

The Current Status of Global Energy Crisis and the Development of Novel Marine Energy Sources

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Abstract. International geopolitical conflicts have caused international oil and gas market switching, which has caused a huge impact on the global oil and gas supply chain and changed the world's energy supply pattern. International fossil fuel prices are likely to remain high, giving the United States more say in energy markets. This paper introduces that this reality has triggered the consideration of energy security and increased the attention of countries to new energy. The ocean is rich in renewable energy, including tidal energy, wave energy, ocean current energy (tidal current energy), offshore wind energy, and so on. This paper points out that these energy sources are abundant, clean, and renewable, and are regarded as one of the most promising alternative energy sources at present. This paper discusses the importance of tidal energy as a renewable energy source due to its clean and stable properties. Although tidal energy has the advantages of high stability and good predictability, its high cost, long construction cycle, and potential ecological impact limit its commercialization. Finally, the development prospect of tidal energy in China is prospected. It is concluded that China is rich in tidal energy resources and has considerable development potential with the support of policies and funds.

Keywords: Energy crisis; Environmental pollution; new energy; Tidal energy; Sustainable development.

1. Introduction

In the current global context, amidst the persistent growth in energy demand, the exploration and utilization of novel renewable energy sources have emerged as a broad consensus within the international community. Smith's research explicitly highlights that the excessive extraction and use of traditional energy sources not only exacerbate resource depletion but also trigger severe environmental issues, contradicting the core principles of sustainable development [1]. Consequently, novel marine energy sources, particularly noted for their clean and stable attributes, have increasingly become pivotal options in addressing this dilemma and have garnered considerable attention from various sectors.

Entering the 21st century, oceans have been regarded as a new frontier for energy exploration. Zhang asserts that the rational development and utilization of marine energy are seen as crucial pathways to fundamentally address human energy shortages, as well as harbingers of diversified energy structures and reduced carbon emissions [2]. Marine renewable energy, broadly defined, encompasses various renewable natural energy resources harbored within oceans, including wind energy, solar energy, tidal energy, wave energy, ocean current energy, as well as ocean thermal energy conversion (OTEC) and salinity gradient energy. These energy forms, by converting the ceaseless motion patterns and abundant natural resources of the sea, offer a vast prospect for humanity to harness marine energy.

In recent years, tidal energy, as a significant component of novel marine renewable energy, has witnessed remarkable progress in its practical development and utilization. Liu's research elaborates

on the global development and application of tidal energy, emphasizing its positive role in mitigating the energy crisis and promoting sustainable development [3].

This paper aims to contribute to the further development and application of marine energy sources such as tidal energy. It focuses on the practical development and utilization of tidal energy, delving into the role of novel marine renewable energy in addressing the current energy crisis and its impact on achieving sustainable development goals.

2. Global Energy and Environmental Crisis Status

2.1. Energy Shortage

At present, there are four main energy sources in the world: oil, natural gas (NG), coal, and nuclear energy. The industrial growth model is a high-energy consumption model, which makes the world's energy consumption demand continue to rise with the promotion and deepening of industrialization, especially focusing on the destructive consumption of primary energy such as petroleum resources.

2.1.1. Energy crisis in developing countries

In China, for example, there are abundant total resources, but due to the large population, per capita resources are lower than the world average. Therefore, from relative numbers, China is a small resource country in the world. However, China faces various challenges and risks in terms of energy security. By 2021, China's energy production (EP) scale reached 4.41 billion tons of coal, but its reliance on external energy is quite high, with an energy self-sufficiency rate of only 82%. In addition, China's EP is decreasing year by year, China is becoming more and more dependent on imported energy, and China's dependence on oil and NG resources is increasing year by year. This is not a good trend, it is a worrying situation and requires proactive measures. Table 1 shows China's primary EP and consumption and crude oil (CO) imports.

Table 1. Production, consumption, and energy gap of China's primary energy in 2019-2023 [4]

Year	Total EP of 10,000 tons of standard coal	Total energy consumption of 10,000 tons of standard coal	The energy gap of 10,000 tons of standard coal
2019	397317	487448	90131
2020	407295	498314	91019
2021	427115	525869	98754
2022	463808	540956	77148
2023	483000	572000	89000

In a newly released report, the International Energy Agency (IEA) said that humanity is facing the first truly global energy crisis. Although Europe is the epicenter of current energy market volatility and shortages, the impact of the energy crisis is global, the report said. According to Tich Birol, developing countries are also victims of this energy crisis, especially oil importers in Africa, Asia, and Latin America.

At present, global energy is transforming, and China's sustainable energy development is gradually advancing. China's energy development strategy, is a key measure to promote the revolution of EP and consumption and build a clean, low-carbon, safe, and efficient energy system. In September 2020, China proposed the "dual carbon" growth direction of implementing "carbon peak and carbon neutrality." To achieve green and low-carbon development in the socio-economic sphere, China's energy system is currently undergoing a challenging transformation process.

2.1.2. Energy crisis in developed countries

Unlike the three previous energy crises in history, which were all characterized as oil crises, the 2021 European energy crisis is primarily marked by a sharp increase in NG prices, reaching record highs.

Taking the United States as an example, people often see from media news reports that since U.S. President Joe Biden took office and began to govern, energy prices have been constantly rising, especially U.S. gasoline prices which have continuously hit record highs. The main reason is that while the United States is massively exporting energy products, it is also massively importing energy products. The United States is completely integrated with the global energy market. After the United States achieved energy independence in 2019, the scale of its energy imports and exports has been growing larger and larger in recent years. In 2021, the United States exported energy equivalent to 25.249 quadrillion British thermal units, while importing energy equivalent to 21.434 quadrillion British thermal units [5-7]. Both energy exports and imports reached significant levels. The U.S. Energy Information Administration believes that the main reason the United States has not been able to avoid the global energy crisis is that its domestic energy market is fully integrated with the international market, even though domestic consumption of oil and NG can no longer rely on any specific country.

The increasing oil consumption by industrialized countries, led by the United States, and the decreasing oil production have led to a growing global oil supply crisis. Some developing third-world countries, such as China and India, which are experiencing rapid economic growth, have begun to emerge as major energy importers, particularly in oil and NG.

2.2. Environmental Pollution

2.2.1. Current status of environmental pollution

Some coastal bays, estuaries, and sea areas are seriously polluted, soil heavy metal pollution is aggravated, drinking water pollution is prominent, and air pollution is mainly soot-type

2.2.2. Causes of environmental pollution

Land-based pollutants, pollutants discharged by ships, the construction of unreasonable marine projects and marine development, artificial dumping of waste pollution, offshore oil exploration and development pollution, and radioactive pollutants brought about by the widespread application of nuclear technology are gradually entering the soil.

As shown in Table 2, taking the Beijing-Tianjin-Hebei region as an example, it can be observed that fertilizer pollution constitutes a significant portion of the pollution sources. These pollutants largely enter the Beijing-Tianjin-Hebei watershed, causing serious water environmental pollution.

Table 2. Total phosphorus emissions in each basin.

River basin	Industrial enterprises	Sewage treatment plants	Livestock and poultry breeding	Rural life	Fertilization	Total
Luan River	23.50	41.27	37.13	27.29	12767.73	12896.92
North Canal	27.40	190.15	47.58	126.44	11940.74	12332.31
Yongding River	14.25	52.34	28.53	37.08	12450.36	12582.56
Daqing River	65.37	764.85	67.21	202.96	80930.34	82030.72
Ziya River	148.99	450.56	109.82	107.05	236478.88	237295.31
South Canal	10.23	94.59	16.98	23.90	31113.55	31259.25
Total	289.74	1593.76	307.26	524.71	385681.59	388397.06

3. Development of New Marine Energy

3.1. Background of Marine Energy Development

3.1.1. Types of new marine energy

The ocean contains a variety of renewable energy sources, including wave energy, tidal energy, ocean current energy, temperature difference energy, salinity gradient energy, etc. These new Marine energy sources are clean, renewable, and sustainable, and can provide a reliable energy supply to coastal communities. As shown in Table 3:

Table 3. Main utilization forms and distribution of Marine energy in China [8].

Mainly form	The amount of resources that can be exploited	The main distribution of resources in China
Tidal energy	220 Million KW	The coastal areas of Fujian and Zhejiang are the most abundant tidal energy resources in China, such as Luoyuan Bay and Sandu 'ao in Fujian, Yueqing Bay and Qiantang Estuary in Zhejiang, the average tidal range is 4~5m, and the maximum tidal range is 7~8.5m
Wave energy	140 Million KW	China's Zhejiang coastal ocean current energy resources are abundant, accounting for more than 50% of the total ocean currents in the country, and have the most waterways in China, reaching 37: along the coasts of Liaoning, Fujian, Taiwan and other provinces in China, the current energy accounts for about 42% of the national total.
Ocean current energy	130 Million KW	Wave energy is widely distributed in the sea area of China, and there are many areas for development and utilization, and the utilizable conditions are the most advantageous along the coast of Taiwan, which accounts for 30% of the total wave energy in China, 40% along the coast of Fujian, Zhejiang and Guangdong provinces, and about 10% along the coast of Shandong Province
Temperature difference energy	1.3 billion KW	The water temperature difference between surface and deep water can reach 20°C~24°C in the area where the temperature difference energy density is higher than that of the soft area
Offshore wind energy	750 million KW	China's offshore wind energy resources are rich, and the exploitable amount is three times that of onshore wind energy resources, among which Shandong, Fujian, Jiangsu and other provinces have superior conditions for the development of Marine wind energy
Ocean energy Biomass energy	There are a large number of oil-rich algae in the sea area of China, which is conducive to the development and utilization of Marine biomass energy	

3.1.2. Comparison with traditional energy

New Marine energy sources are renewable and produce no greenhouse gases, but are costly and intermittent. Conventional energy sources are less costly and reliable, but are non-renewable and produce greenhouse gas emissions. The potential of new Marine energy is huge, but some renewable energy sources are uncertain and still in the development stage, while traditional energy technologies are mature. With the progress of science and technology, the proportion of traditional energy tends to be stable, and the proportion of some energy shows a trend of decreasing, as shown in Table 4 and Table 5.

Table 4. EP in China.

Target	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total primary EP	35104	35878	36221	36219	34595	35887	37885	39731	40729	43300	46600

Continue Table 4.

Crude Coal (CC)	26749	27052	26622	26150	24147	24977	26217	27216	27492	29011	32572
CO	2983	3013	3064	3078	2871	2727	2728	2741	2769	2857	2924
NG	1439	1578	1702	1738	1799	1937	2046	222	244	264	283
Primary electricity and others	3391	4233	4889	5251	5777	6244	6895	7549	8023	8789	8303

Note: The coefficient for converting standard coal for electricity is calculated based on the average coal consumption for electricity generation in the year.

Source: China National Bureau of Statistics

Table 5. Total and share of primary EP.

Target	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total primary EP	35104	35878	36221	36219	34595	35887	37885	39731	40729	43300	46600
Share of CC (%)	76.2	75.4	73.5	72.2	69.8	69.65	69.2	68.5	67.5	67%	69.9
CO (%)	8.5	8.4	8.3	8.5	8.3	7.6	7.2	6.9	6.8	6.6	6.3
NG (%)	4.1	4.7	4.8	5.2	5.4	5.4	5.6	5.6	6	6.1	6.0
Primary electricity and others (%)	11.2	11.8	13.5	14.5	16.7	17.4	18.2	19	19.7	20.3	17.8

Note: The coefficient for converting standard coal for electricity is calculated based on the average coal consumption for electricity generation in the year.

Source: China National Bureau of Statistics

3.2. Development and Utilization of Tidal Energy

Although tidal energy has the advantages of high stability and good predictability, its high cost, long construction cycles, and potential ecological impacts limit its development. Taking the development of tidal energy in China as an example, it can be seen that because of the long coastline of China, tidal energy reserves are very rich. Due to China's vast territory and uneven terrain conditions, the geographical distribution of tidal energy is uneven, leading to greater complexity in its development.

China has abundant tidal energy resources with a theoretical exploitable potential of about 100 GW. At present, the development and utilization of tidal energy in China is mainly focused on the construction of tidal energy test power stations.

4. Potential and Challenges of Marine Renewable Energy

Oceans, as the vastest water bodies on Earth, harbor immense potential for renewable energy, possessing immeasurable value for promoting the sustainable development of the global economy. This section delves into the development prospects of marine renewable energy from both economic and sustainable development perspectives.

4.1. Economic Benefits: Commercialization of Marine Energy Technologies

In recent years, significant advancements in marine energy technologies, coupled with gradual cost reductions, have made commercialization feasible. This trend has not only garnered substantial attention from governments worldwide but also sparked investment enthusiasm in the corporate sector. As depicted in Figure 1, according to the 2022 China Marine Economic Statistics Bulletin, while traditional industries such as marine fisheries, coastal ports, and shipbuilding still dominate the value-added composition of the marine industry, sectors like marine oil and gas, marine engineering equipment manufacturing, and emerging renewable energy fields such as marine electricity also exhibit robust growth momentum. These data not only reflect the diversified development trend of the marine economy but also foreshadow the pivotal role of marine renewable energy in future economic growth. The figure illustrates the proportion of value-added in various industries within China's marine economy in 2022, with marine renewable energy sectors (e.g., marine electricity) showing a relatively small but rapidly growing share, indicating the immense potential and development prospects of this field.

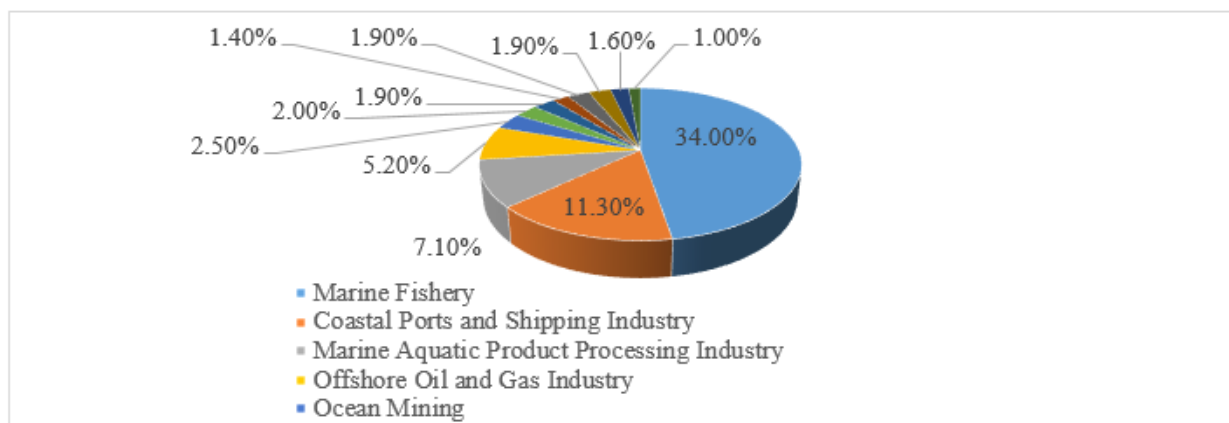


Fig 1. Composition of Marine Industry Value-Added in 2022

[Data Source: China Government Network, China's Marine Economic Statistics Bulletin 2022].

The commercialization of marine renewable energy not only aids in alleviating energy supply pressures but also fosters new economic growth points, promotes employment, and drives industrial upgrading. Consequently, governments and enterprises worldwide should continue to increase investment and propel technological innovation and industrial upgrading, to achieve comprehensive commercialization and large-scale application of marine energy technologies.

4.2. Sustainable Development: A Global Priority in Addressing Climate Change

In the context of escalating climate change, the development of marine energy has emerged as a global priority for mitigating climate change and reducing dependence on fossil fuels. Marine renewable energy, as a clean and renewable energy form, represents a significant pathway towards achieving sustainable development goals. Its development yields multiple benefits. Firstly, it contributes to reducing greenhouse gas emissions and mitigating the trend of global warming. Compared to traditional fossil fuels, marine energy generates almost no greenhouse gases during use, demonstrating remarkable environmental benefits. Secondly, the development of marine renewable energy can promote the optimization and upgrading of the energy structure, decrease dependency on fossil fuels, and enhance the diversity and security of energy supply. Furthermore, it facilitates balanced regional economic development. Since marine energy resources are widely distributed, different regions can develop suitable marine renewable energy projects based on their own conditions, thereby promoting coordinated regional economic development [9, 10].

However, the development of marine renewable energy also faces challenges such as technological bottlenecks, funding shortages, and environmental protection. Therefore, governments and enterprises must strengthen cooperation and exchanges, jointly promote technological innovation and industrial upgrading, while emphasizing environmental protection and sustainable development to ensure the long-term stable development of marine renewable energy. In summary, marine renewable energy, as a vital direction for future energy development, holds immense economic potential and environmental benefits. All countries should seize the opportunity, increase investment, and advance its commercialization process to achieve sustainable development goals [11, 12].

5. Conclusion

This study has found that under the current situation of the increasingly severe global energy crisis and environmental pollution, the depletion of energy resources in various countries has led to shortages of primary energy and renewable energy. Additionally, pollution from sources such as industrial and agricultural development has significantly depleted environmental resources. These factors have driven the development of renewable energy and the exploration of new energy sources.

This study analyzes the energy situation of developed and developing countries and analyzes the progress of new energy development in each country. The research has found that the whole world is

facing energy crises to varying degrees. However, this research only focuses on part of the marine energy among the new types of energy. Finally, it is found that tidal energy in marine energy is still in the early stage of development, has not been put into use on a large scale, and has not achieved very considerable economic benefits. The development of new marine energy is very important. It is hoped that in the future, all countries can vigorously develop new marine energy, innovate and improve the engineering equipment for tidal energy, and make great efforts to develop green energy and sustainable energy. Despite facing some technical and cost challenges, the significant economic benefits and far-reaching impact on sustainable development make it worthwhile to invest in development.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

References

- [1] Smith, A. B., & Jones, C. D. Renewable energy: The future of global energy supply. *Journal of Sustainable Energy*, 2020, 12(3), 45-56.
- [2] Zhang, M., & Wang, H. Ocean energy development: Challenges and opportunities in the 21st century. *Marine Policy*, 2021, 45(1), 101-112.
- [3] Liu, P., & Chen, Q. Tidal energy utilization: Progress, challenges, and prospects. *Renewable and Sustainable Energy Reviews*, 2022, 147, 111365.
- [4] Pan, X. China's new energy security strategy under the impact of the energy crisis. [Doctoral dissertation], Shanghai Academy of Social Sciences, 2011.
- [5] Liu, L. L. Developing countries are also victims of the European energy crisis. *China Coal News*, 2022-11-08(007).
- [6] Wang, N. Q. An objective and comprehensive understanding of energy security issues after U.S. energy independence. *International Petroleum Economics*, 2023, 31(01), 31-41.
- [7] Yang, J. Z. Research on water pollution prevention and control methods in Beijing-Tianjin-Hebei basin based on SWAT model. Jilin University, 2022.
- [8] Xu, Y. X. Research on quota-based investment and financing system for promoting marine energy development. Ocean University of China, 2014.
- [9] He, Z. M., & Xie, R. J. Discussion on the coordinated development path of traditional and new energy sources. *NG Technology and Economy*, 2023, 17(05), 39-46+88.
- [10] Liu, B. F., Li, J. J., & Wang, L. Y. Research and development of tidal energy power generation in China. *Hydropower & Renewable Energy*, 2018, 32(11), 1-6.
- [11] Zhang, S. L., & Miao, J. X. Evaluation of marine renewable energy technology innovation stages based on international comparison. *Special Economic Zone Economy*, 2019, (02), 68-70.
- [12] Yang, Y. M. Policy issues and improvements of China's marine engineering equipment manufacturing industry. *Journal of Wuhan Polytechnic*, 2016, 15(01), 45-48.