

# Green Transformation of Hainan's Manufacturing Industry Addressing Market Distortions in the Energy Sector

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**Abstract:** This paper examines the market distortions in the energy sector of Hainan Province, China, and their impact on the green transformation of its manufacturing industry. We analyze the existing market distortions in energy factors, including improper allocation of energy resources, distorted energy prices, energy subsidy policies, inadequate energy efficiency management, and imperfect regulations and supervision mechanisms. We also discuss the specific impact of these market distortions on innovation efficiency, natural resource endowment, energy price distortion, energy subsidy policies, energy efficiency management, environmental protection, ecosystem impact, talent training, technological innovation, international competitiveness, and social and economic benefits. Finally, we provide policy recommendations to address these challenges and promote the green transformation of Hainan's manufacturing industry.

## 1. Introduction

### 1.1. Research Background

The global industrialization process has significantly increased greenhouse gas emissions, leading to climate change and more frequent extreme weather events. According to the Intergovernmental Panel on Climate Change (IPCC), if effective measures are not taken, the global average temperature could rise by 3-4 degrees Celsius by 2100, which would have profound impacts on human society and natural ecosystems.

Under the Paris Agreement framework, the Chinese government has committed to peak carbon emissions by 2030 and achieve carbon neutrality by 2060. To achieve these goals, the government is actively promoting green transitions across various industries, implementing policies and measures to encourage the development and use of clean energy, and promoting industrial energy saving and emission reduction.

Hainan Province, located in the South China Sea, possesses abundant solar, wind, and biomass energy resources, providing a solid foundation for developing green energy. The construction of the Hainan Free Trade Port offers policy support and development opportunities for the manufacturing sector's green transition. Despite these resources, Hainan still heavily relies on traditional fossil fuels, with a relatively singular energy structure and low energy utilization efficiency. There is also significant room for improvement in energy use and environmental protection within the manufacturing industry.

### 1.2. Research Significance

This study provides an in-depth analysis of the current state and distortions in Hainan's energy factor market, enriching existing literature on energy market distortions and offering new perspectives for future research. By examining the practical aspects of the green transition in Hainan's manufacturing industry, this paper explores policy, technology, and management factors, further refining the theoretical framework for green transitions, and offering valuable insights for academia and policymakers.

The analysis of energy market distortions in Hainan provides a basis for the government and relevant departments to formulate effective energy policies. Specific recommendations include optimizing energy subsidy policies, promoting energy price marketization, and enhancing energy efficiency management. Additionally, this paper guides manufacturing enterprises in identifying and addressing energy market distortions, helping them optimize energy management, improve energy efficiency, and promote the application and adoption of green technologies for sustainable development.

By correcting energy market distortions, this study helps reduce energy waste and pollution, improve ecological environmental quality, and drive the green transition of Hainan's manufacturing industry. Green transition is crucial for achieving sustainable economic, social, and environmental development. This study supports this goal by providing theoretical and practical guidance, contributing to Hainan's high-quality development.

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### 1.3. Research Methods

This study employs a combination of literature review, data analysis, and case studies to systematically analyze the distortions in Hainan's energy market and their impact on the green transition of the manufacturing industry.

Not only review relevant domestic and international literature to summarize the theoretical basis and current research on energy market distortions, clarifying the research questions and framework. But also collect and analyze data on energy use, energy prices, and subsidy policies in Hainan's manufacturing sector to identify specific manifestations and causes of energy market distortions. Finally, select typical enterprises and projects to deeply analyze their practices and challenges in energy use and green transition, summarizing successful experiences and shortcomings.

## 2. Analysis of the existing market distortion of energy factors in Hainan Province

### 2.1 Improper allocation of energy resources

The unreasonable allocation of energy resources is one of the main manifestations of market distortion in the field of energy in Hainan Province.

Some tertiary industries, which rely too much on environmental resources, and it get more energy supplies due to historical reasons or preferential policies. For example, some luxury hotels or resorts like the Sanya EDITION, consume a considerable amount of energy to offer high-quality service and project an image of affluence. [1]. The Fig.1. show the proportion of the three major industries in GDP of Hainan Province, and the change. Hainan's tertiary industry has developed rapidly, some of which have a large demand for energy, and long-term dependence on the energy-intensive tertiary industry is not conducive to the green transformation and development of Hainan.

New green industries and small and medium-sized enterprises face energy shortages and do not have access to energy supplies commensurate with their needs. This unbalanced allocation of resources leads to the expansion of the living space of high-energy-consuming and low-efficiency enterprises, while the development of green and low-carbon industries is limited, forming a structural obstacle that is not conducive to green transformation [2].

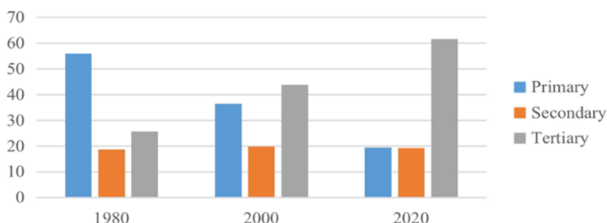


Fig. 1. Composition of Industry Sector Proportion of GDP (%)

There is also an imbalance in the allocation of energy resources in different regions of Hainan Province. More

economically developed regions may have access to more energy supplies, while less developed regions face energy shortages [3]. This regional imbalance has hindered the adjustment of industrial structure and the process of green transformation across the province, affecting the coordinated development of the overall economy.

### 2.2 Distorted energy prices

The distortion of energy price formation mechanism is one of the important factors affecting the green transformation of Hainan Province. Energy prices do not effectively reflect the relationship between supply and demand in the market.

The Hainan provincial government intervenes frequently in energy prices, especially in the fields of electricity and natural gas. As a result of such intervention, energy prices cannot truly reflect the market supply and demand relationship, and enterprises' decision-making on energy use is distorted [4]. For example, in order to ensure social stability and economic growth, the government may provide price subsidies to some high-energy-consuming enterprises to reduce their production costs. Although this subsidy policy is conducive to the survival and development of enterprises in the short term, in the long run, it will lead to the waste of resources and the decline of market competitiveness, which is not conducive to the realization of green transformation.

Due to excessive government intervention, the market cannot effectively regulate the relationship between energy supply and demand through price signals, and enterprises have uncertain expectations of energy prices, which makes it difficult to make long-term production and investment decisions. This failure of market signals has inhibited the enthusiasm of enterprises in energy conservation, emission reduction and green technology application, affecting the green transformation process of the overall economy.

However, if the government only makes a small amount of reasonable intervention, Hainan's green development still has great potential. According to the prediction of the Danish Energy Agency [5] (see Fig.2.), if the Hainan Provincial government pushes forward the construction of Hainan Clean Energy Island (CEI), It can greatly reduce the consumption of non-renewable energy and promote the green transformation development of Hainan.

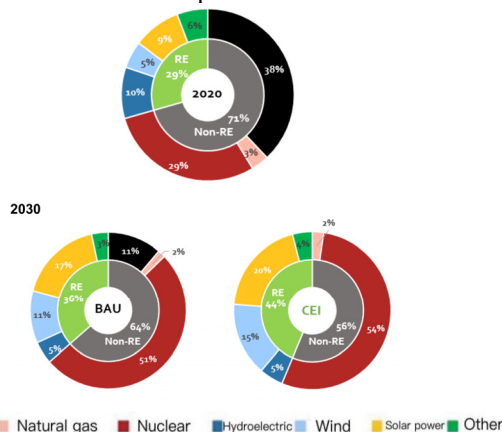


Fig. 2. The composition of power generation energy of Hainan Province in 2020 and the power generation energy situation of conventional development (BAU) and clean energy island (CEI) in 2030 respectively.

## 2.3 Energy subsidy policy

Excessive subsidies for traditional energy sources. Although Hainan Province has put forward the strategic goal of green development, in practice, subsidies to the traditional energy industry are still relatively large [6]. For example, in order to maintain the competitiveness of traditional energy-consuming industries, the government may provide policy support such as preferential electricity prices and tax breaks. Such subsidy policy leads to the reduction of the cost of traditional energy-consuming enterprises, reduces their incentive to carry out green technology transformation, and inhibits the market share expansion of new energy and renewable energy [7].

Compared with traditional energy, new energy and renewable energy subsidies are obviously insufficient. Although the government has proposed the goal of supporting the development of new energy at the policy level, in the specific implementation, the subsidy policies faced by new energy enterprises are relatively few, and the subsidy amount is also low. This imbalance in policy orientation has led to new energy enterprises being at a disadvantage in market competition, which is not conducive to the development and growth of the new energy industry.

## 2.4 Inadequate energy efficiency management

Some enterprises in Hainan Province lack effective management and technical means in energy use, which leads to low efficiency in energy use. These enterprises often lack scientific planning and control in energy consumption, and energy waste is serious. For example, due to the lack of financial and technical support, some small and medium-sized enterprises have insufficient investment in energy conservation and emission reduction, resulting in low energy efficiency [8].

Although the Hainan provincial government encourages enterprises to adopt energy-saving and emission-reduction technologies at the policy level, there are still obstacles to the promotion and application of these technologies in practice. For example, enterprises face high costs in the introduction and application of advanced energy-saving technologies, and the government's subsidies and support policies are not in place, resulting in a low penetration rate of energy-saving technologies, and it is difficult to improve the overall energy efficiency. As a tourism-based enterprise, many high-end hotels in Hainan Province do not pay attention to environmental protection and still adopt many energy-intensive designs in their buildings [9]. In addition, the air transport industry is under great pressure to reduce carbon emissions, but there are no clear measures to promote the green and low-carbon development of aviation in Hainan, resulting in a large number of inefficient and energy-intensive phenomena in the air transport industry [10].

## 2.5 Imperfect regulations and supervision mechanism

In the process of promoting green transformation in Hainan Province, the relevant laws and regulations and supervision mechanism are not perfect. On the one hand, although Hainan has formulated some regulations and policies in promoting green transformation, the overall legal system is still not sound enough, and lacks systematization and continuity. For example, in terms of energy use and environmental protection, relevant laws and regulations are not perfect, and enterprises have policy gaps and implementation difficulties in actual operation. In addition, the existing supervision mechanism is difficult to effectively supervise and manage the energy use and environmental protection behavior of enterprises. For example, the environmental protection department has insufficient human and material resources in monitoring corporate emissions and energy use, which makes it difficult to detect and deal with corporate violations in a timely manner. This loophole in supervision allows some enterprises to evade their environmental responsibility and continue to carry out production activities with high energy consumption and high pollution.

## 3. The impact of market distortions on innovation efficiency in the energy sector

### 3.1 The impact of unreasonable allocation of energy resources on innovation efficiency

High energy-consuming enterprises have access to relatively cheap and abundant energy supplies, so there is no urgent need for technological improvement and innovation in the short term. This reliance on existing cost advantages makes companies lack the incentive to pursue energy efficiency improvements and environmentally friendly technological innovation, resulting in a slow pace of technological progress in the industry as a whole.

The unreasonable allocation of energy resources makes the operation environment of high energy-consuming enterprises relatively stable, and this stability reduces the willingness of enterprise management to take risks in innovation. Enterprises are more inclined to maintain existing production models rather than explore and adopt new technologies, which inhibits the occurrence of innovative activities [11].

### 3.2 The impact of energy price distortions on innovation efficiency

Energy price distortions cause prices to fail to truly reflect market supply and demand, making it impossible for companies to adjust their energy use and innovation strategies according to market signals. The ambiguity of price signals makes it difficult for firms to sense and respond to changes in market demand, impeding the incentive to improve energy efficiency through innovation [12]. At the same time, the administrative intervention in

energy prices has led to the non-marketization of energy prices, and the energy costs faced by enterprises are not transparent and unpredictable. This pricing distortion makes it difficult for companies to develop long-term innovation strategies, especially when it comes to the development and application of energy-intensive technologies, adding uncertainty to corporate decision-making.

Due to insufficient market competition, enterprises lack a sense of urgency in energy utilization to reduce costs through technological innovation. The distortion of energy prices makes the return on investment to reduce costs by improving energy efficiency or developing alternative energy sources lower, companies invest insufficient capital and resources in innovation, and overall innovation efficiency decreases. Also, distortions in energy prices have weakened demand for energy-efficient technologies. In the context of low energy prices, enterprises and consumers lack economic incentives to adopt energy-efficient technologies, and the market demand for these technologies is insufficient, which in turn inhibits the innovation and promotion of related technologies [13].

### 3.3 The impact of energy subsidy policies on innovation efficiency

The mismatch of subsidies is a major cause of stifling innovation. Subsidy policies for traditional energy-intensive industries have enabled these industries to have sustained economic advantages and strengthened their path dependence on existing technologies and production modes. Subsidy mismatch not only makes these industries lack the motivation for green technology innovation, but also causes them to form resistance to emerging green technologies in the market competition, affecting the overall innovation ecology.

New and renewable energy companies receive relatively few subsidies, resulting in greater financial pressure on research and development and innovation. This funding bottleneck restricts these enterprises from carrying out large-scale technology research and development and marketing, and slows down the innovation process of new energy technologies. The imbalance of subsidy policies makes new energy enterprises at a disadvantage in market competition, and it is difficult to compete with traditional energy enterprises that enjoy high subsidies. As the Fig.3. show that the relationship between market distortion, profit and innovation efficiency. Market entry barriers increase the operational risks of new energy enterprises and reduce their enthusiasm and investment in innovation [14].

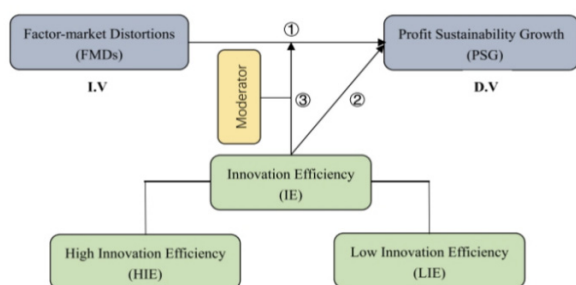


Fig. 3. The relationship between market distortion, profit and innovation efficiency

### 3.4 The impact of energy efficiency management on innovation efficiency

The lack of energy efficiency management ability and experience leads to a serious waste of energy use in enterprises. The waste of resources not only increases the operating cost of enterprises, but also reduces the funds and resources available for innovation, which affects the overall innovation capability and efficiency [15]. At the same time, enterprises lack a scientific energy management system, resulting in low energy efficiency. The lack of management system makes the introduction and application of energy-saving technology limited, and can not make full use of existing technical resources for innovation.

Due to the lack of effective energy efficiency management, the high cost of energy utilization by enterprises limits their investment in innovation. Companies have to devote more resources to maintaining basic operations, while reducing capital investment in the development and application of new technologies, resulting in a decline in innovation efficiency. The shortcomings in energy management limit the promotion and application of energy-saving technologies and slow down the diffusion of technologies. The lack of effective technical exchange and cooperation among enterprises hinders the improvement of the overall innovation level and the realization of technological progress [16].

### 3.5 The impact of imperfect regulations and supervision mechanism on innovation efficiency

Regulations and supervision mechanisms are not perfect, making the cost of violations in energy use and environmental protection low. According to the Wang [17], the weak regulatory mechanism leads to insufficient enforcement of laws and regulations on environmental protection and energy use. Enterprises will evade supervision and continue to carry out production activities with high energy consumption and high pollution in the face of low-risk illegal environment, and lack pressure and motivation to carry out green technology innovation, resulting in innovation slack. This lack of enforcement has left companies without external pressure to make technological improvements and innovations.

## 4. The specific impact on the green transformation of Hainan manufacturing industry

### 4.1 Natural resource endowment

As an island province, Hainan is relatively short of energy resources and low self-sufficiency rate. Although there are some mineral resources, the majority of energy is dependent on external imports, which leads to the instability of energy supplies, increases energy costs and further aggravates the distortion of energy markets. High energy costs make enterprises face greater financial pressure in the process of green transformation.

In addition, Hainan has abundant solar energy and wind energy resources, which are sufficient to meet the energy demand of Hainan Island [18]. However, due to the unreasonable allocation of energy resources, these renewable energy potentials have not been fully developed and utilized. As a result, the proportion of new energy in the energy market is low, unable to provide adequate supply, resulting in the slow progress of new energy projects, restricting the process of green transformation of the manufacturing industry.

According to Tab.1., the industry in Hainan is mainly concentrated in specific areas, such as Haikou and Sanya. From the chart of economic development of major cities in Hainan Province, it can be seen that the economic conditions of Haikou and Sanya are significantly better than those of other cities. It reflects the aggregation of Hainan economy.

The energy demand in these regions is large, which easily leads to the unbalanced distribution of energy resources, which further aggravates the distortion in the energy market. High-energy-consuming enterprises occupy an advantage in the allocation of energy resources, while the green industry is difficult to obtain sufficient resource support, which affects the optimization of the overall industrial structure and green transformation. Moreover, due to the concentration of resources in traditional industries, the green industry faces the disadvantage of resource competition in the early stage of development [19]. The government fails to fully consider the needs of green industries in resource allocation, resulting in these enterprises facing many difficulties in energy acquisition, technology research and development and marketing, and the progress of green transformation is slow.

City	Gross Domestic Product (RMB bn)	Per Capita GDP (RMB)	Operating Income of Industry (RMB bn)	Retail Sales (RMB bn)	Exports (RMB bn)
Haikou	205.7	72,218 <sup>2</sup>	64	105.7	11.05
Sanya	83.5	87,105 <sup>2</sup>	9.74	54.5	1.23
Wenchang	30.9	54,570 <sup>2</sup>	5.96	10	0.54
Danzhou Area	39.5	61,441 <sup>2</sup>	98.55 <sup>2</sup>	11.5	0.02

**Tab.1.** Economic Indicators of major cities

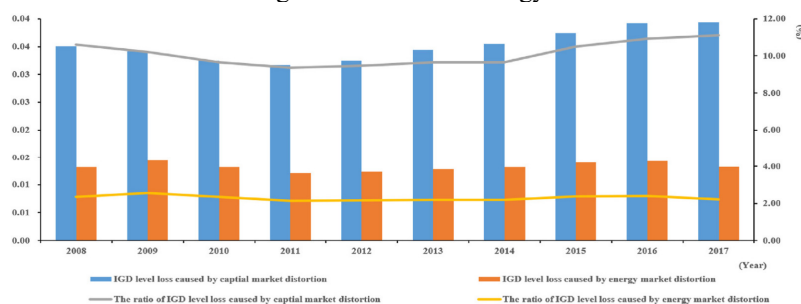
#### 4.2 The impact of energy price distortion on green transition

The distorted energy price mechanism in the field of production is manifested as the average price of traditional energy is lower than the price of green new energy. While this pricing mechanism contributes to economic growth in

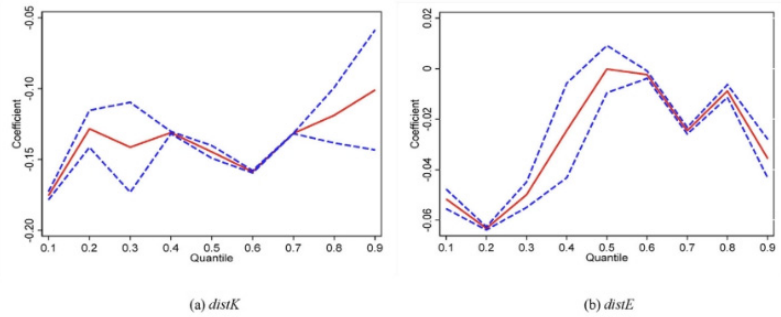
the short term, in the long run it discourages companies from promoting energy efficiency and green technology innovation. High energy consuming enterprises enjoy low energy prices and continue to rely on traditional high energy consumption production methods, which hinders the green transformation of manufacturing industry [20]. In contrast, new energy enterprises are at a price disadvantage in market competition. Due to the low price of traditional energy, the economic benefits of new energy projects are relatively poor, and it is difficult to attract enough investment and users. The distortion of the energy market caused by the distortion of the price mechanism will cause new energy enterprises to face greater market pressure when promoting green technologies and products, which will have a blocking effect in the green transformation of the manufacturing industry.

Distortions in energy prices make it difficult for companies to sense energy scarcity and environmental costs through price signals. Especially in areas such as Hainan, where energy depends on external input, the failure of price signals is more likely to lead to disorderly and wasteful energy use by enterprises, ignoring the necessity of green transformation. Low energy prices not only influence corporate decisions, but also mislead consumer behavior [21]. In the face of low-cost traditional energy, consumers lack the economic impetus to adopt energy-saving and renewable energy technologies, affecting the market demand for green technologies and products, increasing the awareness of the adoption of environmental protection and green energy among the broad masses of people, thus restricting the overall promotion of green transformation [22].

According to Fig.4. Industrial Green Development level (IGD level), we can find that the distortion of capital market and energy market has a significant inhibitory effect on IGD level, that is, the distortion of capital and energy market will significantly have a negative impact on green development. As the quantitative analysis of Fig.5. shows that the inhibitory effect of capital and energy market distortions is significantly heterogeneous and asymmetrical between quantiles, and increased investment in research and development and pollution control will weaken the inhibitory effect. For Hainan to achieve a green and low-carbon transition, capital market mechanisms must be optimized to reduce distortions in investment in clean energy and green technologies, while energy market reform is also crucial to ensure that energy allocation is more efficient and less polluting. This will help Hainan's manufacturing industry better achieve green transformation and overcome the dual obstacles of capital and energy markets.



**Fig. 4.** The evolution trend of IGD level (IGD: Industrial green development)



**Fig. 5.** Change in panel quantile regression coefficients of *distK* and *distE*. (Note: Dotted line correspond to 95% confidence intervals of quantile estimation.)

### 4.3 The impact of energy efficiency management on green transition

Many enterprises in Hainan lack systematic planning and scientific management system in energy management, resulting in low efficiency in energy utilization. The imperfect energy management system makes it difficult for enterprises to fully grasp and optimize the use of energy, and energy waste is widespread, which increases the operating costs of enterprises and affects the process of green transformation. The lack of advanced energy management technologies and means makes enterprises face many obstacles in the introduction and application of energy-saving technologies [23]. The limitation of technology application makes it impossible for enterprises to make full use of existing technology resources to carry out green transformation, which restricts the promotion and application of energy-saving technology.

Due to inadequate energy efficiency management, the high cost of energy utilization limits enterprises' investment in green technologies. High energy costs have forced companies to devote more resources to maintaining basic operations, reducing capital investment in the development and application of green technologies, and affecting the speed of green transition. The shortcomings of the energy management system lead to a lack of innovation resources, and it is difficult for enterprises to carry out large-scale green technology research and development and application. The lack of innovation resources makes it difficult for green technology to be widely used in the market, which affects the green transformation of manufacturing industry.

### 4.4 Environmental protection and ecosystem impact

Due to distortions in the energy market, high energy-consuming enterprises enjoy advantages such as price in energy use, making them continue to rely on highly polluting traditional energy sources. This situation has led to an increase in pollutant emissions, negatively affecting Hainan's air quality, water resources and soil, and damaging the local ecosystem. Market distortion in the energy field has hindered the development of green technologies and clean energy, resulting in insufficient motivation for enterprises to apply energy conservation, emission reduction and environmental protection technologies. The lag of green transformation makes it

difficult to effectively implement environmental protection measures, which further aggravates the deterioration of the ecological environment [24].

While enjoying the competitive advantage brought by the distortion of the energy market, the traditional high energy-consuming enterprises have excessively consumed the limited energy resources, resulting in the increased risk of resource exhaustion. Such unsustainable energy use runs counter to the goal of green transformation and affects the strategic layout of Hainan's sustainable development. In addition, pollution and ecological damage from energy development and use have affected Hainan's ecosystem services, including soil and water conservation, biodiversity and climate regulation[25]. The decline of ecosystem services not only has a negative impact on environmental protection, but also limits Hainan's competitiveness in green development.

### 4.5 Impact of social and economic benefits

Market distortions in the energy sector continue to dominate energy-intensive industries, limiting the development of green and high-tech industries. The backward upgrading of industrial structure not only affects the quality and efficiency of economic development, but also limits the position of Hainan in the national economic pattern. Distortions in the energy market have led to an economic growth mode that relies on traditional energy sources, hindering the diversity of innovation-driven and green development, and affecting the sustainable development of Hainan's economy. The single mode of economic growth makes Hainan's manufacturing industry less resistant to global economic changes.

Because the more traditional energy-consuming manufacturing industry in the energy field still occupies a dominant position in social production, it can provide a large number of employment opportunities, thus achieving significant advantages in social resources and labor resources. In contrast, due to the disadvantageous position in the field of energy competition, green enterprises are smaller in scale, can accept a smaller scale of labor force, and need a higher quality of workers [26]. In contrast, in order to meet the employment needs of the people, it is necessary to retain enterprises that can absorb more employment, so it is impossible to carry out in-depth reform and optimization adjustment of traditional enterprises in the production field of high energy consumption, and ultimately hinder the process of green transformation of Hainan's manufacturing industry.

## 5. Specific policy suggestions

### 5.1 Optimize the allocation of energy resources

Through the government financial allocation and social capital cooperation model, funds are raised to establish a special fund for green energy, focusing on supporting renewable energy projects, green technology research and development and application, and promoting the optimization of the energy structure. Studies have shown that increasing technology endowments can reduce energy emissions and thus promote green development.

According to Fig.6, technological progress can reduce emissions through substitution effects, but it can also have a rebound effect through budget effects, increasing emissions. Thus, while technological advances have important potential to reduce emissions, their specific effects depend on the balance between substitution effects and budgetary effects. Therefore, we must find a balance between the two, in order to better promote the green transformation and development of Hainan. So government must focus on supporting the development and technological innovation of renewable energy projects such as solar energy, wind energy and ocean energy, especially ocean energy projects that meet the geographical characteristics of Hainan. For example, the advantages of energy synergy and complementarity of wind and wave power generation combined power generation should be fully utilized, so as to further promote the development of renewable environmental protection energy and promote the green transformation in the energy field [27]. At the same time, local enterprises and scientific research institutions are encouraged to cooperate to promote the research and development and industrialization of green technologies [28].

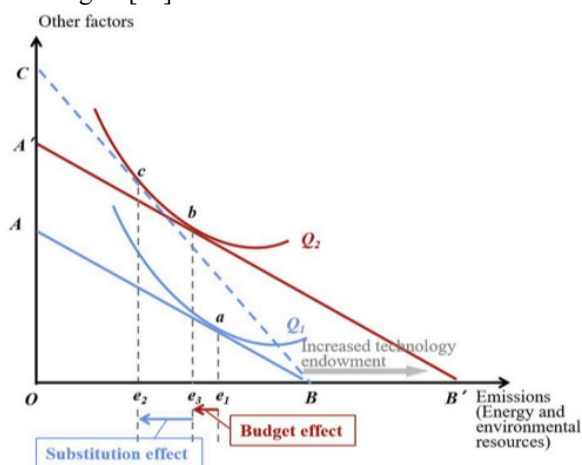


Fig. 6. The impact of increased technology endowment on emissions.

Encourage the construction of diversified energy supply channels, reduce dependence on external energy, improve energy security and supply stability, and thus promote the development of zero-carbon production industry in Hainan Province [29]. The government has introduced policies to support diversified energy projects, such as providing tax incentives and preferential land use policies to attract enterprises to invest in solar, wind and

ocean energy projects. Increase investment in the construction of modern energy infrastructure, such as smart grids, energy storage systems, etc., to improve the efficiency and stability of the energy system and ensure the stable supply of renewable energy [30]. The introduction of advanced energy storage technology at home and abroad, improve the storage and utilization efficiency of renewable energy, solve the problem of renewable energy intermittency, and ensure the continuity and stability of energy supply.

### 5.2 Improve the policy of encouraging new energy and renewable energy

We will increase financial subsidies for renewable energy projects, reduce their initial investment and operating costs, and promote the development of green energy. Formulate clear subsidy standards and application procedures to ensure the fairness and effectiveness of subsidies [31]. Eligible renewable energy projects are given initial investment and operation subsidies to reduce the financial pressure on enterprises. Set up a special subsidy examination and approval agency, simplify the examination and approval process, and improve the examination and approval efficiency. It accepts subsidy applications through an online platform and provides one-stop services to facilitate enterprises to apply for and obtain subsidies. Finally, it is necessary to establish a supervision and evaluation mechanism for the use of subsidies to ensure the transparency and effectiveness of the use of subsidy funds. Regularly evaluate the effect of subsidy policies, adjust and optimize according to the actual situation.

For enterprises that have made outstanding achievements in the research, development and application of green technologies, a special incentive fund will be set up to provide financial support and tax incentives. Establish a review mechanism for enterprise green technology innovation, and regularly select excellent projects and enterprises. Evaluation criteria should include technological innovation, market prospects, environmental benefits and other factors to ensure the scientific and fair selection. Various forms of support will be provided to award-winning enterprises, including financial incentives, tax relief, and preferential access to government procurement. At the same time, more policies and resources will be given to innovative enterprises to support their further development [32]. At the same time, through media, exhibitions and other channels to promote award-winning enterprises and projects, establish a model of green technology innovation, and encourage more enterprises to participate in the development and application of green technology.

### 5.3 Strengthen energy efficiency management

Promote the application of advanced energy management technology, improve the energy utilization efficiency of enterprises, and reduce energy waste. Set up an energy management technology promotion center to provide technical training and consulting services to help

enterprises understand and master the latest energy management technologies and methods. Select a group of representative enterprises, implement advanced energy management technology demonstration projects, summarize and promote successful experience, and promote the energy management level of the whole industry. The government supports and encourages the introduction of advanced energy management technologies and equipment at home and abroad, and supports enterprises in upgrading. Through government procurement and preferential loans, the cost of introducing and applying advanced technologies will be reduced for enterprises.

#### **5.4 Improve regulations and supervision mechanism**

We will formulate and improve relevant laws and regulations on energy use and environmental protection, carry out environmental protection work on the track of the rule of law, clarify the responsibilities and obligations of enterprises, and increase penalties for violations. A special legislative revision committee has been set up to regularly evaluate and revise existing regulations to ensure that they are scientific and forward-looking. In particular, in terms of energy use and environmental protection standards, combined with international advanced experience, we will formulate high-standard regulations that meet the actual conditions of Hainan [33]. Strengthen the publicity and training of regulations, help enterprises and the public understand and master the relevant regulatory requirements, and enhance the enforcement and popularization of regulations. Establish an energy and environmental protection regulatory information system to monitor the energy use and emissions of enterprises in real time. Through big data and intelligent means, improve the real-time and accuracy of supervision. Increase law enforcement personnel and equipment, and enhance the professional quality and capacity of law enforcement teams. Regular law enforcement training and exchanges are carried out to improve the professional level and law enforcement skills of law enforcement personnel. Through various forms of publicity and training, improve the environmental protection awareness and law-abiding consciousness of enterprises and the public. Step up law enforcement to ensure strict implementation of regulations. Increase law enforcement personnel and equipment to improve law enforcement capacity and efficiency. Companies that violate regulations will be severely punished and publicly exposed to form a strong deterrent effect.

#### **5.5 Promote personnel training and technological innovation**

Cooperate with well-known universities and scientific research institutions at home and abroad to set up special scholarships and research funds to attract outstanding students and researchers to join the field of green technology. Establish a green technology research center and practice base to provide students with practical

opportunities to enhance their practical ability and innovation. Policies have been introduced to attract domestic and foreign green technology experts and high-end talents to work in Hainan. Provide preferential conditions such as housing and children's education, create a good working and living environment, and retain outstanding talents.

Build a green technology innovation platform, provide technical support and resource sharing for enterprises, and promote technological innovation and the transformation of achievements. Establish green technology incubators and innovation centers to provide research and development equipment, technical support and office space to help small and medium-sized enterprises and start-ups conduct technology research and innovation. Set up a special fund to support the research and development of green technology innovation projects. Through project funding, venture capital and other ways to help enterprises solve financial problems and accelerate the transformation of technological achievements. Green technology forums and seminars are held regularly to invite domestic and foreign experts and enterprises to participate and promote technological exchanges and cooperation. Promote the establishment of an international green technology cooperation network, introduce advanced technology and experience, and enhance the level of green technology innovation in Hainan.

### **6. Conclusion**

The distortion of energy market is the result of many factors. The main reasons include improper allocation of energy resources, price distortion, unreasonable subsidy policies, insufficient efficiency management and imperfect supervision mechanism. These problems lead to reduced innovation efficiency, unequal distribution of resources, environmental degradation and diminished international competitiveness.

Energy market distortion has a profound impact on the green transformation of Hainan's manufacturing industry. In response to these challenges, this paper puts forward specific policy suggestions such as optimizing the allocation of energy resources, reforming the energy price mechanism, adjusting subsidy policies, strengthening energy efficiency management, improving the supervision mechanism, and promoting personnel training and technological innovation. These policy recommendations, which take into account Hainan's geographical and economic characteristics, aim to address market distortions in the energy sector, promote the green transformation of Hainan's manufacturing sector and achieve sustainable development goals. With the joint efforts of the government, enterprises, scientific research institutions and all sectors of society, Hainan is expected to become a demonstration zone for green transformation and sustainable development, providing useful experience for the whole country and even the world.



## Acknowledgment

This research is supported by the Hainan Provincial Natural Science Foundation of China (No. 721RC527), the Social Science Research Fund of Hainan University, China (No. kyqd(sk)2103), and Hainan Provincial “The South China Sea Rising Star” Philosophy and Social Science Talent Platform Project.

## References

1. Zeng, Z., & Chen J. (2022). Can the construction of Hainan Free Trade Port transcend the stage of industrialization? *Journal of hainan university (humanities and social science edition)*, 40 (5), 98-106. <https://doi.org/10.15886/j.cnki.hnus.202201.0710>
2. HKTDC Research. (2022a.). Data and Profiles - Mainland China Provinces and Cities - Provinces Hainan: Market Profile. <https://research.hktdc.com/en/data-and-profiles/mcpc/provinces/hainan>
3. HKTDC Research. (2022b.). The Hainan Free Trade Port (3): Development Directions of Key Cities. <https://research.hktdc.com/en/data-and-profiles/mcpc/provinces/hainan>
4. Zhang J. (2016). Measurement, change mechanism and government intervention effect of factor allocative efficiency in China's manufacturing industry. *Journal of Statistical Research*, 33(3), 72-79.
5. Zhong, R., (2017). Research on factor price distortion in China's manufacturing industry: Empirical data from A-share manufacturing listed companies. *Science and technology and management*, 19 (3), 41-47. <https://doi.org/10.16315/j.stm.2017.03.007>
6. Lingchi, K., Bo, G., & Yanni, H. (2017). Provincial market opening, local government investment and manufacturing structure differences in China. *Caijing Yanjiu*, 43(07), 133-144. <https://doi.org/10.16538/j.cnki.jfe.2017.07.011>
7. Zhang, S., Luo, J., Huang, D., & Xu, J. (2023). Market distortion, factor misallocation, and efficiency loss in manufacturing enterprises. *Journal of Business Research*, 154, 113290. <https://doi.org/10.1016/j.jbusres.2022.08.054>
8. Li, J., & Li, M. (2022). Research of carbon emission reduction potentials in the Yellow River Basin, based on cluster analysis and the Logarithmic Mean Divisia Index (LMDI) method. *Sustainability*, 14(9), 5284. <https://doi.org/10.3390/su14095284>
9. Lu, S., Wei, S., Zhang, K., Kong, X., & Wu, W. (2013). Investigation and analysis on the energy consumption of starred hotel buildings in Hainan Province, the tropical region of China. *Energy Conversion and Management*, 75, 570-580. <https://doi.org/10.1016/j.enconman.2013.07.008>
10. Wu, G., Zhang, Z., Wang, Z., Miao, Q., Wang, N., Zhang, Y., Chang, S., & Jia, K., (2023). Green and Low-Carbon Development of Aviation Manufacturing Industry. *Zhongguo gong cheng ke xue (Online)*, 25(5), 157-164. <https://doi.org/10.15302/J-SSCAE-2023.05.008>
11. Daish Energy Agency (2020.). Hainan island of clean Energy power sector transformation path. The Chinese government. [https://m.sohu.com/a/499017784\\_121112996/?pvid=000115\\_3w\\_a](https://m.sohu.com/a/499017784_121112996/?pvid=000115_3w_a)
12. Zheng, Z., & Liu, Y. (2013). Empirical analysis of the effect of factor price distortion on R&D expenditure: Based on the panel of large and medium-sized industrial enterprises. *Social Scientist*, 7, 63-66.
13. Shi, J. (2021). Government Subsidies and innovation inputs: The moderating effects of property rights Nature and factor market distortions. *Journal of Suihua University*, 41(3), 13-15.
14. Qiao, S., Shen, T., Zhang, R. R., & Chen, H. H. (2021). The impact of various factor market distortions and innovation efficiencies on profit sustainable growth: From the view of China's renewable energy industry. *Energy Strategy Reviews*, 38, 100746-. <https://doi.org/10.1016/j.esr.2021.100746>
15. Fang, K., Hong, X., Li, S., Song, M., & Zhang, J. (2013). Choosing competitive industries in manufacturing of China under low-carbon economy: A Three-stage DEA analysis. *International Journal of Climate Change Strategies and Management*, 5(4), 431-444. <https://doi.org/10.1108/IJCCSM-09-2012-0054>
16. Liu, X., Feng, Q., Liu, Y., & Sun, T. (2023). Research on Comprehensive Performance Evaluation of High-Quality Development of China Provincial Manufacturing Industry Based on Low-Carbon Constraints. *Polish Journal of Environmental Studies*, 32(2), 1265-1276. <https://doi.org/10.15244/pjoes/156414>
17. Wang, R. (2020). The dynamic relationship between environmental regulation and green technology innovation: a reexamination of Porter's Hypothesis. *Science and technology management research*, 40 (8), 243-250. <https://doi.org/10.3969/j.issn.1000-7695.2020.8.031>
18. Bin, Y., Jie, T., & Qiang, L. (2012). Feasibility analysis of renewable energy powered tourism island—Hainan, China. *Journal of Renewable and Sustainable Energy*, 4(6). <https://doi.org/10.1063/1.4767836>
19. Shi, D., & Wang, T. (2015). Empirical analysis of the relationship between industrial structure adjustment and regional economic growth in Hainan Province. *South China Sea Journal*, 1(1), 29-35.
20. Chen, Y., Wong, C. W., Yang, R., & Miao, X. (2021). Optimal structure adjustment strategy, emission reduction potential and utilization efficiency of fossil energies in China. *Energy*, 237, 121623. <https://doi.org/10.1016/j.energy.2021.121623>

21. Jiang, C., & Jiang, A. (2023). Development of Green manufacturing service industry and its integration with manufacturing industry. *Journal of Shanxi Normal University (Social Science Edition)*, 50(1), 19-25.
22. Gao, K., & Yuan, Y. (2022). Does market-oriented reform make the industrial sector “Greener” in China? Fresh evidence from the perspective of capital-labor-energy market distortions. *Energy (Oxford)*, 254, 124183-.  
<https://doi.org/10.1016/j.energy.2022.124183>
23. Peng, S. & Sun, X. (2014). Research on the main challenges and strategic countermeasures of China's green economy development. *China's population, resources and environment*, 24 (3), 1-4.  
<https://doi.org/10.3969/j.issn.1002-2104.2014.03.001>
24. Wang, L. (2020). Study on the Influence of Marine Environment Control on Industrial Structure Adjustment of Manufacturing Industry in Hainan Province. *IOP Conference Series: Earth and Environmental Science*, 560(1), 12058-.  
<https://doi.org/10.1088/1755-1315/560/1/012058>
25. Zhu, X., & Lu, Y. (2017). Open economy, environmental fiscal expenditure, and pollution control: Empirical evidence from provincial and industry panel data in China. *China's population, resources and environment*, 27 (10), 10, 18.  
<https://doi.org/10.12062/cpre.20170423>
26. Kang, Z., (2012). The impact of catch-up behavior and factor market distortion on employment in China: Data analysis from micro firms. *Chinese Journal of Population Science*, 1, 60-69.
27. Li, B., Li, J., Chen, W., Liu, J., & Shi, P. (2022). Meteo-Climatic Conditions of Wind and Wave in the Perspective of Joint Energy Exploitation: Case Study of Dongluo Island, Hainan. *Atmosphere*, 13(7), 1076-.  
<https://doi.org/10.3390/atmos13071076>
28. Song, Y., Huang, H., & Gan, X. (2024). Collaborative governance on industrial pollution and carbon emissions through synchronous development of factor markets: Impact and mechanism. *Environmental Impact Assessment Review*, 105, 107355-.  
<https://doi.org/10.1016/j.eiar.2023.107355>
29. Liu, C., Zhang, S., Chen, X., Xu, W., & Wang, K. (2022). A comprehensive study of the potential and applicability of photovoltaic systems for zero carbon buildings in Hainan Province, China. *Solar Energy*, 238, 371–380.  
<https://doi.org/10.1016/j.solener.2022.04.057>
30. [30]Wang, J., & Xiong, S. (2014). A hybrid forecasting model based on outlier detection and fuzzy time series – A case study on Hainan wind farm of China. *Energy (Oxford)*, 76, 526–541.  
<https://doi.org/10.1016/j.energy.2014.08.064>
31. Chen, F. (2008). Potential application of renewable energy sources in the island of Hainan, China. *Energy Sources. Part B, Economics, Planning, and Policy/Energy Sources. Part B, Economics, Planning and Policy*, 3(3), 251–258.  
<https://doi.org/10.1080/15567240601057586>
32. CICC Research, C. G. I. (2022). *Guidebook to Carbon Neutrality in China: Macro and Industry Trends under New Constraints (1st ed. 2022.)*. Springer Nature.  
<https://doi.org/10.1007/978-981-16-9024-2>
33. Wang, X. (2017). The development of low carbon manufacturing industry in Hainan Province. *MATEC Web of Conferences*, 100, 3019-.  
<https://doi.org/10.1051/matecconf/201710003019>