NATIONAL TECHNOLOGY INITIATIVE IN ENERGY

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Abstract

The energy policies of Türkiye, in a general sense, are based on meeting increasing demand in an affordable and sustainable manner and development of environmentally sensitive energy systems. Türkiye as a developing country, transformed its energy sector in order to meet its increasing energy demand historically. Different concerns triggered this energy sector transition in different terms. In the 1980s and 1990s, reforms were made in order to increase use of natural gas, to establish a legal and regulatory framework for enabling private sector investments to meet increasing energy demand, to restructure of state entities, and to increase infrastructure investments. In the 2000s, the establishment of energy markets, increasing energy security, ensuring energy efficiency, and use of nuclear energy were revealed as main policies. While seeking to meet its energy demand in an uninterruptable and secure manner, Türkiye has been realizing its clean energy transition by considering energy costs as a net energy importer country and its own specific energy dynamics. Türkiye aims to decrease its costs and emissions by utilizing clean and domestic sources, contribute to minimize its carbon intensity to the level possible by producing power from nuclear energy and increase energy efficiency applications. The energy transition of Türkiye has entered a new era after the ratification of Paris Agreement in 2021 and announcement of 2053 net zero target. Türkiye will continue to increase use of clean energy sources and promote integration of clean technologies into the energy systems to secure its sustainable development and to reach a net zero target. In this regard, Türkiye targets to utilize hydrogen into the energy sector as a new source as well as to digitalize the energy sector and minimize its carbon intensity to the level possible. Nationalization of the essential technologies forming the energy value chain has an importance if we define elements of the energy systems as exploration, production, transmission, distribution, market structuring and consumption. The new era that is shaped towards net zero emission is pursuing a development-oriented approach. In this regard, the biggest opportunity within this period is to become an exporter of decarbonization technologies by means of a move towards technology development.

Keywords

Türkiye, Energy, Transition, Renewable, Technology, Digitalization

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Climate Change and Energy Transition

Gases such as carbon dioxide (CO_2), methane (CH_4), water vapor (H_2O), and ozone (O_3), which have the ability to trap heat in the atmosphere, are called greenhouse gases (Intergovernmental Panel on Climate Change, 2022a). These gases accumulate in the atmosphere, trapping the solar radiation reflected from the earth and keeping the earth at a livable temperature for humans, animals, and plants. Greenhouse gases are produced naturally by plants, oceans, and volcanoes. However, the threat of climate changes the world is facing today, especially as of the Industrial Revolution, arises with the spread of greenhouse gases into the atmosphere as a result of human activities for heating, shelter, production, consumption, transportation, and nutrition. It is defined as the climatic changes experienced by the deviation of the temperature curves from the normal cycle and warming of the atmosphere as a result of trapping the radiation from the earth in the atmosphere.

The Intergovernmental Panel on Climate Change (IPCC), established within the United Nations (UN) in 1988, makes comprehensive scientific assessments, prepares reports and recommendations on the status of climate change, and also prepares strategies within the scope of combating and adapting to climate change by evaluating the social and economic effects of climate change. The IPCC has 195 member states. Since its establishment, the IPCC has prepared assessment reports and these reports have guided international climate policies (Intergovernmental Panel on Climate Change, 2022b).

In order to fight against the threat of climate change and take the necessary measures under the United Nations, the infrastructure was established with the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, and a process has been carried out until today. The Convention demands to reduce their emissions from developed countries, which it sees as historically responsible for greenhouse gas emissions, which are the main cause of climate change, and also demands from advanced developed countries to provide financial, technology, and capacity-building support for developing countries to combat climate change. In this way, the Parties within the scope of the Convention have been classified as (i) Annex-2 list, which includes the most developed countries and which is responsible for both greenhouse gas reduction and financial and technological assistance, (ii) Annex-1 list, which is a subset of Annex-2 list, and (iii) non-Annex-1 countries, which are assumed no responsibility in the process under the assumption of a developing country, and that are eligible for financial and technological support from Annex-2 countries.

The negotiation process under the contract is carried out in line with the necessary preparatory meetings during the year and the decisions taken at the Conference of the Parties (COP), where all parties come together at the end of the year and the final decision is made.

The first assessment report prepared by the IPCC in 1990 emphasized the global impact and consequences of climate change and the necessity of global cooperation, paving the way for the United Nations Framework Convention on Climate Change (UNFCCC) to be signed by 165 countries in 1992 (Intergovernmental Panel on Climate Change, 2022b). UNFCCC entered into force in 1994 and the first conference of parties (COP1) to which 197 countries are parties to the convention was held in 1995 (United Nations Climate Change - UNFCCC, 2022a). The second evaluation report prepared by the IPCC in 1995 started the process leading to the signing of the Kyoto Protocol within the scope of COP3 in 1997, and also with the third (2001) and fourth (2007) evaluation reports, the emphasis

was placed on the implementation of the Kyoto Protocol and especially on adapting to the effects of climate change. (Intergovernmental Panel on Climate Change, 2022b).

The Kyoto Protocol entered into force in 2005 and has 192 parties. Based on the provisions of the UNFCCC and its annexes, the Kyoto Protocol has adopted that climate change will affect all countries and that all countries should work to reduce these effects. Nevertheless, it has placed the greatest responsibility for the increase in greenhouse gas emissions on industrialized countries (within the scope of Annex-1) and thus became a binding Protocol for developed/industrialized countries (United Nations Climate Change - UNFCCC, 2022b). Countries within the scope of Annex-2 of UNFCCC are countries that have agreed to provide financial and technical support to developing countries (not within the scope of Annex-1) within the scope of combating climate change (United Nations Climate Change - UNFCCC, 2022c). The first period of the Kyoto Protocol ended in 2012, and the second period ended in 2020.

With the fifth (2014) evaluation report prepared by the IPCC, scientific data that will form the basis for the signing of the Paris Agreement were presented in order to keep the global temperature increase below 2 °C after the Kyoto Protocol in other words post-2020, compared to the period pre-industrial period. The Paris Agreement is an internationally binding historical agreement on climate change that was signed by 196 countries in 2015 within the scope of COP21 and entered into force in 2016. The main goal of the Paris Agreement is to keep the global temperature increase below 2 °C compared to the pre-industrial period and to limit this increase at 1.5 °C if possible. In order for the Paris Agreement to reach its goals, countries have to submit their work every five years under the name of nationally determined contributions (NDC) and update and improve these declarations. The Paris Agreement is a milestone in the multilateral fight against climate change, as it is the first agreement to bind all countries in their efforts to combat and adapt to the effects of climate change (United Nations Climate Change - UNFCCC, 2022d).

Within the scope of UNFCCC, Türkiye was among the Annex-1 and Annex-2 countries, but this situation was not found fair by her and Türkiye was excluded from the Annex-2 countries at the request of Türkiye in 2001 and remained as an Annex-1 country with special conditions. Thus, it was exempted from the obligation to provide financial and technical support to developing countries. Türkiye became a party to the UNFCCC in 2004 and the Kyoto Protocol in 2009. Türkiye has no target to reduce greenhouse gas within the scope of the Kyoto Protocol.

Türkiye signed the Paris Agreement on 22 April 2016 and ratified the Agreement on 7 October 2021 with a declaration on the implementation of the Agreement and its mechanisms without prejudice to her right to economic and social development. Türkiye submitted the intended nationally determined contributions (INDC) to the UN secretariat in 2015 and it is anticipated that greenhouse gas emissions will be reduced up to 21% from the business-as-usual level by 2030 (the Republic of Türkiye, 2012). Türkiye made her statement at the Presidential level in 2021 that Türkiye would achieve the net zero emission target by 2053. The last Conference of Parties (COP27) was held in Egypt on 6 -18 November 2022 and Türkiye announced its updated NDC as 41 % decrease from the business-as-usual level by 2030 and peak its emission by 2038.

The IPCC is currently preparing its sixth evaluation report; the report prepared by the third working group was published in April 2022, and the synthesis report, which includes the contributions and findings of the three working groups, was published in September

2022 (Intergovernmental Panel on Climate Change, 2022c). There are critical messages that should be taken into account from the latest report of the IPCC in the sixth evaluation process. According to the report, it is stated that in order to keep the global temperature increase below 1.5 °C, it is essential that global greenhouse gas emissions reach the highest level before 2025 at the latest, and then decrease by 45% by 2030. In order to limit global warming, solid transformation is required, especially in the energy sector. For this, it is stated that the use of fossil fuels should be reduced, electrification should be expanded, energy efficiency should be increased, and the use of alternative fuels such as hydrogen should be widespread. With the establishment of the right policies, the introduction of infrastructure and technologies, and lifestyle and behavioral changes, a 40-70% reduction in greenhouse gas emissions will be possible by 2050 (Intergovernmental Panel on Climate Change, 2022d).

Since the energy sector is responsible for three quarters of the total greenhouse gas emissions, it is the sector that needs to undergo the fastest change and transformation globally (International Energy Agency, 2021a). The most important cause of global warming and climate change is the gases released as a result of the consumption of hydrocarbons such as coal, oil, and natural gas. Therefore, the transformation to be realized in energy, industry, transportation and residential areas is important in terms of limiting the global average temperature increase and reducing the effects of climate change, as well as the adaptation of the ecosystem to the current changes and the continuation of economic development in a sustainable way. The International Energy Agency encourages all countries to deepen and implement their energy and climate policies to meet their net zero emission targets by 2050 (International Energy Agency, 2021a). Although the net zero emission energy sector is generally similar in countries, the energy system will be transformed according to the characteristics of each country.

The European Union (EU) announced its Energy Union Strategy in 2015. Within the scope of the Energy Union Strategy, the EU's energy policies are shaped for five purposes: diversification of energy resources to ensure energy security, increasing the functionality of the integrated energy market, reducing import dependency by increasing energy efficiency, transitioning to a low carbon economy in line with the Paris Agreement, and research and development of clean energy technologies (European Parliament, 2021).

With the European Green Deal announced in 2019, the European Commission declared that all Union members agreed to reduce emissions by at least 55% from 1990 emissions by 2030, in order to transform Europe into the first climate neutral continent by 2050. Within the framework of the European Green Deal, it is aimed to increase the share of renewable energy sources in the energy sector to 40% and reduce final and primary energy consumption by 36-39% by 2030 by increasing energy efficiency (European Commission, 2021).

Within the framework of the net zero emission target by 2050, the EU aims to increase the use of renewable energy sources in the transformation of the energy system, as well as to increase the use of hydrogen from renewable energy sources and to make the energy system suitable for producing, storing and transporting hydrogen. Considering that the EU will gradually reduce the use of natural gas due to supply problems and increasing costs, as well as the high carbon emissions due to natural gas consumption, the conversion of existing natural gas pipelines to hydrogen transport is one of the most important elements of the hydrogen market envisaged by the EU.

Energy Transition of Türkiye

Türkiye's energy demand is increasing in direct proportion to its growing economy and while the annual increase in electricity demand in Türkiye in the 2000-2022 period was 4.4%; this rate in the world was realized as 3% on average. Türkiye meets its increasing energy demand with imports and the rate of imports in primary energy sources in 2021 was at the level of 77.9%. In 2021, the share of natural gas in the primary energy sources was 31%, the share of oil 28%, the share of coal 25% and the share of renewable resources 16% (Ministry of Energy and Natural Resources, 2022). Natural gas consumption, which was 48 billion m^3 in 2020, increased by 22.99% in 2021 and reached 59 billion m^3 (Energy Market Regulatory Authority, 2021). Of the natural gas consumed in 2021, 35.2% was consumed in electricity generation, 28.8% in industry, 27.5% in residential, and the rest in service, transportation, and other sectors (Energy Market Regulatory Authority, 2021).

While the share of natural gas in total electricity production in Türkiye was between 30-50% in the period 2001-2019; this rate in the world increased to 18% in 2001 and 24% in 2019 (Presidency of the Republic of Türkiye, 2021). While the share of natural gas in electricity generation was 23.1% in 2020, this share was 32.7% in 2021 (Turkish Electricity Transmission Corporation, 2021). Türkiye meets almost all of its natural gas demand through imports (International Energy Agency, 2021b). Türkiye provided 88.6% of its total energy supply from fossil fuels in 2020. In 2021, it met almost all of its natural gas consumption, 92% of oil consumption, and 57% of coal consumption through imports (Ministry of Energy and Natural Resources, 2022). Türkiye in the most general sense has been adopting its energy policies and strategies to reduce its energy bills by reducing energy imports.

Although the natural gas reserve of 540 billion m^3 discovered in the Sakarya Field in 2020 may enable changes in the natural gas sector in the coming period, Türkiye aims to reduce its hydrocarbon consumption and meet its energy demand by domestic and clean resources in order to reduce its import dependency and meet its emission targets. To this end, within the scope of 11^{th} Development Plan by the end of 2023, Türkiye targets to reduce the share of natural gas in electricity generation to 20.7%, to increase the share of renewable resources in electricity generation to 38.8%, to increase the amount of electricity generated from domestic resources to 219.5 TWh, and to increase its installed electricity capacity to 109,474 MW (Presidency of the Republic of Türkiye, 2019).

Table 1. *Electricity Installed Capacity, Generation, Consumption*

	Unit	2010	2015	2019	2020	2021
INSTALLED CAPACITY	**MW**	**49524**	**73147**	**91267**	**95892**	**99820**
THERMAL	**MW**	**32182**	**41541**	**46500**	**46309**	**46193**
Domestic Coal	MW	9161	10085	11317	11336	11366
Imported Coal	MW	3281	6064	8967	8987	8994
Natural Gas	MW	18231	24945	25904	25675	25576
Others	MW	1526	446	312	312	258
RENEWABLE	**MW**	**17342**	**31606**	**44767**	**49582**	**53627**
Hydro	MW	15831	25868	28503	30984	31493
Wind	MW	1320	4503	7591	8833	10607
Solar	MW	0	249	5995	6668	7816
Others	MW	191	986	2678	3098	3712
GENERATION	**GWh**	**211208**	**261783**	**303898**	**306703**	**331492**
THERMAL	**GWh**	**155370**	**177608**	**170518**	**177066**	**212987**
Domestic Coal	GWh	40515	36180	52499	43306	49313
Imported Coal	GWh	14532	39986	60395	62506	54889
Natural Gas	GWh	98144	99219	57288	70931	108449
Others	GWh	2180	2224	336	323	337
RENEWABLE	**GWh**	**55838**	**84175**	**133379**	**129637**	**118505**
Hydro	GWh	51795	67146	88823	78094	55695
Wind	GWh	2916	11652	21731	24828	31135
Solar	GWh	0	194	9250	10950	13292
Others	GWh	1126	5183	13576	15764	18382
IMPORT	**GWh**	**1144**	**7136**	**2212**	**1890**	**2329**
EXPORT	**GWh**	**1918**	**3194**	**2789**	**2484**	**4187**
CONSUMPTION	**GWh**	**210434**	**265724**	**303320**	**306109**	**329634**

Source: (Ministry of Energy and Natural Resources, 2022)& (Turkish Electricity Transmission Corporation, 2021)

Türkiye, as a developing country, has developed and been transforming its energy sector in order to meet its growing energy demand in the process of historical energy sector development. This transformation was triggered by different concerns in different periods. In the 1980s and 1990s, studies were carried out to increase the use of natural gas, create a legal and regulatory framework in which the private sector can invest to meet the growing energy demand, restructure state institutions, and increase infrastructure investments.

In the 2000s, efforts were made to increase the use of renewable resources, ensure energy efficiency and energy savings, initiate the use of nuclear energy, and create a natural gas market in order to enhance energy security and reduce import dependency. With the establishment of the Energy Market Regulatory Authority and energy markets in 2001, policies covering clean energy resources were incorporated into the energy policies which were mainly created on the axis of supply security in the previous periods, by taking into account global developments.

With its Intended Nationally Determined Contribution submitted to the UN secretariat in 2015, Türkiye reported that the largest share in 2012 total emissions was from the energy sector with 70.2% (Türkiye Cumhuriyeti, 2012). Within the scope of the aforementioned declaration, Türkiye had plans and policies to be implemented for the energy sector to increase the capacity of production of electricity from solar power to 10 GW by 2030; to increase the capacity of production of electricity from wind power to 16 GW by 2030; to tap the full hydroelectric potential; to commission one nuclear power plant by 2030; to reduce electricity transmission and distribution losses to 15% at 2030; to rehabilitate public electricity generation power plants; to establish micro-generation, co-generation systems, and production on site at electricity production (Türkiye Cumhuriyeti, 2012). Studies are ongoing to update the plans and targets by taking into account the developments in the energy sector and the 2053 net zero emission target. Türkiye updated its Nationally Determined Contribution as 41% decrease from business-as-usual scenario and peaking emissions by 2038 and will submit to the UN secretariat coming days.

Türkiye ratified the Paris Agreement and announced its 2053 target for net zero emission in 2021. In line with this development, it is inevitable that the environmental, climate and sustainability dimensions will have even deeper effects on Türkiye's energy sector transformation. Therefore, as a net importer country that meets its energy needs mostly from hydrocarbons, the transition to low-carbon energy resources and clean technologies will further accelerate. Transformation in the energy sector is critical for Türkiye to reach its net zero emission target in 2053. It will be possible to reach the net zero emission target by replacing hydrocarbon resources with clean energy resources as much as possible, deploying carbon capture, utilisation, and storage (CCUS) technologies in energy production from hydrocarbon resources, increasing the ratio of new and clean energy resources; and ensuring energy efficiency and electrification.

Within the scope of COP26 held in Glasgow in 2021, Türkiye held briefings regarding the plans for the net zero emission target and the green development revolution and stated that 3 billion 157 million US dollars of finance to be provided to Türkiye within the scope of the Paris Agreement will be used in all sectors primarily in energy sector that will support green development and will be spent on public and private sector projects in many areas such as renewable energy, hydroelectric development and rehabilitation, energy efficiency, low carbon production, biogas energy production (Ministry of Environment, Urbanization and Climate Change, 2021).

Ensuring the integration of all sectors into the low carbon economy will contribute to reducing energy imports and increasing energy security. In this context, it is important to increase the use of domestic and clean energy resources and to ensure energy efficiency and savings.

Türkiye has been working on increasing the use of renewable energy resources in terms of domestic and clean resources since the 2000s. Within the scope of these studies, it was not only aimed to increase the use of domestic resources but also encouraged to develop and utilize domestic technology.

Efforts are underway to meet the increasing energy need at low cost and uninterruptedly and to develop environmentally friendly energy systems, and today targets are set to reduce the use of fossil fuels and to increase the use of green energy resources.

In Türkiye where hydropower, among renewables, is predominantly used, in 2005 with the enactment of the Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy (Renewable Energy Law), the sector has developed towards a very different direction. In addition to the achievements in an increase of renewables, various achievements have been achieved so far in the decrease of greenhouse gas emissions, recovery of wastes, protection of the environment, and development of the manufacturing sector needed for the realization of these purposes (Presidency of the Republic of Turkiye, 2005).

Considering the high investment costs of electricity generation from renewable energy sources, the Renewable Energy Resources Support Scheme (YEKDEM) was established with the amendments made to the Renewable Energy Law in 2010. The purchase prices for the licensed power plants that will come into operation after 1 July 2021 within the scope of YEKDEM have been updated according to the resource used in hydroelectric power plants, wind and solar power plants, geothermal power plants and biomass power plants. In addition, the Renewable Energy Resource Guarantee System (YEK-G) to promote the use of renewable energy resources was put into operation, which allows electricity end users to certify that they make their consumption based on renewable energy resources (Presidency of the Republic of Türkiye, 2021).

The first step regarding the unlicensed production from renewable energy resources was taken in 2007 and the scope of "unlicensed generation" (or distributed generation) was expanded in 2013 and with the Law on Electricity Market generation facilities based on renewable energy resources with an installed capacity of up to one megawatt were exempted from the obligation to obtain a license and to establish a company (Presidency of the Republic of Türkiye, 2013). Thus, investment especially in unlicensed solar power plants has increased. By the end of 2021, the unlicensed renewable installed power has reached to 7548 megawatts.

In order to develop domestic production in renewable energy technologies and increase the capacity of qualified human resources, the Renewable Energy Resource Areas Regulation was published in 2016 and the Renewable Energy Resource Area (YEKA) model was created. With this investment model, it is aimed to increase job opportunities together with the sub-industry by paving the way for especially localization in renewable energy technologies (Ministry of Energy and Natural Resources, 2022a).

At this point, Türkiye increased the ratio of its renewable installed power to the total installed power to 54.5%, ranked 5th in Europe and 12th in the world with its renewable

installed power, and increased the share of wind and solar installed power to 18.5%, and increased the ratio of electricity generation from solar and wind to total generation to 13.1%. In addition, Türkiye avoided 76 million tons of greenhouse gas emissions by providing 43% of its electricity production from renewables in 2020, and 71 million tons of greenhouse gas emissions by providing 36% in 2021.

In addition to domestic production in electricity generation from solar energy, Türkiye has established a strong ecosystem with its research and development activities. Thanks to the YEKA model, it has the first and only integrated photovoltaic module production facility in the Middle East and Europe. It is the 4th largest manufacturer in the world with a total annual module production capacity of 7.8 GW.

Türkiye has been keeping nuclear energy on its agenda since the 1950s. The Atomic Energy Commission was established in 1956, and Türkiye became a founding member of the International Atomic Energy Agency in 1957. In 1976, the license was issued by the Atomic Energy Commission for the site of Akkuyu nuclear power plant. Türkiye became a member of the OECD Nuclear Energy Agency in 1984. Türkiye took the most important step towards its goal of establishing nuclear power plants in order to ensure resource diversity in electricity generation and decarbonize the electricity system with the agreement on cooperation in relation to the construction and operation of a nuclear power plant at the Akkuyu site, signed with Russia in 2010. According to the agreement, four VVER 1200 type nuclear reactors with a total installed power of 4800 MW will be constructed. Works are ongoing for the power plant which is planned to annually produce 35 billion kWh of electricity when it is put into operation. The foundation of the first reactor of Akkuyu Nuclear Power Plant was laid in 2018 and construction activities for the first reactor started. The first reactor is planned to be put into operation in 2023, and the other reactors are planned to come into operation by the end of 2026. Studies are ongoing on issues such as site selection, site license, and cooperation with companies or countries for the establishment of two more nuclear power plants apart from Akkuyu (Ministry of Energy and Natural Resources, 2022b).

Measures to be taken in terms of energy efficiency and savings in order to meet Türkiye's increasing energy needs by ensuring supply security in an uninterrupted, sustainable, and cost-effective manner and in line with environmental and climate policies will bring very important gains. Increasing efficiency in energy production, transmission, and consumption will increase competitiveness in the global economy as well as reduce energy costs. Türkiye has made an appropriate determination regarding its commitment to reduce emissions by especially emphasizing its Strategy on Energy Efficiency in the Intended Nationally Determined Contribution submitted to the UN secretariat in 2015. Türkiye has recently put forward its policies and studies in this area and has implemented practices together with regulatory elements. It is aimed to reduce Türkiye's energy intensity with energy efficiency implementations by at least 20% by 2023, compared to 2011. Türkiye's first energy efficiency action plan, National Energy Efficiency Action Plan entered into force in 2018 (Ministry of Energy and Natural Resources, 2022a).

Within the scope of the National Energy Efficiency Action Plan implemented between 2017-2023, it is aimed to reduce Türkiye's primary energy consumption by 14% in 2023 with 55 actions defined in 6 categories, including buildings and services, energy, transportation, industry and technology, agriculture and horizontal issues. It is foreseen to save 23.9 MTEP cumulatively by 2023 and to invest 10.9 billion USD for this saving. Based on 2017 figures, the cumulative savings to be achieved until 2033 is 30.2 billion USD, and

the effect of some savings will continue until 2040 (Ministry of Energy and Natural Resources, 2017).

According to the Action Plan monitoring, between 2017 and 2021 6.5 billion dollars were invested in energy efficiency in Türkiye, the annual savings exceeded 1 million TOE record high in 2021, and the total annual savings was 4.5 million TOE, and the economic size of this savings is equivalent to 1.6 billion dollars per year. Within the scope of the Action Plan, 12000 jobs were created; and imports of 3.4 billion cubic meters of natural gas and 0.85 million tons of petroleum/petroleum products were avoided. Thanks to energy efficiency practices in 2021, 16 million tons of greenhouse gas emissions were prevented.

According to the statistics of the last 20 years, although Türkiye is among the world's average in energy intensity improvement with 1.4%, the International Energy Agency recommends that this rate be increased to 4.2% for the net zero emission target.

At this point, Türkiye has started the preparations for the 2030 Energy Efficiency Vision and Strategy and the 2nd National Energy Efficiency Action Plan (2024-2030) in order to more efficiently begin next decade in 2030 which is the first intermediate stop for 2053 net zero emissions target. Within the scope of these preparations, it is aimed to hold workshops in all sectors and provinces with the highest representation of the sector, and to consult with all stakeholders. Within the scope of the studies, workshops are held with energy start-ups as well and the National Technology Initiative in Energy is consulted.

The Ministry of Energy and Natural Resources (MENR) has been considering environmental protection, prevention of pollution, and climate change combat within the scope of environmental and climate policies, while determining all its strategies and targets for energy supply security and energy efficiency. The objectives determined within the scope of MENR Strategic Plan for the Period of 2019-2023 (Ministry of Energy and Natural Resources, 2019) were established to support the green development revolution. In this context, in order to ensure sustainable energy supply security, the ratio of the electricity installed power based on domestic and renewable energy resources to the total installed power will be increased from 59% to 65%; nuclear energy will be among the sources of supply and efforts to increase its share in energy supply will continue; strengthening the electricity infrastructure will be ensured and technological transformation practices will be implemented in the electricity sector. Efforts will continue to prioritize and increase energy efficiency; the market will be further developed to enable demand-side participation in electricity; studies will be carried out to increase public awareness of energy efficiency; energy system planning for electric vehicles will be made. Works will be carried out to increase the rate of domestic production in equipment for technology development and localization in the field of energy and natural resources; R&D projects of strategic importance will be increased; clustering projects will be implemented; it will be ensured national systems to be used in energy infrastructures.

Although Türkiye's energy sector has undergone a transformation by taking the security of supply at its center in the historical process, environmental concerns with Türkiye's increasing dependence on imports have recently enabled different dimensions to be considered while assessing energy transformation; and efforts to achieve clean energy transition have accelerated. In order to achieve the sustainable development goals and the net zero emission target by the middle of this century, the use of clean resources should be increased, and the integration of clean technologies into systems should be encouraged as

well. In this context, Türkiye aims to further diversify its energy resources with hydrogen and to further implement digitalization in energy sector and to decarbonize the sector.

When we define the energy system as a value chain involving the process of linking specific functions from upstream, midstream, and through downstream, it is significant to localize the technologies required in the entire value chain. The new era shaped in line with the net zero emission target is advancing with a focus on technological development. In this direction, the biggest opportunity offered by the process is to become a country that exports decarbonization technologies with the technology development initiative to be realized as a whole. The high technology adaptation capacity of Türkiye, which is an important and large market on a global scale, offers significant advantages in terms of utilizing opportunities.

Developing Working Fields in Terms of Technological Advances for Türkiye

Hydrogen

Hydrogen has been considered as a "clean energy source" in line with the aim of decarbonizing the energy system by energy system transformation. It is an important advantage that hydrogen is widely used in many fields such as heavy industry, iron-steel-cement, and petro-chemistry, where it is more difficult to reduce emissions. Hydrogen can be produced from fossil fuels, renewable energy sources, or nuclear energy sources and is classified according to the emissions released during production. Clean hydrogen is the hydrogen produced by using renewable energy sources or nuclear energy sources or fossil fuels by using carbon capture, utilization, and storage technique (CCUS). It has been announced by the International Energy Agency that approximately 70 MW of electrolysis capacity was installed doubling the previous year's record, and two facilities producing hydrogen from fossil fuels with CCUS became operational, expanding production capacity by ~15% in 2020 (International Energy Agency, 2022).

While the studies of blending hydrogen into natural gas pipeline networks at certain ratios keep going in many countries in the EU; Türkiye's first "Power to Gas" project was initiated under the coordination of GAZBİR-GAZMER, and hydrogen was gradually blended into natural gas at the Clean Energy Technologies Center. It has been concluded in experimental studies that blending may not require major investment or modification to the infrastructure and can be done in a safe manner at relatively low hydrogen concentrations up to 20 % in volume (GAZBIR-GAZMER, 2022). Studies are carried out on the production, storage, and transportation of hydrogen and it will be possible to talk about national or regional hydrogen markets in the coming period. It will be possible to prevent imbalances that may occur as a result of increasing the system connection of renewable energy sources by means of hydrogen storage. The fact that existing natural gas pipelines can be used for blending hydrogen into the natural gas grid might kick Türkiye as a regional leader with its advanced natural gas pipeline infrastructure and connections.

In this context, Türkiye should accelerate its research and development studies on the production, storage, and transportation of hydrogen, as well as its implementation studies on a regional scale, especially considering its renewable energy resource potential and nuclear energy in electricity generation. It is highly important to prepare a key points strategy document including the determination of Türkiye's hydrogen potential and usage areas, and the planning of the production, storage and transportation infrastructure

investments required for the widespread use of hydrogen and make this road map among the hydrogen promoting energy policies. Studies on this subject are still going on. Türkiye has the capacity to be a European base for green hydrogen production, as its largest renewable energy potential, the lowest costs in terms of power plant installation costs, and the most advanced transmission network in Europe,

Distributed Generation and Demand Side Management

The transmission of the electricity produced in central power plants to the end users via transmission and distribution lines brings out some difficulties. Generating electricity at the location of the energy source and delivering it directly to the consumer close to the generation will provide increasing system flexibility and some benefits such as increasing efficiency, reducing costs, and reducing losses/leakage. Therefore, it is aimed to increase system flexibility by transforming central energy systems and ensuring distributed generation and demand-side participation and to expand production close to consumption points by increasing the integration of distributed renewable energy sources into the system. For flexibility in the network, steps can be taken to decarbonize the system by using methods such as demand management supported by demand coupling mechanisms, providing reserves from renewable power plants, in addition to market coupling mechanisms over storage systems and interconnection lines (Istanbul Policy Center, 2021). Besides, the use of combined heat power systems, renewable resources, and useful/waste heat in district heating and cooling processes, the use of heat pumps in industry and buildings can contribute to both self-consumption and the circular economy.

As digitalization is carried out on both supply and demand sides, the efficiency and sustainability of the system will increase. With the implementation of distributed generation and storage, smart and microgrids will be connected to each other and the main grid, thus providing flexibility in the control of generation and storage. In order to solve possible incompatibilities that may arise as a result of the further increase in the use of renewable energy resources, the management of the demand side by connecting the producer and consumer systems will be possible with the widespread use of digital control systems.

By means of the participation and management of the demand side, it will be possible to determine in advance in which region, when and how much electricity will be needed, and to provide low-cost electricity supply on time. Therefore, during the daytime or seasonal periods when the demand is increasing, the energy sources should be added to the system in a way that will produce the least amount of emission with the lowest cost or the electricity usage of the users is encouraged when the electricity consumption is low, or the storage is provided when the usage cannot be increased requires both holistic and regional management of the system and provides cheap electricity to users. This fact will also be beneficial in clearing the way for the generation of electricity from completely green resources.

Türkiye updated the regulation that will allow residences and industrial facilities to produce the electricity they need within certain limits without a license and to give the surplus to the system in 2019. With this regulation, an increase in distributed generation investments has been expected. However, this will cause the balance of power to shift from the transmission system to the distribution system, and as a result, it will bring along some sectoral additional regulations (determining the tariff to reflect the real cost, changing the duties of the distribution company).

Türkiye aims to integrate financial supports and distributed energy resources into the system, as well as legislative arrangements in order to ensure energy security, reduce energy prices and reduce emissions by considering the benefits of distributed generation and demand-side participation in the transition to a carbon-free, smart electricity system.

Digitalization

As in all sectors, the management of increasing data is important in the energy sector. Digital technologies that are used for determining actions by collecting production, transmission, distribution, and consumption data, and evaluating and interpreting this data will increase efficiency and quality as well as increase time and quality. High technology software and hardware, which will connect each link of the supply chain to each other, will ensure the effective use of energy resources, savings, and reduction of emissions from the sector.

As a result of the increase in distributed generation over time, consumers will also take the role of producers, and thus will bring the need to process big data for the optimization of energy systems. After the integration of the data on the demand side, a decision support system can be established in which energy demand can be met from domestic and renewable sources at an optimum level.

In addition to the digitalization of the energy infrastructure, the steps to be taken toward the digitalization of all the elements connected to the infrastructure will also facilitate the determination and intervention of what needs to be done in order to reduce the emissions originating from the energy sector.

Developing and updating the digital and hardware elements used in existing infrastructure and power plants will play a major role in reducing maintenance and repair costs, as well as reducing losses, increasing the safety and lifetime of infrastructure and facilities. With smart technologies to be used in energy supply and demand management, priorities will be determined more accurately and quickly, and thus decision-making processes will change.

In this context, integrating high technology software and hardware systems such as scada systems, artificial intelligence, machine learning, and the internet of things into all segments of the energy sector will bring innovations and developments in the human resources required by the sector. Therefore, the new business areas and opportunities will be ensured, and efforts to train human resources suitable for these new job descriptions will accelerate.

Electrification

Electrification plays a substantial role especially in transportation, industry and buildings as all machines, and vehicles can be operated with electricity in order to provide clean energy transformation. Meeting increased electricity demand as a result of electrification with electricity produced from clean sources is important for safe, smart, and sustainable electrification. Therefore, in order to ensure electrification transformation in an environmentally friendly manner with low emissions, production and infrastructure requirements must be planned and investments must be made in accordance with these plans. Effective demand-side participation and management will reduce the investment cost of upgrading existing systems. As a result of this transformation, electricity production and consumption will increase. Electrification will play a major role in improving the existing system, increasing efficiency, disseminating smart grids and integrating them with storage systems.

One of the most important elements of research and development studies in terms of energy storage systems is to transform underground resources into products with high added value domestic technology. The lithium facility commissioned by Eti Maden has been among the most recent developments at the end of 2020. Lithium is used in the batteries of all mobile devices, including electric cars, smartphones, tablets, laptop computers and electrical tools. Considering that energy storage will play an even more critical role in the future, lithium-ion batteries offer the best solution in this sense. Eti Maden has started to produce lithium from the liquid wastes generated in the production of refined boron, with its unique production method, as a result of the research and development studies that have been carried out for three years. It is anticipated that half of Türkiye's lithium need will be met by domestic production with the full capacity operation of the facility.

Conclusion and Recommendations

According to the Intergovernmental Panel on Climate Change, all countries must take urgent action to keep global temperature rise below 2 °C compared to pre-industrial levels by the middle of this century, and limit by 1.5 °C if possible. It has also been emphasized that emissions should be reduced by 45% by 2030 in order to achieve net zero emission targets until 2050, and in this context, it is essential to realize a fundamental transformation, especially in the energy sector.

International Energy Agency also states many times that the sector that needs to undergo the fastest change and transformation globally in terms of revealing three-quarters of the total greenhouse gas emissions is the energy sector by emphasizing the gains that all countries can achieve through clean energy transformation. For the last thirty years, countries have been making changes in the energy sector in line with their own needs. Recently the global energy sector is undergoing a transformation with the guidance of climate and environmental policies with the announcement of net zero emission targets until 2050 by countries,

Türkiye aims to meet its increasing energy needs in an uninterrupted and safe manner. It has started the clean energy transformation by considering its unique energy dynamics, with the policies it has developed to reduce the increasing energy costs due to its dependence on imports. Steps have been taken to increase energy savings with action such as reducing costs and emissions by promoting the use of clean and domestic resources; decarbonisation of the system by switching to electricity generation with nuclear energy sources; and energy efficiency policies and implemented practices. This energy transformation initiated by Türkiye will undoubtedly enter a new era after ratifying the Paris Agreement in 2021 and announcing its net zero emission target. It is highly important to update energy policies within the framework of environmental and climate policies that will be updated in this new period, to create energy plans, programs, and strategies in line with short-medium-long-term goals, and to ensure improvements by regularly checking the clear and measurable targets to be determined.

The production of hydrogen, which is foreseen as the clean fuel of the future in terms of the energy sector, from domestic and renewable resources in an economy that can compete with fossil resources, will provide important commercial opportunities for Türkiye in the future. Apart from this, studies to increase the usage areas of hydrogen will also be decisive in terms of our national energy technologies. Industrial solutions for fuel cell systems working with hydrogen is an important area where national technology can be developed,

especially considering that the internal combustion engines working with fossil fuels will be replaced by carbon-free or low-carbon systems in the coming years.

Türkiye supports research and development activities in order to expand domestic supply in all fields of energy and to ensure independence in technology. While aiming to expand the use of domestic resources in its policies aimed at reducing the dependence on imports of energy resources, it also takes measures to reduce foreign dependency in technology by encouraging the development and use of domestic technologies. In the past, it has also encouraged the development and dissemination of technology in the country within the scope of efforts to increase the use of renewable and nuclear energy sources. The knowledge and experience gained by the new investment models implemented in the development of renewable and nuclear energy technologies, as well as the measures taken to eliminate the deficiencies identified during the production and use of domestic equipment and components in these areas can be applied to projects to be developed regarding new and clean resources such as hydrogen.

On the digitalization side, the improvement of the communication between the internet of things and energy systems and optimization systems that will balance the power in the transmission and distribution networks by managing the renewable distributed generation capacity will be the key technologies required for the sector. Besides, it will be possible to create suggestions that will increase energy efficiency, schedule infrastructure investments, and create more accurate projections for the future by processing the energy consumption data of consumers.

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