

References

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APPLICATION OF INDUSTRY 4.0 CONCEPTS

The energy industry's Industry 4.0 mainly uses digital technology to update different information differences in the energy work system, realize the deep integration of energy and information, and optimize the operation system and production methods. In the traditional energy production process, different production methods and processes usually lead to delays or errors in efficiency and energy generation, thereby reducing production efficiency and causing waste of resources. If Industry 4.0 technology is introduced into the traditional energy industry, it will reduce delays and errors in the summary of equipment and manufacturing processes, enable the entire industry to share information platforms, share and collaborate with each

other, and all departments will jointly produce energy under accurate data, and efficiency will be greatly improved [1; 2].

Recent studies have extensively examined the impact of Industry 4.0 technologies on China's energy sector and have drawn a series of conclusions. Innovation through digital operation and maintenance systems is an important guarantee for improving efficiency. Through technical means such as condition monitoring (CBM), drone inspections, and remote operation and maintenance centers, the traditional "periodic maintenance" model is gradually shifting to an "on-demand maintenance" model. For example, with the help of technical means such as vibration analysis and infrared thermal imaging, the health status of equipment can be diagnosed in real time to minimize unnecessary losses caused by downtime; the implementation of digital solutions requires strengthening policy coordination and technological innovation. On the one hand, it is necessary to promote the formulation of energy data sharing standards and the construction of new power market mechanisms to create a compliant environment for technology applications; on the other hand, it is necessary to promote in-depth cooperation between energy companies and ICT manufacturers to break through technical bottlenecks in the fields of intelligent algorithms, industrial software, and edge computing (Table 1).

Table 1. Impact of digital technology on Chinese energy companies

Data Types	Impact	Years
State Grid Information & Telecommunication Co., Ltd.	The company's power digital business revenue was approximately US\$283.93 million, an increase of 24.43%	2024
Green transformation and energy companies	For every 1% point increase in the level of digitalization, the green transformation level of energy companies will increase by 0.0242 %	2024

Source: made by the authors based on [3]

According to the (table 1), it is proved that the use of digital applications by Chinese energy companies can indeed increase the income of related businesses and bring positive impacts. For every 1% increase in the degree of digitalization, the green transformation of energy companies will increase by 0.0242%, which quantifies the

correlation between digital technology and energy companies. Technological innovation and supportive policies such as "National Innovation Pilot City" have enhanced this positive impact. In addition, the adaptive adjustment of the talent structure cannot be ignored, and human support for the transformation needs to be provided through skills training, cross-border talent introduction and other means.

Liu, L mentioned in "Artificial intelligence and energy intensity in China's industrial sector: Effect and transmission channel" [4] that many energy industries in China have improved their production capacity due to the addition of intelligent robots. In 2017, China has promulgated the "National Intelligent Development Plan" and the "New Generation Artificial Intelligence Development Plan" and established the goal of making China a global artificial intelligence innovation center by 2030. Practical applications can be reflected in remote debugging equipment. For example, China will import, or export artificial intelligence mechanized smart equipment in the future. If debugging still takes a lot of time and money, remote debugging can reduce the debugger's travel costs by about 60% and shorten the service after-sales response quality by at least two-thirds, which will positively affect the user experience.

China's current energy efficiency is quite good. Before the popularization of clean energy, China used natural, non-environmentally friendly energy such as fossil fuels, including thermal power plants, which are still very popular today. These energy production activities have a great impact on China's environment. According to the "China Ecological Environment Bulletin 2019", of China's 337 cities, only 46.6% of the cities (157 cities) have met the air quality standards, of which the main pollutants are PM_{2.5}, ozone (O₃) and PM₁₀ [5]. The main pollutants, headed by ozone, are emission pollution problems, with non-clean energy production and consumption accounting for the highest proportion. According to the "China Ecological Environment Bulletin 2023", of China's 339 cities, 59.9% of the cities have achieved normal air quality [6]. Judging from the two sets of data, the reason for the improvement in urban air quality is that China has begun to transform from non-clean energy to clean energy. The Chinese government has paid attention to the current environmental problems, but it still needs to strengthen its goals and move towards

sustainable development. For example, it can increase welfare systems to encourage people to use more clean energy and heavily subsidize new energy vehicles to achieve the goals of emission reduction and environmental protection. From the perspective of externality theory, inefficient use of energy will produce negative externalities such as environmental pollution, and market failure needs to be corrected through government intervention (such as taxation and subsidies).

According to (Figure 1), from 2019 to 2023, China's renewable energy, except for hydropower, showed a trend of continuous growth. This means that China has made positive progress in the development of renewable energy (such as solar energy, wind energy, biomass energy, etc.). Between 2019 and 2021, the growth was relatively small and the growth of power generation was relatively slow, indicating that the growth rate of renewable energy power generation was relatively slow during this period. Between 2021 and 2022, the slope of the curve became significantly larger and the growth of power generation accelerated, indicating that China may have new policy promotion, technological breakthroughs or large-scale projects in renewable energy power generation during this period. The growth trend will be maintained in 2022-2023, but the growth rate will be slower than that in 2021-2022.

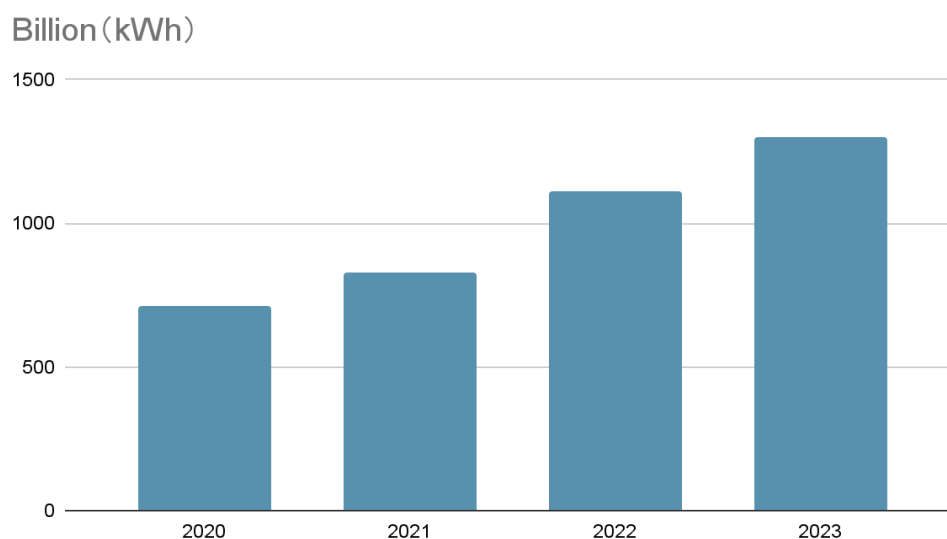


Figure 1. China's renewable energy generation (2019-2023).

Source: World Bank data Electricity production from renewable sources, excluding hydroelectric (kWh) - China [6].

It is recommended that the government start from the three key links of regulations, economy and technology to build a comprehensive and multi-level policy support framework. In terms of regulatory construction, the formulation of high-efficiency energy efficiency standards covering energy production, transportation, consumption and other links should be rapidly promoted. Through the functions of multiple departments such as industry and information technology, ecological environment, etc., a cross-departmental energy big data supervision platform should be jointly built to achieve real-time dynamic monitoring of key energy-consuming enterprises and ensure standardized and orderly energy utilization.

The integration of Industry 4.0 concepts into China's energy sector enhances efficiency, digitalizes production processes, and reduces environmental impact. The use of artificial intelligence, remote maintenance, and big data analysis helps lower costs, minimize downtime, and support green transformation. Positive changes are reflected in increased company revenues and improved air quality. Further progress requires stronger policies, standardization of energy data, and investment in human capital.

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ЦИФРОВІЗАЦІЯ ЯК ЧИННИК АКТИВАЦІЇ ІННОВАЦІЙНОГО ПОТЕНЦІАЛУ ПРОМИСЛОВИХ ПІДПРИЄМСТВ В ПІСЛЯВОЄННИЙ ПЕРІОД

У післявоєнний період трансформаційних викликів особливої актуальності набуває питання активізації інноваційного потенціалу промислових підприємств як ключового драйвера економічної реконструкції та сталого розвитку. У цьому контексті цифровізація постає не лише як інструмент технологічної модернізації, але й як мультиплікативний чинник, що переосмислює парадигму виробничих процесів, управлінських практик та