DISCUSSION PAPER

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Digitalisation: An enabler for the clean energy transition

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Glossary

3D printing
3D (three-dimensional) printing, or additive manufacturing, is a computer-controlled technology that builds objects by depositing layers of material.

Artificial intelligence (AI)
The simulation of human thinking processes by machines, especially computers. These processes include learning, reasoning and self-correction; one subfield of AI is machine learning.

Building Information Modelling (BIM)
Digital representation of a building's whole life-cycle physical and functional characteristics.

Big Data
Large amounts of data gathered from diverse sources, often in near real time.

Blockchain
Also called distributed ledger technology. A decentralised data structure in which a digital record of events (i.e. a transaction) is collected and linked by cryptography into a chain of time-stamped 'blocks' together with other events.

Carpooling
Car-sharing for regular trips such as commuting or long-distance travel.

Carsharing
A model of car rental where people can rent cars from private individuals for short periods of time.

Cloud computing
Using a network of remote servers hosted on the internet to store, manage and process data rather than a local server or personal computer.

Digital twins
Virtual replicas of physical objects or systems that can be used for simulation, testing and analysis.

Distributed energy resources
Small-scale energy resources (e.g. solar PV, wind power, batteries) that generate or store power near the point of consumption. Distributed energy resources are typically connected to the electricity grid at the distribution level.

Green hydrogen
Also called renewable hydrogen. Hydrogen is produced via electrolysis (i.e. splitting water into oxygen and hydrogen gas) by using renewable electricity (rather than fossil fuels).

Internet of Things (IoT)
Everyday physical objects or devices (e.g. cars, thermostats, kitchen appliances, fridges) connected to the internet. When equipped with sensors, software or other technologies, data can be exchanged between them.

Flexibility of power systems
The ability of power systems to cope with the variability of solar and wind energy, whose output can be predicted only hours or days in advance.

Mini-grid
Also called a microgrid. Small electricity grid system linking several households or other consumers.

Mobility as a Service (MaaS)
MaaS identifies mobility solutions that are consumed as a service, enabled by platforms that integrate different mobility options and offer a unified trip-making and payment platform.

Peer-to-peer (P2P)
In the context of energy systems, connecting system users and market participants with each other to enable direct trading.

Ridesharing
Passengers are matched with drivers of vehicles for specific trips.

Sensor
A device that detects or measures some type of input from the physical environment (e.g. daylight, temperature, motion or pressure).

Smart charging
A charging strategy for electric vehicles that uses intelligent algorithms and other digital technologies connectivity and other digital technologies to shift battery charging to times when overall electricity demand and/or electricity prices are low.

Smart meter
An electronic smart-metering system measures electricity fed into the grid, or electricity consumed from the grid, providing more information than conventional meters in close to real time.

List of acronyms

AI	artificial intelligence
BIM	building information modelling
EED	Energy Efficiency Directive
ENISA	European Union Agency for Cybersecurity
EPBD	Energy Performance of Buildings Directive
EPREL	European Product Registry for Energy Labelling
GHG	greenhouse gas
HVAC	heating, cooling, ventilation and air conditioning
ICT	information and communication technology
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
IoT	internet of things
kWh	kilowatt hours
MaaS	mobility as a service
P2P	peer-to-peer
PV	photovoltaic
RED	Renewable Energy Directive
SMEs	small and medium-sized enterprises

Executive summary

Russia's invasion of Ukraine and the resulting energy crisis are a painful reminder that Europe must reduce its dependence on fossil fuels. For a sustainable, secure and affordable energy future, the coming years will require a massive scale-up of renewable energy across the EU and a tremendous effort by European businesses and households to cut their energy consumption.

A twin transition, which helps improve Europe's energy systems, can support these efforts. This has been recognised in the European Commission's recent EU Action Plan on digitalising the energy system, the first comprehensive plan for a twin green and digital transition in the European energy sector.

While this plan is undeniably commendable, it is just a start. To fully unlock the potential of digitalisation in the transition towards sustainable energy systems built around the active participation of consumers, significant shares of renewables, energy savings and efficient energy use, the EU and its member states need to:

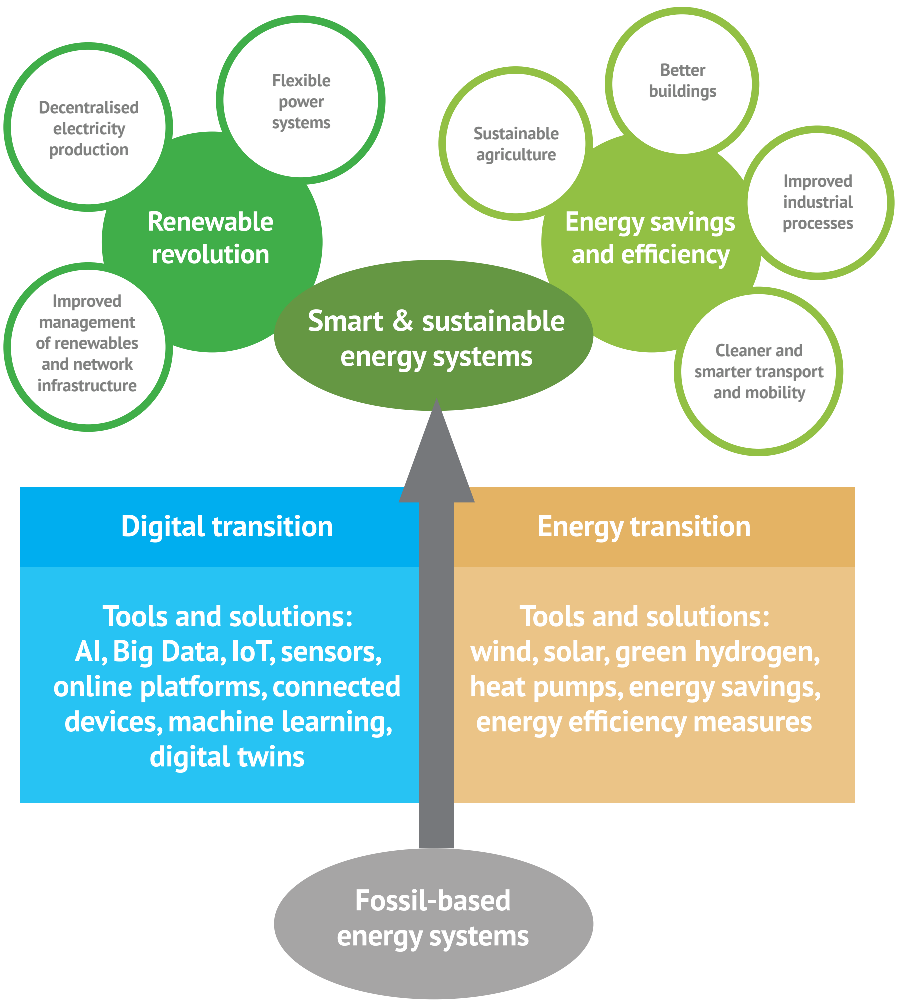
1. **Accelerate work on a common European energy data space**, characterised by interoperable data standards, adequate incentives for data sharing and data protection and privacy safeguards for consumers.

2. **Ensure that citizens possess the necessary digital skills** and information to reap the full benefits of the twin transition in terms of consumer empowerment and access to affordable and clean energy.

3. **Put in place the necessary safeguards regarding cybersecurity of energy networks** to ensure that digital transformation does not jeopardise the resilience of EU energy systems.

4. **Use financial tools to accelerate the deployment of digital solutions** in the energy sector and equip existing networks with the necessary digital infrastructure.

TOWARDS SMART AND SUSTAINABLE ENERGY SYSTEMS



Introduction

Never has the rationale for a clean energy transition in the EU presented itself clearer than today. As the Russian invasion of Ukraine and the ensuing energy crisis have demonstratively shown, the over-reliance on fossil fuels is not just responsible for most of the EU's greenhouse gas (GHG) emissions, but is also a major threat to European security, prosperity and economic competitiveness. Reducing the dependence on fossil fuels by accelerating the roll-out of renewables, saving energy and increasing energy efficiency offers the sole solution for a sustainable, secure and affordable energy future in Europe and a climate-neutral continent by 2050.

As the EU, its member states, regions, businesses and households are looking for ways to accelerate the clean energy transition, there is one enabler for change that deserves to be looked at more closely: digitalisation (see Fig. 1-2). As this paper will show, turning digitalisation into an enabler for the clean energy transition – a 'twin' green and digital transformation of the European energy sector – offers numerous possibilities and opportunities (see Fig. 1).

The use of data and digital solutions can help improve the overall functioning of energy systems by fostering system integration and breaking down barriers between the production, transmission, distribution, and consumption of energy. They can facilitate the uptake of variable and intermittent renewables such as solar photovoltaic (PV) and wind energy by increasing supply-side and demand-side flexibility in power systems. They can also help boost energy efficiency and savings in buildings, transport and industry by enabling and enhancing smart management of energy demand. Furthermore, they can contribute to the decentralisation of energy systems by connecting small-scale, distributed energy resources such as solar panels on houses' rooftops to the grid and empower European citizens to take active part in the energy transition by turning them into so-called prosumers – simultaneous producers and consumers of energy.

That said, digitalisation of the energy sector will not automatically improve the energy system, and associated risks must be addressed from the start. The use of data

Fig. 1

ALIGNING THE GREEN AND DIGITAL TRANSITIONS CAN SUPPORT THE CLEAN ENERGY TRANSITION

and digital solutions can also have negative side-effects for the security, sustainability and affordability of the European energy supply. Lastly, while digital technologies can be drivers of energy efficiency, they can also be or become significant consumers of electricity.

To build on the true potential of the twin green and digital transition in the energy sector, and to address its risks and concerns, the EU needs a coherent policy and investment framework at the European level to guide and incentivise needed action. The European Green Deal with its vision and objectives provides the strategic direction, and it is now time to ensure that the concrete measures are aligned with the set goals.

This Discussion Paper aims to contribute to the related discussions and developments. It presents results of the EPC's project 'Digitalisation for a clean energy transition', implemented in collaboration with the Vodafone Institute for Society and Communications.

The findings in this paper build on:

- A review of the relevant legislation, policy documents, studies, and academic literature;
- Correspondence with relevant stakeholders;
- Findings from two online workshops organised by the EPC.

The Discussion Paper is divided as follows: the first section examines how digitalisation can help facilitate the integration of renewables into the grid and function as a driver of energy savings and more efficient energy use. It also outlines the main challenges and risks to using digitalisation as an instrument for the clean energy transition. The second section analyses the policy framework regarding the digital transformation of the energy sector at the EU level. The final, third section, formulates recommendations for European policymakers to turn digitalisation into a true driver and enabler of the EU's clean energy transition.

1. Digital solutions for the clean energy transition

1.1. DIGITALISATION AS A CATALYST

Renewable energy sources play a critical role in decarbonising power systems, reducing the EU's dependence on imported fossil fuels and ensuring affordable supplies for European households and businesses. The use of data and digital solutions can support and help accelerate the 'renewable revolution' in a variety of ways. They can boost the flexibility of power systems by allowing for higher shares of renewables in the EU's electricity mix. They can foster the integration of distributed energy resources (e.g. residential solar panels, micro-wind turbines) into the grid, and enable peer-to-peer (P2P) energy trading and the deployment of renewable 'mini-grids'.

Digital tools can also be deployed to optimise the development and operation of renewable assets. For instance, they can be used to improve maintenance, which may in turn result in better performance and extend the operational lifetime of renewable power plants.[1]

The following sections provide an overview of how digital applications can advance Europe's renewable revolution.

1.1.1. Power system flexibility

The share of variable renewables such as solar PV and wind power in the EU's electricity mix is expected to grow significantly in the coming years. Given their inherently intermittent nature, their output can only be predicted a few hours or days in advance. This means that power systems must become much more flexible to ensure the affordability and security of electricity supply.

EXAMPLES OF DIGITAL SOLUTIONS FOR POWER SYSTEM FLEXIBILITY

Existing solution: The Sun4Cast solar power forecasting system, the result of a public-private-academic partnership led by the US National Center for Atmospheric Research, integrates various forecasting technologies based on **machine learning** and other advanced data techniques to improve the accuracy of solar power forecasts at the local level. These forecasts are shared with utilities for real-time decision-making, which helps these companies to reduce their reliance on spot purchases to fulfil customer demand. This, in turn, increases the commercial viability and thus the roll-out of solar PV.[2]

Emerging solution: Since 2012, the German Meteorological Service, the Deutscher Wetterdienst, has carried out various research projects (EWeLiNE, ORKA I, ORKA II, PerduS) using **AI** to predict renewable generation on the basis of data gathered from solar sensors, wind turbine sensors and weather forecasts. This can help reduce the uncertainty of electricity generation from wind and solar farms, thus allowing for higher shares of variable renewables in the energy mix without compromising the security of electricity supplies.

Digitalisation can be a major driver of power system flexibility and can facilitate the integration of renewables into the grid in a cost-effective way. On the supply side, digital solutions can enable advanced weather forecasting to minimise the uncertainties related to wind and solar generation, as well as a more flexible operation of conventional (gas-, coal- and oil-fired) power plants, thus contributing to flexibility.[3]

On the demand side, digital solutions can enhance access to consumer data and analysis, in turn enabling more accurate forecasting of electricity demand. In addition, the digitalisation of home appliances (via e.g. smart fridges, smart thermostats, smart lighting) can improve and automate demand-side management for households. For instance, they can enable remote control via smartphones and increase consumers' responsiveness to price signals. By charging when renewable energy is plentiful or spreading out charging demand over time, smart charging of electric vehicles can also become a crucial source of demand-side flexibility as the electrification of road transport continues. For more on demand-side possibilities and solutions, see section 1.2.

1.1.2. Integrating distributed generation, renewable mini-grids and P2P energy trading

With the proliferation of distributed energy resources such as rooftop PV installations, the power sector is becoming more decentralised. Digital tools can facilitate the physical integration of such distributed generation into the grid and enable new, previously impossible, forms of power system operation. They can foster the emergence of renewable mini-grids and P2P energy trading.

Regulatory frameworks are rarely adapted to accommodate direct trading between peers without the intervention of intermediaries and have unclear or prohibitive rules regarding tariffs or grid access for prosumers.

Blockchain technology, for instance, can enable the direct trading of electricity in local communities of consumers and prosumers (e.g. households or small businesses with solar panels on their rooftops) by removing the need for a central authority to clear transactions.[4] Since the mid-2010s, blockchain-based pilot projects have seen a meteoric rise in the energy sector. Most of these are located in Europe but they can also be found in many other parts of the world.[5] However, for blockchain-enabled P2P electricity trading to become more widely available, many barriers still need to be addressed. Regulatory frameworks are rarely adapted to accommodate direct trading between peers without the intervention of intermediaries and have unclear or prohibitive rules regarding tariffs or grid access for prosumers. This continues to hold back innovative schemes.[6]

EXAMPLES OF DIGITAL SOLUTIONS FOR DISTRIBUTED RENEWABLE GENERATION AND P2P ENERGY TRADING

Existing solution: Brooklyn Microgrid, developed by the New York-based start-up LO3 Energy, is a pilot mini-grid using **blockchain** technology. It allows residential and commercial owners of solar PV installations in Brooklyn, New York City to sell their electricity surpluses to a local network of neighbourhood participants. Blockchain technology helps connect buyers and sellers in a reliable way, thus supporting P2P transactions of locally produced clean energy.

Existing solution: With SolarEdge Home, Israeli company SolarEdge offers households with rooftop PV installations a variety of smart energy solutions, including smart inverters, electrical vehicle chargers, batteries and an app for monitoring and managing smart home devices, allowing them to maximise solar power production, storage and self-consumption.

1.1.3. Development, operation and management of renewable energy assets

The use of data and digital solutions can enhance and optimise the development, operation and management of renewable energy assets and electricity networks in many ways. Big Data techniques can be used to support network planning and improve the design of renewable energy projects, for instance by helping find the ideal location for a new solar or wind farm to optimally supplement existing infrastructure, boost benefits for consumers, minimise grid integration costs, and maximise the output of the farm itself.[7]

Smart sensors can help cut down operation and maintenance costs by enabling predictive maintenance, which requires accurate and current data about various components – both highly challenging and costly to gather manually.[8]

Such predictive maintenance, in turn, can help extend the operational lifetimes of solar panels, wind turbines and hydropower plants, thereby reducing the need for investment in the power system and lowering prices for consumers. However, predictive maintenance is a double-edged sword as it can just as well lengthen the operational lifetimes of conventional power plants. This could lock energy systems into fossil fuels and thus slow down rather than accelerate the roll-out of renewables.[9]

EXAMPLES OF DIGITAL SOLUTIONS FOR DISTRIBUTED RENEWABLE GENERATION AND P2P ENERGY TRADING

Existing solution: Wind energy company Vestas uses **AI-controlled** steering systems for turbine rotors to deflect the wake of upstream wind turbines away from downstream turbines, which in turn increases the overall output of their wind farms.

Emerging solution: Green hydrogen is increasingly seen as an important part of the decarbonisation puzzle and an alternative solution in sectors where electrification is unfeasible or expensive, such as heavy industry (e.g. steel production, chemical industry) and long-distance transport.[10] Digital solutions can function as enablers of the 'green hydrogen revolution' in many ways. For instance, **digital twins** can help developers test and optimise the design of green hydrogen projects to maximise return on investment and minimise investor risk, which can compensate for this technology's lack of data and low level of maturity. A combination of **AI** and **IoT** can play an important role in certifying that hydrogen is green, i.e. produced from renewable electricity rather than fossil fuels such as natural gas or coal. Hydrogen installations equipped with AI and IoT technology can automate the certification process, avoiding manual processing and thus human error. These technologies can help trace green hydrogen along its full life cycle, 'from cradle to grave'.[11]

1.2. DIGITALISATION AS A TOOL TO SAVE ENERGY AND USE ENERGY MORE EFFICIENTLY

Energy efficiency measures offer the quickest, easiest way to reduce Europe's dependence on fossil fuels, including from Russia. The cheapest energy is the one not used. Reducing energy consumption is also the most sustainable way forward and crucial for the EU's competitiveness and security. There is great untapped potential to save energy, for example in buildings, transport, agriculture and industrial processes, and digitalisation can do a lot to support these efforts.

The cheapest energy is the one not used. Reducing energy consumption is also the most sustainable way forward and crucial for the EU's competitiveness and security.

1.2.1. Smart energy management in buildings, during construction and renovation

Buildings are responsible for 40% of the EU's total energy consumption and for 36% of greenhouse gas emissions.[12] Digital solutions can help cut energy use and increase energy efficiency in buildings, with the greatest potential in heating and cooling, as well as in the construction sector itself.

In buildings, digital tools can be used to adjust energy supply to consumer demand. Smart appliances use IoT, AI, machine learning and sensors to provide consumers with information about an appliance's energy use. The use of smart light bulbs in combination with apps that control lighting, set schedules, turn off lights remotely and dim lights, for example, can help reduce the energy consumption of lighting systems which is especially significant for commercial buildings.[13] LEDs with sensors can also be used to gather information about occupancy, activity and daylight in certain rooms, which allows the energy consumption of the heating and cooling systems to be improved. By adding smart thermostats and smart blinds or motorised window shades, additional data can be gathered about household routine and weather forecasts.

The combination of these smart devices can allow consumers to further optimise their electricity or heating and cooling consumption according to the seasons and their needs. However, while these tools can help cut energy use and improve energy efficiency, users first need to understand their energy consumption and how to change it.

Smart meters can be valuable tools in this regard. For example, they can store information about energy consumption on an hourly or more detailed basis and provide real-time information about the electricity fed into the grid. This allows for more efficient energy use; customers can also regulate their consumption based on when tariffs are lower, thus helping them save money. For consumers to benefit from these solutions, however, they not only need data, but knowledge and the means to adopt more energy-efficient behaviours.

Furthermore, the energy performance of a whole building can be monitored and linked to data from the energy grid. This would allow for a closer alignment of real energy use with supply and demand in the energy system.

As well as optimising energy in buildings, there is also great untapped potential to reduce energy consumption when renovating or constructing buildings. Every part of the construction process takes energy, from the equipment used to the appliances installed in the new building. Transportation, materials, tools, insulation, windows, appliances, lighting, heating and cooling systems all use energy. Technologies such as IoT, AI, robots and digital twins can reduce the energy footprint of both building processes and materials.

EXAMPLES OF DIGITAL SOLUTIONS FOR ENERGY MANAGEMENT IN BUILDINGS

Existing solution: In the Dutch pilot project Your Energy Moment (Jouw Energiemoment) led by Enexis between 2012-15, households were equipped with smart meters and **smart appliances** such as washing machines. Through their **Home Energy Management Systems**, users could monitor their energy use, prices and local energy production from photovoltaic systems and adjust the running of their appliances accordingly. As a result, dynamic energy tariffs led energy consumers to change their consumption behaviour and shift their consumption to periods with low energy tariffs. The energy consumption for dishwashers, washing and drying machines in particular changed drastically.[14]

Existing solution: Smart thermostats such as Google Nest or Qivivo can help reduce energy use in heating and cooling. They can use temperature, presence and humidity **sensors**, assess previous energy consumption patterns and consider outdoor weather conditions, for example, to adapt heating accordingly. A study commissioned by Google found that energy consumption in heating, cooling, ventilation and air conditioning (HVAC) could be reduced through smart thermostats such as Google Nest by between 10% and 12%.[15]

Existing solution: The Verv home energy assistant, a clamp attached to the electricity or smart meter cable and a hub connected to the power supply, uses **AI** to identify individual home appliances and analyses their energy efficiency. It can detect irregularities in the running of devices or if they are left on, consuming unnecessary electricity when the consumer is not at home, notifying them of energy usage via an app. Consumers can then monitor and regulate the energy usage of their appliances when given consumption thresholds are reached. The assistant can be used to identify the energy-inefficient appliances.[16]

Existing solution: nhance Digital Buildtech offers smart lighting systems for commercial buildings and workplaces, using occupancy **sensors** to turn off lights automatically when not needed.

Existing solution: In the UK, a **cloud-based monitoring system** was created by Hark Systems to aggregate data on energy use from existing heating, cooling, ventilation and air conditioning (HVAC) systems as well as power and lighting assets. This system helps businesses monitor and improve their energy use. In Sainsbury's stores, for example, this platform has helped detect anomalies and brought about a 4.5% saving in lighting costs.[17]

Existing solution: The INTERREG project 'Effective Financing Tools for implementing Energy Efficiency in Buildings' (EFFECT4buildings) has mapped technological solutions for energy efficiency in buildings in the Baltic Sea region, such as **smart lighting control** by Aura Lights in Sweden and **smart electricity meters** by the Latvenergo Group in Latvia.

Existing solution: Azure Digital Twins by Microsoft is an **IoT platform** which can be used to create a digital representation of real-world things, places, business processes, and people. For example, Brookfield Properties in New York uses Azure Digital Twins for one of their properties to optimise energy usage. The building operators can better maintain HVAC equipment and reduce the number of lights needed in certain areas at a specific time.

EXAMPLES OF DIGITAL SOLUTIONS FOR CONSTRUCTION AND RENOVATION

Existing solution: In Oslo, for the big urban regeneration project the Fjord City advanced digital construction technologies that were used to develop energy-efficient buildings and reduce the carbon footprint of the construction process and materials used. For example, the facade and rooftop of the new library were designed with the help of **BIM and 3D modelling** for low energy consumption, with windowpanes and translucent walls supported by insulation and sun protection.[18]

Existing solution: Knauf Energy Solutions has teamed up in Belgium and the UK with social housing companies to implement smart retrofit projects. For example, in Halle a neighbourhood of 184 dwellings was renovated. **Sensors and machine learning** were used to measure the energy efficiency level before and after renovation.[19]

Existing solution: To support its Long-term Renovation Strategy, Estonia is developing a **digital tool** for building owners that allows them to design and take best possible measures for efficient energy use. After entering building parameters such as wall type, window type, heating system and ventilation system, the owners can test options for energy efficiency improvements (e.g. insulation thickness, triple glazing, the possible installation of heating or ventilation systems or solar panels). Estonia is also developing a tool for property owners to help them estimate a building's energy costs and make recommendations to reduce them based on the building's technical specifications.[20]

Emerging solution: the Horizon 2020 StepUP project aims to develop a new process for deep renovations using **digital twins** to fill data gaps. It focuses on the most cost-effective renovations to reduce energy consumption.

In addition to improving energy use in buildings, there is also great untapped potential to reduce energy consumption when renovating or constructing buildings.

With Building Information Modelling (BIM) and digital twins, architects, engineers and contractors can simulate construction and possible retrofits, understand real-time energy use and increase energy efficiency and reduce consumption.[21] Moreover, digital twins can not only simulate single buildings but entire cities, thereby allowing the energy impact of infrastructure policies and projects to be tested.

Unfortunately, the construction sector is the least digitalised sector in the EU. In 2021, 70% of construction firms dedicated less than 1% of their revenues to digital and innovative projects, and the uptake of BIM remains particularly low.[22]

1.2.2. Smart, connected vehicles, automated driving and new mobility models

The way we travel and transport goods is undergoing a significant change, yet much more needs to be done to achieve the Green Deal goal of reducing GHG emissions in transport by 90%. Transport emissions represent around 25% of the EU's total greenhouse gas emissions, and as road transport accounts for around 70% of this, it should be a key area for action.[23] The challenge is real and growing: CO2 emissions from heavy-duty vehicles were 28% higher in 2019 than in 1990 due to increased activity and slow improvements in efficiency.[24]

There is great potential for digital solutions to help both businesses and individuals reduce energy consumption and related emissions in road transport. Solutions such as automated deliveries and drones can be used by businesses to improve logistics and reduce the number of vehicles on the road and thus related fuel usage. In an automated highway system, freight trucks can drive together in single file, reducing the distance between the vehicles. This 'platooning' reduces air resistance and cuts fuel use.[25]

A growing number of solutions are becoming available for people to support and benefit from cleaner road transport. When connected to a network, vehicles can communicate with other vehicles and infrastructure such as Intelligent Transport Systems (ITS). The vehicles collect and analyse data to improve individual driving behaviour, trip planning and traffic management, which can help reduce emissions and energy consumption. Automated vehicles use sensors, algorithms and machine learning to drive without human involvement. Cloud-based battery management systems using IoT can check

EXAMPLES OF DIGITAL SOLUTIONS FOR TRANSPORT AND MOBILITY

Existing/emerging solution: Postal services in France and Germany have been testing **autonomous robotic technologies** for drone delivery services. The delivery service providers La Poste in France and DHL in Germany tested drones to deliver consumer goods in hard-to-reach areas and announced that the technologies are ready to mainstream.[26]

Existing solution: The Swedish real estate company Vasakronan uses ProptechOS, an **IoT** solution that uses Microsoft Azure and Azure Digital Twins to reduce energy consumption and costs related to electric vehicles. Vasakronan uses Azure **Digital Twins**, for example, to gain insights into the charging patterns of electric vehicles in their buildings – when and how vehicles are connected, when they are fully charged and when stations are not used. This information can be used to adapt the amount of electricity buildings use from the grid.

Existing solution: The Horizon 2020 project '5G-CARMEN' built a **5G**-enabled cross-border trial corridor between Munich and Bologna to provide a platform for vehicles to exchange data on speed, position, intended trajectories or manoeuvres. The on-board systems then build on this information to suggest an optimised driving strategy for improved traffic flow. Information can be shared between vehicles or with infrastructure.

Existing solution: In urban areas, several **shared mobility services** are available for cars, e-scooters or bikes such as Uber, Poppy, CarAmigo, BlaBlaCar, EkoRent, lime, Bolt, SEVici (Sevilla), BICIKE(LJ) (Ljubljana), villo (Brussels) or vélib (Paris). WunderMobility helps manage vehicle sharing services.

Existing solution: In Finland, the app Whim has benefited from **open public data**. It provides information about multiple transportation modes (such as train, taxi, bicycle) and allows customers to pay for the travel via the **app**. Users can either opt for monthly subscriptions or the pay-as-you-go method. Apps such as Jelbi in Berlin provide multimodal options for mobility. Trafi provides MaaS solutions for both citizens and city authorities.

Existing/emerging solution: In 2021, the **online platform** Google Maps launched a new routing model in the USA that shows fuel or energy-efficiency estimates for some routes based on the vehicle's engine type. Since then, the feature has been made available also in Canada and Germany and more is to follow.[27] Calculations are based on **data** from the US Department of Energy's National Renewable Energy Laboratory and the European Environment Agency, including factors affecting fuel and energy usage as well as CO2 emissions.

the charging status of batteries in electric cars. Smart charging, in which the electric vehicle, charging station and charging operator are connected to each other via a data link, enables the charging process to be adapted to times of lower electricity demand or higher renewable energy supply and feed electricity back into the grid. This can also bring wider benefits to the entire energy system by enabling more efficient grid operation and the integration of more renewable energy within it.[28]

A growing number of digital solutions are becoming available for people to support and benefit from cleaner road transport.

Moreover, better use of data and digital solutions can enable a transition to a more sustainable mobility system as a whole. This entails reducing vehicle use, increasing the use of public transport and encouraging multimodal mobility: walking, cycling and travelling via rail.[29] Shared mobility services via platforms or apps can facilitate car sharing, carpooling and ridesharing, which can lead to reduced car ownership, private car use and fewer cars on the road. Bike-sharing services can encourage bike use, especially in cities. Platforms for mobility as a service (MaaS) can contribute to bringing different modes of transport together, thereby enhancing multimodal mobility and reducing car ownership or car use.

EXAMPLES OF DIGITAL SOLUTIONS FOR INDUSTRY

Existing solution: BeeBryte is a software that uses **AI** for real time control of heating and cooling systems in commercial and industrial buildings. It aims to improve the energy efficiency of large HVAC systems, for example in temperature-controlled storage facilities, food industry production sites and in clean rooms as well as large commercial buildings such as shopping centres, office towers or universities. On the basis of advanced weather forecasts, occupancy, consumption and electricity price signals, BeeBryte can help reduce energy by up to 40%.

Existing solution: e-F@ctory developed by Mitsubishi Electric is a solution that can be used across industrial sectors. The technology uses **AI** to collect and analyse data from the shop floor to improve production and energy consumption.[32]

Existing solution: In Romania, the manufacturing company Arcelik measures the energy data of its washing machines. Using smart **algorithms and IoT**, the energy consumption of each product can be tracked and consequently reduced.[33]

Platforms and apps can furthermore be used to create transparency about the climate and environmental footprint of different travel options or logistical choices.

1.2.3. Smart and green factories

Industrial energy consumption accounts for almost 40% of global emissions and is still dominated by fossil fuels.[30] While European industry has made great efforts to improve its energy efficiency, more could be done to use smart sensors, data analytics, industrial robots, machine learning and improved connectivity to reduce energy consumption.

In a smart factory, connections between machinery and equipment can make production more energy efficient. Digital twins can replicate factories to model production processes virtually. Combined with artificial intelligence, this enables experimentation, which would require a lot of energy and resources in a real industrial plant.

As another example, 3D printing can accelerate the prototyping process to produce new objects that consume less energy. As a downside, however, 3D printing processes can be lengthy, consume a lot of energy themselves and come with a high cost, and thus they are not yet interesting for many operators.[31]

1.2.4. Smarter, more sustainable agriculture

Agriculture is a major consumer of energy, via the use of machinery such as tractors and irrigation pumps, and indirectly via the heating of livestock stables and greenhouses. It accounts for 3% of total energy use in the EU.[34] However, there are regional variations: in the Netherlands, a major food producer, agriculture accounts for 9% of total energy use, followed by Poland and Latvia with 6% each.[35] More than half of the EU's agriculture and forestry sector's total direct energy consumption in 2020 was from oil and petroleum products.[36]

Agriculture is a major consumer of energy, both directly via the use of machinery and the heating of livestock stables and greenhouses, as well as indirectly, as fossil fuels are used to produce fertilisers and pesticides.

Agriculture also consumes energy indirectly, as fossil fuels are used to produce fertilisers and pesticides. Packaging and food processing require energy, as does the transportation of products to and from the farm. Given the scale and intensity of animal farming in Europe, both the energy needs and the related emissions of the sector are considerable.

EXAMPLES OF DIGITAL SOLUTIONS FOR AGRICULTURE

Existing solution: Skaha Remote Sensing employs **sensor technology** to measure soil moisture over large areas. Based on these measurements, farmers can reduce both water and energy usage more efficiently.

Existing solution: Libelium is a **sensor technology and cloud-based management system** that allows farmers to observe, measure and respond to the environmental conditions, diseases and pests that affect their agricultural production, and can be used to reduce the use of pesticides, fertilisers, energy and water while boosting yields.

Existing solution: Flourish is a project that has developed **AI** for precision farming. Aerial **robots** collect environmental data (on e.g. soil, crops, pests), which is then used by unmanned ground vehicles to spray optimal amounts of pesticides and fertilisers onto the field.

Emerging solution: IoF2020 (Internet of Food and Farm 2020), a H2020 project, tested use of **IoT** and automated tractors for precision farming.

Existing solution: Organix is a French **digital platform** launched by Suez; a marketplace for organic waste. Farmers can connect with methane producers to convert their waste into energy. The aim is to facilitate 'the recovery of waste and the production of new energy and organic resources via local distribution channels, for the benefit of the circular economy'.[37]

It is also worth noting that, while not without concerns, the farming sector can be an important source of renewable energy. Organic agricultural waste can be turned into biogas and biomethane, thereby replacing fossil fuels in energy and transport systems.

Many of the digital solutions for achieving energy savings and efficiency and for integrating renewables, covered in this paper, are also relevant for improving the agri-food system. Moreover, while several digital solutions are already used to improve agricultural practices more generally, it is worth recognising their potential also for energy use and production. For example, smart sensors can be used to improve knowledge and decisions on energy use. Satellite imagery, sensors, the IoT, automation, drones and robots can support precision farming[38] and reduce energy consumption both directly and indirectly (by limiting and optimising the use of pesticides and fertilisers). Enhancing information transfer can help improve the use of large agricultural machinery and materials with a high energy footprint. Moreover, digital platforms have already proved useful in selling organic waste for energy.

1.3. CROSS-CUTTING RISKS AND CHALLENGES TO DIGITALISING ENERGY SYSTEMS

While digital solutions can be a significant asset in the clean energy transition, several challenges and cross-cutting risks need to be addressed to unlock their true potential.

1.3.1. Energy and climate footprint of data and digital solutions

The information and communication technology (ICT) sector, including data centres, devices and communication networks, has a significant energy and climate footprint – estimated at between 2.1%-3.9% of global greenhouse gas emissions in 2020, putting it on a par with aviation industry emissions.[39] If nothing changes, this share could increase to over 14% by 2040.[40]

In the EU, data centres are significant users of energy. In 2018, EU data centres accounted for 2.7% of electricity demand in the EU.[41] This is projected to increase by over 200% between 2020 and 2030 as more cloud services and high-performance computing (HPC) are used for computing and storage.[42] The mining of cryptocurrencies and blockchain technologies used in energy markets and trading also consume great amounts of energy, about 0.4% of the global electricity consumption in 2022.[43]

Shifting to renewable energy sources and using energy more efficiently are central to making data centres more sustainable. More efforts are needed to reduce emissions associated with the production and operation of data centres, water consumption and the demand for rare metals.

Consequently, digitalisation can be a truly sustainable solution for the clean energy transition only if the energy performance of ICT technology is improved and its climate footprint is reduced.

Additionally, the lifecycle emissions of user devices account for about 50% of the total ICT footprint. While the International Energy Agency (IEA) estimates that by 2040 the global energy consumption of control devices in buildings is expected to be lower than the expected energy savings, the challenge should not be overlooked. Connected devices consume energy even when they are not in use, to maintain connectivity. Smart lighting systems in buildings in standby mode for example can consume as much as 25-kilowatt hours (kWh) per light fixture or bulb if left running 24 hours a day year-round.[44] A connected lamp can consume more energy per year in standby mode than when used, which cuts the net energy efficiency gain by more than half.[45] Consequently, digitalisation can be a truly sustainable solution for the clean energy transition only if the energy performance of ICT technology is improved and its climate footprint is reduced.

1.3.2. E-waste

Digitalisation comes with a considerable environmental footprint. Electrical and electronic equipment, especially ICT equipment, is made from critical materials and precious metals, as well as iron and aluminium. Mining, materials processing and product manufacturing contribute to greenhouse gas emissions, pollution, water stress and biodiversity loss.

Moreover, computers, smartphones and other electronic or connected devices such as smart meters eventually become waste, or e-waste. This is currently one of the fastest-growing waste streams. In 2019, 12Mt of e-waste were generated in the EU, contributing to around 53.6Mt worldwide. The trend points to rising numbers, with global e-waste predicted to reach 74.7Mt by 2030.[46] Multiple device ownership, the growth of cloud computing services, short product lifespans and replacement cycles are contributing to a growing e-waste phenomenon, meaning a loss of resources and significant costs for the economy. In addition, if not handled well in its end-of-life phase, the hazardous substances in e-waste pose a pollution threat to public health and the environment.

For digitalisation to become a sustainable enabler for the clean energy transition, the devices used must also become more sustainable, more circular.

For digitalisation to become a sustainable enabler for the clean energy transition, the devices used must also become more sustainable and more circular.[47] This means preserving the value of products and materials for as long as possible and reducing resource consumption and waste by increasing repair, reuse, remanufacturing and recycling of materials and products.

1.3.3. Risk of increased cyberattacks

The European Union Agency for Cybersecurity (ENISA) warns against numerous challenges that could threaten cybersecurity, including an increase in digital surveillance and loss of privacy, an increase in targeted attacks due to more connected devices, more advanced hybrid threats, human failures, outdated cyber-systems, a lack of skilled workers, misuse of artificial intelligence (AI) and cross-border ICT service providers as a single point of vulnerability.[48]

As more devices are connected to the energy infrastructure and the energy system is increasingly digitalised throughout buildings, transport, agriculture and industry, cybersecurity risks increase as well. If these risks are not addressed adequately, digitalisation may turn into a source of energy insecurity instead of functioning as a driver of the transition towards renewable and more efficient energy systems. As electricity grids and pipelines are closely interconnected not only across Europe but internationally with other critical infrastructures, a cyberattack could, for example, disrupt electricity supply in numerous countries and cause significant problems in sectors such as transport, banking and financial markets, health, public administration, space, water and food.

1.3.4. Concerns over data protection and privacy

When more data is collected and shared, concerns arise about privacy and the ownership of this data. As the slow roll-out of smart meters shows, digital solutions will only be picked up if they are trusted. Consumers have been reluctant to install intelligent metering systems because they are worried about sharing more detailed data with their energy provider. Another concern is digital surveillance. An increased and constant monitoring of habits can impact digital rights and consumer rights if it leads to energy companies charging consumers differently according to their patterns of energy consumption. Concerns around data protection are often also a barrier to sharing data among relevant stakeholders. Operators are sometimes reluctant to share data that could be used for multimodal and interoperable travel information, ticketing and payment.

When more data is collected and shared, concerns arise about privacy and the ownership of this data.

1.3.5. Lack of harmonised standards and interoperability

Inadequate data exchange is a barrier to the clean energy transition and the full deployment of renewable energy infrastructure. For example, supporting the uptake of renewables requires data-sharing for advanced weather forecasting to help predict the output of wind turbines and solar PV installations more accurately. Data needs to be interoperable and sharable across borders, also to allow for automated, connected cars to travel from one country to another or for MaaS solutions to work in all of EU.

The lack of commonly agreed standards and low interoperability are also an obstacle to the use of digital tools, for example, in the construction sector.[49] Common standards are needed for connected devices in buildings to communicate with other devices, the building management and the energy grid.

1.3.6. Lack of skills and costs

For many consumers, lacking skills are a barrier to using digital tools at home. The same applies for companies, including small and medium-sized enterprises (SMEs). A good example is the construction sector, which suffers from a lack of necessary digital skills.[50]

In industry, the cost of certain digital solutions such as 3D printing can hinder their uptake. Consumers are unlikely to use these devices if they have to pay for expensive smart meters and their installation.

1.3.7. Rebound effects

While data and digital tools can help with energy savings, efficiency and the use of renewable energy sources, the real gains will depend on the behavioural and other systemic responses that follow. If introducing new technologies leads to greater energy and resource consumption than before, this is a negative rebound effect.

This would be the case if a lower heating bill after building insulation leads to the purchase of new and more energy-intensive lighting in the home, or if an energy-efficient lighting system saves energy but, by making lighting cheaper, causes people or businesses to light larger areas more intensively over longer periods of time. In transport, for example, the availability of carsharing services or the replacement of a private car with a more fuel-efficient model, can lead to an increase in trips and a greater number of vehicles on the road. These rebound effects are difficult to measure but they need to be addressed by providing guidance to consumers and businesses.

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2. EU policy framework

2.1. ENABLING FRAMEWORK FOR THE CLEAN ENERGY TRANSITION

Accelerating the twin green and digital transition and realising the true potential of data and digital solutions require meeting certain pre-conditions. Achieving the clean energy transition starts with using tools available, from policies to funding, to address the basic and fundamental hurdles that are still hindering the development and uptake of renewables as well as energy efficiency and savings.

2.1.1. Renewable energy

Achieving a renewable revolution requires developing and deploying renewables fast and on a massive scale. The EU is contributing to these efforts through several initiatives.

Under the Fit for 55 Package, the European Commission tabled a legislative proposal for a third revision of the Renewable Energy Directive (RED), the EU's legal framework for the development of renewables across all sectors of the economy. This included increasing the binding target for renewables in the EU's overall energy mix from 32% to at least 40% by 2030. In the aftermath of Russia's invasion of Ukraine, the Commission proposed to further increase the ambition to a 45% share for renewables by 2030. While this new target was backed by the Parliament, the Council's insistence on keeping the target at 40%,falls short of the needed ambition.[51] As the negotiations on the revision continue, there is still scope to ensure that the EU does what it takes to accelerate the uptake of renewables.

Further push is coming via the Commission's REPowerEU plan, presented in May 2022, 'to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition'.[52] It put forward additional measures to speed up the deployment of renewables in the EU, including non-binding targets for domestic biomethane production, the production and import of green hydrogen and the roll-out of heat pumps, as well as a phased-in legal obligation to install solar panels on new public, commercial and residential buildings. The Commission also recommended streamlining permit procedures for renewable energy projects in member states, and more recently suggested a new (temporary) emergency regulation to fast-track and simplify permits for renewable energy plants.[53] The Council has rightly agreed that the development of renewables is in the overriding public interest and set strict time limits for permit-granting to different types of renewable projects such as solar PV installations, heat pumps and upgrades to existing infrastructure.

2.1.2. Energy savings and energy efficiency

Data and digital solutions can support energy savings and energy efficiency only when consumers are first provided with adequate incentives and tools to reduce their energy use. While the increased prices of energy are driving consumers to change energy usage, the EU is also supporting these efforts.

Data and digital solutions can support energy savings and energy efficiency only when consumers are first provided with adequate incentives and tools to reduce their energy use.

The Energy Efficiency Directive (EED) sets a binding EU-wide energy efficiency target and rules to implement the efficient use of energy resources as a priority across all sectors of the economy. The Commission first proposed to revise the directive with a requirement for member states to collectively reduce their energy consumption by 9% by 2030 compared to 2020, as part of the Fit for 55 Package. Against the backdrop of the Russian invasion of Ukraine, the Commission increased the target to 13%, like the revision of the Renewable Energy Directive, this proposal has been rejected by the Council.[54] This is undeniably a missed opportunity, as saving energy offers the quickest solution to address the ongoing energy crisis. A more ambitious target would have reflected the importance and the urgency for needed measures.

In addition to the EED, the EU is working on several sector-specific initiatives. For buildings, there is the Energy Performance of Buildings Directive (EPBD), also undergoing revision as part of the Fit for 55 Package. Via stricter minimum energy performance standards, this revision aims to make all new buildings zero-carbon by 2030 and all existing buildings zero-carbon by 2050. For industry, there is the Industrial Emissions Directive (IED), for which the Commission tabled a proposal for revision in April 2022. The directive mainly addresses pollution from large industrial installations and the revision aims to introduce mandatory minimum energy efficiency levels for these industrial plants.

For transport and agriculture, work is also ongoing on utilising digital solutions for improving these sectors' energy efficiency. The Commission has proposed the Sustainable and Smart Mobility Strategy coupled with a variety of specific initiatives to make European transport greener, more resilient and affordable, including with the help of intelligent transport systems and digital solutions. It correctly stresses the importance of a multimodal transport system and the possibilities with automated mobility, which can be enabled by digital tools. To address existing shortcomings such as lack of data, cooperation, and interoperability, the Commission wants to update existing interoperability rules and to create the common European mobility data space, which would work in synergy with the other planned data spaces, notably the common European energy data space.[55]

For the agricultural sector, there are several important initiatives and developments that could help address this sector's large energy footprint directly and indirectly, including with the help of digital solutions. The Common Agricultural Policy as well as the EU's Farm to Fork Strategy recognise the role digital solutions can play in improving the farming sector. Moreover, the Commission's strategy for data envisages the establishment of a common European agricultural data space to help process and analyse production and other data, which can support greater sustainability, including energy savings and energy efficiency.[56]

When it comes to addressing the indirect energy footprint, the disruption to the supplies and higher prices of petrochemical fertilisers, caused by the Russian war, is an opportunity to reduce related vulnerabilities by improving nutrient and pest management, and accelerating uptake of biological alternatives. While the Commission's recent Communication on fertilisers could have pushed this more strongly, it proposes a new European Innovation Council, which will offer €65 million to support AgTech start-ups for the fast development of 'deep-tech innovations to maintain and improve crop yield with environmentally friendly technologies'.

2.2. ENABLING FRAMEWORK FOR DIGITALISING THE ENERGY SYSTEM

In October 2022, the Commission released the EU Action Plan on digitalising the energy system.[57] The Action Plan recognises the potential of digital solutions to drive the necessary deep digital and sustainable transformation of the energy system as part of the European Green Deal.

The Action Plan on digitalising the energy system recognises the potential of digital solutions to drive the necessary deep digital and sustainable transformation of the energy system as part of the European Green Deal.

This plan is a welcome addition to the EU's existing regulatory and policy framework on energy. While digitalisation has been considered in individual initiatives in different ways (e.g. the Renewable Energy Directive (RED), Energy Efficiency Directive (EED), Energy

Performance of Buildings Directive (EPBD)), the Action Plan could help the EU shift from a fragmented to a more comprehensive approach when it comes to enabling and driving the twin green and digital transition.

For digital transition to succeed, several basic preconditions must be met. This requires infrastructure. It requires skills. It requires addressing concerns related to data protection and privacy as well as cybersecurity. The Action Plan rightly builds on these needs, and puts forward proposals also for an energy data space and improving the energy consumption of the ICT sector itself.

The plan is, however, not complete. For example, when it comes to enabling energy efficiency and energy savings on the demand side, the plan assumes that the roll-out of digital tools such as smart meters will automatically change user behaviour by giving them access to information about their energy consumption. This fails to recognise that consumers also need guidance and advice on what to do with the information collected on their energy usage.

Given the urgency to accelerate the clean energy transition and the potential for data and digital solutions to support these efforts, the EU must implement the proposed steps in the Action Plan and start aligning the energy and digital transitions without delay.

It is very important that the Action Plan considers the energy consumption of electronic products, data centres and blockchain. Given the urgency to accelerate the clean energy transition and the potential for data and digital solutions to support these efforts, the EU must implement the proposed steps in the Action Plan and start aligning the energy and digital transitions without delay.

2.2.1. Energy data space, consumer protection and empowerment

One important enabler for the digital transformation of the energy system can be the common European energy data space. While the Action Plan does not specify in detail which data should be shared in the energy data space, it foresees that the data gathered can support flexibility services for the energy markets and grids, smart charging of electric vehicles as well as smart energy management in buildings.

The EU Data Strategy adopted in 2020 set out the idea of establishing a single market for data based on common European data spaces. To facilitate data sharing and improve the interoperability of data, these EU-wide data spaces are to be developed in several strategic sectors in addition to energy, such as health, environment, agriculture, mobility, finance, manufacturing, public administration, and skills. The basis for a European data space for energy was laid out in the Data Governance Act, adopted by co-legislators in May 2022, which aims to improve access to and facilitate data sharing across sectors and EU countries.

The Action Plan rightly refers to the importance of sharing energy-related data via secure data transfer. It also aims to align the energy data space with the other EU data spaces, in particular the mobility data space. The steps to prepare the deployment of the energy data space described in the Action Plan include setting up a Smart Energy Expert Group, including a Data for Energy working group to ensure that the need for data exchange is balanced with data privacy considerations. As the Commission still needs to adopt implementing acts, it remains to be seen how far interoperability of data exchange and access to data within this space will be ensured. Considering that the digitalisation of the energy system is a policy priority for the Commission and that easy data exchange is very much needed for the integration of more solar panels, heat pumps and electric vehicles in the energy system, the energy data space should be deployed as soon as possible.

The slow roll-out of smart meters in the EU might be an additional barrier to the development of the energy data space. The Action Plan rightly highlights that all consumers should be aware of the energy consumption of their homes through smart meters and of their appliances through the European Product Registry for Energy Labelling (EPREL). It also recalls that these tools need to be available to all consumers at an affordable price. While the Action Plan does not specifically address consumers' reluctance to embrace intelligent metering devices, high investment price and data privacy concerns, member states have a huge responsibility to speed up the introduction and use of smart meters and to address their citizens' concerns.

On consumer protection more generally, the Action Plan highlights that requiring consumers' consent should a third-party wish to access their data can be important for guaranteeing consumers' privacy. This would be addressed in the proposal for a Data Act, which is still negotiated by the co-legislators. As additional efforts may be needed for consumer protection, when digitalising the energy sector, the Commission's plan to launch a Fitness Check of EU consumer law on digital fairness should be implemented without delay.

The Action Plan recognises that digital literacy is a basic precondition for consumers to use the digital tools. This is a challenge: only 54% of EU citizens in 2021 had basic digital skills.[58] The Commission therefore rightly identifies the necessity for digital tools that consider the needs of consumers, such as older people, by design. To push for the development of such consumer-focused digital tools, the Commission plans to bring research and innovation projects together by mid-2023 to identify strategies for engaging consumers in the design of digital tools. Another welcome initiative is the Commission's plan to develop a common reference framework with the member states for developing an app with customised energy savings tips.

2.2.2. Digitalisation of the electricity grid, participation of energy communities and the need for trained professionals

To support the digitalisation of energy infrastructure, the Action Plan envisages the establishment of a digital twin of the European electricity grid over the next few years. On the one hand, the digital twin can provide a holistic, real-time overview of the grid, and therefore be an opportunity to simulate the integration of renewables, interconnector and possible cyberattacks. On the other hand, by further connecting the electricity grid to IoT, the digital twin can increase the risk of cybersecurity threats, which need to be addressed with strong cybersecurity measures. Moreover, the future definition for common smart grid indicators by the European Union Agency for the Cooperation of Energy Regulators (ACER) and the national regulatory authorities announced in the Action Plan is a welcome initiative.

The Action Plan rightly recognises the potential of digital tools to support (renewable) energy communities and drive collective and citizen-led energy-related actions for the benefit of the clean energy transition.

The Action Plan also considers the potential of digital tools to support (renewable) energy communities and drive collective and citizen-led energy-related actions for the benefit of the clean energy transition.[59] These can take the legal form of an association, a cooperative, a partnership, a non-profit organisation or an SME. Energy communities make it easier for citizens to team up and invest together in energy assets or renewable installations and can involve whole villages or towns, facilitating a scale-up of interaction with the electricity grid. The community can then engage in energy sharing or P2P trading of the electricity produced from joint investment. Digital Platforms can support such energy sharing and P2P exchange.

To get the best out of digital solutions in support of energy communities, the Action Plan announces an Energy Communities Repository to list relevant digital tools and provide guidance for energy sharing and P2P trading. Additionally, an experimentation platform for the simulation of energy communities, including blockchain-enabled energy trading, will be set up. This guidance should be published soon and be accompanied by advice on cybersecurity measures for energy sharing and P2P exchange.

The EU desperately needs workers with the right skillsets, including digital skills, to support the rapid deployment of clean energy. As part of the EU's Pact for Skills, the Action Plan announces a new large-scale partnership on the digitalisation of the energy value chain by the end of 2023, and hopefully sooner, given its importance.

Additionally, the EU's Digital Compass aims at increasing the number of ICT specialists to 20 million by 2030 and ensuring that a minimum of 80% of the population have basic digital skills. By 2030, 75% of European companies should be using Cloud, AI, Big Data and more than 90% of SMEs should reach at least a basic level of digital intensity. The EU institutions have reached agreement on the policy programme Path to the Digital Decade that underpins these objectives. Progress on the Digital Compass will be measured by key performance indicators based on an enhanced Digital Economy and Society Index (DESI). A first annual report on the 'State of the Digital Decade' should be adopted in June 2023.

2.2.3. Cybersecurity

The Action Plan rightly recognizes the importance of cybersecurity. It mentions the recently published proposal for a Cyber Resilience Act, which aims to establish harmonised cybersecurity rules for products with digital elements and a duty of care for the whole lifecycle of these products. Smart meters would be classified as critical products representing a greater cybersecurity risk and would therefore need to undergo stricter conformity assessment procedures than other products.

The Action Plan also refers to the soon to be adopted review of the Network and Information Security Directive (NIS), which aims to define the energy sector as critical infrastructure and provide obligations for cybersecurity as well as coordinated risk assessments of critical supply chains. Particular attention is expected to be paid to the renewable energy grid and the supply chain.

The Commission also plans to propose delegated acts on establishing a network code for cybersecurity aspects of cross-border electricity flows and on the cybersecurity of gas and hydrogen networks. Furthermore, the Commission has already proposed a Council Recommendation for better resilience of critical infrastructures in priority sectors, including energy, and a Directive on the Resilience of Critical Entities. This would create an overarching framework to address the resilience of critical infrastructure in respect of natural and man-made, accidental and intentional hazards.

These are important steps to increase the cybersecurity of connected devices and to create a digitalised energy infrastructure. However, cybersecurity provisions should also be part of other EU legislation related to digital tools and data use in buildings, transport and industry.

2.2.4. Energy consumption of the ICT sector

As another important development, the Action Plan addresses the growing energy demand of the ICT sector (electronic products, data centres and blockchain) that comes with increasing digitalisation.

Electronics already need to comply with certain efficiency requirements set by the Ecodesign Directive and have an energy label as set by the Energy Labelling Directive. New electronics are to be accompanied with a QR code which enables access to product information through the EPREL database. Access to information on EPREL depends on the profile of the user (e.g. citizens do not have the same access as law enforcement authorities).

Looking beyond current ecodesign requirements, the Commission's proposal for the Ecodesign for Sustainable Products Regulation aims to introduce a framework for digital product passports with information about energy use and set mandatory minimum sustainability requirements for the public procurement of electronic and ICT products.

As products such as smartphones and tablets are not currently covered by ecodesign-related legislation, it is good that the Action Plan aims to further extend ecodesign rules. The Plan is also correct in identifying the need for action to address the energy consumption of devices in use. The Commission wants to propose energy labelling for ICT devices in operation such as computers. This information needs to be made available in a user-friendly way if it is to be read and used by consumers.

The Action Plan also addresses the energy consumption of telecommunication networks and rightly announces the development of common indicators for the environmental footprint of electronic communications services and an EU Code of Conduct for the sustainability of telecommunication networks. Addressing the energy consumption during daily digital actions, such as emailing, video streaming or archiving of digital files, with a planned awareness-raising and communication campaign for European citizens is a good start that should be extended to other daily digital activities.

Data centres must become climate-neutral, energy-efficient and resource efficient by 2030. Central to this will be increasing the share of renewables in powering data centres.

To tackle the expected increase in energy consumption by data centres in years to come, the Action Plan envisages the setup of a new environmental label for data centres, although only by 2025. Introducing an energy label for servers and data-storage products under the revised ecodesign rules is a good initiative that should not be delayed. Furthermore, the Commission is expected to explore options for introducing separate reporting lines for large companies and businesses listed under the new Corporate Sustainability Reporting Directive regarding indirect greenhouse gas emissions related to the purchase of cloud computing and data centre services.

However, the EED announcement to establish sustainability indicators for data centres, to measure how efficiently energy is used, how much energy comes from renewable energy sources, the reuse of waste heat and the usage of freshwater to be used on a voluntary basis, is not mentioned further in the Action Plan.

The Action Plan re-emphasises the goal to ensure that data centres become climate-neutral, energy-efficient and resource efficient by 2030. Central to this will be increasing the share of renewables in powering data centres. The Action Plan however neglects the role that data centres can play in the demand-side management of renewable sources in the energy system. As big users of energy, they could play a role in contributing to increasing flexibility and allow a higher share of variable renewable energy, such as solar and wind, to be integrated to the system.[60] As a good step for resource efficiency, the Commission plans to promote the use of waste heat from data centres to heat homes and businesses under the provisions of the revised EED and RED and fund research on storage systems for waste heat.

As cryptocurrency mining and other blockchain technologies in energy markets and trading use a great amount of energy, it is good that the Action Plan announces international cooperation to develop an energy efficiency label for blockchain. Furthermore, the Commission is expected to publish a report about the environmental and climate impact of technologies in the crypto-asset market by 2025. As additional measures, the Commission invites member states to lower energy use by crypto-asset miners and to no longer offer tax breaks to crypto miners. Even though crypto mining can use renewable energy sources and apply more energy efficient mechanisms for blockchain operations, it remains an energy-intensive activity.[61]

2.2.5. EU funding programmes to support the digital transformation of the energy system

The EU Action Plan on digitalising the energy system is supported by several funding instruments at the EU level.

Under its 'Climate, Energy and Mobility' cluster, the Horizon Europe Programme provides funding for research and innovation pertaining to digital transformation in the European energy sector. This includes projects on establishing the grounds for a common energy data space, reinforcing digital know-how of local energy ecosystems, the development of digital solutions for existing hydropower operation and maintenance, and on the digital solutions for defining synergies in renewable energy value chains.

Other programmes aim to accelerate the twin green and digital transition in the energy sector in more direct ways. The Digital Europe Programme, designed to bridge the gap between digital technology research and market deployment, co-funds and supports the deployment of data and digital solutions in the energy sector through its AI Testing and Experimentation Facilities and so-called Digital Innovation Hubs.

The Connecting Europe Facility – Digital programme, on the other hand, aims to close the investment gap in digital infrastructure in Europe by using EU funds to leverage private sector financing. Its priorities include 'retrofitting' existing energy infrastructure across Europe with the required cross-border digital connectivity infrastructure.[62]

3. Policy recommendations

These recommendations are intended for the EU – namely, the European Commission, European Parliament and member states – unless specified otherwise.

► Strategic direction[63]

To achieve the objectives of the European Green Deal and reduce the dependence on fossil fuel imports, the EU must accelerate the clean energy transition. It must use all tools available to achieve this, including building on the power of data and digital solutions to speed up the development and roll-out of renewable energy and enhance energy efficiency and savings. It must play a pioneering role and aim to become the world's best in aligning the green and digital transitions for the benefit of people, business and the planet.

This twin energy and digital transition must unlock the potential, address the challenges and mitigate the risks related to digitalisation as an enabler of the clean energy transition. This includes addressing concerns around cybersecurity as well as the climate and environmental footprint of digitalisation itself.

The EU must use all the tools available, including its convening power, policies and financial tools, to harness the possibilities that sustainable digitalisation can offer for the clean energy transition. It must do so fast, through concrete actions, and in a comprehensive manner.

► The basics: Clean energy systems

- The EU must adopt ambitious 2030 targets for renewables and energy efficiency. The Renewable Energy Directive and Energy Efficiency Directive must be revised in accordance with the targets proposed by the Commission under REPowerEU (respectively 45% for renewables and 13% for energy efficiency compared to 2020 levels), not the original targets proposed under the Fit for 55 Package (respectively 40% and 9%).

- The EU's efforts to accelerate permissions for renewables must benefit from the digitalisation and cross-border harmonisation of national administrative processes and the establishment of 'one-stop permit-granting shops' for renewable project developers at member state level, while avoiding unwanted consequences, e.g. for the environment.

- The electricity market reform must ensure that adequate incentives for investments in clean energy remain in place, while allowing consumers to reap the benefits of low-cost, low-carbon electricity produced from inframarginal technologies such as renewables and nuclear.

- More must be done at both EU and member state level to mobilise citizens and small businesses to save energy, still by far the easiest and cheapest measure to reduce utility bills, deal with the energy crisis and address the climate emergency. The use of data and digital solutions can help with the outreach as well as with quantifying the budgetary benefits of simple actions households can take, such as turning the thermostat down by a few degrees.

- National measures to shield households and businesses from high energy prices must ensure that incentives to reduce energy use are retained. Direct intervention in market pricing via mechanisms like price caps is to be avoided. Targeted income support to vulnerable households and the worst affected businesses, financed via taxes on windfall profits generated by utilities and the oil and gas industry, must be prioritised.

► The basics: Smart energy systems

- Digital infrastructure:
  - The EU must ensure that basic digital infrastructure such as electronic components, software platforms, IoT, AI as well as 5G coverage are in place.

- Cybersecurity:
  - With cyber threats expected to increase in the future, the EU must adopt a forward-looking approach to cybersecurity and emerging technologies. It cannot afford to repeat the mistakes made with 5G, where the EU created a 5G Security Toolbox only after much delay and after the member states had taken very different approaches.
  - For safe data sharing in the EU common data space, including the energy data space, the EU should ensure that the body tasked with monitoring these spaces and advising the Commission on higher cybersecurity standards for data sharing – the European Data Innovation Board - works in a complementary way to ENISA.
  - The newly proposed Cyber Resilience Act, which follows a security-by-design approach for all products with digital elements, must be swiftly adopted by EU legislators.
- Data protection, privacy and sharing:
  - The EU should support the development of tools and means that allow citizens to decide at a granular level what happens with their data. These can include consent management tools, personal data management apps and data cooperatives or trusts that act as neutral intermediaries. As these tools are still to be developed, the EU should support research and development in this area and build on lessons learned and the wishes and needs of citizens.
  - As personal data spaces (mentioned also in the European Strategy for Data communication) can allow people to control their personal data. Negotiations on the Data Act between the Commission, Parliament and member states should carefully consider the potential of these spaces, including the right to portability of data for individuals.
  - Citizens and businesses should be enabled and empowered to use digital tools such as smart meters to get a better overview of their energy consumption and understand how to reduce it. As data protection concerns hinder the roll-out of smart metering, the EU should ensure that personal data is protected, and digital surveillance is avoided when using such metering tools.
  - As the common european data space is being developed, the EU should make sure that the EU energy data space is aligned with the other data spaces, including on mobility, agriculture, smart manufacturing and construction. Cross-references between the spaces are needed to guarantee a consistent system for data exchange. The common European Green Deal data space should be the overarching data space to ensure that all data spaces contribute to achieving the objectives of the Green Deal.
  - The Data for Energy working group, which will support the Commission in the roll-out of the energy data space, must bring together relevant stakeholders from the EU institutions and member states, while also considering the input of relevant business and civil society stakeholders.
  - To realise the full potential of the energy data space, it is necessary to ensure that it becomes a single platform for bringing together data on the generation, transmission, distribution and consumption of electricity, gas and heat in Europe.
- Digital skills:
  - Considering that 2023 is the European Year of Skills, the EU must step up its efforts and use available financial instruments to equip citizens with the necessary skills to make full use of digital tools in reducing their energy consumption and unlocking their potential to become prosumers in the energy system. The availability of innovative digital technologies does not automatically lead to their uptake or (smart) usage, and people's different levels of knowledge and needs must be addressed if the EU is to tackle the digital skills gap and benefit from existing and emerging digital solutions.
  - The EU should make sure that companies, especially SMEs, have access to available support through EU programmes such as Digital Europe to enable them to invest in digital technologies and improve the digital skills of their employees and workers through training. Initiatives to reach the objectives of the Digital Compass should be aligned with the EU Pact for Skills.
- Education and awareness raising:
  - Citizens should be informed about what it means to be a prosumer and how they can best use data and digital solutions such as smart meters to contribute to and benefit from the clean energy transition.
  - The EU, member states and local municipalities should roll out information campaigns on saving energy, including with the help of smart meters, and offer educational guidance on using existing digital solutions for energy efficiency.
  - Information campaigns should not only focus on the benefits digital tools can bring, but also explicitly address citizens' concerns about, for example, privacy, data protection, and electromagnetic radiation. Trust in digital technologies will be crucial to maximise uptake and enable the twin green and digital transition in the energy sector.

► Digital solutions for energy efficiency

- The EU's energy policies should better recognise and build on the potential of data and digital solutions to support the clean energy transition. The revised Energy Efficiency Directive and REPowerEU, for example, raise the ambition for energy efficiency but fall short in realising the potential of digital solutions to reduce energy consumption. As the Commission, the Parliament and the Council negotiate the revisions for the Energy Efficiency Directive and Energy Performance of Buildings Directive, they must actively consider how the EU can utilise data and digital solutions to enhance energy savings and efficiency, in alignment with the EU Action Plan on digitalising the energy system.

► Renewables

- Regulatory barriers at EU and national levels hindering prosumers from accessing the grid must be removed. The EU's electricity market reform must be 'prosumer-centric' and ensure that innovations, such as local P2P electricity trading schemes are incentivised instead of obstructed.

► Buildings and construction

- Rating the smart readiness of buildings – the capability to improve energy efficiency, and adapt the energy operation to the occupants' needs and to signals from the grid – should be mandatory under the Energy Performance of Buildings Directive.

- The European Commission must ensure that the Energy Performance Certificate databases, Building Renovation Passports and Digital Building Logbooks complement one another by automatically feeding information into each other.

- The EU must support local actors responsible for public and private buildings to invest in the renovation efforts of entire neighbourhoods or districts instead of single buildings. They should access information on how to use building information modelling and digital twins to assess the existing energy situation and model possible outcomes to plan the integrated energy efficiency measures.

- Property owners must be supported through training opportunities in the use of digital tools to assess the energy efficiency of their properties in order to incentivise renovation measures.

- The revision of the Energy Performance of Buildings Directive should be aligned with the objectives of the Sustainable and Smart Mobility Strategy, especially on private recharging infrastructure. Provisions for charging electric vehicles in the Energy Performance of Buildings Directive should be extended to existing buildings and all charging points should be ready for smart charging.

► Transport

- The EU, national and local policymakers must roll out incentives for shared mobility, the use of public transport as well as cycling and walking, and exchange on good practices with using data and digital solutions towards this aim.

- The EU should facilitate the development of digital solutions, such as online platforms that people can use to compare and choose sustainable travel options across Europe.

- The common european mobility data space should benefit from interoperable data from public authorities, including member states' national access points and private companies. This data space should underpin value-added services, including European sustainable mobility apps and urban planning. Particular attention should be paid to enabling data sharing with linked sectors such as buildings, energy, environment or health to fully leverage the benefits of e-mobility.

- The EU should explore possibilities to develop labels for mobility apps, with a grading system similar to that of the energy labels. European labelling encourages the development of common indicators, standardised measurement methods, and competitive comparison. The common European mobility data space should provide the required data about the emissions of different transport modes.

- Once the Commission has published its legislative proposal on multimodal digital mobility services to facilitate ticket buying for different modes of transport and to better integrate public transport, buses, coaches and rail services in the EU, it should be a priority of the co-legislators, the European Parliament and member states to make the proposal a reality.

► Industry

- The upgrade of the existing register on industrial emissions to a comprehensive and integrated industrial emissions portal, proposed under the revised Industrial Emissions Directive, must be implemented quickly so that data on the environmental performance of large industrial companies can be fed into the European Green Deal data space.

- Authorities in EU member states must ensure that prior to providing a permit for new industrial installations, the best available techniques, including digital solutions, boost energy savings and energy efficiency.

- As the first Digital Innovation Hubs (DIHs), the one-stop shops that provide companies with access to technical expertise and testing should become operational The EU should explore how DIHs can advise companies on using digital tools to save energy and to use energy more efficiently.

- **Agriculture**

  - The EU must continue to encourage, and where needed support, the use of data and the uptake of digitally enabled solutions in the agricultural sector to make it more sustainable and resilient, including by reducing its direct and indirect energy consumption. The Common Agricultural Policy (CAP) and initiatives such as the European Innovation Council's support for fast development and uptake of solutions will be important here.

  - Farmers should receive training to improve their digital skills. This could be achieved with the financial support of the European Agricultural Fund for Rural Development.

- **Energy and climate footprint of data and digital solutions**

  - Given the urgent need for energy efficiency improvements and the significant energy and climate footprint of the ICT sector, the EU must address the energy consumption of data centres, telecom networks and digital products. The Commission should publish the related initiatives, proposed in the EU Action Plan on digitalising the energy system, as soon as possible, preferably before 2025.

  - To reach the set objective of climate neutral data centres by 2030, the EU should support and accelerate the uptake of renewable energy to power data centres.

  - While the EU Action Plan on digitalising the energy system recognises the potential of data centres as a source of waste heat, urgent measures are needed to put this heat to use in surrounding communities.

  - The sustainability indicators for data centres, proposed in the Energy Efficiency Directive but not mentioned in the EU Action Plan on digitalising the energy system, should be quickly developed. These indicators should be mandatory for member states.

- **E-waste**

  - The EU must accelerate the transition to a circular economy, which also addresses the growing e-waste challenge. The EU must redouble its efforts to introduce ecodesign standards to make products more durable, recyclable and energy efficient.

  - The EU must revise its waste legislative framework to facilitate movements of e-waste across the Union, where it aims to enhance repair and recycling and support the circular economy.

  - The Commission should publish the proposals for an energy label for computers and possible new ecodesign rules for smartphones and tablets, announced in the EU Action Plan on digitalising the energy system, rapidly and before the end of 2024.

Conclusion

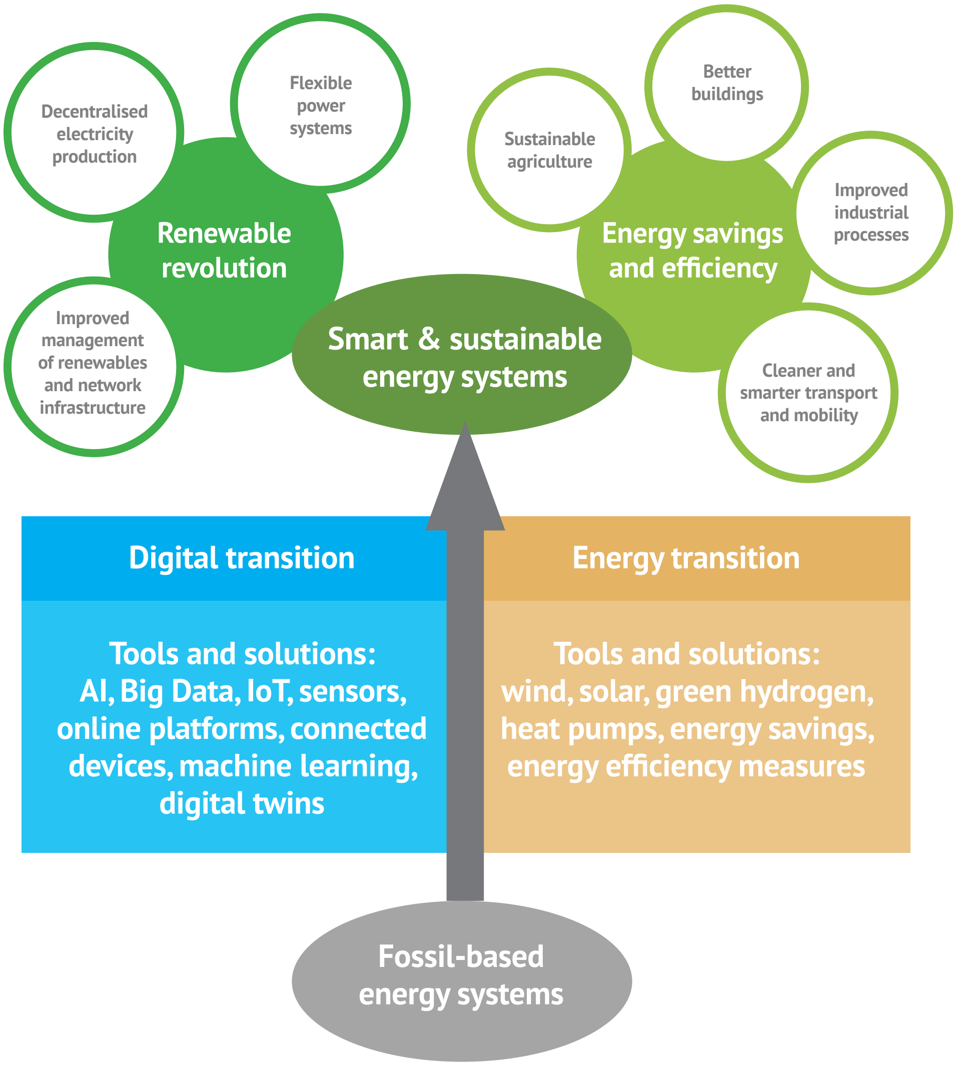
It is in our interest to steer the power of data and digital solutions to solve the greatest, most challenging problems we face in our societies and economies today. It is in our interest to turn digitalisation into a real enabler of the clean energy transition to accelerate the renewable revolution and support efforts for energy efficiency and savings. It is in Europe's interest to play a pioneering role in harnessing the possibilities of a digitalised energy transition.

At the same time, for the digital transition to become a true driver, enabler and catalyst for the energy transition, the climate and environmental footprint of digital solutions themselves need to be addressed. We want a sustainable digital revolution.

For digitalisation to deliver, it needs to be steered in the right direction. For this we need an adequate policy and financing framework to make sure that the twin transition contributes to greening the digital transition and ICT sector, and accelerates the clean energy transition by empowering people and businesses to play an active role (see Fig. 2). The European Commission's recent proposal for an EU Action Plan on digitalising the energy system serves as a valuable starting point, but implementation must now follow. In the middle of the biggest energy crisis in decades, the EU must use all tools available to accelerate a transition to a sustainable, secure and affordable energy system.

Fig. 2

TOWARDS SMART AND SUSTAINABLE ENERGY SYSTEMS



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NOTES

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The **Sustainable Prosperity for Europe** (SPfE) programme explores the foundations and drivers for achieving an environmentally sustainable and competitive European economy. While the climate crisis is a complex challenge to be addressed, non-action is not an option. Prospering within the planetary boundaries requires rethinking the existing take-make-dispose economic model, reducing pollution and being smarter with the resources we have.

The Paris Agreement and the Sustainable Development Agenda provide a direction for travel, and SPfE engages in a debate on the needed measures to achieve a fair transition to an environmentally sustainable economy and society. It focuses on areas where working together across the European Union can bring significant benefits to the member states, citizens and businesses, and ensure sustainable prosperity within the limits of this planet.

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