

**CHINA'S EAST TOKAMAK PROGRAM AND THE EFFECTS OF FUSION ENERGY ON
ENERGY IMPORT DEPENDENCY: A STRATEGIC ASSESSMENT FOR TÜRKİYE**Lecturer Hayriye TAŐCI (Ph.D.)^{*} **ABSTRACT**

This study assesses the implications of fusion energy for energy-import-dependent economies by examining China's Experimental Advanced Superconducting Tokamak program and its relevance for Türkiye. A qualitative research design is employed, combining a systematic review of scientific literature, technical reports, and official data with a comparative, scenario-based analytical framework. The findings show that progress in fusion technology is strongly linked to institutional capacity, long-term science and technology policies, and sustainable financing arrangements. Fusion energy offers potential advantages for long-term supply security, price stability, resource diversification, and low-carbon transition goals. Given Türkiye's high dependence on imported natural gas and its exposure to external shocks, fusion should be viewed as a strategic long-term option rather than an immediate solution. The study concludes that early engagement in fusion research and international cooperation can improve technological preparedness and support future energy security and macroeconomic resilience.

Keywords: Fusion Energy, EAST Tokamak, Energy Import Dependency, Energy Security, Türkiye.

JEL Codes: Q40, Q48, Q33.

1. INTRODUCTION

Global energy systems have undergone a significant transformation over the past two decades due to both increased demand and vulnerabilities on the supply side. The current fossil fuel-based structure is becoming increasingly unsustainable due to price volatility, geopolitical tensions, and climate change pressures. Projections by the International Energy Agency indicate that energy demand will continue to grow, particularly in Asia, while emission pressures will necessitate structural changes in energy production technologies (IEA, 2023). This scenario has led to a rapid increase in interest in new generations of low-carbon, high-efficiency energy technologies.

One of the most notable aspects of this transformation is the renewed focus on fusion energy, which has been the subject of theoretical and experimental studies for many years. Controlled use of

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fusion reactions, similar to those occurring in the Sun, for energy production is being discussed as an important alternative due to its high energy density, relatively abundant fuel source (especially deuterium), and carbon-free nature. Tokamak-type reactors based on magnetic confinement represent the most advanced experimental platforms in this field. Experiments conducted at facilities such as JET Joint Undertaking, KSTAR Research Center, and EAST Team have produced promising results regarding the technical feasibility of fusion (Lindley, Roulstone, Locatelli and Rooney, 2023; Song, Zou, Gong, Becoulet and Buttery, 2023). However, fusion technology is not yet mature enough to provide energy production on a commercial scale; therefore, discussions in this field are largely conducted based on medium- and long-term scenarios.

The economic and energy policy dimensions of fusion energy have received relatively limited attention in the literature. While a significant portion of studies focus on technical issues such as plasma physics, magnet technologies, and reactor engineering, research on what fusion could mean for energy-importing countries is relatively scarce. However, economies with high energy imports are more vulnerable to fluctuations in fossil fuel prices and supply shocks. In countries such as Türkiye, where energy demand is increasing and a large portion of supply is met from external sources, the potential contribution of fusion to long-term energy security discussions needs to be addressed within an analytical framework. This need makes it imperative to evaluate fusion technology not only as a technical issue but also as an economic and strategic one (TCMB, 2021; Özlale and Pekkurnaz, 2010).

This study aims to examine the potential effects of fusion energy on global energy markets and its significance for Türkiye, focusing on the tokamak-based program of China, one of the leading countries in fusion research. China's fusion program, centered around the EAST tokamak, provides a noteworthy example in terms of both experimental results and institutional structure. Examining this example provides important clues as to how fusion technology can be developed within a science policy, financing model, and international cooperation framework (EAST Team, 2024; Hu et al., 2023). Based on this experience, the study proposes a unique assessment framework for Türkiye called the "Türkiye Tokamak Energy Strategy (TTES)" and discusses how fusion could present a set of opportunities in the medium and long term for an economy with high energy import dependency.

In this context, the article first outlines China's fusion strategy and the EAST program, then discusses the potential impacts of fusion on global energy markets and countries with high import dependency. It then evaluates the opportunities that fusion could create within the framework of Türkiye's energy supply structure and natural gas dependency. The final section presents policy recommendations and general conclusions based on the TTES approach. The main contribution of the study is that it takes fusion energy beyond the technical literature and addresses it from a holistic perspective in terms of energy imports, macroeconomic fragility, and long-term energy security.

2. METHOD

This study is based on a qualitative research design aimed at examining the potential impacts of fusion technology in the context of energy import dependency. A two-stage method was adopted in the research process. In the first stage, China's institutional structure in fusion research, its financing model, and the experimental findings obtained in the EAST tokamak program were examined through a literature review; scientific articles, technical reports, and official laboratory records were used as primary data sources. In the second stage, the potential impacts of fusion energy on countries that are major energy importers were evaluated from a comparative perspective, and an analytical scenario framework was developed specifically for Türkiye in terms of long-term energy security. Data on Türkiye's natural gas imports were compiled from accessible data sets of international and national institutions such as the IEA, BP Statistical Review, and EPDK; graphical representations were prepared using these data. This method enabled a comprehensive analysis linking the technical dimensions of fusion energy with economic and strategic assessments.

3. CONCEPTUAL FRAMEWORK

The relationship between fusion energy and the energy policy and macroeconomics literature forms the basic conceptual framework of the study. This framework is based on three main axes: energy security, technology and innovation economy, and macroeconomic vulnerabilities based on energy imports. The first axis, energy security, includes elements such as the continuity of energy supply, price stability, and the management of external dependence. Energy security issues become more pronounced in countries with high import dependency, and international fluctuations in oil and natural gas prices create pressure on the economy. Therefore, the evaluation of alternative technologies based on domestic production capacity, such as fusion, has become an integral part of long-term energy policies (IEA, 2023).

The second axis, the technology and innovation economy, emphasizes that fusion research is a multi-layered process requiring not only scientific but also institutional and financial capacity. Fusion technology has a structure that advances through the convergence of materials science, high-temperature physics, superconducting technologies, and advanced control systems. Therefore, countries with strong technology development capabilities gain a competitive advantage in fusion research. China's EAST tokamak program provides an important example of the impact of planned R&D investments and interdisciplinary collaboration on technological progress (Song et al., 2023; Hu et al., 2023). In this regard, the development of fusion depends not only on physical experiments but also on a holistic innovation ecosystem.

The third axis is understanding macroeconomic vulnerabilities based on energy imports. Global movements in energy prices have a direct impact on inflation, current account deficits, and production costs, particularly in countries with high dependence on natural gas imports. In the case of Türkiye,

various studies have shown that natural gas imports exert significant pressure on economic indicators, with price increases quickly reflected in both consumer prices and the trade balance (TCMB, 2021; Özlale and Pekkurnaz, 2010). Therefore, ensuring diversity in energy supply and increasing resilience to external shocks is of critical importance for macroeconomic stability. In addition to price volatility effects, empirical evidence for Türkiye also demonstrates a long-term relationship between energy consumption and economic growth. Yapraklı (2010) finds cointegration between energy use and output, suggesting that energy dependency is structurally embedded in macroeconomic performance. This finding implies that external energy shocks may have persistent effects on growth dynamics in energy-importing economies such as Türkiye.

When these three conceptual axes are evaluated together, a natural link emerges between the technical characteristics of fusion energy and its effects on energy policy and the economy. The analytical framework of the study is based on evaluating this connection through both global examples and the Türkiye perspective. In this way, the potential contributions of fusion are considered not only as a technological innovation but also in the context of energy security and reducing economic fragility.

4. LITERATURE REVIEW

The literature on fusion energy has long been concentrated primarily in the fields of plasma physics, magnetic confinement technologies, and reactor engineering. Studies on the physical limits of tokamak-based systems, achieving stable plasma, and the performance of superconducting magnets constitute the fundamental sources shaping the technical dimension of fusion research. In their study comparing magnetic confinement designs, Huang and Li (2018) emphasize that critical elements such as plasma stability and material durability must be improved for fusion to become a viable long-term energy production technology. More recent assessments indicate that tokamak platforms have made faster progress compared to other fusion technologies, thanks to their research capacity supported by international collaborations (Zohm, 2015).

Studies on experimental tokamak systems such as EAST, KSTAR, JET, and WEST detail the progress made in superconducting magnets and long-duration plasma production. Hu (2023) states that EAST has gained a significant advantage in long-duration plasma experiments thanks to its fully superconducting structure and that these experimental results are used as a direct reference in the ITER design. The high-temperature and long-duration plasma experiments reported by Song et al., (2023) are also among the important indicators of the applicability of fusion. The technical reports of the EAST Team (2024) show that the data obtained is openly available to international researchers and strengthens China's capacity for knowledge sharing in this field. Recent bibliometric and patent trend analyses of tokamak research from 2014 to 2024 reveal that China has emerged as a leading producer of fusion research publications, while other significant contributors include countries in Europe, Japan, and South

Korea; these analyses further show that international collaboration networks have expanded markedly over the past decade (Chang, 2025).

The literature on energy imports and macroeconomic vulnerabilities takes a different perspective. Numerous studies examine the effects of increases in fossil fuel prices on the current account, inflation, and growth, particularly in energy-importing economies. Empirical analyses conducted on Türkiye show that changes in oil and natural gas prices have rapid and significant effects on macroeconomic indicators. Özlale and Pekkurnaz (2010) emphasize that increases in energy prices quickly disrupt Türkiye's current account balance, while the Central Bank of the Republic of Türkiye (CBRT, 2021) has highlighted the effects of oil price volatility on financial markets and borrowing costs. Findings that energy imports increase economic vulnerability make it understandable that countries with high energy dependence, such as Türkiye, are increasingly interested in alternative energy technologies.

When evaluating the general framework of the current literature, it is seen that while technical studies on fusion energy are quite comprehensive, studies discussing what fusion means for countries dependent on energy imports are limited. Similarly, although there is significant literature on energy policies and economic vulnerabilities in Türkiye, there are no analytical studies addressing fusion in this context. This study aims to fill this gap; it contributes to the literature by relating the experiences gained from China's fusion program to Türkiye's energy dependency dynamics.

5. CHINA'S FUSION STRATEGY AND EVALUATION OF THE EAST PROGRAM

The progress China has made in fusion research in recent years demonstrates that fusion energy is increasingly prioritized among the country's science and technology policies. National research programs led by the Chinese Academy of Sciences (CAS) position fusion not only as a scientific pursuit but also as a strategic investment area related to energy supply security, carbon neutrality goals, and high-tech production. Experimental developments within the EAST tokamak program reflect this institutional commitment. Wan and EAST Team (2020) report significant advances in high β_p plasma performance and steady-state operational strategies, indicating the presence of coordinated long-term research planning and large-scale scientific infrastructure. This approach reveals that fusion research is part of a broader technology development ecosystem supported by state-led scientific programs and interdisciplinary collaboration.

The EAST tokamak, at the heart of the fusion program, is one of the most important indicators of the country's capacity in this field. Designed with a fully superconducting magnet structure, the device can provide the stable magnetic environment necessary for conducting long-term plasma confinement experiments. Technical assessments of EAST indicate that the device's geometry and magnetic control systems have been optimized for long-term operating conditions. Hu (2023) demonstrates that this structural design offers significant advantages in terms of high-temperature operation and reduced energy losses.

Experiments conducted on EAST in recent years provide strong findings that reduce uncertainties regarding the applicability of fusion technology. Song et al., (2023) report achieving plasma confinement times approaching 1,000 seconds at temperatures of approximately 100 million °C; this progress is considered a direct reference to the operating conditions required in ITER and similar large-scale reactor designs. Recent records published by the EAST research team also show that stable H - mode discharges exceeding 400 seconds can be repeated and that these experimental results have been shared with the global research community (EAST Team, 2024).

The strength of China's fusion strategy lies not only in technical advances but also in the integrated execution of research with national energy and industrial policies. The multidisciplinary structure created in areas such as materials science, superconducting technologies, control algorithms, and high-performance engineering strengthens China's domestic technology production capacity and solidifies fusion's place in the national innovation strategy. Chang (2025) bibliometric review reveals that China has significantly increased both its publication output and international collaboration network in fusion/research over the past decade.

From an energy policy perspective, China's shift towards fusion is driven by key factors such as energy supply security, carbon neutrality targets, and reducing dependence on fossil fuels. IEA (2023) data shows that China ranks among the world's largest oil and natural gas importers and has an energy structure that is vulnerable to global price shocks. Therefore, fusion is not only an area of technical success ; it is also considered a strategic tool in terms of diversifying the energy portfolio, reducing external dependence, and creating sustainable long-term supply capacity. Furthermore, fusion research supports domestic production capacity in areas such as materials engineering and superconducting technologies, which is also consistent with high value-added industrial policies (Carayannis, Draper and Bhaneja, 2021).

Overall, the Chinese experience demonstrates that the development of fusion energy is not solely dependent on technical advances at the laboratory scale; it is a multi-layered process requiring institutional stability, interdisciplinary collaboration, continuous funding, and long-term strategic planning. This framework provides an important reference point for how fusion can become a policy component for countries with high energy import dependency.

6. THE IMPORTANCE OF FUSION FOR COUNTRIES WITH HIGH IMPORT DEPENDENCY

Countries that are highly dependent on energy imports are directly affected by price fluctuations and supply shocks in global energy markets. The vast majority of these countries exhibit a structure characterized by rapidly growing energy demand, limited domestic production capacity, and dependence on specific regions for fossil fuel supplies. Data from the International Energy Agency shows that many economies in Asia and Europe are heavily dependent on external sources, particularly for natural gas

and oil imports (IEA, 2023). Therefore, long-term supply security and economic stability are central to the policy priorities of energy-importing countries.

Although not yet commercialized, fusion energy is considered a strategic option for the future for countries with high import dependency. The main reason for this is that the fusion fuel cycle is largely independent of global geopolitical risks. The widespread availability of deuterium in seawater and the high energy density offered by fusion reactions create the potential to strengthen countries' long-term supply security. These characteristics are particularly important in economies dependent on natural gas and oil imports in terms of reducing price volatility and limiting supply risks.

Japan, South Korea, Italy, Germany, and Türkiye stand out among countries with high energy demand. These countries share the common characteristics of having limited fossil fuel resources and meeting a large portion of their energy consumption through imports. For example, Japan and South Korea support their energy systems with fossil fuels that are almost entirely imported, while European countries are dependent on supply chains centered on Russia and the Middle East. Price shocks in these countries are quickly reflected in economic indicators; inflation, current account balance, and production costs are directly affected. This vulnerability highlights the importance of diversifying the energy portfolio.

Assuming that fusion technology can contribute to energy supply in the medium and long term, these countries could gain significant benefits in terms of energy security. If fusion becomes commercialized, both production costs becoming largely independent of foreign markets and supply becoming uninterrupted could fundamentally change the energy strategies of import-dependent countries. Furthermore, the carbon-free nature of fusion will support long-term energy transformation in line with climate policies.

In this context, although fusion energy is not seen as a short-term solution for countries with high import dependency, it has the potential to strengthen economic stability in the long term. As the transformation of global energy markets accelerates, it is becoming a medium-term strategic necessity for these countries to participate in fusion research, engage in technology transfer processes, and strengthen international cooperation.

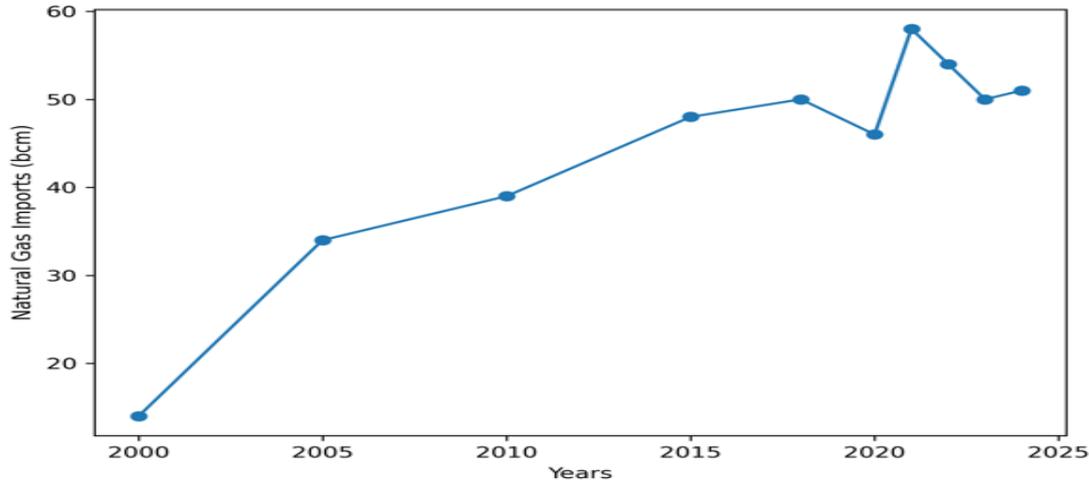
7. STRATEGIC AND ECONOMIC SCENARIO FOR TÜRKİYE

One of the most distinctive features of Türkiye's energy supply structure is the high share of natural gas in energy consumption and the fact that almost all of this source is met through imports. Natural gas, which has become a critical input in electricity generation, residential consumption, and industrial activities, makes Türkiye highly sensitive to global price movements and supply shocks. Data from the International Energy Agency (IEA) and EPDK show that Türkiye's natural gas imports have created a long-term structural dependency, particularly due to increasing demand over the last twenty

years. This dependency exerts significant pressure on macroeconomic indicators such as the current account balance, inflation, and budget balance.

The long-term trend in Türkiye's natural gas imports highlights the fragility of energy supply security. The data in the graph below clearly shows the continuing upward trend in natural gas imports since the early 2000s. Despite fluctuations in demand in recent years, natural gas imports have remained high, and dependence on external energy supplies has remained a fundamental policy issue.

Figure 1. Türkiye's Natural Gas Imports (2000-2024)



Source: EPDK (2024), BP Statistical Review (2023), IEA Natural Gas Data.

The trend shown in the graph indicates that natural gas will continue to play a significant role in Türkiye's energy strategy for a long time. This situation causes global volatility in energy prices to be quickly reflected in economic indicators. Considering natural gas's share in electricity production in particular, price increases inevitably create high pass-through to inflation. Similarly, the energy bill exerts persistent pressure on Türkiye's foreign trade balance. Therefore, alternative energy technologies play a critical role not only in terms of environmental goals but also in terms of economic stability and reducing external dependency.

Although fusion energy has not yet reached the commercialization stage, it can be considered a strategic option for Türkiye in long-term energy security discussions. The widespread availability of deuterium, the basic fuel for fusion, and the fact that the production process is not affected by external geopolitical conditions, can contribute to ensuring supply diversity in Türkiye's energy portfolio. Furthermore, the potential advantage fusion offers in terms of price stability can limit macroeconomic vulnerabilities by increasing the predictability of energy costs.

Türkiye's direct integration into fusion technology does not seem feasible in the short term; however, participation in international projects, the development of research capacity, and steps towards technology transfer could strengthen its position in this field in the medium term. Considering the

economic pressures created by natural gas dependency, fusion energy is thought to be able to play a supporting role in long-term energy strategies.

In this context, the scenario for Türkiye should be approached from the perspective of technological preparedness, institutional capacity building, and strategic positioning, rather than a future scenario in which fusion makes a direct contribution to the energy system. Such an approach will both strengthen energy supply security and create a long-term policy framework aimed at reducing external dependence.

8. DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

This study aimed to evaluate the potential role of fusion energy in the global energy system using the example of China and to analyze what kind of strategic consequences this could have for countries that are highly dependent on energy imports. The findings generally show that, although fusion is not yet a commercialized technology, it has significant potential in the context of long-term energy security, supply diversity, and price stability. China's research model, centered around the EAST program, demonstrates that fusion energy must be supported not only by technical advances but also by institutional structures, interdisciplinary collaboration, and sustainable financing policies. This approach serves as a guide for countries that view fusion technology as a future-oriented energy investment.

When evaluated from the perspective of economies dependent on energy imports, the economic repercussions of fluctuations in global energy prices are evident. In the case of Türkiye, natural gas's high share in electricity production and its import-intensive structure cause movements in energy prices to have a rapid and powerful impact on both inflation and the foreign trade balance. Therefore, evaluating fusion energy as a long-term supply security component is not only a technical innovation expectation but also carries significance in terms of reducing economic vulnerabilities. The low fuel cost of fusion, its independence from geopolitical risks to a large extent, and its ability to provide uninterrupted production offer important advantages that can increase the resilience of the energy system against external shocks.

Within this framework, the main findings of the study can be summarized in three key points. First, as seen in China's fusion strategy, progress in this field requires the harmonious establishment of science policy, institutional capacity, and technical infrastructure. Second, the potential impact of fusion technology on global energy markets represents a strategic opportunity for energy-importing countries, particularly in terms of reducing price volatility and strengthening supply security. Thirdly, although the direct contribution of fusion technology in the short term is limited in countries with high natural gas dependency such as Türkiye, it is important to initiate the preparatory phase for diversifying the energy portfolio in the medium and long-term.

In light of these assessments, policy recommendations are shaped around two axes. The first axis is geared towards strengthening technology and institutional capacity. It is critically important for Türkiye to train human resources specialized in plasma physics, superconducting technologies, and advanced engineering; to develop cooperation between research centers, universities, and industrial organizations; and to establish closer ties with international fusion projects. The second axis relates to energy security strategies. Rather than positioning fusion as a direct source of production in Türkiye's long-term energy policies, it would be a more realistic approach to focus on establishing a preparatory process that will enable adaptation to future technological transformations. This process can make a strategic contribution in terms of diversifying energy supply, reducing external dependency, and supporting the transition to a sustainable energy system.

In conclusion, although fusion energy will not play a decisive role in the current energy system in the short term, it may become an important option in the future in terms of energy security and economic stability. China's experience shows that this technology is not merely a scientific goal but a national strategic area requiring long-term planning. Developing a similar perspective in Türkiye will both increase the flexibility of its energy policies and enable it to maintain its competitive strength in a period of accelerating international energy transformation.

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