Digitalization to Advance Sustainability

CCICED Scoping Study Report

中国环境与发展国际合作委员会
China Council for International Cooperation on Environment and Development

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1. Introduction

Digitalization has made its way into many aspects of people's everyday life, significantly changing **economic, societal, and cultural patterns**. At the same time, the commitment to **carbon neutrality, biodiversity protection, and sustainability** requires reimagining the well-established governance models, business practices, and lifestyles. This is especially true for **China**, as the country acts as a role model for emerging economies that strive to innovate and grow sustainably.

China is home to around **1 billion internet users** (more than in the USA and European Union (EU) combined), pioneering companies, and a government that issues future-oriented policies, which together are creating a **multifaceted and cross-industry digital ecosystem** [1]. Such evolution has contributed to the country's growth, reshaped its commercial landscape, and also extended its influence beyond national borders. China's **14th Five-Year Plan** (FYP) also emphasizes pursuing a higher quality, more technologically advanced development model, with specific focus areas including digitalization, telecommunications (5G), artificial intelligence (AI), big data, and quantum computing. Digitalization as an application for existing industries is also a focus with the contribution from the **core digital industries** targeted to **reach 10% of GDP by 2025 in the 14th FYP**. At the same time, sustainability is embodied in the concept of ecological civilization, which is considered an important dimension of this high-quality development. It is therefore important to foster the linkage between digitalization and sustainability.

Today, **digital development and the green economy** are the two megatrends that will serve as the new power to foster economic development in China. Therefore, it is necessary to strategically combine these two fields, which are currently treated separately: as a matter of fact, the digital economy is also vital for China to achieve its development goals and deliver on its **carbon peak and neutrality pledges.** The digital evolution has also strong implications for **sustainable development**, thus calling for studies on how digital and green technologies can lead the economy and society towards a fair and prosperous future.

In such context, this scoping paper aims to explore the link between digitalization and sustainability; address major challenges regarding the environmental and social impacts of China's digital transformation towards sustainability; provide recommendations and directions for future research. The paper is organized as follows:

Chapter 1 after this introduction, reviews the latest trends regarding digitalization and related public debates in China, analyzes the challenges and opportunities to make digitalization and sustainability mutually supportive, and discusses how digitalization could enhance China's sustainable development.

Chapter 2 briefly reviews the development of China's digital sector, examines the major sustainability challenges connected to it, and emphasizes the need for greening the digital sector.

Chapter 3 suggests the **missing links between** digitalization and sustainability, highlights the relationship of the twin green and digital transition (hereafter "twin transition") with the **achievement of the United Nation's Sustainable Development Goals (UN SDGs), reducing social inequality and improving gender equality**, and calls for the adoption of a **holistic approach that brings together digital innovations and sustainable development**.

Chapter 4 presents Chinese and international perspectives on a range of application scenarios to foster the green and digital transitions.

Chapter 5 describes the **role of the Chinese government** in the digital transition towards sustainability and provides **recommendations for the CCICED to focus on fostering the linkage of digitalization and sustainable development**. Finally, the chapter suggests possible **avenues for future research**.

2. Greening the digital sector

Digitalization is spreading through all areas of our society and economy. Rapid development in digital technology such as AI, big data, and virtual reality will not only play an ever-greater role in the future economic and social activities but also can be important enablers for the transformation towards sustainability while unleashing also the great potential in greening the digital sector itself. We must consider the potential direct and indirect environmental impact of digitalization and its significance for environmental policy. This section shares insights on the status-quo of greening the digital sector in China and global best practices.

2.1 The digital sector in China

Over the past decade, rapid digitalization has considerably contributed to productivity enhancement and economic growth in China, at the same time showing many synergies with the effort to achieve pollution reduction and carbon neutrality [2]. The country gained world leadership in several areas, such as e-commerce and mobile payments. As a matter of fact, China has the largest online retail market: in 2020, it represented about 24.9% of the total retail sales in the country – up from 20.7% in 2019 – and e-commerce in China accounted for more than 50% of worldwide retail online sales. In comparison, the United States generates 19% of global e-commerce sales, whereas the United Kingdom accounts for only 5%. Furthermore, digital payments represent four out of five transactions in China.

There is no standard definition of the digital economy, and its measurement poses challenges to scholars from all over the world [3],[4]. According to the International Monetary Fund (IMF), in 2008 the size of the so-called "**digitalized economy**" – which includes both digital sectors and digitalized traditional industries – amounted to **15% of the Chinese GDP**. In 2020, the China Academy of Information and Communications Technology (CAICT), a government-affiliated think tank, found that such share **surged to 40%**, and it is projected to grow even further over the next years [5-6].

The Chinese government adopted a rather narrow definition of the digital economy. The government issued the classification of digital industry in China in May 2021[7], which identifies the scope of digital economy industries into five broad categories:

1) **Manufacturing Industry for Digital Products**, including the manufacturing of computers, information, and telecommunication technology (ICT) devices, robots and electronic components, etc.

2) **Service Industry for Digital Products**, such as the wholesale, retail, rental, and repair of digital products

3) **Industry based on the Application of Digital Technology**, such as software development, internet services, telecommunications, etc.

4) **Digital Factor Driven Industries**, including internet platforms, e-commerce, e-finance, ICT infrastructures, etc., and

5) **Digital Efficiency Enhancement Industry**, including smart manufacturing, smart agriculture, smart mobility, logistics, etc.

Among them, categories 1 to 4 in this classification are defined as the core industries of the digital economy. The 14th FYP for Digital Economy Development, issued in January 2022, aims to reach the share of the core digital industries to **10% by 2025**. In the classification system, category 5 plays a significant role in the twin transition towards a green and digital society. Therefore, it is suggested to expand the definition of core digital industries by including category 5 and set targets accordingly, in order to promote the efficiency enhancement of many economic sectors. In our scoping study, for the term “digital sector”, we refer to all categories from 1 to 5. China’s digital sector has a significant **environmental footprint** and has therefore received increased research attention. A 2021 analysis conducted across multiple Chinese regions found that a **1% increase** in the level of development of the digital economy potentially **reduces haze concentration** in the region by approximately **0.2%** [8]. In the same year, another study analyzed data from Chinese provinces and proved the existence of a **positive correlation** between the digital economy and air quality, defined as the level of particulate matter in the air [9].

Despite these benefits, the **lack of data at the corporate level** hinders a systematic assessment of such effects. In fact, 30% of the top 50 listed companies operating in the digital sector in China **did not issue any Environmental, Social and Governance (ESG) reports** in 2020, and among the companies that published them, some still followed the conventional Corporate Social Responsibility (CSR), **without providing sufficient data** to measure their performance against sustainability indicators.

2.2 The status-quo of the green transition of the digital sector

Digital technologies also bring **new challenges** such as environmental issues, labor disruption, e-waste, privacy infringement, emerging oligopolies, and financial risks [10]. Some of them are global, whereas others are more prominent in the Chinese context. The ecological footprint of digitalization is significant. For example, according to a study by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), 4% of the global CO2 emissions can be attributed to digitalization and the energy consumption of digitalization is rising by around 9% annually. More details of the ecological footprint of digitalization can be found in Fig.1.

Data centers are at the heart of the digital sector, playing an important role in driving the digitalization process as they host computing and storage systems that enable the provision of web services. These structures consume vast amounts of energy and are also a major source of greenhouse gas (GHG) emissions worldwide. In 2019, data centers accounted for **more than 80% of Facebook’s total emissions**, and data centers worldwide consumed around **1% of global electricity** [11].

In China, data centers are often called “electricity tigers” due to their huge energy demand. In 2020, they consumed more than **200 billion kWh** of electricity, accounting for **2.7% of China's total consumption**. This share is much higher than at the global level, and such a growing trend is likely to continue in the future [12]. In 2022, the National Development and Reform Commission (NDRC) has **approved a mega-project involving the construction of eight national computing hubs and plans to build 10 national-data center clusters, indicating that its strategy to channel more computing resources from the country's eastern regions to its less developed yet resource-rich western regions is in full swing** [13]. The east-to-west computing resource transfer project enables companies and institutions to utilize the abundant renewable energy resource in the west while satisfying the computing demand in the developed region in the east. As an example, Huawei already moved part of its data centers to Gui'an New Area, in Guizhou, where it was able to save **over 1 billion kWh** of power and **810,000 tons of carbon emissions** annually [14]. Looking at the big picture, if every data center in China was powered by green energy, emissions could be cut by **320 million tons per year.**

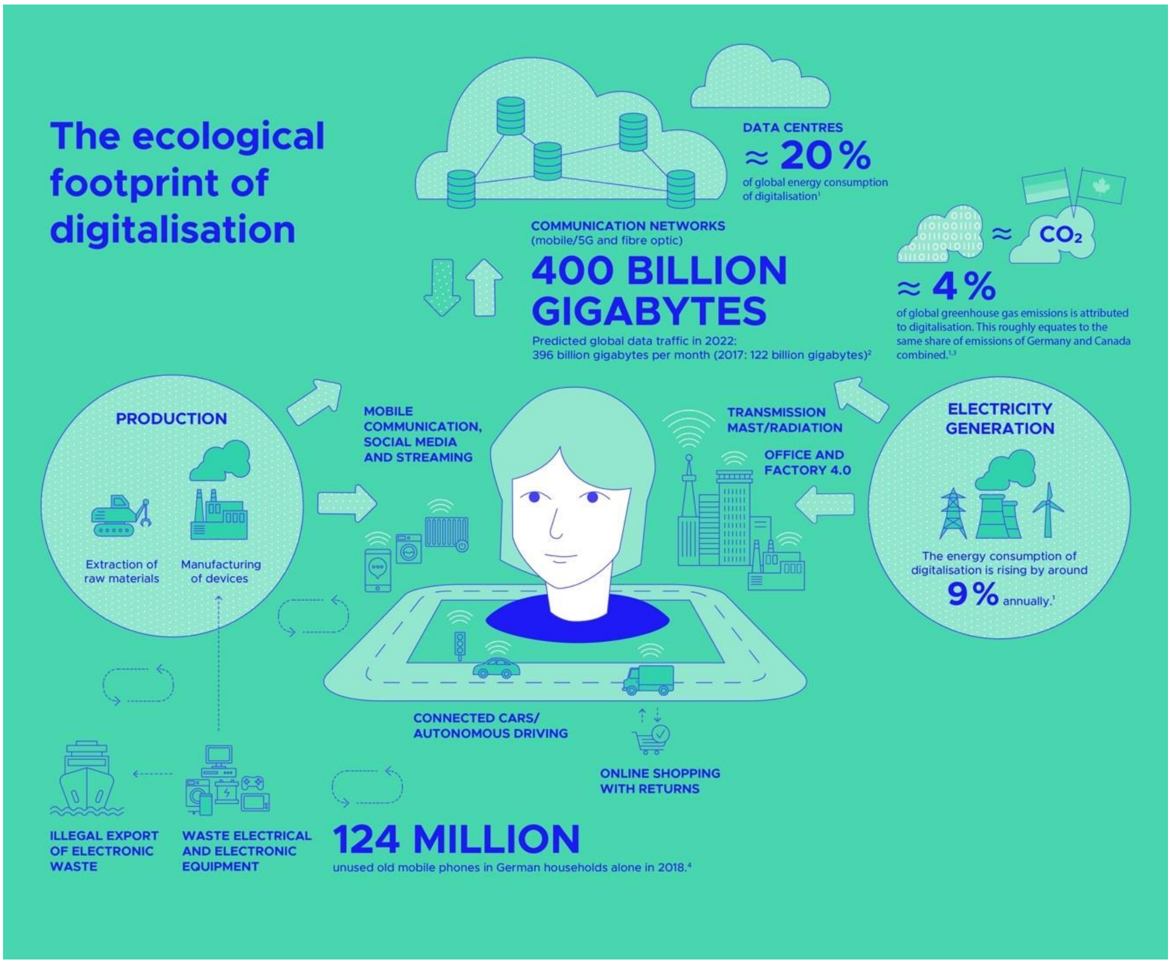


Fig 1. The ecological footprint of digitalization [15].

Also, outside China, many governments and companies are helping accelerate the green transition of the digital sector by promoting **sustainable initiatives**. For instance, in 2021, 26 CEOs of ICT companies formed the **European Green Digital Coalition (EGDC)** and signed a declaration to support the green and digital transformation of the EU. With such a document, they committed to investing in the development of solutions that improve the efficiency of the digital sector, as well as to develop effective instruments to measure its environmental impact [16].

Another example of connecting data centers with renewable energy is, that, some companies, including Google, Microsoft, Green Mountain, and DigiPlex, have moved their server farms into **renewable-based areas**, such as Norway, due to the regulation of the data-center market. In the past years, the Norwegian government has made electricity cheaper for the data center industry, adopting the same tax model used for power-intensive industries like ironwork [17].

In addition to the benefits already mentioned in section 2.1, a recent paper found that production factors related to **the (traditional) digital industry had a significant negative effect on embodied carbon emissions in China** from 2002 to 2017 [18]. Moreover, a study analyzing energy production from renewable sources in Northwestern China found that in a 7-year span, the **short-term prediction accuracy** of the energy output coming from renewable sources improved year by year – **from 84.2% in 2012 to 91% in 2019** – thanks to the advancing progress and deeper penetration of digital technologies. As a result, from 2016 to 2019, the use of renewable energy **increased significantly**. In general, the energy transition, the core of the climate actions, is closely linked to the digital technologies, both from the energy demand and supply sides.

Apart from improving energy system operational efficiency, digitalization connects the various parts of the energy system and provides enormous potential to transform the energy system from an integrated approach [19].

BOX 1. Climate Neutral Data Center – Self Regulatory Initiative in Europe

To administer the self-regulatory initiative for climate-neutral data centers, Cloud Infrastructure Service Providers in Europe (CISPE) and the European Data Centre Alliance (EUDCA) created a governance coalition called Climate Neutral Data Centre Pact (the Pact). The **Pact** serves as an initiative among data center operators and trade associations in Europe. It aimed at fulfilling the European Green Deal and at making data centers fully sustainable by 2030 [20].

The Pact has carried out the following actions to achieve its climate-neutral goal:

1) **Energy Efficiency:** data centers and server rooms in Europe will meet a high standard for energy efficiency, which will be demonstrated through aggressive power use effectiveness (PUE) targets.

2) **Clean energy:** data centers will match their electricity supply through the purchase of clean energy. Data center electricity demand will be matched by 75% renewable energy or hourly carbon-free energy by December 31, 2025 and 100% by December 31, 2030.

3) **Water:** by 2022, data center operators will set an annual target for water usage effectiveness (WUE), or another water conservation metric, which will be met by new data centers by 2025, and by existing data centers by 2030.

4) **Circular economy:** data centers will set a high bar for circular economy practices and will assess for reuse, repair, or recycling 100% of their used server equipment. Data center operators will increase the quantity of server materials repaired or reused and will create a target percentage for repair and reuse by 2025.

5) **Circular energy system**: data center operators will explore possibilities to interconnect with district heating systems and other users of heat to determine if opportunities to feed captured heat from new data centers into nearby systems are practical, environmentally sound, and cost-effective.

3. Fostering the twin transformation

3.1 The missing links between digitalization and sustainability

Digitalization offers an enormous range of possibilities for supporting the transformations toward Sustainability. However, up to now, digital resources and projects have been mainly used for conventional growth in established markets characterized by international competition. Sustainability is not the primary purpose of digital progress in these contexts; the dominant aspects are entertainment, convenience, security, and, not least, short-term financial gain. Overall, digitalization processes today tend to act as ‘fire accelerants’, exacerbating existing non-sustainable trends such as the overuse of natural resources and growing social inequality in many countries. The following graphic (Fig.2) illustrates the huge spectrum of potential benefits and risks in the context of digitalization and sustainability. Given the broad and disruptive changes that digitalization as a megatrend brings to our age, we must consider questions on how digitalization is changing our societies and the demands of sustainability, and even how it is transforming our concepts of “human development”.

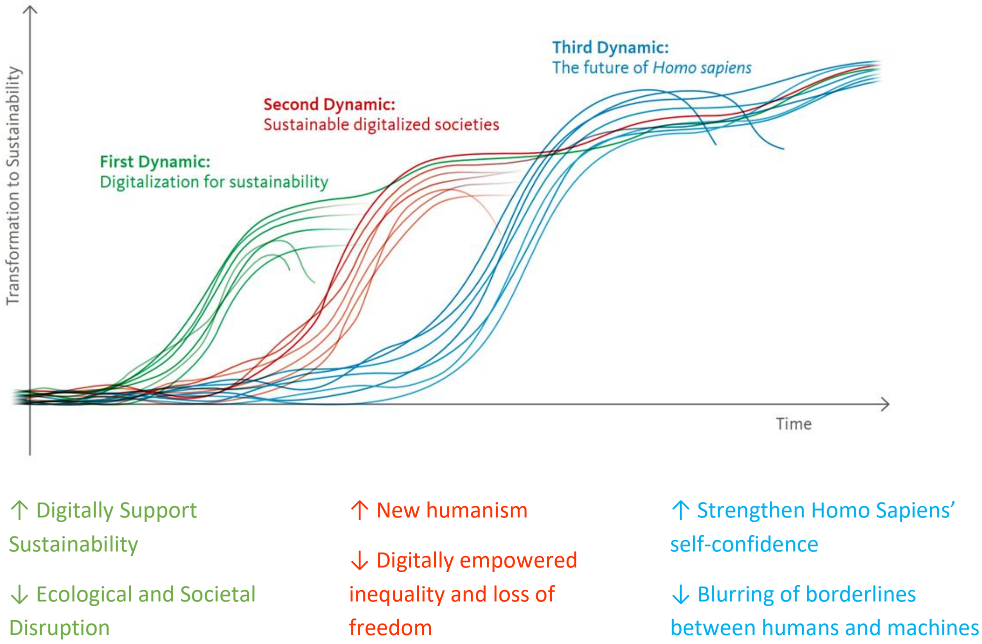
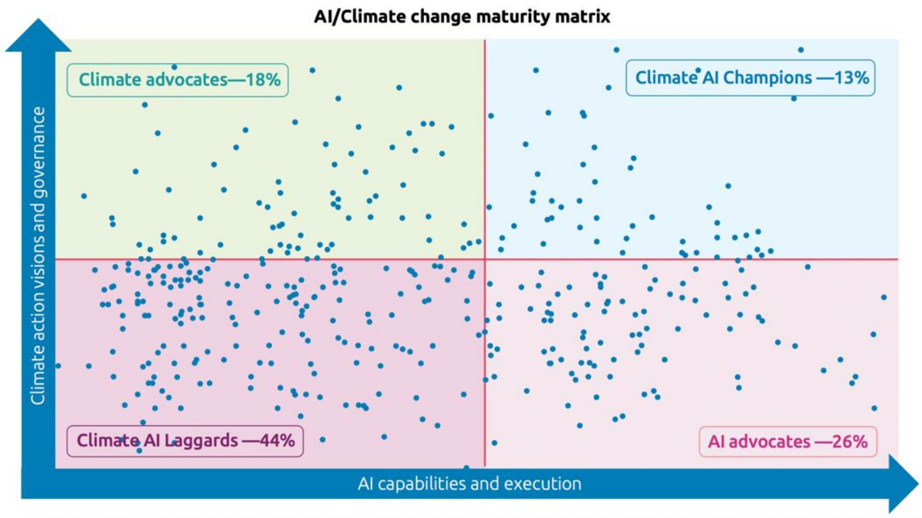


Fig.2 Three Dynamics of the Digital Age. Source: WBGU

- **First Dynamic**: 'Digitalization for sustainability' – using digitalization to protect the Earth system and ensure social cohesion: Here, the focus is on the 2030 Agenda and its SDGs. On the one hand, the aim is for digitalization to make valuable contributions towards improving and accelerating solutions to global environmental and development problems. On the other hand, digitalization can also massively exacerbate existing sustainability problems and lead to severe societal distortions if no countermeasures are taken.
- **Second Dynamic**: 'Sustainable digitalized societies' – realizing a new humanism: This idea focuses on dealing with the fundamental societal upheavals triggered by digital change. Positive and negative development opportunities with corresponding challenges on how to deal with them are also apparent here. In the positive scenario, there is hope that digitalization will bring us closer to a humanist vision of a sustainable world society in the Digital Age. In the negative scenario, however, digitalization entails the risk that digitally empowered inequality and loss of freedom will destroy any previous sustainability achievements.
- **Third Dynamic**: 'The future of Homo sapiens' – discourses on drawing boundaries: This Dynamic deals with the most fundamental of all sustainability issues: the future viability and identity of the human being itself, embedded in society and in the environment in which it has transformed. Here, the German Advisory Council on Global Change (WBGU) asks questions that sound futuristic, but are already highly topical today.

The three dynamics show the near-, mid-, and long-term impacts of digitalization on society, the economy, and people. For companies, there is a great potential to adopt a cohesive climate strategy backed by AI capabilities. However, in reality, only very few companies have aligned their climate vision and strategy with their AI capabilities, as shown in Fig. 3.



Climate Advocates

While they have a strong climate change vision and execution capability, they lack the AI capabilities to deliver (18% of organizations).

Climate AI Champions

They have a mature climate change vision, strategy, and strong record of accomplishment of AI implementation for climate action. They constitute 13% of all surveyed organizations.

Climate AI Laggards

They lack both climate change vision and execution capability and do not possess the required AI capabilities (44% of organizations)

AI Advocates

They have strong AI skills but lack climate change governance, vision, and execution (26% of organizations).

Fig. 3 Only 13% of organizations combine climate vision and execution with AI capabilities [21]

As AI has become an increasingly ubiquitous topic in the last decade, intergovernmental, national, and regional organizations have developed policies and strategies around AI governance. These actors are driven by the understanding that it is imperative to find ways to address the ethical and societal concerns surrounding AI while maximizing its benefits. Active and informed governance of AI technologies has become a priority for many governments around the world. However, the linkages between the research communities of AI and environment, energy, and sustainability are weak. In 2021, the leading primary topics were Privacy, Safety, and Security; Innovation and Technology; and Ethics (Figure 3). Among the AI topics to receive comparatively little attention from tracked organizations are those that relate to energy and the environment, humanities, physical sciences, and social and behavioral sciences.

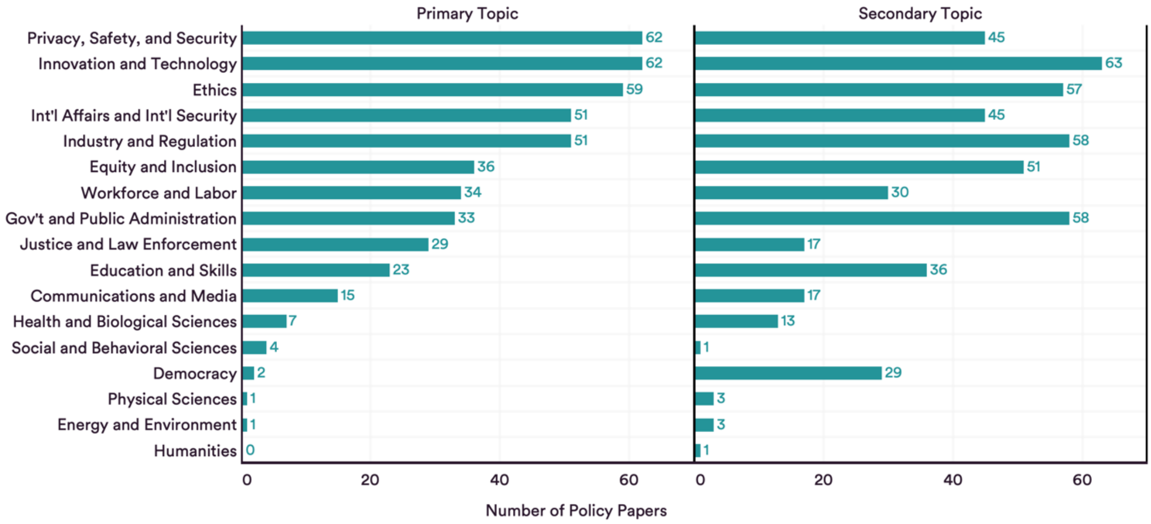


Fig. 4 Number of AI-related Policy Papers by the U.S. - based Organizations by Topic, 2021[22].

3.2 Social dimension of the twin transformation

The development of smart tools and new technologies could offer great possibilities to increase the inclusiveness of the Chinese society and reduce environmental impact, at the same time booming economic development. A 2019 IMF report showed that digitalization enhances productivity by lowering transaction costs; reducing information asymmetry; better matching demand and supply; enhancing production efficiency.

Zooming on the employment landscape in China, one could notice that digital transformation is bringing significant changes. On one hand, technological innovations have led to a so-called "**technical unemployment**" – i.e., a **reduction in the number of employed workers**, especially those involved in the production lines [23]. As a matter of fact, a 2021 paper argued that, in the industrial sector, the number of employed people has fallen by **9 million** since 2012. On the other hand, the digital economy has generated important benefits at the macro level in the last few years [24]. The previously mentioned study by the IMF showed that digitalization **has created several new professions in the e-commerce and sharing economy** – e.g., Alibaba's platform involves almost 11 million small and medium-sized enterprises (SMEs), which have created over **30 million jobs** over the past decade [25]. Furthermore, digital transformation has **significantly increased the number of flexible job positions**, especially among young people (aged between 16-24), who suffer from the highest unemployment rate in China. Overall, the **net impact** of digitalization on employment is likely to be **positive** in China [26].

As far as **income inequalities** are concerned, the impact of digitalization is still **unclear**. Digitalization can help reduce poverty by **connecting suppliers in remote regions to consumer markets in city centers** – e.g., Alibaba's Taobao villages help improve rural interconnection and raise income at the local level. Digitalization can also contribute to increasing financial inclusion in China, by making various financial services easily accessible to rural residents with a smartphone [27]. An empirical research based on data from the "Digital Inclusive Financing Index of Peking University" (2011 - 2018) showed that **digital empowerment has reduced the urban-rural income gap in China** [28]. Nevertheless, in general, the spread of digitalization could happen at the expense of **low-skilled workers**, and thus potentially widen inequality [29].

There is a growing concern regarding **workers' conditions** in the digital economy. In fact, the rapidly growing e-commerce sector and the sharing economy have created millions of jobs, but employment terms are often problematic. For instance, food delivery platforms require a large number of riders, but the hiring relationship between these two parties is often loose and involves other entities. As a result, the platform may not have to assume the necessary responsibility as an employer. In addition, algorithms may experience problems in calculating the delivery time, sometimes eating up minutes and putting great pressure on riders. Such concerns do not call for a halt in these platforms' operations, but for clearer regulations that balance the stimulus for innovation with the protections of stakeholders' and workers' rights. China has already put a focus on improving the workers' conditions under the digitalization background. In July 2021, the Ministry of Human Resources and Social Security together with seven other departments, recently issued the *Guiding Opinions on Protecting the Labour Rights and Interests of Workers under New Forms of Employment*. The Guiding Opinions stress protecting the labour rights and interests of workers under new forms of employment.

Digital financial services in China have penetrated the excluded and underserved communities, especially the low-income communities, via mobile devices. Digital financial inclusion provides them with access to payments, savings, credit, insurance, etc., which will positively enhance their capacity to benefit from the financial system [30] than others [31].

In general, digitalization could serve as an enabler for the achievement of SDGs in China, just name a few, Clean Water and Sanitation (SDG 6), Affordable and Clean Energy (SDG 7), Decent Work and Economic Growth (SDG 8), Sustainable Cities and Communities (SDG 11), Responsible Consumption and Production (SDG 12), Climate Action (SDG 13). Digitalization also shows great potential in fostering SDG 5 on Gender Equality.

3.3 Gender Perspective of the Twin Transformation

Improving access to digital technologies could help to tackle **gender equality related issues**. As a matter of fact, in China women still lag behind men in labor force participation – the ratio of women to men taking part in labor force activities is **81%** – and an increase in gender equality could generate a **13% growth in GDP by 2025 in China**. In this perspective, e-commerce and gig-economy can foster flexibility in terms of work possibilities, helping women balance work and family commitments. Digital technologies can also enable women to access wider markets and better economic opportunities. For instance, in 2015, **55% of new internet businesses were founded by women**.

Chinese women's digital literacy level could be raised by **public-private partnerships** that organize training and networking events. For example, in recent years **SAP** – a leading business software provider – has partnered with the UN to **train 100,000 female entrepreneurs** in digital technologies and business skills in China, especially in smaller cities [32].

BOX 2. Digitalization empowering women entrepreneurship

Digital technologies can potentially add **USD 13-18 billion in additional combined annual GDP** just by giving internet access to 600,000 women in developing countries. This can impact gender equality by widening the range of economic opportunities and increasing women's participation rate in business activities, empowering them to take part in political and social activities as well as to develop their professional skills [33].

In 2016, Microsoft China launched a series of workshops aimed at inspiring young women interested in science and technology, and at supporting female students graduating in computer science to successfully shift from school to work. The company has held four annual events, plus ten additional Ada Workshop events in Chinese universities, inviting female role models to share their personal stories. As a result, in 2020, more than **1,300 students** took part in the annual workshop, which attracted over 6,000 total viewers and more than 2,900 bullet comments [34]

3.4 Strengthening the linkage between digitalization and sustainability

The present paper pointed out how **digital innovations could be relevant across all industries** and have an impact on China's entire **economy, society, and sustainable development**. Nevertheless, digitalization and sustainability often move in different directions and are treated separately, both at the policymaking and corporate strategy levels. That is why, as the scope of this study is expanded, it is necessary to collect evidence on how these two macro-trends could be further connected in three main areas: **governance, business, and research**.

With the aim to strive to bring digitalization and sustainability together, **national and international authorities** should aim at increasing the level of environmental sustainability through the implementation of **ad-hoc policies** that increase the overall level of digitalization of the economy, thus boosting environmental efficiency. For example, the 'twin transformation: digital and green transition' supported by the EU and the leading companies committed to integrating the two transformations and also involve actions at the national level (24 EU countries plus Norway and Iceland) had joined the declaration to support the green and digital transformation of the EU.

From the government's perspective, the following macro-framework to link the digitalization and sustainability can be considered:

- **Shifting innovation visions** and patterns of digital pioneers towards sustainability is of vital importance. These pioneers can influence the ecology of the ICT sector, thus shifting the narrative of digital development towards the service of sustainability.
- **Mobilizing markets** is another important angle to consider, for example, through green tax reforms. This also includes shifting the roadmaps and goals of the markets to reduce emissions and resource consumption.
- **Modernizing the state** by building digital capabilities as a precondition for governing digital change.
- **Building strong networks** between digital and sustainability research communities.
- **Creating dialogue structures** between civil society, state, private business, and science to shape digital and sustainable futures

For organizations, there are also opportunities to **build synergies among themselves and within their fields of expertise**. For instance, a paper issued by the World Economic Forum suggests that companies could use digitalization to enhance their green efficiency by setting data-analytics strategies to **collect sustainability data** across business units; enabling process automation to **create** measurable **efficiency gains** and **improve resources use**; using digital platforms to **collect customer feedback** for environmentally sustainable digital business model innovations [35], [36].

The choice of analyzing the nexus of digitalization and sustainability is a relatively new trend in the research field. Indeed, as shown by a study, research tends to focus on a specific element of digitization or only addresses one form of sustainability (ecological, economic, or social) [37].

Therefore, in many cases, these two communities of researchers are still **very fragmented.** Connecting these disciplines and fostering direct collaboration enables new perspectives and in-depth insights. In the same direction goes, during the 75th UN General Assembly on the 22nd of September 2020 **President Xi Jinping** announced that China will set up an **International Research Center of Big Data for SDGs**. The center will help UN agencies and the UN Member States implement the 2030 Agenda by playing the roles of public science and technology platform; serving as a think tank for big data and sustainable development; being a hub for developing talent and improving human capacity through education and training. The German Environment Agency (UBA) increases the number of employees with an educational background in IT, AI, or digitalization in general.

BOX 3. Coalition for Digital Environmental Sustainability (CODES)

The **CODES** is an international multi-stakeholder alliance created in March 2021. The main objective of CODES is to reorient and prioritize the adoption of digital technologies in pursuing the UN SDGs to make the 2030 Agenda a reality. As a result of a consultative process, CODES has established an action plan aimed at promoting digital transformation as a positive force for sustainable development. The plan establishes a set of priorities, goals, and timelines to encode social and environmental sustainability into the digital revolution. It is based on the identification of three shifts that should be addressed simultaneously in order to fulfil the ambitions of the alliance. The first one implies the alignment of visions, values, and objectives of digitalization with those of sustainable development; the second one aims to ensure sustainable digitalization by mitigating the negative impact of digitalization; the third one is focused on steering innovation towards digital sustainability [38].

4. Innovative Digital Solutions to foster the Green Transformation

The impact of digitalization on sustainability appears to be particularly relevant in China, considering the size of this field in the country. China is the **second-biggest digital economy** after the United States, consolidating its international presence at a rapid pace [39], [40]. This section of the paper offers a glimpse of the **key fields and case studies** on which research should focus in order to understand how digital advancements could help the country achieve its sustainability goals.

4.1 Core digital capabilities for low-carbon development and sustainability

Reduction in CO2 emissions enabled by technologies can help fight the impact of climate change. According to the Global e-Sustainability Initiative (GeSI), digitalization will enable a **20% reduction in global CO2 emissions by 2030**. Specifically, energy efficiency technologies such as smart grids and integrated energy management systems are projected to generate savings of up to 1.8 gigatons of CO2e globally by 203041]. As figure I shows, the GeSI study estimated that by implementing digital solutions in different sectors of the economy, total global carbon dioxide equivalent (CO2e) emissions could be reduced by 12 gigatons (Gt) by 2030, providing a path to sustainable growth.

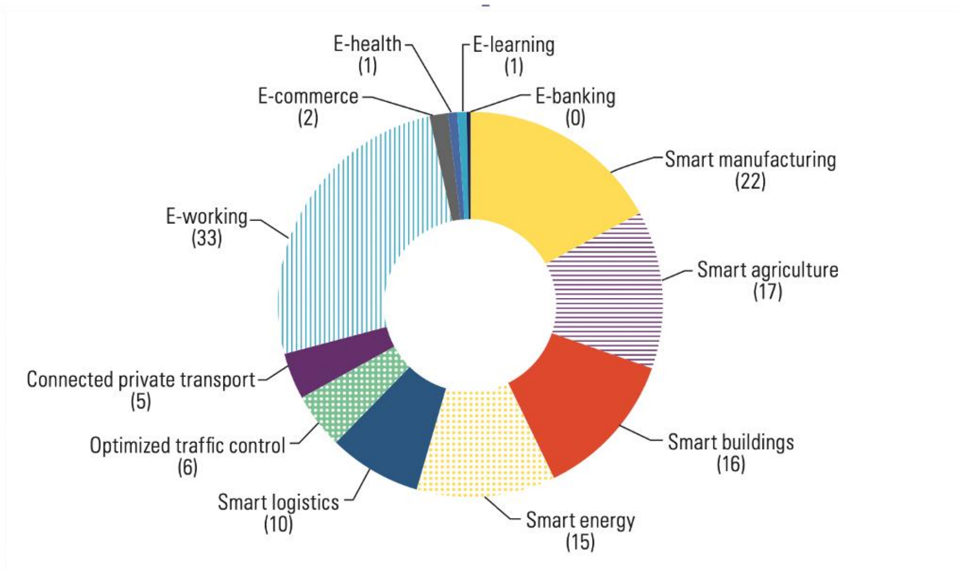


Fig.5 Potential for reducing carbon dioxide by 2030, by type of digital solution. Source: GeSI

Table 1. Core digital capabilities for sustainability solutions

Key Functions	Technologies	Applications
Map, integrate, analyze, visualize data	AI, Machine Learning (ML), data science, visualization tools …	Understanding and managing complex systems (VC, cities et al.); databased governance: GHG, ecosystems, resources
Optimize and predict	AI, ML	All economic sectors; ecosystems – improve sustainability governance
Simulate	Digital twins, AI, ML	Smart grids, buildings, value chains, ecosystems

Sense, connect, steer	5G, IoT, sensors, satellites,5G, AI, ML	Building, understanding & driving high-connectivity systems; automated systems
Track and verify	Blockchain, visualization tools, AI, ML	Monitoring and govern resource flows, green footprints, circular economy
Across sectors	Set of technologies	Green potentials for governance, de-materialization and virtualization

4.2 Green and digital transformations in various sectors

This section identifies several areas that can accelerate the transformation process towards more sustainable businesses and societies, describes the benefit that digitalization could generate in those fields, and provides evidence through international case studies. More specifically, it will explore **smart manufacturing; sustainable mobility; digital transition in cities & infrastructures; climate-smart agriculture; energy and water consumption**.

4.2.1 Smart Manufacturing

The application of industry 4.0 technologies in China could lead to a strong **reduction in carbon emissions**. More specifically**, emission reductions** enabled by digital technologies are projected to reach **112 Mt CO2e per year** by 2030 [42].

According to a 2018 academic paper, the application of digital technologies to industrial processes could enhance sustainability through the following innovations: [43].

- **Real-time data** enables the awareness of resource consumption, allowing for responsive and more efficient changes;
- **Internet of Things (IoT)** enables the acquisition of energy consumption data. The analysis of machine and production line performances improves energy-aware decisions;
- **Optimization software** applied to production processes can generate energy savings;
- **Additive manufacturing** is more resource-efficient than traditional methods due to its ability to reuse waste material, creating objects through 3D printing;
- **Blockchain technology** integrated with industry 4.0 innovations can promote new business models, as it enables the creation of reliable information.

BOX 4. Re-manufacturing for Circular Economy Solutions

Remanufacturing, i.e. the reprocessing and reuse of used (industrial) products, is an important component of the circular economy. One of the greatest challenges of remanufacturing is to reliably identify the industrial products returned from the market and assess their condition. In the EIBA project, Circular Economy Solutions GmbH is working with partners to develop an AI-based identification and assessment system for end-of-life parts. Many industrial products are already suitable for the circular economy. However, until now there has often been a lack of incentives and the necessary know-how in the companies to actually have the corresponding parts recycled and reprocessed. This is where C-ECO's Industry 4.0 business model comes in. It develops services to return the parts to be reprocessed from the market in a structured way at the end of the use phase and to evaluate them. According to its own information, C-ECO returns around three million end-of-life parts annually via a network of 22 logistics bases worldwide. At present, the identification of parts is still mainly done manually.

The biggest challenge is to ensure the same standards and evaluation benchmarks for the individual parts globally. What does a product consist of? What is usable? Which reprocessing strategy is suitable? To answer these questions, products must be clearly identified and evaluated. Experts often only have a few seconds to do this. However, many models differ only slightly from each other, and soiling and wear make the evaluation even more difficult. AI is to provide support in the future. The project is developing a machine that observes and evaluates the product. Sensors such as depth cameras or a scale identify the old parts and assess their condition.

4.2.2 Green Consumption 4.0

In the **USD 1 trillion** markets of global consumer electronics, **less than 20% of electronic waste is recycled** [44]. This lack of recycling practices also causes a loss of USD 57 billion in raw materials. In addition, the production of new Electrical and Electronic Equipment (EEE) causes severe greenhouse gas emissions that could be drastically reduced.

Specific technologies can **improve production and consumption patterns**, enabling the transition towards a circular economy and smart manufacturing - e.g., Industrial Internet of Things (IIOT) technologies, Machine-to-Machine (M2M) devices, data analytics & cloud computing [45].

BOX 5. Product Digital Passport

The EU is strengthening digital sustainability-oriented product information for consumers through the development and introduction of a digital "product passport" by 2025. At the EU level, that will serve as a basis for Europe-wide information requirements for all products.

The Digital Product Passport is a set of data summarizing a product’s components, materials, chemical substances, and/or information on reparability, replacement parts, and proper disposal. The data originates from all phases of the product life cycle and can be used for various purposes in all these phases (design, manufacture, use, disposal). Structuring data in a standardized, comparable format enables all stakeholders in the value and supply chain to work together towards a circular economy. At the same time, the Digital Product Passport is an important basis for reliable consumer information and sustainable consumer choices in both stationary and online retail.

4.2.3 Sustainable mobility

Research forecasts that digital innovation applied to transportation will save between **161 and 234 Mt CO2 emissions per year** by 2030 in China [46]. More specifically, **Mobility as a Service (MaaS)** could help **reduce congestion and emissions** by fostering the usage of shared mobility and green transportation solutions. An increase in the usage of public transport could also lead to the saving of more than **35 Mt of CO2 emissions** per year – equivalent to the amount of CO2 absorbed by more than 1.5 billion mature trees [47].

The implementation of smart traffic-control systems and the increasing usage of optimum route-finding apps, then, will **make traffic flows more efficient and lower distances traveled** per vehicle. GeSI estimates that more efficient routes and traffic control could bring to a yearly reduction of **24 Mt CO2 emissions**, whereas an increase in smart electric vehicle charging points could lead to a further reduction of nearly **4 Mt CO2 emissions** per year in the condition that the charging facilities are powered by renewable energies [48].

In China, the continuous urbanization process, the need for faster and cheaper ways of traveling, and the growing digitalization led to the **spread of shared mobility systems**, such as car- and bike-sharing, and ride-hailing [49]. A survey revealed that **33%** of Chinese preferred shared mobility over other transportation means; this is in line with the findings of another research, which showed that in 2020 shared mobility expenditure in China accounted for **11.3% of urban residents' transportation costs**. In the same year, over **95% of shared cars were new energy vehicles (NEVs)**, making car-sharing a key contributor to sustainable transportation in China [50].

Currently, China is now largest Electric Vehicle (EV) market in the world: nearly 1.29 million EVs were sold in 2020 alone, with a **40.5% share of global sales** last year, and an 8.3% growth year-on-year. Data proves the importance of this type of car for the country's sustainable future. Xie Chunping, a policy fellow at the London School of Economics, argues that lifetime emissions of electric vehicles are **19% to 34% lower** than comparable gasoline vehicles [51]. At the same time, it is important to point out that the development of EVs may have significant implications for the global mining industry. It was estimated that **USD 10 trillion** worth of lithium, cobalt, nickel, and copper may need to be mined globally in order to meet the needs of the industry, and the environmental impact in this regard would be relevant [52].

BOX 6. Autonomous driving along prescribed local passenger transport routes: Easyride in Munich

Many German cities are currently hosting autonomous mobility system tests for passenger transport. The concepts under investigation range from purely private usage to deployment in local public transport. Fleets of autonomous "robotaxis" and buses (also known as "people movers") are empowering passenger transport utilities to tailor mobility to the needs of the individual. Right now, there are nearly 40 test routes for autonomous vehicles in local public transport applications. These activities are currently concentrated in three German states: North Rhine-Westphalia, Baden-Württemberg, and Berlin.

One of these pilot projects is "**Easyride – Experience the Future**" in Munich. Here, municipal utility SWM and local passenger transport company MVG are trialing the use of **autonomous shuttle buses** along two predefined routes in the Olympic Park. Shuttle buses of the type e.GO Mover (from e.GO Moove GmbH, a subsidiary of Aachen-based E.GO Mobile AG, founded in 2018) has been deployed.

During the first pilot test phase, the minibuses are not yet automated and use sensor technology to collect environmental data in anonymized form. Based on this data, autonomous driving will be trialed in the second pilot phase. By the end of 2020, the initial aim was to test automated and connected driving in live practice. Technological development is focused on individualized public transport and automated ride-pooling fleets. The latter is to be controlled by algorithms that have interfaces to existing transportation systems and that therefore facilitate optimal routing and pooling. Beyond this, the hope is that the pilot project will yield insights into customer acceptance of these solutions.

4.2.4 Smart agriculture, smart energy and water management

As shown by the World Bank in 2021, agriculture employs **25% of Chinese active workers** [53]. **According to the '2021 China and Global Food Policy Report',** in 2018, this sector was responsible for **5.4% of China's GHG emissions, and agricultural land emissions and enteric fermentation account for more than 60% of the GHG emission from this sector**; in 2017, 28% of agriculture emissions were due to synthetic fertilizers [54].

According to the State Council of the People's Republic of China, **autonomous agricultural machinery** could **increase work efficiency by over 50%** and **reduce the use of pesticides and fertilizers by over 30%**, playing a very positive role in agricultural production and sustainability. China's sales of self-driving agricultural machinery equipment and systems reached more than 11,700 units in the first half of 2020, with strong **year-on-year growth of 213%** [55].

Other **innovative agricultural practices** could help make this sector more sustainable. For instance, big data technologies can enable the analysis of data regarding soil, weather, and production processes, increasing farmers' ability to **predict crop yields**. Digital tools can improve timing in the farming processes to maximize crop yields. Moreover, by analyzing input and output variables – such as natural disasters, climate, or soil – digital technologies help farmers **select the most appropriate crop** for a specific area.

Digitalization **improves energy efficiency**, gives access to more **affordable energy,** and fosters increases in the generation and use of **renewable sources** thanks to several technologies – e.g., smart grids, sensors, demand-response systems, and predictive analytics. According to GeSI~~,~~ **digitalization could generate 1.3 billion MWh of energy savings** globally by 2030 [56]. Moreover, the implementation of digitally-enabled measures could lead to **cost savings** in power generation of around **USD 80 billion per year** globally over the period 2016-2040, or about **5%** of total annual power generation costs [57].

According to the US Energy Information Administration, China is the **world's largest energy consumer**. In 2019, it consumed **150,000 quad BTU** of energy, 50% more than the US consumption and one-quarter of the global energy consumption [58]. In the same year, approximately **602 billion m^3** of water were consumed in China – equivalent to around one-sixth of the global water consumption [59].

Digital tools such as **smart meters** can help reduce energy and water waste by measuring consumption and allowing for more efficient resource utilization. More specifically, smart electricity grids use smart meters to allow for **real-time recording of electricity consumption and off-grid production using renewable sources**. This enhances the possibility to optimize distribution networks with real-time monitoring, automation, and dynamic storage, allowing networks to operate at higher capacities [60]. Smart meters can also be used to **track water usage** and provide more accurate measurements. In this way, they can enable the identification of leaks and accurately measure water consumption, while allowing for more precise billing [61].

5. Policies, pathways and potential elements of a Special Policy Study

5.1 Policies and pathways

Until 2013 the Chinese Government did not intervene much in the digital economy. As a result, internet users were able to access free digital contents in the domestic market, which increased the **penetration of digital services**. The absence of a centralized approach in the early stages of the digitalization process gave innovators plenty of space to experiment solutions [62], which until today has positive and negative impacts.

Governmental institutions have considerably **tightened their oversight of the digital sector.** More attention is paid to the development of the digital economy and the digitalization of the Chinese economy. In the past decade, the government has had an increasingly higher impact by taking **three key roles as** a policymaker, investor, and sustainability sponsor.

With the **13th FYP (2016-2020**), the government implemented a selection of initiatives to **upgrade the Chinese digital infrastructure**, for example strengthening high-speed transmissions, cross-border cable infrastructure, wireless networks (4G/5G), or developing an "Online Silk Road" in collaboration with Arab countries. The **14th FYP (2021-2025)** further stresses the importance of creating a higher quality digital and integrated economy with a related increase in GDP and at the same time, it promoted sustainability in the concept of an Ecological Civilization Indeed, the government explicitly states the intention to promote domestic digital industries, encouraging the main economic sectors to adopt new technologies to strengthen China's efficiency and reliability [63]. **There is not yet a clear link between digitalization and sustainability targets, though both are part of the 14th Five-Year Plan and are important pillars for high-quality development in China.**

To become carbon neutral in 2060, the government has introduced various **green initiatives** in the past years. However, China needs an estimated additional USD 6.4 trillion to USD 19.4 trillion to finance the green transition and therefore is looking for additional revenue sources. A **carbon tax** has been imposed to help fund climate-change policies, in addition to the attempts made to attract more **green investments** [64].

China has the potential to reinforce its leadership position in the digital sector by **taking ownership of shaping the nexus of digitalization and sustainability**. A comprehensive and **objective assessment of the environmental and social impacts of the digital sector** is needed to address the **missing links** between domestic priorities and international agendas, public goals and corporate strategies, academic research, and business R&D. **The Scoping Study suggests the CCICED to further explore the following aspects of the nexus of digitalization and sustainability to support the Chinese agenda on the green transition:**

1. Understand the dimensions of the twin transformation, including how digitalization drives economic and social change and how to utilize the potential of digitalization as a tool for a sustainable economy and social development.
2. Create long-term values and benefits through impactful innovations in connecting communities in treating digitalization as a cross-cutting discipline. Communities come from the digital and environmental research fields, but also the public and private sectors and civil society.
3. Study the opportunities of digital-social-environmental transformation, which goes beyond productivity increases. How can digitalization enable sustainable practices, reduce inequalities (digital divide) and improve the well-being of humankind and the environment?

4. How can the foresight of disruptive technologies and an environmental resource perspective reduce negative impacts?
5. How can China make the core of the digital sector, the ICT and ICT infrastructure, less harmful to the environment?

5.2 Potential elements of a Special Policy Study

Based on the findings of the Scoping Study on Digitalization to Advance Sustainability, the German Environment Agency (UBA), the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, and the World Economic Forum (the Forum) would like to propose a Special Policy Study (SPS) which explores, how to put digitalization at the service of sustainability and the construction of an Ecological Civilization, which entails the development of a green, circular and low carbon society and economy. The potential for a digital sustainability transformation is not an automatic process.

In the past two decades, digitalization has worked as an accelerator of economic processes that are still predominantly based on fossil energy and resource extraction. However, **the disruptive impact of digitization on sustainability can be leveraged to accelerate and enhance a sustainability transformation**. Both digital and environmental transformation will increasingly shape our economies and societies. The proposed SPS will examine how the **"missing links" between digitalization and sustainability** can be created, the status quo, the challenges, and opportunities existing in the digital sector itself as well as the traditional industries which undergo the digitalization process. Furthermore, the SPS will focus on the **key emerging innovations and analyze their significance for the environment and development**. Last but not least, the SPS will explore global **best practices** and the enabling environment to support China using its full potential in this respect. The SPS would also provide the attractive possibility to conduct field research together with other SPSs, as digitalization is a crucial cross-cutting issue.

Element 1 Sectors-Perspective: **A SPS intends to explore how to accelerate a green transition of the digital sector** itself, including greening IT in terms of resource- and energy-use of data centers and blockchain technology, as well as how digital and the "Fourth Industrial Revolution" (4IR) technologies which is characterized by a fusion of technologies that is blurring in lines between the physical, digital and biological spheres, such as AI, IoT, nanotechnologies, materials sciences, etc., could **enable the green transition of traditional sectors**, such as energy, building, mobility, agriculture, manufacturing, etc., including respective value chains. In this regard, the SPS will examine, 1) the status quo, the trends, and challenges these sectors are facing, the emerging green solutions that are enabled by 4IR technologies as well as the enabling environment for **large-scale implementation**; 2) how to **balance** scaling up digitalization for its carbon emission reduction potential while keeping the carbon footprint of digitalization low; 3) the underlining indications of these **disruptive digital innovations in the transition to the green economy**, with a focus on the opportunities and trends for new green products, services, and low carbon business models that resulted from the industrial-, sectoral- and system-level transformation for high-quality economic growth, especially with a cross-cutting perspective for integrated approaches; 4) the **risks** of not doing it right; 5) harnessing the 4IR technologies for environmental and climate governance to i**mprove policy-making**.

Among other sectors, **manufacturing, which accounts for more than ¼ of China's GDP, could be the highlight** of such a SPS. The key issue of the manufacturing sector is to make smart manufacturing and green manufacturing mutually supportive to improve productivity, increase efficiency and reduce environmental impacts, including the green value chain. Firstly, an overview of the total effect of digitalization on the production side of low-carbon development can be analyzed through case studies. For example, we can assess the effect of the incorporation of AI into decision-making on resource management and the burden on the environment. Secondly, a SPS can explore the potential of the digital transformation of the production sector in enabling new management models, new business models, and new production models by selecting inspiring case studies within and outside China. To be more specific, the digital solutions in production and processing we are focusing on include process automation, digital plant, predictive analysis on demand and production capacity, business-to-business platform, component printing, traceability, etc. Last but not least, product design such as fast prototyping and 3D printing, business-to-consumer platforms for product design cooperation, and its combination with eco-design can be interesting angles to observe as well.

Element 2 Innovations-Perspective: Research on breakthroughs of the recent digital innovations and their significance for the environment, climate, economy, and governance. The SPS can examine the key innovations by 1) identifying the latest digital technological trends and assessing ahead its' possible influence on the environment and development. This includes for example Digital Twins for the meaningful use of environmental data or in the means for a sustainable circular economy; 2) analyzing the specific opportunities and obstacles for deploying innovations e.g., in connectivity, funding, and providing deployment guidance; 3) analyzing the role of digital innovations in an integrated governance and reducing inequality for an inclusive society; 4) identifying and analyzing the key innovations in environmental and sustainability management, where interdisciplinarity is an important quality feature and great potentials exist in interfaces to AI and data science; 5) reskilling to support the digital and green innovation. As application-orientated digital/ AI research and environmental and sustainability research are mainly unconnected, the SPS will examine China's potential to link these research communities to show, how and in which fields these communities can target-oriented work well together.

Element 3 Cities-Perspective: the **SPS can also extend the scope of research to the future of cities** that are low carbon, sustainable and resilient through harnessing the digital and 4IR technologies to reduce negative environmental impacts, increase wellbeing, and urban economic activities. In this regard, the SPS will examine 1) the new urban system for production, consumption, mobility, working, and living by harnessing the digital and 4IR technologies to improve health, sustainability, and inclusiveness; 2) the gaps and opportunities in deploying the smart city technologies; 3) the best practices in smart city and enabling environment for upscaling the smart city practices.

Attachment: Twin transformation trends

China has experienced a decade of accelerated digitalization driven by heavy Research and Development spending, flourishing entrepreneurial activities, and raising venture capital investments. New business models and technologies emerged and grew at a very high speed, generating innovation in many fields. This section explores **key evolving trends in China**, thus identifying avenues for future research.

All these fields are fully embraced by the **Fourth Industrial Revolution technologies**, which include all those advances "merging the physical, digital and biological worlds in ways that create both huge promise and potential peril[…], forcing us to rethink how countries develop, how organizations create value, and even what it means to be human" [65].

Attachment 1. Industry 4.0 to improve efficiency and reduce the environmental burden

Industry 4.0 refers to the intelligent networking of machines and processes for industries with the help of information and communication technology. Such digitally-enabled systems allow the optimization of manufacturing productivity by ensuring the convergence of Operational Technology with Information Technology through more efficient, sustainable, and data-driven production processes [66]. Moreover, the adoption of digital technologies and services helps improve industry performance and economic conditions through the upgrade of industrial processes, the optimization of resource allocation, and the creation of higher-quality jobs [67].

There are many ways for companies to use intelligent networking to improve efficiency, thus leaving less burden on the environment and climate. The possibilities include, for example:

- **Flexible production**: In manufacturing a product, many companies are involved in a step-by-step process to develop a product. In being digitally networked, these steps can be **better coordinated** and the machine loads better planned.
- **Convertible factory**: Future production lines can be built in modules and be quickly assembled for tasks. Productivity and **efficiency would be improved**; individualized products can be produced in small quantities at affordable prices.
- **Customer-oriented solutions**: Consumers and producers will move closer together. The customers themselves could **design products** according to their wishes—for example, sneakers designed and tailored to the customer's unique foot shape. At the same time, smart products that are already being delivered and in use can send data to the manufacturer. With this usage data, the manufacturer can improve his or her products and offer the customer novel services.
- **Optimized logistics**: Algorithms can calculate **ideal delivery routes**; machines independently report when they need new material—smart networking enables an **optimal flow of goods**.
- **Use of data**: Data on the production process and the condition of a product will be combined and analyzed. Data analysis provides guidance on how to make a product more efficiently. More importantly, it's the foundation for completely **new business models and services**. For example, lift manufacturers can offer their customers "predictive maintenance": elevators equipped with sensors that continuously send data about their condition. Product wear would be detected and corrected before it leads to an elevator system failure.
- **Resource-efficient circular economy:** The entire life cycle of a product can be considered with the support of data. The design phase would already be able to determine which materials can be recycled.

BOX 7. Industry 4.0

In China: **China Aerospace Science & Industry Corporation (CASIC)** has developed **the INDICS platform**, which targets governments and SMEs in traditional industries and provides them with cloud-based tools and smart manufacturing solutions enabling matchmaking and resource sharing. According to the CASIC, the platform had 1.6 million registered users in 2018, with a total transaction value exceeding USD 64 billion. **SAIC**, a Chinese automotive company, has established a **digital platform that allows buyers to customize their orders via 3D digital car simulations**. Information about the vehicle configuration is then transmitted to suppliers to start production, **reducing the time to market by 35%**. AI tools continuously monitor the production progress to identify errors: as a result, the company increased its order configuration accuracy to 99.8% [68].

International: The **Global Lighthouse Network**, launched by the World Economic Forum, in collaboration with McKinsey & Company, has demonstrated the true potential of the Fourth Industrial Revolution technologies to transform the manufacturing industry; Out of the 90 lighthouses, 1/3 of them are from China.

In **Germany**, the **platform industry 4.0** is steered and led by the Federal Ministry for Economic Affairs and Climate Action (BMWK) as well as the Federal Ministry of Education and Research (BMBF), and high-ranking representatives from **industry, science, and the trade unions**. Experts from business, science, associations and the trade unions **develop operational solutions** together with representatives from various federal ministries in thematic working groups.

Attachment 2: Smart cities

In the past three decades, about 600 million people moved from rural areas to cities. As a result, China has become the country with **the greatest number of 1-million population cities** in the world. With other **300 million Chinese people** expected to relocate to urban centers over the next 30 years, this phenomenon will increase the pressure on the environment [69]. The main causes are increased pollution, traffic congestion, and supply and demand of resources. Therefore, China is focusing on the creation of **smart cities**.

Smart cities could improve urban eco-efficiency as a result of three main effects. First, the **technology effect** can boost energy savings and clean production technologies, reducing pollution and resource consumption. Second, thanks to the **industrial structure enhancement effect**, innovation will create new opportunities for R&D, design, development of software, information, and business services. Finally, the **resource allocation effect**: technological systems can effectively solve the problem of resource management and deploy them where they have the highest impact and efficiency [70]. In conclusion, the concept of Smart City aims at improving urban management, achieving **sustainable city development**, and enhancing residents' **quality of life** with technology.

Nowadays, China is home to around **500 smart cities – half of those present in the whole world**. One of the reasons behind this is the government's active role in providing policies and guidance for their development. The investment in smart cities, which is currently about **USD 26 billion**, is expected to exceed the threshold of **USD 40 billion** in 2023, and there are around **800 Chinese urban centers** ready to make this transition [71].

In the future, research should concentrate not only on the best tools and technologies to make cities more efficient in terms of energy consumption, water management, and transportation solutions, but also on ways to **identify the urban areas that should be made "smarter"**, and those that do not need to be transformed.

BOX 8. Model project "Berlin lebenswert smart" – 5 pilot projects[72]

As part of the model project "Berlin lebenswert smart", the city of Berlin is adopting a new Smart City Strategy – and is working on five concrete pilot projects. These projects are funded as part of the model project and are planned to start in January 2020. Participatory formats will play an important role in both the pre-project phase as well as during the implementation phase.

- **Smart City Spaces:** Hardenbergplatz in Charlottenburg-Wilmersdorf, a typical station forecourt with high usage, is being redesigned smartly and flexibly - i.e., depending on the event, day, weather, and season – for all forms of mobility.
- **Data Governance & Data-driven Administration:** Together with the Einstein Center Digital Future and Siemens AG Data-Governance, the Smart City model project is developing exemplary concepts for pilot areas that integrate municipal and private-sector interests and processes in a way that balances the common good.
- **Community Budgeting and Smart Participation:** In the context of participatory processes, interests tend to be distorted by low participation. Reallabor StadtManufaktur, BBBlockchain, CityLAB, and the mobile CityLAB are supposed to help reach more people with activating, digitally supported participation.
- **Smart Water – Modelling and Governance:** The impact of extreme weather events is obvious, but difficult for decision-makers and the public to comprehend. The project models the effects of spatial heterogeneity and homogeneity on the water cycle and develops a participatory digital wall panel.
- **Data in everyday life and crisis – Kiezbox 2.0:** Local data on climate, air quality, etc. are generally obtained during regular operation. In the event of a crisis (e.g., power failure), solar or battery-powered hotspots for example can form an emergency Wifi network that informs the local population.

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