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Review

Environmental Policy and Risk Regulatory Framework for Sustainable Tidal Current Energy in China

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Abstract

The advancement of sustainable energy is a key component of the achievement of the Sustainable Development Goals. Technology advancements have made tidal current energy (TCE) a promising renewable energy source. China possesses abundant TCE resources and has gradually incorporated TCE into its energy and marine development policies. In China, TCE projects are currently being implemented on a large scale. However, despite policy-level recognition, TCE development in China has received limited regulatory attention, particularly with respect to environmental protection and ecological risk governance. Existing governance frameworks largely rely on general marine environmental and ecological policies, which are insufficient to address the three-dimensional, underwater characteristics and cumulative ecological risks. This study analyzes the evolution of China's TCE-related laws and policies and identifies key deficiencies in current environmental regulation. To promote the sustainable TCE projects, the paper proposes tentative recommendations to promote the sustainable development of TCE in China, including the formulation of specialized environmental impact assessment guidelines grounded in the precautionary principle, future policies for addressing the cumulative environmental impact of large-scale TCE deployment, and the establishment of an environmental risk assessment system tailored to the data limitations and ecological characteristics of TCE exploitation.

Keywords: tidal current energy; marine renewable energy; environmental policy; environmental law; risk regulatory; China

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1. Introduction

The 2030 Agenda for Sustainable Development, adopted by the United Nations General Assembly in 2015, aims to "make the world a better place by 2030" [1,2]. Sustainable energy systems are a prerequisite for sustainable development [3,4], as the latter depends critically on meeting ever-increasing global energy demand in an environmentally responsible manner [5]. The transition from fossil fuels to renewable energy sources represents one of three major technological transformations required for sustainable energy development [6,7]. Long-term energy system planning is essential to anticipate and meet future energy needs, and various strategies have been proposed to achieve this objective [8]. Meanwhile, we are entering the era of artificial intelligence (AI) [9]. Aside from the large language models (LLMs) and AI agents we are familiar with, the success of AI depends on coupling "energy-storage-data-algorithm-ecology-governance" across the entire stack [10–17]. As AI has been widely applied, energy consumption has increased substantially [18,19].

In response to the escalating energy demand, the Chinese government is allocating increased attention to the development of renewable energy sources [20]. As a developing sector, marine renewable energy (MRE) could play a significant role in providing clean, renewable energy and steering the energy industry towards a sustainable future [21,22]. Tidal current energy (TCE) has unique superiority over other intermittent renewable sources [23,24].

TCE is becoming more technologically advanced as project development continues to grow rapidly [25]. China possesses abundant TCE resources, with an annual average power output of approximately 13.95 Gigawatt (GW), primarily concentrated in the North Yellow Sea (2.31 GW), East China Sea (10.96 GW), and South China Sea (0.68 GW) [26]. Zhejiang Province, which is located along the East China Sea, has a theoretical TCE potential of 7.09 GW—accounting for 50.8% of China's national total TCE—with channel power densities ranging from 15 to 30 Kilowatt (kW)/m^2 [27]. It is evident that key sites within the Zhoushan Archipelago, such as the Jintang, Guishan, and Xihoumen channels, and Hangzhou Bay, demonstrate average power densities that exceed 20 kW/m^2, and peak flow velocities that surpass 5 m/s [27,28]. These locations are considered to be optimal for the purpose of electricity generation. At present, there are over 20 TCE devices with capacities in excess of 10 kW, which have been installed in this region [22,29–31]. Sea trials have been completed by approximately 40 units, with a maximum single unit power of 650 kW [22]. In total, TCE offers several significant advantages: Firstly, this technology is highly regular and predictable. Second, TCE processes emit no pollutants in comparison with thermal power plants, etc. Thirdly, TCE equipment is usually installed on the seabed or floats on the ocean surface, requiring no land resources. Fourthly, TCE boasts a higher energy density than wind and solar energy—approximately four times that of wind energy and thirty times that of solar energy [22,32,33].

Those in positions of decision-making are increasingly being tasked with acting in a sustainable manner and pursuing policy paths that are conducive to sustainable development [34]. In pursuit of sustainable development, the Chinese government has initiated a series of initiatives to advance the ecological civilization construction [35–37]. In addition to the multifarious scientific and technological factors [22,38], the government's policy guidelines play a pivotal role in ensuring sustainable development, which includes the utilization of TCE. The Chinese government has identified TCE as a priority in the new energy transition, evidenced by its inclusion in relevant laws and government policies. The economy, society, and environment are typically prioritized when discussing sustainability [39]. The continued sustainability of TCE is contingent upon a number of factors, including technological maturity, effective cost control, and the balanced integration of social and environmental benefits [40]. In the context of TCE, the environmental implications of the turbine usage have been observed to result in an increase in underwater noise levels. It has been demonstrated to induce stress and potentially inflict tissue damage in fish, marine mammals and birds [32,41–43]. Further issues may include fish being struck by turbine blades and the collision of marine mammals with tidal farms [32,42,44]. The impact of TCE converters and arrays on benthic habitats is multifaceted, encompassing alterations to water flows, substrate composition, and sediment dynamics [42]. These alterations, in turn, have been shown to affect bed morphology and benthic ecosystems [45]. Despite the existence of numerous factors, there remains scope for further investigation into specific instances of harm resulting from the deployment of tidal current devices in the environment [32,42,46].

Hangzhou Lin Dong Ocean Energy Technology Co., Ltd. established China's first tidal power station in April 2013, the LHD (Zhoushan) Ocean Tidal Energy Project (LHD project) in China [47]. On 25 May 2017, it was connected to the national grid [48]. As of 20 October 2025, the LHD project, with an installed capacity of 3.3 Megawatt (MW) had produced 8.34 million kilowatt-hours of electricity and had maintained uninterrupted grid connectivity for over 100 months [49–51]. It is anticipated that the financial outlay required for the generation of tidal energy will decrease to a figure lower than 0.3 Chinese yuan ($0.042) per kilowatt-hour upon the completion of the seventh-generation LHD unit [49]. In February 2025, a joint initiative was undertaken by six Chinese government departments, who collectively issued the *Guiding Opinions of the Ministry of Natural Resources, the National Development and Reform Commission, the Ministry of Industry and Information Technology, the Ministry of Finance, the Chinese Academy of Sciences, and the National Energy Administration on Promoting the Utilization of Marine Energy at Scale* (GOPUMES) with the objective of promoting large-scale marine energy utilization [52]. The ambitious target set for 2030 is to achieve an installed capacity of 400 MW of marine energy [53]. In September 2025, a 100 MW tidal power project was officially launched in Zhoushan [49].

TCE appears to be in the process of industrialization at present. While at the same time, it is necessary to avoid the occurrence of cumulative environmental impacts [44,54]. A policy refers to the guidelines that determine the rules of a certain historical period, which are formulated by a government or a political party [55]. North America, Europe, Korea, and other countries have all adopted their own TCE policies. However, while their goals are similar, their actual progress is not the same [32,56–61]. This study aims to collect comprehensive Chinese TCE policies, and to determine whether these policies and risk regulatory frameworks meet the requirements for promoting a sustainable development of the TCE industry by analyzing the existing environmental policies and risk regulatory frameworks. The rest of the paper is structured as follows: Section 2 describes the materials and methodology used in the study. Section 3 analyzes and evaluates perspectives on the main stages of TCE policies and related environmental content. In Section 4, we discuss current gaps in the field. Conclusions and future policies are presented in Section 5.

2. Materials and Methods

For this study, the PKULaw database (also known as Beida Fabao) was selected as the database for obtaining the materials [62,63]. In 1985, Peking University established PKULaw, the country's first and most comprehensive legal database, renowned for its authoritative data collection [64,65]. It encompasses legislation and regulations, judicial cases, law journals, the practices of law firms, and judicial examinations [62]. Therefore, the present study employs the PKULaw database as the fundamental retrieval system to analyze the present policy focus of China on TCE.

Current Chinese policies do not provide a clear definition of TCE, and these concepts are not consistently covered in policy texts. Specifically, the GOPUMES hold the view that tidal energy is made up of both TCE and tidal range energy, and that this constitutes a significant category within ocean energy. The *13th Five-Year Plan for Renewable Energy Development* (FYPRED) and the *Outline for the Development of Marine Renewable Energy (2013–2016)* (ODMRE) follow the same logic [66,67]. *The National Marine Functional Zoning (2011–2020)* (NMFZ) [68] emphasizes that both wind energy and TCE fall under the category of renewable energy. Ocean energy is a macro-level target with no logical connection to the energy category. Although there are some differences in classification, they all essentially adhere to the conceptual logic that TCE is a form of both ocean and renewable energy. Therefore, this study used four key terms (KT) including "energy," "renewable energy," "ocean energy," and "tidal current energy" to retrieve and source policy texts. All central-level and local-level policies (including laws, regulations, normative documents and working documents) were scanned using these four key terms in the PKULaw database. Policies that are no longer in effect, have not yet been implemented or only briefly mention TCE were excluded from the selection. Where different departments had issued related notices for the same normative document, the higher-level policy was retained. Up to 27 September 2025, 229 policy texts were identified, of which 180 were irrelevant, and 49 were included the TCE content effectiveness (see Figure 1).

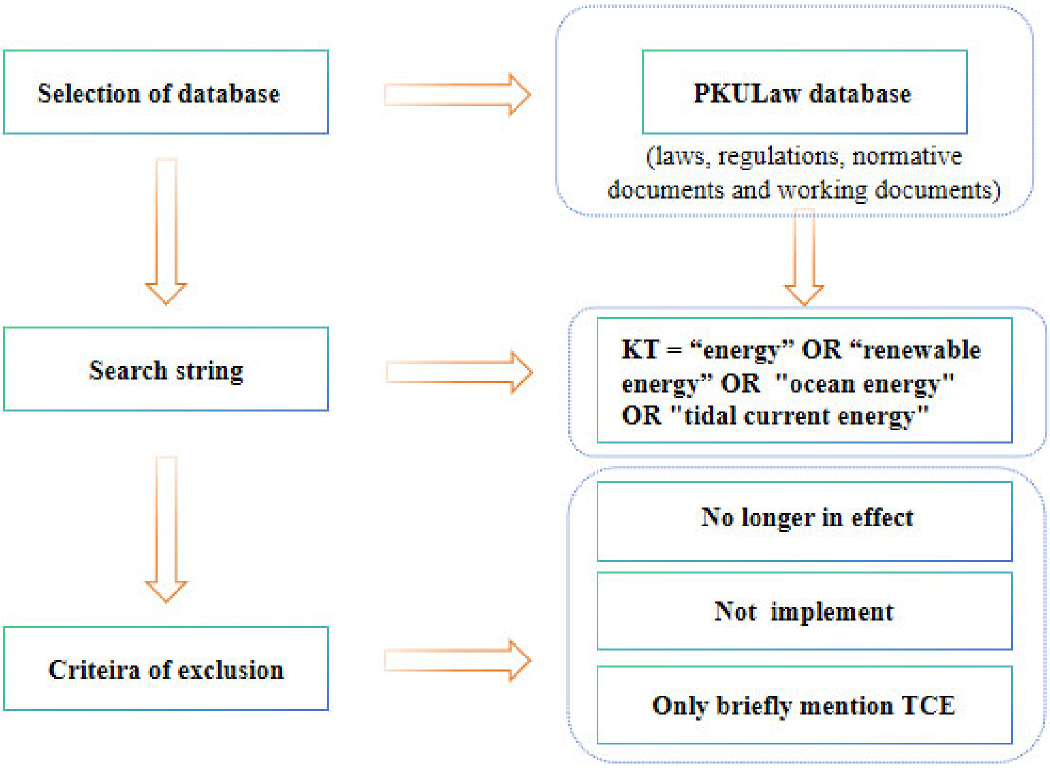

Figure 1. Overview of TCE-related policy selection process (source: own illustration).

As a powerful research tool, policy analysis enables us to understand how and why governments enact certain policies, as well as their subsequent effects [69–71]. Texts form the way in which we see the world [72]. An increasing amount of research has focused on policy documents as texts [73]. The policy texts embedded in national and local documents represent significant outcomes of political struggles and are essential for analyzing policy formulation, enactment and implementation [73,74]. This study mainly examines and discusses China's TCE issues using a policy analysis method.

ROST CM6 (Version 5.8.0.600) is a content mining and word frequency analysis software that has been widely employed by scholars to analyze structured policy texts [75–78]. The software offers multiple functions, including keyword frequency statistics, semantic element extraction, sentiment analysis, and the construction of social relationship networks. These capabilities facilitate the identification of core content and key points of the policy texts in question. In line with the objectives of this study, each policy document was treated as an individual unit of analysis. ROST CM6 was primarily utilized to examine TCE-related policies, primarily through word frequency analysis and social network analysis.

3. Results

In 1986, the central government issued the *Opinion on Strengthening Rural Energy Construction*, which incorporated ocean energy into the framework of "developing long-term planning for rural energy development". This marked an early recognition of ocean energy (primarily tidal energy at the time) as part of broader rural renewable energy sources, alongside biomass, solar, and geothermal energy. However, targeted policies specifically for TCE emerged later.

3.1. Main Stages

Three stages were identified in this study with respect to the TCE policies released since 2009. The representative policies of each stage are intuitively illustrated in the policy evolution diagram (Figure 2).

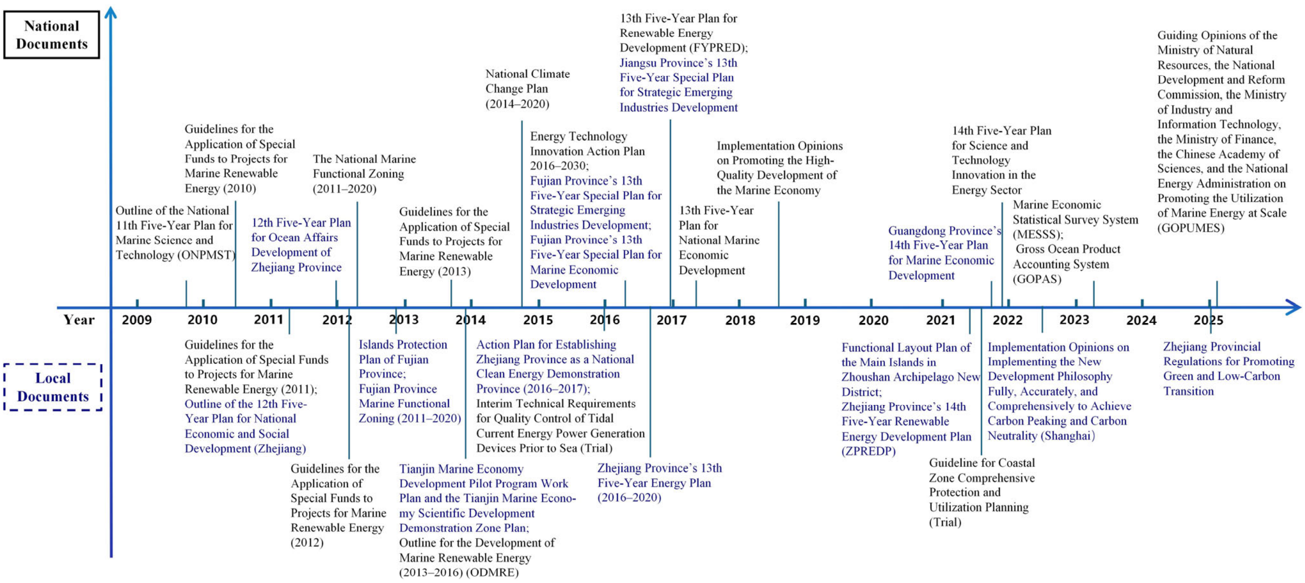

Figure 2. Time axis of representative policies of TCE in China (source: own illustration).

Stage I: 2009 to 2012. This period represents the infancy of the TCE policy. *Outline of the National 11th Five-Year Plan for Marine Science and Technology* (ONPMST), China's first national marine science and technology development plan, outlined overarching objectives for marine science and technology development in 2009 [79]. To propel the growth of the marine economy, it explicitly called for the development of TCE technology. As a priority area for support, TCE was listed alongside other energy technologies for the first time. Together with the Ministry of Finance, the State Oceanic Administration (SOA) has successively issued the *Guidelines for the Application of Special Funds to Projects for Marine Renewable Energy* since 2010, supporting TCE technology research through project funding. The NMFZ also reserves marine space for the development of TCE as one of the key tools for marine spatial planning [80]. China's coastal provinces, including Zhejiang, Guangdong, and Fujian, have incorporated TCE into their marine economic development strategies. It is noteworthy that Zhejiang authorities have successively released the *Outline of the 12th Five-Year Plan for National Economic and Social Development*, the *Marine Economic Development Demonstration Zone Plan (Zhejiang)*, and the *12th Five-Year Plan for Ocean Affairs Development of Zhejiang Province* in order to advance the implementation of the TCE projects [81].

Stage II: 2013 to 2022. Under the policy encouragement, this period represents the pilot stage for TCE projects. Some of the key aspects include:

(1) Continuing to issue policies regarding TCE projects that make use of spatial reservations and applicable scenarios. At the central level, the Ministry of Natural Resources (MNR) [82] released the *Guideline for Coastal Zone Comprehensive Protection and Utilization Planning (Trial)* [83] in 2021. Locally, the Tianjin Municipal People's Government developed the *Tianjin Marine Economy Development Pilot Program Work Plan and the Tianjin Marine Economy Scientific Development Demonstration Zone Plan* in 2013. The Zhejiang Provincial Development and Reform Commission and the Zhoushan Archipelago New District Administrative Committee issued the *Functional Layout Plan of the Main Islands in Zhoushan Archipelago New District* in 2021 [84].

(2) Incorporating TCE into broader renewable energy policy frameworks. The SOA released the ODMRE in 2013, while the National Development and Reform Commission and the National Energy Administration released the *Energy Technology Innovation Action Plan 2016–2030* and the FYPRED in 2016. At the local level, taking Zhejiang as a precedent, the province successively issued an *Action Plan for Establishing Zhejiang Province as a National Clean Energy Demonstration Province (2016–2017)* in 2015, *Zhejiang Province's 13th Five-Year Energy Plan (2016–2020)* in 2016, and *Zhejiang Province's 14th Five-Year Renewable Energy Development Plan* (ZPREDP) in 2021.

(3) Integrating TCE into the marine economy and industrial development process. There are many policy documents, including the *13th Five-Year Plan for National Marine Economic Development* in 2017, *Fujian Province's 13th Five-Year Special Plan for Strategic Emerging Industries Development* in 2016, *Fujian Province's 13th Five-Year Special Plan for Marine Economic Development* in 2016, *Jiangsu Province's 13th Five-Year Special Plan for Strategic Emerging Industries Development* in 2016, and *Guangdong Province's 14th Five-Year Plan for Marine Economic Development* in 2021. In 2018, the MNR and the Commercial Bank of China issued *Implementation Opinions on Promoting the High-Quality Development of the Marine Economy* [85], which specifically supports the development of TCE industries from a financial perspective.

(4) Adapting and mitigating climate change through the use of TCE. The *National Climate Change Plan (2014–2020)* has been released since 2014, and Shanghai Municipal Committee of Communist Party of China and Shanghai Municipal People's Government have issued the *Implementation Opinions on Implementing the New Development Philosophy Fully, Accurately, and Comprehensively to Achieve Carbon Peaking and Carbon Neutrality* by 2022, in which technological advances, demonstration projects, and industrial applications are identified as essential measures to reduce greenhouse gas emissions.

(5) Investing in TCE technology research and regulating its quality together. Industrialization of TCE requires corresponding equipment. In addition to the special funds for marine renewable energy, the *14th Five-Year Plan for Science and Technology Innovation in the Energy Sector*, the *Zhejiang Province's 14th Five-Year Plan for Fundamental Research and Development*, and other policies continue to support TCE technology research. In order to standardize TCE testing standards [86], the SOA issued a policy in 2015 entitled *Interim Technical Requirements for Quality Control of Tidal Current Energy Power Generation Devices Prior to Sea (Trail)*. It has been through the encouragement and guidance of policy that China has achieved a successful transition from basic research technology to practical implementation in the industry of TCE.

Stage III: 2023 to 2025. TCE projects are moving toward large-scale implementation. Including TCE in gross ocean product accounting is one of the best indicators that the project is maturing into industrialization. TCE projects were explicitly incorporated into the *Marine Economic Statistical Survey System* (MESSS) and the *Gross Ocean Product Accounting System* (GOPAS), released by the MNR in 2023 [87]. In 2025, the *Zhejiang Provincial Regulations for Promoting Green and Low-Carbon Transition* expressly supported the large-scale utilization of ocean energy, including TCE. According to the GOPUMES, it is imperative to support the power generation of TCE as a green energy supplementary solution for coastal areas and islands in areas abundant with TCE resources. There is a call for implementing "hundred-megawatt-scale TCE key projects" [52]. These developments suggest that large-scale TCE deployment is progressing faster than initially anticipated.

3.2. Analysis of the Frequency of Terms and Social Network Semantic Analysis

As shown in Table 1, the top 20 most frequently occurring terms in TCE policy texts are based on the results of ROST CM6 after removing semantically redundant terms. Technological innovation and development are the core focus of TCE policies from an overall perspective. Even though this study used TCE as the keyword for policy text retrieval, its term frequency (286) ranks relatively low, accounting for only 3% of the frequency of "technology" terms. The TCE is recognized in China's policies, but receives limited attention as it is primarily positioned as a new form of marine renewable energy. However, from another perspective, these policy initiatives highlight TCE's cutting-edge nature and significance.

Table 1. Frequency of Terms.

Number	Key Terms	Frequency
1	technology	10,042
2	ocean	6185
3	development	5726
4	construction	4452
5	research	4301
6	energy	3577
7	innovation	3491
8	exploitation	2520
9	utilization	2405
10	advance	2303
11	resource	2168
12	system	2002
13	key	1970
14	launch	1933
15	strengthen	1893
16	ecology	1855
17	engineering	1779
18	enterprise	1784
19	project	1748
20	economy	1708

In addition, ROST CM6 was used to generate social network and semantic network analysis diagrams (Figure 3). A high-frequency word is represented by a node in the diagram, and the number of lines connecting nodes indicates the strength of the link between them. The semantic connections between words and the deeper structural relationships within the policy texts are reflected here [88]. Currently, TCE remains within the scope of ocean construction. Among the most frequently occurring core keywords, "technology" exhibits high levels of association with "development," "construction," and "innovation." Based on this analysis, current policy priorities are focused on increasing the development and utilization of TCE, promoting projects, and achieving industrialization. The prevalence of action-oriented terms such as "enhancement," "acceleration," "advancement," and "promotion" further indicates that TCE is currently moving from technology development to project implementation and engineering application. Additionally, enterprises are explicitly encouraged and supported to enhance their technological capabilities and research capacities in marine renewable energy, including TCE. There is a co-linear relationship between "ocean," "ecology," and "environment." Accordingly, TCE governance is largely governed by marine environmental and ecological regulations ordinarily. The frequency of "ecology" and "environment" is considerably lower than that of technology-and development-related terms, suggesting that environmental and ecological considerations, while present, do not constitute the primary focus of current TCE policies.

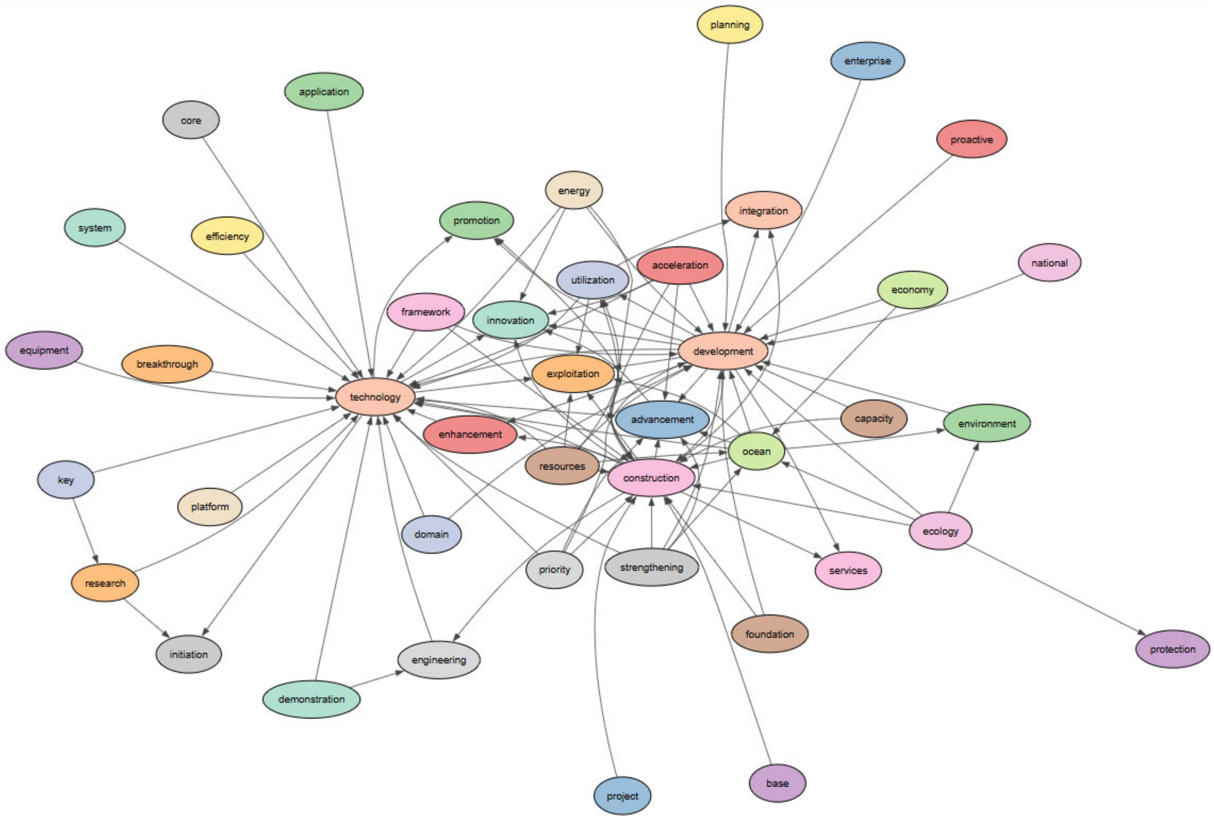

Figure 3. Analysis of social and semantic networks (source: own illustration with minor aesthetic modifications).

3.3. *Specific Analysis of the Original Text Including Keywords*

This study examines the content of policy texts in detail after conducting a term frequency analysis and a social network semantic analysis. It is important to note that text content, as an explicit and objective system description, can accurately present the current focus of research, enabling decision-makers to make the most informed decision about where to direct their efforts. Coastal regions such as Zhejiang, Shandong, Fujian, Guangdong, and Hainan possess relatively abundant marine energy resources, according to policy texts. One of the most significant marine energy reserves in China is in Zhejiang. This study performs a foundational classification based on keyword and semantic network analysis. Having removed action-related conjunctions and meaningless content, the policy texts can be categorized into three categories (Table 2).

Based on the fundamental classification of TCE policies, it is evident that the current focus is on technological R&D and engineering applications. Firstly, the main policies supporting the TCE technology application. In China, the main policies encourage the use of marine technologies, such as power generation technologies and equipment technologies, that are compatible with the characteristics of Chinese TCE resources, encouraging R&D of TCE resource exploration and energy supply platforms, miniaturization and modularization of marine energy, and the comprehensive utilization of TCE technology. The fundamental logic of technology-driven TCE utilization is reflected in all central and local policies related to TCE R&D. Secondly, these policies promote TCE technologies to engineering construction projects. Marine energy power systems, marine energy demonstration bases, TCE stations, TCE plants, and offshore TCE test sites are encouraged by policies. Using this engineering approach, it is possible to scale up the use of TCE technologies. It is possible to develop TCE projects and their underlying platforms in order to establish a fundamentally complete TCE utilization system, which will facilitate the subsequent creation of management systems and policy frameworks that are aligned with industrial development. Thirdly, marine economies should be developed in regions that are abundant in TCE. Nearshore waters are primarily targeted for the industrialization of TCE technologies. The development of TCE should be prioritized as a key task for the growth of the marine economy. Moreover, TCE contributes to the creation of low-carbon energy systems that support carbon peaking and sustainable economic growth by increasing power generation efficiency and reducing electricity costs.

Table 2. Main classification with related content.

Main Categories	Related Content
Technology	Research Technology, Technology Utilization, Technological Innovation, Energy Technology, System Technology, Equipment Technology, Demonstration Technology, Platform Technology, Ocean Technology
Construction	Ocean Construction, Construction Innovation, Resource Construction, Energy Construction, Construction Engineering, Project Construction, Base Construction
Development	Economic Development, Marine Development, Energy Development, Resource Development, Ecological Development, National Development, Enterprise Development, Development Planning

Overall, environmental and ecology policies for TCE development constitute a very small portion of all policy documents.

4. Discussion

4.1. Environmental and Ecological Impacts of TCE

The use of TCE as a renewable energy source has many advantages. In the process of moving towards a large scale, however, it can have disproportionately negative impacts on the environment and ecology. These mainly include:

(1) Disruption of marine ecosystems and habitats. By acting as an artificial reef and increasing habitat heterogeneity, TCE installations accelerate flow around the devices and create highly mixed flows in their wakes [24,89,90]. As a result of the installation and operation of tidal energy devices, the seabed and benthic ecology are directly disturbed [91,92]. In addition, tidal energy exploitation can produce both near-field and far-field environmental effects depending on their proximity to devices or arrays [93]. There was little effect of tidal energy extraction on water level, according to most studies [31,94–96]. However, the tidal arrays could alter the tidal range upstream by approximately 5–42%, and the intertidal mudflats could decrease by 14–32%, resulting in habitat loss near shore [93,97]. It is likely that our concern will not be of concern for one device, but for a number of devices, which will become a significant threat to sensitive species as the number of devices increases [98]. A number of questions remain regarding the effects of tidal energy devices on marine wildlife, as well [99].

(2) Disturbances of the visual and auditory systems. During the installation phase, there is a potential for disturbance of seabirds and others [91]. Noise from turbines disrupts species that rely on sound for communication, orientation, predation, and evasion, as well as electromagnetic fields generated by power cables and moving parts of turbines that affect animals that use magnetic fields to navigate and hunt [89,100–103].

(3) Risks associated with collisions. Many tidal turbines, like wind turbines, are designed to pose collision risks with marine organisms [104]. According to some studies, the collision risk is very low [105,106]. Research on collision risks associated with the deployment of large-scale TCE turbines is lacking; however, existing studies suggest evaluating their potential risks over time [41,107].

(4) Ecological risks in the lifecycle of TCE projects. It is possible that oils, grease, and lubricants may leak from TCE devices, and antifouling and anticorrosion paints on TCE devices may contaminate the seawater over time [91,108]. In the conventional manufacturing of turbine blades, reinforced polymer composite materials are not recycled [109]. There will be an increase in blade waste as a result of increasing TCE capacity. There may be an environmental impact associated with the manufacture, transportation, installation, operation, and decommissioning of tidal turbine equipment [109].

Since interactions between devices and ecosystems are complex and dynamic, the ecological impacts of TCE projects remain unclear [89,104]. Although technological advances may be able to address potential risks in the future, they must not be overlooked in the process of large-scale expansion.

4.2. Limited and Poorly Applicable Environmental and Risk Regulations

Although a few policies refer to environmental standards and risk regulations for TCE, these references appear to be very simple or principled. In the *Fujian Province Marine Functional Zoning (2011–2020)*, for instance, there is a strict control over the scale, scope, and intensity of nearshore mineral and energy development [110]. But specific standards are lacking, only requiring scientific assessment. However, this excessive reliance on scientists' single decision-making approach cannot guarantee effective protection of the environment and ecology. When an island is primarily used for TCE project utilization, including building infrastructure for TCE. The *Islands Protection Plan of Fujian Province* strengthens the protection of islands' ecological environment and prevents potential damage to their terrain, beaches, island ecosystems, and marine environment [111]. As a result of the lack of detailed implementation rules, specific environmental rules and risk regulations are not easily applied to TCE projects.

Due to TCE's status as a renewable energy source, its environmental regulations are also applied to general laws and regulations. Laws such as the *Renewable Energy Law* (REL), the *Island Protection Law*, and the *Wetland Protection Law* are examples of these laws [112]. As a TCE construction project is a type of marine engineering project, it is also subject to laws that regulate environmental risks associated with marine engineering. These laws include the *Environmental Protection Law*, the *Marine Environment Protection Law* (MEPL), and the *Law on Environmental Impact Appraisal* (LEIA), among others.

It should be noted, however, that these regulations are sparse, broadly defined due to their diverse scope of application, and similarly hindered by the lack of detailed implementation guidelines. During the enforcement inspection of the REL, the Inspection Group of the Standing Committee of the National People's Congress (NPC) of China highlighted issues such as insufficient policy coordination between renewable energy development and utilization and ecological environment protection, as well as inadequate regulatory coordination among the appropriate departments in 2019 [113]. The MEPL must be followed when approving environmental impact reports for marine projects, including TCE [114]. Among the topics covered in Chapter 5 of MEPL is pollution damage caused by construction projects to the marine environment [115]. Environmental pollution challenges are unique to TCE projects. The MEPL requires that appropriate environmental monitoring and supervisory standards be developed in accordance with Article 23. There is, however, a relative lack of standards regarding TCE. MEPL encourages the public to become involved, but the lack of environmental information regarding TCE prevents this from happening. It has limited practical applicability and operability. The potential environmental impacts of TCE may not have received special attention from MEPL. Alternatively, it does not adequately consider the need for environmental and ecological protection in TCE projects. The LEIA requires assessments to be conducted to analyze, predict, and mitigate adverse environmental impacts [116]. Construction projects subject to classified management of environmental impact assessments are one of the most important rules of the IEIA [117]. TCE is not directly included in the revised draft of the classified management list released by the Ministry of Ecology and Environment in December 2025 [118].

5. Conclusions and Future Policies

5.1. Aiming for More Reasonable and Comprehensive TCE Policies

As we move towards a future with a greater focus on sustainability, green energy is becoming an increasingly important part of the picture [119–122]. A recent report estimates that the global wave and tidal energy market will grow from USD 0.98 billion in 2023 to USD 19.75 billion by 2032 [123]. China is endowed with abundant TCE resources, positioning it favorably in this emerging sector. At least in China, we are currently experiencing an era of large-scale industrialization of TCE.

In China, the development of TCE policies can be divided into three stages. Despite increasing recognition in national and provincial policy frameworks, TCE exploitation policies specifically addressing environmental and ecological aspects constitute only a minor proportion of the overall policy corpus. Given that tidal turbines are typically deployed at specific depths (hub heights) within the water column, TCE extraction poses a complex three-dimensional environmental challenge, predominantly underwater [93]. General environmental laws and policies have not yet effectively addressed the associated risks. As large-scale TCE industrialization is now underway, the urgent development of targeted risk regulation policies is more critical than ever.

5.2. Research Limitations and Future Polices

When interpreting the findings of this study, it is important to keep in mind the numerous limitations of this study. First, TCE projects are managing the beginning stages of China's large-scale development. As many enterprises consider details regarding TCE projects, especially those that involve environmental and ecological challenges, to be confidential, this study does not provide a specific case analysis. Second, the scope of policy texts covers all publicly available policies, but many working documents are not fully disclosed. We find it difficult to keep up with the latest developments in the unpublished policy documents relevant to the environment and ecological protection within government agencies. The third limitation is that this study does not provide a comprehensive overview of TCE policy in China based on quantitative impact assessments due to the insufficient amount of data available. Despite these limitations, this study provides insight into the shortcomings of environmental policies in the large-scale process of TCE projects, as well as directions for future policy innovation.

To ensure sustainable TCE in China, and even in the world, some targeted environmental policies and risk regulations are recommended:

First, dedicated EIA guidelines for TCE projects should be developed. China must strengthen its EIA policy framework by adhering to the principle of risk prevention. There are provisions in general environmental laws, especially in the Ecological and Environmental Code (approved on 12 March 2026) [124], but given the unique nature of TCE's environmental impacts and the difficulty of supervision, it is unlikely that specialized regulations will be introduced to address potential TCE risks owing to the limited legislative resources in China. At a minimum, specific EIA technological guidelines grounded in the precautionary principle should be introduced to promote the long-term sustainability of TCE projects. Additionally, the application of fuzzy logic offers a promising, innovative approach to enhancing TCE-specific EIA processes [125].

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Second, future policies should explicitly address the cumulative environmental impact of large-scale TCE deployment. In view of the fact that research has focused on the nature of marine resources and the technological aspects of exploiting them, there are few observations from which we can draw conclusions [89,126]. Although it is reasonable to assume that extracting only a small fraction of natural energy fluxes should have minimal ecological implications, it is difficult to determine acceptable limits of extraction [89,107]. The research suggests that impacts vary by location and season, by design and scale of devices and arrays, and may be cumulative, both over time and with an ever-increasing number of TCE projects [89,92]. For large-scale TCE projects, it is important to predict the potential changes in the hydrodynamic regime [97]. Accordingly, assessments of cumulative effects on marine ecosystems, biodiversity, and coastal processes must be systematically incorporated into planning and approval procedures.

Third, a comprehensive environmental risk evaluation system should be developed specifically for TCE. On 24 December 2025, the National Marine Energy Industry Alliance (NMEIA) was established [127]. The NMEIA, a national-level cooperation platform for marine energy industries that consists of leading enterprises, research institutes, and universities, is designed to facilitate collaborative innovation, technology sharing, risk sharing, and mutual benefits among marine energy industries [127]. The industry standard "Laboratory Testing Methods for Combined Wave Energy, Tidal Current Energy, and Offshore Wind Energy Generation Devices" was released for public comment on 30 December 2025 [128]. The development of large-scale marine renewable energy projects, including TCE projects, represents a major future trend, driven by the imperatives of marine economic growth, climate change mitigation, and even by the need for corporate profits [129,130]. An industry-specific environmental risk assessment system applicable to TCE projects is recommended as one of the best options [108].

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