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International projects on energy and science career opportunities[1]

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Abstract

While there are alarming developments in climate and energy all over the world, there are also exciting developments in the fields of renewable and sustainable energy. Clean energy sources are seen as one of the essential solutions to environmental pollution and the climate crisis. Considering the climatic changes, the point of no return has been reached, and all living life is endangered ecologically and economically. In this context, we can state that interest in technologies based on solar energy, one of the clean energy sources, is increasing. Artificial Solar Energy (fusion energy) has offered humanity a safe, clean, sustainable, and non-intrusive option in recent years. Especially against the energy crisis that will occur in the coming years, experts draw attention to the consequences of nuclear fusion (Artificial Solar Energy) energy, which is expected to be activated in a few decades, in social, economic, and educational systems. Artificial Solar Energy (fusion technology) is a bright candidate, representing an infinite form of energy that is free from the dangers of pollution and nuclear explosions and has an abundance of fuel. The power of energy to close an era in the past and open a new one continues today with the Energy 4.0 version, heralding the beginning of a new era. This presents several career opportunities for both science education and science graduates. For these reasons, the career opportunities that such projects, which many states cooperate with and support, can offer through science education are intriguing. This study, which is a vision paper, focuses on career opportunities in science education and provides information on Artificial Solar Energy, fission and fusion reactions, EAST, and ITER projects.

1 Introduction

The limited energy resources worldwide, the harmful effects of fossil fuels on the environment, and the increasing need for energy with developing technology have increased the tendency towards renewable energy sources (Morse, 2018). Waste-free, clean energy is one of the most

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essential goals of renewable energy technology. In the near future, energy demand is expected to increase, especially from developing countries and non-OECD (Countries that are not members of the Organization for Economic Co-operation and Development) sectors (Figure 1). As per the 2021 report from the US Energy Information Administration, it is projected that 2050 global energy consumption in the baseline scenario will surge by approximately 50% compared to the levels recorded in 2020. This substantial increase is primarily attributed to the economic expansion of non-OECD countries and the concurrent population growth, particularly in the Asian region. Considering the climatic changes, the point of no return has been reached, and all living life is endangered ecologically and economically (Aengenheyster et al., 2018). For the specified reasons, many institutions and legal entities, from scientists to energy organizations and government ministries, have been supporting projects in recent years. Developing a safe, clean, non-intrusive, and sustainable energy source would be widely embraced within the global community. In this context, we can state that interest in technologies based on solar energy, which is one of the clean energy sources, is increasing (Khan & Arsalan, 2016). Especially in the face of the energy crisis in the coming years, experts draw attention to nuclear fusion energy (Artificial Solar Energy), which is expected to become operational in the first few decades (Sinman & Sinman, 2000). Artificial Solar Energy (fusion technology) is a bright candidate, representing an infinite form of energy, free from dangers such as environmental pollution and radioactive explosions, and with an abundance of fuel (Sinman & Sinman, 2000). The power of energy to close an era and open a new one in the past continues today with the Energy 4.0 version and heralds the beginning of a new era. The states with a say in this technology are expected to control energy in the future, in other words, to steer the world. So, this study focuses on the developments in energy in recent years. Since energy constitutes a locomotive power worldwide, it is important for the future of countries to predict its possible effects on different fields and take action. We can say that science education is one of the central points of these developments. For these reasons, this study is a vision document investigating the possible effects of international energy projects on science education career opportunities. Vision Documents explore and present long-term challenges and opportunities rather than incremental improvements or evaluations of current solutions or practices. They include bold calls to action for potential new directions supported by a well-motivated scientific intuition or argument and well-founded predictions of what research and practice will look like in the distant future (EASE [Evaluation and Assessment in Software Engineering], 2020).

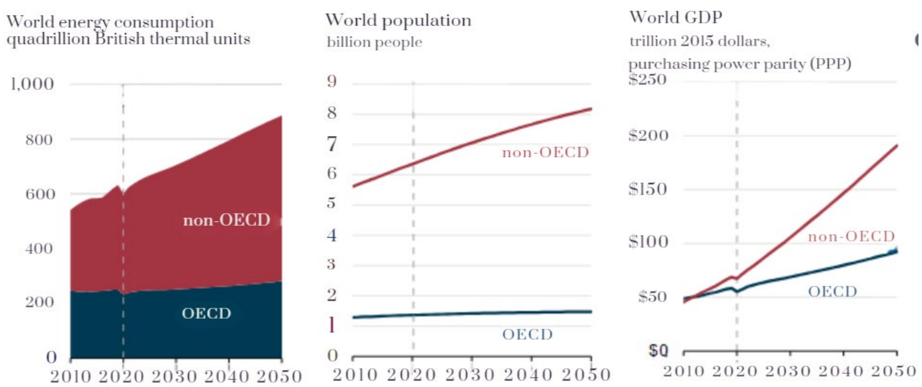
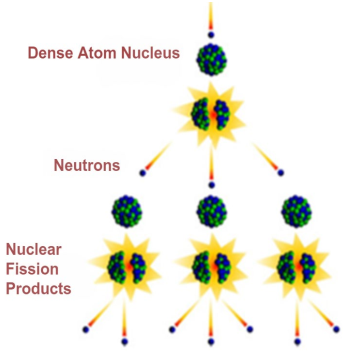


Figure 1 Worldwide energy use-World Population-World GDP (Gross Domestic Product) projections over the next three decades (U.S. Energy Information Administration International Energy Outlook, 2021)

Figure source: https://www.eia.gov/outlooks/ieo/consumption/sub-topic-03.php

The fact that Artificial Solar Energy is a kind of nuclear energy, and the use of the term "reactor" recalls the public's memory. Therefore, it causes the discussion of phenomena such as radioactive explosions, radioactive waste, and environmental pollution. However, all reactors on Earth are currently "fission reactors." Therefore, it is beneficial to emphasize the difference between radioactive reactions (fission) and fusion reactions.



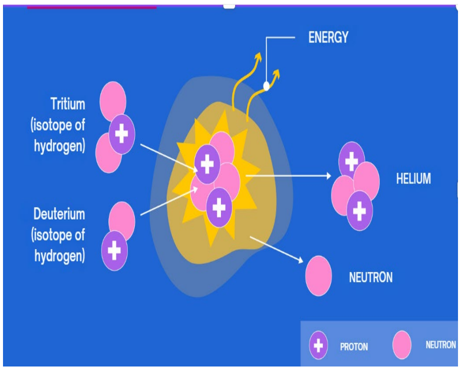


Figure 2 Fission Reaction (TAEK, 2009) **Figure 3** Fusion Reaction (IAEA, 2023)

Figure source 2: http://taek.gov.tr/nukleer-guvenlik/nukleer-enerji-ve-reaktorler/169-nukleer-enerji/457-nukleer-enerji-nedir.html
Figure source 3: https://www.iaea.org/newscenter/news/what-is-nuclear-fusion#:~:text=Nuclear%20fusion%20is%20the%20process,rele asing%20massive%20amounts%20of%20energy.

Fission reaction refers to the process of splitting a heavy atomic nucleus into binary or ternary fragments under specific conditions (Schunck and Regnier, 2022) (Figure 2). The fusion reaction involves the interaction of specific light atomic nuclei, resulting in the release of energy (Morse, 2018). During this reaction, as in our Sun, a single heavier atomic nucleus is formed, and a large amount of energy is released (International Atomic Energy Agency -IAEA-, 2023) (Figure 3). The sun undergoes a process that converts 600 million tons of hydrogen into helium per second, resulting in the generation of substantial energy. The condition that makes this possible is the gravitational pull of the Sun. The starting point of fusion studies comes from the question, "Can we create these conditions on Earth?". Many fusion technologies have been produced based on the question of how we can obtain such energy power and capacity. However, we know that the most crucial device that has made progress in application today is a device called TOKAMAK, which is a simple transformer (Figure 4). Soviet researchers initially developed the TOKAMAK in the late 1960s (ITER, 2024). The word is a Russian acronym meaning "Toroidal Chamber with Magnetic Coil" (Artsimovich, 1971).

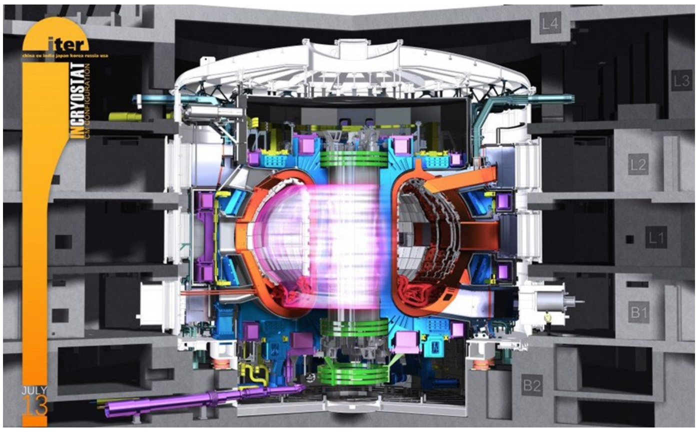


Figure 4 TOKAMAK (ITER, 2024)

Figure source: https://www.iter.org/mach/Tokamak

Under extreme heat and pressure, the TOKAMAK converts gaseous hydrogen fuel into hot, electrically charged (positive nuclei and negative electrons) plasma. In any star, plasmas create the environment for light elements to fuse and generate energy. Due to the significantly lower density and high temperatures of the plasma environment, magnetic coils are utilized to shape and control the plasma (ITER, 2024). The system is constantly being redesigned by scientists using supercomputer models to eliminate existing theoretical problems (The Royal Institution, 2017). The most recent experimental design study was conducted by the People's Republic of China through the "EAST" project. "Although "EAST" literally means "east", it is an acronym that stands for "Experimental Advanced Superconducting TOKAMAK" (Figure 5). With this experiment, China has added a significant milestone to its nuclear fusion efforts (ITER project - International Thermonuclear Experimental Reactor) (Table 1).

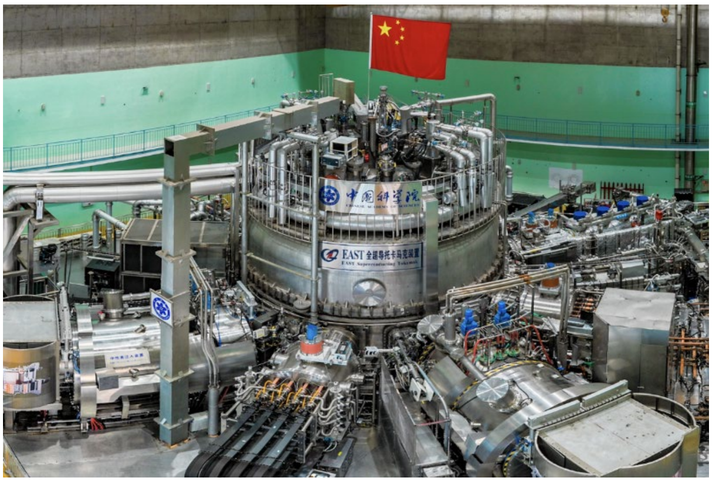


Figure 5 Superconducting EAST Project center (Wang, 2021)
Figure source: Wang, 2021-https://doi.org/10.1007/978-981-16-3887-9_6

In 2007, a plasma at a temperature of 20,000,000 °C could be held constant for 101.2 seconds, and in 2012, a plasma at this temperature could be held constant for 411 seconds (Wang, 2021). In May 2021, a plasma with a temperature of 120,000,000 °C could be held constant for 101 seconds, while in December 2021, a plasma with a temperature of 70,000,000 °C could be held constant for 1056 seconds. These data have created great excitement for the ITER project (**Figure 6**).

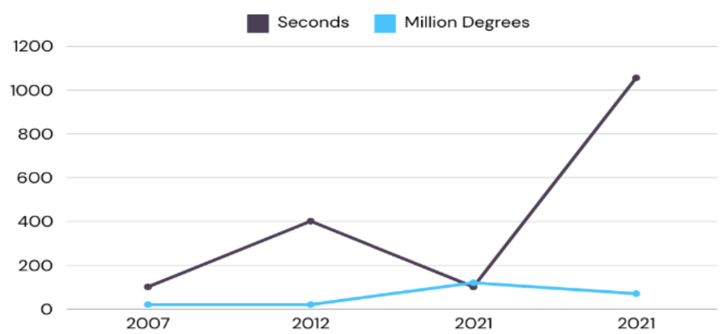


Figure 6 EAST Project's Temperature-Staying Constant Time Data by Years

The ITER project, derived from the Latin term "The Road," represents one of the most ambitious energy projects in the world today (ITER, 2024). The ITER project, which began in 1985, involves 35 countries collaborating to build the world's largest Tokamak in Southern France. The Tokamak is a magnetic fusion device designed to demonstrate the feasibility of fusion as a large-scale, carbon-free energy source, based on the same principle that powers our Sun and the stars. The primary objective of the ITER project is to advance the science of fusion and lay the groundwork for the fusion power plants of the future. We can say that this project is one of the largest experimental projects on Earth after the ISS and CERN (Figure 7).

Figure 7 ITER Project

Figure source: https://www.iter.org/

Figure 8 Comparison of solar and ITER data

Figure source: Solar data; Fusheng, Shiyang, and Yan, 1997; ITER data; ITER, 2024

Reviewing the data in Figure 8, we see that the ITER project aims to produce almost 10 times as much energy as our Sun. Although it is theoretically possible to produce enough energy to heat a couple of kettles of water, many governments worldwide support the work, following a small amount of proof for producing this clean energy. Together, they will benefit from the full experimental results and the intellectual property generated by the project (ITER, 2024). The countries involved are shown in Figure 9.

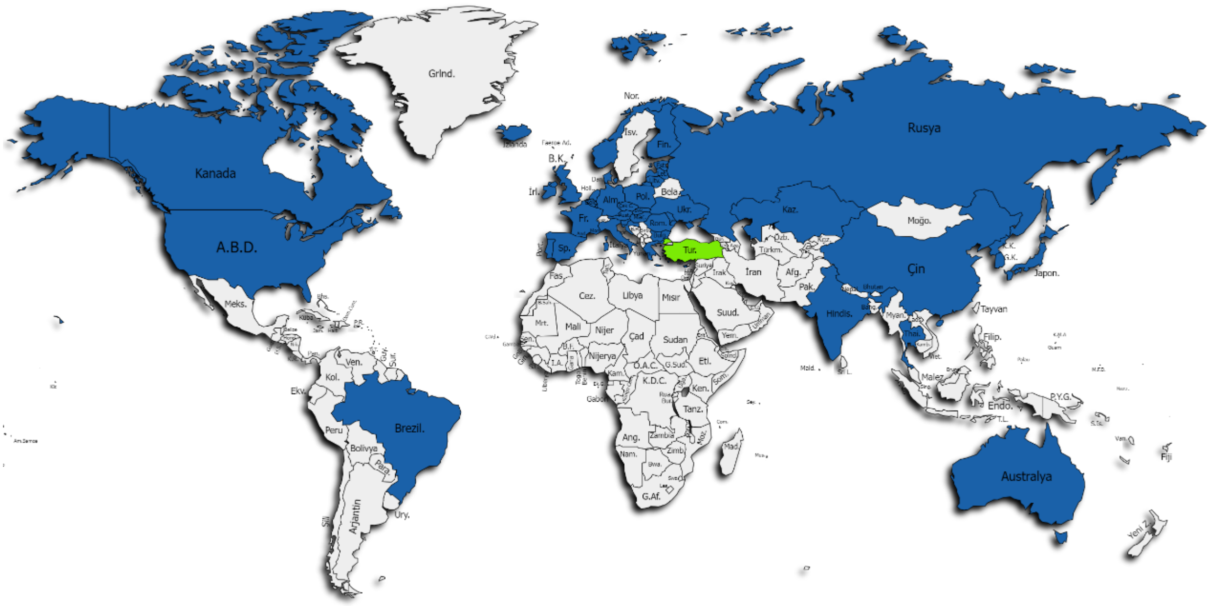


Figure 9 Distribution of countries involved in the ITER project

Türkiye is not among the countries supporting the project. It would be relevant to draw attention to Türkiye's situation in Figure 9, especially that all of its neighbors and all countries that want to benefit from the energy market in the world and have implemented social-educational awareness on energy are involved in this project. Like other nations, we can state that our country should focus its human resources on innovative energy fields. The visibility of our country in international projects will only increase with the education our young people will receive. The EU Green Paper on Energy Efficiency in 2006 also proves the crucial role of education in enhancing energy efficiency (Malinauskaite et al., 2020). Educating younger generations about sustainable and clean energy sources is vital for fostering a clean and bright environment in the future. Preparing students for their future careers on energy, real-world experiences, and hands-on activities are crucial parts of their education. Research projects and laboratories are excellent teaching aids, allowing students to apply the theories learned in the classroom. Interdisciplinary applied renewable energy projects are vital in modern society and fundamental across all science and engineering disciplines (Yildiz et al., 2012). In addition to the career opportunities such projects offer, understanding energy concepts and forms leads to an awareness of energy resources, their limitations, and the environmental impact of energy misuse (Yildiz et al., 2012). To meet the demands of rapid progress in an interconnected and multidisciplinary ecosystem, education and training are pivotal in preparing a well-rounded and socially aware educated population with a strong understanding of sustainability (Skowronek, et al., 2022). It is among the duties of educators to ensure that developments that can affect the fate of the world and nations are followed and to ensure that our young people are aware of energy, sustainability, renewability, and career opportunities. Perhaps the biggest difference between us and these countries is awareness. It is important to train and educate the workforce that will take part in these projects. Considering the investments made for the execution of the projects, finding qualified personnel is one of the most important issues. In the midst of a major global economic bottleneck, science education can offer students a choice in guiding their future. Renewable energy is one of the prioritized issues in all over the world (Iram et al., 2021) and if the relevant project is realized, it is seen that career opportunities will be created in many STEM and computer technologies fields, including in our country. The World Economic Forum's Future of Jobs 2023 report predicts rapid growth in jobs related to renewable energy and climate change mitigation, indicating an anticipated increase of approximately 1 million jobs. The official website of the ITER project explicitly states that trained, professional staff will be needed in many fields, including plasma physics, engineering sciences, computer and data science, robotics, materials science, instrumentation and diagnostics engineering, control systems, and operations (ITER, 2024). These clearly stated career opportunities should be accessible to students, and their curricula should guide them. Therefore, many countries have added themes under the title of "Energy" to their curricula, especially in science curricula for a clean energy future (Eş & Sarıkaya, 2010; Karalı et al., 2021). In contrast, some of them, like the United States, the United Kingdom, Japan, Australia, Canada, and the European Union, have incorporated EE into national education and have established professional energy educators in the system with significant achievements. One example is China's science curricula, which has had great success with the “ITER” and “EAST” projects. In China, energy education is currently dispersed among other subjects at the junior high school level and related university majors without forming an independent discipline system (He, 2023). On the other hand, the changing standards aimed to make students science literate, and the principle of science and inquiry-based science teaching was adopted for all students. It is stated that two approaches were followed in this modernization. One approach is to update science content with the latest developments, while the other is to integrate science content with the technology encountered in students' daily lives (Liu, 2011). This situation has been reflected in educational goals, especially in the STEM/Energy field in the last decade. China's success in achieving its goals in this field can be attributed to the goals and objectives of the science education system and programs.

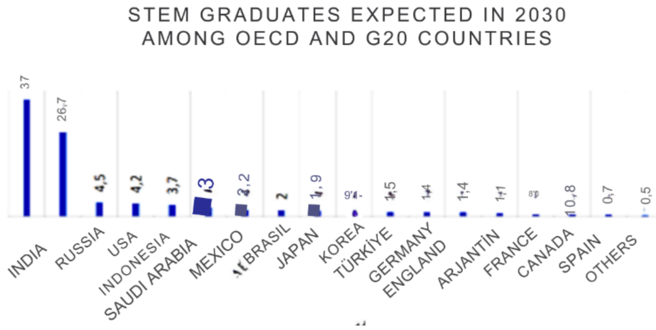


Figure 10 Expected proportion of STEM graduates among OECD and G20 countries in 2030 (OECD, 2015).

Figure source: http://www.oecd.org/education/skills–beyondschool/ED IF%2031%20(2015)--ENG--Final.pdf

In this context, while the Chinese education and training system can produce 37% STEM graduates and meet the need in this field, it is seen that only 1.5% of the need that will arise in our country can be met (Figure 10). TÜSİAD (2017) confirms the OECD (2015) report in its report. According to this report, Turkey will need approximately one million people in STEM professions by 2023, but only a small portion of this potential can be met. According to Çorlu (2013), studies and projects on STEM education at universities in Turkey are not very common. STEM education studies that strengthen the integrated teaching knowledge of teachers and teacher candidates within the scope of in-service training and in faculties of education are also insufficient (Yenilik ve Eğitim Teknolojileri Genel Müdürlüğü (YEĞİTEK), 2016). However, in recent years, STEM centers accessible to students and teachers have started to be opened in a few universities in our country. The first initiatives in this regard were undertaken by Hacettepe University and Istanbul Aydın University. Today, we know that STEM educator certificates are given in many universities and graduate programs are opened. It is stated that choosing a STEM-oriented career and continuing in this profession depends on the interest in STEM professions (Wiebe, Unfried, & Faber, 2018). In the same study, it is stated that elementary school students establish attitudinal relationships between their academic and life experiences and future science and STEM careers (Wiebe et al., 2018). How much can we convey what is happening in the world with the current science education, and how much can we provide these positive academic attitudes and life experiences to our students? In this context, only a few studies have been found to examine what the science curriculum offers for career opportunities with energy/environmental education/renewable energy/sustainability education (Türeyen, 2020; Çöklü & Alkan, 2022; Erten et al., 2022; Kıyıcı & Atabek Yiğit, 2023). Some of the common views of these studies are that there are not enough learning outcomes on the subject, STEM applications are insufficient, associations with daily life need to be improved, and according to country comparisons, we are neither very inadequate nor at the best level. However, with the importance of energy and its potential for our young people, it is important to design a multidisciplinary energy curriculum that emphasizes more quantitative changes in energy, what energy is, why it is important, what is meant by energy types/forms, transformation, transfer and conservation, current energy projects, and to develop these projects or strive to add new ones and career opportunities. Philosophical discussions about the relationship between experiment and theory/real-world experiences and the meaning of scientific concepts and opportunities for science careers and entrepreneurship should be particularly important in making curriculum development decisions. Integrating energy as a separate discipline into the national formal education system, supplemented by community education and social education, is the primary way to pursue academic success in energy fields (Han Q, 2015).

2 Limitations and future directions

This vision paper focused on possible developments in energy and how they could provide opportunities for science students' careers. It can be said that more research is needed in the fields of STEM and energy education. For this reason, we predict that energy themes, topics, outcomes, and related skills, which have been ignored in our new science curriculum, should be added to the curriculum with an interdisciplinary approach. Within the framework of the country's energy policies, it is important to determine what kind of qualified personnel is needed in which field. A workforce potential focused on this supply-demand relationship can be created with the contributions of science education and other branches.

- A multidisciplinary energy curriculum can be designed. It is recommended that this program be realized by considering the country's energy policy and vision.
- Besides the existing stakeholders, the opinions of employers and employees in the energy sectors should also be reflected in the program design. Such a study can ensure that the renewable and clean energy types that are likely to exist in the future and the supply-demand relationship are reflected in the curriculum.
- The content of the curriculum should include carefully designed and sequenced activities that are simple but not simplistic, that offer students opportunities for exploration and research, and that gradually increase in complexity.
- A problem-solving-based approach can be adopted that promotes reasoning through both observation and inference from the model and enables students to build, reason, and revise their models rather than relying on authority to give the "right" answer.
- Current energy projects and career opportunities should be included as a separate section in the curricula to make students aware of career opportunities and entrepreneurship in the renewable energy sector.
- Today's economic and technological developments have made the borders between countries flexible. It is important to create international aspects of the energy curriculum to prepare our students for job potentials in our country and other countries.

3 Conclusion

This study demonstrates that a solar hydrogen/deuterium economy can last for billions of years and has the potential to produce significantly more energy than our current energy consumption. This encourages discussions about future possibilities (Abbott, 2009), such as science education and student career opportunities. In order for renewable energy to be implemented in projects, qualified personnel must be in place before the projects can be realized (Yildiz et al., 2012). This calls for urgent measures regarding planning, design, and education curriculums. Upon examination of the results of previous studies and the latest developments in the energy field, it becomes evident that existing curricula and instructional approaches simply don't deliver the integrated understanding students need to apply energy ideas meaningfully in either scientific or practical contexts. It is clear that even in countries at the forefront of the energy field, with their impressive projects and curricula, there is still room for improvement (Han Q, 2015; Herrmann-Abell & DeBoer, 2018; Lacy et al., 2022). In addition to traditional face-to-face education in the field of renewable energy, informal learning environments should be created. Stokes (2013) emphasizes the need for high-level political support to drive large-scale societal changes towards renewable energy. Without government support, renewable energy will remain a theoretical interest rather than a practical reality for individuals and communities. Global competition in creative industries and exports is projected to increase, particularly in technical fields such as sustainable energy and artificial intelligence. Preparing students for the sustainable energy workforce involves collaborative interdisciplinary communication and a holistic learning environment to foster greater inclusion and diversity (Skowronek, et al., 2022).

4 Statement of Researchers

4.1 Researchers contribution rate statement

Meral ÇELİKOĞLU: Introduction, methodology, review, and editing.

Erol TAŞ: Methodology, review, editing.

4.2 Conflict statement

The authors declare that they have no conflict of interest.

4.3 Support and thanks

Due to the scope and method of the study, ethics committee permission was not required.

This article is the final version of the paper titled "International Projects on Energy And Science Career Opportunities", which was presented as an oral presentation at the International Congress of Integrated Social Research and Interdisciplinary Studies held between May 30 and June 01 and the summary of which was published in the congress proceedings summary book.

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