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The Transformation and Upgrading Path of High-Energy-Consumption Manufacturing Industry under the "Dual Carbon" Goal

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Abstract

The transformation of energy-intensive manufacturing industries is one of the important measures to achieve the "dual carbon" goal. To explore the transformation and upgrading path and countermeasures of the high-energy-consuming manufacturing industry, this paper analyzes the factors affecting the high-energy-consuming manufacturing industry from both macroscopic and microscopic perspectives. The study finds that, from a macro perspective, the construction and improvement of the carbon evaluation system, monitoring and inspection system for emission reduction target, and carbon emissions trading market are important factors affecting the transformation and upgrading of high-energy-consuming manufacturing industries; from a micro perspective, different manufacturing industries have their sore points, the upgrading and transformation paths are also different, however, technological innovation and industrial structure transformation have become important trends in the transformation of high-energy-consuming manufacturing industries. The transformation of high-energy-consuming manufacturing industries should comprehensively consider macro policies and specific industry conditions to explore efficient and feasible transformation and upgrading paths.

Keywords

Manufacturing; Transformation; Upgrading; Carbon Reduction.

1. Introduction

In September 2020, Xi Jinping claimed, at the 75th United Nations General Assembly, that China will strive to achieve carbon dioxide peak by 2030 and carbon neutrality by 2060. Carbon peaking refers to the process of carbon dioxide emissions reaching a peak and showing a trend of decline. Carbon neutrality refers to the offsetting of carbon dioxide as well as other greenhouse gas emissions and carbon sinks to achieve net-zero greenhouse gas emissions. According to *The Statistical Report on National Economic and Social Development in 2010*, high-energy-consuming manufacturing industries in China mainly include ferrous metal smelting and rolling processing industry, chemical raw material and chemical product manufacturing, non-ferrous metal smelting and rolling processing industry, and non-metallic mineral production industry, petroleum processing coking and nuclear fuel processing industry, electricity and heat production and supply industry. At present, the energy-intensive manufacturing industries represented by electricity, steel, cement, non-ferrous metal smelting, and petrochemical and coal chemical industries have made a huge contribution to carbon emissions in China, and have also become the main targets for achieving the "double carbon" goal. Due to the complex sources of carbon emissions, key industries play an obvious role in supporting the development of the national economy, meanwhile, carbon emission reduction

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is difficult. The transformation and upgrading of high-energy-consuming manufacturing industries are even more important. This study will rank the top in carbon emission reduction responsibilities through comparative analysis. The paper aims to compare and analyze the ferrous metal smelting and rolling processing industry, non-metallic mineral manufacturing industry, petroleum processing, coking and nuclear fuel processing industry, which rank the top three in the carbon emission reduction responsibility to explore the pain points and development trends in the upgrading and transformation of high-energy-consuming manufacturing industries. The above analysis will have certain reference significance for the transformation of other high energy consumption manufacturing industries and policy formulation in China

2. Analysis of the Construction of Carbon Emission Reduction System for High-Energy-Consuming Manufacturing Industries from a Macro Perspective

2.1. Allocation of Emission Reduction Responsibilities Remains to be Clarified

Based on the TOPSIS comprehensive evaluation method based on entropy weight [1], some domestic scholars have calculated the carbon emission reduction responsibility of the manufacturing industry in China from 2020 to 2030 and found that the manufacturing industry needs to complete 35.52% of the total carbon emission reduction responsibilities in China. It further affirms the core position of the manufacturing industry in achieving the "dual carbon" goal. At the industry level, ferrous metal smelting and rolling processing industry, non-metallic mineral manufacturing industry, petroleum processing, coking and nuclear fuel processing industry are the top three industries with emission reduction responsibility, and in two-thirds of provinces, ferrous metal smelting and the carbon reduction responsibility of the rolling industry is the highest, followed by the non-metallic mineral manufacturing industry. Affected by economic scale, industrial structure, energy intensity and energy structure, different regions are in different stages of carbon emissions. Taking the carbon emission intensity in 2018 as the benchmark, it can be divided into low-carbon development domestic cities according to the carbon emission intensity of different cities in China. Leading, high level, need to be improved, low level and urgent need to improve several levels [2].

Therefore, in the case of different carbon emission intensities in different industries and different regions, the clear allocation of carbon emission reduction responsibilities is very important. Due to the intersection of regions and industries, the analysis of carbon emission sources becomes complicated.

The accounting of carbon emissions needs to establish a more complete system, and adopt a more standardized method, and the relevant policies for carbon emission reduction also need to be adapted to local conditions. High-energy-consuming manufacturing industries are represented by ferrous metal smelting and rolling processing industries, and non-metallic mineral manufacturing industries need to focus on and assume major responsibility for emission reduction.

2.2. The Carbon Evaluation System has Yet to be Perfected

At present, there are three carbon evaluation models in China, which can be summarized as service type, subsidiary type, and independent type, but they all have their limitations [3].

A Service type

This type of carbon model uses the carbon emission evaluation results as the basis for the paid allowances that enterprises need to purchase. The expected policy objectives of the carbon assessment system under the dual-carbon background cannot be fully realized.

B Subsidiary type

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It incorporates carbon evaluation into the energy-saving evaluation and adds relevant content of carbon evaluation to existing energy evaluation. The scope of carbon assessment is mainly limited to carbon emissions in energy utilization activities, and cannot fully reflect the carbon emissions of fixed-asset investment projects.

C Independent type

It implements an independent carbon assessment based on the existing pre-assessments such as energy assessment and environmental assessment. It is not in line with the requirements of governing the country by law and the direction of administrative system reform, the time for dual-carbon legislation is not yet mature, and independent carbon evaluation cannot obtain a clear legal basis in the short term.

The core content of the service-based carbon evaluation model is to use the carbon emission evaluation results as the basis for the paid allowances that enterprises need to purchase. However, this model is mostly aimed at new projects at the end of the decision-making chain. The achievement of the expected policy goals of the evaluation system is not good. The subsidiary carbon evaluation model introduces the content of carbon evaluation into the energy conservation evaluation, but this model is limited to energy utilization activities and ignores the carbon emissions of fixed-asset projects. The independent carbon assessment model tends to implement independent carbon assessment based on energy assessment and environmental assessment, but it cannot be implemented due to the immaturity of legislation and the lack of a clear legal basis. Thus, some scholars proposed an institutional path to incorporate carbon assessment into EIA based on institutional, legal, and technical considerations. However, before the carbon evaluation system is perfected and completely established, any proposal needs to be tested in practice. Therefore, there is still a long way to go to build the construction of carbon assessment system.

2.3. A Unified and Scientific Carbon Emission Reduction Standard Measurement System Needs to be Established Urgently

A unified and scientific carbon emission reduction standard system is the basis for realizing industrial structure adjustment, rational allocation of carbon emission reduction responsibilities, and improving the carbon trading market and carbon evaluation system. However, the current carbon emission reduction standard system in China is not perfect, and there are basic data Insufficient, backward accounting methods, inconsistent standards, and imperfect evaluation mechanisms.

A large amount of data acquisition and verification work makes it difficult to obtain accurate basic data. At the same time, the enterprises included in the carbon emission trading market lack the statistics of basic carbon emission data in energy consumption and industrial production. The reporting system is not perfect.

In addition to the lack of basic data support, the accounting method for carbon emissions in China is also relatively backward. Compared with the field measurement method with few intermediate links, high accuracy, and real-time upload of carbon emission information, Chinese enterprises mainly use the carbon emission factor measurement method with low accuracy.

Besides, because of the lack of sufficient guarantee mechanisms, the quality of carbon emission accounting in my country is also lacking. Due to the differences in the accounting standards and scope of different companies and regions and the final report form, it is difficult to compare the carbon emission accounting results; in addition, the current carbon emission accounting is mainly conducted by companies included in the carbon emission trading market according to the greenhouse gas released by the country. The accounting guidelines are self-examined and supplemented by third-party verification. Due to the differences in the methods of accounting

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standards and the lax supervision of third-party institutions, it is difficult to guarantee the quality of carbon emissions accounting in my country.

The construction of the carbon emission reduction standard system not only relies on advanced and precise methods but also requires the cooperation and attention of enterprises and governments, as well as strict and reasonable supervision and incentive mechanisms. High-energy-consumption manufacturing, which bears a huge responsibility for carbon emission reduction, actively promoting and adopting advanced carbon emission and detection systems, and strengthening the data collection of its carbon emissions is important and necessary to achieve the upgrading and transformation path.

2.4. Carbon Emissions Trading Market

The mechanism of the carbon emission trading market is to use carbon dioxide emission rights as a commodity under the condition of total control and market trading, and carbon emission reduction enterprises realize the trading of carbon dioxide emission rights with the help of the market mechanism. The total amount control mainly refers to the issuance of carbon allowances, while the market transaction mainly refers to the sale and purchase of carbon emission rights by enterprises in the market.

However, the premise of the role of the carbon emission trading market is that the carbon emission reduction enterprises in the market cannot realize the cost transfer when facing emission reduction targets, so they must choose between emission reduction behavior and purchase of carbon emission trading rights. Studies have shown [5] that the preference for cost transfer, the price elasticity of supply and demand, and the ability of factor substitution are the main factors that affect the degree of cost transfer in the carbon emission reduction industry. At the same time, the study also specifically pointed out that among the eight pilot industries that implement carbon emission trading market policies in China, the petrochemical and power industries have the highest degree of cost transfer, and there are differences in cost transfer between different industries. Pass-through preference scores the highest, while the electricity sector scores the highest on the price elasticity of supply and demand and factor substitution. Therefore, to maintain the effectiveness of the carbon emission trading market, the government needs to prescribe the right medicine and formulate reasonable and effective policies for the transfer of carbon emission reduction costs of different enterprises.

The carbon emission trading system mainly realizes energy conservation and emission reduction by forcing enterprises to improve energy efficiency through technological innovation, promote the transformation of energy structure and optimize industrial structure. To maintain the effectiveness of the carbon emission trading market, it is necessary to pay attention not only to carbon allowances, regulations, and issuance but also to carbon pricing.

As the basis of carbon market trading, carbon allowances play a very crucial role. The purpose of the carbon quota system is to encourage enterprises to achieve industrial structure transformation and energy conservation and emission reduction through technological innovation, energy substitution, and output control. If there are too many carbon quotas, enterprises will rely on free quotas, thus losing the enthusiasm for voluntary emission reduction. If the carbon quota is too small, under the pressure of greater emission reduction, the economic performance of the enterprise will be affected, thereby inhibiting its development. In addition to carbon allowances, the issue of carbon pricing is also worthy of attention. Companies that always exceed carbon emissions (especially the six energy-intensive manufacturing industries mentioned above), often need to purchase carbon emission rights to maintain production. Effective market transactions and reasonable carbon pricing can promote technological innovation of enterprises, realize industrial structure upgrading, and vigorously promote the development and growth of green and energy-saving enterprises. big business. However, because certain key domestic industries (such as the power supply industry) play a

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supporting role in the national economy, and due to reasons including energy substitution and immature development of new processes, the industrial structure has not been successfully upgraded. The price should not be too high, otherwise, the cost of this type of industry will rise sharply, which is not conducive to the sustainable and healthy development of the industry.

3. Development Status, Problems, and Upgrading Paths of Key High-Energy-Consumption Manufacturing Industries

Macro-level policies often guide the upgrade path and development direction of the manufacturing industry. Therefore, the formulation of macro policies needs to take into account the current development status of various manufacturing industries, the problems they face, and other factors. However, since the problems faced by each manufacturing industry are often different and the development status of the industry is uneven, it is necessary to analyze the key manufacturing industries that bear a great responsibility for carbon emission reduction. In the following, through the discussion and specific analysis of the ferrous metal smelting industry dominated by the iron and steel industry, non-metallic mineral manufacturing industry dominated by the cement industry, petroleum processing and coking industry, the current pain points of high energy consumption manufacturing industry will be summarized and relevant policy suggestions will be put forward.

3.1. Steel Industry

Although the iron and steel industry has made progress in energy conservation and emission reduction in the past three decades, and the increase in carbon dioxide emissions has shown a decreasing trend from 1991 to 2019 [6], so far, its carbon dioxide emissions have contributed to the national total carbon dioxide emissions. The contribution of carbon dioxide emissions is still relatively high, and the total carbon dioxide emissions and crude steel production have a greater correlation.

The reason for the high carbon dioxide emissions in the steel industry in China is mainly because of the problems with its production mode and energy structure [7]. Since the production model of the iron and steel industry is mainly based on the production process of blast furnace and converter, a high proportion of crude steel will be produced in this mode. The main raw material of this production process is iron ore. Compared with the production process of scrap steel and electric furnace that uses scrap steel as the main raw material, the production process of blast furnace and the converter will not only cause steel production in China to rely heavily on the international iron ore market but also will the environmental problems of high energy consumption and high pollution [8]. In addition, the energy structure of the steel industry in China is dominated by coal, which has become the main source of carbon emissions in the steel industry.

In response to the above problems, the steel industry can achieve industrial transformation and upgrading by controlling crude steel output, adjusting the industrial structure, promoting the research and development of energy-saving and emission-reduction technologies, carbon tax, and changing the energy structure model.

(1) Control crude steel output

It can be seen from the related research [6] that carbon dioxide emissions are strongly related to the output of crude steel. Therefore, it is necessary to control crude steel production to achieve the carbon peaking target. On the one hand, high-quality ecological steel products should be developed. And on the other hand, the export of primary products such as low-value-added steel and pig iron should be restricted to achieve total control over crude steel production.

(2) Speed up the adjustment of the industrial structure of the steel industry

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By changing from the high energy consumption and high pollution production process of blast furnaces and converters to the production process of scrap steel and electric furnace using scrap steel as raw material, it will help to achieve energy savings and emission reduction. To achieve this goal, it is necessary to reduce the output of crude steel, adjust the flow of the steelmaking process, and further increase the recycling of scrap steel resources. At the same time, we will eliminate outdated production process equipment and technical equipment with high energy consumption.

(3) Strengthen the research and development of energy-saving and emission-reduction technologies

At present, technical research and development related to hydrogen metallurgy have been conducted. At the same time, this technology can also be combined with carbon dioxide storage and capture technology to improve the carbon emission reduction potential of the steel industry. Improving and developing low-carbon technologies with independent intellectual property rights and strengthening the demonstration role of relatively mature low-carbon technologies in the industry will help promote the research and development and application of energy-saving and emission-reduction technologies.

(4) Imposing a carbon tax.

Using market-based means to control carbon emissions is an important means to achieve energy conservation, emission reduction, transformation and upgrading in the iron and steel industry. By levying a carbon tax on the export trade of primary products such as steel and pig iron, the total amount of crude steel output can be controlled. At the same time, the implementation of carbon tax transactions by industry and the collection of carbon taxes by stages, products and manufacturing processes are favorable levers to achieve low carbon emissions in the steel industry [9].

(5) Change the energy structure model.

Improving energy efficiency is the core content of the transformation of the energy structure of the steel industry. Using coal as the main energy source for blast furnace ironmaking has become a major problem in the iron and steel industry that emits a large amount of carbon dioxide. Therefore, the steel industry needs to reduce coal consumption and improve renewable energy utilization technology. In addition, promoting the coupling of the development of the steel industry with other industries can also be used to improve energy efficiency levels. For example, the use of steel slag to make cement can realize the coupling of steel and building materials; the industrial tail gas of steel smelting can be used as a resource to separate the raw materials (CO, H2, etc.) required for the production of the petrochemical industry. The substitution role of non-fossil energy cannot be ignored. Accelerating the application of non-fossil energy and improving its substitution role for fossil energy is an important measure to achieve energy conservation and emission reduction.

3.2. Cement Industry

Because cement production needs to consume a large amount of lime and clay raw materials, the production of the cement industry is characterized by a strong dependence on mineral resources. Carbon dioxide emissions from cement production can be divided into two types: direct emissions and indirect emissions. The direct emissions mainly come from the carbon dioxide generated by the decomposition of silicate during the cement raw material processing, and the carbon dioxide emitted from the fuel combustion to provide high temperature during the cement processing. Indirect emissions mainly refer to the comprehensive power consumption of various production equipment in the cement production process. Studies have shown that [10], the carbon dioxide emissions from raw material processing and fuel combustion in cement production account for 50% and 46% of the carbon emissions in the cement production process, respectively, and the carbon dioxide emissions from indirect

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power consumption only account for 4%. It can be seen that direct emission is the main source of carbon emission in the cement industry, and it is also the main direction and focus of emission reduction. At present, carbon dioxide emission reduction in the cement industry can be achieved by reducing both direct and indirect emissions.

(1) Use alternative raw materials.

In terms of raw material usage, the cement industry can reduce carbon emissions by using alternative raw materials. For example, calcium raw materials such as carbide slag are used to replace calcareous raw materials that generate carbon dioxide when decomposed; the amount of mixed materials is increased in the clinker to reduce the use of clinker. In terms of fuel usage, alternative fuels such as biomass fuels can be used to replace fossil fuels, thereby reducing carbon dioxide generated during the combustion of fuels.

(2) Develop low-calcium cement varieties.

In the 1970s, National Building Materials Research Institute in China successfully developed sulfoaluminate, and the use of sulfoaluminate cement to replace Portland cement will reduce the calcium oxide content in the clinker, thereby reducing the carbon dioxide produced by the decomposition of limestone. In addition, since the calcination temperature required for calcining cement from sulfoaluminate is lower than that of silicate, energy consumption and carbon dioxide emissions can be significantly reduced.

(3) Adjust the technical structure.

The traditional cement production process mainly uses the shaft kiln, wet kiln, Liboer kiln, hollow dry kiln and other calcination equipment to make cement. The traditional production process has high energy consumption, low energy utilization rate, and high carbon emission. At present, there are new dry process production technologies with low energy consumption, good product quality, and high labor productivity in China. Therefore, it is the only way for energy conservation, emission reduction, transformation and upgrading of the cement industry to eliminate the backward cement production process and equipment and replace them with a new dry process.

(4) Low-temperature waste heat power generation reduces comprehensive power consumption.

The indirect emissions of carbon dioxide from the electricity consumed by various production equipment during cement production are also of concern. Using waste heat to generate electricity is an effective way to reduce power consumption. Waste heat power generation is the introduction of medium and low-temperature waste gas discharged from main equipment such as coolers and preheaters in the cement production process into a steam boiler for power generation [11]. Since the use of waste heat power generation does not require burning coal or transmitting electricity from the outside, it can reduce carbon dioxide emissions and help the cement industry save energy and reduce emissions.

3.3. Coal Chemical Industry

Coal, as the main energy source, occupies an important strategic position in my country's industrial production. At present, the coal chemical industry in China is showing the development status of gradually increasing industrial scale, improving production and operation level, leading comprehensive technology level, and improving security level [12]. However, as a manufacturing industry with coal as the main energy source, the coal chemical industry is also facing problems such as high pollution and high energy consumption, which has become the main focus of energy conservation and emission reduction. In addition to energy consumption and pollution problems, the coal chemical industry itself also has challenges such as a single product structure and the need for breakthroughs in production technology.

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Carbon dioxide emissions from the coal chemical industry are mainly from process emissions and coal-fired emissions from boilers in self-provided power plants. The process of washing methanol at low temperatures will produce high concentrations of carbon dioxide emissions, and the coal-fired boilers that provide steam and required electricity for the entire plant will also produce carbon emissions. Through the analysis of carbon emission sources, it can be found that the modern coal chemical industry should reduce carbon emissions from two paths: process emission reduction and combustion emission reduction.

(1) Improve product structure.

The four major industries of the modern coal chemical industry are coal-to-oil, natural gas, olefin, and ethylene glycol. Since coal has more carbon and less hydrogen, and the synthetic gas produced has a higher proportion of hydrogen, in the production process, the excess carbon is converted into carbon dioxide and discharged. Therefore, one of the major measures to reduce process emissions is to reduce carbon emissions by changing the proportion of carbon and hydrogen in the product. Some studies have pointed out [13] that the coal chemical industry is more suitable for the production of oxygenated compounds and carbon fiber products, and the production of products such as methanol and ethylene glycol will be more conducive to reducing carbon emission intensity.

(2) Coupling with new energy hydrogen production.

In addition to changing the product structure, process emission reduction can also improve the utilization rate of carbon in coal by increasing the proportion of hydrogen, thereby reducing carbon emissions. At present, hydrogen production from green electricity, such as hydropower, wind power, photovoltaic power generation, etc., can be used to produce hydrogen by green electricity hydrolysis. The proportion of carbon and hydrogen is reduced, and the carbon emissions generated in the process flow are also reduced.

(3) Combustion emission reduction.

The main function of the self-contained power plant in the coal chemical industry is to provide steam and required electricity for the whole plant. Captive power plants mainly generate electricity by burning coal in boilers, producing a large amount of carbon dioxide. Therefore, for the electricity required in the production process, green electricity can be purchased from new energy power generation; for the production process that can be driven by electricity instead of steam, electricity should also be used as much as possible to reduce coal-fired power generation in self-provided power plants.

(4) Speed up technological innovation.

Coupling with new energy for hydrogen production and using an electric drive instead of a steam drive are both important innovative processes in the coal chemical industry. Accelerating the implementation of innovative processes can help reduce carbon emissions at the source. In addition, accelerating the research and development and application of carbon capture and storage technologies is also an important measure for energy conservation and emission reduction.

4. Policy Recommendations

On the whole, at the macro level, the transformation and upgrading of the high-energy-consuming manufacturing industry involve the carbon emission reduction responsibilities of different industries and regions, the construction of a carbon evaluation system, the construction of a carbon emission reduction testing standard system, and the improvement of the carbon emission rights trading market. and many other issues. The technological processes of the high-energy-consuming manufacturing industries represented by the iron and steel industry, cement industry, and coal chemical industry are all characterized by high energy

consumption and high carbon emissions. To sum up, this paper proposes relevant policy recommendations from the following aspects:

1. Improve the carbon emissions trading system and give full play to the role of the carbon emissions trading market

Give full play to the role of the market mechanism, increase the production costs of high-carbon emission and high-energy-consuming manufacturing industries in the market by formulating appropriate carbon pricing and carbon quota systems, and stimulate such enterprises to carry out energy conservation and emission reduction through technological innovation and reduction of energy consumption. , but also better protect and promote the development of those enterprises with low energy consumption and low carbon emission, so as to realize the industrial structure transformation of high energy consumption manufacturing industry.

2. Establish a scientific and objective carbon emission standard measurement system, and speed up the construction and improvement of the carbon evaluation system

To achieve carbon emission reduction, it is necessary to accurately locate the source of carbon emissions. The main carbon emissions of some high-carbon manufacturing industries come from their energy-intensive processes. The carbon emissions in some regions mainly come from some high energy consumption that needs to be paid attention to. Therefore, scientific and objective carbon emission measurement standards are crucial for accurately locating the source of carbon and carbon emissions and rationally distributing carbon emission reduction responsibilities.

3. Change the energy structure and speed up the development and use of new energy.

At present, high-energy-consuming manufacturing industries such as the steel industry, cement industry and coal chemical industry all have problems such as combustion and carbon emission. For example, the blast furnace-converter production process in the iron and steel industry burns more coal, which results in higher carbon dioxide emissions; similarly, the cement industry emits carbon from fuel combustion; and the coal chemical industry emits carbon from coal-fired boilers. Therefore, the application of non-fossil energy and the use of green electricity has become an important transformation direction for high-energy-consuming manufacturing industries.

4. Eliminate outdated production processes and accelerate technological innovation.

In addition to the problems of energy structure, the backward production process of energy-intensive manufacturing is also an important reason for its high carbon emissions. Compared with the scrap-electric furnace production process, the blast furnace-converter process in the iron and steel industry has higher carbon emissions; the traditional production process in the cement industry has low energy utilization and high energy consumption; the low-temperature methanol washing process in the coal chemical industry will produce relatively high concentrations of carbon dioxide. Therefore, eliminating outdated production processes and realizing technological innovation in energy-saving and emission-reduction technologies has also become a key factor and important link for energy-saving emission reduction and transformation and upgrading of high-energy-consuming manufacturing industries.

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