

R&D TRANSFORMATION IN ENERGY, NUCLEAR AND MINING TECHNOLOGIES: TENMAK

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Abstract

Global governance is in understanding of safer and healthier conditions. One of the most important indicators of this global debate is the sustainable development centered arguments. One of the most important indicators of this global debate is focused on sustainable development. Sustainable development, emphasizing the distribution of resources between generations, draws attention to the effective use of the resources. The solutions to the problems based on climate issues in the world today draw attention to the effective use of the resources. In this context, many issues such as energy resources, efficiency, transformation and its policies have become more and more frequently discussed and R&D activities in this field have become hot topic. In this study, the role of TENMAK, that was established with the purpose of providing technology-based solutions to the issues such as dependence on foreign resources- raw materials and energy, in the ecosystem with its R&D activities in the fields of energy, nuclear and mining and history are discussed.

Keywords

R&D, Energy, Nuclear, Mining, TENMAK

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Overview: Sustainability Goals and R&D Concept

Sustainable development is based on the idea of meeting the needs of the present and development without compromising the ability of future generations to meet their own needs. Sustainable development model, which started to take place on the world agenda towards the end of the 20th century, is considered as continuous and balanced development (İletişim Başkanlığı, 2021, p.17). While economic growth focuses only on per capita income and gross national income; economic development examines sustainability in the axis of parameters such as environment, health, education and gender equality.

In terms of global governance systems, the search for perspectives in the axis of climate problems, Covid pandemic and economic crisis, brings sustainability to the fore. The “2030 Sustainable Development Goals”, which are based on the *UN Sustainable Development Summit* held at the United Nations Headquarters on September 25-27, 2015, and determined as *seventeen basic goals* are as follows (İletişim Başkanlığı, 2021, p.20-21).

- No Poverty
- Zero Hunger
- Good Health and Well-being
- Quality Education
- Gender Equality
- Clean Water and Sanitation
- Affordable and Clean Energy
- Decent Work and Economic Growth
- Industry, Innovation and Infrastructure
- Reduced Inequality
- Sustainable Cities and Communities
- Responsible Consumption and Production
- Climate Action
- Life Below Water
- Life on Land
- Peace, Justice and Strong Institutions
- Partnerships for the Goals

The multidimensional structure of sustainable development goals reveals the importance of energy resources. Issues such as items related to economic growth which are directly related to economic activities, and access to clean water resources which are handled with a development perspective, will be more easily accessible with the effective use of energy resources. However, the title of “Affordable and Clean Energy” directly emphasizes the energy field. It is necessary to underline the importance and necessity of research and development activities in this field (SBB, 2019, 96). *In this age, which is called as Informatics Age or Information Age*, where the direction of the scientific transformation we are in is determined, the way of gains that can be achieved in the changes that occur in the technologies used in science, industry and related fields, passes through R&D activities.

For countries to gain competitive advantage, it is necessary to develop and use technological knowledge effectively with every aspect of knowledge (Türkan and Yaşa, 2021, p.33).

Countries that are in competition with each other in the fields of science, industry and technology will be able to stand out in the ecosystem they are in thanks to the steps they take in R&D studies. With its definition in the Frascati Manuel prepared by experts from OECD countries; Research and experimental development (R&D) is the creative work carried out on a systematic basis to increase the knowledge of people, culture and society and to use this knowledge to design new applications (OECD, 2015, p.30). R&D activities, on the other hand, include studies aimed at obtaining new technical information, developing production, methods and processes, making original designs, reducing product costs and increasing quality standards (Dağ, 2020, p.197). The production and added value generated by Türkiye's research and development activities have begun to be supported by the country's needs and priorities. At this point, the national technology initiative strategy has provided an important opportunity for all relevant stakeholder organizations to collaborate and be guided. Following the national technology initiative, TENMAK reevaluated and revised its own strategies and priorities.

In this context, we sought to transfer scientific and technological advancements to production methods and to ensure the development of new products and processes. In other words, R&D expenditures are in the nature of investment and the return to be obtained from the investment can be much higher than the value of the R&D investment. In this context, the contribution of high value-added products obtained with the developed technologies to the economies of companies and countries becomes increasingly visible. In order to ensure sustainability in light of the effects of global warming, which have become evident with the rise of environmental problems in recent years, expenditures on R&D activities in many fields, especially energy, have increased. In this case, efficient use of energy and obtaining more efficiency with less energy were determined as a goal and studies in this area gained momentum. However, countries that are dependent on foreign energy have accelerated R&D studies in many areas, especially storage solutions, in order to balance supply and demand.

Technology Readiness Level (TRL) is used as a comprehensive measurement system to direct R&D activities, which enables the evaluation of the maturity of a technology and enables the consistent and systematic comparison of maturity between different technologies (Mankins, 1995, p.1). The purpose of use of TRL is to show the development of a technology at a certain time and to create a general and understandable language for the development of technology (Babaçoğlu et al, 2014, p.7). The first three stages of this approach are concluded with the technological research processes designed with a focus on problem-solving and the development of its fundamental technology. The seventh level of TRL is attained through the implementation of technological developments and the production of prototypes. After this point, the prototype produced is presented to the technology market with business developments and commercialized, reaching the ninth TRL level, which is the final level. There are also processes in which these processes take place in interaction and flexible, not with a strict hierarchy.

The relationship between R&D stages and TRL levels in an R&D project is shown in bold shaded in the table below, along with the questions representing each TRL level and the corresponding R&D stages to these questions.

Table 1. TRL Levels Table

TRL Level	Question	R&D Stages			
		Basic Research	Applied Research	Technology Development	Prototype Development
1	Have the fundamental principles of the technology been researched and documented?	----			
2	Have the applicability of the basic principles been theoretically proven?	----	----		
3	Have the characteristics and critical functions of the basic principles been proven by analytical or experimental studies?		----	----	
4	Has the desktop prototype applied to the fundamentals been validated in the lab environment?			----	
5	Has the desktop prototype consisting of key technological components been validated in the simulated working environment?			----	
6	Has the system/subsystem model or prototype been tested in a simulated environment?				----
7	Has the prototype system been demonstrated in real working environment?				----
8	Has the actual system been qualified by completed tests and demonstrations?				----
9	Has the success of the actual system in a joint mission operation environment proven?				----

Source: Babaoğlu (2014), p.32

R&D Need in the Energy Sector

Energy has been one of the most important and indispensable needs throughout human history. The fact that water, which is the raw material of life, is also an important source of energy is one of the most obvious examples of this situation. Considering the interdependence between economic activity and energy today, it is clear that energy is an indispensable element for the sustainability of supply and demand dynamics. Energy resources which are not enough to meet the global needs, do not *meet the demand*, bring uncertainties about the future and feed geopolitical risks. Considering that these resources can be exhausted and some of them have negative effects on the environment, the importance of efficient use of energy resources emerges (Naimoğlu, 2021, p.36).

R&D studies in the field of energy have focused on sustainability in all aspects, especially in terms of leaving a world where they can live for future generations, producing and exploring alternative energy sources, and in this way, efficiency and environmental awareness. Developing new technologies that can meet the energy supply created by production and

development without reducing the welfare level of countries is an important issue especially for policy makers.

Renewable energy, which is expressed as environmentally friendly energy, offers various opportunities in terms of ensuring energy efficiency and is at the center of R&D studies. *Renewable energy* investments and R&D studies to be carried out for this purpose have a serious importance all over the world and especially in developing countries that are dependent on foreign energy. The economies of countries that increase their share of renewable energy both get the opportunity to reduce foreign dependency and can ensure the protection or increase of energy efficiency. In addition, the reduction of greenhouse gas emissions, which absorb and emit radiation of certain wavelengths, is among the important gains of the use of renewable energy sources. Among the renewable energy sources, geothermal energy, bio-material energy, solar energy, hydroelectric energy and wind energy come to the fore. As the reason for this, it can be stated that the energies mentioned are both green, clean, environmentally friendly and have low installation costs. Therefore, investments to be made in the field of renewable energy and technological innovations in this field are of great importance for the future of the world (Naimoğlu, 2021, p.36).

The importance of R&D, which plays a key role in the economic development and growth of countries and provides competitive advantage in national and international markets, is increasing day by day for private, public and other sectors. For this reason, many countries have determined road maps for themselves to develop different, renewable and efficient technologies in the field of energy, in other words “to do R&D”. The entire ecosystem in all countries proceed with this global purpose.

R&D Need in the Field of Energy in Türkiye

When evaluated from an economic and social point of view, in summary, there is a direct correlation between energy and the development and welfare levels of countries on the *path of sustainable* development goals. The improvement in energy production, energy storage and R&D studies on energy will contribute to the raise of welfare and development levels of the countries. Development and energy are interconnected because development increases production and production increases energy need. Türkiye, which is highly dependent on foreign energy sources, becomes more sensitive to the fluctuations of the energy market economically as its energy needs increase. Thus, in Türkiye, which is struggling with the current account deficit, energy emerges as a very important issue that causes the current account deficit.

According to the findings obtained from the studies, it is possible to say that there is a close positive relationship between energy imports, energy prices and current account deficit in most of the countries that are dependent on foreign energy such as our country. Increasing energy consumption due to increasing energy demand causes serious increases in the imports of oil, natural gas and other primary energy sources, and this increase is reflected in the entire economy (Dilara and Karış, 2019, pp.382-383). Countries that are in the position of net importers in terms of energy experience pressure on external deficit and budget deficits.

Within the scope of combating the negative effects of climate change and the global average temperature increase, after the Paris Agreement, which was also approved by Türkiye at the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties, a major change is taking place in the field of energy worldwide. Additionally, Türkiye has put its name to the Paris Climate Accord. While countries change their

investment behaviors in their relevant decisions, intensive R&D studies are carried out on clean, renewable and alternative energy sources. R&D studies to be carried out on energy, which has a negative impact on the current account deficit in Türkiye, will offer the opportunity to move into the driver's seat in the new energy ecosystem that is taking action. For this reason, R&D activities in this field are indispensable for Türkiye.

The importance of R&D, which plays a key role in the economic development and growth of countries and provides superiority in national and international markets, is increasing in terms of private, public and other sectors. In order to expand the fields of activity in this direction and increase R&D expenditures and performance, the necessity of public intervention with policy tools has emerged. Considering the R&D studies carried out separately by the affiliated, related and related institutions of the Ministry of Energy and Natural Resources, TENMAK (Turkish Energy, Nuclear and Mineral Research Agency); with its experience, infrastructure, place in the ecosystem, mission and vision, it is an institution that can carry out many different R&D studies under a single roof, especially in the field of energy, and can create a strategic and synergetic effect.

Role of TENMAK in the R&D Ecosystem of the National Technology Initiative: Why, What For and When?¹

The multi-disciplinary nature of energy, nuclear and mining technology fields necessitates extensive R&D activities including all of these fields. It has come to the fore to carry out R&D studies with a holistic approach and to distinguish the focus and task areas of those whom benefit from technology and whom produce technology.

R&D activities related to energy, nuclear and mining technologies research on a global scale were generally not seen as an activity that should be under the responsibility of only the relevant ministries, and were carried out both with universities in our country, public and private sector companies, private research institutes and international cooperation on a global scale.

When the situation in the world is examined, it is seen that the regulatory bodies and R&D organizations are structured separately, especially in the nuclear field. R&D studies on nuclear energy are generally carried out by specialized institutions, universities/institutes or semi-private companies. In the studies, not only the concern of obtaining a commercially marketable product is pursued, but also R&D studies are carried out in the fields of nuclear technology, radiation protection and nuclear materials.

Considering the global exemplary institutions and organizations, it can be evaluated in the TENMAK's strategic plans, TENMAK's research institutes should have the means to carry out R&D activities, develop and commercialize various products, cooperate with national and international organizations in order to ensure Türkiye's technological progress in the fields of energy, nuclear and mining technologies.

It is also important to understand the developments in the field of energy, nuclear and mining technologies in the world and in Türkiye in order to evaluate TENMAK's fields of activity and the mission it undertakes in all these fields from a strategic point of view. TENMAK has gained its corporate identity in order to create a synergetic effect by bringing together different institutions under a single roof and creating new institutions. TENMAK, which was established with the restructuring in 2020; is a mission-oriented R&D institution

¹ The following two sections have been formed mainly by utilizing the TENMAK Strategic Plan.

in the fields of energy, nuclear and mining technologies. In this context, development in each field of activity should be handled separately in order to understand TENMAK's strategies and its role in the ecosystem.

Within the scope of the specialized studies carried out in the field of energy in our country, the foundations of the studies in the nuclear field were laid in 1956 with the establishment of the Atomic Energy Commission General Secretariat in Ankara under the Prime Ministry with the Law No. 6821.

In 1982, the General Secretariat of the Atomic Energy Commission was restructured as the Turkish Atomic Energy Agency and its duties were counted as; to conduct research, development and examination studies on atomic energy; to carry out regulatory and supervisory activities related to nuclear safety, security and assurance; to establish the necessary laboratories and facilities in line with its duties, powers and responsibilities; establish and operate radioisotope production, quality control, measurement and distribution facilities; to carry out radioactive waste management; making national and international collaborations related to the subjects within its field of duty, educating people in these areas and participating in legislative studies. With the Decree Law No. 702 in the year of 2018, the Nuclear Regulatory Authority (NDK) was established and the duties of TAEK were reorganized as developing policies for the benefit of the country in the field of nuclear energy, radiation and accelerator technology, to conduct research and to support research and product development activities in this field, to prepare the National Radioactive Waste Management Plan regarding radioactive waste management, to establish and have radioactive waste facilities established when necessary, to provide measurement analysis, calibration, dosimetry, metrology, irradiation and intervention services.

As TENMAK BOREN, under the umbrella of National Boron Research Institute TENMAK, it carries out projects in cooperation and coordination of the university-public-private sector in order to research and develop boron products and technologies and to expand their usage areas. In addition, interdisciplinary studies are carried out in which information about boron is produced; technique and experience are developed and ultimately transformed into technology.

Obtaining rare earth elements (REE) and other critical elements, which are needed in order to reduce the foreign dependency of the developing energy sector and our industry in raw materials, from our domestic resources, ensuring the continuity of the supply chain in terms of the defense industry and the use of REE as an instrument in trade wars in the international arena in recent years have shown that the issue should be handled strategically at a high level in our country. For this reason, targets for the development of REE technologies were determined in the upper policy documents and the Rare Earth Elements Research Institute (NATEN) was established with the Presidential Decree to carry out studies specifically for REE.

TENMAK NATEN is a research institute that creates the necessary information for our country's short-, medium- and long-term policies and strategies on REE and other critical elements, carries out activities and coordinates studies in this field in order to obtain REE and other valuable elements and products containing these elements, to develop products and technologies related to these elements, and to ensure the wide use of these elements in advanced technological products.

Besides, in order to consolidate existing institutional capacity for synergetic effect as well as to accentuate this effect the Clean Energy Research Institute (TEMEN) and the Energy Research Institute (ENAREN) are two TENMAK institutes whose formation phase is relatively new, TEMEN, one of these institutes, has focused on the development of clean energy conversion technologies from fossil fuels. One of the main objectives of this institute is to carry out R&D activities to reduce and prevent the emission of CO₂ gas, as well as other elements that are harmful to the environment, while producing energy.

ENAREN, on the other hand, aims to use energy efficiently after energy is produced, to distribute it efficiently and to reduce losses. The history of TENMAK is summarized in Figure 1.

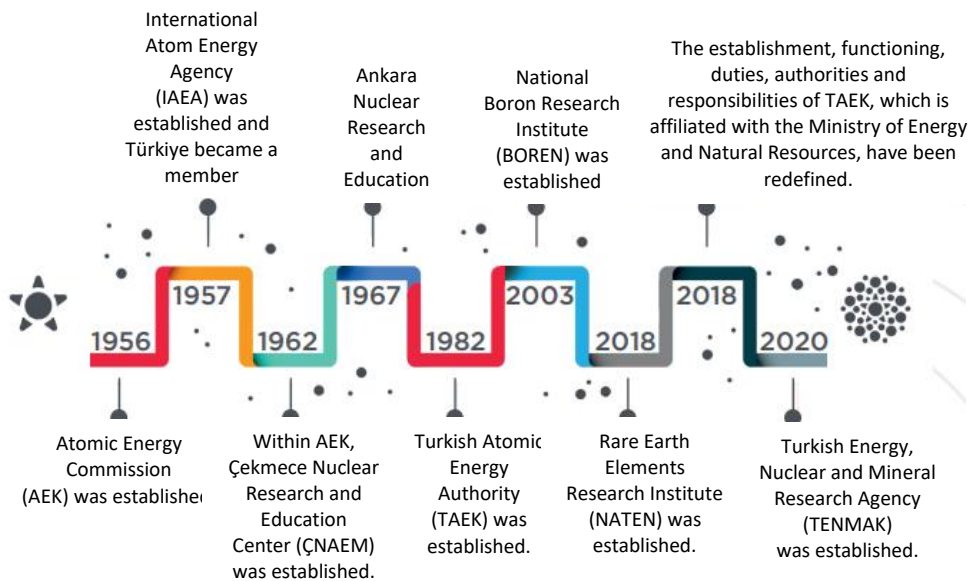


Figure 1. History of TENMAK

In summary, TENMAK was established as an R& D institution in all fields of energy, nuclear and mining technologies, and its duties are; to serve the country and humanity in the fields of energy, nuclear, ionizing radiation, particle accelerators and mining technologies, to increase and sustain Türkiye's competitiveness, to meet the need for innovation, to ensure the production of new products and the development of existing ones, to provide a scientific environment for researchers, to conduct scientific researches in cooperation with public and private law persons, to coordinate these researches, to encourage them, to contribute to research and development activities, to carry out scientific, technical and administrative studies, to have them done, to organize, to support, to establish and coordinate cooperation.

The Future of TENMAK in the R&D Ecosystem: Where and How?

TENMAK, having the vision of becoming a leading institution Within the scope of the National Technology Initiative a global scale in the fields of energy, nuclear and mining technologies, will carry out R&D activities in the long term to ensure supply security and reduce foreign dependency by increasing localization rates in the fields of energy, nuclear and mining technologies.

With the developing industry, increasing population and income level, it is aimed to increase the need for underground/surface resources and energy, as well as to provide our country with the infrastructure suitable for technological developments in the world. In this context, TENMAK carries out innovation studies to meet the needs in the fields of energy, nuclear and mining technologies.

It is aimed to reduce foreign dependency in energy with the effective and efficient use of our mines, which have an important role in energy, the development of nuclear energy technologies and the transfer of clean energy technologies. In addition to the products and technologies in the processes of clean energy production from all energy sources, especially renewable energy sources, it is among TENMAK's vision to carry out activities in the fields of energy efficiency and localization of products and technologies in the production, transmission, distribution and consumption of energy sources.

Energy, nuclear and mining technologies; has a very common use in many fields such as medicine, industry, agriculture, education-research. It is necessary to establish a national innovation system and develop a value chain in order to create a strong, sustainable and competitive sector for the activities carried out in this field. Developing an innovation ecosystem and value chain by increasing institutional, sectoral and national R&D capacity is an important task of TENMAK. In line with this vision, the important components of TENMAK's strategic location preference are as follows:

- Integration with National Development and Competitiveness Studies
- Being a Pioneer and Leader
- Focus on Energy and Clean Energy
- Using Nuclear Technology for Peaceful Purposes
- Prioritizing the Technology Needs of Affiliated, Related and Associated Institutions of the Ministry of Energy and Natural Resources (ETKB)
- Prioritizing Intersecting Areas in R&D

In summary, in line with TENMAK's duties; it was established with the aim of bringing together the Turkish Atomic Energy Authority, National Boron Research Institute and Rare Earth Elements Research Institute under one roof, and together with the Clean Energy Research Institute and the Energy Research Institute to carry out activities in the fields of energy, nuclear and mining technologies from a single source. This structuring, which was created by considering the needs of the R&D ecosystem, aims to create a synergy and develop R&D culture by taking into account the crosscutting services.

Conclusion and Evaluation

TENMAK, that is established in a structure that will be an R&D base in all fields of energy, nuclear and mining technologies, has a strong heritage. These areas are also a topic of high priority for the technological initiatives being undertaken by the Türkiye. Its supports provided to state institutions and organizations especially in areas such as national security and food safety, its radiological metrology function, big science activities, and its facility and waste management experience demonstrate the importance of TENMAK.

TENMAK will accelerate R&D activities in its field of duty, attach importance to technological and commercial outputs, and will increase R&D literacy, with the scholarship and support programs it will construct, the strategic international relations it will conduct, the policy texts it will create, the projects it will carry out and support, the industrial product

and service range it will expand. TENMAK, which started its activities due to both global regulations and the needs of our country in all fields of energy, will primarily aim to support projects with high TRL level, but will also focus on niche areas. It is an important goal to contribute to the national economy by meeting the R&D needs in the field of energy in the light of our strategic mines, rare earth elements and our knowledge in the nuclear field.

When all its fields of duty are evaluated, TENMAK, which interacts with many fields from health to education, from archeology to industry has focused on continuously improving its institutional capacity and accelerating its steps in order to effectively carry out the role given to it.

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