old ones[18]. Hence, while some geographies have the economic capacity to implement a faster-paced digitalization process, others may face affordability issues and logistical challenges in their attempt to accelerate the deeper systemic transformation. Therefore, continuous monitoring of the benefits and costs of digitalizing the electricity systems is essential in the attempt to have an equitable approach on potential distributional effects.

As climate policies often steer the energy consumption towards electricity, a significant rise in electricity demand might be expected. Furthermore, societal dependence on electricity will increase, causing the cost of electrical grid failures to be much higher. A more granular measurement and management of electric energy resources and loads at the asset-level, enabled by the digitalization ecosystem, is needed.

However, as data demand has exponentially increased over the last several years, an important element is the increased number of data centres and their intensive electricity consumption. Although data centres are important drivers for deployment of new renewable energy generation capacities (through bilateral power purchase agreements) and even as more attention has been given recently to the data-energy demand nexus, no standardization of sustainable metrics and energy performance of data centres is currently available.

Additionally, an increased need for data storage and processing capacity, as well as other digital technologies in continuously changing energy systems, will require – just like the overall process of energy system transformation – significant volumes of critical materials. Given the current geopolitical context and considering the surge in prices recorded over the past years, the increasing costs of digitalization may discourage decision makers to take decisive and immediate actions towards digitalization. One solution in this area is blockchain that allows for decentralized infrastructure such as, for example, a decentralized energy asset registry that would also increase interoperability, cyber security, and efficiency of complementary energy services. Many blockchains today use a very limited amount of electricity to operate since they rely on a different validation mechanism than the original proof-of-work validation.

Interoperable computing, networking, and storage infrastructure must exist to gather data from multiple energy assets and devices, enabling sharing, analysis, and use of data streams. In doing so, cyber security standards ought to be considered from the design level, to ensure security-proof standards across all systems components. Any investment or research project should explicitly address elements of the technology infrastructure required for successful deployment focusing on real-time data flows, data security, interoperability standards, synchronization, and distribution, while also addressing identity protection and privacy. Open-source solutions should be prioritised to ensure the required interoperability.

Another consequence of current climate policies, already present in many geographies, is the increased penetration of DER and the advent of prosumers. Their numbers will continue to increase in the coming years, raising significant planning challenges for network operators. Moreover, intermittency of DER output (predominantly renewables such as rooftop solar) will also be difficult to manage as the system operators will need to ensure both the well-functioning of the overall network and the prosumers' demand in off-load hours. Thus, the expanding prosumer ecosystem (which includes grid and household storage or energy management) – entirely based on digital technologies and services – will raise challenges for network operators. At the same time, if managed properly, DER can transform from a challenge to a solution, supporting grid flexibility and reducing congestion. This may be further supported with advanced capabilities built into new load resources such as electric vehicles, where large portions of the demand can provide the grid with additional flexibility and essential reliability services if designed to do so. For this reason, individual investment in DER should be facilitated. This includes simplifying the installation process and allowing individuals to participate more actively in local energy markets by streamlining the process of establishing energy communities and other types of microgrids. Such local energy markets can be a valuable source of flexibility, especially if peer-to-peer and community trading is encouraged by legislation and coupled with dynamic grid tariffs as a congestion management tool by grid operators. There are multiple demonstration projects in this domain and a more agile regulatory approach is needed to accelerate scaling of successful pilots.

In the current geopolitical context, the cyber security topic becomes even more prominent. While specific case studies on cyber-attacks on electricity systems exist and lessons should be learned from them, no general and prolonged attacks on critical energy infrastructure have been recorded so far. As systems become more digitalized – thus arguably more vulnerable to security risks – the need for securing system data, as well as ensuring the confidence of users, is vital in ramping up digitalization. This will generate financial cost to protect the system from cyber-attacks as well as to develop professionals in the field. It will also raise the trust aspect between economic and political entities, including in supply chain.

Moreover, even without cyber-attacks, privacy concerns among users are likely to increase. Although, for instance, digitalization will eliminate human interaction with user's data – thus increasing the privacy of personal data – customer sensitivity to sharing their demand data is expected to increase. For these reasons, reinforcing the roles and responsibilities of data management for all the actors involved (e.g., grid operators, energy suppliers, data aggregators, central and local authorities, customers, prosumers, etc.) will play an important role in the years to come.

As in other transformation processes, digitalization raises important social and economic questions related to labour markets, as its penetration will cause current human-intensive activities to reduce their operations resulting in a potential loss of jobs. While some activities will become obsolete, many new economic subsectors will be created in the process. Planning, producing, installing, operating, or maintaining different components of the digitalization ecosystem translates into additional jobs and economic value-added. To offset any potential job losses, consistent upskilling and reskilling programmes must be developed in advance of deploying digitalized ecosystems. Importantly, digitalization will also increase market inclusivity and provide many marginalised groups of society with new opportunities.

5.0 Conclusions and Recommendations on Public Policies to Realize the Full Benefits of Electricity Systems Digitalization

Understanding the opportunities of digitalizing the electricity systems, as well as identifying the measures to offset or decrease the risks of implementation, are key to unlocking the full potential of digitalization and its contribution to transforming the electricity system.

Creating favourable regulatory frameworks and providing core infrastructure (e.g., smart meters) to support new or improved business models focused on digitalization of the electricity system will be an important priority for stakeholders. Fostering public awareness of the benefits of services offered by such digitalization and further engaging individuals within the energy market should also be a key step in creating a sustainable, long-term digital culture among customers, business owners, and decision makers. In the short-term, public awareness campaigns – driven mostly by think tanks, NGO, and businesses – can spark interest and drive action among current customers (whether households or industrial consumers) to adapt their behaviour and consider a more active role as a prosumer or consumer in a microgrid or local energy market. In parallel, for short- and medium-term impact, reskilling and upskilling campaigns and trainings are needed for current professionals to capitalize on the increased level of digitalization in the electricity grids and to reduce the social and economic impact on the labour markets. Finally, shaping the current academic curriculum – for technical, social, or economic students – to address the intersection between digital technologies, energy systems, and sustainable development goals will generate a long-lasting effect.

Including customers and civil society, business operators, central authorities, and local decision makers is critical in the digitalization process of the electricity systems. In this context, both opportunities and challenges can be exhaustively assessed, as stakeholders are impacted differently by potential public policies. Moreover, decisions taken with a wide participation of all types of stakeholders will result in a timely development of strategies, execution of designed plans, or monitoring of the results.

Table 2 presents a set of recommended public policies and business strategies that can be implemented to increase the digitalization level of the electricity systems, with major benefits in the decarbonization process, ensuring security of supply, and maintaining the affordability of electricity.

Possibilities to improve energy efficiency in production, transmission, distribution, and consumption of energy as much as it proves operationally, technically, and economically feasible, should be given priority to ensure reduction and improved management of overall energy demand before investing in any energy supply infrastructure. In this context, attention should also be turned to digital solutions aimed to improve energy efficiency, which are characterized by their short deployment time thus bringing almost immediate and tangible positive effects.

The electricity sector is ripe for realizing value from the digital transformation. By leveraging the building blocks of digitalization, such as service platforms, smart devices, cloud computing and advanced analytics, companies in the industry have the opportunity to increase the asset life cycle of infrastructure, optimize electricity network flows by levering flexible resources, and innovation with customer-centric services. New pools of value could also be tapped 'beyond the electron' by harnessing Big Data across sectors. Likewise, governmental actors may exploit the potential that digital technologies bring to the electricity sector, in order to drive transparency, inclusiveness and accountability in energy policy decision-making.

Table 2: Public policies and business strategies that can be implemented to increase the digitalization level of the electricity systems

Policy / Business Strategy	Impact		
	0-2 years	2-5 years	5-10 years
Prioritization of digital solutions in core infrastructure development such as smart meter rollout in national energy strategies and development plans or investments by central and local authorities and grid operators, prioritising interoperable and, where available, open- source solutions	Low	High	High
Implementing dynamic grid fees and enabling peer-to-peer and community trading to foster local energy markets	Medium	High	High
Simplifying procedures for adopting and subsidizing prosumers and initiating and operating local energy markets, while also redefining their role in the wholesale electricity markets	High	High	Low
Encourage demand-response technologies and local energy trading both among business and household customers	High	High	High
Developing specific standards for new and existing data centres operations and development (technical and energy consumption dimensions), in line with climate and energy policies and 2) considering decentralised data management solutions (governance), specifically a decentralised energy asset registry to support energy efficiency and interoperability	Low	High	High
Foster increased collaboration among public authorities, private companies, civil society and academia to raise awareness and upskill in the area of energy digitisation	High	High	High
Increase focus on research and development of new technologies in the electricity systems and ensure mainstreaming of successful pilot projects	Low	Medium	High
Implement reskilling and upskilling programmes for jobs at risk from increased digitalization in the energy sector	High	Medium	Low
Adjust the current academic curriculum and accommodate digital- related subjects to create a digital-culture for future graduates	Low	Medium	High
Plan and run awareness campaigns to promote the benefits of digital energy services, as well as tackle concerns (data protection, data privacy, etc.)	Low	Medium	High
Develop cyber security protection policies and encourage a higher attention from business operators	High	High	High

6.0 Annexure

The Task Force on Digitalization in Energy created a survey to understand more about how digitalization is perceived and evaluated among different stakeholders in the energy sector, to better grasp the challenges and opportunities of digitalizing the energy systems across geographies. The survey was conducted between 1 and 15 April 2022; it gathered 60 observations from 20 member States of the United Nations Economic Commission for Europe (ECE) and from 11 non-ECE member States. While the results presented may not be representative for some geographies, they are indicative on how the digitalization concept is perceived globally.

I. Questions

1. What is your field of expertise/sector of work? *
   (a) Public authority
   (b) Private sector
   (c) Academia
   (d) Think Tank/Non-Governmental Organization (NGO)
   (e) International Organization
   (f) Other
2. In which country are you working most often? *
3. What is holding this country back from implementing digital technologies quicker? *
   (a) Lack of awareness on the potential/benefits of digitalization of the energy systems

(b) Assumption that disadvantages outweigh benefits of digitalization
(c) Lack of funding for digitalization
(d) Reluctance related to prioritizing the investments in digitalization (versus other objectives)
(e) Financial impact on consumers
(f) Risks related to data protection and cybersecurity
(g) Social concerns (job reduction for manual labour, market concentration, social inclusion, etc.)
(h) Lack of digital skills (upskilling, reskilling, etc.)
(i) Other

4. What needs to happen to overcome the barriers selected above?
5. In your geography, what are the main benefits that digitalization could bring in the energy sector? *
   (a) Technical benefits (flexibility to integrate distributed generators, increase of grid adequacy and flexibility, efficiency at system and consumption levels, etc.)
   (b) Environmental benefits (better integration of renewable generation, energy savings, better integration of alternative transportation, etc.)
   (c) Social benefits (job creation, economic growth, etc.)
   (d) Economic benefits (savings for utility companies and customers, energy affordability improvements, etc.)
   (e) Educational skills (upskilling, reskilling, etc.)
   (f) Other
6. What strategies can be implemented to take advantage of the above-mentioned opportunities?
7. Regarding data, its management, and utilization, where do you see the biggest challenge across your geography? *
   (a) Data Collection (this is the acquisition of data; could also include making a copy)
   (b) Data Governance (includes Curation, Availability, Sharing, and Security)
   (c) Data Storage, Modelling and Standardization (could be user-specific, and optimization-based; e.g., detailed for analytics, aggregated for reporting; also includes administration of data (backups); this option is specific to the storage of the data)
   (d) Data Interpretation (on the analyst side, accurately understanding the definitions of the data)
   (e) Talent Cultivation (the Industry is changing rapidly and technology evolution is moving too fast to be industry-specific; universities need to teach ready-to-work specialists)
   (f) Data Model and Process Standardization (the standardization of data models and model processes across the utility industry; e.g., raw data looks different depending on where it comes from; data and models should be handled in a predictable way)
   (g) Other
8. Has any of these reasons held you (and/or your partners/stakeholders) back in the past, or is holding you (and/or your partners/stakeholders) back, to implement digitalization? *
   (a) The costs/effort to change were/are too high
   (b) I was/am scared to fail when implementing digitalization
   (c) I did not/do not gain enough from implementing digitalization
   (d) I did not/do not want to implement digitalization
   (e) I did not/do not believe implementing digitalization is worth it
   (f) I rather set myself goals for what not to do, instead of what to do
   (g) I believed/believe that I can reach my goals without digitalization
   (h) Other
9. How would you rate the digitalization literacy level in your geography?

Actor	Digitalization literacy level				
	Very low	Low	Moderate	High	Very high
Government (central and local)					
Businesses					
Academia					
Think Tanks/NGO					
General public/Customers					
Media					

10. To improve the level of digitalization literacy of the above-mentioned actors, what concrete steps would you propose?

II. Responses and Interpretation of Results

Distribution of respondents by sector

Distribution of the respondents is outlined in Figure 2.

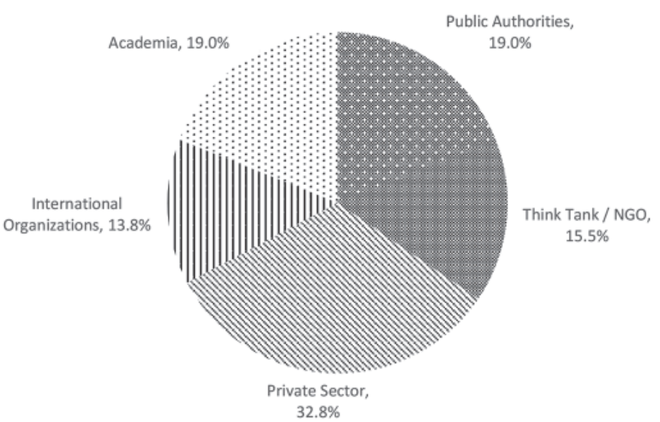

Figure 2: Distribution of respondents by sector

A. Key barriers holding countries back from implementing digital technologies

The survey has showed that the lack of awareness on the benefits of digitalization, the lack of funding, as well as the lack of digital skills are the main barriers in a fast-paced implementation of digital technologies in the energy systems. Figure 3 outlines key barriers identified through the survey, which are holding countries back from implementing digital technologies quicker.

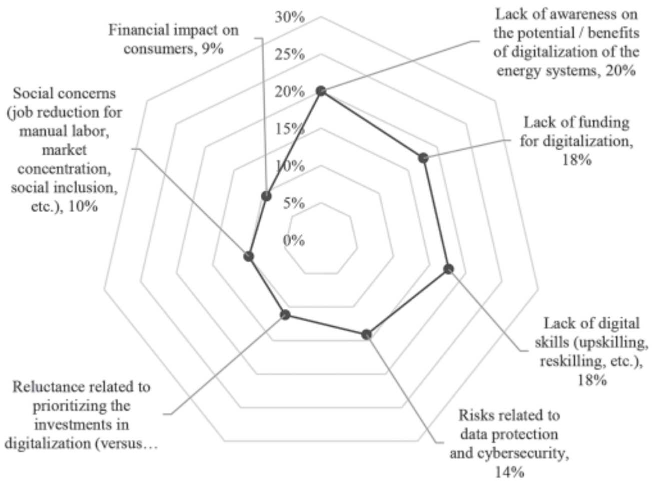

Figure 3: Survey results: key barriers that are holding countries back from implementing digital technologies quicker

Among the suggestions on how to overcome these issues and other barriers, the respondents have suggested:

(a) Raising awareness among decision makers on the benefits of digitalizing the energy systems. That includes (i) rethinking the importance of digitalization, as a key sector of national economies; (ii)) running studies and analyses with the high engagement of stakeholders, to reveal the concrete benefits of these investments; (iii) develop and run "capacity building" programmes to increase the digital literacy among all authorities involved;

(b) A need for a better coordination between different stake holders, such as the utility companies, grid operators and local administrations;

(c) Develop dedicated funds and financial tools to unlock wide-spread investments in digitalization of energy sectors;

(d) The need to increase the cybersecurity level and translate these achievements for the general public's attention, as a driver to unlock a higher demand for digital technologies among customers;

(e) Increase the number of educational programmes (in universities and high- school) and professional courses (upskilling, reskilling) to gradually increase the level of digital literacy among the current and future employees in the energy sectors;

(f) Awareness campaigns for general public.

B. Main benefits that digitalization could bring in the energy sector and strategies that can be implemented to take advantage of them

While social and economic benefits of digitalizing the energy sector have been clearly recognized by the respondents, the highest benefits identified were technical and environmental benefits of scaling up digital investments.

The survey results suggest the following main benefits that digitalization could bring in the energy sector (Figure 4).

When it comes to strategies needed to implement digitalization and capitalize the above-identified benefits, the respondents have suggested:

(a) Same increase of decision makers awareness on the economic and social benefits brought by a higher level of digitalization in the energy systems;

(b) An increased need for information at the general public's level. The benefits of digitalization should be promoted among the end-users, to also generate a bottom-up demand for higher digital tools for energy consumption and management;

(c) Funding opportunities were also identified as solution to both 1) initiate pilot projects that can showcase different social, economic, and environmental benefits and 2) scale up existing successful digitalization projects to benefit from increased overall benefits at system level and customer level.

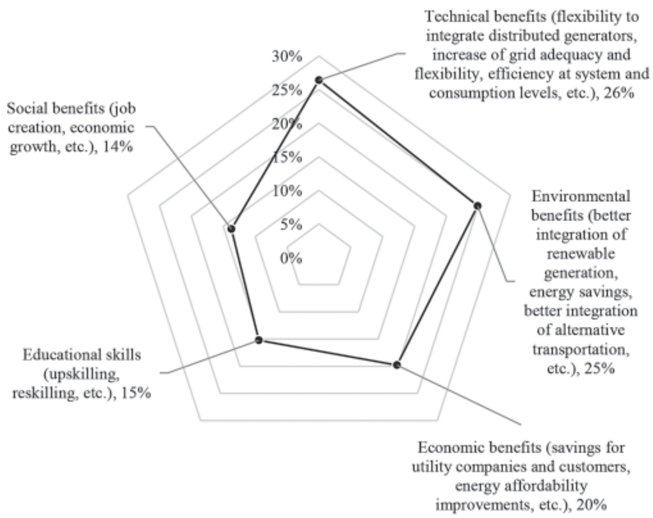

Figure 4: Survey results: main benefits that digitalization could bring in the energy sector

C. The biggest challenges of data and its management and utilization

Data governance and data collection represent half of the challenges identified by the respondents, when it comes to Big Data and its utilization. The main challenges regarding data, its management, and utilization, identified by the respondents, are presented in Figure 5.

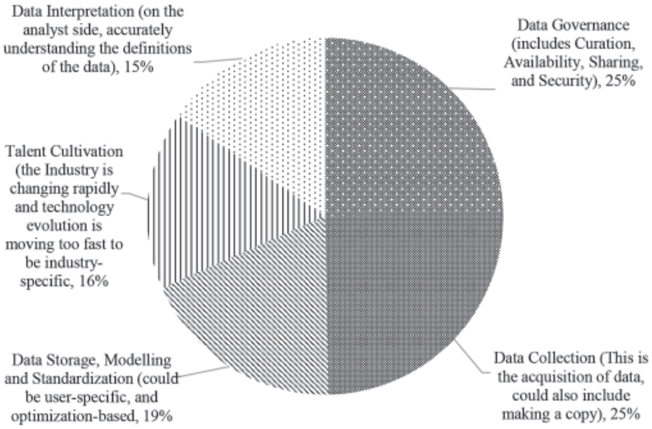

Figure 5: Survey results: main challenges regarding data, its management, and utilization

D. Reasons holding back implementation of digitalization in the energy sector

The costs and efforts to implement or scale-up digitalization in the energy sector were reported as the main problems identified across geographies by respondents and their partners (Figure 6).

To some extent, this issue connects with the previously identified needs to develop specific funds and or financial/ de-risking tools for increasing both the pace and the penetration level of digitalization.

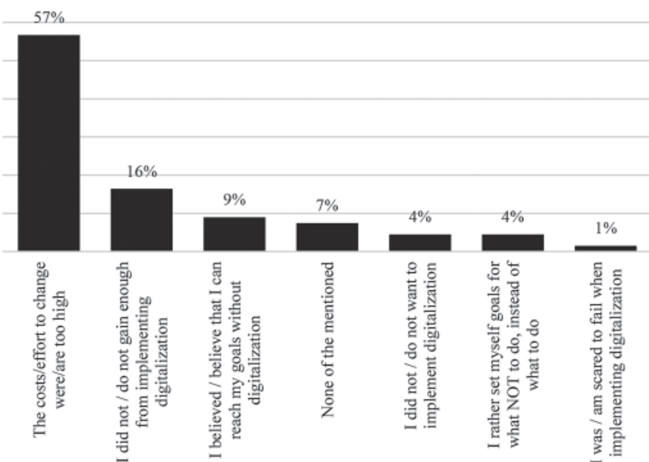

Figure 6: Survey results: main reasons holding back implementation of digitalization in energy

Additionally, low-perceived gains from digitalization (second highest concern identified) may come from either not properly understanding the full range of benefits or by not scaling digital technologies to a minimal threshold level, where various benefits start to emerge.

E. Digitalization level among stakeholders and how to increase it

Based on the responses received, the private sector and think tanks/NGO are recording the best high and very high levels of digital literacy, closely followed by media. As highlighted in the previous questions, governments and the general public are identified with low and very low levels of literacy (Figure 7).

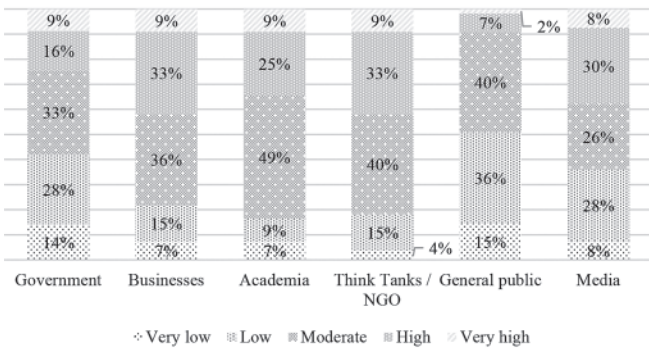

Figure 7: Survey results: distribution of responses on rating of digitalization literacy among the selected stakeholders (per cent)

The solutions offered to previous questions are also solutions suggested for increasing the digitalization level among stakeholders:

(a) Skilling and upskilling and educational programmes (universities and high school) dedicated to digitalization and its benefits in the energy sector;
(b) Better communication strategies (including media campaigns) are needed to promote the advantages of digitalization among customers and end-users;
(c) Link and promote more the relation between costs and benefits of digitalizing the energy systems.

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5. Active energy consumers, often called 'prosumers' because they both consume and produce electricity, could dramatically change the electricity system. Various types of prosumers exist: residential prosumers who produce electricity at home – mainly through solar photovoltaic panels on their rooftops, citizen-led energy cooperatives or housing associations, commercial prosumers whose main business activity is not electricity production, and public institutions like schools or hospitals.
6. It is assumed that "Electricity companies" and "Digital economy companies" subsume the most relevant business-developing actors at the electricity-digital economy nexus.
7. Mention of any firm, product, service or licensed process does not imply endorsement or criticism by the United Nations. The designations employed do not imply the expression of any opinion whatsoever on the part of the United Nations Secretariat concerning the legal status of any country, territory or area, or of its authorities.
8. International Energy Agency, "Power Systems in Transition", Report extract: Cyber resilience, Available at: https://www.iea.org/reports/power-systems-in-transition/cyber-resilience (accessed 10 May 2022).
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10. DER are non-synchronous (inverter-based) resources, defined broadly as resources sited close to customers that can provide all or some of their immediate electric and power needs and can also be used by the system to either reduce demand (such as energy efficiency) or provide supply to satisfy the energy, capacity, or ancillary service needs of the distribution grid. The resources, if providing electricity or thermal energy, are small in scale, connected to the distribution system, and close to load. Examples of different types of DER include solar photovoltaics, wind, combined heat and power, energy storage, demand response, EV, microgrids, and energy efficiency.
11. BPS is defined as facilities and control systems necessary for operating an interconnected electric energy transmission network (or any portion thereof), and electric energy from generating facilities needed to maintain transmission system reliability. The term does not include facilities used in the local distribution of electric energy.
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