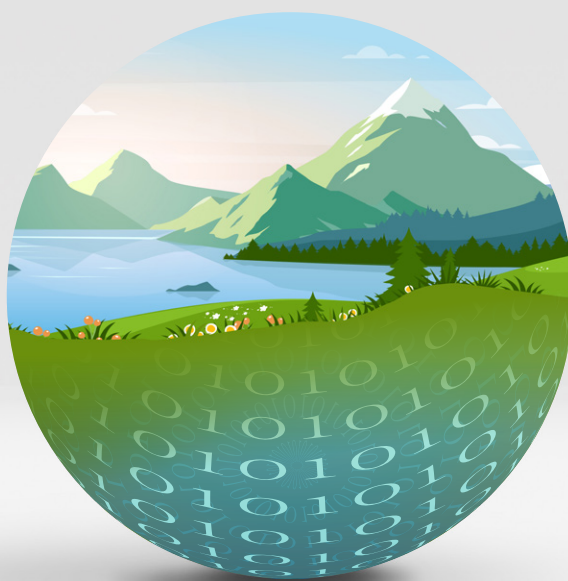


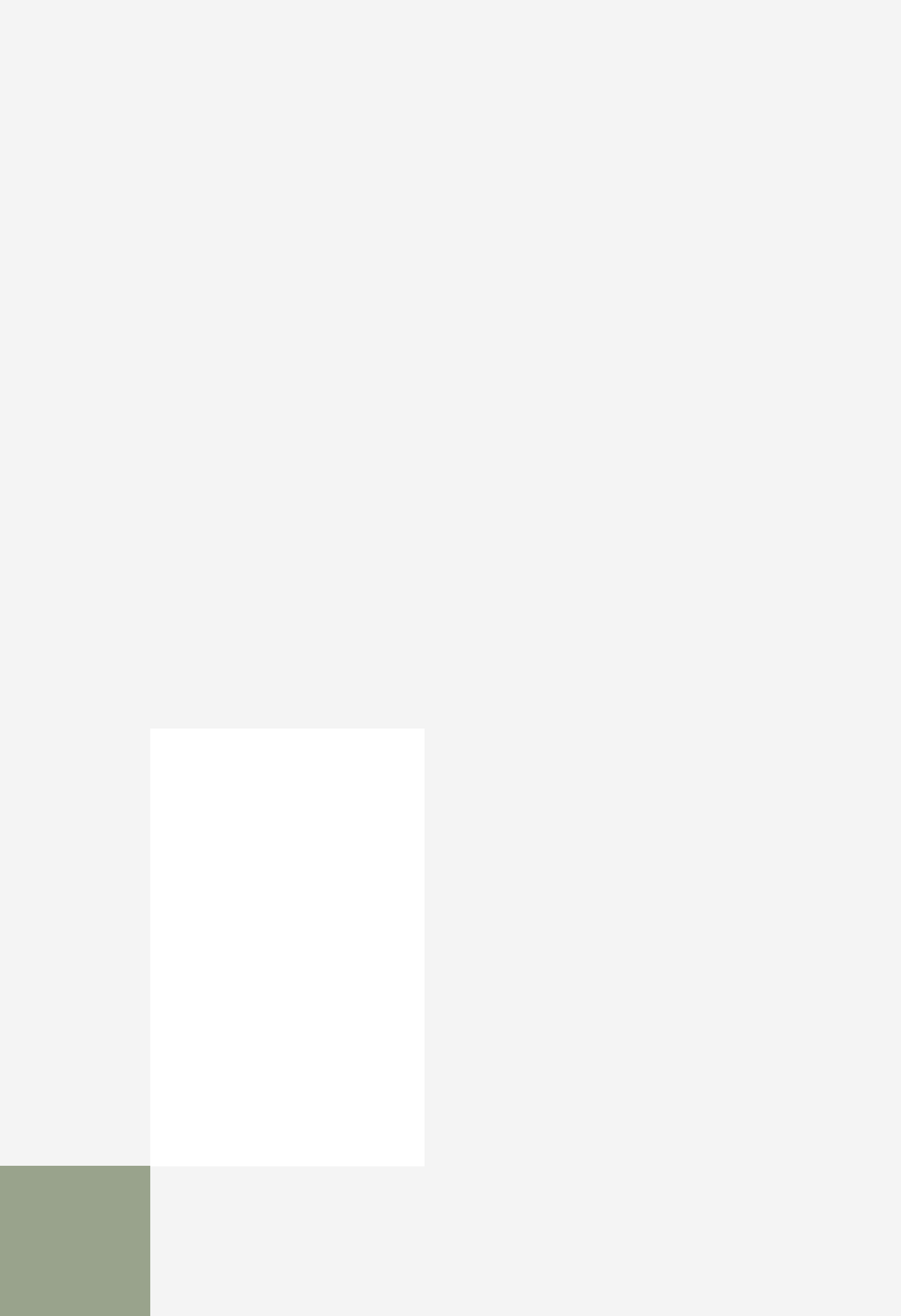


# Green Development 2030



Building a Fully Connected,  
Intelligent World

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GREEN

DEVELOPMENT

2030



# Foreword

The world continues to face unprecedented challenges. Our biosphere is under threat from rising carbon emissions. Our society sees persistent inequality and lack of access to basic services. Our economy continues to drive unsustainable consumption. Urgent action is required, and digital technologies can and need to contribute more. Businesses have a big role to play in changing the dynamics to helping our world thrive.

As we face the challenges that come with a global pandemic, the critical role of digital technology and innovation is becoming more visible in keeping society moving. Yet, to fully activate the world-changing potential of digital technology, the information and communications technology (ICT) sector must lead the way by managing the responsible development, deployment, and use of its products and services.

The main impact of Digital is in enabling other sectors to reduce their footprint. It is a fundamental catalyst for the digital transformation of businesses, cities, and public services. It is

a catalyst for Industry 4.0, bringing sensibility, intelligence, and automation to new generation production processes for greater competitiveness. It is the catalyst for the transformation of cities into smart and inclusive cities that improve the quality of life of their citizens. It is the catalyst for more efficient and more comprehensive public services that educate better, offer better health to more people through the remotisation of less critical care and better use of resources in more critical care, accelerate transactions in the economy, maximise the use of resources and provide greater security for all.

Digital technology is connected with everything that we do. But technology alone is not enough to deliver impactful change. The way solutions are created and deployed is what can make a real difference for our planet, and the time to act is now.

Green development envisions a world of harmonized green, low-carbon and circular development power through the force of innovation

and technology. While technological rebound effects need to be addressed and controlled, the downsides of digital technologies are much less significant than their potential to improve the planet. That is why we need to focus on solutions.

Data from GeSI research highlights that the deployment of existing technologies will, on average, accelerate progress towards sustainable development by 22% and mitigate downwards trends by 23%.<sup>1</sup>

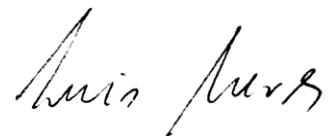
Smart solutions for mobility, manufacturing, agriculture, building and energy have the potential to maintain global CO<sub>2</sub>e emissions at 2015 levels, decoupling economic growth from emissions growth.<sup>2</sup>

Additionally, ICT is good for growth and could deliver over \$6 trillion in revenues and close to \$5 trillion USD in cost savings.<sup>3</sup>

The opportunity to achieve great change is enormous.

I am deeply convinced that this report will contribute and accelerate the journey towards building a more sustainable and resilient world. Innovation in our energy efficiency practices, industries, and renewable energy solutions will be crucial to enable the transformation needed to ensure a better future for all.

I would like to congratulate Huawei for producing the “Green Development 2030 report” showing on how green development will change our lives and future industries. Thanks for contributing in a very transparent and candid manner to better shape the debate and better frame policy development across the industry.



**Luis Neves**  
GeSI CEO

1. GeSI, *Digital with Purpose: Delivering a Smarter 2030*.

2. WRI, IPCC, World Bank, GeSI, Accenture analysis & CO<sub>2</sub> models

3. WRI, IPCC, Gartner, FAO, GeSI, Accenture analysis & CO<sub>2</sub> models

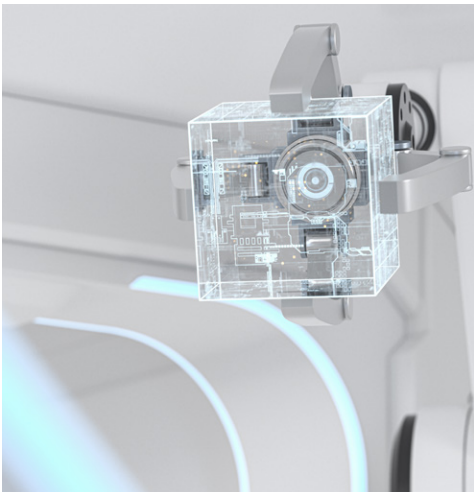
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## Executive Summary

Huawei is working to build a fully connected, intelligent world. But it's increasingly clear to us that this world also needs to be green.

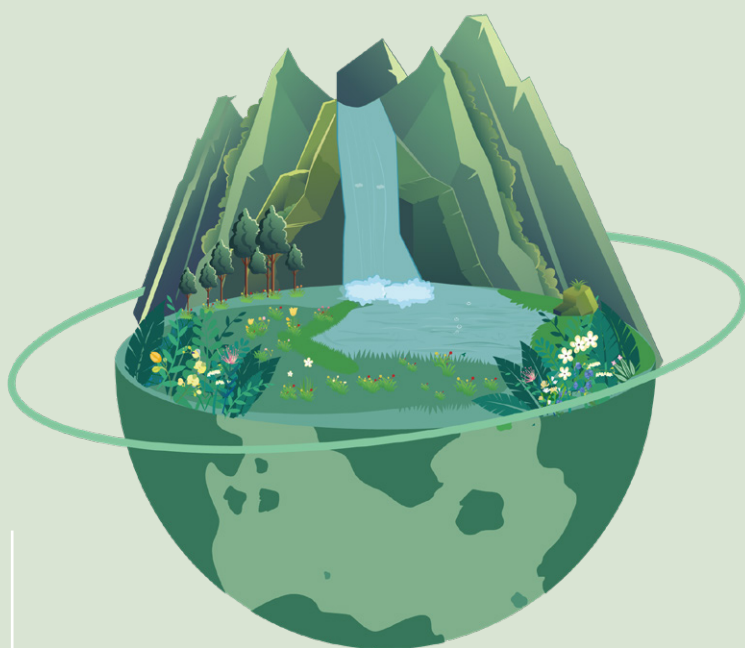
The intelligent world we envision for the year 2030 will see low-carbon living truly gain traction. It will see virtual tourism help people from all walks of life, wherever they may be, explore our planet whenever they want. It will also see lifelike holograms used in virtual classrooms, allowing students to fully immerse themselves in a universe of knowledge. In this future, buildings will use far less energy, allowing people to live and work in a better environment. Electric and intelligent vehicles will bring an end to traffic jams and make green travel a reality. Industrial production will go green with virtual factories where experts from around the world can create and collaborate in real time from the comfort of their homes. New forms of flexible production will help manufacturers more precisely match supply with consumer demand, while clean energy will see wider adoption as renewables go mainstream. By 2030, we expect 80% of digital infrastructure to use energy from renewables and expect energy efficiency to

increase 100-fold.

In this report, we will focus on how green development will change our lives and future industries. We aim to paint a compelling picture of a future where low-carbon living, renewable energy, fully-electrified transport, net-zero carbon buildings, as well as green industrial sector and digital infrastructure will play an active role in our lives. We believe that digitalization and decarbonization are the two most powerful driving forces behind green development. Digitalization enables decarbonization which, in turn, will unleash the infinite potential of digitalization.

In order to achieve green development, we identify three areas where more innovation is needed: improving the energy efficiency of digital infrastructure, increasing the share of renewables in electricity generation, and enabling green industries. A green and intelligent world is fast approaching, and we firmly believe that collaboration and nonstop exploration are the only way forward. 

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## A NEW ERA OF GREEN DEVELOPMENT



Modern industry has evolved over the course of three major revolutions in technology: steam, electricity, and information technology. And while these technologies have pushed total economic output to new heights, their over-reliance on fossil fuels has also led to an exponential increase in carbon dioxide emissions. We now find ourselves in a position where the effects of climate change pose an exponential threat to society and the world around us.

Recently, we have seen a sharp uptick in global adoption of green development principles. Green development is a new sustainable development system that aims to promote steady economic growth while minimizing damage to the natural environment and ensuring that natural assets are used in a sustainable way.

Many nations are actively promoting green industry as part of broader initiatives to restructure their economies, and the rollout of green infrastructure is also picking up pace. Countries like China, Japan, and the US – alongside many European nations – have released carbon reduction plans and roadmaps that place green development on par with the digital economy in terms of its long-term importance. This momentum is unprecedented.

In the US, in addition to the Green New Deal, which if passed will commit the country to 100% carbon pollution-free electricity by 2035, the Biden administration's spending framework devotes US\$555 billion to areas like infrastructure and clean energy, as well as consumer subsidies for electric vehicles and household rooftop PV systems.



The EU has similar plans to invest an additional €350 billion annually between 2021 and 2030 to promote the use of electric vehicles and facilitate the reduction of carbon emissions in the public transport sector.

In Germany, the Renewable Energy Act (EEG) has been amended to speed up the construction of renewable energy infrastructure with a focus on wind and solar power. With this change, Germany hopes to see its energy come from all renewable sources by 2035.

Japan and China have also committed to reaching carbon neutrality by 2050 and 2060, respectively. Both countries have outlined clear action plans for reducing carbon emissions in specific priority sectors, backed with supporting policies that incentivize green development in the private sector.

These trends will go a long way to protect the environment that we depend on, and they also present incredible opportunities for many countries – especially those in emerging and developing regions – to promote economic restructuring and realize rapid economic growth.

As we enter this new era of green development, digital technology will play an increasingly critical role. This report provides specific examples of how digital technologies such as 5G, cloud, big data, and AI can boost the generation of renewable energy and help industries go green. It delves into the relationship between decarbonization and digitalization, and also discusses the importance of reducing the carbon footprint of digital infrastructure itself. 🌱

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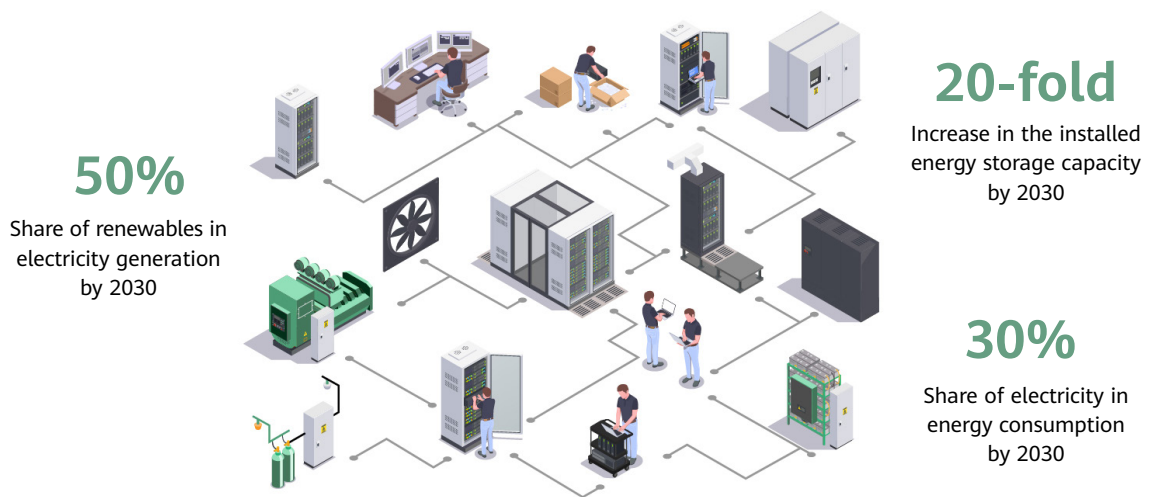
## VISION FOR GREEN DEVELOPMENT 2030

It is clear that green development will transform the way people work and live, and these changes will be most apparent in sectors like energy, industry, transport, buildings, and digital infrastructure.

## Renewable energy is going mainstream

In the future, floating PV plants and wind turbines with a diameter of over 200 meters will be common at offshore locations. The vast Sahara will be home to the world's largest PV power plant, and a super power grid will carry electricity between continents. With a converged, open, and intelligent energy cloud, virtual power plants will break down boundaries between traditional power plants and users, and coordinate distributed wind energy, solar PV, energy storage systems, and other flexible loads. Energy storage, wireless charging and discharging, and converged charging and discharging on the consumer side will become a reality for thousands of households.

### Renewable energy is going mainstream



The large-scale application of upcoming advancements in digital and intelligent technologies will make it possible for electricity to be managed in a comprehensive, independent, and collaborative manner. These technologies will allow electricity to be measured, controlled, and regulated, no matter where it is produced, transmitted, distributed, consumed, or stored. Energy storage technologies and distributed green power supplies will also allow for the convergence of energy and information flows, greatly improving the reliability, stability, and security of energy systems.

Electricity production will go green and low-carbon. In the next decade, clean energy will be used for an increasing number of applications, and renewable energy generated from wind, solar, and hydro will gradually replace traditional fossil fuels. By 2030, renewables are expected to account for over 50% of all electricity generation worldwide.

The Levelized Cost of Energy (LCOE) of PV plants will fall to US\$0.01 per kWh, and global installed PV capacity will reach over 3,000 GW, a more than 10-fold increase from 2020.

Electricity transmission and distribution will also become more intelligent. Digital technology will enable comprehensive management of electricity transmission and distribution networks through intelligent O&M, status monitoring, and fault diagnosis. Network operations will be monitored in a real time so operators can immediately troubleshoot equipment faults. Functions such as automatic collaboration, detection, and monitoring will also make O&M much more efficient, as they can help O&M personnel accurately locate and quickly rectify faults in energy systems. Virtual power plants will connect rooftop PV systems, small wind power plants, electric vehicles, and home energy storage systems to provide stable power supply.

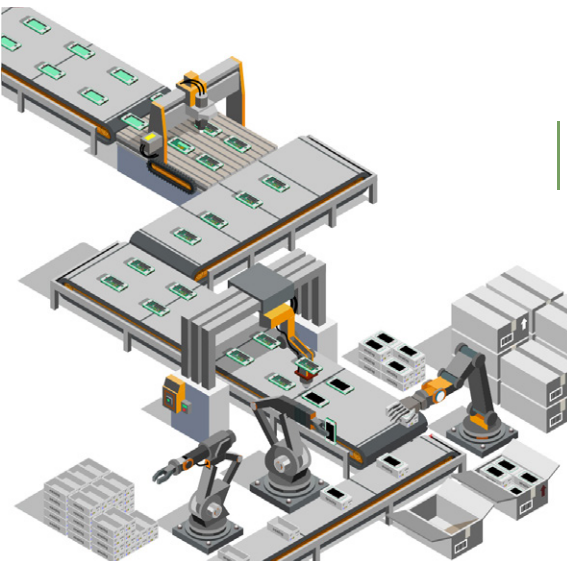
Electrification of energy consumption will accelerate, gradually replacing the mass use of fossil fuels in both the transport sector and industrial sector. According to the *Intelligent World 2030* report, the share of electricity in global final energy consumption will increase from about 20% in 2020 to 30% by 2030. In addition, users will be able to use digital technology to accurately and quickly detect activities that consume high amounts of energy and emit large amounts of carbon dioxide, allowing them to manage their energy consumption in a more refined manner. This will also help them optimize power scheduling and better match power generation with demand, to make power consumption more efficient and reduce carbon emissions.

Finally, as energy storage technology becomes more advanced and sees large-scale rollout, energy

storage installations will become an important regulator of the energy system. The global installed capacity of energy storage systems is expected to increase from 17 GW in 2020 to 358 GW in 2030 – a more than 20-fold increase. While energy generated through renewable sources such as wind, solar, and hydro has traditionally been considered unstable, inconsistent, and poor quality, new advantages in energy storage technology will help effectively overcome these issues. The convergence of digital technology and power grids will also make it possible to connect all parties involved in power generation, grids, loads, and storage. This will help them better address the needs of peak load shaving, demand response, peak clipping, and energy supply balancing to build a more flexible, efficient, stable, reliable, and low-carbon power grid.

## The industrial sector will go green

In the future, digital factories will be staffed by robots that can independently complete tasks such as material feeding, production and manufacturing, quality inspection, packaging, packing and warehousing, and loading. Virtual factories will bring together engineers, designers, and experts from all over the world to perform complex tasks such as product planning, design, and simulation, and even complete the entire product planning process. Platforms that support collaborative content creation will facilitate the creation and simulation of virtual 3D worlds with high fidelity to the real world. 3D printing will eliminate the need for molds in industrial production, and digital flexible manufacturing will eliminate the need for mold manufacturing, production line adjustment, and more, allowing consumers to design and produce on their own and creating a personalized production model. The upstream and downstream along the supply chain will be fully transparent and visualized, allowing enterprises to monitor material and information flows in real time.



### The industrial sector will go green

It is estimated that by 2030, every 10,000 workers will work with **390** robots

In the future, digital technology will make robots more intelligent, driving wider adoption. On production lines and in warehouses, for example, autonomous mobile robots (AMRs) implement intelligent picking, movement, stock-in and stock-out, and material feeding and unloading procedures through rich environmental awareness, dynamic route planning, flexible obstacle avoidance, and global positioning. This will significantly reduce labor costs. Huawei's *Intelligent World 2030* predicts that by 2030, every 10,000 workers will work with 390 robots.

Digital flexible manufacturing is expected to change everything, from production to consumption. The massive amounts of data provided by digital technology will enable enterprises to understand customer needs more directly and accurately. What's more, the modular design in flexible manufacturing will get consumers more involved in the production process. Product design, process design, equipment functions, logistics, and distribution will all be reshaped to become more flexible and serve new consumer-centric production models. Digital flexible manufacturing will make green, low-carbon industrial sector a reality by greatly shortening the product R&D cycle, speeding up capital turnover, and reducing energy and resource waste.

In the future, factories will become digital, intelligent, and green. With the application of digital technologies such as 5G, AI, IoT, cloud computing, digital twins, and blockchain in industrial manufacturing, data collection and monitoring, intelligent analysis, precise control, and refined management of material, energy, and information flows can all be integrated into the production process. Through intelligent production and management, smart factories will greatly improve the efficiency of manufacturing and O&M services, and reduce carbon footprint throughout the entire process, from production to O&M, quality inspection, and packaging.

Digitalization will also help supply chains become more transparent and predictable. Supply chain digitalization is about collecting and analyzing upstream and downstream orders, logistics,



inventories, and other related information on the supply chain. This can make the supply chain more transparent and visualized and thus greatly reduce supply chain risks. In addition, companies can use various sensors to monitor warehouse conditions (e.g., temperature, humidity, dust and smoke) in real time. IoT, RFID, and QR code technologies are used to automatically identify and register goods, and access the warehousing status data of goods. With supply chain digitalization, the operation data of various transportation vehicles in the logistics system will also become available. GPS, AI, 5G, IoT, and other technologies will be used to monitor the transportation process when they are in transit, enabling companies to rapidly optimize transportation resources and routes to ensure the timely and safe delivery of goods.

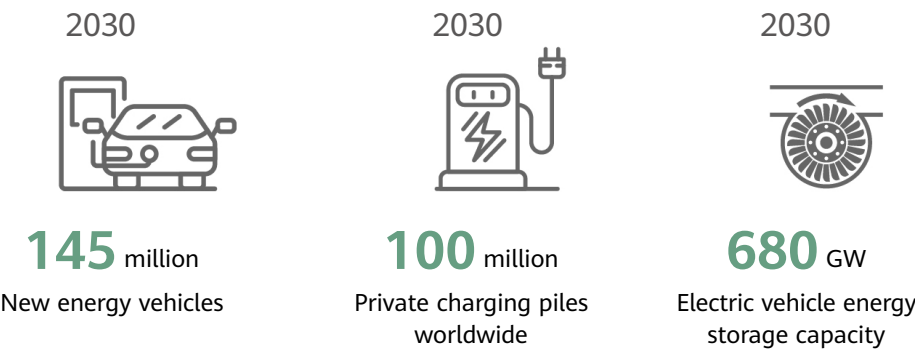
With the adoption of ICT technologies such as cloud computing, IoT, big data, and AI, the supply chain will transform into a supply network. In this network, the upstream materials required by every link will have multiple alternative sources, and they can be sourced through multiple routes. A multi-contact collaborative supply ecosystem will be created by enhancing the internal and external interconnectivity of enterprises. The failure of any single link will not result in paralysis across the whole supply network.



# Comprehensive electrification in transportation

By 2030, 145 million new energy vehicles worldwide will support autonomous driving and provide shared services. Tens of thousands of blended wing body aircraft powered by new energy will shuttle passengers between international airports. New energy cargo ships powered by offshore PV plants will be found traveling between ports across the globe. A transport Internet will even coordinate the management of new energy vehicles, public transportation, shared bicycles and motorcycles, and sidewalks to identify the best means of transportation for passenger transfer and goods delivery, reducing traffic congestion and carbon emissions.

## Comprehensive electrification in transportation



In the future, the electrification of transportation will accelerate alongside the rise of electric vehicles. Intelligent collaboration between vehicles, charging piles, power grids, and energy storage devices will result in safer, greener, and smarter travel.

In the future, robust electricity infrastructure and advanced battery technology will make electricity the most important clean energy alternative in road and rail transportation. Electric vehicles will serve as critical hubs for the integration of power systems and transport systems as they involve transportation, power consumption, and energy storage. As battery costs decline, performance improves, and autonomous driving technology evolves, electric vehicles will become increasingly popular among consumers, with more than 40 million electric vehicles expected to be sold globally by 2030, equaling the expected sales of fossil-fuel vehicles.

However, a green transport system requires solid

support, meaning charging facilities for electric vehicles will need to develop rapidly. According to the International Energy Agency (IEA) and other related reports, by 2030, the global number of private charging piles is expected to reach 100 million, collectively delivering a total charging power of 1,500 GW and a total charging capacity of 800 TWh. In addition, the number of public charging piles is expected to reach 20 million by 2030, with a total charging power of 1,800 GW and a total charging capacity of 1,200 TWh.

Wi-Fi devices, microwave detection devices, and BeiDou ground stations are all starting to see large-scale deployment and autonomous driving and 5.5G/6G-enabled Harmonized Communication and Sensing (HCS) will be widely used by 2030. This will lead to leapfrog development in multi-dimensional sensing, information sharing, automatic device control, independent decision-making, and the intelligent management and control of highway

and railway networks. For example, centimeter-level positioning and imaging up to millimeter-resolution will become a reality. Traffic infrastructure, such as highways, bridges, and traffic lights will share information to achieve automatic control. They will also collaborate with vehicles and traffic participants to proactively detect runtime exceptions in road networks, promptly report road congestion and device faults, and release cross-region traffic and accident information online. At the same time, an integrated system for monitoring vehicle operations and road conditions is expected to become a reality as vehicles become more intelligent and gain the ability to comprehensively sense road network operations. Whenever traffic exceptions are detected, this system will be able to independently implement intelligent services, such as vehicle-road coordination, management of regional road network

coordination, and travel information services.

Advancements in energy storage technology and intelligent, flexible power grids will make it possible for micro energy storage units, such as electric vehicles, to fully participate in two-way interactions within energy systems. The IEA's Global EV Outlook 2021, released in April 2021, predicted that the number of electric vehicles worldwide will continue to grow over the next decade, reaching 145 million by 2030. By that time, their energy storage capacity could be 40 times what it was in 2020, reaching 680 GW. Electric vehicles, which will act as highly flexible load and adjustable energy storage units, will be able to purchase and sell electricity in the market as required, reducing the impact of charging on power grids and providing more flexible and distributed energy resources for power systems.

## Future buildings will operate at net-zero carbon

All new buildings around the world will operate at net-zero carbon by 2030. Net-zero carbon buildings will significantly reduce the use of lights, air conditioning, heating, etc. through new building designs, eco-friendly materials, and natural energy resources such as wind and solar energy. The use of energy sources such as solar energy, wind energy, and biomass generated from organic waste fermentation would enable buildings to achieve net-zero energy consumption. Rainwater collected from the roof could be used to flush toilets or water plants, reducing the need for running water and thus enabling net-zero waste water of buildings. Turning inorganic waste into furniture or building materials would make net-zero waste possible.

### Future buildings will operate at net-zero carbon

All new buildings will operate  
at net-zero carbon by

2030



All buildings will operate at  
net-zero carbon by

2050



According to the 2021 Global Status Report for Buildings and Construction published by the Global Alliance for Buildings and Construction, in 2020, the construction sector accounted for 36% of global final energy consumption and 37% of energy-related CO<sub>2</sub> emissions, as compared to other end use sectors. At the same time, new buildings are springing up rapidly each year around the world. The 2019 Global Status Report for Buildings and Construction released by the IEA and the United Nations Environment Programme shows that, the global population is expected to reach 10 billion by 2060, two-thirds of whom will live in cities. To accommodate this population, an additional 230 billion square meters of floor area will be needed, equivalent to doubling the number of existing buildings. Such a huge demand for construction means that greenhouse gas emissions from the building sector will continue to rise.

It is expected that all new buildings will operate at net-zero carbon by 2030, and all buildings will achieve this by 2050.

Through in-depth application of digital and

intelligent technologies, net-zero carbon buildings will be able to automatically interact with their environment through sensors. Sensors monitor and generate data about a building in real time, including its environment and condition, and connect control systems and core systems such as lighting, electricity meters, water meters/pumps, heaters, fire alarm systems, and water chillers. Intelligent, cloud-based systems allow net-zero carbon buildings to automatically decide how they can minimize energy use. For example, a complete automated system could use IoT devices to check the number of people in a building in real time, and then decide when to switch air conditioners and lights on or off in different parts of the building. Such a system would also be able to manage elevators, hallways, and shutters, depending on actual human activity. In addition to the environmental benefits, net-zero carbon buildings will also make people's lives more comfortable. Automated systems can keep indoor temperatures at agreeable levels, while soundproofing materials can keep outside noise down to a minimum, supporting regular sleeping patterns.

## Green digital infrastructure is becoming a basic requirement

According to the *Intelligent World 2030* report, by 2030, there will be 200 billion connections, the total amount of general computing will have increased 10-fold, and the total amount of AI computing power will have increased 500-fold. Renewable energy is becoming mainstream in energy supply for data infrastructure, and ICT infrastructure O&M is becoming fully automated. Technologies such as neural networks, knowledge graphs, and domain shift will greatly improve O&M efficiency, eliminate a large amount of repetitive and complex manual work, and improve the fault prevention and prediction capabilities of digital infrastructure using big data. Data-driven differentiated service models will enable highly automated and intelligent operations of digital infrastructure.

## Green digital infrastructure is becoming a basic requirement

By 2030, the energy efficiency of digital infrastructure will increase by

**100-fold**



Building a green and low-carbon, flexible, efficient, intelligent, and automated digital infrastructure will be a priority for future development.

In the future, green energy will become mainstream in energy supply for digital infrastructure, and renewables like wind, solar, and hydro will become the main sources of energy supply. In addition, over 80% of digital infrastructure will be powered by distributed and small wind and solar power systems over the next decade. For example, distributed PV plants are built on data center campuses and rooftops, and large-scale terrestrial PV plants, wind farms, and other types of clean-energy structures are built in the surrounding areas to directly supply data centers. Energy storage technology will be widely used in digital infrastructure. This can offset the variability of renewable energy generation, and enable two-way power supply between digital infrastructure and smart grids, maximizing the commercial value of digital infrastructure. The application of new materials, components, architectures, algorithms, and theories will increase the energy efficiency of digital infrastructure by 100-fold.

Future digital infrastructure construction will become more flexible and efficient. Most of today's data centers are built indoors. In the future, what once filled an equipment room will be squeezed into a single cabinet, and what once filled a cabinet will be mounted on a single pole. Traditional concrete data center buildings will be replaced by prefabricated modular data centers. This will make data center construction and expansion more flexible and efficient, and reduce footprints, construction cycles, and costs. Traditional concrete buildings housing 1,000 cabinets usually take about 20 months to build. In the future, such a data center can be built in just a few months, meeting the requirements for rapid service rollout.

As big data, AI, neural networks, and other technologies gain traction, digital infrastructure O&M will become intelligent and automated. With massive amounts of data and intelligence, digital infrastructure can prevent and predict problems that arise in operations in real time. This will lower the costs and time needed for O&M, improve responsiveness and reliability, and increase digital infrastructure utilization and operating benefits.

# Low-carbon living is gaining traction

## Low-carbon living is gaining traction



### E-Health

By 2030, the global telemedicine market is expected to be worth US\$ **431.8** billion, almost a **10-fold** increase

### Online Education

By 2030, China's online education is expected to increase by **23-fold**



### Digital Tourism

By 2030, it is estimated that **1** billion users will take virtual tours through AR and VR



By 2030, technologies such as IoT and AI, sensitive biosensors, massive amounts of health data stored on the cloud, and portable medical devices will enable people to access telemedicine services from the comfort of their homes. Patients will be able to consult doctors online and get electronic prescriptions. According to a report of Allied Market Research, by 2030, the global telemedicine market is expected to be worth US\$431.8 billion, almost a 10-fold increase. In addition, telemedicine will significantly reduce the need for patients to travel between their homes and hospitals. This is especially true for patients living in remote areas who travel all the way to major cities to see a doctor. In this sense, telemedicine benefits both doctors and patients, and helps healthcare providers greatly reduce their carbon emissions.

Online education will be more popular in 2030. With advances in technologies such as AI, big data, cloud computing, IoT, virtual reality (VR), and augmented reality (AR) online education will further transcend the barriers of time and space, allowing students from thousands of miles away

to receive the same quality education as local students. Morgan Stanley expects China's online education market to increase by 23-fold by 2030. This will bring high-quality education concepts and content to more students, especially those in remote areas, reduce greenhouse gas emissions, and facilitate green education.

Data will create many digital spaces by 2030, such as virtual tourist attractions. These digital spaces, together with the physical world, will form a hybrid world. Virtual tours can give us a true-to-life experience of scenery on the other side of the world. They will also allow us to have wide-ranging conversations with luminaries of the ancient world. According to the *Intelligent World 2030* report, the number of AR and VR users is expected to reach one billion by 2030. 🌱

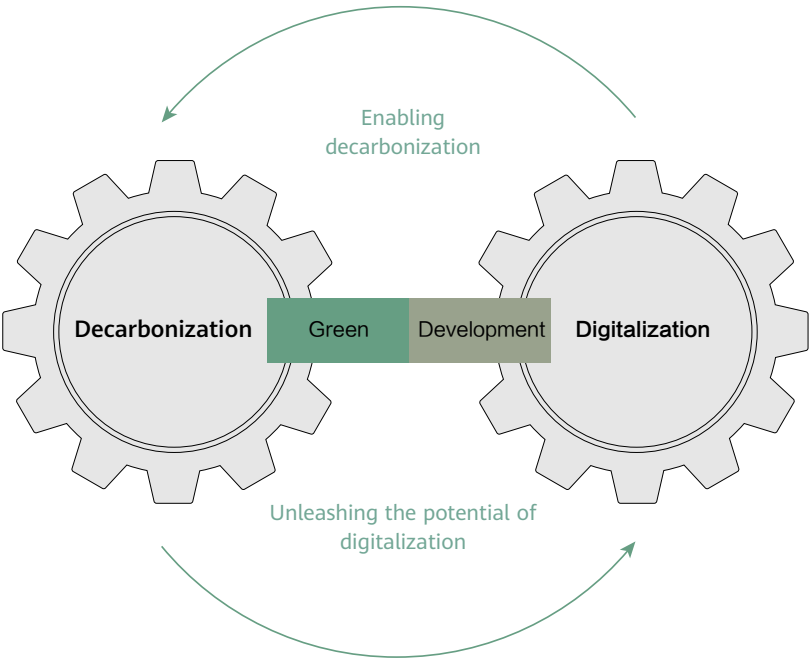
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## DIGITALIZATION AND DECARBONIZATION: POWERING GREEN DEVELOPMENT

## Two drivers of green development

### Digitalization and decarbonization: Two drivers of green development

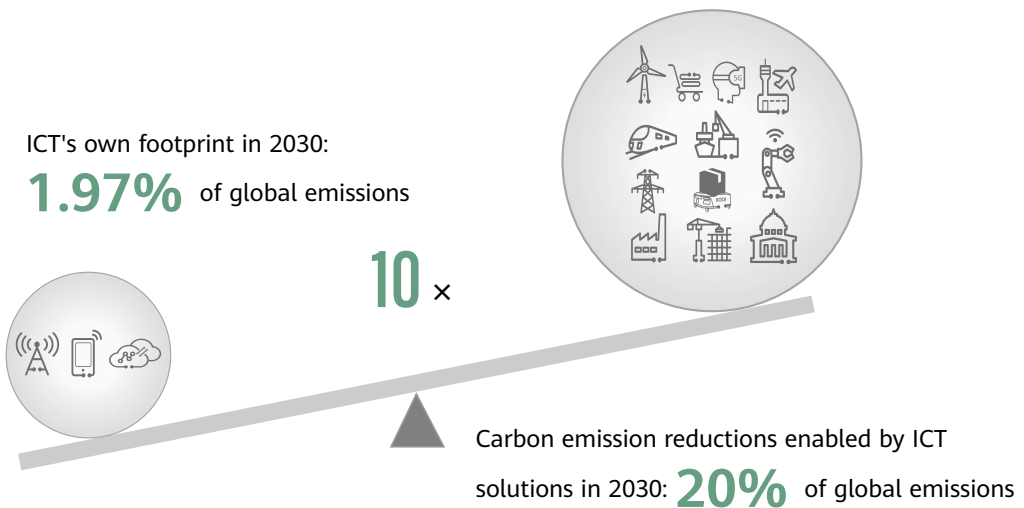


Green development is essential for global economic growth and ultimately for social advancement. At the same time, the digital economy is becoming a key driver of economic development, and so numerous industries are going digital. As climate change becomes an increasingly pressing issue, the general consensus is that economic development

and social advancement must not be achieved at the cost of environmental degradation. More and more industries are therefore shifting to low-carbon operations. Simply put, digitalization drives development, and decarbonization ensures that this development is sustainable. These are the two drivers of green development.

## Digitalization enables decarbonization

### Digitalization enables decarbonization



Matter, energy, and information are the three basic elements of our world. By focusing on them and their interactions, we can start moving towards green development. As digital technologies like AI, cloud computing, big data, IoT, and 5G drive the digital revolution, information flows will help matter and energy flow faster and cut carbon emissions. Looking into the future, digital technology will also play a key role in reforming the energy mix and boosting productivity across a wide range of industries. They will essentially be the key to green and low-carbon development.

While the ICT industry itself accounts for less than 2% of global carbon emissions, it is a leverage point that can be exploited to achieve really disproportionate emissions reductions. According to the SMARTer2030 report published by the Global Enabling Sustainability Initiative (GeSI), ICT has the potential to enable a 20% reduction of global carbon emissions by 2030 – 10 times the ICT industry's own footprint.

In all sorts of industries, ICT is powering low-carbon development by using networking, digital,

and intelligent technologies. In the public sphere, ICT helps modernize government regulations and public services, driving a shift to greener models of living and working and ultimately facilitating green socioeconomic development.

Digital technology is also playing an important role in carbon emissions reduction, carbon removal, and carbon management. To achieve carbon neutrality, carbon emissions must equal carbon removed, and effective carbon management must run throughout this process.

Digital technology is essential to reducing carbon emissions in energy supply and consumption. Carbon emissions come from two sources: energy supply and energy consumption. Energy supply includes traditional energy and clean energy. Digital technology can boost supply efficiency and reduce the environmental impacts of traditional energy sources while helping accommodate renewable energy and ensure stable supply.

Energy consumption occurs in many sectors,



including industry, buildings, transport, and consumers. Digital technology also plays a critical role in cutting emissions in energy consumption. It can enable green, intelligent manufacturing and energy management, help buildings cut carbon emissions throughout their lifecycles, facilitate more efficient traffic flows, and increase the efficiency of transport service providers. Digital technology will play an especially important role in our everyday lives. It will enable intelligent healthcare, education, cultural activities, tourism, and finance.

When it comes to carbon removal, digital technology helps ecosystems increase the efficiency of carbon storage. Digital technology also plays a critical role in carbon management, including carbon accounting and monitoring, carbon trading, and carbon finance.

According to some in the industry, digitalization may cause a rebound effect<sup>4</sup>. However, this is a non-technical, dynamic, and systemic issue more related to economics and human behavior. During the digital transformation of power, transport, buildings, and the industrial sector, digital technology will play a neutral role. Regardless of the efficiency gains and cost savings digital technology enables, the intensity and total amounts of carbon emissions coming from these carbon-intensive industries will still

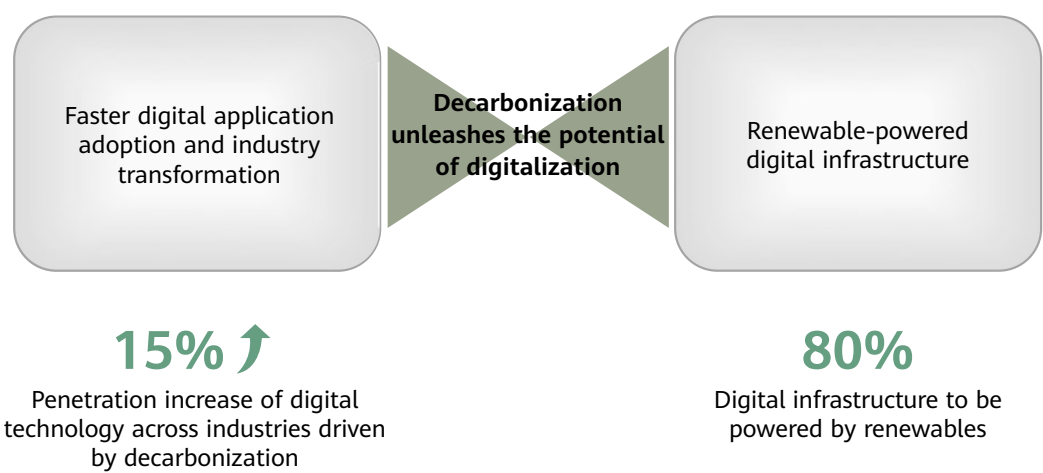
need to be actively controlled through system-level emissions reduction mechanisms like carbon trading and carbon pricing. By empowering traditional industries, digital technology is directly and indirectly changing people's behavior and the relationships between people and between people and organizations. During this process, proper policy support, like the Carbon Generalized System of Preferences, can help protect against rebound effects.

However, this is a non-technical, dynamic, and systemic issue more related to economics and human behavior. During the digital transformation of power, transport, buildings, and the industrial sector, digital technology will play a neutral role. Regardless of the efficiency gains and cost savings digital technology enables, the intensity and total amounts of carbon emissions coming from these carbon-intensive industries will still need to be actively controlled through system-level emissions reduction mechanisms like carbon trading and carbon pricing. By empowering traditional industries, digital technology is directly and indirectly changing people's behavior and the relationships between people and between people and organizations. During this process, proper policy support, like the Carbon Generalized System of Preferences, can help protect against rebound effects.

4. Rebound effects occur when a product or service becomes cheaper due to increased efficiency. With other conditions remaining unchanged, this will spur demand. Many people are therefore concerned that emissions reductions made possible with the use of digital technology may be partially or completely offset by this effect, or that even more CO<sub>2</sub> will be emitted.

# Decarbonization unleashes the potential of digitalization

## Decarbonization unleashes the potential of digitalization



Decarbonization can unleash the potential of digitalization. As green and low-carbon development is becoming increasingly important in the global agenda, many countries are pushing the digital industry to pursue sustainable development and encouraging other industries to adopt digital applications. This is especially true in traditional industries where technological innovation in carbon- and pollution-intensive processes will not be enough. These industries will also need to reduce resource waste caused by poorly aligned supply and demand and underuse of resources.

Digital transformation will be the way forward for these industries. Digital technology can help translate the data generated in the course of production into new information and knowledge flows. With intelligent processing, this data can help boost productivity and establish shared, collaborative, and data-driven production chains. This will in turn give rise to new business models centered on shared and circular economies, and

boost energy and resource efficiency.

As the world moves closer to a full decarbonization, we will also see a significant shift toward renewable energy, particularly in digital infrastructure like data centers. Digital infrastructure deployment will increase demand for electricity, but the impact of this demand can be offset by renewable energy purchasing quotas. Facilities that generate electricity from renewable energy can be also deployed directly at data centers and customized to account for their loads and power supply systems. This can address the increase in energy consumption by digital infrastructure and also cut the cost of digitalization, which, in turn, drives up the adoption of digital technology.

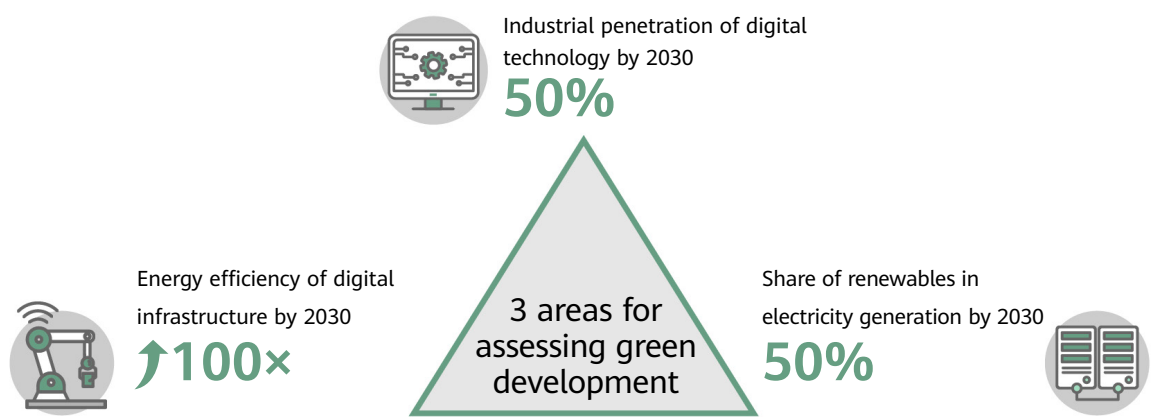
China has already launched initiatives to balance the distribution of computing power across the country's eastern and western regions. By deploying more data centers in China's western regions, these initiatives are better leveraging the abundant

renewable energy resources available in those regions. This means greater economies of scale, more efficient use of computing power, and lower energy consumption per bit. These initiatives are effectively addressing the rebound effect caused by digitalization while meeting the growing industrial demand for computing power, especially in China's

eastern regions. In addition, the cost reductions made possible by large-scale deployment are making digital technology more affordable for both industrial customers and consumers. This will help apply more low-carbon technologies and solutions to industry applications, creating a virtuous circle.

# Digitalization and decarbonization combine to drive green development

## Areas for assessing green development



The coordinated development of digitalization and decarbonization is essential to high-quality economic development. To better assess their role in driving green development, Huawei has identified three assessment areas: energy efficiency of digital infrastructure, renewable energy development, and industry digitalization. We predict that by 2030, digital infrastructure will be 100 times more energy efficient, more than 50% of electricity will come from renewable energy, and 50% of businesses will have adopted digital

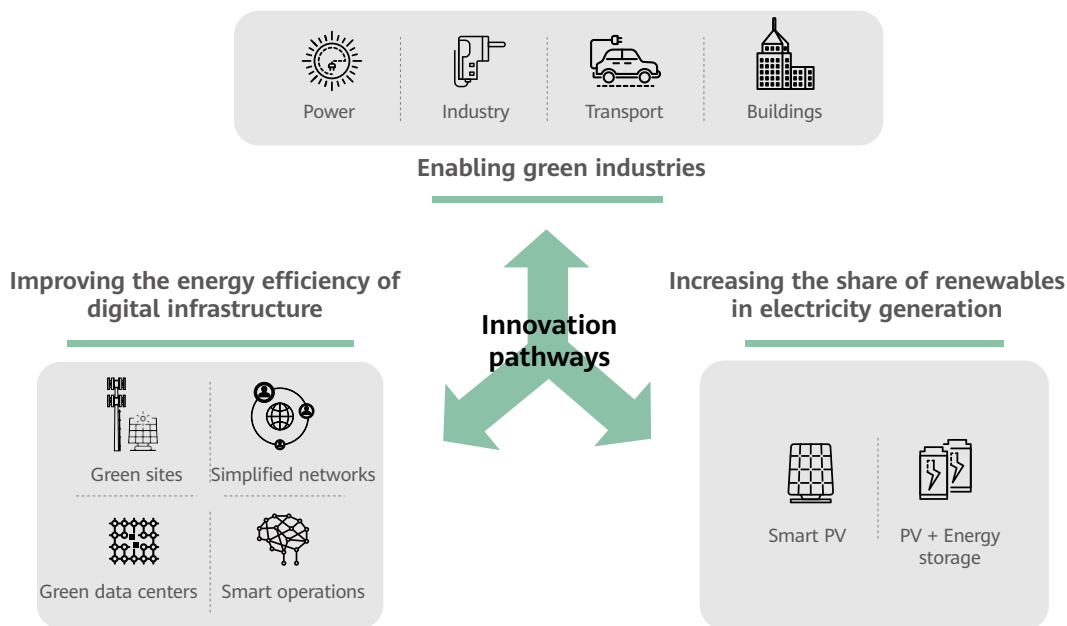
technology. Creating synergies between digitalization and decarbonization will be very important. As digital infrastructure becomes more energy-efficient and the renewable energy industry grows, digital technology will play a greater role in empowering industry digitalization and decarbonization. This will in turn help industries develop faster and more sustainably while pushing the green agenda forward.

# 4



THREE INNOVATION PATHWAYS:  
HOW DIGITALIZATION AND  
DECARBONIZATION POWER  
GREEN DEVELOPMENT

## Three innovation pathways of green development



Digital technology is evolving faster than ever before and digital infrastructure is starting to be deployed at scale. According to the *Intelligent World 2030* report, by 2030, there will be 200 billion connections, and we will see a 10-fold increase in general computing power, and a 500-fold increase in AI computing power. To address the resulting growth in energy consumption, we will need to continue increasing the energy efficiency of digital infrastructure.

Currently, renewable energy makes up 28.6% of the global electricity generation. To increase this ratio to 50% by 2030, we need to innovate by integrating

digital and power electronics technologies.

In addition to boosting productivity and driving faster development, digital technology will also enable the shift to decarbonization. However, only 20% of businesses are currently using digital technology. Green development will therefore require increased penetration of digital technology.

Ongoing innovation will be needed to improve the energy efficiency of digital infrastructure, to increase the share of renewables in our electricity generation, and to enable green industries. These efforts combined will ultimately contribute to a greener world.

# Pathway 1: Improving the energy efficiency of digital infrastructure

## Improving the energy efficiency of digital infrastructure

### Smart operations



#### Network operations:

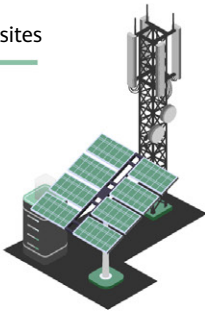
Using an evaluation index to accurately measure and optimize energy efficiency



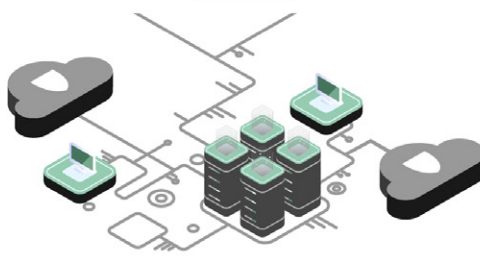
#### User operations:

Migrating users to release legacy equipment and resources and improve energy efficiency

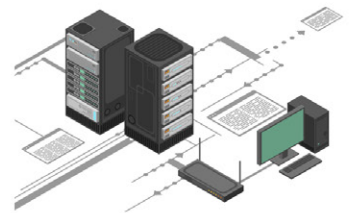
### Green sites



### Simplified networks



### Green data centers



Improvement in energy efficiency of digital infrastructure requires innovation at multiple levels, including sites, networks, data centers, and operations. At the site level, new theories, materials, components, and architecture can be introduced to drive improvement in energy efficiency of equipment. For example, we can explore extremely large antenna arrays (ELAAs) and optoelectronic integration. Network-level energy efficiency can be improved through architecture and software innovation. In data centers, multi-dimensional innovations are required to achieve an ideal power usage effectiveness (PUE). For operations, an evaluation index and low-carbon, autonomous driving networks can be introduced to encourage network users to shift towards energy-efficient digital infrastructure and bring PUE closer to 1.0.

**Building green sites through innovations in theories, materials, components, and**

## architecture

Communications sites can be divided into wireless and wired sites. In a communications site, power is mainly consumed by communications equipment and auxiliary systems such as air conditioners and power supplies. For auxiliary systems, introducing renewable energy and changing the form factor of the site are two major pathways. For equipment, the use phase is the key. 80% of the carbon emissions of communications equipment in a site comes from the use phase, 11.5% from raw material processing, and 4.6% from production and transportation.

**Wireless sites: Natively energy-efficient equipment and simplified site architecture for systematic and multi-dimensional energy efficiency improvement**

The next decade will see a 100-fold increase in

wireless data as users demand better network experiences, everything becomes connected, and digital transformation continues. In addition, industries around the world are moving towards green operations, which will inevitably result in a linear increase in the power consumption of mobile networks if left unchecked. To prevent this, we need to develop natively green sites across the full links and full lifecycle of communications networks and increase energy efficiency per bit by 100 times.

Traditional designs of mobile communications equipment mainly focus on performance improvement. Moving forward, equipment energy efficiency must become a basic consideration during site design. Key green technologies should be considered to cover every link of the energy transmission chain, including auxiliary equipment that supplies energy, the main base station equipment that consumes energy, and devices whose energy consumption can be cut by introducing green design in the air interface.

A simplified site design can help improve the energy efficiency of the site power supply system by improving conversion efficiency at each node, reducing line losses of power supply links, and cutting power consumption of auxiliary equipment such as air conditioners. Innovations in site architecture, such as integrated BBUs and outdoor sites that do not require air conditioning, can substantially save energy. By changing the form factor of sites, i.e., replacing equipment rooms with cabinets or even poles, we can improve the site energy efficiency from 60% to 97%.

Existing equipment rooms can be modernized with precise cooling and power boosts. This can increase energy efficiency to 80% while also negating the need for new equipment rooms, changing cables, or new air conditioners. When constructing new sites, we can use cabinets instead of equipment rooms, which can improve energy efficiency from 60% to 90%. For communications sites with no mains supply or unstable supply, we can make full use of solar power to eliminate the need for diesel generators, and provide green and affordable power supply.

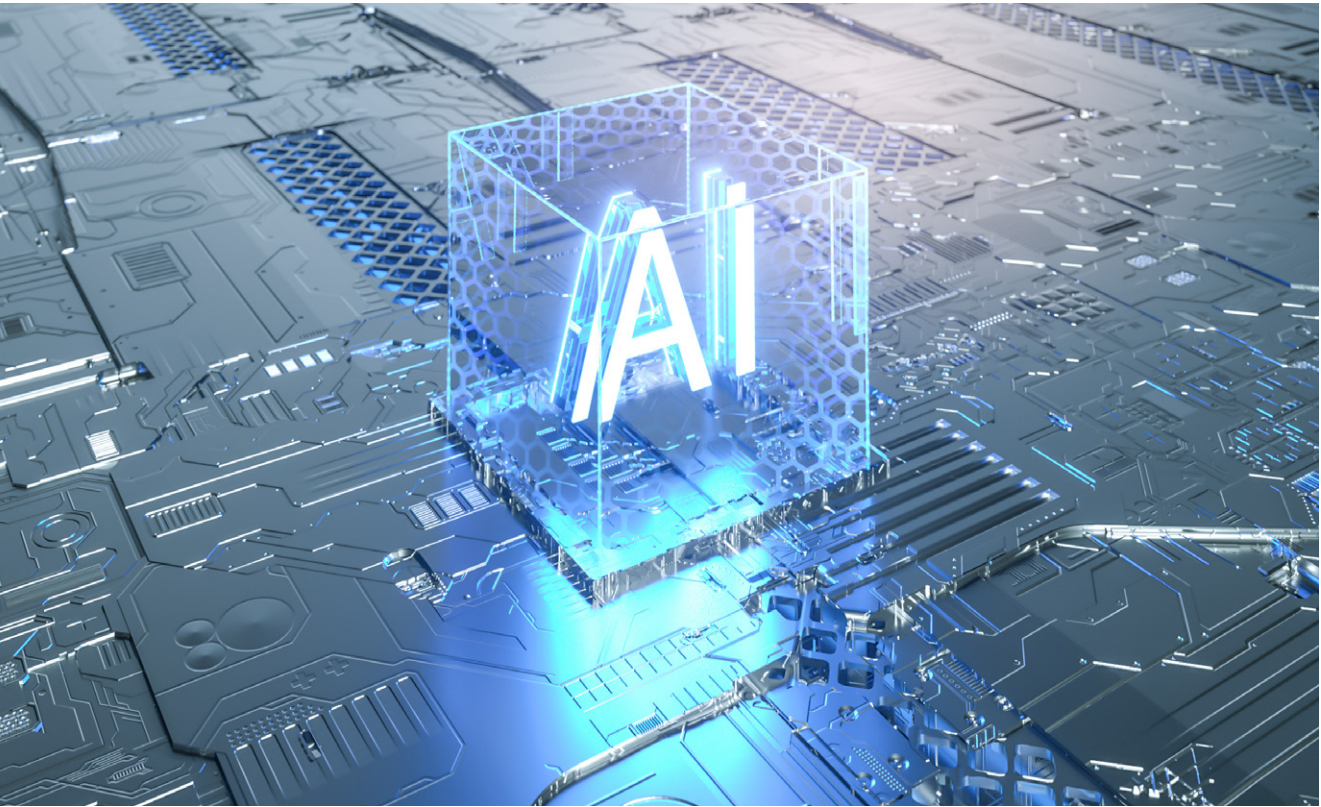
China Mobile Hangzhou and the China Mobile Design Institute modernized outdoor sites with a simplified design, which increased the power efficiency of the sites from 89% to 96%. In addition, the reduced footprint was used for the installation of a photovoltaic power generation system, which would reduce annual carbon emissions by eight tons per site.

The development of natively energy-efficient equipment can help improve energy efficiency. To make this happen, we need to adopt modular design and explore new architecture, processes, materials, and algorithms to find new ways of saving energy across time, frequency, space, code, and power domains.

Another pathway to pursue is introducing extremely large antenna arrays, which means shifting from focusing solely on improving active RF power to improving both active RF power and passive antenna aperture. This represents a key path to reducing the power consumption of AAUs. For any given cell, the larger the antenna aperture, the less transmitter power output (TPO) is required. This means that larger antenna apertures greatly reduce the power consumption of a site. Dynamic adjustment capabilities of the equipment itself are also important, which means the equipment always operates at the maximum energy efficiency per bit, whether it is busy or idle. In addition to the above measures to improve energy efficiency, more research is needed in other energy efficiency technologies and theories, such as optical wireless base stations, semantic communications, and intelligent hypersurfaces.

### **Wired sites: Optoelectronic integration and intelligent hibernation for higher energy efficiency**

Over the next decade, the global penetration rates of gigabit and 10-gigabit home broadband networks will reach 55% and 22% respectively. In addition, the average monthly Internet traffic in households will increase 8-fold to 1.3 TB. To address the resulting increase in energy consumption, we will need to continue improving the energy efficiency of wired sites. Currently, we mainly rely



on replacing active components with passive ones to improve the energy efficiency of wired sites. For home users, we are using FTTH to replace copper cables, which can lead to an estimated 60% increase in energy efficiency. On campuses, the adoption of passive optical LANs (POLs) can improve energy efficiency by 100–150%. Compact, low-degree all-optical switches are used to build wide-coverage sites, improving the energy efficiency by 80–100% compared with electrical switches. Moving forward, we need to explore new ways to improve the energy efficiency of equipment. The optoelectronic integration approach promises to improve energy efficiency by 30%. Another area for research is dynamic hibernation technologies, which can improve the energy efficiency of equipment by about 10–20%.

**Optoelectronic integration: Co-packaged optics and optical switching for higher energy efficiency**

Depending on the site, the power consumption of key components, such as chips, serializers/deserializers (SerDes), and optical-to-electrical converters, can account for 60–80% of the

power consumption of all equipment in a site. The key technology to address this challenge is optoelectronic integration, which includes co-packaged optics (CPO) and optical switching.

With a conventional architecture, optical modules are connected to equipment chips through SerDes, which require long cables and consume 17–30 pJ/bit of power. The CPO technology integrates optical transceivers and equipment chips on a complementary metal-oxide-semiconductor (CMOS) substrate, eliminating the need for functions such as clock and data recovery (CDR), decision feedback equalizer (DFE), continuous time linear equalizer (CTLE), and feed forward equalizer (FFE). Research shows that CPO can cut the power consumption for data transmission to about 6 pJ/bit. With the application of new optoelectronic materials, this can be further reduced to less than 1 pJ/bit, which means that the SerDes energy efficiency can be improved by 80% with CPO.

In the past, the energy efficiency of switching chips mainly relied on process improvement, with

each generation about 30% more efficient than the previous one. However, as Moore's law and Dennard scaling will no longer apply, the energy efficiency brought by advancements in process techniques can no longer keep up with the fast-growing bandwidth. As chips evolve from 28 nm to 5 nm, the bandwidth increases by a factor of 50 while the energy efficiency only improves by a factor of 5, resulting in a surge in power consumption per unit. To address this problem, industry players have begun to explore optical packet switching chips, which have been shown to further improve chip energy efficiency by 50%.

CPO is expected to be commercially available by 2025. Some academic institutions are researching optical cell switching technology that could potentially replace electrical switching networks. Optoelectronic products using optical buses and optical cell switching technology are expected to be developed by 2030. Further into the future, chip-level products that combine optical computing, optical RAM cores, and general-purpose computing cores will likely emerge.

#### **Intelligent hibernation: Introducing AI-enabled dynamic hibernation to resolve the conflict between user experience and energy consumption**

When network equipment or individual components are idle or operating under relatively light loads, they can automatically shut down or switch to a low-power mode to save energy. This requires a hibernation state between the on and off states of the equipment. When a piece of network equipment is idle, it can quickly switch to the hibernation mode to reduce energy consumption. Dynamic hibernation can also be applied to individual network components such as cache, optical, forwarding, and switching modules to save energy at different levels. In addition, self-adaptive network traffic control technologies need to be introduced so that equipment and individual components can detect traffic patterns, which helps develop effective hibernation policies and find the optimal conditions and timing for hibernation switch and activation. This will help avoid packet loss and extra power consumption caused by mode switching.

## **Building simplified networks that are more energy efficient through innovations in system architecture and software**

### **Network architecture: Networks need to be reconstructed based on the nature of the services they carry and give way to simplified networks built upon an optical foundation**

Network architecture determines the number of sites and equipment needed, and how different pieces of equipment are connected and the connection media they use. Architecture is therefore a decisive factor in the energy consumption of networks. For example, compared to a 32T32R 5G network, a 64T64R Massive MIMO 5G network can provide the same coverage with about 25% fewer sites. Extending low-degree optical cross-connect to the edge is expected to reduce energy consumption by about 55%.

As we work to continuously simplify network architecture and improve energy efficiency, we must not forget that the ultimate goal of network architecture is to support services. Therefore, we must not seek overly simplified networks at the expense of user experience. Networks of the future need to be reconstructed based on the nature of the services they carry, and built upon an optical foundation of 100% fiber-to-the-site connections and all-optical cross-connect (OXC or ROADM), including access (wired/wireless), bearer, and core networks. Building on slicing technologies such as FlexE and native hard pipes (NHP), these networks can become greener with improved utilization.

### **Energy saving through network software: Using energy-efficient routing to maximize network resource utilization and approach "0 bit, 0 watt"**

The way network traffic is scheduled greatly impacts the energy consumption of networks. For example, dynamic scheduling can be used based on the tidal effect of traffic to reduce the power consumption of networks according to reductions in network traffic while ensuring network connectivity and quality of service. This will minimize the

energy consumption of equipment that transmits network traffic, with an ultimate goal of achieving "0 bit, 0 watt". Another example is energy-efficient routing technology, which calculates and configures energy-efficient routing paths based on network load changes, and puts idle, redundant network resources into hibernation to reduce network energy consumption. This technology has two specific technical solutions: Elastic Tree and Energy-aware Routing for General Topologies (ERGT). Analysis shows that when the network is 50% loaded, energy-efficient routing technology can reduce the power consumption by about 24–29%.

## Building green data centers through multi-dimensional innovation from L1 to L3

Data centers currently account for about 1% of global electricity consumption. The total energy consumption of general-purpose computing has been doubling every three years. The push toward carbon neutrality will drive a 100-fold increase in both the computing power and energy efficiency of data centers. In a data center, the energy consumption of physical infrastructure (L1) accounts for about 55% of the total energy consumption (air conditioners: 40%; power supply: 10%; and lighting: 5%), while IT hardware (L2) and IT software (L3) account for the remaining 45%. The energy efficiency of the physical infrastructure, IT hardware, and IT software of a data center all needs to be improved.

To improve the energy efficiency of the physical infrastructure of a data center, we must build green data centers by reshaping cooling and power supply:

- Reshaping cooling: We can adopt indirect evaporative cooling technology to make the most of natural cooling sources. In addition, the application of AI can enhance data center cooling. Sensors in data centers collect data on temperature, power levels, pump speed, power consumption rate, and settings, which is then analyzed using AI. The data center operations and control thresholds are then

adjusted accordingly, reducing costs, increasing efficiency, and slashing data center PUE.

- Reshaping power supply: All links within the power supply and distribution systems will be visualized and manageable, while the utilization of equipment, air conditioners, power supply, and lighting can be optimized based on big data analytics. Through this process, data center PUE can be reduced by 8–15%.

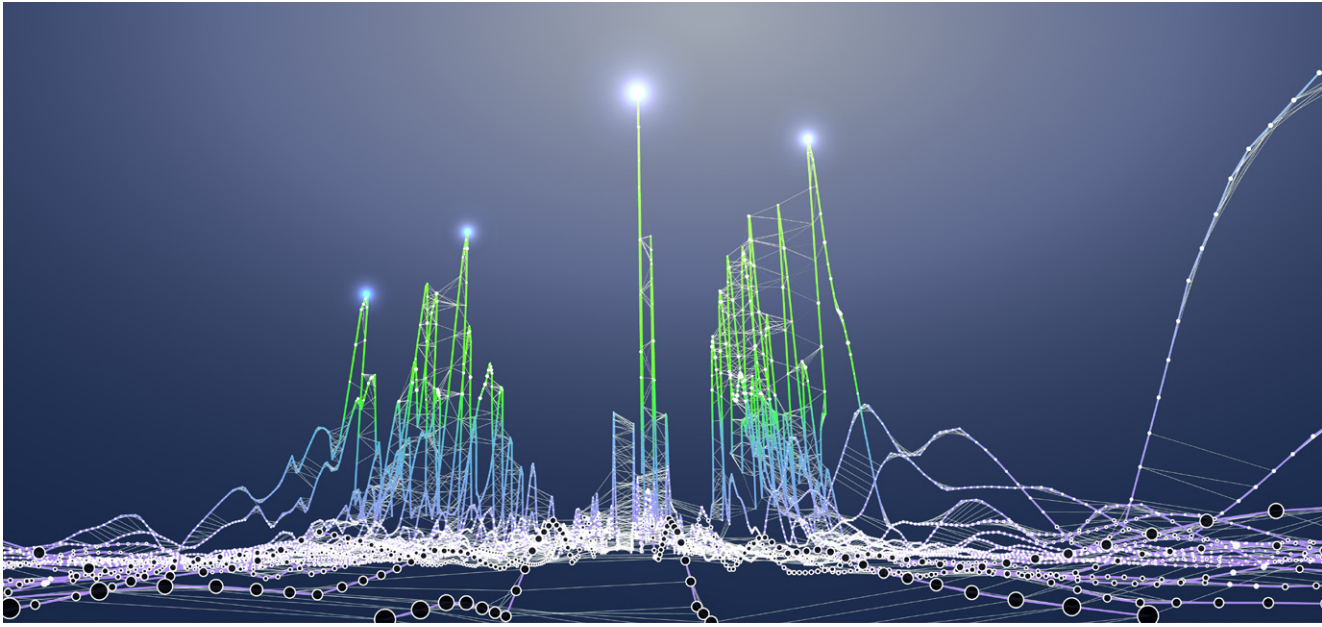
To improve the energy efficiency of IT hardware and software, we will make ongoing improvements to chip packaging and chip architectures, ensuring a constant increase in computing power density, storage density, and energy efficiency. Advanced computing architecture will be data-centric, greatly improving data exchange efficiency. In terms of networks, lossless Ethernet technology will double the energy efficiency of computing power.

### **3D storage technology: Superior performance and 5-fold higher energy efficiency than conventional architectures**

New storage technology is evolving towards all-flash storage and all-flash memory. IEEE believes that 3D NAND flash will be scaled beyond 600 layers in the near future. This increase will mean the layers become thinner, NAND cells become smaller, and storage capacity is boosted. Moving forward, the number of 3D NAND flash layers is expected to reach 1,000. By 2030, the adoption of novel storage media in data centers will reduce energy consumption by 70%, equivalent to 25 million fewer tons of carbon emissions every year.

### **2.5D chiplet packaging and integration technology: Continuing to improve chip computing power and doubling energy efficiency**

2.5D silicon/fan-out (FO) interposer plus chiplet technology can increase die yield, reduce chip costs, and greatly improve chip performance through stacking and integration. In addition, the energy consumption per bit is just half that of the board-level interconnection solution used in conventional packaging. It is estimated that by 2025, the size of a 2.5D silicon/FO interposer will



be more than four times that of a reticle, and the substrate is expected to be larger than 110 mm x 110 mm. Larger 2.5D and substrate processes pose engineering challenges in terms of yield, lead time, and reliability. To address these challenges, converged, innovative substrate architectures will be needed.

**3D chip technology: Superior chip performance and dozens of times higher energy efficiency than conventional architectures**

3D chip technology has significant advantages in interconnection density, bandwidth, chip size, power consumption, and overall performance. The technology will be critical to chip and system integration in key scenarios such as high-performance computing and AI.

3D chip stacking requires the use of ultrahigh-density bonding technology with pitches smaller than 10  $\mu\text{m}$ . 3D chips have significant advantages over 2.5D packaging in bandwidth and power consumption, and power consumption per bit is expected to fall by 90%. Ongoing research into technologies for working with smaller through-silicon vias (TSVs) is required, in terms of both materials and processes.

**Data-centric advanced computing architecture: Significantly improving data exchange efficiency**

In the future, data will be processed in the right place using the right amount of computing power, reducing data migration and boosting overall system performance. For example, network data will be processed on nearby data processing units (DPUs) and neural network models will be trained on neural network processing units (NPUs). Computing power will be everywhere. Peripherals such as hard disks, network adapters, and memory will all gradually become capable of data analysis and processing. In the computing domain, ubiquitous near-data computing (e.g., near-memory computing, near-storage computing, and in-memory computing) is the way forward, and is expected to be at least 10 times more energy efficient than the traditional Von Neumann architecture.

In addition, new lossless Ethernet technology for data centers is expected to reduce energy consumption per unit of computing power by 47%. Experimental data shows that a data center suffering a 0.1% packet loss rate results in a 50% loss in computing power while also doubling the computing duration. According to hydrodynamic test data gathered by the Wuhan AI Computing Center, it takes 375 ms for a traditional network and 198 ms for an Ethernet with zero packet loss to complete the same task. This means the energy efficiency per unit of computing power of the Ethernet with zero packet loss is nearly double that of a traditional network.

Intelligent technology will help data center O&M become fully autonomous, and big data and AI will be used to further analyze and optimize energy efficiency and equipment utilization. In addition, the DigiPowerCloud and digital twins can be used to track the carbon footprint of data centers in real time.

The Gui'an Data Center, the largest data center built by Huawei Cloud, will be able to accommodate one million servers after full completion. The data center has green and intelligent technologies incorporated into its design, adopts indirect evaporative cooling technology to make the most of natural cooling sources, and uses AI to increase energy efficiency. The data center's PUE is only 1.12, and it generates 810,000 tons fewer carbon emissions every year compared with a conventional one.

### Smart operations: Measuring carbon emissions through an index and building low-carbon autonomous driving networks

The ICT industry currently lacks a unified standard to measure the carbon emissions of digital infrastructure. On one hand, carriers from different countries and regions adopt different approaches to network rollout. On the other hand, digital

infrastructure covers numerous domains, and its carbon emissions vary greatly from domain to domain, making it almost impossible to fully achieve green and efficient operations. Moving forward, our efforts must focus on developing capabilities in green and low-carbon operations and strengthening the "brain" of digital infrastructure. We will need to create an index and build low-carbon autonomous driving networks, in order to make digital infrastructure more energy efficient and blaze a trail to net-zero emissions.

#### **Establishing a robust index for green and low-carbon development, unifying standards, and reaching a consensus**

Our industry must jointly define an index for the green and low-carbon development of digital infrastructure, establish unified measurement standards, and form a consensus. This will help us better manage the energy consumption and carbon emissions of digital infrastructure.

At Mobile World Congress Shanghai 2021, Huawei and Informa released a white paper titled *The Path to Net Zero for ICT Requires Technology Innovation*. This white paper proposed the Network Carbon Intensity (NCI) index, which defines the carbon emissions per bit of data traffic as a new metric for green digital infrastructure. The white paper calls for active collaboration among all industry players. This aims to jointly optimize the index that manages the carbon emissions of networks, balance the relationship between the traffic, coverage, KPIs, user experience, and energy consumption of networks, and boost network energy efficiency.

#### **Network operations: Building low-carbon autonomous driving networks**

The autonomous driving network is evolving toward L4/L5 – a higher level of intelligence. Based on the network nervous system, we will bring together data and knowledge assets related to green and low-carbon development to build low-carbon autonomous driving networks that are automated, autonomous, self-healing, and self-optimizing, and enable new low-carbon services that offer optimal customer experiences, autonomous O&M, and



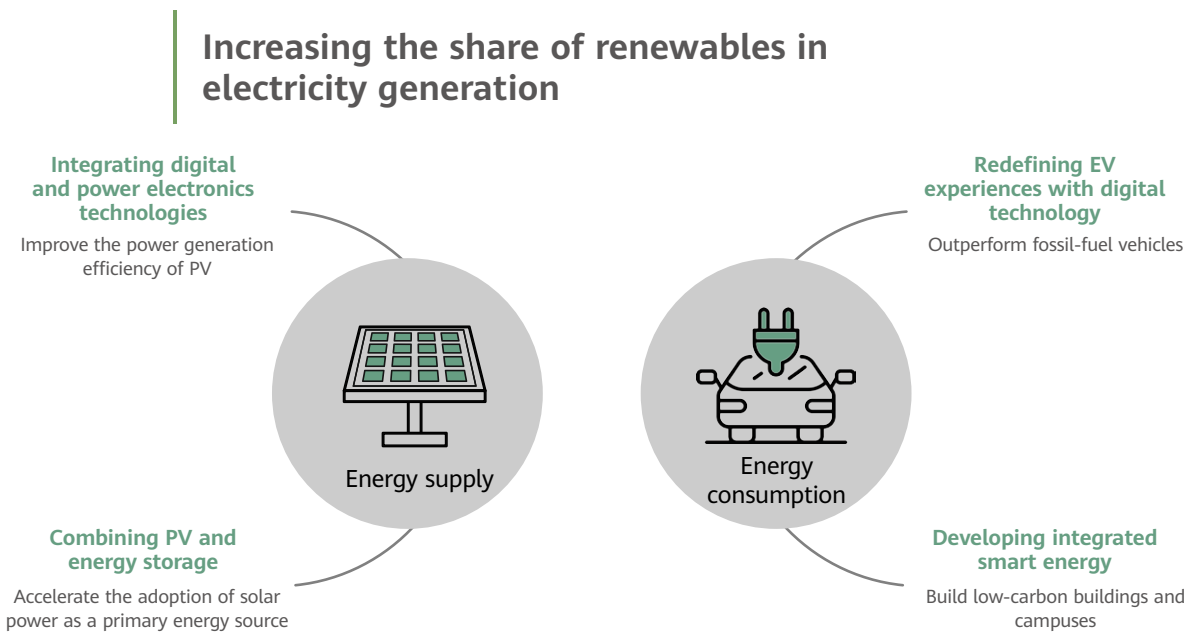
highly efficient resource and energy utilization.

In terms of autonomous energy saving, technologies such as automation, AI-powered intelligent platforms, and robotic process automation (RPA) will be introduced. In addition, multi-indicator spatiotemporal series forecasts and deep neural network algorithms will be used to proactively predict network energy consumption and enable the automated closed-loop management of energy saving policies and the self-evolution of energy saving models. Data will be automatically collected and analyzed, and policies will be automatically delivered and maintained to maximize both energy savings within networks and the balance between energy consumption and KPIs.

**User operations: Encouraging users to switch to energy-efficient infrastructure for optimal energy efficiency**

Energy-efficient infrastructure enables users to increase the amount of data transmitted within a certain period of time by 100-fold or even 1,000-fold, allowing them to more efficiently handle the numerous services that will be required in the future intelligent world while further reducing power consumption per bit. After users switch to energy-efficient infrastructure, the legacy digital infrastructure resources will be released, the strengths of energy-efficient infrastructure will be fully leveraged, and overall energy consumption will be reduced.

## Pathway 2: Increasing the share of renewables in electricity generation



**Key to green development in the energy domain: Supplying more clean energy and increasing the share of electricity in energy consumption**

The energy development strategies and practices adopted by major economies around the world have proven that reducing reliance on fossil fuels is key to

green development in the energy domain. In terms of energy supply, we must step up efforts to develop renewable energy and significantly increase the share of solar and wind power so that renewables gradually replace fossil fuels as the main source of electricity. In terms of energy consumption, we must greatly reduce the consumption of fossil

fuels by introducing green power and accelerating electrification across a number of industries.

## Areas of innovation in energy supply

When it comes to energy supply, solar power is set to become a major source of electricity. The integration of digital and power electronics technologies will be key to building a new power system based on renewable energy.

### Integrating digital and power electronics technologies to improve the power generation efficiency of PV

- **PV plant systems: Supporting higher voltage**

As input voltage increases, so does output voltage. This can reduce line loss in direct current systems and loss in low-voltage transformer winding, significantly increasing system efficiency. In addition, solar inverters and transformers will become more compact, translating into huge reductions in transport and O&M workloads. By 2030, the voltage of PV plant systems will exceed the current mainstream voltage of 1,500 V, further slashing the LCOE.

- **Solar inverters: Higher power density and efficiency**

Solar inverters will deliver higher power density and efficiency because of advanced materials like silicon

carbide (SiC) and gallium nitride (GaN), better heat dissipation in chips, and topology technologies. These materials and technologies increase solar inverters' voltage, operating temperature, and frequency, and reduce energy loss. By 2030, solar inverters will see their power density grow by over 70%.

- **Adoption of modular, standardized components: Reducing O&M costs and improving system availability**

Solar inverters, power control systems, energy storage, and other key systems will use standard interfaces that allow for flexible capacity expansion and rapid deployment. All internal DC and AC circuit breakers, inverters, controllers, and heat dissipation components will be modularized. This will eliminate the need to enlist experts for maintenance work, slash O&M costs, and enhance system availability. Full modularization at the system and equipment levels will be the way forward.

- **AI-powered PV plants will be digitalized inside and out**

As digital and PV technologies converge, they will make O&M, production, and asset management simpler, more intelligent, and more efficient. With AI, PV plants will transform into intelligent systems. AI will handle tasks that used to be performed by highly-trained experts, and support autonomous and collaborative optimization inside PV plants. Intelligent tracking algorithms make it possible for PV modules, trackers, and solar inverters to work in tandem to continuously find the maximum power point (MPP) of solar panels, thus maximizing power output. With AI, fault location will be more precise and O&M times can be reduced from months to minutes. Other benefits of AI include higher electricity generation efficiency, better O&M experiences, and greater productivity and safety. By 2030, AI is expected to be used in 90% of PV plants.

- **PV generators ensure stable power grid operations by proactively managing frequency and voltage fluctuations**

PV power generation technologies have the potential to make power grids more resilient. PV power generation fluctuates wildly over time, so



it can only meet the energy dispatching demands of power grids when supported by regular power supply services such as peak shaving and backup. As more PV generators are brought onto a power grid, the grid itself becomes more vulnerable. For example, the power grid's inertia may drop, and its ability to regulate frequencies and control system voltage may suffer. What's more, the characteristics of faults and oscillations on the power grid may change significantly. In response, power systems based on new energy will need to simulate the technical indicators of conventional synchronous generators that are used in fossil fuel power plants and hydropower plants. This is the only way they can proactively support grid frequency and voltage fluctuations. The goal will be to help power grids become safer and more reliable.

PV power generation technologies combine power electronics, energy storage, and digital technologies to simulate the electromechanical transients of synchronous generators. When connected to power grids, PV generators have many of the same external characteristics as synchronous generators, such as inertia, damping, primary frequency regulation, and reactive voltage control. As a result, PV generators can offer technical specifications that are similar to those of the synchronous generators used in fossil fuel power plants. PV power generation technologies can also proactively support the operations of power systems based on new energy and make these systems more grid-friendly. This will help new energy go mainstream and provide a solid technical foundation for incorporating new energy into power grids.

In Qinghai province, China, Huawei has helped Huanghe Hydropower Development build the world's largest renewable energy base using wind, solar, and hydro. The base hosts a 2.2 GW PV plant that produces nearly 5 billion kWh of clean electricity each year. This plant covers 56 km<sup>2</sup> and has more than 7 million PV modules. Each string of modules is precisely managed with intelligent, digital technologies. This improves energy yields by over 2% and O&M efficiency by over 50%, while reducing the LCOE. This project has also greatly improved local ecosystems. Now, sheep can be found grazing under the rows of solar panels, and

an oasis has reappeared in the desert.

### **Combining PV and energy storage to accelerate the adoption of solar power as a primary energy source**

Energy storage, as a class of flexible resources, can be used in every link of a power system, from power generation and transmission to distribution and consumption. It can support frequency regulation and peak shaving to stabilize power grid frequency, alleviate grid congestion, and ensure flexible power generation and consumption. By combining renewable energy generation and energy storage technologies, we can overcome the power fluctuations inherent in wind and solar power generators. This makes their output controllable and dispatchable, boosts the capacity of power grids to absorb electricity generated from renewable energy sources, and addresses wind and PV curtailment. Energy storage is therefore a key enabling technology making renewable energy a primary energy source.

Electrochemical energy storage is currently most common, but batteries are only part of energy storage systems. A complete energy storage system integrates electrochemical, power electronics, digital, heat dissipation, and even AI technologies. The controllability of power electronics and digital technologies addresses battery inconsistencies and uncertainties, which in turn helps ensure higher electrical discharge, optimized investment, simplified O&M, and higher safety and reliability.

The Red Sea Project, a key part of Saudi Vision 2030, will be located in Tabuk Province, east of the Red Sea, encompassing a planned area of 28,000 km<sup>2</sup>. This project will see the construction of the world's first city to be powered solely by PV with energy storage, which will supply power to one million people. It will be the world's first large-scale application of PV and energy storage as primary energy sources. It will also be the world's largest microgrid energy storage project, and will set a benchmark for the global energy storage sector.

### **Areas of innovation in energy consumption**



On the energy consumption side, fossil fuels account for more than 60% of the global final energy mix. We estimate that by 2030, the share of electricity in global final energy consumption will increase from the current 20% to 30%, and over 50% of vehicles sold will be electric.

### **Redefining EV experiences with digital technology to outperform fossil-fuel vehicles**

The electric vehicle (EV) sector in particular has been developing rapidly, with more than 6.5 million EVs sold worldwide in 2021. However, charging availability, battery life, and safety remain the three major concerns that put consumers off from going electric. In the future, digital technology will redefine EV travel experiences. EVs will deliver better driving experiences than fossil-fuel vehicles in terms of performance, range, charging, and safety. This will accelerate the adoption of EVs.

- **New materials and digitalization will redefine EV experiences**

Extensive application of wide-bandgap semiconductor materials and digital control technologies will be collaboratively used to help EVs achieve an optimal energy efficiency ratio. As power components, topologies, and control algorithms related to power electronics advance, power devices will deliver record high efficiency. The application of new technologies and materials such as silicon carbide will increase bandgap width almost 3 fold and electric field strength 15 fold, double electron saturation rates, and triple thermal conductivity when compared with traditional silicon. An end-

to-end architecture covering charging, driving conditions, power transmission, power conversion, heating, cooling, and energy recovery will be constructed and continually upgraded to deliver system-level efficiency optimal for EVs.

Digitalization is also redefining the EV experience. EVs are delivering better driving experiences than fossil-fuel vehicles in terms of acceleration and control as battery energy density increases, battery management improves, and the electric control systems become increasingly precise in calibration. High-power EVs with fast acceleration are becoming more and more common. 300 kW, 400 kW, 600 kW, and 800 kW EVs now regularly outperform fossil-fuel vehicles. Distributed electric drives are replacing mechanical limited-slip differentials (LSDs) in fossil-fuel vehicles to archive faster acceleration at curves and better off-road driving, making EVs more enjoyable to drive. In addition, digital technology allows software features to be updated throughout the entire lifetime of an EV's power domain.

- **On-board and off-board synergy improves range and charging experience**

Range and charging availability are the two major factors that influence consumers' acceptance of EVs.

From a technical perspective, EV range can be increased by improving battery energy density. Digital technology enables intelligent electrothermal synergy, intelligent torque distribution algorithms, and intelligent electro-hydraulic braking distribution that will be used to achieve high efficiency at every level from components to systems and from the power domain to vehicle operation. To further save

energy and maximize EV range, a hyper-converged and domain-based control architecture will be needed to implement multi-energy scheduling through coordinated control of electric energy, kinetic energy, thermal energy, and energy recovery and to achieve high vehicle-level efficiency in all aspects such as power charging, storage, and consumption. This way, intelligent electrothermal synergy will allow heat from the motor and inverter to be intelligently recaptured through the heat pump system to the passenger compartment for heating. Drive torque will be intelligently distributed to balance braking ability and energy recovery. Other technologies such as optimal distribution between motor braking and hydraulic braking will also extend EV range.

For off-board units, high-voltage fast charging will greatly improve users' charging experience. Take electric passenger cars, for example. Mainstream charging voltage is expected to rise from 500 V to 1,000 V by 2030, bringing the EV sector into the kilovolt era. Each charging gun will be able to deliver 480 kW of power, up from the current 60 kW, speeding up charging. Today a full charge takes about an hour, but this could be brought down to less than 10 minutes in a few years. This is comparable to how long it takes to refuel a fossil-fuel vehicle. EV power systems will also evolve to the kilovolt level and become intensive, integrated, and well-coordinated to decrease current and reduce energy loss. High-voltage platforms and precise high-rate charge/discharge curve design will enable efficient coordination between charging, discharge in driving, and kinetic energy recovery. High-voltage technologies will be widely used in charging infrastructure systems. For example, high-voltage silicon carbide technology will promote high-efficiency and high-density application and support the evolution of high-voltage platforms. Based on the ChaoJi charging technology roadmap, a 1,000 V (1,500 V) charging voltage platform will support a maximum charging power of 900 kW. This type of supercharging technology will be widely deployed on intercity highways.

### **Developing integrated smart energy to build low-carbon buildings and campuses**

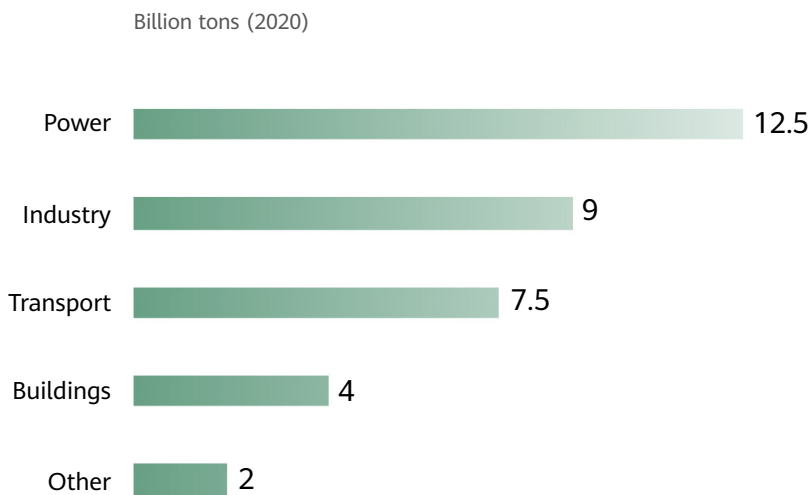
According to the United Nations Environment Programme, the building sector is responsible for about one-third of global final energy consumption. In developed countries and regions like the US and Europe, buildings account for about 40%–50% of carbon emissions from human activities. In China, energy consumed by buildings, including their construction and operation, make up more than 30% of the country's total energy consumption. As urbanization continues and living standards improve, buildings and campuses are becoming one of the fastest growing areas of final energy consumption and carbon emissions.

The convergence of power electronics and digital technologies has made integrated smart energy a reality, which will drive a new energy revolution and promote low-carbon campus construction. Leading digital and power electronics technologies, such as building integrated photovoltaics (BIPV), AC/DC microgrid architecture, smart energy management, scenario-based energy saving design, and advanced energy storage systems, will be used to help build energy infrastructure and energy management platforms for campuses. Continuous exploration and innovation will be needed to help construct campuses that integrate power generation, grids, loads, and storage, with buildings that can combine PV generation, energy storage, direct current distribution, and flexible electricity use. These campuses will also rely on intelligent equipment O&M and digital carbon emission management.

One example of such a campus is the Shenzhen International Low Carbon City Convention and Exhibition Center, which uses digital technology to expand energy sources and reduce energy consumption. It is developing smart PV power generation systems and energy storage systems to increase capacity, while reducing energy consumed in buildings through greener ventilation, air conditioning, and lighting. What's more, this center has incorporated a full lifecycle energy management system for improved governance. Once put into operation, this center is expected to achieve self-sufficiency, as it can produce 1.27 million kWh of green electricity every year, saving about 606 tons in annual carbon emissions.

## Pathway 3: Enabling green industries

### Global carbon emissions by sector



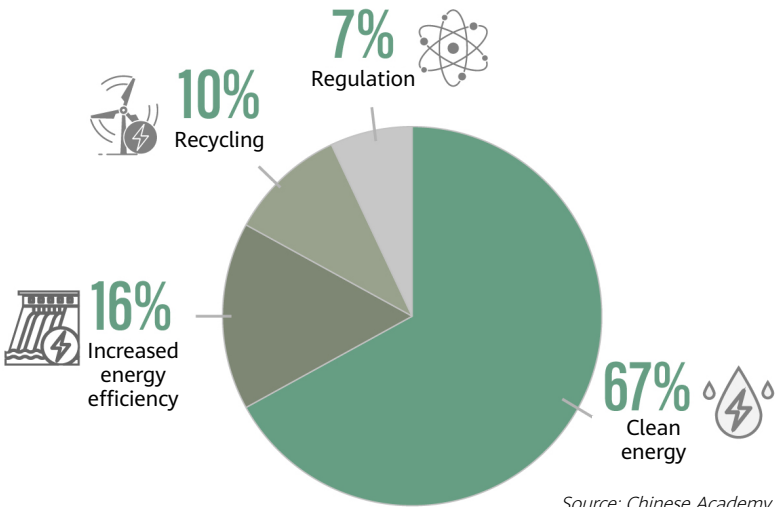
Sources: IEA and bp's Energy Outlook

According to the IEA and bp's Energy Outlook, global carbon emissions in 2020 came to 35 billion tons. 12.5 billion tons were from the power sector, 9 billion from the industrial sector, 7.5 billion from the transport sector, and 4 billion from the building sector. These four sectors were responsible for 94.2% of total carbon emissions.

Therefore, deep decarbonization in sectors like power, industry, transport, and buildings is essential

to achieving global carbon neutrality. Research shows that these sectors can reduce carbon emissions with four approaches: using clean energy (67%), increasing energy efficiency (16%), recycling (10%), and regulation (7%). Digital technology has an important role to play in the implementation of these four approaches. The following provides a detailed analysis of how digital technology enables these carbon-intensive sectors to improve efficiency and quality for green, low-carbon development.

Four approaches to reducing carbon emissions and their contributions (%)



## Power: Digital technology helps build new power systems based on new energy

The key to building a green, low-carbon power sector is to reduce carbon emissions across power generation, grids, loads, and storage. Power generation marks the beginning of this low-carbon process. Power grids act as the hubs that accommodate new energy and ensure the security and stability of power supply. Loads are the final link in low-carbon energy consumption, which means low-carbon loads are critical for a low-carbon world. Power storage is also key to maintaining the security and stability of power supply that could be disrupted by renewable energy that is unpredictable and unstable.

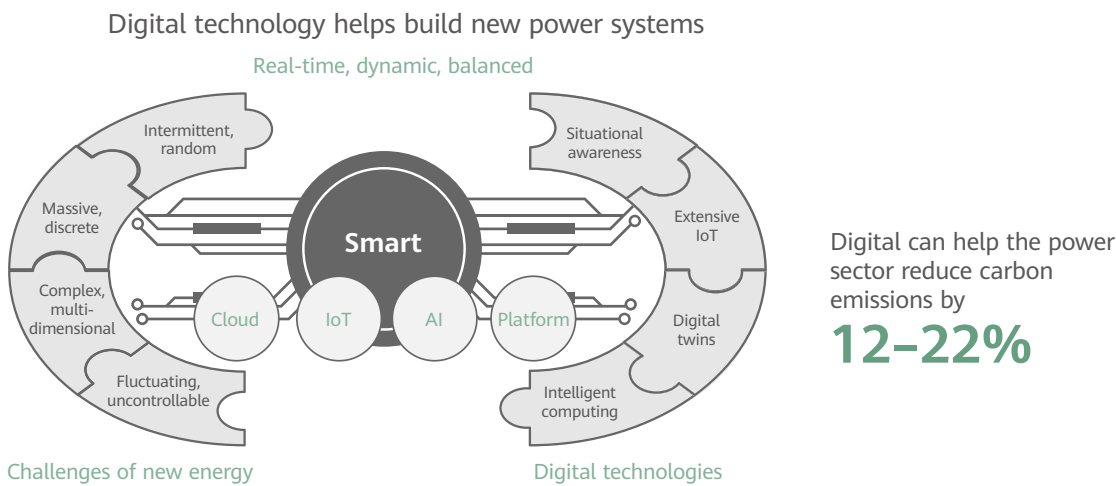
Moving forward, distributed power systems will become more widespread, gradually replacing the old, centralized generation model. In addition, balancing supply and demand necessitates intelligent power transmission and distribution networks, intelligent power consumption

management systems, and digital energy storage systems. It also requires multi-dimensional interaction and coordination between power generation, grids, loads, and storage, which can facilitate large-scale peak shaving. Such safer, more flexible, and more controllable power systems can be built with digital technology that provides extensive connections and intelligent interactions.

Power grids face instability issues associated with heavy reliance on new energy, the rising share of electricity in final energy consumption, and distributed loads. Smart grid technologies can effectively address such issues by fully integrating physical and digital grids. They can also further improve the security, reliability, and flexibility of power supply, as well as power quality and energy efficiency.

Smart transmission creates digital twins of transmission facilities, allowing transmission facilities to be digitally monitored and regulated in real time. This smart transmission integrates small and micro smart sensors, connected sensing devices, AI, and power electronics technologies.

## Digitalization enables green electricity





Smart transformation is a combination of digital technologies and flexible direct-current technologies. It can handle voltage instability, wideband oscillation, inertia reduction, and frequency instability that may arise when new energy is connected to grids at scale.

Smart dispatch uses situational awareness and digital twins to achieve collaboration between power generation, transmission, and distribution, enabling the flexible use of large amounts of distributed resources.

Smart distribution involves edge computing terminals, local data storage, and computing and analytics. They make online distribution equipment monitoring, O&M, and inspection more intelligent.

Building on advanced ICT, distributed multi-supply technologies can create digital twins of energy stations and support the comprehensive utilization of energy. They can meet user demand for different types of energy, such as electricity, heat, cooling, steam, and domestic hot water. This cascade utilization of energy can improve overall energy utilization to 70–90%.

Power loss in transmission and distribution has

always been a problem, but it has become more difficult to ignore with the growth of electrification and electricity consumption. One effective solution is to adopt digital technology for data collection, analysis, situational awareness, fault diagnosis, and intelligent O&M, so as to reduce energy consumption and carbon emissions. For example, troubleshooting, detection, and replacement in power grid O&M management are traditionally done manually, which is time-consuming, labor-intensive, costly, and inefficient. Digitalization can make power grids run more efficiently. Digital technologies like drones and robotics can be used for equipment inspection, and image recognition can be applied to monitor equipment in real time. Massive amounts of historical O&M data amassed by big data platforms can be used to build risk assessment models for equipment. This will allow faults to be predicted more accurately, which in turn facilitates prompt equipment upgrades and replacements and faster responses to faults.

Digital technologies such as AI, IoT, and big data analytics enable better demand management. Collection and analysis of power consumption data allows all users, including businesses and households, to precisely manage their power consumption, quickly locate energy-intensive and



carbon-hungry activities, intelligently analyze their consumption behavior, and predict future consumption. This helps users optimize power usage, boost power efficiency, and reduce carbon footprint.

Advances in energy storage technologies can help address the instability of renewable energy sources. The application of digital technology in energy storage helps significantly smooth out fluctuations, match supply and demand, shave peaks, and improve the quality of power supply. Digital energy storage systems represent a deep integration of energy storage system technologies and information technologies. Under this Internet-based management and control model, O&M of energy storage systems becomes more automated and energy storage resources are used more efficiently. This model also allows energy storage systems to fully play their diverse roles in the energy Internet. Today, on the user side, significant amounts of energy sit idle in batteries. These scattered, fragmented resources can be consolidated within a large-scale distributed energy storage system, allowing power grids to redirect energy to where it is needed. This can be achieved

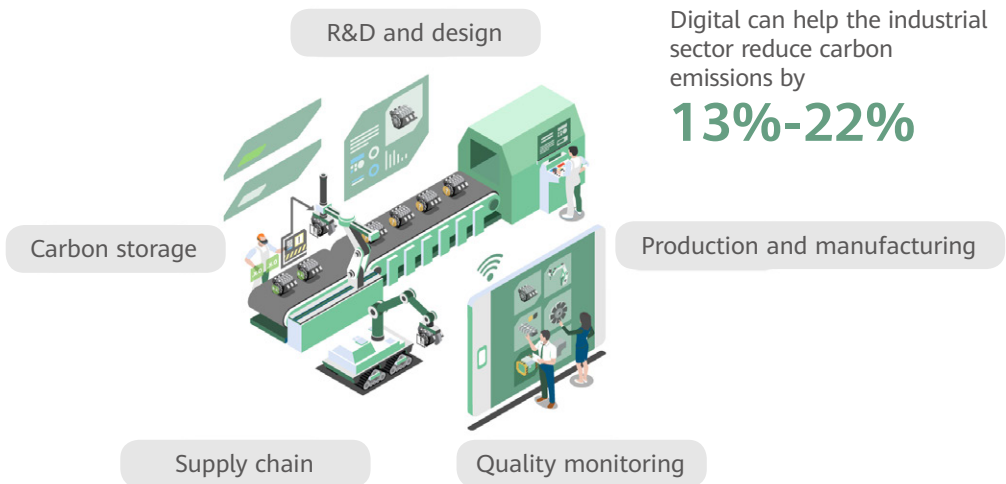
through digital means such as battery energy exchange systems and cloud platforms for battery energy management and control.

## Industrial sector: Digital makes green and smart manufacturing possible

In addition to a technological transformation, the industrial sector needs digital technology to reduce carbon emissions. Digital technology plays a big role in industrial R&D and design, manufacturing and production, quality monitoring, collaboration across the supply chain, and carbon storage, and will help the industrial sector go green and low-carbon.

Here, we would like to elaborate on the use of digital technology in R&D and design to minimize carbon emissions. The steel and petrochemical industries approach R&D in a very experiment-focused manner. The development of new petrochemical technology is slow, as the process includes many small-scale tests, pilots, and technology verifications, before even considering

## Digitalization enables green industry



Source: White Paper on Digital Carbon Neutrality, CAICT

commercial production. This drives up R&D costs and keeps efficiency low.

However, digital technology can be used to increase efficiency during the modeling and simulation phases by referencing the physical and chemical characteristics of raw materials and features of industrial production. This approach can greatly reduce the number of experiments required, thereby shortening the R&D cycle. This also lowers R&D costs and brings down carbon emissions by reducing raw material consumption.

Digital technology can also be used to reduce the carbon emissions of the production and quality control stages of manufacturing. By applying digital technologies such as the industrial Internet, a company can manage all aspects of production in real time, such as equipment monitoring, raw material supply, and quality inspections. Ongoing optimization of technical parameters and raw materials for production and constant refinement of production operations will minimize the material, energy, and even finished product waste that is often caused by unreasonable operations.

For example, a glass manufacturer can use AI to upgrade their furnace stability control system, allowing it to predict temperature changes inside furnaces over the next hour. With better predictions, the company can identify problems as early as possible and take steps accordingly. Through the use of AI, this company is also able to employ a data-based and visualized approach to identifying common trends related to bubble boundaries during glass production. Digital technology can also be used to share best practices and techniques between production lines. By applying these solutions, one glass company has been able to maintain the same production quality while cutting its natural gas consumption by 3.29%, leading to an annual saving of over 50 million yuan each year.

In some industrial enterprises, production lines cannot stop operating during production. An effective solution for ensuring continuity is to use intelligent monitoring devices to collect data on operating equipment and then compare the collected data with the historical data. This real-time monitoring of operating status will facilitate early warnings of any potential problems. This will

prevent production lines from being shut down due to equipment faults, thereby improving operating efficiency and reducing O&M costs.

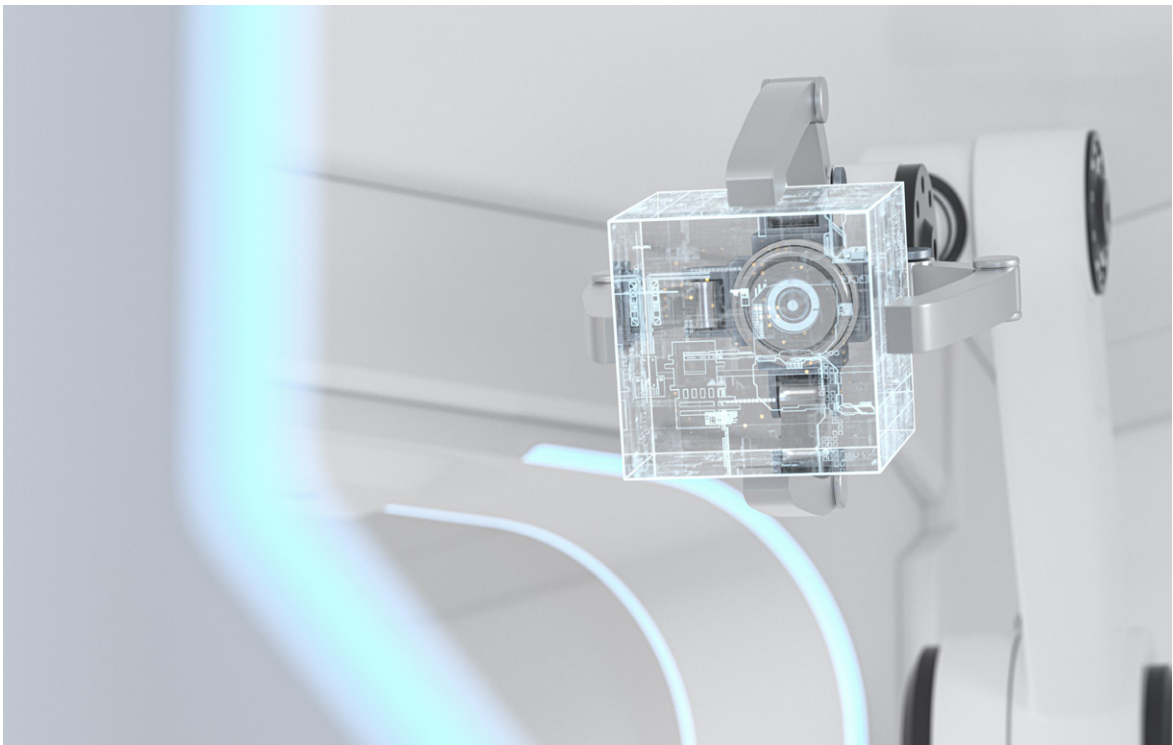
For example, one industrial enterprise uses 3D modeling to build a three-dimensional digital twin of its industrial campus at campus, production line, and workshop levels. Now, it can monitor the status of production lines and equipment in real time. In the past, to check distribution cabinets, inspectors had to shut down the power supply, meaning production lines also had to be stopped. With new digital systems, sensors can detect the humidity of distribution cabinets in real time, and alarms are immediately triggered when the humidity exceeds a set parameter. Through analysis of data and videos, such systems can also detect water leakage and condensation problems in cooling pipes. In this way, these problems will be handled promptly, averting interruptions to production.

Digital technology also has a role to play in facilitating the collaborative development of the supply chain. Industrial enterprises are located in the midstream of the supply chain, and need to maintain smooth exchanges with their raw

material suppliers upstream and consumer enterprises downstream. These exchanges cover multiple domains such as information, materials, logistics, and finance. In this regard, e-commerce platforms and digital supply and sales platforms supported by digital technologies can facilitate online transactions, and shorten the procurement process between raw material suppliers, industrial enterprises, and consumer enterprises.

Moreover, digital technologies such as blockchain can help ensure transaction security and reduce transaction costs. Achieving system interconnectivity between industrial enterprises and logistics companies ensures smooth flows of logistics information. In this way, industrial enterprises and logistics companies are able to arrange production and distribution resources more efficiently, while also reducing carbon emissions during inventory and logistics processes.

Carbon capture, utilization, and storage (CCUS) technologies are also important technical means for cutting carbon emissions from the industrial sector. Aiming for carbon fixation, CCUS technologies capture carbon dioxide before it enters the



atmosphere. The captured carbon dioxide is then either (1) purified for recycling or (2) transported to an injection location where it is compressed and injected into underground geological formations for storage.

With digital technology, we can set up data analytics, prediction, and early warning systems to collect, analyze, and monitor data from carbon dioxide generation, capture, transportation, utilization, and storage processes. This will enable all participants to have a transparent overview and accurately control all these processes, and will provide accurate data to inform subsequent activities like trading. Over the next 20 years, the annual amount of carbon dioxide stored this way is expected to reach up to one billion tons, and the costs are expected to fall precipitously.

Transport: Digital technology helps vehicles go electric faster and build smart transport systems

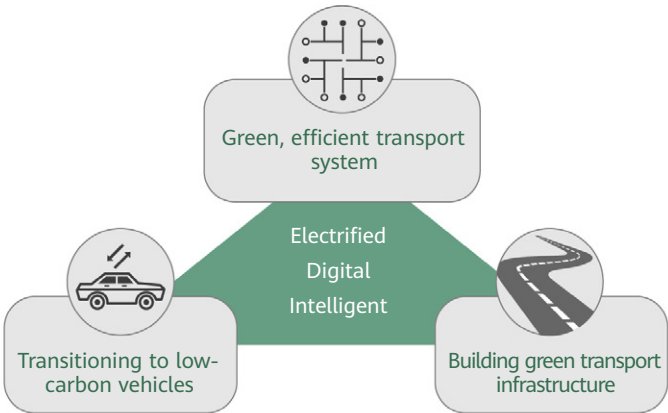
In 2020, transportation accounted for nearly one-quarter of global carbon emissions. Within the transport sector, road transport accounted for about

80% of emissions, shipping for 10%, and aviation for 9%. Each segment of the sector faces different challenges as they attempt to reduce their carbon footprint, but all are turning to digital technology in order to meet their energy consumption and green development goals.

Given its share of carbon emissions, road transport is the top priority in transport decarbonization. Digital technology can play a crucial role in creating a more energy-efficient, greener transport sector. Specifically, it can help build more energy-efficient electric vehicles, develop smart and green transport systems, and integrate transport and energy networks.

One approach to decarbonizing transport is to reduce the energy consumption of conventional fossil fuel vehicles through the application of digital technology. Statistics show that there were 302 million vehicles on the road in China as of the end of 2021. 97.2% of these were fossil fuel vehicles, consuming more than 260 million tons of gasoline and diesel annually. This makes them the largest source of carbon emissions in the transport sector. Intelligent vehicle technologies and Internet of Vehicles (IoV) provide insights into how vehicles are operating, helping us better understand how to make them more energy-efficient. For example,

Digitalization enables green transportation



Three-pronged approach to accelerating green development of transportation

Digital can help the transport sector reduce carbon emissions by  
**10–33%**

Source: White Paper on Digital Carbon Neutrality, CAICT



when digital, intelligent technologies are used in a mining truck, they can collect large amounts of data about fuel consumption, operating conditions, the driver's driving behavior, and more. The data helps the truck's control system make more informed decisions regarding speed, accelerating, braking, and other key elements, thereby reducing the fuel consumption of the truck by about 20%.

Technological advances in and the mass adoption of electric vehicles could also significantly reduce greenhouse gas emissions. According to China's State Grid EV Service, the share of renewable energy consumption is expected to reach 58% by 2050, which would help reduce annual CO<sub>2</sub> emissions by more than 50%.

However, this transition has its own share of challenges like charging and power management. Fluctuating electricity prices make it difficult for electric bus operators to manage charging and charging expenses. Big data and AI algorithms can make charging management intelligent to deliver high efficiency at lower costs. In 2017, Shenzhen Bus Group Co., Ltd. became the first to have a fully-electric bus fleet. In partnership with Huawei, the company piloted a smart charging algorithm,

enabling the buses to charge more when electricity prices were low and charge less when electricity prices peaked. This algorithm has made charging management much easier and is expected to help the company reduce annual electricity costs by 5–10%.

Digital technology is also key to the construction of green, intelligent transport systems. They make travel more efficient and reduce carbon emissions. As we move closer to fully green and intelligent transport systems, road networks themselves are becoming more intelligent, making vehicle-road synergy a reality. This synergy will reduce congestion and wait times, decreasing total carbon emissions.

For example, when applied to traffic management, digital technology connects people, vehicles, roads, stations, and the cloud. This helps more efficiently manage traffic at intersections, make guidance systems more accurate, and allow objects to sense beyond their lines of sight, thereby improving driver safety and vehicle operating efficiency. When it comes to shared mobility, connected and autonomous taxis, coupled with road-vehicle and vehicle-platform synergy, will make driving safer



and increase road network operating efficiency.

The aviation industry is also actively exploring new approaches to digitalizing its operations. Airports fully equipped with digital platforms and AI can automatically and intelligently schedule various resources, including boarding gates, check-in counters, baggage carousels, and security checks, overcoming existing challenges with resource shortages. This machine-centric approach helps improve key indicators like the percentage of aircraft that can directly dock at a jet bridge and the rate at which jet bridges are allocated. It will also extract more value from resources, save energy, and reduce emissions.

Some airports are already using emerging technologies such as AI, video cloud, and big data to design an intelligent resource allocation solution centered on three key business domains – operation control, security, and services. This solution has helped extract maximum value from aircraft stands, baggage transfer resources, and other facilities. At a single airport, this solution has reduced the number of passengers needing to be shuttled across the tarmac by 2.6 million each year, saving 299,000 kWh of electricity annually.

Historically, weather forecasts for air traffic control were unreliable or slow due to data silos, increasing the number of planes that were either turned away from their destination or needed to wait for extended periods of time before they could land. Thanks to more accurate AI-assisted weather forecasts powered by algorithms, big data, IoT platforms, and other new technologies, an airport can now reduce the number of delayed flights by more than 20 and increase flight punctuality by about 4% during a thunderstorm.

In water transportation, 98% of the world's ports still primarily depend on human labor to load and unload containers. This backbreaking work is inefficient and makes it difficult to achieve low-carbon development goals. To digitalize and decarbonize port operations, real-time data about workers, equipment (e.g., quay cranes, gantry cranes, and driverless shipyard transporters), and berths will need to be acquired from across all terminals.

With such data, ports can use digital technologies like autonomous driving, dynamic business maps, and AI algorithms to plan dynamic routes for multiple shipyard transporters and adjust their

speeds during transit, increasing the safety of transporters and enabling simultaneous multiple-transporter operations. These advances also decrease manpower requirements, reduce driver fatigue, boost transporter operating efficiency, and minimize power consumption.

The Port of Tianjin has recently unveiled the world's first zero-carbon smart terminal, which has entered service in Section C of Beijiang Harbor's intelligent container dock zone. Thanks to new technologies like 5G and AI, this terminal has become the world's first to realize autonomous driving of various types of vehicles and 5G-powered remote control of cranes within the shipyard. This terminal also has an automated horizontal transport system, which has helped reduce the number of container operations by 50% and increase the designed operational efficiency to 39 containers/hour. Finally, 100% of the electricity used by this terminal is generated from green sources, making the terminal truly intelligent, green, and safe.

### Building sector: Digital enables green and low-carbon operations of buildings

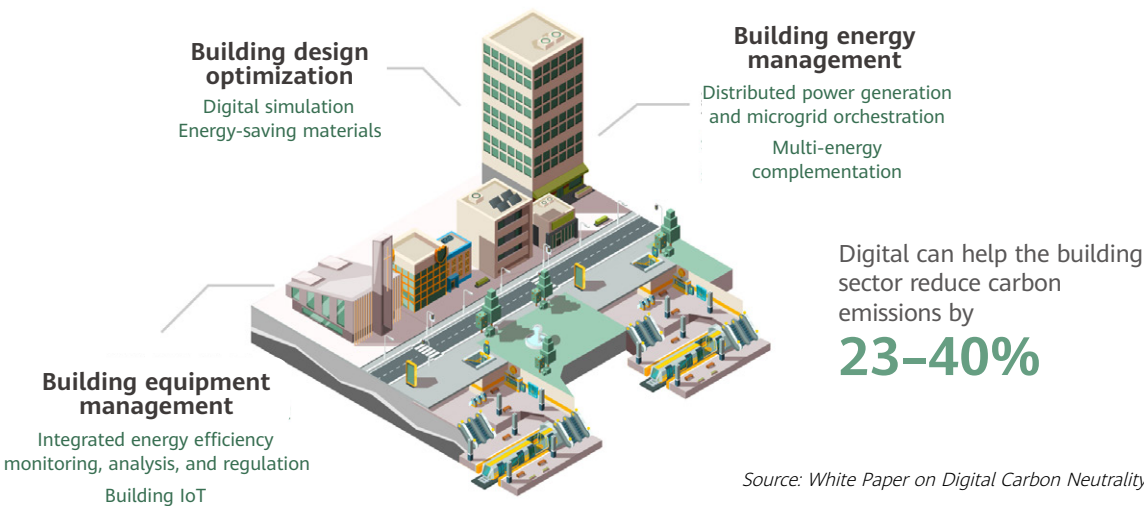
Carbon emissions reductions in the building sector

require innovation in design, operations, and many other aspects. Data collection, statistical measurement, and intelligent control, coupled with cloud computing and AI-assisted data analytics, can be used to customize the structure, systems, services, and management of buildings to meet customer demands. This strikes a balance between efficient operations and resource utilization, thereby improving energy savings and minimizing carbon emissions.

During building design, digital technology can be applied to the development of building information modeling (BIM). This will allow BIM to support new model creation, data collection, data integration, and fine-grained design, and help determine which materials will ensure the lowest energy consumption.

A prime example of this can be seen in the headquarters of an enterprise in Shenzhen. Through the digital simulation of natural ventilation during BIM, the company was able to adapt the design of its building to the surrounding landscape. This led them to conclude that a horizontal atrium that runs through the building from south to north could be used to create a natural draft. This design provides the building with 2,000 hours of natural ventilation each year, reducing its total carbon

### Digitalization enables green buildings



Source: White Paper on Digital Carbon Neutrality, CAICT

dioxide emissions by 140 to 160 tons. It is thus named a "breathable office building".

Numerous sensors have also been placed throughout the building to collect data about external lighting. By analyzing the building's exposure to sunlight and shade, the construction team was able to come up with an energy-saving curtain wall and shading system. This system cuts down on exposure to solar radiation by 40% each year, significantly reducing the use of air conditioning. The company also installed green spaces on the roof and terraces of the building, making the building carbon-negative on multiple levels.

Many of today's buildings do not stand alone, but are part of larger complexes. Vehicle transportation, infrastructure, vehicles, and people within campuses of these complexes are major sources of carbon dioxide. Operations currently account for 46.2% of the carbon emissions generated during a building's lifecycle, with energy management and equipment energy consumption management making up the bulk of this.


In terms of energy management, a comprehensive, digital energy management system can be adopted to enable onsite production, balancing, and consumption of clean energy. Horizontal synergies between multiple energy sources like electricity, heat, cold energy, and gas, along with vertical synergies between microgrids for power generation, grids, loads, and storage, will help campuses evolve towards a low-carbon energy structure. AI algorithms and system policies enable the statistical analysis of energy consumption and energy scheduling for scenarios such as solar power, energy storage, charging, and load management, maximizing economic gains while minimizing carbon emissions. In addition, IoT can be used to more accurately and promptly monitor carbon emissions.

Today, Yancheng Low-carbon & Smart-energy Innovation Park in Jiangsu mainly operates on the different types of new energy it generates. It currently uses solar panels installed on building roofs and curtain walls, solar umbrellas, power generation

footpaths, wind turbines, geothermal energy, air source heat pumps, cold and heat storage, battery storage, AC and DC charging piles, V2G charging piles, and an AC and DC hybrid microgrid. This campus has developed four capabilities, namely the integrated use of energy from multiple sources, smart energy management to hit its low-carbon target, efficient management, and innovative services. To date, this campus generates 85% of its energy through new sources, reducing carbon emissions by 5,600 tons and total electricity usage by three million kWh per year.

In terms of equipment energy consumption management, both digital technology and platforms can be applied to compile and analyze data from equipment operations, including equipment warning data. This will help facility management staff better monitor their facility and equipment operations, reducing required operational manpower and boosting operational efficiency.

Refrigeration units, air conditioning, and lighting consume the majority of energy in buildings. By leveraging AI to craft an embedded energy consumption model and an abnormality diagnosis library in the cloud, intelligent data analytics and equipment system control can be used to create new energy consumption diagnostic analysis and optimization strategies. IoT and sensing technologies can take this even further by sensing and automating temperatures, light, and flows of people, both indoors and outdoors, in real time. The implementation of these technologies will significantly increase the power efficiency of buildings and campuses. Lights will even turn off automatically when nobody is in a room.

One museum has installed sensors in 3,000 locations to collect and monitor ambient environment data in real time, and then used these sensors to create a digital system that automatically adjusts the temperature, light, humidity, and air conditioning to best accommodate the exhibits and visitors. The museum has managed to cut greenhouse gas emissions by 35% and electricity expenses by 32%, boosting the efficiency of its heating, ventilation, air conditioning, lighting, and water resources. 



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MOVING  
FORWARD

More and more countries and regions are actively embracing green development, and the world is moving towards a new green era faster than ever before.

But we still have many challenges ahead. We need to make further breakthroughs in digital technology, flesh out regulations, systems, and standards, and promote greater coordination between different industries. This will require joint innovation in both digital technology and low-carbon growth, as well as greater collaboration across all communities, industries, value chains, and ecosystems.

Digital innovation is key to achieving low-carbon growth. The two are mutually reinforcing, so we need to keep strengthening investment in research and development to deliver the right enabling technologies.

These efforts should focus on innovation in three domains: green and low-carbon digital infrastructure, renewable energy, and industrial transformation. This will help improve energy efficiency and pull more renewables into the global energy mix, paving the way for truly green and low-carbon growth.

As green and low-carbon growth guides the direction of future socioeconomic development, it will in turn spur new innovation in digital

technology. This virtuous circle of mutual reinforcement is the most effective way to achieve lasting green development.

At the same time, the world currently lacks unified standards for low-carbon growth. We urgently need to improve emission reduction standards for digital systems, strengthen the development of emission-related big data, and establish standards for measuring the carbon footprint of digital infrastructure.

Measures should also be taken to ensure effective implementation of these standards. For example, we should establish digital systems to monitor carbon emissions in real time, and work together to develop carbon emission standards and systems for digital infrastructure.

Finally, it is also critical to strengthen ecosystem collaboration between industries and enterprises up and down the supply chain. For example, technical models like carbon handprint standards help promote more engagement on green practices between governments, industries, and enterprises, and reduce carbon emissions across the entire supply chain. We also need to strengthen international cooperation and coordination in technology, funding, standards, and actual projects to jointly advance systematic climate governance at the global level.



# 6

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- International Energy Agency
- UN Environment Programme
- World Bank
- Global Alliance for Buildings and Construction

As well as many Chinese government agencies, enterprises, and research institutions including:

- National Development and Reform Commission
- Ministry of Commerce
- Ministry of Science and Technology
- Ministry of Ecology and Environment
- Ministry of Transport
- Ministry of Industry and Information Technology
- National Energy Administration
- Institute of Resources and Environment Policies of the Development Research Center of the State Council
- Institute of Enterprise Research of the Development Research Center of the State Council
- China Academy of Information and Communications Technology
- China Electricity Council
- State Information Center
- China Intelligent Transportation Systems Association
- Guangdong Academy of Greater Bay Area Studies
- China Association of Building Energy Efficiency
- Cyzone
- Renmin University of China
- Tongji University
- Beihang University
- North China Electric Power University
- Chongqing University
- China Electric Power Planning and Engineering Institute
- Hainan Green Finance Institute
- Beijing Building Industrialization Group
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- Sinolink Securities
- Southwest Securities

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# GREEN DEVELOPMENT 2030

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