Annual Meeting of the New Champions 2018

2018新领军者年会

The 4th industrial revolution and the innovative society

第四次工业革命与创新型社会

Environmental Governance Under New Technological Transformations

新技术变革下的环境治理

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Environmental Governance Under New Technological Transformations

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Abstract: New technological transformations are becoming important strategic resources and route for capacity enhancement in environmental governance. New generation of technological breakthroughs is leading to a series of transformations, namely optimized structure of environmental governance, smart monitoring, precise decision-making and governing models with platform. Various approaches brought by new technologies will turn these transformations into reality. “Cloud+” sensors provide all-round monitoring 24/7. Integrating technologies of AI offer smart solutions for environmental protection. Blockchain leads to new ways for coordination in environmental governance. Big data pushes environmental awareness to a new height, improving forecasting and decision-making means. In the future, technological transformations will continue to deepen. When advanced technologies such as data lakes, fog computing, and IoT embedded systems turn from concepts

to real-world applications, isolated information islands will disappear and environmental governance will have access to online intelligent support and great low-cost technological innovation everywhere. The whole process of environmental governance will be intelligent. In this context, “intelligent environmental protection” may become the basic blueprint for systematic innovations in environmental governance. Looking forward into the future, it is necessary to use wisdom to ensure new changes and bright prospects. We need to tackle problems and risks in promoting new technologies sober-mindedly and adopt new ideas to embrace new transformations. We also need to take concrete actions and multiple measures to promote technological innovations in environmental governance. What's more, we need to be open-minded and cooperate with third-party, so as to innovate cooperation mechanisms in environmental governance.

Catalog

1 Systematic transformations in environmental governance brought by new technologies

The historic missions of the 4th industrial revolution and global environmental governance have been intertwined. The industrial revolution has been seen as watershed not only in history of social and economic development, but also between environmental pollution and treatment. Though unleashing great productivity, the previous three industrial revolutions have also caused climate change and global environmental crisis due to large-scale barbaric exploitation and low efficient use of natural resource, especially fossil fuel, as well as discharge of pollutants. Fortunately, human beings have heightened their environmental awareness with greater capacity for treatment. The 4th industrial revolution has emerged amidst reflections on previous unsustainable model of development. It is an integrated technological reform across information, digital and intellectual fields, physics, biology and other areas. The 4th industrial revolution also has an inherent tendency for environmental friendliness and sustainable development. The new round technological breakthroughs will restructure the basic mode of industrial production by bringing about cleaner, safer and more efficient energy and better environment-friendly materials. The breakthroughs will also shape the landscape for green development and lead to huge transformations on traditional landscape of

environmental governance that was based on past technologies.

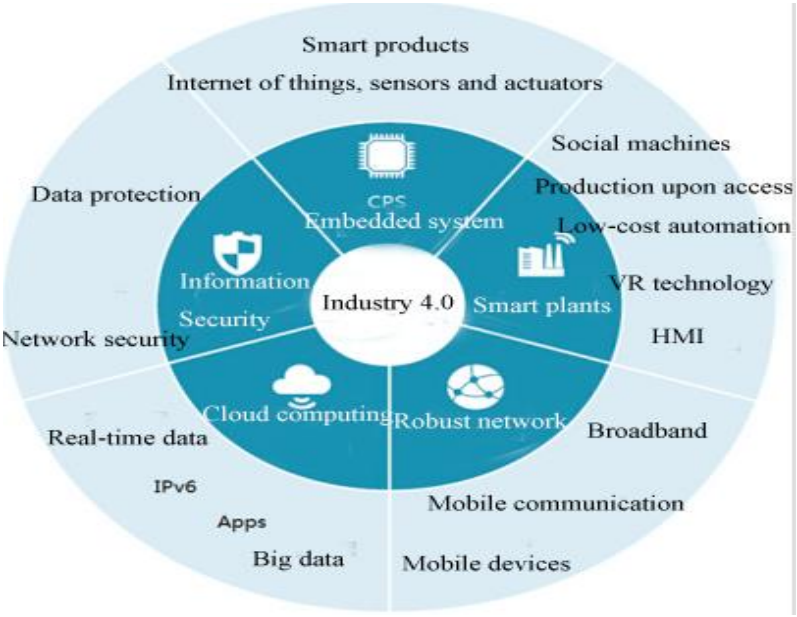

Figure1 new generation of information technology in Industry 4.0

Source: BITKOM

New technologies will become strategic resources for global environmental governance and new tools for governments to enhance their capacity in this regard. Currently, environmental decision-makers face multiple managerial problems like lack of ecological and environmental data, independent operation of relevant departments, weak development and single supervising body. New technologies such as Internet, cloud computing, big data, and Internet of things can help us establish and perfect various types of ecological

and environmental databases. We can also strengthen ecological monitoring and management with big data, and pool all the data together from pollution source supervision, environmental quality monitoring, environmental treatment, and environmental industries, so as to facilitate our effort in finding answers to the above-mentioned problems. Therefore, we can enhance our capacity in environmental governance with a sound model featuring source control, process supervision, comprehensive treatment and broad participation. It is predictable that application of new technologies will bring about a series of systematic transformations to environmental governance, such as optimization of its global structure, more intelligent supervision, more precise decisions, and better platforms for good models.

1.1 Optimized structure of environmental governance due to new technologies

1.1.1 Diversified players in environmental governance made possible by new technologies

Traditional environmental governance mainly adopts the "top-down" model dominated by governments, leading to insufficient public participation in policy innovation. As a result, public decisions about environment may not always put public interests first. The new generation of information technology is open, accessible, personalized and networked. Its revolutionary impact will

cover all aspects of social governance and profoundly change the way human society is organized and governed.

With new technology, government will no longer be the only player in environmental governance. The status and role of government relative to social forces will change dramatically in environmental governance. In particular, the new age of information and media technologies will make all public information more transparent. Individuals can make their voice heard more easily, making public opinion a more powerful guide for policies. Therefore, social forces enjoy greater influence and involvement in decisions about environmental governance. The government can use Internet and big data to pool people's wisdom in designing policies, so as to reach consensus among various interest groups, enhancing government credibility and people's democratic participation. In the future, application of new technologies will create a more flexible and efficient coordinating mechanism among academics, business, government, social organizations and the public, so that every force can participate in environmental governance to form a synergy.

The government can use new technologies to build various forms of public service platforms so as to facilitate the participation of all social forces. With Internet technology and its inherent messaging and interactive functions, the government and especially environmental authorities can have better access to data, enabling clearer understanding of public demand on environment. As a result,

differentiated, precise and multi-layered environmental services are made possible. A combination of government services and public supervision in environmental governance can pool people's wisdom in terms of data, technologies and manpower, so as to overcome shortage in government decision-making resources.

1.1.2 Order in global environmental governance due to new technologies

In recent years, the world economic landscape and international forces are constantly changing. The willingness and ability of emerging economies to participate in global economic and environmental governance continues to increase. Developed countries are seeking cooperation with developing ones, especially emerging economies, due to their declined capacity in supplying public goods globally. The pattern of "North and South" cooperation has taken shape in global environmental governance. Under the traditional framework of climate change and environmental governance, developed countries led the efforts in formulating climate conventions and governance standards. However, the complex nature of global environmental issues triggered by economic globalization and reindustrialization in developed countries requires multilateralism in global environmental governance. A governance structure featuring coordination among developed countries, emerging countries, developing countries, international organizations, and cross-border civil groups is taking

shape. This is determined by the principle of safeguarding the equal status of all participants in global governance. Under the support of new technologies, the multilateral system of global environmental governance enables participants to interact frequently and reach check and balance through mutual influence.

The new generation of information technology turns the spreading and processing of information from “one on one”, “one on many” to “many on many”. Convenient and diverse sources of information and massive data processing capabilities provide material platforms and technical support for multiple entities to participate in environmental governance. Participants can use network terminal equipment to learn about, participate in, express opinions about and follow developments in global environmental governance, because the threshold for the participation of developing countries and international civil organizations has been much lower. Driven by new technologies, the global environmental governance system with complex network structures can become more advanced and more orderly, so as to make overall arrangement and scientific organization for its subsystems. As a result, the whole system has more functions with higher quality.

1.2 Intelligent environmental monitoring as a result of new technologies

The government's monitoring plays a fundamental role as the

"bellwether" in the environmental governance system, because effective monitoring is the basis for good environmental governance. Pollution treatment and environmental protection involve complex technical and economic issues that call for expertise and professionals. The smart models and tools are important for intelligent environmental protection. After collection of widely distributed sensor data, the "Internet+" technology is applied to process it. By taking advantage of cloud computing and big data, artificial intelligence can assist in environmental management and adjustment of governance models, so as to tackle environmental issues in a smart way.

1.2.1 Intelligent environmental monitoring driven by new technologies

Traditional environmental monitoring presents the following problems. For example, networks cannot cover all the areas and factors. Standards and regulations are inconsistent. Information is neither digital nor shared. Control measures are not always based on monitoring results. The data quality of monitoring results needs to be improved. All these problems have undermined the accuracy and authoritativeness of monitoring as well as government credibility. Traditional data technologies can only collect and process a limited volume of eco-environmental data. Restricted by the traditional mode of information exchange, environmental monitoring has been noticeably empirical. Information data has not been circulated in a

timely manner. Environmental monitoring is difficult to provide timely, accurate and comprehensive support for decision-making in environmental governance. Meanwhile, some governance standards cannot meet the needs of time, because it has taken too long for them to be updated.

The new generation of information technology provides a more accurate basis for the formulation and updating of environmental governance standards. It can collect a large volume and a wide variety of monitoring data, so as to enhance the governing authority's analysis capabilities. It can filter real-time and effective information from the massive data, and make both formulation and implementation of standards more scientific, reasonable, accurate, and timely. These capabilities will greatly increase the effectiveness of control when problems emerge.

The environmental governance authority can conduct automatic diagnosis based on the massive data collected by the system and "prescribe drugs accordingly", so as to realize intelligent decision-making and precise management in a real sense. Through establishing an environmental case database with big data technologies, the governing body can draw up experience, refine practice, improve the system in a timely manner, and pick the best timing to release typical cases and data to the community. The operation of this system can provide guidance and experience for follow-up governance, and also a warning system to prevent risks.

By constructing a distributed and multilateral data platform, the environmental governance department can promote multi-regional and multi-level organizational interaction and establish a smooth interactive network featuring big data, so as to assess the effectiveness of policy implementation in a comprehensive and dynamic way.

1.2.2 Refined environmental warning due to new technologies

Long-term prediction of ecological evolution is made possible by new technologies, such as big data and cloud computing, which can predict potential changes in environmental data by exploring hidden laws in historical data and suggest preventative measures. For example, by collecting and analyzing data on hydrology, plants, precipitation and other factors in severely desertified areas, we can effectively assess environmental deterioration and changes of the plants, so as to provide scientific evidence for the prevention and control of land desertification.

New technologies can enhance the accuracy and timeliness of early warning system, because they can provide regulatory authorities with access to data on the industries, regions, volume, size, and trends of pollution sources. Comparing these data with historical ones and using visualization technology in big data, the regulatory authorities can learn the actual situation of environmental pollution through intelligent analysis. Through data collection,

mining, and analysis, the regulatory authority can issue early warnings on the existing sources of pollution, and make preliminary judgment about local ecological structure, industrial mix, economic development, and market demand. As a result, authorities can take the pulse of economic development, and anticipate the future of environmental protection, so as to take proactive measures in sustainable development.

1.3 Precise decision-making in environmental governance due to new technologies

With the help of new technologies such as artificial intelligence, drone surveillance, and environmental sensing, we can go beyond human limitations without human bias, and overcome issues like data loss, data distortion, and data monopoly. As a result, we can better understand the link between economic activities and ecological crisis as well as the link's underlying patterns, in order to monitor the trend of the ecological environment and the effectiveness of policy implementation. Consequently, new understanding and practice will take place to improve the accuracy, efficiency, and predictability of environmental governance.

1.3.1 More scientific and precise environmental decisions due to new technologies

Data is the basis for decision-making. By establishing a complete database about ecological environment, government decisions are no

longer based on a small amount of “sample data” or “limited cases”. Data speaks. It not only provides an important foundation for national environmental governance, but also makes decision-making more scientific and accurate.

More importantly, with big data and Internet, data can be shared between both central and local environmental authorities, among departments of various regions, and from government, enterprises to the public. Consequently, resources can be saved because various departments do not need to collect the same data repeatedly. Data will be more accurate so that government decisions will be less casual or impulsive and environmental treatment will be more comprehensive and systematic.

1.3.2 More efficient and forward-looking environmental decisions due to new technologies

Big data, cloud computing, Internet of things and mobile Internet make real-time monitoring, dynamic management, and whole-industrial-chain intervention possible for key pollution sources. Multi-dimensional, multi-layered, and chronological analysis can be done so that patterns of the relation between economic activities and environmental changes will be better understood to facilitate forecast about future changes. Through access control, graded protection, user management, third-party test and other technical means, we can ensure the reliability and security of data by tackling data conflicts and data fraud. A system has to be

established to identify, analyze and grade environmental risks. An early warning and treatment system featuring prevention, contingency plans, and post-disaster treatment has to be put in place, so that pollution control can be preventative, refined, and routine. Consequently, efficient and forward-looking decision can be made based on facts presented by data and environmental governance will be precise, sustainable and long-term based.

1.3.3 More diversified and people-oriented government environmental services due to new technologies

Massive data storage technologies and interactive data visualization applications will make environmental data more accessible and public information more transparent, leading to innovative mechanism of government environmental service. We will use Internet thinking to restructure the environmental governance system, and promote the connectivity between eco-environmental data and transportation, public health, urban resources, and public opinion online. The practice of “Internet plus environmental government services” will improve the efficiency in sharing and transferring data among environmental departments, so as to provide efficient, rich, and timely services. Cloud computing can be used to analyze the trend of public opinion on environmental issues like climate change, pollution, and construction of chemical plants, facilitating government to better understand people’s demand on environment, properly settle conflicts caused by environmental

issues and meet people's demand for a better environment.

1.4 Platforms for environmental governance created by new technologies

Traditionally, environmental data belongs to individual departments who may not share information with each other. The new generation of information technology becomes a force in integrating these data. With the great power of cloud computing and big data in processing information, “Internet +” and artificial intelligence can help managers handle all kinds of environmental problems by integrating resources. Therefore, environmental governance will enjoy good platforms.

Big data center and integrated service platform can lead to smart measures in links of environmental protection from pollution sources monitoring, environmental quality test, to decision-making and law enforcement. By comprehensively applying technologies such as sensors, global positioning systems, video surveillance, satellite remote sensing, infrared detection, and radio frequency identification, the environmental governance platform can collect real-time information about pollution sources, environmental quality, and ecological conditions. As a result, a comprehensive, multi-level, and full-covered network of environmental monitoring can be set up to deliver information efficiently and accurately.

2 Transformed means of environmental governance brought by new technologies

Whether new technologies can exert far-reaching impact on environmental governance effectively depends to a large extent on how many technologies can be directly applied. The 4th industrial revolution has offered all kinds of new technologies and new answers to environmental governance. If applied appropriately, they will bring about fundamental changes to our means and equip us with the capacity to meet future needs in environmental governance.

2.1 "Cloud +" sensors offering 24/7 all-round environmental monitoring

Environmental monitoring and data yielded are the prerequisite for environmental governance. Lack of background data and belated and inaccurate measurement of pollution have long been major obstacles to environmental governance. Because of leaping progress and widespread application of inter-cloud connectivity, automated traffic, digital simulation, and intelligent remote sensing technology, the "cloud +" sensor will completely replace the traditional means of equipment monitoring operated by humans. Therefore, 24/7 all-round and fully automated data as well as dynamic digital simulation will be available.

2.1.1 All-round monitoring by drones and sensors on land, air and sea

At present, satellite remote sensing has been widely used in air pollution and meteorological monitoring. Remote sensing technology

employed by drones and robots, coupled with real-time data transmission from cloud, will greatly expand the horizon of environmental monitoring, improve the data accuracy and achieve automated monitoring. Being flexible and precise is the biggest advantage of mobile remote sensing monitoring. Thanks to this new technology, wide areas can be monitored precisely in a short period of time. Monitoring on polluting companies can be non-intrusive. Emergencies can be handled more promptly. And dangerous or harsh areas can be monitored remotely.

The startup company McFly Technology combines drones, remote sensing monitoring and AI big data to monitor and prevent farmland pests and diseases. The remote-sensing UAV flies over the farmland to generate spectral maps and transmit acquired data to the cloud. The AI algorithm can identify whether the farmland has diseases or pests. And if so, it will also calculate the route for machine to automatically spray pesticides.

The Qinghai Quma River monitoring station, at an altitude of over 4,200 meters, has deployed cable robots, flow velocity measurement with radar technology, satellite communications and on-line monitoring to realize automated hydrological monitoring in places of more than 1,000 kilometers away from Xining. It has become the first automated remote-controlled hydrological monitoring station in Qinghai, overcoming the harsh natural conditions that pose great risks to human beings surveying the Sanjiangyuan area.

It can be foreseen that with these new technologies, real-time environmental monitoring can be done from the entire river basin to a single company's sewage facilities, and from the bustling cities to remote or dangerous wild areas. By that time, even the best-hidden pollution will be exposed because there is no more blind spot in environmental monitoring. Nature and community environment will be under more transparent monitoring.

2.1.2 Dynamic environmental monitoring from micro- to macro-level

Environmental sensors are like human sensory organs in helping people understand various physical environments. Especially when deployed with AI, inter-cloud connectivity, and big data mining, smart sensors will make a breakthrough in intelligent signal processing and identification, self-calibration of device, and automated data analysis and transmission, making intelligent monitoring more powerful. Meanwhile, smart sensors have become smaller and cost efficient, so they can be widely installed in various machines, equipment, urban infrastructure, and open spaces. As a result, sensors can provide us with dynamic data from micro- to macro-level and bring any subtle changes in environment to our attention.

The New York State government has initiated a “new generation of water resources management plan”, which widely uses sensory monitoring and dynamic simulation to carry out the ecological

treatment of the Hudson River. Since the 1980s, managers have installed sensors throughout the Hudson River. These sensors transmit various physical, chemical, and biological data, namely river salinity, turbidity, chlorophyll concentration, and particle size, to the computing center via a real-time network. The data is generated and processed continuously and compared with historical ones. The backstage computing center visualizes the data in a three-dimensional way, showing a virtual Hudson River. When the water is contaminated, the chemical, physical, and biological changes are shown. Using this information, scientists can simulate the Hudson River's environmental model and treatment program to assess the combined effects of different interventions on the Hudson River. Under this new technology, after years of efforts, the Hudson River has become clean and beautiful again.

There are more and more such successful cases with more advanced technologies around the world. The National Natural Science Foundation of the United States funded the “CitySense: An Urban-Scale Sensor Network” project. The project installed sensors on streetlights in Cambridge, Massachusetts, USA, to monitor pressure, temperature, relative humidity, wind speed, wind direction, precipitation, rainfall intensity, CO_2, noise, etc., and transmit information wirelessly to the database. At the same time, Virtual Earth and Sensor Map developed by Microsoft can visualize acquired data on the map. Environmental managers and researchers

can track the spread of pollutants through this database and conduct long-term monitoring of the city's air to develop a more scientific program.

2.1.3 Wearable technology enabling everyone to be “green supervisors” with “green assistant”

The “cloud+” sensor can be not only deployed by environmental managers and scientists in professional settings, but also worn by average people in everyday life. At present, various micro devices have been widely worn by people to conduct real-time monitoring and offer intelligent suggestions regarding their health. In the future when people are more aware about environmental protection, they can wear devices to promote a greener lifestyle. For example, they can measure their carbon footprint just like calculating calorie consumed by heartbeat, sleep, and exercise. They can also judge a product by its environmental impact after scanning the green label on its packaging, rank it online so that people can take environment into account when making purchase decisions. Low carbon practice can also be shared online. Everyone will have an intelligent “green assistant”. What’s more, people can also use smaller yet more powerful civil sensors to monitor the environment of residential buildings, office buildings, outdoor area, and shopping centers in their community in real time, so as to set up an early-warning system by sharing data. Public monitoring goes hand in hand with professional monitoring by government agencies and research

institutions, providing multi-sourced data, a richer and more comprehensive monitoring basis for environmental governance. As a result, government agencies and research institutions recruit an army of volunteer “environmental supervisors” because everyone can be a “green supervisor” in their community. The sources of environmental information will be less hierarchical with in-depth public participation.

2.2 Integrated AI offering new smart means for environmental governance

Every industrial revolution in human history has greatly empowered people. The artificial intelligence that surpasses human beings in some areas may be one of the most important forces empowering human beings in the 4th Industrial Revolution. Integrating AI with quantum computing, big data, Internet of things, new materials, new energy, and biological genetics can bring groundbreaking changes to the way human produce and live. Green production, circular economy, and clean energy will change from concepts and small-scale experiments to universal reality. At the same time, approaches in environmental governance have become more intelligent.

2.2.1 Environmental control from source by green manufacturing and smart factory

Industry 4.0 will fully integrate AI into the whole value chain of

production and services. Future production activities will be customized, intensive, recyclable, and making the most efficient use of resources and energy. Smart factory will go digital in employing intelligent processes and systems to build a people-oriented plant that is energy-efficient, and environmentally friendly. In addition to using environmentally friendly materials in manufacturing, and be more vigilant about pollution, the smart factory can also work with upstream and downstream manufacturers to carry out green management throughout products' life cycle. As a result, effective circular manufacturing can be achieved from resources, materials, design, manufacturing, to waste recycling.

Borgward's smart plant in Beijing has introduced the world's first 8-model flexible line to maximize production in the Industry 4.0. The smart plant preserves environment and saves energy while improving production quality and efficiency to the best of its capacity. Borgward adopts the 100% automated welding technology with intermediate frequency, which can effectively reduce energy consumption by 40% while ensuring the welding quality. The paint shop adopts an environment-friendly water-based paint and special coating approach, making the paint more secure and reliable. Zeolite wheel + RTO gas treatment can remove over 98% of VOC, not only meeting the strictest environmental requirements in Beijing, but also saves cost for the plant. Borgward Smart Factory also plans to set up solar energy systems, which can supply 20% of the plant's power.

Smart factories and smart manufacturing have turned green manufacturing a reality. Traditional approach of "pollution first, treatment later" will be replaced by control from its source.

2.2.2 Sustainable energy consumption with AI and clean energy

Human progress in clean energy may be a way out of the current energy crisis. The application of artificial intelligence to energy development, transmission, utilization, and management can further improve energy efficiency, optimize energy storage and distribution mechanisms, ensure energy security, and promote sustainable energy use, thereby greatly enhancing human capacity of environmental governance in energy. The Internet of energy with AI at its core is an important direction for future development. Taking power as an example, with AI widely used in power grid security and control, power transmission and transformation, power distribution, new energy, information and communication, the Internet of things and high-voltage large-scale are the trend of power grids. The integration of artificial intelligence with grid application technology will effectively improve the ability to handle complex power grids. Creating the "AlphaGo" for energy and power systems will be possible.

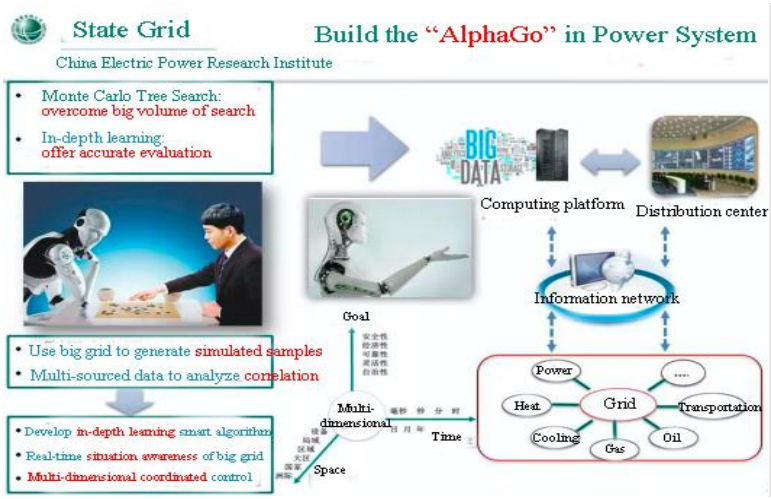

Figure2 Design of Smart Power System

In turn, the application of artificial intelligence is also conducive to the development of clean energy. Working with academic institutions in the United States, Toyota Research Institute currently invests about US$35 million in the integration of computer material modeling, new sources of experimental data, machine learning, and artificial intelligence. It aims to use AI to identify new battery and fuel materials, so as to accelerate the development of new energy technologies.

2.2.3 Machine learning empowering environmental governance with new approaches

An important strength of artificial intelligence is automatic recognition and deep learning, which can replace human to achieve more precise, timely, and better environmental governance. At

present, AI has been applied innovatively in the fields of water resources management and water treatment. Riverway and IBM's Joint Innovation Laboratory has developed a cognitive image recognition and interactive voice solution for water treatment, providing AI support for long-term management of rivers.

Riverway's smart image recognition program can satisfy all-round needs in machine identification and intelligent analysis of rivers and waterways. For example, the program can identify water level, surface line (submergence range), floating objects, water color (water quality, illegal discharge), bank collapse, illegal intrusion, damage to buildings, water plant growth (such as cyanobacteria), etc. The accuracy of video image recognition can be higher than 95%. After identification, the system can also analyze the corresponding data and issue an early warning of any unusual situation, avoiding the social problems like supply disruption caused by water pollution incidents or drowning.

This technology expands the platform of Internet of things in water treatment. Through image recognition, situation in every part of the river, and areas along the river can be learned at a glance, making river management more systematic and scientific.

2.3 Innovative coordination in environmental governance by block chain

Among quantum computing, artificial intelligence, DNA

sequencing, and other technological innovations that can drive the 4th industrial revolution and green development, block chain may bring about the most fundamental change in coordination and cooperation of environmental governance. In the future, any environmental activities involving bilateral or multilateral stakeholders, such as allocation and transactions of environmental resources, certification management, and non-profitable cooperation, can all use block chain to ensure a solid and trustworthy relationship, thereby creating more flexibility in collaboration.

2.3.1 Transformation of allocation and trading mechanism of environmental assets by block chain

Through secure, transparent, and distributed ledger to record transactions among parties, block chain can fundamentally change the allocation and trading mechanisms of environmental resources.

Power Ledger is a leader in block chain applications in the water sector. It is currently working with the city of Fremantle in Australia to develop a blockchain-based trading system that makes full use of smart metering data. Using this technology, relevant stakeholders from households, market players, to management authorities make informed decisions based on data on water quality and water volume. Such transparency will help consumers decide when to store or use water. At the same time it can also help prevent local authorities from arbitrarily changing data on water quality.

Blockchain can also support management on peer-to-peer transaction of water rights within a particular area. For example, farmers accessing the same waters can decide whether to trade their water resource quotas based on the latest weather information, crop prices, market trends and long-term climate trends, thus achieving autonomous and transparent distribution of water resources within the region. This real-time and transparent allocation of environmental resources can greatly alleviate the tension between some regions around the allocation of environmental resources, and effectively promote environmental cooperation between regions.

2.3.2 Environmental management and green consumption promoted by blockchain

With blockchain technology, people can comprehensively track products' environmental impact, including carbon footprint, raw material source, production process, and waste composition. This will help managers and trading parties discover illegal fishing, judge products' environmental friendliness, certify legitimate products, so as to improve the efficiency of environmental management and promote the production and consumption of green products. For example, the Dutch waste management agency is experimenting with regulatory certification of cross-border transport of waste through a combination of blockchain technology and mobile applications. With the joint support of WWF, many blockchain startups (such as

ConsenSys) and tuna fishing and processing company (Sea Quest Fiji), Pacific Islands have used blockchain to identify illegal fishing and transaction of tuna.

2.3.3 Innovative approach to tackle climate change by blockchain

Blockchain technology will play an innovative role in promoting global coordination in environmental governance. The United Nations launched “Climate Chain Coalition” which has attracted at least 32 institutional members to maintain accurate records and improve the reporting and verifying process of climate change through blockchain, so as to provide more powerful monitoring and better climate solutions. Being accessible and non-changeable, the blockchain will store data of global climate change more transparently, giving countries another reason to adhere to climate conventions and enhance global cooperation in climate governance.

2.3.4 New guarantee for non-profitable environmental program by blockchain

Thanks to the credit and confidentiality mechanism provided by blockchain, many problems in non-profitable cooperation can be solved. Projects like “recycle to coin” and “Plastic Bank” are trying to use cryptographic token to reward recycled behavior and follow its volume, cost and impact. If this becomes common practice, it can vigorously promote circular economy and sharing economy. Blockchain makes it possible to establish solid and trustworthy

relationship among strangers from around the world, so as to facilitate various collaborations in environmental governance.

2.4 Better forecast in environmental governance by big data

"Cloud +" smart sensors collect massive environmental data. AI crunches the data to come up with smart solutions for environmental problems. Blockchain facilitate collaboration in environmental governance. Harnessing the synergy of all these technologies will innovate forecast and decision-making means in environmental governance based on big data. Currently, big data has been widely applied into public administration, including environmental governance. Using big data to do what has been unthinkable is a prediction coming true. In the future, environmental changes and factors causing them will be precisely quantified, systematically evaluated, comprehensively mined and visualized. Environmental decisions depend increasingly on big data analysis and forecasting results. The unparalleled insight and analytical power of big data will make environmental predictions precise and decisions scientific and effective.

2.4.1 Better cognitive means in environmental governance by big data

Big data is changing the way we understand the world. It has a "4V" feature, namely volume, velocity, variety and value. Through in-depth analysis of multi-sourced heterogeneous data, underlying

correlations among variables and pattern of man and nature interaction can be revealed, creating great cognitive value and benefits in environmental governance.

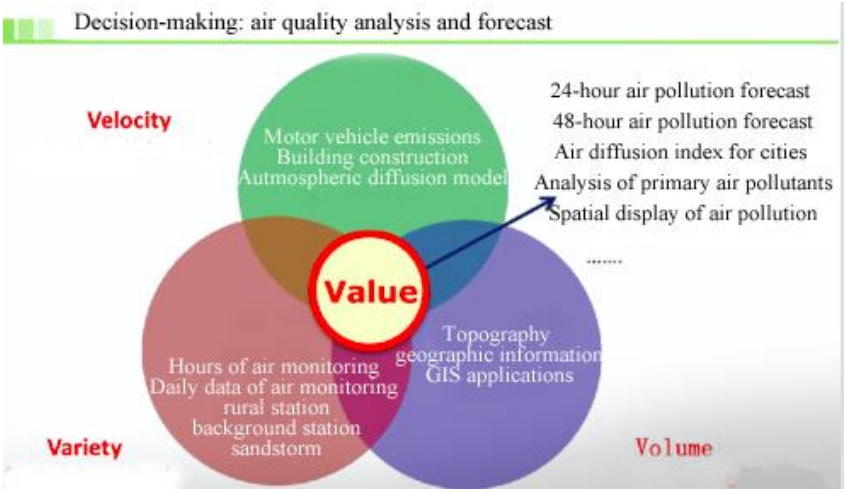

Figure3 Composition and application of big data

U-Air, jointly developed by Microsoft and environmental agency, is using big data to analyze and predict air quality in every 1km × 1km area within cities. This is mainly achieved by integrating two types of data. The first type is real-time data and historical ones of air quality. The second type is data related to air quality, including weather, traffic, passenger flow, road structure, points of interest, and so on. By modeling these data, the observer can learn about air quality at any point in the past 6 hours and effectively forecast for the next 6-12 or 12-24 hours. Currently, the smallest area that U-Air can work on is 1km × 1km. In the future, the area can be narrowed

further. It takes U-Air just a few seconds to predict citywide air quality. Therefore, this model based on big data is far superior to the traditional one in terms of accuracy, coverage, and speed.

Based on big data in environmental governance, regulators can notice any subtle changes in the environment, quantitatively monitor any factor and its impact, predict and quantify environmental risks, and scientifically assess the effect of any measure, so as to optimize solutions and make timely response.

2.4.2 Big data becoming "infrastructure" of environmental governance in future "smart cities"

Thanks to new technologies, more and more cities have upgraded the concept from "digital cities" to "smart cities" for sustainable development. Through smart management, urban managers hope to solve challenges in various development aspects such as water supply, drainage, sewage treatment, gas, transportation, and environmental protection. The "Smart City" will meet people's needs with limited resources and energy, while ensuring that resources are sustainable and recycled. The environmental governance of smart cities depends on the collection, integration, mining, and application of data. Sensors, connectivity, data, computing, and intelligence are ubiquitous in smart cities. Big data is more than data or means for forecast. It constitutes an important "infrastructure" of the entire city, collects data from every link of urban operation, and quantifies

activities and environmental conditions in the entire city.

Future city operations will be based on extensive big data analysis. Various big data application platforms, such as environmental risk assessment, public opinion analysis, emergency response, law enforcement support, corporate environmental credit management, and recalling polluting products, will help governments and relevant institutions to go beyond traditional means and solve problems efficiently. The new model of environmental governance supported by big data will greatly enhance the efficiency of environmental governance.

3 The future path for environmental governance: meeting challenges posed by new technologies

3.1 Prospects for innovative environmental governance by new technologies

After several rounds of scientific and technological revolutions, the speed of progress has grown exponentially. New technological innovation will go beyond our expectation. Information technology may achieve new breakthroughs in the following three aspects: scalability, power efficiency and security. Scalability means that capacity for information processing can be multiplied by billions. With much higher power efficiency, the system can perform self-testing, self-diagnosis, and self-repairing to improve security. In the new round of technological and industrial revolution, new

technologies will be applied more widely into environmental governance with more breakthroughs, better technical standards and more advanced technologies.

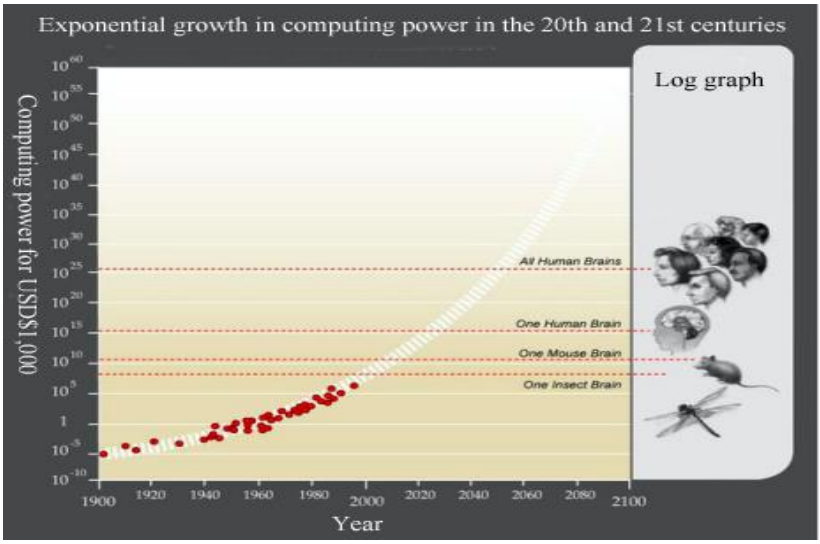

Figure4 Growth of computing capacity after 20th century

3.1.1 Real-time efficient processing of massive data with data lake

Data Lake is a repository for multi-source information, including data from the Internet of Things. One of its values is to bring together different types of data. Another is that it does not require a predefined model to perform data analysis. As a form of cloud service, Data Lake can analyze, process, and store various data at any time, so that public data will no longer be isolated and sharing will be a practice to tap data's underlying value. Big data and Data Lake will carry out more types of real-time data analysis, in order to

provide reference for the government to formulate refined environmental policies and manage environment dynamically.

3.1.2 Smart services everywhere by fog computing

A key feature of new technologies is their ability to take advantage of ubiquitous digital and information technology. As an extension of cloud computing, fog computing can bring cloud-based services closer to IoT devices and sensors. It can directly process and store data that does not need to be put on the cloud at the network edge to improve efficiency. Due to its wide geographical distribution, large-scale sensors with numerous network nodes, and support for high mobility and real-time interaction, fog computing will be widely used in various fields. The development of edge equipment and fog computing will establish a data analysis network to provide data analysis for each stage. Combining data analysis and machine learning, solutions will be more intelligent and automated and make distributed intelligence possible. What's more, combining cloud computing and fog computing will provide ubiquitous intelligent services for environmental governance.

3.1.3 All-round governance promoted by IoT embedded system

Sensors and the Internet of Things are bridges between the digital and physical world. With a large number of embedded devices and sensors in information systems, the number of client devices per server can reach tens of thousands. With further improvement of artificial intelligence and computer processing speed, different fields

such as data science and machine learning can draw meaningful information from the Internet of Things data and take actions accordingly. More than collecting and analyzing data, the IoT embedded system can offer intelligent state-driven solution. If the sensor is equivalent to human sensing organs, then the embedded system technology is similar to the human brain that sorts out information. In the future, the distribution of sensors will be networked. Combining networked sensors with embedded system will achieve all-round intelligent governance by applying environmental sensing and other technologies into every link of environmental governance.

3.1.4 Low-cost technologies in environmental governance offered by NB-IoT

The breakthrough of NB-IoT technology has accelerated the development of the entire IoT industry. Cellular-based narrowband IoT boasts wide coverage, many connections, low cost, and power efficiency. It consumes only about 180KHz of broadband, prolongs battery life to 10 years, and can provide all-round coverage of cellular data connection. An unprecedented market is being created by narrowband Internet of Things, whose conditions for the large-scale industrial development are taking shape. The next 2-3 years will become a key period for the development of the Internet of Things industry. Narrowband Internet of Things can be widely used in environmental monitoring, providing lower-cost and efficient

underlying technology solutions for hardware monitoring and online monitoring data transmission platforms, thereby presenting monitored organization's environmental information more securely, reliably, accurately, and comprehensively with smart solutions.

3.2 Future-oriented smart environmental protection

Opportunities presented by unthinkable technological innovations means that precise and intelligent management focusing on prevention would surely become a new trend. "Smart Environmental Protection" is arriving. Back in early 2009, IBM put forward the concept of "Smart Earth" to change the way governments, companies, and the publics communicate through the new generation of information technology. Inspired by this concept, the concept of "Smart environmental protection" came into being, which aims to make full use of various environmental technologies to perceive, analyze and integrate all types of information, and respond to demands intelligently manner, so that decisions can better meet the needs of environmental development.

"Smart Environmental Protection" is an extension of "Digital Environmental Protection". Based on existing platform, it comprehensively uses the new-generation information technologies such as the Internet of Things, sensors, cloud computing, satellite remote sensing (RS), global positioning (GPS), and geographic information system, GIS and Virtual Reality (VR). It deploys sensors

and equipment in environmental monitoring, and builds the Internet of Things through supercomputers and cloud computing to make management and decision-making smarter, so as to establish the system of “smart environmental protection”.

Smart environmental protection is different from current effort in the following ways. First, current informationization in environmental protection focuses on paperless and automated management and data collection while smart efforts stress wide applications of information devices and advanced sensing tools. Second, the main task for current effort is to digitize every step in environmental protection, while smart protection aims to connect the whole process of prevention and treatment. IoT data platform will collect and analyze information in real time and make more comprehensive environmental decisions.

The smart environmental platform consists of two parts: data collecting hardware and software system in data center. The hardware collects on-site environmental data, including air temperature and humidity, soil temperature and humidity, CO_2 concentration, light intensity, dissolved oxygen concentration, pH value, etc., and transmits it to the data center. The intelligent software system in data center is responsible for storing, analyzing, summarizing and presenting data. When data exceeds the threshold set by the system, an alarm will be issued by sound and light, short messages, and pop-up windows, so that staff can turn on or off

relevant equipment to adjust environment.

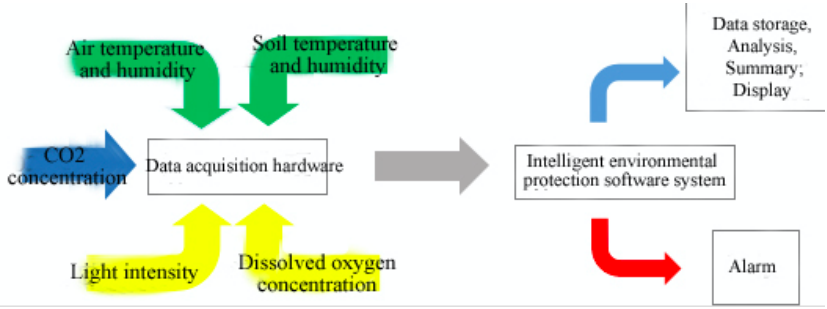

Figure5 Smart platforms for environmental protection

The basic structure of smart environmental protection includes: sensing, transmitting, smart analysis and service.

a. Thorough sensing: coverage of all pollution sources

Any device, system or process that can sense, measure, capture, and transmit information anytime, anywhere will be used to achieve a thorough insight of environmental governance, pollution sources, ecology, and radiation.

b. Comprehensive interconnectivity: information exchange and sharing

Special networks, operators' networks, 5G and social communication technologies will be used to exchange and share environmental information from personal devices, organizational and government systems to achieve more comprehensive interconnectivity.

c. In-depth intelligence: mass storage and deep mining

Cloud computing, virtualization, and high-performance computers

will be used to integrate and analyze massive cross-regional and cross-industrial environmental information, so as to realize in-depth intelligence featuring mass storage, real-time processing, in-depth mining.

d. Smarter Decision: customer-oriented information service portal

Cloud service model will be used to establish a customer-oriented application system and information service portal to provide "smarter decisions" for environmental governance, pollution prevention, environmental protection, and radiation management.

At present, smart environmental protection has been conducted on trial basis in China. For example, Shenzhen "Smart Environmental Protection" has established a spatial data platform, which can provide 31 special services in 7 areas. Using these map services, staff can present original maps, administrative maps, satellite images and basic ecological control lines at the same location, so that they can quickly understand environmental fragility and protection targets around the area of interest without making a field trip. Staff can also analyze the influence of regional pollution, simulate environmental quality in real time and make forecast or alarm, so as to provide technical support for relevant decisions. Jiangsu's "1831" smart system can visualize data of water, sound, radiation, automobile emission, and other environmental factors to form a series of high-precision maps, which are presented in an integrated geographic information system. Therefore, a unified platform integrating

systems, networks, data, hardware, software will be established to enhance security and service. What's more, smart environmental protection will have more integrated functions that can be promoted throughout the country.

3.3 Wisdom to tackle new technologies in environmental governance

As mentioned above, the rapid development of new technologies has brought about systematic changes to environmental governance, presenting more solutions and a prominent prospect. Greater application of new technologies to environmental governance not only calls for our courage to actively embrace them, but also for our wisdom to overcome challenges and risks in their promotion.

3.3.1 Be sharp and wisely handle challenges in promoting new technologies

The promotion and application of new technologies in environmental governance will run into some problems and even risks, such as technology monopoly, value-cost trade-off, data security, etc., which need to be resolved intelligently.

First, the promotion of new technologies will face international barriers. Most new technologies originated from developed countries, which often set up technical barriers in the name of intellectual property protection, restricting the dissemination and popularization of core technologies. On one hand, developing countries should strengthen core technological innovations with independent

intellectual property rights. On the other hand, they should actively advocate openness, mutual benefit, and win-win cooperation concept and make joint efforts in global environmental governance based on consultation, and innovate the multi-level global cooperation mechanism among central and local government, business, science, social organizations and groups. As a result, cooperation in technology, scientific research, trade and investment will be boosted, in order to improve the global system of environmental governance, and make concerted efforts in building a community of human destiny.

Second, cost is an important factor in the promotion and application of new technologies. Some new technologies can improve the level of environmental governance at a high cost, so we need to weigh its benefits against cost. Cost is an indispensable factor in determining whether to adopt a new technology, but we also need to keep other factors in mind, such as economic benefits, social benefits, and ecological benefits. If the value is worth the cost, then we adopt the new technology. In addition, rapid technological development may lead to sunk cost when new technologies are fully adopted by market before more advanced ones emerge. This requires policy makers to have strategic wisdom, choose the right timing, so as to avoid sunk costs.

Finally, data and information security should be highlighted in the promotion and application of new technologies. But it should not be

an excuse for keeping data isolated. It is necessary to improve information security awareness, strengthen R&D, invest more in network and data security systems, and improve technical standards and legal norms to prevent accidental failure of digital infrastructure. Data need to be shared when security can be ensured.

3.3.2 Adopt new concepts and embrace reform

To give full play to the role of new technologies, we must embrace them more proactively. Government leaders' awareness of new technologies determines how committed they are to their promotion. New technology's life cycle is very short because more advanced technology and model keep popping up and opportunities pass away quickly. In the face of waves of new technologies, to embrace actively or to wait and see will bring about very different results for regional development. The first thing a government leader can do is to awaken awareness, focusing on how to adapt to the new reality instead of sticking to traditional way of governance. Government leaders should take the lead in adopting new ideas. They should neither turn a blind eye to new technologies nor blindly promote them. Instead, they should use constructive wisdom, strategic vision, and creative thinking, and be open-minded. Policies need to be formulated according to dynamics of new technologies and ground conditions, so that government can adapt to the new environment, promote wide application of new technologies in environmental

governance, and modernize its governance. Enterprises, social organizations and individuals also need to fulfill their respective roles in meeting the environmental changes brought about by new technologies. They should also actively follow the concept of "smart environmental protection", promote new ideas, develop and adopt new technologies, and support new products, so as to embrace the era of "smart environmental protection".

3.3.3 Take multiple actions to promote technological innovations in environmental governance

a. Build a public platform for smart governance of ecological environment. In particular, build a public technology platform to incorporate basic environmental technologies developed by government-funded research and open the platform to relevant companies, universities, research institutions, and professional, so that new technologies can be employed more widely in environmental governance. According to the requirements of the "Overall Plan of Environmental Big Data Development" issued by the General Office of the Ministry of Environmental Protection, we need to do a good job in building mechanism of eco-environmental big data management, meeting technical standards, operating and maintaining systems of information security, big data protection cloud, big data management and big data application.

b. Cultivate high-level talents in environmental governance. Adapting to new technologies and applications, we will train

high-level talents who understand both environmental engineering and next-generation information technology, so as to integrate the two fields better. Therefore, it is necessary to break the boundaries of disciplines and carry out coordinated research and talent cultivation across disciplines.

c. Innovate environmental policies and information disclosure, and promote informationization and collaborative governance in environmental protection. Promote e-government to provide one-stop service for enterprises and the public. Enhance the administrative efficiency and innovate ways to disclose environmental information so that the public can participate in environmental protection online anytime and anywhere. Build a sound environmental governance system and use information technology to create an Internet service platform that is free from spatial and geographical constraints, efficient, convenient and multi-channeled. Promote coordinated environmental governance, so that government agencies in different fields and at various levels can coordinate well and offer all-round services to the public.

d. Make eco-environmental data public and tap information resources deeply. In order to make government data public and use big data to improve environmental governance, information resources about ecological environment need to be integrated. In addition, establish a big data center and a shared service platform to gradually share data owned by environmental departments, so that

everyone can share environmental information, coordinate business and connect with each other through the platform. As a result, information resources will be tapped more deeply and environmental governance more transparent.

e. Promote international exchange and cooperation of environmental technologies. Attract foreign technologies and business in environment and encourage domestic ones to go global at the same time. Take market demand as a guide in developing environmental technologies, release information on governments' needs for environmental governance, and strike a balance between supply and demand in technology market. Offer information service for design, development and follow-up assessment in environmental projects. Pay special attention to matching supply with demand in environmental technologies, smart forwarding and solution. Promote financing for environmental industries, market transactions, and expert consultation, so to guide the development of environmental technologies and industries in China. In line with "One Belt and One Road", we need to enhance the global competitiveness of China's environmental enterprises.

3.3.4 Bring third-party into innovative and cooperative mechanism in environmental governance

One region or department alone cannot get the entire job done in environmental governance, which is complicated and calls for cooperation. The new technology brought by "Internet+" not only requires greater cooperation, but also provides more convenience and

possibility for governing bodies to cooperate across regions.

a. Encourage market players to promote the internal environmental governance. The government has to give enterprises more incentives to adopt new technologies for environmental governance by setting up university-industry cooperation platforms, offering favorable taxations, innovating mechanisms to encourage energy efficiency and emission-reduction. It also encourages enterprises to invest more in environmental technology and equipment and apply new technologies such as big data, smart sensors, and the Internet of Things into production, so as to generate more profits from new technologies and reduce cost for technology development and application. As a result, technologies can facilitate environmental governance for both enterprises and government.

b. On the basis of government-enterprise and university-industry cooperation, third-party involvement is important not only for faster application of new technologies, but also for mechanism innovation in the context of new technologies. PPP and green financial funds can be established to attract private capital, so as to make up for the shortage in this regard and the high costs of duplicate investment. As a result, application and promotion of new technologies for environmental governance can be accelerated.

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