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2022 STRATEGIC FORESIGHT REPORT

Twinning the green and digital transitions in the new geopolitical context

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CONTACT
Unit A.5 Foresight & Strategic Communication
Secretariat General, European Commission, Brussels, Belgium
SG-FORESIGHT@ec.europa.eu
https://ec.europa.eu/info/strategy/strategic-planning/strategic-foresight_en

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A comprehensive, future-oriented and strategic approach to the twin transitions, recognising their inherently geopolitical nature, is necessary to further reinforce their synergies and address tensions.

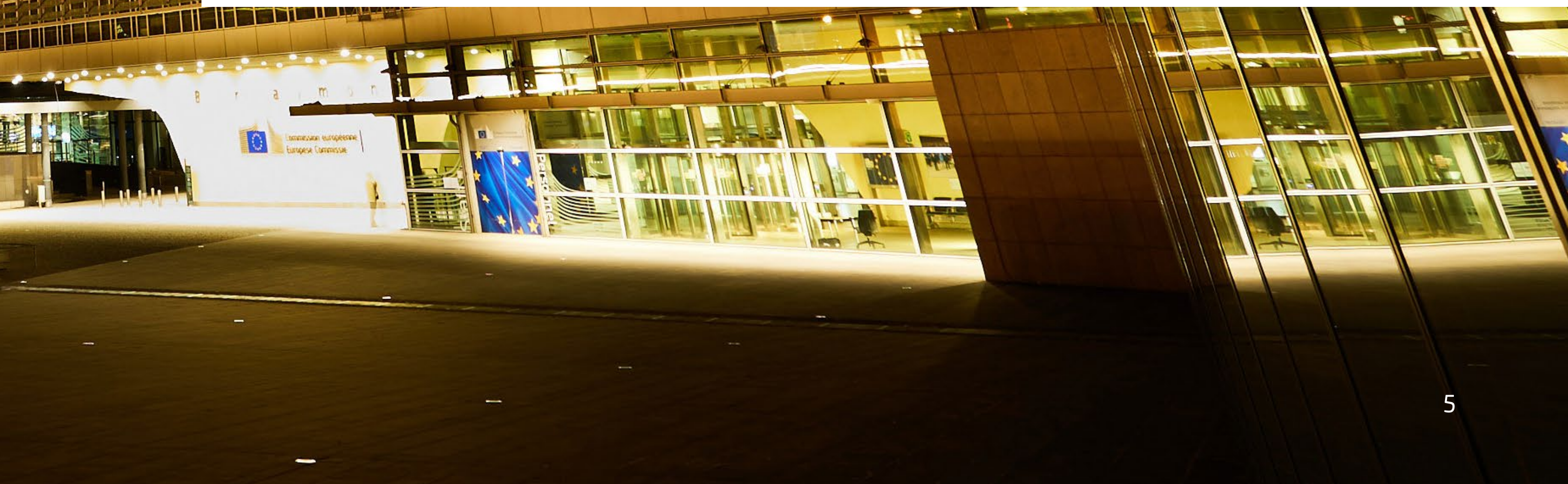
INTRODUCTION

1

The world is experiencing tectonic geopolitical shifts, reinforcing the megatrends already affecting the EU.[1] The long-term implications of Russia's military aggression against Ukraine, including for energy, food, economy, security, defence and geopolitics, will clearly affect Europe's path to achieving fair green and digital transitions. However, these and other future challenges will not divert the European Union from its long-term objectives. With the right set of policies, they can serve as a catalyst to speed up achieving them. Ultimately, this could foster our resilience and open strategic autonomy in various areas, from energy, food, security and critical supplies – including raw materials needed for the transitions – to cutting-edge technologies.

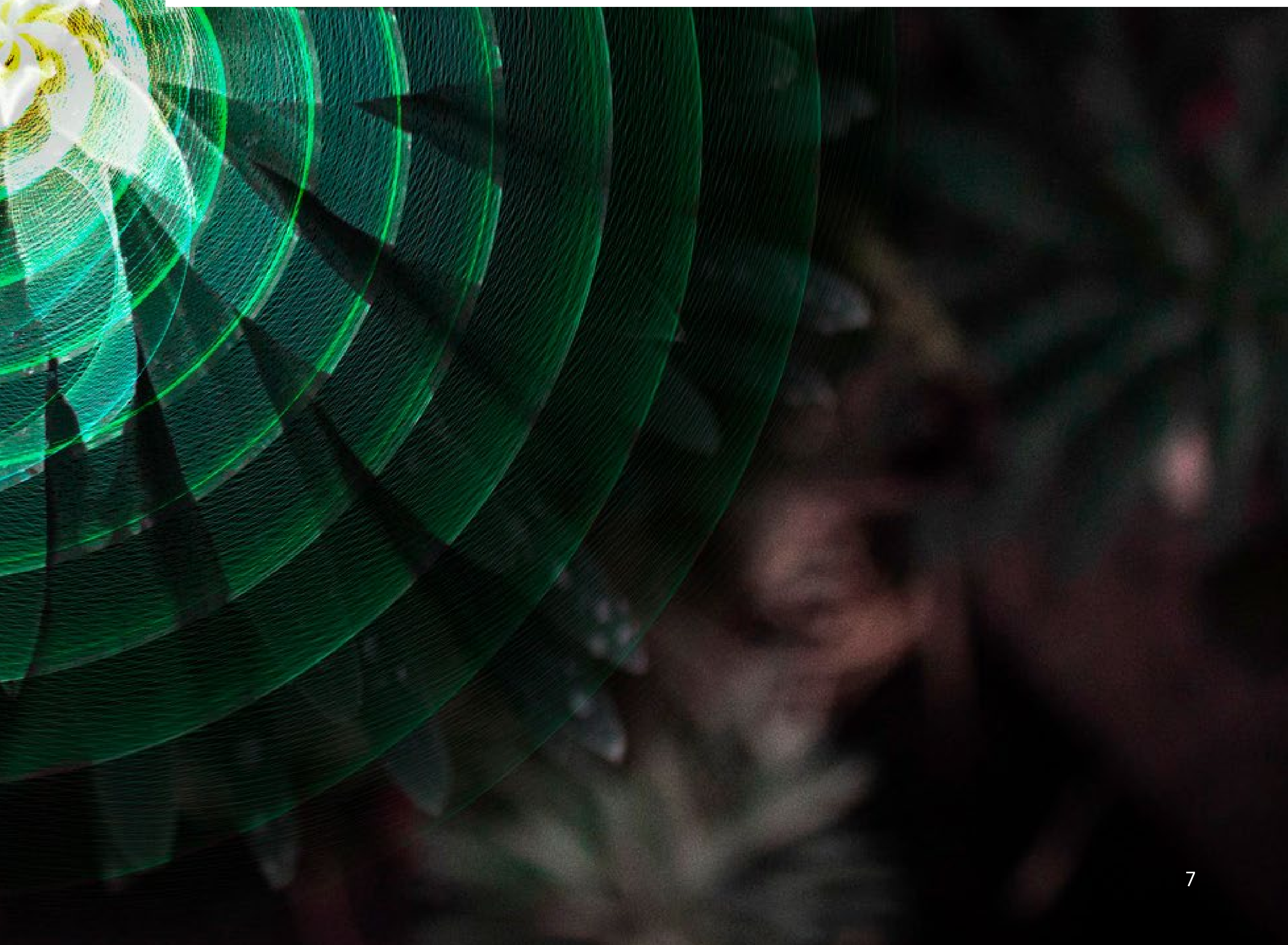
Against this new geopolitical backdrop, and drawing on a fully-fledged foresight exercise[2], the 2022 Strategic Foresight Report presents a forward-looking strategic reflection on the interactions between the green and digital transitions. Both are at the top of the EU's political agenda and their interplay will have massive consequences for the future. Their success will also be key for achieving the United Nations Sustainable Development Goals. While they are different in nature and each subject to specific dynamics, their **twinning** – i.e. their capacity to reinforce each other – deserves closer scrutiny. The green transition will not happen without the targets and policies set out in the European Green Deal, a cross-cutting strategy to reach climate neutrality and reduce environmental degradation by 2050. Until recently, the digital transition progressed with only limited sustainability considerations. To diminish adverse side effects and deliver its full potential for enabling environmental, social and economic sustainability, the digital transition requires appropriate policy framing and governance, as presented in the Digital Compass and Fit for 55[3].

On the path towards 2050, twinning will depend on the ability to deploy existing and new technologies at scale, as well as on various geopolitical, social, economic, and regulatory factors. Based on their analysis, this Communication identifies ten key areas where action will be needed. A comprehensive, future-oriented and strategic approach to the twin transitions, recognising their inherently geopolitical nature, is necessary to further reinforce their synergies and address tensions.



SYNERGIES AND TENSIONS BETWEEN THE GREEN AND DIGITAL TRANSITIONS 2

Digital technologies could play a key role in achieving climate neutrality, reducing pollution, and restoring biodiversity. By measuring and controlling inputs, and with increased automation, technologies like robotics and the internet of things could improve resource efficiency and strengthen the flexibility of systems and networks. Energy efficient blockchain-based data management across the lifecycle and value chain of products and services could galvanise the progress towards a more circular economy and competitive sustainability.[4] Digital technologies could also support monitoring, reporting and verification of greenhouse gas emissions for carbon pricing. Digital product passports enable enhanced material, component and end-to-end traceability and make data more accessible, which is essential for viable circular business models. Digital twins[5] could facilitate innovation and the design of more sustainable processes, products, or buildings. Quantum computing will facilitate simulations too complex for classical computers. Space-based data technologies providing real-time global information monitor progress towards sustainability. Data sharing or gamification can increase public participation in steering the transitions and co-creation of innovations.



Pursuing the green transition will also transform the digital sector. Renewables, renewable hydrogen, nuclear energy (including small modular reactors) and nuclear fusion technology[6] will all be important in the context of growing energy needs in the digital sector. Fostering policies aiming at climate neutrality and energy efficiency for data centres and cloud infrastructures by 2030, including by meeting their electricity demand with solar or wind energy, will support the greening of data-based technologies, such as big data analytics, blockchain, and the internet of things. However, delays in the deployment of renewable generation capacity and infrastructure can pose a challenge. Better location planning and use of suitable technologies could allow reusing the heat produced by data centres in tertiary sectors. Sustainable finance will help mobilise climate neutral investments in the digital sector. Better design, more circular business models and production patterns can help reduce electronic waste. On the demand side, consumption and practices of businesses and citizens will be important to reduce energy consumption when using digital technologies.

Unless digital technologies are made more energy-efficient, their widespread use will increase energy consumption. Information and communications technology (ICT) is responsible for 5-9% of global electricity use and around 3% of greenhouse gas emissions.[7] The lack of an agreed framework for measuring the environmental impact of digitalisation, including possible rebound effects[8], lead to marked variations in these estimates. However, studies show that ICT power consumption will continue to grow[9], driven by increasing use and production of consumer devices, demand from networks, data centres, and crypto assets. Power consumption will also rise due to the increased use of online platforms, search engines, virtual reality concepts such as the metaverse[10], and music or video streaming platforms. On the other hand, deployment of next generations of low-power chips[11] and more efficient connectivity technologies (5G and 6G, networks powered by artificial intelligence) might reduce the overall footprint of ICT.

Further tensions will emerge in relation to electronic waste and environmental footprints of digital technologies. Greater reliance on electronics, phones and computer equipment is accelerating the global production of electronic waste, which could reach 75 million tonnes by 2030.[12] In the EU, currently only 17.4% of this is properly treated and recycled[13], while electronic waste production is increasing annually by 2.5 million tonnes.[14] Without appropriate policies, every switch to new standards or technologies will require a massive replacement of equipment. For example, 5G and 6G will require users to replace equipment to fully reap their benefits, as most existing smartphones, tablets, and computers would only be backwards compatible.[15] Progress in digitalisation will also increase water usage, e.g. for cooling data centres or chip manufacturing. Mining and processing of the raw materials necessary for the transitions raises environmental and ethical concerns. Finally, climate and environmental risks will affect the lifespan and functioning of critical digital infrastructures. Over the next 30 years, the cost of damage from extreme weather events across the EU might rise by 60%.[16]

Overall, if properly governed, digital technologies can help create a climate neutral, resource-efficient economy and society, cutting the use of energy and resources in key economic sectors and becoming more resource-efficient themselves.

ARTIFICIAL INTELLIGENCE
supports connected mobility, helps to improve traffic management and to lower fuel consumption

BLOCKCHAIN
ensures greater transparency in the lifecycle and value chain of products, e.g. production, reuse, recycling and disposal of batteries

INTERNET OF THINGS
helps to monitor the condition of agricultural land or biodiversity

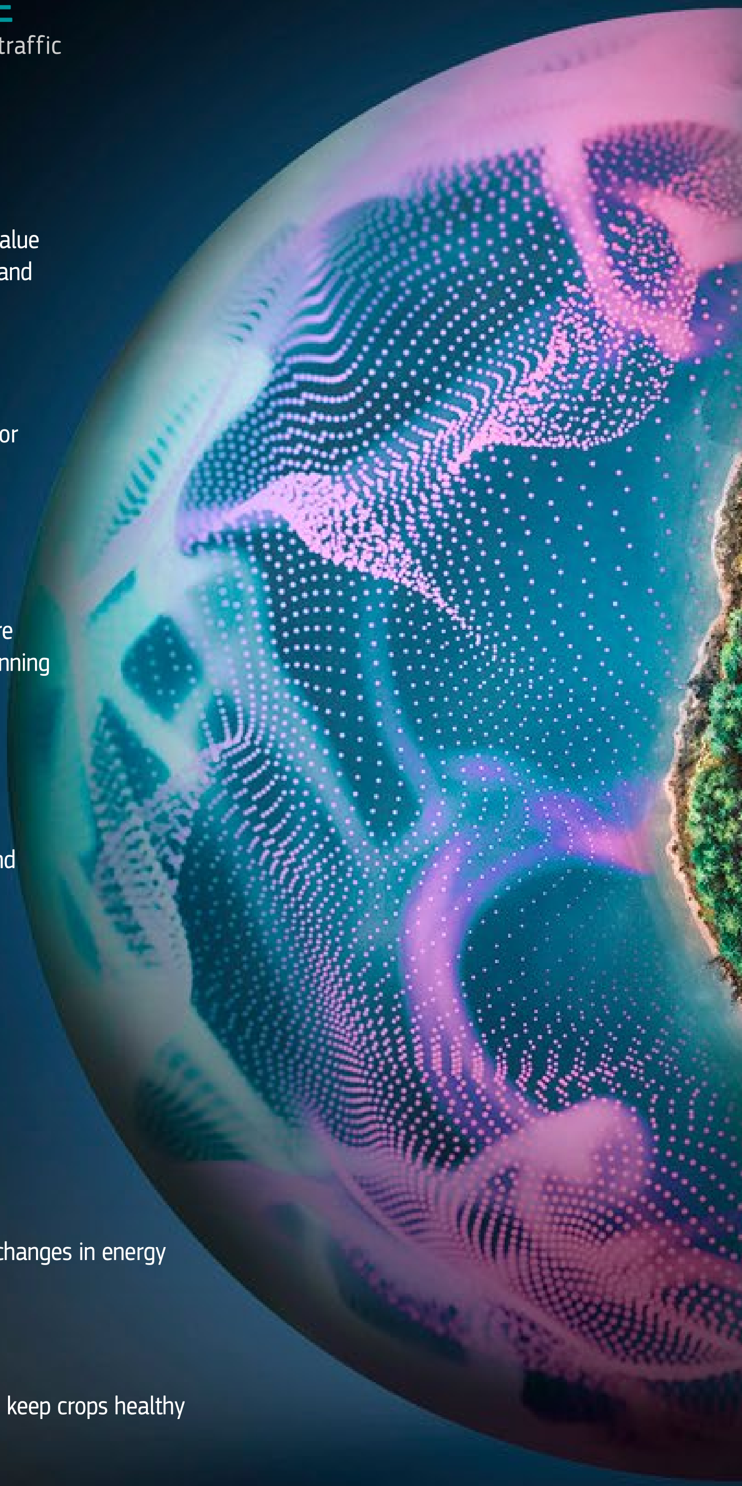
DIGITAL TWINS
facilitate innovation, testing and the design of more sustainable solutions, e.g. in buildings or urban planning

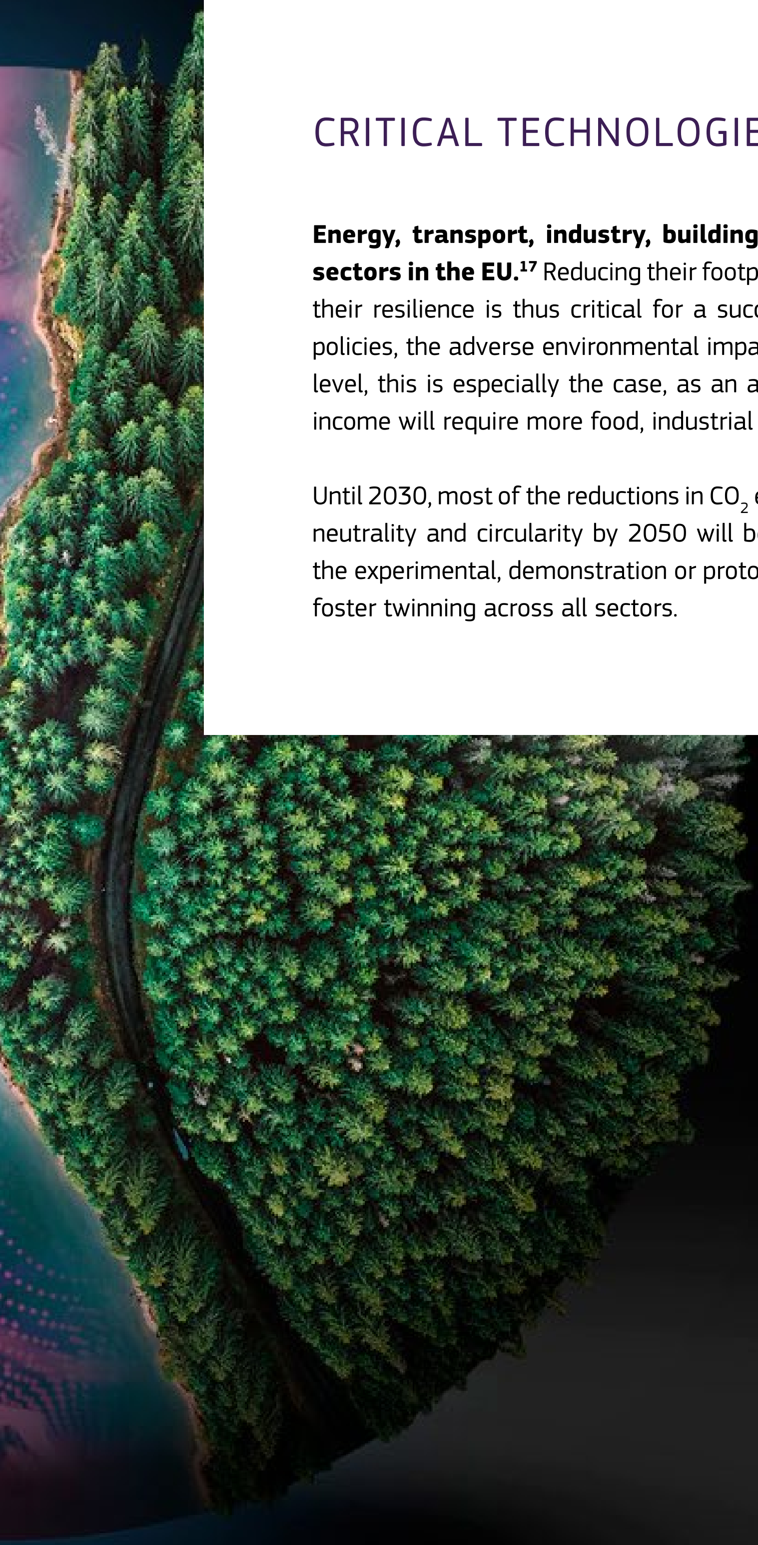
QUANTUM COMPUTING
improves our understanding of the biological and chemical processes needed to reduce pesticides and fertilisers

SENSORS
help measuring and controlling inputs to improve resource efficiency in industry

MICROGRIDS AND SELF-ORGANISED GRIDS
automatically monitor energy flows and adjust to changes in energy supply and demand, as well as weather conditions

SPACE-BASED SERVICES
support precision farming to reduce pesticides and keep crops healthy





CRITICAL TECHNOLOGIES FOR THE TWINNING 3

Energy, transport, industry, buildings, and agriculture are the most greenhouse gas emitting sectors in the EU.[17] Reducing their footprint, as also envisaged by the Fit for 55 package, and strengthening their resilience is thus critical for a successful twinning. However, without appropriate technologies and policies, the adverse environmental impact of these sectors might be more difficult to abate. At the global level, this is especially the case, as an anticipated population of 9.7 billion by 2050 with higher average income will require more food, industrial products, energy, housing, mobility, and water.

Until 2030, most of the reductions in CO_2 emissions will come from technologies available today. Yet, climate neutrality and circularity by 2050 will be enabled by the development of new technologies, currently at the experimental, demonstration or prototype phase.[18] This includes various digital technologies that might foster twinning across all sectors.

DIGITALISING ENERGY

Russia's military aggression against Ukraine has increased the importance of the geopolitical aspects of the clean energy transition, highlighting the need to accelerate it and to join forces to achieve a more resilient energy system and a true Energy Union.[19] The EU has put forward ambitious options to mitigate the impact of high energy prices on consumers (especially vulnerable and at risk of energy poverty) and industry and to strengthen the security of the EU's energy supply. In the medium term, an integrated EU system largely based on producing clean energy, diversifying energy supplies, as well as increasing energy savings and energy efficiency in all sectors, is the most cost-effective solution to reduce the EU's dependence on fossil fuels. For example, full implementation of the Fit for 55 package would lower the EU's gas consumption by 30% by 2030.[20] This is even more relevant as progress of the twin transitions will increase the demand for electricity.

Digitalisation can strengthen the EU's energy security. Digital technologies can support more efficient flows of energy carriers and increase interconnectivity between markets. They can provide the necessary data to match supply and demand at a more disaggregated level and close to real time. The forecasting of energy production and demand can be improved by digital technologies, novel sensors, satellite data and blockchain. This would allow smart grids to adjust consumption to weather conditions affecting the production of variable renewable energy. That will enable the effective management and distribution of renewable energy, facilitate cross-border exchange and prevent interruptions. Digitalisation will empower people and businesses, allowing them to shift consumption to green energy sources, adjust consumption, or even trade energy. 'Energy-as-a-service'[21] and data-driven innovative energy services can change the way energy suppliers and consumers interact. In addition, microgrids and self-organised grids can become a bottom-up way of managing the energy system. To increase resilience against hybrid threats, the digitalisation of energy systems will require enhanced cybersecurity capacities and secure, autonomous, and ubiquitous communications systems, such as secure space-based connectivity.

CHALLENGES

The EU needs to accelerate the clean energy transition, also in light of the current geopolitical context.

Novel sensors, space-based services and energy efficient blockchain will allow to adjust consumption to weather conditions affecting the production of variable renewable energy. They can also facilitate renewable energy management, distribution, cross border exchange and prevent interactions.

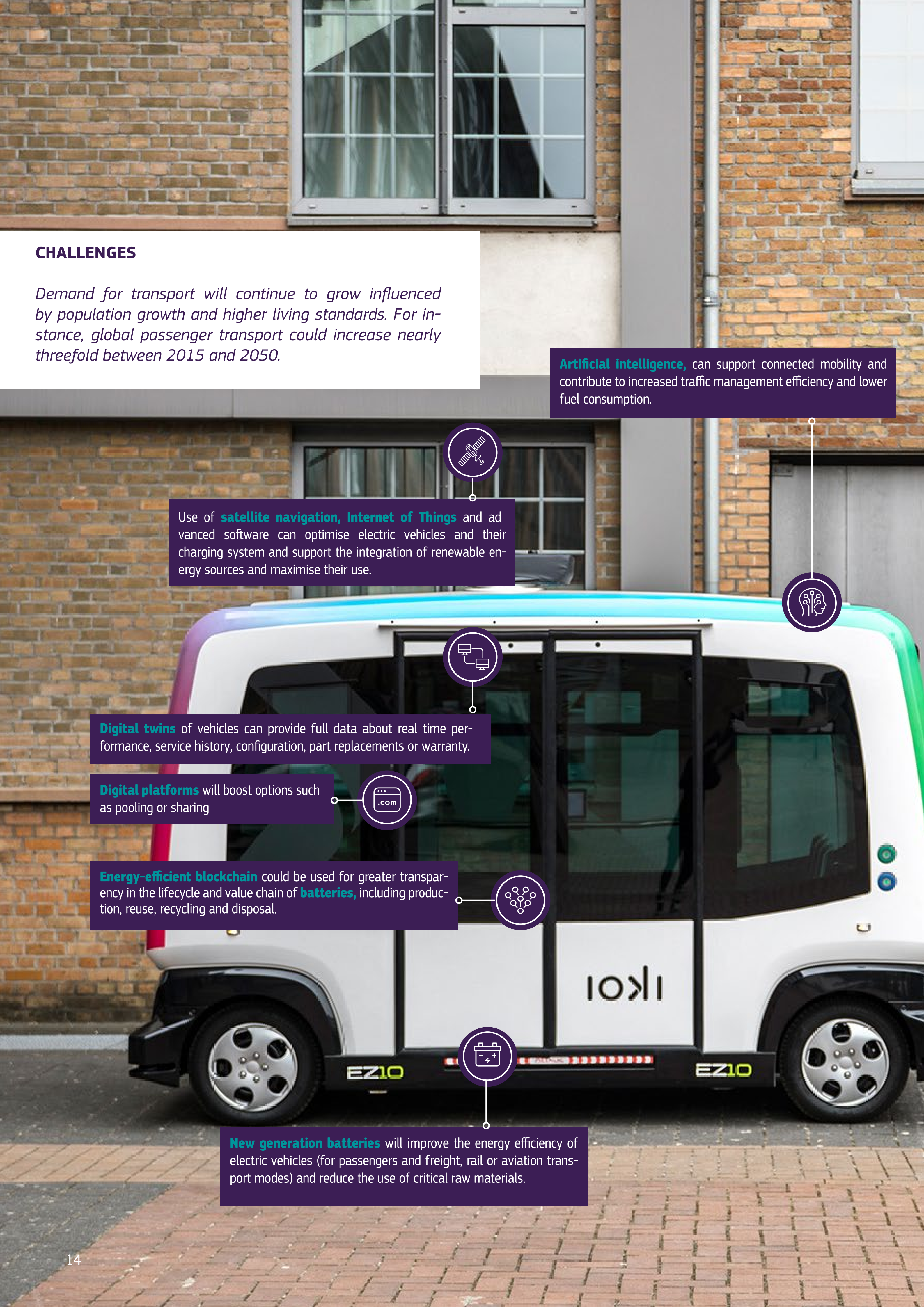
Energy-as-service (business model where energy service providers offer turnkey energy products and not only a simple form of energy) **and data-driven innovative energy service can empower people and business** to shift to green energy sources, adjust their consumption or even trade energy

Hydrogen technologies will enhance the use of green hydrogen as an energy carrier.

Microgrids, self-organised grids are more little and easier to manage than traditional grids, allowing for more flexibility, reaching for example more remoted areas. They are a more bottom up way of managing the energy system and make it easier to integrate in it renewable energy sources.

CHALLENGES

Demand for transport will continue to grow influenced by population growth and higher living standards. For instance, global passenger transport could increase nearly threefold between 2015 and 2050.



Artificial intelligence, can support connected mobility and contribute to increased traffic management efficiency and lower fuel consumption.

Use of **satellite navigation, Internet of Things** and advanced software can optimise electric vehicles and their charging system and support the integration of renewable energy sources and maximise their use.

Digital twins of vehicles can provide full data about real time performance, service history, configuration, part replacements or warranty.

Digital platforms will boost options such as pooling or sharing

Energy-efficient blockchain could be used for greater transparency in the lifecycle and value chain of **batteries,** including production, reuse, recycling and disposal.

New generation batteries will improve the energy efficiency of electric vehicles (for passengers and freight, rail or aviation transport modes) and reduce the use of critical raw materials.

ENABLING GREENER TRANSPORT WITH DIGITAL TECHNOLOGIES

Coupled with population growth and higher living standards, the demand for transport will continue to grow. Globally, passenger transport could increase nearly threefold between 2015 and 2050. In the EU, road passenger transport is expected to grow by around 21% and freight transport by 45% by 2050, notwithstanding efforts to shift more traffic to other modes such as rail or waterborne.[22] Urbanisation, growing consumer awareness, evolving costs of sustainable transport options (still relatively high today), and new business models (including when it comes to supply chain management) will also affect the sector. In addition, digitalisation may further accelerate the hybridisation of the workplace, affecting workers' local and cross-border mobility.

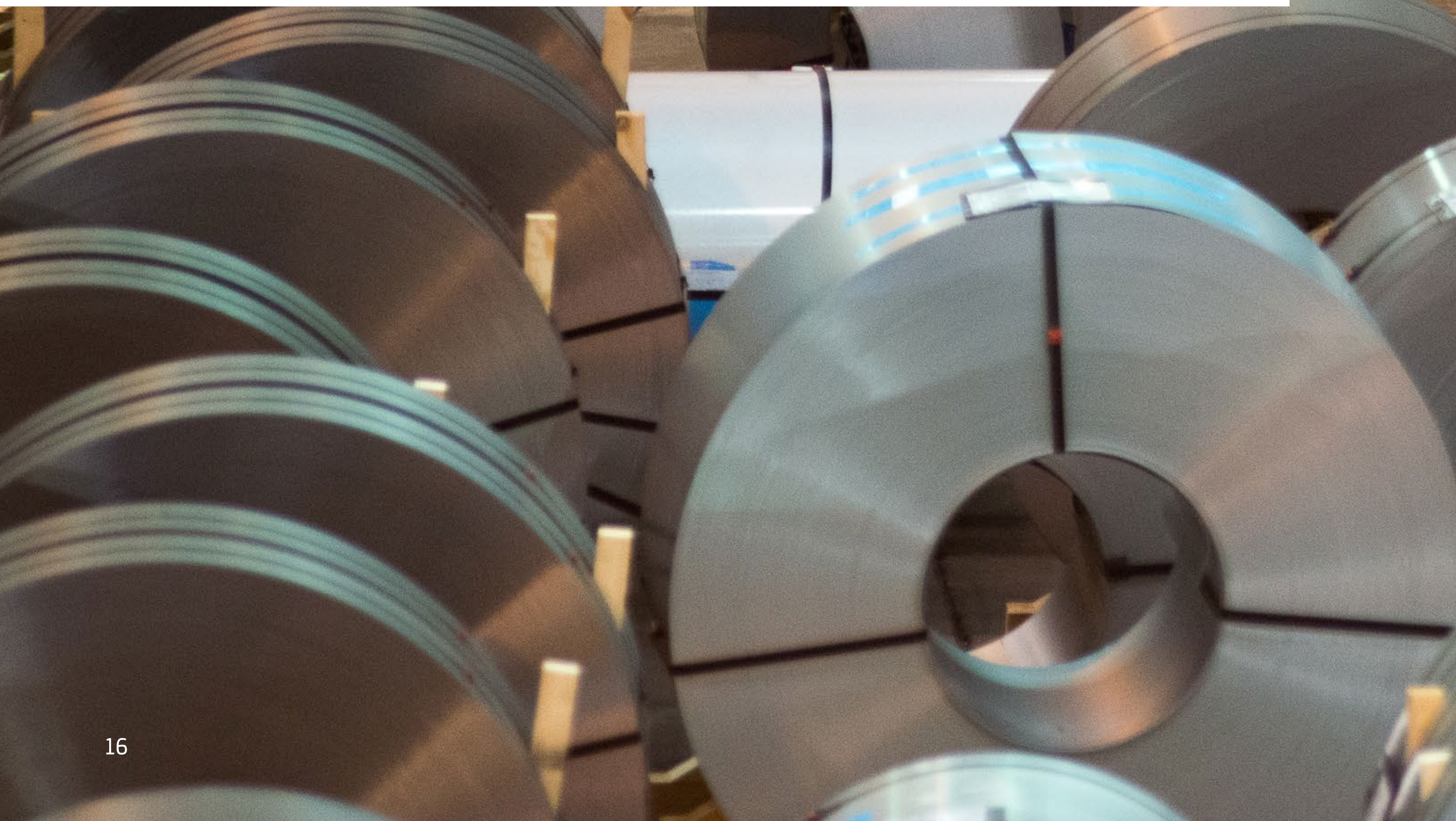
Combined with digital technologies, broader applications for next-generation batteries[23] will enable a major shift of mobility towards sustainability. This applies to various modes of transport, including passenger and freight, heavy-duty trucks, or aviation. For example, electric aircraft could potentially connect small regional airports throughout the EU. Managing the additional demand for electricity from transport, both for direct electrification and for mass production of renewable and low-carbon fuels for hard-to-decarbonise sectors such as aviation and waterborne, must be matched with improving the energy-efficiency of electric vehicles. It also requires a system-level approach for integrating sensors, computing power and advanced software. The use of data from vehicles and their environment can optimise charging. Bi-directional charging could provide flexibility to smart electricity grids, supporting the integration of renewable energy and maximising its use. Moreover, in combination with space-based services, digitalisation can support reliable solutions for connected and automated (including autonomous) vessels and vehicles, contributing to increased efficiency of traffic management and lower fuel consumption. Experimental designs such as test beds or living labs, which allow testing mobility solutions in a real-world environment, can help better understand the needs of end-users. Digital twins of vehicles can provide full data about real-time performance, service history, configuration, parts replacement, or warranty. Smart mobility will require major investments to develop new technologies and infrastructures, and access to various digital technologies such as artificial intelligence, cloud, or semiconductors. Moreover, to reach a critical mass and avoid dependence on large dominant actors, players in the sector will need to build partnerships, pool investments, and agree on common standards, infrastructures, platforms, and governance frameworks. Social acceptance of self-driving vehicles and the cost-related accessibility will also be key.

Digitalisation and artificial intelligence will also boost the emergence of more efficient multimodal mobility solutions, by combining all modes in a single, interoperable platform, such as 'mobility-as-a-service' or 'transport-as-a-service'. This might raise efficiency, consumer choice, accessibility, and affordability, notably of public transport. In addition, digital platforms will boost other options such as pooling and sharing. Digital technology is also key to ensuring that connected multimodal mobility services emerge in cities, as well as remote and rural regions, allowing citizens and businesses to access and choose between different options for both passenger and freight transport. In addition, new low-emission, digital and artificial intelligence-based technologies and solutions, such as drones, have the potential to offer a wide spectrum of new applications and services, from goods' delivery to medical assistance. This will require further interoperability between different modes, operators and platforms, and ubiquitous connectivity. In particular, better and broader access to mobility data will help public authorities monitor and plan transport activities, infrastructure and services and better match supply and demand at a lower cost and environmental impact. Access to data is also key to improving traffic management and giving customers and businesses a wider choice of sustainable mobility solutions.

GALVANISING THE INDUSTRY'S CLIMATE-NEUTRALITY THROUGH DIGITAL TECHNOLOGIES

To be on track for climate neutrality in 2050, already by 2030 the EU industry will need to decrease its CO_2 emissions by 23% compared with 2015.[24] Industry is globally responsible for about 37% of total final energy consumption[25] and about 20% of greenhouse gas emissions.[26] Four energy-intensive industries – steel, cement, chemicals, pulp, and paper – account for around 70% of its total global CO_2 emissions. They are also the largest EU industrial energy users.

Digital technologies will be important to manage the supply and demand of large industrial energy users in a system with diverse sources and feedstock. Smart meters, including sub-meters, and sensors could increase energy efficiency, by providing real-time information about its consumption and feeding into the energy management tools. Supervisory control, big data analytics and data acquisition[27] systems will improve the efficiency of industrial processes as well as process data to enable smarter decisions. Digital twins will help improve system designs, test new products, monitor and ensure preventive maintenance, assess the product lifecycle, and select optimal materials. Data-driven optimisation will help improve existing materials, develop greener alternatives, and prolong their lifetime. Monitoring and tracking provide information on materials or parts used in products, which could boost circularity through better maintenance and high quality closed loop recycling. Integration of manufacturing, digital and other advanced technologies, such as robotics or 3D and 4D[28] printing, will also have a major role to play. Uptake of digital solutions by the industrial sector requires higher levels of technological readiness and cybersecurity to protect the data of industrial processes and the integrity of their functioning.



CHALLENGES

To achieve the 2050 target for climate neutrality, the EU industry will need to cut its CO_2 emissions by 23% already by 2030.

Digital twins will improve systems process design, test new products and select optimal materials.

Data driven optimisation will improve existing materials, develop greener alternatives, prolong their lifetime and increase the possibilities for recycling.

Sensors will increase energy efficiency providing real time information about consumption, feeding into energy management tools.

GREENING BUILDINGS WITH DIGITALISATION

Demographic trends and urbanisation will drive changes in demand for buildings. Growing urban population will double the size of the global building stock by 2060. In the EU, the number of people living in predominantly urban and intermediate regions might reach 80% by 2050.[29] There will also be more small-size households, likely to consume more energy per person than those bigger in size. These trends, matched with the use of digital appliances for remote work, education, smart or independent living, will intensify the energy consumption of buildings. In the EU, this sector currently accounts for 40% of energy consumption, while 75% of the building stock is energy inefficient.[30]

To achieve climate neutrality and significant benefits from a zero-pollution perspective, new buildings will need to be zero-emission by 2030 and one fifth of the existing ones will need to be retrofitted.[31] Reaching climate neutrality in the sector would require replacing fossil fuel heating with sustainable alternatives, such as heat pumps, reducing the carbon footprint from water use and improving overall energy performance, while ensuring that solutions are available to all. This will contribute to the EU's objective of renovating 35 million energy-inefficient buildings by 2030.[32] Smart buildings and meters could help achieve these goals and tackle energy poverty. By 2030, building information modelling could further increase the sector's energy and water efficiency, providing long-term analysis of design choices in construction and use of buildings. Availability of anonymised data, smart appliances, as well as consumer behaviour will enable targeted investments in renovations. Digital logbooks and life-cycle analysis will be necessary to assess, report, store, and track information on whole-life emissions, and will help reduce the environmental impact of materials and help prevent the use of toxic ones. Digital twins could change the way urban spaces are planned, monitored, and managed. This could translate into reduced urban emissions, increased resource efficiencies and quality of life, better use of building space, and could make buildings more resilient to hazardous events.

CHALLENGES

Demographic trends and urbanisation will boost the changes in demand for buildings. Growing urban population will double the size of the global building stock by 2060.

Digital twins could enhance planning, monitoring and management of urban spaces. It could also translate in reduced urban emissions, increased resource efficiencies and quality of life, increasing the resilience of buildings.

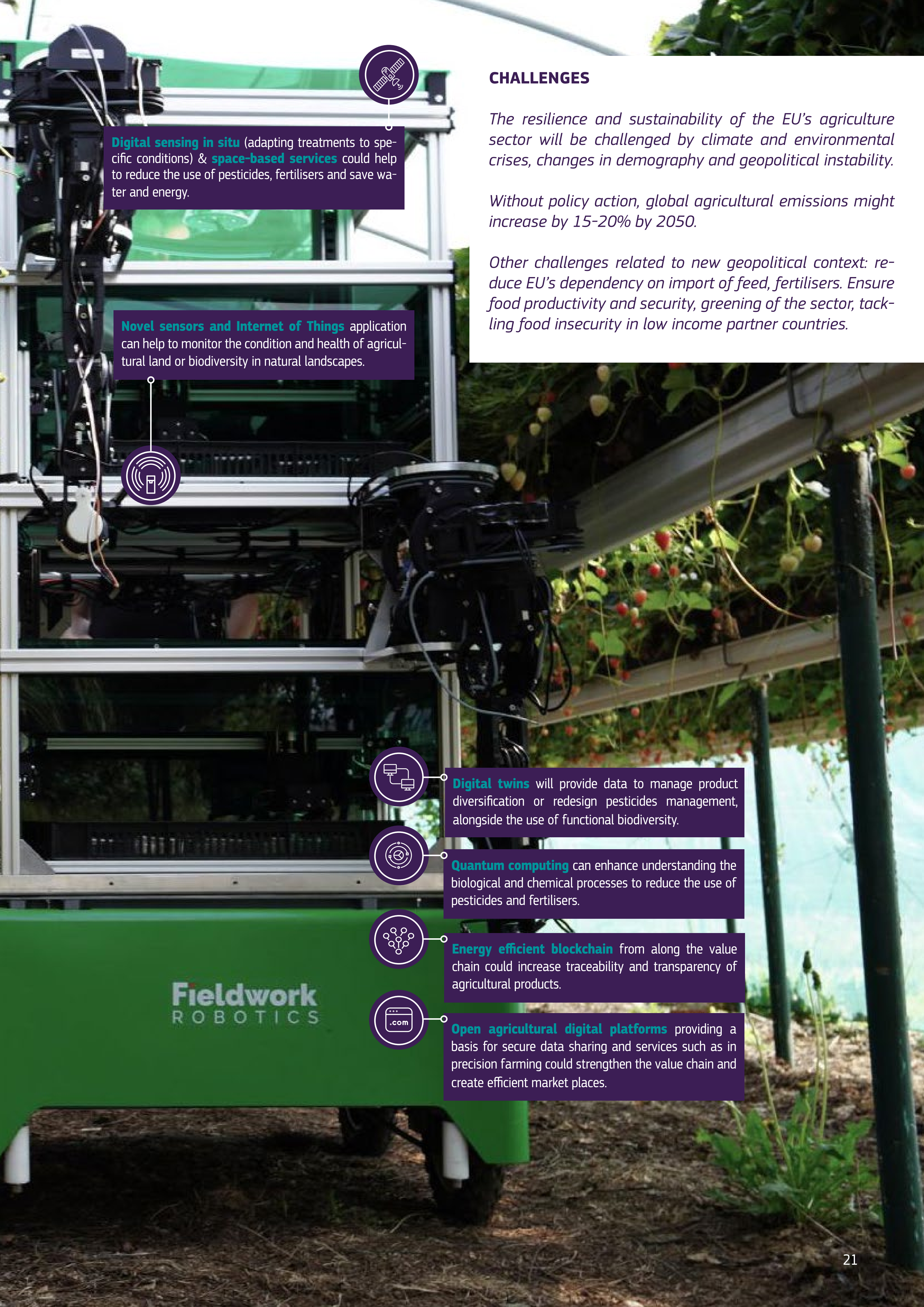
Building information modelling could increase the sector's energy efficiency, providing long-term analysis of design choices in construction and building use.

Digital logbook and **life cycle analysis** will help reduce the environmental impact of materials, tracking information on emissions.

SMARTER AND GREENER AGRICULTURE

Climate and environmental crises, changes in demography and geopolitical instability will challenge the resilience of the EU's agriculture and its path to sustainability. Without policy action, global agricultural emissions might increase by 15-20% by 2050. By that time, 10% of the global area currently fit for crops and livestock is projected to be climatically unsuitable.[33] Other threats will appear for the biosphere, water, soil, or biodiversity. In the new geopolitical context, the EU needs to reduce its dependence on import of feed, fertilisers, and other inputs. This has to happen without undermining productivity, food security or the greening of the sector, and while tackling food insecurity in low-income partner countries.

If properly deployed, digital technologies can enable smart and greener farming. The increased use of digital sensing in-situ (to adapt treatments to specific conditions) and EU space-based services could reduce the use of water, pesticides, fertilisers, and energy, which will also benefit human and animal health. Digital twins will provide data to manage the diversification of products and use functional biodiversity to redesign pest control. Quantum computing, in combination with bioinformatics and plant genomics, can enhance the understanding of the biological and chemical processes needed to reduce pesticides and fertilisers. Digital platforms facilitating local distribution and avoiding food waste could boost local production and shorten consumption circuits. Satellite data, sensors, blockchain, and data from along the value chain could increase traceability and transparency. Open agricultural digital platforms providing a basis for secure and trustworthy data sharing and digital services, such as precision farming, could strengthen fair collaboration in the value chain and create efficient marketplaces. Broader uptake of these technologies will require lower installation and maintenance costs and higher connectivity in peripheral and rural areas. In addition, digital solutions developed for standardised processes will need to support more diversified farming models. Trust, high levels of security, and appropriate skills will determine the uptake of twinning-related technologies.



CHALLENGES

The resilience and sustainability of the EU's agriculture sector will be challenged by climate and environmental crises, changes in demography and geopolitical instability.

Without policy action, global agricultural emissions might increase by 15-20% by 2050.

Other challenges related to new geopolitical context: reduce EU's dependency on import of feed, fertilisers. Ensure food productivity and security, greening of the sector, tackling food insecurity in low income partner countries.

Digital sensing in situ (adapting treatments to specific conditions) & **space-based services** could help to reduce the use of pesticides, fertilisers and save water and energy.

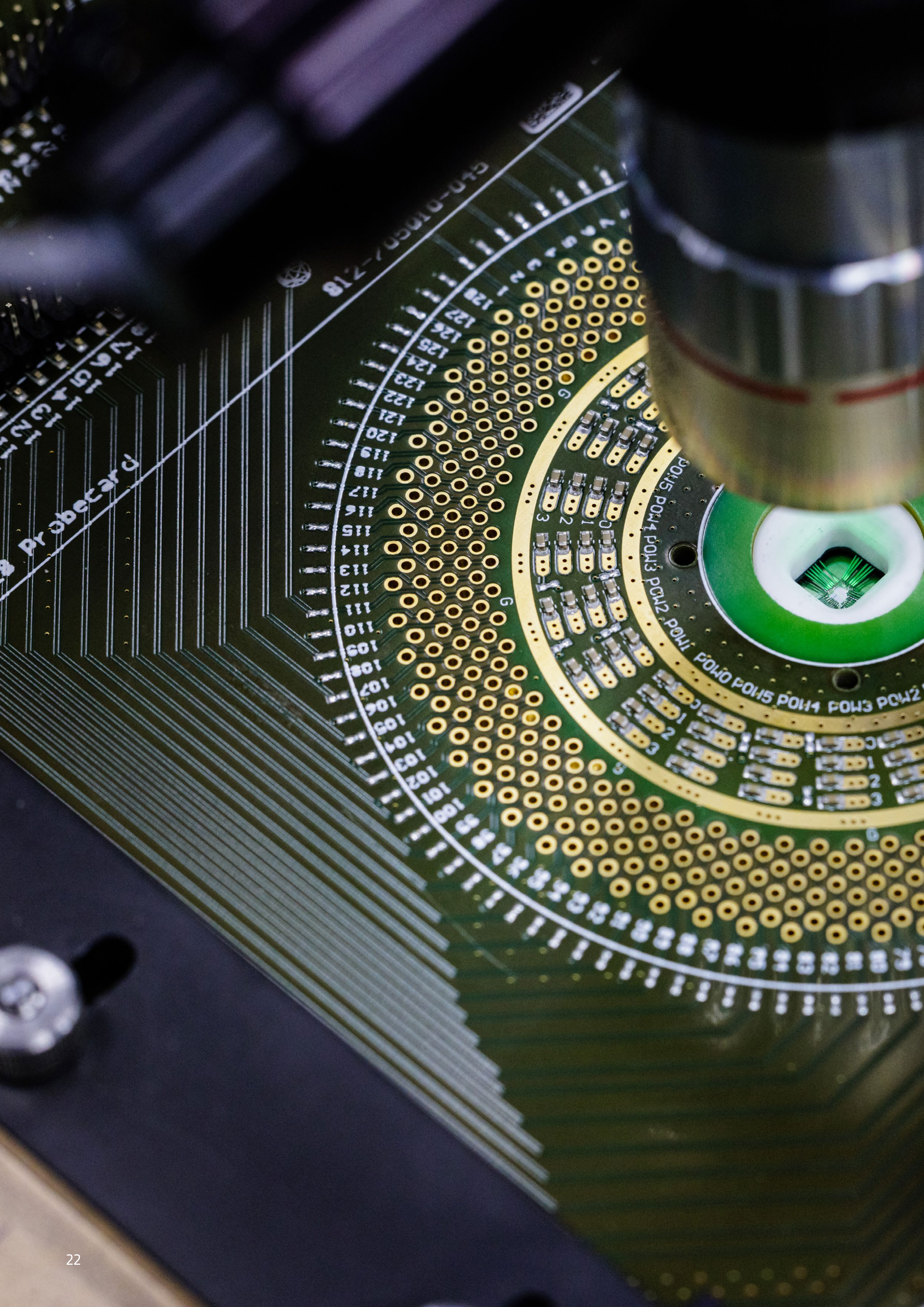
Novel sensors and Internet of Things application can help to monitor the condition and health of agricultural land or biodiversity in natural landscapes.

Digital twins will provide data to manage product diversification or redesign pesticides management, alongside the use of functional biodiversity.

Quantum computing can enhance understanding the biological and chemical processes to reduce the use of pesticides and fertilisers.

Energy efficient blockchain from along the value chain could increase traceability and transparency of agricultural products.

Open agricultural digital platforms providing a basis for secure data sharing and services such as in precision farming could strengthen the value chain and create efficient market places.



GEOPOLITICAL, ECONOMIC, SOCIAL AND REGULATORY FACTORS DETERMINING TWINNING 4

The current geopolitical shifts confirm the need to accelerate the twin transitions, reinforcing the EU's resilience and open strategic autonomy. The repercussions of Russia's military aggression against Ukraine have already changed geopolitical and economic realities. This includes various factors relevant for twinning: soaring energy and food prices and related social implications, the potential need to temporarily increase the use of coal, further pressure on public finances, higher inflation rates, increased cyber risks, issues with supply chains, and impaired access to critical raw materials and technologies. The new sense of urgency to speed up the transition away from fossil fuels could prove to be a tipping point for the green transition. The geopolitical situation will also galvanise the transformation of supply chains, resulting from changes in global labour and production costs, as well as the repercussions of the COVID-19 pandemic. It will add pressure to move to less vulnerable, more diversified, and more reliable supply chains and, possibly, 'friend-shoring'[34]. This could in some cases also reduce the carbon footprint and foster circular economy. In this context, EU partners such as South Korea, the United States, and Japan have for instance also put in place or recently started building up supply chain monitoring systems and domestic capacities.

Securing access to critical raw materials will be paramount for the EU's twin transitions. Currently, the EU's dependence on third countries, including China, for a number of critical raw materials is even greater than that on Russia for fossil fuels[35]. The EU's own production accounts for only 4% of the global supply chain of critical raw materials used in the production of digital equipment, such as palladium, tantalum, or neodymium.[36] The EU also lacks an adequately scaled-up mining, processing, and recycling industry. Progress in developing domestic deposits, including those of strategic importance for the economy, has been insufficient so far, notably as projects continue to face significant obstacles. At the same time, reaching our clean energy goals will require increasing amounts of various raw materials, e.g. a 3500% increase in the use of lithium, a key component for electric mobility. Chile currently holds 40% of lithium deposits, while China hosts 45% of its refining facilities worldwide.[37] In addition, a 330% increase in the use of cobalt, and a 30-35% increase in the use of aluminium and copper are expected.[38] Trade, cooperation, and partnerships with a diversified array of mineral-rich and like-minded countries remain of particular importance. The global surge in demand heightens the competition for resources and is likely to worsen the production concentration thus creating additional geopolitical risks on the supply. Beyond the access to critical raw materials, the ability to set environmental and social standards, ensuring the sustainability of mining, refining, and recycling activities, and production of energy, will be key in the new geopolitical context.[39]

Coupled with enough investment, increased circularity[40] and precision in production might help reduce these strategic dependencies. Digitalisation might further accelerate circularity, by improving design, increasing accuracy in production, and improving repair, refurbishment, and recycling processes. For instance, after 2040, recycling could be the EU's major source of supply for most transition metals, together with the continued need for primary metals.[41] Recycling will be even more important, as, for instance, production of steel or aluminium from scrap is significantly less energy-intensive than from raw materials.[42] Both the quantity and quality of recycling are relevant. For instance, copper contamination of steel and aluminium leads to major losses in value and consequent higher energy use and emissions.

The geopolitics of technologies will gain in importance. Access to critical technologies will provide a competitive advantage and reduce strategic dependencies. The EU's currently limited capacity in some horizontal technologies weakens its position.[43] Technological competition could rapidly increase, leading to the fragmentation of global innovation ecosystems. This can increase costs and cybersecurity risks especially for dual-use technologies, e.g. 5G and 6G infrastructure or digital technologies in agriculture.[44] This is even more relevant as the amount of collected data, including on consumers' habits and behavioural patterns, and the number of connected appliances will massively increase. Moreover, rivalries based on values and societal models are also expected to grow. This is already visible in different approaches to the internet. For instance, limiting access to specific content (e.g. China, Russia), pursuing a value-based approach (e.g. EU focus on data privacy and trustworthy artificial intelligence) or promoting specific models of governance (e.g. largely privatised, like in the US, or driven by the state, as in the Chinese cyber-sovereignty).[45] There are growing concerns about links between malicious cyber activities and disinformation, which threaten democracy, aggravate divisions, and hinder access to accurate information. This is relevant, as the last 30 years of democratic progress has been eradicated[46]: the average level of global democracy in 2021 is down to its 1989 level. In addition, the current geopolitical context might affect twin transitions-related projects in partner countries, which are already facing financial and supply constraints due to the consequences of the COVID-19 pandemic. This challenge is becoming even more vital, as, for the first time, progress at global level towards the United Nations Sustainable Development Goals has been reversed.[47]

Adjusting our policies towards a new economic model will be key to achieving the twin transitions. This entails reorienting the traditional view of economic progress towards a more qualitative one evolving around wellbeing, resource efficiency, circularity, and regeneration. Ultimately, reaching climate neutrality, sustainable resource use, zero pollution and halting the decline in biodiversity, entails a profound change of the economic and social policies, driven by an appropriate mix of market-based instruments (for example, carbon pricing) and investments into sustainable projects, by both the public and private sectors. The growth of social enterprises and investments for impact is also a galvanising factor for this shift.

The twin transitions will be fair or will not be: inclusiveness and affordability will condition their success. People with low and medium income are more vulnerable to the impacts and costs of the twin transitions, e.g. job automation, access to digital solutions and digital public services, higher energy and food prices, financing improvements in buildings' energy efficiency, or transport poverty[48]. There is also a gap between tech-savvy firms and those technologically lagging behind. Regional disparities in the level of economic development and social prosperity may further exacerbate these dichotomies. Frictions in the labour and capital market could make them more lengthy and costly. In this context, achieving climate neutrality and environmental sustainability will only be possible if accompanied by measures supporting these groups in bearing the related financial burdens and by bridging disparities.[49] Reaching the objectives of the EU Digital Decade and the European Pillar of Social Rights will be crucial to close these gaps, but more action may be needed. This is even more compelling in view of the fact that those for whom the transition is most difficult to bear are those who are on the lowest end of emissions. Indeed, currently the richest 10% of Europeans emit per capita more than three times as much as the rest of Europe's citizens.[50]

The twin transitions will result in profound shifts in the EU labour market and related skills. Sectors and regions with heavy dependency on coal mining, fossil fuel extraction, and related processing and supply chains will see job losses.

On the other hand, new jobs will be created as a result of the green transition, e.g. in clean energy, renovation, and the circular economy.[51] Similarly, the digital transition is likely to create new employment and business opportunities, e.g. in advanced technologies, while leading to the loss of other jobs, fully or partially automated. Further digitalisation, accelerated by COVID-19, will also affect conditions and patterns of work, as well as access to social protection. These processes will not necessarily be simultaneous, and their impact on different companies, sectors and regions will be uneven, implying potential economic and labour market imbalances. The transformed content of jobs and the reallocation of employment will require different skill sets. Overall, the labour market effects of the twin transitions are potentially complementary, with amplifying and cancelling effects that merit further research.

Production and consumption patterns will evolve. Technologies such as cloud computing, the internet of things or big data analytics will increasingly enable new business models, including servitisation – selling services, rather than products. For example, manufacturing-as-a-service will allow smaller companies to use more efficient cutting-edge manufacturing facilities. Consumption patterns, also underpinned by demographic change, will be of major importance, as household consumption drives up to 72% of global greenhouse gas emissions.[52] Consumer choices, such as using an electric vehicle, installing a heat pump, or retrofitting a house, could reduce cumulative CO_2 emissions by around 55% globally.[53] Behavioural choices, e.g. changing diet, using public transport or cycling, will also be key, both for the environment and the overall health of the population. Digital technologies will also affect consumption patterns. With the rise of e-commerce, they will facilitate consumption and shape consumer decisions, increasingly based on digital information. They will also galvanise the social, sharing, and circular economies, as well as shifts from owning to producing and trading assets, e.g. renewable energy or second-hand items, like fashion. Personal monitoring of pollution exposure or contribution and access to environmental data through networks of micro-sensors and smart devices will empower people in their choices.

Standards will be important for enabling the twinning. They can support the development of testing methods, management systems or interoperability solutions necessary for the twin transitions. In many cases they are a requirement to access the market and support the implementation of EU legislation and policy objectives, such as the EU's harmonised approach to sustainable products. Data standards will play an important role in ensuring that the exponential increase in the volume from different origins and private data[54] can be used efficiently and reliably. While standardisation is vital for implementing our policy objectives, many non-EU countries increasingly use it assertively, to provide their industries with increased market access and technology rollout. In that sense, the role of the EU in shaping global standards, and the voice of EU companies in regional standard setting bodies, will remain key.

Public and private investment will remain key for the transitions, also supported by 'twinning-friendly' capital markets. The EU's 2021-2027 long-term budget, coupled with NextGenerationEU, totals EUR 2.018 trillion. At least 30% will be spent on fighting climate change – the highest share ever, from the largest EU budget ever. In addition, in 2026-2027, 10% of the annual spending under the long-term budget will support biodiversity. 25 plans adopted so far under the Recovery and Resilience Facility dedicate 40% to green and 26% to digital objectives, though with a somewhat limited focus on the potential use of digital solutions to achieve the climate goals. Specific funding mechanisms, e.g. the Innovation Fund55 or the Just Transition Fund, will also be important. Nevertheless, the additional private and public investment needs for the twin transitions might amount to nearly EUR 650 billion per year up to 2030.[56] In the current geopolitical situation, these estimates are likely to be at the lower end of the actual needs, especially for the green transition. [57] Additional investments are needed, while taking into account the risks of increasing public debt, repositioning public finance priorities and an uncertain economic outlook. For instance, a possible rise in defence spending may affect public budgets earmarked for the twin transitions. This increases the importance of prioritising spending, improving the quality and composition of public finances and of civil-military synergies, especially in the field of technologies and space systems. Finally, avoiding significant stranded assets and lock-in mechanisms will require increased focus on future-proof investment decisions so that, e.g. buildings, energy or industrial infrastructure do not need to be decommissioned before the end of their lifetime, but can instead be repurposed or retrofitted. This is also important so as not to give existing technologies an advantage over new entrants.

KEY AREAS FOR ACTION 5

With a renewed sense of urgency linked to the rapid evolution of the geopolitical situation, appropriate policies are needed to strengthen opportunities and minimise potential risks related to the interaction between the green and digital transitions up to 2050.

1. In a shifting geopolitical environment, the EU needs to continue strengthening its resilience and open strategic autonomy in critical sectors linked to the transitions. In the energy sector, intensified efforts are needed on green energy sources, replacing our reliance on fossil fuels, while diversifying sources during the transition period. Developing stockpiling solutions and storage capacities for current and future energy carriers like renewable hydrogen would also be key. The ‘energy efficiency first’ principle applied across society and all sectors of the economy would considerably reduce energy consumption. Openness and international cooperation will be crucial as drivers for fostering innovation and technological development, while assuring that reciprocity and a level playing field are respected. An enabling environment for the development of EU digital industrial business-to-business and business-to-consumer platforms and facilitating strategic collaboration across industrial ecosystems will help to strengthen our position in technological competitiveness. It will also support the emergence of EU innovators in new marketplaces in crucial sectors. The work of the EU Observatory of Critical Technologies and a periodic review process will be important in the context of current and future risks of (technological) strategic dependencies. Building on ongoing modernisation efforts, the trade, customs, competition[58] and State aid policy toolbox will also need to be kept up-to-date to respond to challenges resulting from the twin transitions and other market developments, resulting notably from the geopolitical situation. This would protect the EU against unsustainable products and processes from third countries, while cushioning the effects of the inevitable short-term costs both within and outside Europe. Similarly, the contribution of the Common Agricultural Policy to food security, as well as other actions to reinforce the resilience of food systems, will be considered more strategically with a view to the twinning and of Europe’s open strategic autonomy in the new geopolitical context.

2. The EU needs to step up efforts to galvanise the twin transitions globally. Rules-based multilateralism and values-based international cooperation should be prioritised. Global cooperation, including through a proactive research and innovation agenda with like-minded partners, will be important to accelerate the development of twinning technologies and to address concerns related to digitalisation. The costs and benefits of the twin transitions should be clearly conveyed to partner countries, especially those likely to be more negatively affected. Green and digital diplomacy and outreach, leveraging the power of regulation and standardisation and promoting EU values, should be stepped up. The EU’s experience in emissions trading by capping them, pricing pollution, and generating revenues to speed up the decarbonisation and support the most vulnerable could inspire other countries to use similar schemes. Mutually beneficial strategic partnerships, notably with neighbouring and African countries, should be pursued. That includes financial support for projects related to the twin transitions, based on undistorted trade and investment, also in line with the EU’s Global Gateway. This will require developing physical green and digital infrastructure (secure 5G and 6G, clean transport corridors, alternative energy sources, clean power transmission lines) and providing an enabling environment for projects. Green bonds could be an effective tool to finance twin infrastructure projects to ensure benefits for all.

3. The EU needs to strategically manage its supplies of critical commodities to achieve the twin transitions, while strengthening its defence capabilities and preserving the competitiveness of its economy. Developing domestic capacities and diversifying sources of supply along the value chain will be instrumental to significantly reduce the existing strategic dependencies and avert the risk of replacing them with new ones. This is of particular importance in the area of critical raw materials, which requires a long-term and systemic approach.[59] The EU should enhance its capacity to monitor global commodities markets to anticipate and mitigate supply chain disruptions and equip itself, where appropriate, with instruments like stockpiling and joint procurement options to be prepared for the next supply disruption. Securing their sourcing will require the creation of strategic partnerships with mineral-rich partner countries, especially likeminded ones, as well as the development of domestic mining and processing projects, while ensuring a high level of environmental protection. The EU also needs to support and accelerate the development of the most valuable strategic European projects, including by streamlining and fast-tracking permitting procedures, in full compliance with environmental *acquis* and harmonised standards for public engagement. This must be complemented by investments in innovation and transition to the circular economy, development of urban mines and creation of a market for secondary raw materials by introducing collection, recycling efficiency and recycled content targets: longer lasting products and higher levels of quality recycling will decrease dependencies on the sourcing of primary resources after 2035. Efforts are needed to promote the highest sustainability standards and innovation, minimise the environmental and social footprint of the raw materials value chain, as well as mobilise the network of trade and investment agreements and the Team Europe financial firepower to attract investment across the entire raw materials value chain assets in the EU and third countries.

4. The EU needs to strengthen social and economic cohesion along the transitions. Workers, companies, sectors, and regions in transition require tailored support and incentives to adapt. Social dialogue, investments for quality job creation, and timely development of partnerships between public employment services, trade unions, industry and educational institutions are key. This also calls for reinforcing social protection and the welfare state, including mechanisms to prevent or address in a targeted manner the negative impacts on low- and medium-income communities and households and fight against poverty, as well as employment rescue facilities and policies assisting labour market transitions to cope with shocks. Regional development strategies and investments, supported by cohesion policy, should underpin the twin transitions, while reducing economic, social and technological disparities, including environmental injustice. Seamless and secure connectivity, including in rural and remote areas, in combination with capacity and skills building, will be key to ensuring all citizens and businesses can benefit from twinning.

5. Education and training systems need to be adapted to the new socio-economic reality. This entails both learning skills to adapt to a rapidly transforming technological reality and labour market, as well as green skills and climate awareness to support value creation in the green transition and responsible citizenship. Ensuring that the twin transitions are fair to all depends on substantially increasing twinning-related social expenditure, e.g. in education and lifelong learning, within a just transition framework. Labour mobility across sectors and targeted legal migration need to increase. Supporting sustainable, '1.5-degree' lifestyles, by engaging citizens and businesses, ensuring affordability, shaping policies and infrastructures animating them, will also be essential.

6. Additional investment should be steered into technologies and infrastructures supporting twinning. To strengthen the EU's resilience and facilitate the twin transitions, targeted reforms and investments need to tackle vulnerabilities at national and EU levels. Relevant macro-economic and sectoral policies need to be closely coordinated. A further shift in investments towards long-termism, and sustainable assets is required. The EU will need to leverage additional private and public long-term investments in twinning, especially in R&I across critical technologies and sectors, uptake and synergies between technologies, human capital, and infrastructures. This requires an enabling framework. Completing the Banking Union and Capital Markets Union will be essential to increase the robustness of financial markets, mitigate possible future financial stability risks, and ensure deep and liquid financial markets. This includes promoting sustainable finance frameworks to increase private investments in sustainable projects. The EU taxonomy and the underlying 'do no significant harm' principle are an important step in this direction. Additional investments will require financing tools combining private and public resources. Multi-country projects could facilitate the pooling of EU, national and private resources. Green public and private procurement should be expanded to sustainable digital technologies. Subsidies for sustainable production and consumption should be considered. Social entrepreneurship and impact investment by private players will be important. Fiscal policies and taxation need to be adapted to the twin transitions, spare additional investment towards projects promoting them[60], and provide the right price signals and incentives to producers, users, and consumers.

7. Steering the transitions requires robust and reliable monitoring frameworks. The four dimensions of competitive sustainability, i.e. fairness, environmental sustainability, economic stability, and productivity require an ambitious and integrated policy design that pays attention to both synergies and tensions. The needed shift towards a new economic model calls for an integrated approach to measuring and monitoring wellbeing beyond GDP, looking at current and future generations, in the EU and beyond. To guide political decisions that deliver on its full sustainable potential and to benefit from sustainable finance, a new and sound EU-level framework is needed for measuring both the enabling effects of digitalisation and its overall footprint in terms of greenhouse gas emissions and energy and resource use, including minerals and rare earths.[61] Having accurate, reliable information and official statistics can help citizens, businesses, and public authorities take informed decisions. Ultimately, data monitoring can help the EU assess whether additional measures are necessary.

8. A future-proof and agile EU regulatory framework, with the single market at its heart, will be conducive to sustainable business models and consumption patterns. The single market and its various dimensions, e.g. on data or energy, need to continuously evolve to accompany the twin transitions. A better regulatory framework, with incentives for innovation, is needed to promote circularity, create enabling markets, strengthen industrial ecosystems and ensure diversity of market players. Administrative obstacles should be systematically removed, to facilitate twinning-related projects and infrastructure. The rising role of intangible assets will require a fit-for-purpose intellectual property framework. EU policymaking should further exploit the use of digital solutions, such as digital twins, artificial intelligence for forecasting, or modelling in impact assessments. The twinning could be better analysed in evaluations of existing legislation, by looking at combined effects.[62] Consumers should be protected against deceptive practices, such as greenwashing or planned obsolescence. Benefits and challenges of the transitions need to be discussed with the public. Participation in decision-making could be enhanced with digital technologies or living labs. The use of artificial intelligence to support citizens' engagement in policymaking, as has been the case for the digital platform developed for the Conference on the Future of Europe, should be further explored.

9. Setting standards will be key for twinning and ensuring the EU's first-mover advantage for competitive sustainability. Product design, based on the 'reduce, repair, reuse and recycle' principle should become mainstream. Current action to ensure the sustainability of physical goods in the EU needs to be matched with standards for all sectors, to reverse overconsumption and planned obsolescence. The recent Commission proposals[63] to oblige traders to provide consumers with information on the durability and reparability of products could provide a solid basis for this. The EU must develop a more strategic approach to international standardisation activities in relevant global formats.[64] To ensure their implementation, international standards need to be matched with tracking and traceability. For instance, establishing a global standard for batteries could require a digital passport to track the ethical and environmental footprint of their components. Using standards to ensure that twinning technologies and infrastructures are interoperable will also enable the integration of EU partners in the implementation process.

10. A stronger cybersecurity and data sharing framework will be needed to unlock the potential of twinning technologies. Improved interoperability between different owners, generators, and data users in the EU, including national and subnational information systems, will facilitate data sharing by different actors: public authorities, businesses, civil society, and researchers. A strengthened and more secure data sharing framework that clarifies ambiguity on liability and ownership when transferring data will protect people and businesses; it will also help build trust and acceptance in twinning technologies. Common approaches to cybersecurity benchmarks for products and services, including comprehensive sets of rules, technical requirements, standards, and procedures will be important. Moreover, the resilience of critical entities and infrastructures needs to be strengthened with an all-hazards EU framework to help Member States ensure that critical entities can prevent, resist, and recover from disruptions. Affordability of cybersecurity technologies will also be key.

TWINNING THE GREEN & DIGITAL TRANSITIONS

Strengthening **resilience and open strategic autonomy** in sectors critical for the twin transitions in an increasingly unstable geopolitical environment.

Strategically **managing critical supplies** to increase diversification and minimise risks of new dependencies, also stepping up action to ensure availability of critical raw materials.

Supporting the transition to new quality jobs, by adapting the **education and training systems.**

Developing **monitoring frameworks** for measuring wellbeing beyond GDP and assessing the enabling effects and overall footprint of digitalisation.

Setting **standards for greening digitalisation** and ensuring the EU's first mover advantage in competitive sustainability.

Stepping up **green and digital diplomacy,** by leveraging regulatory and standardisation power, promoting EU values and fostering partnerships.

Ensuring cohesion by strengthening **social protection and the welfare state,** including via compensating mechanisms.

Mobilising **additional strategic investment,** in particular in R&I and new technologies, to accelerate the twin transitions.

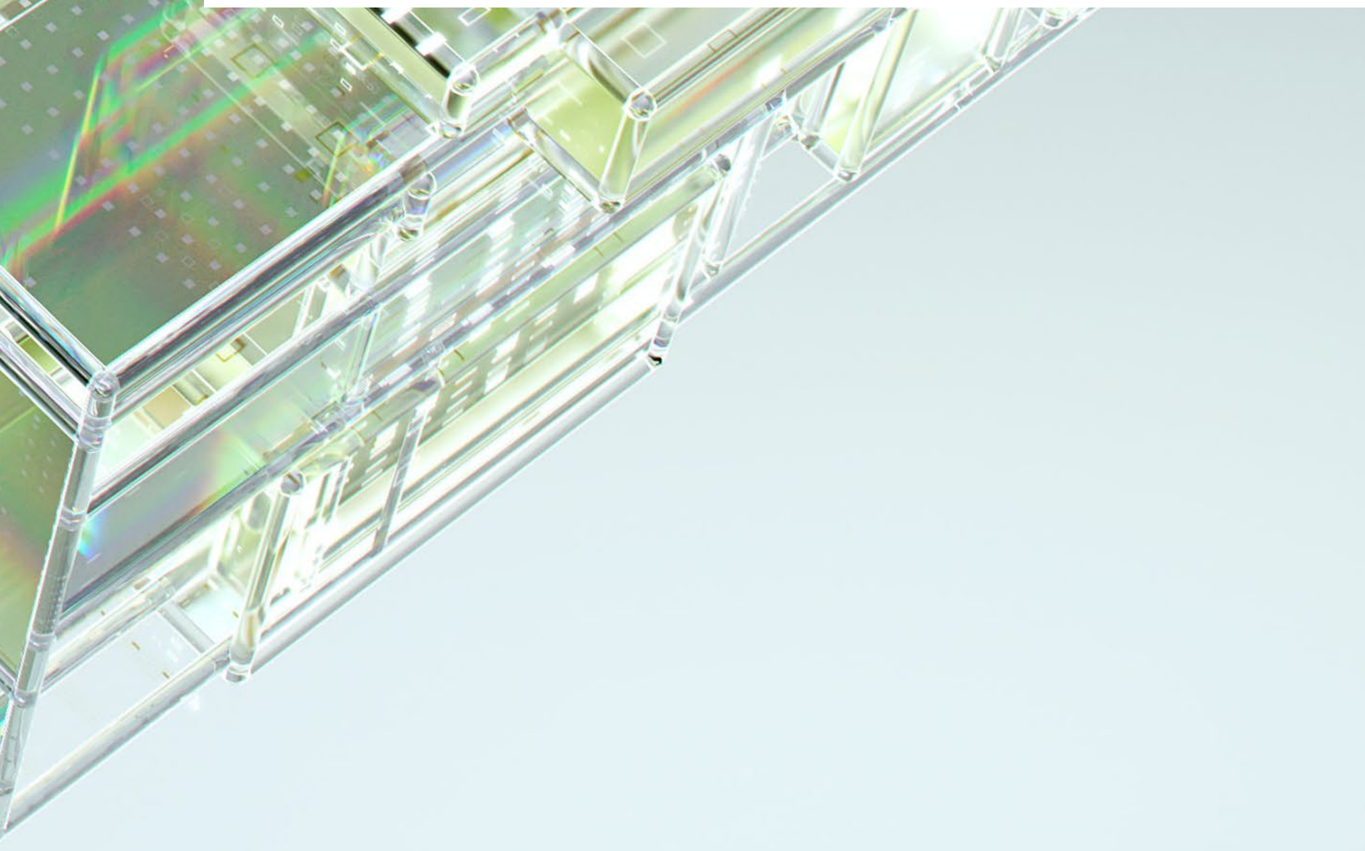
Providing a **future-proof and conducive regulatory framework,** also by using more artificial intelligence for policymaking and citizens' engagement.

Promoting strong **cybersecurity and data policies,** so that data fuelling the twinning are protected and shared.

CONCLUSIONS 6

Better understanding the interactions between the green and digital transitions is key for successful twinning, amidst various future megatrends and unforeseen events. The areas of action presented in this Communication (see left) respond to the need of maximising the synergies and addressing tensions between the twin transitions. This requires a dynamic approach to anticipating change and adapting policy responses, while firmly maintaining the course towards long-term objectives. In this way, by 2050 a successful twinning will support a new, regenerative, and climate-neutral economy, cutting the levels of pollution, restoring biodiversity and natural capital, enabled by sustainable digital and other technologies. It will help to position the EU as a champion of competitive sustainability and strengthen its resilience and open strategic autonomy. This will go hand in hand with a just transition benefitting all people, communities, and territories, in Europe and beyond.

The next annual Strategic Foresight Report will focus on the key upcoming challenges and opportunities that Europe will face in the decades to come, providing strategic insights relevant for strengthening the global role of the EU.



END NOTES

1 The 2021 Strategic Foresight Report identified climate change and environmental degradation, digital hyperconnectivity and technological transformation, alongside pressure on democracy and values, as well as shifts in the global order and demography, among the key mega-trends that will impact the EU's open strategic autonomy in the coming decades. (COM (2021) 750 final).
2 This Communication builds on the Joint Research Centre's Science for Policy report 'Towards a green and digital future. Key requirements for successful twin transitions in the European Union' [https://publications.jrc.ec.europa.eu/repository/handle/JRC129319]. The preparation process included consultations with experts and stakeholders, publication of a call for evidence, discussions with partners from the European Strategy and Policy Analysis System, and Member States in the EU-wide Foresight Network.
3 Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality, COM(2021) 550 final.
4 The ability of the EU's economy, industrial ecosystems, and companies to move towards a sustainable, productive, fair, and stable macro-economic model, enabled by digital and clean technologies, making Europe a transformational frontrunner and a competitive first-mover at global level. (COM(2019) 650 final).
5 A digital twin is a virtual representation of an object or system that spans its lifecycle, is updated from real-time data, and uses simulation, machine learning and reasoning to help decision-making. The development of the EU Destination Earth (DestinE) and its digital earth twins is key to predicting the effects and building resilience to climate change. In addition, the Digital Twin of the Ocean will help to design the most effective ways to restore marine and coastal habitats, support a sustainable blue economy, mitigate, and adapt to climate change.
6 35 countries are collaborating to build the world's largest magnetic fusion device, to prove the feasibility of fusion as a large-scale and carbon-free energy source based on the same principle that powers stars.
7 Freitag. C, et al (2021). The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations, Patterns 2.
8 Behavioural responses to improved efficiency that counterweight potential savings.
9 E.g. according to Andrae, A. (2022), Net global effect of digital - power and carbon, the ICT electricity footprint could grow from 1988 ter-awatt-hours in 2020 to 3200 in 2030.
10 Council of the European Union (2022). Metaverse- virtual world, real challenges.
11 With the European Chips Act (COM(2022) 45 final), the EU aims to address semiconductor shortages and strengthen its technological lead-ership, i.a. by increasing the production capacity to 20% of the global market by 2030.
12 Discarded products with a battery or plug (United Nations Institute for Training and Research https://ewastemonitor.info/gem-2020/).
13 WEEE Forum (2021): https://weee-forum.org/ws_news/international-e-waste-day-2021/.
14 ITU (2020). The Global E-waster monitor.
15 EIT Digital (2022). Digital Technologies and the Green Economy report.
16 EEA (2022). Economic losses and fatalities from weather- and climate-related events in Europe.
17 In 2019 they represented the following part of greenhouse gas emissions per sector in the EU: energy supply 27%; domestic transport 23%; industry 21%; residential and commercial 12%; agriculture 11%. (European Environmental Agency greenhouse gases data viewer 2021).
18 International Energy Agency (2021).
19 REPowerEU Plan, COM(2022) 230 final.
20 COM(2022) 230 final.
21 Business model where energy service providers do not simply offer a form of energy but rather a 'turn-key energy product' such as keeping the temperature in a building in a certain target range.
22 Compared with 2015, based on the Fit for 55 MIX scenario. European Commission (2021), Policy scenarios for delivering the European Green Deal.
23 For example, solid-state, cobalt-free lithium-ion, or those using DRX materials (disordered rock salts with excess lithium, which allow battery cathodes to be made without nickel or cobalt).
24 SWD(2021) 601 final.
25 International Energy Agency (2020).
26 United States Environmental Protection Agency (2021).
27 Computerised system gathering and processing data and applying operational controls over long distances.
28 4D-printed objects can change shape or self-assemble over time if exposed to a stimulus such as heat, light, water, magnetic field, or other form of energy that activates the process of change.
29 Source: Eurostat. The COVID-19 pandemic showed growing interest in moving to rural areas. Whether this is a short-lived or could remain a longer-term trend will depend, among other things, on the connectivity of rural areas. See more: A long-term Vision for the EU's rural areas (COM(2021) 345 final) and Scenarios for EU rural areas 2040, https://data.europa.eu/doi/10.2760/29388.
30 COM(2021) 802 final.
31 COM(2021) 558 final; COM(2021) 802 final.

32 COM(2020) 662 final.
33 IPCC (2022). Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Intergovernmental Panel on Climate Change Sixth Assessment Report.
34 Deliberately sourcing critical materials, goods or services with allies who share the same values.
35 Strategic dependencies and capacities, SWD(2021) 352 final; EU strategic dependencies and capacities: second stage of in-depth reviews, SWD(2022) 41 final.
36 China alone accounts for 86% of the global supply of neodymium. Palladium is mostly provided by Russia (40%), and tantalum by the Democratic Republic of the Congo (33%). European Commission (2020). Critical Raw Materials for Strategic Technologies and Sectors in the EU: a foresight study.
37 European Commission (2020). Critical Raw Materials for Strategic Technologies and Sectors in the EU: a foresight study.
38 Metals for Clean Energy: Pathways to solving Europe's raw materials challenge, KU Leuven and Eurometaux, 2022.
39 Danino-Perraud R. (2021), Géoéconomie des chaînes de valeur: les matières premières minérales de la filière batterie, Études de l'Ifri, Ifri.
40 E.g. the EU could meet 52% of lithium demand, 49% for nickel and 58% for cobalt in 2050 for electric mobility by recycling end-of-life batteries. Rizos, V., Righetti, E., (2022) Low-carbon technologies and Russian imports: How far can recycling reduce the EU's raw material dependency?, CEPS Policy Insight.
41 Metals for Clean Energy: Pathways to solving Europe's raw materials challenge, KU Leuven and Eurometaux, 2022.
42 Recycling can vastly reduce energy consumption by a theoretical factor of 27 for steel and a practical factor of 30 for aluminum. (Komiyama, H. (2014), Beyond the Limits to Growth: New Ideas for Sustainability from Japan, Science for Sustainable Societies).
43 For example, in quantum computing 50% of the top companies are in the US, 40% in China and none in the EU. In 5G, China captures nearly 60% of external funding, the US 27%, Europe 11%. In artificial intelligence, the US captured 40%, Europe 12% and Asia (including China) 32%. In biotech in 2018–20, the US spent $260 billion, Europe $42 billion, China $19 billion. McKinsey Global Institute (2022). Securing Europe's future beyond energy.
44 Angyalos, Z. & Botos, S. & Szilagyi, R. (2021). The importance of cybersecurity in modern agriculture, Journal of Agricultural Informatics.
45 The Economist Intelligence Unit (2022). Five ways in which the war in Ukraine will change business.
46 Boese, V., et all (2022). Democracy Report 2022: Autrocratization Changing Nature? Varieties of Democracy Institute, V-DEM.
47 This includes reducing inequality, lowering carbon emissions and tackling hunger, where progress stalled or reversed. UN (2021). Progress towards the Sustainable Development Goals: report of the Secretary-General.
48 Either due to the cost, or because the services do not exist.
49 This also includes taking into account gender-specific consumption and investment patterns.
50 https://wir2022.wid.world/chapter-6/
51 European Commission (2021). The Future of Jobs is Green.
52 United Nations Environment Programme (2020). Emissions Gap Report 2020.
53 International Energy Agency (2021). Net zero by 2050 - A Roadmap for the Global Energy Sector.
54 Projected figures estimate that global data volume will increase 530%, from 33 zettabytes in 2018 to 175 zettabytes in 2025, (COM(2020) 66 final).
55 One of the world's largest funding programmes for commercial demonstration of innovative low-carbon technologies. It will provide around EUR 38 billion in support up to 2030, depending on the carbon price.
56 COM(2021) 662 final.
57 COM(2022) 600 final.
58 In line with the Communication "A competition policy fit for new challenges", COM(2021) 713 final.
59 The RePowerEU Communication stresses that the EU must urgently provide, including through a legislative proposal, an adequate framework to support Member States' and industry's efforts in this area.
60 The recent proposal to introduce a debt-equity reduction allowance and to limit the deductibility of interest for corporate tax purposes (COM(2022) 216), will have an important role in fostering the twin transitions.
61 Some efforts in this direction are being made under the European Green Digital Coalition.
62 Recommendation of the Fit for Future Platform draft opinion on "How to favour interconnectivity between the digital and green transition, including through simplification".
63 COM(2022) 143 final.
64 In line with the "EU Strategy on Standardisation", COM(2022) 31 final.