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POLICY DRIVERS OF CHINA'S INTEGRATED ENERGY SERVICES: A CURRENT STATUS REVIEW

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Abstract

Conventional energy production and consumption patterns seriously restrict global sustainable development. In the energy transformation process, integrated energy services play a key role in integrating clean energy and renewing energy consumption patterns. The European Union, the United States, and Japan are leading in developing policy frameworks and integrating integrated energy services. This paper compares and analyzes how the European Union, the United States, Japan, and China respond to the challenges of energy transformation through different energy policy systems. The energy policy systems of the European Union, the United States, and Japan are discussed for reference by China. The review reveals that (1) assigning tasks based on the energy transformation strength of each region is conducive to accelerating the speed of carbon emission reduction in each region; (2) continuous government support and targeted incentives are conducive to attracting market capital, thereby stimulating the advancement of energy technology; and (3) formulating energy efficiency standards for basic equipment can lay a good foundation for energy transformation.

Keywords: Sustainable Development, Sustainable Energy, Energy Transition, Energy Systems, Regulatory Frameworks

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INTRODUCTION

Energy serves as an essential basement for both societal advancement and day-to-day living across geopolitical borders (Rosa et al., 1988). Since the advent of the Second Industrial Revolution, global economies have witnessed exponential growth, at the same time escalating the demand for fossil fuels such as coal (Atkeson et al., 2001). Such a traditional paradigm of energy production and consumption poses significant limitations on the sustainable and secure progression of the global energy landscape. Consequently, the quest for renewable energy sources that are both clean and safe is no longer optional but has emerged as an unequivocal direction for future research and development (Panwar et al., 2011; Abou Amer et al., 2023). The integrated optimization of a diversified energy portfolio thus becomes an indispensable pathway for sustainable growth (Gao et al., 2014).

To mitigate against such energy inefficiencies, energy services are imperative to diversify the avenues and overall availability of varying energy types, thereby fortifying the material infrastructure requisite for the transformation of energy resources and assets into utilizable capital (Bunse et al., 2011). Simultaneously, energy services accelerate the energy transition through technological innovation and the construction of energy networks, which are essential to facilitate green development (Li et al., 2022).

An overhaul of the existing energy systems is crucial to create a market environment that is conducive to the efficient conversion of energy assets into capital (Gray, 1996). Notwithstanding the existing initiatives, China's energy sector still lags significantly behind those of developed nations. Bridging this gap demands concerted international collaboration as well as indigenous innovation, particularly in the fields of energy technology and associated technical disciplines, to bolster China's energy security. The current energy reforms and strategic international partnerships also lay the groundwork for China's future implementation of a low-carbon development strategy (Liping, 2011). This study aims to comprehensively review the successful experiences of some developed countries, combined with the impact and effectiveness of China's existing energy policies, to help China achieve its goals of energy transformation and carbon emission reduction.

INTEGRATED ENERGY SERVICES

Integrated energy services (IES) include four aspects- energy supply, energy control system, energy consumption optimization, and integrated energy management. IES can optimize the energy supply structure, improve the energy service system, reduce energy consumption, and manage energy usage. IES can optimize the energy supply structure, improve the energy service system, reduce energy consumption, and manage energy usage, in order to achieve the goals of higher energy efficiency, lower carbon dioxide (CO_2) emissions, and stronger energy supply stability (Wu et al., 2016).

Energy supply is gradually getting rid of sole reliance on traditional energy (Luo et al., 2021). Moreover, integrating renewable energy with traditional energy can improve the reliability and sustainability of energy supply (Zawawi et al., 2024). IES, through the energy supply method that combines conventional energy with renewable energy, not only complies with changing market demands and environmental regulations but also increases the stability of energy supply to social users (Christophers, 2019). The integration of different energy forms requires a strong support framework, including energy storage systems and distributed energy architecture (Li et al., 2010). Energy storage systems are critical to mitigating supply and demand imbalances because renewable energy sources tend to be intermittent in nature (Ibrahim et al., 2008), unlike large power plants that require extensive grid infrastructure and are prone to transmission losses. Distributed energy systems are optimized for local supply. The scope of this localized supply approach could include distributed energy installations and localized "heat, cooling, and power" systems, thus increasing energy security while minimizing transmission costs and inefficiencies (Yang et al., 2015). **Figure 1** shows the IES specific components and optimization measures.

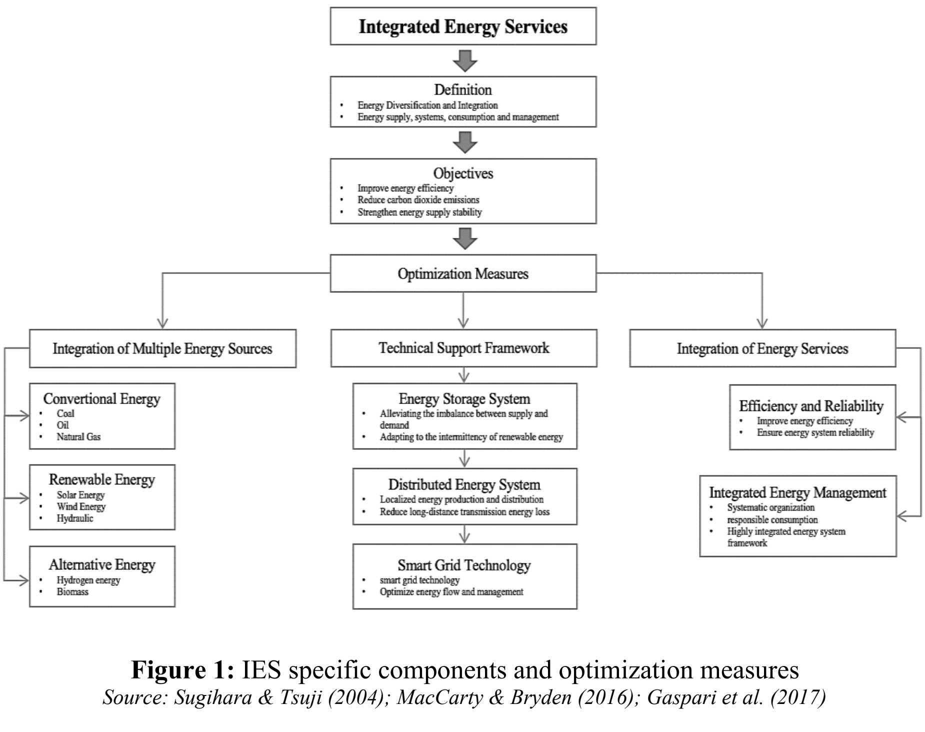

Figure 1: IES specific components and optimization measures
Source: Sugihara & Tsuji (2004); MacCarty & Bryden (2016); Gaspari et al. (2017)

ENERGY DEVELOPMENT IN DEVELOPED COUNTRIES

Before the oil crisis in the 1970s, oil was widely viewed as a cheap and abundant energy source (Stork, 1973). However, the oil crisis shattered this notion and revealed the risks of reliance on a single energy source. The oil crisis also caused a spike in oil prices, affecting global economic activity and inflation rates (Baffes et al., 2015). As awareness of oil dependence deepens, environmental and climate issues are increasingly receiving attention (Ozturk et al., 2013). Therefore, the oil crisis has prompted many countries to explore sustainable energy development to slow down climate change and environmental degradation (Roeder, 2005).

The Kyoto Protocol, established in 1997, serves as a pivotal international accord aimed at mitigating the ramifications of global climate change. The treaty mandates that participant industrialized nations, as well as select economies in transition, curtail their greenhouse gas (GHG) emissions to specified percentages below 1990 levels during the 2008-2012 period (Protocol, 1997). The Kyoto Protocol has catalyzed Western nations to expedite the proliferation and integration of renewable energy sources, including but not limited to wind, solar, hydro, and biomass energies (Omer, 2008). This has culminated not only in reducing dependency on fossil fuels but also in the market expansion for alternative energy sources, simultaneously generating employment in the green sector.

The Paris Climate Agreement, formalized in 2015, represents a cornerstone of international climate policy. The Agreement's strategies include expediting carbon neutrality, fostering renewable energy investments, advancing energy services, and prioritizing climate-related concerns in developing nations (UNFCC, 2024). The EU's 2019 "European Green Deal" plans for the EU to reduce net GHG emissions by at least 55% compared with 1990 in 2030 and strive to become the first climate-neutral continent by 2050 (Fetting, 2020). In terms of investment in renewable energy, the Paris Climate Agreement recognizes the increase in renewable energy targets and the concept of a carbon trading mechanism. Therefore, a large amount of capital flows into renewable resources such as wind energy, solar energy, hydropower, and geothermal energy in Western developed countries (Ram et al., 2022). The Paris Climate Agreement responds to the impact of climate change by strengthening the environmental protection responsibilities of Western developed countries and providing financial and technical support to developing countries in areas such as renewable energy development (Peake & Ekins, 2017). **Figure 2** shows the energy development timeline after the oil crisis in 1970.

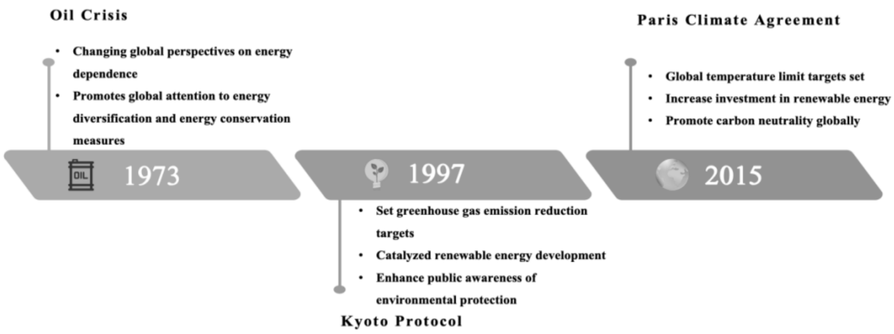

Figure 2: Energy development timeline after 1970
Source: Klimenko & Tereshin (2019)

COMPARISON OF MAIN ENERGY POLICIES IN EU, US, JAPAN AND CHINA

This study extensively compares the energy service policies between China and three developed regions- the EU, the US, and Japan. It explores how these policies promote renewable energy development and improve energy efficiency, highlighting the differences and potential lessons for China. By comparing their policy evolution and achievements in different years, the impact of these policies on promoting sustainable energy development and improving energy efficiency is evaluated (Sorrell, 2007; Saidur et al., 2010; Abdmouleh, 2015).

In the EU context, frameworks such as the "2020 Climate and Energy Package" and the "European Green Deal" unequivocally underscore a robust commitment to both renewable energy sources and energy efficiency (IEA, 2021). Such legislative enactments have increased a propitious market ecology, enabling IES enterprises to offer holistic solutions encompassing energy provision, demand-side governance, and combining renewable resources. In contrast, US policies, exemplified by initiatives such as the Clean Power Plan, Energy Policy Act, and Corporate Average Fuel Economy Standards, have sought to encourage the renewable energy marketplace and enhance the competitive standing of energy service corporations (U.S. EPA, 2024). These policies have achieved this through fiscal mechanisms, including tax exemptions and escalated investment initiatives, thereby diversifying the energy technologies and business model options available for renewable energy and IES development. Japan, meanwhile, has emphasized energy security and technological innovation as the cornerstones of its Strategic Energy Plan and Basic Energy Plan (Ministry of ETI Japan, 2024). Particularly in the post-Fukushima landscape, Japanese policy has increasingly gravitated toward the exploration of alternative, secure, and reliable energy modalities, such as hydrogen energy. Consequently, Japanese IES has preferred efficient, resilient, and agile systems accommodated to the nation's unique geographic and economic settings. Notably, Japan's investment in research and development for renewable energy and distributed energy systems has offered cutting-edge technological underpinning for its energy services.

In China, the government usually promotes the development of IES through a series of "five-year plans". The government attracts social enterprises to participate in construction through national guidance documents, financial support, and national pilot project initiatives. In addition, the government raises public awareness of comprehensive energy services and sustainable energy development through the promotion of policy documents (NEA of China, 2024). Thus, in the face of the global challenge to catalyze sustainable energy progression, the policy systems of the US, the EU, and Japan offer invaluable referential frameworks for conceptualizing and implementing China's own IES policies. Each of these three economic powerhouses boasts an extensive repository of experiential wisdom and lessons learned in the domains of energy policy articulation, the incentivization of renewable energy sources, and the cultivation of IES- a corpus of knowledge from which China stands to derive considerable insights. **Table 1** shows Energy Policies in the EU, the US, Japan, and China.

Table 1: Energy Policies in the EU, the US, Japan, and China

EU	USA	Japan
➢ 2020 climate and energy package (2007) ➢ EU energy efficiency directive（2012） ➢ 2030 Climate and Energy Framework (2014) ➢ EU energy efficiency directive（2018） ➢ Sustainable and smart transport strategies (2020) ➢ Green Deal (2023)	➢ Energy Policy Act (2005) ➢ Energy Independence and Security Act (2007) ➢ American Recovery and Reinvestment Act (2009) ➢ Clean Power Plan（Abolished in 2017） ➢ Inflation Reduction Act (IRA) (2022)	➢ Top Runner Program (1998) ➢ Japan's carbon trading system (2010) ➢ Japanese Feed-in Tariff Scheme for Renewable Energy (2012) ➢ Hydrogen Strategy (2017) ➢ Strategic Energy Plan（6th）(2022)
China		
➢ Notice on Further Promoting the "Contract Energy Management Mechanism" (2000) ➢ Interim Measures for the Management of Financial Incentive Funds for Contract Energy Management (2010) ➢ Several opinions on further deepening the reform of the electric power system (2015) ➢ Key points of industrial energy conservation and comprehensive utilization in 2018 ➢ Energy work guidance in 2021 ➢ Guiding Opinions on Energy Work in 2022 ➢ "14th Five-Year Plan" Modern Energy System Planning (2022)		

Source: European Commission; U.S. Environmental Protection Agency; Ministry of Economy, Trade and Industry, Japan; International Energy Agency; National Energy Administration of China.

In summary, the EU allocates different energy transformation and emission reduction tasks to its member states based on the development conditions of member states through framework agreements such as the Green New Deal. The US, in turn, facilitates the development of large-scale solar and wind energy projects and encourages social enterprises and residents to choose environmentally friendly energy equipment, such as household photovoltaics and new energy vehicles, through tax exemptions and other means. Japan is gradually improving the energy efficiency of specific products and equipment through its strategic energy plan. China's energy policy promotes national documents and funding to support China's energy transformation through a series of five-year plans and pilot projects. Through the operation of pilot projects, the cooperation and coordination between government agencies and social enterprises are deepened to accelerate the development and innovation of China's energy system.

COMPARISON OF MAIN EMISSION REDUCTION ACHIEVEMENTS IN THE EU, US, JAPAN AND CHINA

Building on the policy comparisons, this section evaluates the emission reduction achievements of the EU, the USA, Japan, and China. Examining their renewable energy capacities, clean energy consumption percentages and CO_2 emissions reduction targets of these regions will provide a clear understanding of the effectiveness of their distinct approaches. This comparison provides valuable insights into how different policy frameworks translate into tangible progress in emission reductions.

The EU's renewable energy capacity stands at 705.8 GWh, with a clean energy consumption percentage of 31.6%. The EU has set a CO_2 emissions reduction target of 55% by 2030. The EU has made the most significant progress in reducing total carbon emissions, achieving 47.13 billion tons in 2020, down from 56.0 billion tons in 2010. The EU's investment in carbon reduction as a percentage of GDP is -2.8%, demonstrating the effectiveness of its stringent regulatory frameworks and coordinated efforts across member states in driving substantial emission reductions. Meanwhile, the USA has achieved a renewable energy capacity of 305 GWh and a clean energy consumption percentage of 22%. Its CO_2 emissions reduction target by 2030 is 50%. The total carbon emissions in the USA were 26.15 billion tons in 2020, down from 34.0 billion tons in 2010. The US's investment in carbon reduction as a percentage of GDP is -1.8%. These achievements are driven by fiscal incentives and technological diversification, promoting renewable energy through tax exemptions and increased investment initiatives. Notably, Japan's renewable energy capacity is 105 GWh, achieving a clean energy consumption percentage of 20.3%; its target is a 50% reduction in CO_2 emissions by 2030. Japan's total carbon emissions in 2020 were 10.46 billion tons, down from 12.0 billion tons in 2010, with an investment in carbon reduction as a percentage of GDP at -0.8%. Significantly, Japan has excelled in improving energy efficiency, achieving high energy utilization despite its smaller renewable energy capacity. This reflects Japan's policy emphasis on technological innovation and energy efficiency.

Correspondingly, China boasts the highest renewable energy capacity at 1213 GWh and the highest clean energy consumption percentage at 47.3%. China has set an ambitious target of a 65% reduction in CO_2 emissions by 2030. In 2020, China's total carbon emissions were 106.68 billion tons, up from 91.0 billion tons in 2010. Its investment in carbon reduction as a percentage of GDP is -4.5%. While China has made impressive progress in renewable energy capacity and clean energy consumption, the substantial scale of its carbon emissions underscores the need to learn from the successful policies of the EU, USA, and Japan to continue making strides in emission reductions. Accordingly, **Table 2** presents data on renewable energy capacity, clean energy consumption percentages, investment in Carbon reduction as a percentage of GDP, total carbon emissions (2010 and 2020), and target CO_2 emissions reductions by 2030 for the EU, the USA, Japan, and China. **Figure 3** presents comparisons of renewable energy capacity, clean energy consumption percentages, investment in carbon reduction as a percentage of GDP, and total carbon emissions (2010 and 2020) among the EU, the USA, Japan, and China.

Table 2: Key Metrics of Renewable Energy and Carbon Reduction Efforts in EU, USA, Japan, and China

	EU	USA	Japan	China
Renewable Energy Capacity (Unit: GWh)	705.8	305	105	1213
Clean Energy Consumption Percentage (%)	31.6	22	20.3	47.3
Investment in carbon reduction as a percentage of GDP (%)	-2.8%	-1.8%	-0.8%	-4.5%
Total carbon emissions (2010) (Unit: 100 million tons)	56.0	34.0	12.0	91.0
Total carbon emissions (2020) (Unit: 100 million tons)	47.1	26.2	10.5	106.7
Target CO_2 Emissions Reduction by 2030 (%)	55	50	50	65

Source: World Bank 2021 ; The United Nations Economic Commission for Europe 2020; International Ener gy Agency 2021

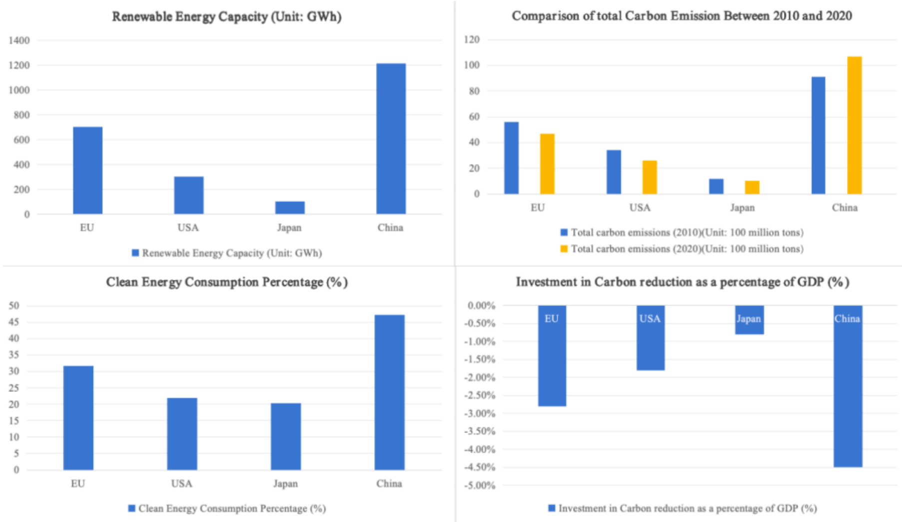

Figure 3. Comparative Analysis of Renewable Energy and Carbon Reduction Efforts among the EU, the USA, Japan, and China
Source: Fragkos et al. (2021) IEA (2021) World Bank (2021) UNECE (2021)

Lamentably, China's carbon emissions from 2010 to 2020 have continued to rise, in contrast to the trends observed in the EU, USA, and Japan. Despite substantial investments in carbon reduction, the highest renewable energy capacity, and the highest clean energy consumption percentage, China's total carbon emissions increased from 91.0 billion tons in 2010 to 106.7 billion tons in 2020. This rise highlights a significant challenge, i.e., even with aggressive renewable energy initiatives and substantial investment in carbon reduction, the total emissions have continued to grow. This stands in significant contrast to the other regions, which have seen reductions in their carbon emissions over the same period.

The EU, USA, and Japan have attained notable successes through their unique policy approaches, and China has also achieved significant progress in renewable energy capacity and clean energy consumption. The EU leads in total carbon emissions reduction, Japan excels in energy efficiency, and the USA demonstrates effective fiscal incentives and technological diversification. From 2010 to 2020, China's carbon emissions increased significantly, whereas the EU, USA, and Japan managed to reduce their total carbon emissions. This indicates that despite China's efforts, additional strategies and policy adjustments are necessary to reverse the trend of rising emissions. China leads in renewable energy capacity, clean energy consumption percentage, and investment in carbon reduction as a percentage of GDP. As these efforts have not yet translated into a reduction in total carbon emissions, China continues to move toward its carbon reduction and energy transition goals by drawing on these countries' rich experiences and best practices to improve its policies further.

POLICY RECOMMENDATION

According to the comparisons, the EU, the US, and Japan have different policy designs and priorities for IES. Their significant contributions to global climate change offer valuable lessons for China.

Firstly, the EU's "Climate and Energy Framework" and Japan's "Strategic Energy Plan" are constantly updated to improve the development strategy of integrated energy services. Through evolution, these policy frameworks address the issues of sustainable energy development and supply. Moreover, during the evolution process, these policies will continuously adjust emission reduction targets based on the member states' and regions' energy transformation capabilities.

Secondly, the EU's electricity market integration plan and the US Renewable Energy Finance Act both improve energy efficiency by stimulating related markets for IES and renewable energy. At the same time, both the EU and the US attach great importance to public participation. Social media and other means can absorb public feedback on energy transition policies and efficiency improvement and enhance public awareness of sustainable development. These frameworks promote technological upgrading and innovation in IES-related industries. It also ensures that policy development meets public needs and sustainable development goals.

Thirdly, the US and Japan have provided China with rich policy cases in terms of energy portfolio diversification and energy efficiency priority. The US encourages businesses and residents to give priority to renewable energy equipment through tax relief and other bills, thereby promoting the development of a diversified energy supply in society. Through policies and standards, Japan imposes mandatory requirements on the energy efficiency of the equipment itself. The above cases provide China with policy-making directions and solutions when dealing with complex energy transitions and efficiency improvements.

CONCLUSION

Since the oil crisis in the 1970s, developed countries have gradually realized the importance of developing renewable energy and improving energy efficiency. Therefore, they began to improve energy service solutions by gradually formulating corresponding energy policies and ultimately achieving the goal of reducing CO_2 emissions and mitigating global climate change. IES provides excellent energy service solutions. This energy service model includes energy supply, energy system, energy consumption, and energy management. IES achieves energy sustainability goals by integrating multiple energy sources (including traditional energy and renewable energy), improving the level of energy supply in the energy system, reducing energy consumption, and optimizing energy management. The signing of international agreements such as the Kyoto Protocol and the Paris Agreement marks that the international community has officially set sustainable energy development and carbon emission reduction as global goals. China, as the largest developing country, has also begun to promote changes in its energy industry after the Kyoto Protocol. Since then, China has also listed IES as an essential way to achieve energy transformation and energy efficiency improvement to achieve this goal.

By analyzing and comparing the different policy systems of the EU, the US, and Japan, in response to the challenges of energy transformation, this study proposes references that are significant for China's energy policy system. The study shows that the energy frameworks and plans of the EU and Japan have been continuously updated to improve the development strategy of IES and solve the problem of sustainable energy development and supply. The US and Japan provide rich policy cases in terms of energy portfolio diversification and energy efficiency priority. Moreover, the US encourages enterprises and residents to give priority to renewable energy equipment through tax relief and other bills, which promotes the development of a diversified energy supply. Correspondingly, Japan has put forward mandatory requirements for equipment energy efficiency through policies and standards. These experiences provide China with policy formulation directions and solutions in dealing with complex energy transformation and efficiency improvement. By learning from the successful experiences of these developed countries and regions, China can further improve its own energy policy system and better achieve its emission reduction goals.

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