Energy System Analysis, Simulation and Modelling Practices in Turkey

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Abstract Humankind first began to use simple machines instead of arm force. Subsequently, more advanced and sophisticated energy technologies introduced to our lives since the industrial revolution. Relatively advanced machines have begun to replace the simple mechanical systems in order to meet the various needs of humanity. Continuous improvements in related technologies have triggered the emergence of more compact, modular and more efficient vehicles over time. The rapid advances in technology naturally manifested itself also in energy technologies. Drivers in a national economy, particularly environmental problems caused by energy production and consumption, have been an area of interest in recent years. Energy technologies include increasing productivity, producing relatively more energy, or working towards an upward trend. In this perspective, this chapter aims to give an overview of the recent analysis of an energy system and modelling studies conducted by the energy joint workgroup at Marmara University and Naval Academy of National Defence University, Istanbul, Turkey.

Keywords Energy system analysis · Energy modelling · Turkey

1 Introduction

Humankind first began to use simple machines instead of arm force. Subsequently, more advanced and sophisticated energy technologies introduced to our lives since the industrial revolution. Relatively advanced machines have begun to replace the simple mechanical systems in order to meet the various needs of humanity. Continuous improvements in related technologies have triggered the emergence of more compact, modular and more efficient vehicles over time. The rapid advances in technology naturally manifested itself also in energy technologies.

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Drivers in a national economy, particularly environmental problems caused by energy production and consumption, have been an area of interest in recent years. Energy technologies include increasing productivity, producing relatively more energy, or working towards an upward trend.

In this perspective, this chapter aims to give an overview of the recent analysis of an energy system and modelling studies conducted by the energy joint workgroup at Marmara University and Naval Academy of National Defence University, Istanbul, Turkey.

1.1 Setting up the Reference Energy System to Be the Base of MARKAL Energy Model of Turkey

Energy modelling activities at Marmara University has been started with this study. The study emphasized that; as soon as the MARKAL Model of Turkey will be prepared, the phase of local and national decision support will be backed to join global energy resource management.

The initial step in energy system analysis and modelling studies is shaping the reference energy system (RES) of the analyzed environment. For this, the aim of this analysis has been determined to develop and make operational the RES and MARKAL Database to be used for the MARKAL Energy Decision Support System of Turkey. Related to this aim, resource technologies and energy carriers that are in use and can be used, conversion-process technologies and demands have been decided, their relations and situations in the MARKAL hierarchy have been determined, and a detailed network of energy from source to end-use, namely a RES has been created. In this phase, the statistical data of the network was unidentified, because of the missing data-statistical values i.e. technical efficiency, investment costs, fixed/variable operation and maintenance costs, transmission efficiency, the lifetime of the technologies, amount of demand; and therefore the energy balance could not be obtained.

After this step, the system was simplified and a secondary RES has been created in a more generalized level, then this network was specified by the relevant data and energy balance has been obtained; namely, the Base scenario has been constructed. Results of the Base case have been compared with the future projections in official development plans and it was seen that the reference energy system and the database are correct, with other alternative scenarios and proven that the model was operational. As a result of this study Reference Energy System of Turkey is constructed in two ways: simplified and detailed, the database has been constituted as an operational tool (Koç 2005).

1.2 Analysis of the Effects of Greenhouse Gas Emission Reduction Strategies on Turkish Energy and Economy Systems

Additional to the efforts given under the first study; the aim of this study has been determined as "to analyze the effects of different scenarios, particularly how to decrease greenhouse gas emissions on the Turkish energy and economy systems, by using Turkey MARKAL Energy Decision Support System and ANSWER software (Vardar 2005)."

2 Establishing Energy Efficient Utilization and Cost-Effective Energy Technologies Selection Strategies for Turkey Using MARKAL Family of Models

After above mentioned two studies; a more comprehensive study came out to bring up an operational improved model for Turkey, by using Standard MARKAL energy modeling platform, used by more than 40 countries around the world, and it has been established in the analysis period of years 2000–2025.

In this study; energy carriers, energy technologies, and demands are created in a database, their interplays and relations in MARKAL structure have been defined and a general network of energy from source to end-use has been constructed. Technical, economic and environmental effects were analyzed on the base scenario for the stated future cases by creating alternative scenarios (Sulukan 2010).

2.1 Establishing Mitigation Strategies for Energy-Related Emissions for Turkey Using the MARKAL Family of Models

This study has the aim to make a cost-effective contribution to the Turkish energy subsector about emission-related with energy in Turkey and integrate it into the world solution efforts.

The Standard MARKAL model which has been used in this work can connect the whole Turkish energy system ingredients like energy demands, subsidies, investment costs, capital requirements, greenhouse gas emissions, conversion, resource and process technologies in the same modeling platform. The model makes it easy to reach the right economic and environmental decisions by finding the best solution that meets the energy demand at the lowest cost by selecting energy supply and technologies.

The main priority for the creation of greenhouse gas emission reduction alternative is the use of relatively inexpensive types of non-polluting energy, especially in electricity generation, and the connection of electricity generated from renewable energy sources to the grid. It may be preferable to use electricity generated from renewable sources, especially for small consumption of non-mobile, residential, commercial, industrial or similar sectors. According to the results of this study, 50% of renewable energy use in electricity generation should be targeted in the first stage (Sağlam 2010).

2.2 A Preliminary Study for Post-Kyoto Period for Turkey by MARKAL Model

In this analysis, the RES of Turkey that has been developed by MARKAL is analyzed with the two alternative scenarios for reducing greenhouse gas emissions (GGE). The scenarios are theoretically requesting that they forecast considerable mitigations in GGE. Of course, this has seriously affected not only the prevention of economic development but also the large investment requirements for renewable energy sources.

It is unlikely that policymakers for whom economic development is of great importance will realize the significance of the scenarios focusing on the combat against climate change and its adverse effects. However, the scenarios described in this analysis demonstrate MARKAL's flexibility and suitability for developing energy analyzes for decision-makers (Sulukan et al. 2010a).

2.3 Determining Optimum Energy Strategies for Turkey by MARKAL Model

A comprehensive energy database has been developed in this study with the priority of technology selection strategies. After developing the RES for the energy system of Turkey, respective alternative scenarios have been offered to be applied against the developed Base Scenario. This process provides us with analyzing the possible effects for further and in-depth Turkey-MARKAL studies:

- The course of actions to increase the efficiency of thermal power plants by selecting their energy production, consumption and service levels in order to decrease greenhouse gas emissions,
- Analyses of future power plant growth plan to forecast the annual amount of investment and electricity capacity,
- Analyzing the possible effects of the transmission of electricity generation contributions of hydraulic, wind, solar and wave energy sources to the national grid.

- Possible options to maximize the combined heat and power contribution in sectors, especially power generation and industrial sub-sectors,
- Analyzing the possible outcomes of future nuclear power plants installed in the national energy system,
- Possible options to maximize the utilization of domestic renewable energy potentials in electricity production,
- Determining the greenhouse gas emission (GHG) mitigation scenarios to develop a sustainable energy action plan,
- Natural gas import fees possible instability is analyzed by the economic effects (Sulukan et al. 2010b).

2.4 Greenhouse Gas Emission Assessment from Maritime Transportation for Turkey by MARKAL Model

Maritime transportation is one of the anthropogenic sources of greenhouse gas (GHG) emissions which constitutes approximately 4% of the global total. Although this problem is currently being discussed at the international maritime organization and the United Nations Framework Convention on Climate Change (UNFCCC), policy effort on greenhouse gas emissions from maritime transport is insufficient yet. Shipping is the most environmentally and friendly mode of transport among other options in terms of GHG emissions.

However, it is predicted that the growth of emissions from ships will boost by 150–200% by 2050 if no precaution is taken, while it is estimated that emissions from ships will increase by 150–200% by 2050 if no action is taken. In this respect, the GHG emission inventory of Turkey is analyzed in order to determine the present state and future projection options of the maritime transportation sector as well as other sectors in the country. This study is carried out via MARKAL and its user-friendly Windows OS based interface ANSWER. MARKAL is a family of models that have been used in a variety of energy systems since the 1980s. The system is used by over 80 institutions in 40 countries.

In this study, the maritime transportation sector is designated as the main focus and the GHG emission inventory of Turkey has been identified to the model's database in the Base Scenario.

A basic GHG projection of Turkey is obtained by this study under the main assumptions. The maritime section of this inventory may give some remarkable insights in case of continuation with the Base Scenario. These issues will address the political, economic, environmental and technological measures as a part of the ongoing accession process to the European Union (Çelebi 2011).

2.5 Deliberating Lower-Cost Emission Reduction Options

In this study, the base scenario of Turkey MARKAL model indicates the current position that is carried out by the present policies which mainly back up the use of fossil fuel despite their huge emissions. In the base scenario, energy consumption and emission data for the base year were entered and analyzed in an integrated manner with the capacities and emission coefficients of the technologies. Even though the use of renewable energy, the most effective solution method to reduce emissions, is at a low level in Turkey, it is expected to be added to the national power system as long as economically viable. Owing to this model, we can test that not only in which renewable energy is invested in by the investors, but also determine whether we need nuclear energy to generate sustainable energy by applying alternative scenarios against the base scenario (Sağlam et al. 2013).

2.6 Developing Reference Energy System for Agricultural Sector and Modeling Biomass-Based Biofuel Production

Searching alternative energy sources and efficiently utilization of energy issues gains importance by gradual depletion of fossil fuel reserves. When the environmental effects are also considered, renewable energy sources are preferred in first order among other alternatives. Apart from solar and wind energy, biofuel production from biomass is specified as a significant work area in terms of relatively low cost and low greenhouse gas emissions; foreign dependency reducing effect and contribution to agricultural development.

With this perspective; firstly, the reference energy system is developed for the agricultural sector, then MARKAL energy-economy-ecology integrated model is generated including irrigation and all agricultural demands of the country from biofuels by biodiesel production from canola and bioethanol from sugar beet. MARKAL model generator is currently being improved by the Energy Technology System Analysis Programme (ETSAP); which is already a continuing multinational program under the International Energy Agency (IEA). MARKAL model is also used for scenario analyses in World Energy Outlook reports which are annually published by IEA. The model basically consists of six columns, where domestic canola and sugar beet are used as resources, biomass-based power plants, and biofuel production processes are conversion and process technologies. Electricity, biodiesel, bioethanol, (bio) hydrogen, biogas, and glycerin production is modeled as final energy carriers; these products are identified as demand technologies, which are electricity and biodiesel utilized by irrigation pumps, tractor, and agricultural transporters.

The generated energy meets the main demands of agricultural irrigation; land preparation and agricultural transportation and agricultural fertilizers, agricultural chemicals and liquid carbon dioxide consist of other products of the system as the other demands in this area (Şahbaz and Sulukan 2015).

2.7 Reference Energy System for Land Transportation in Turkey

Increasing energy consumption often adversely affects the transport sectors in developing countries. Integrating energy planning for the transport sector in these countries can diversify the options to change its suboptimal organization and reduce energy consumption.

The MARKAL family of models show a range of practical decision support tools for energy planning analyzes, as well as their relationship to environmental impacts. In the past, the model was a simple optimization program used only by researchers, but today it has turned into a very complicated package with many potential applications, from scientific research to analysis of energy/environmental policy and planning of questions.

Users who are not familiar with programming or optimization theory can use the model framework more easily through the Windows-based interface ANSWER. The MARKAL family is one of the most common decision support tools used to translate global commitments to reduce greenhouse gas emissions into projects and actions. The economic and ecological benefits of these individual activities and the additional benefits arising from the opportunities for cooperation should be assessed. The MARKAL model family makes informed decision-making with a flexible, well-understood, proven, verifiable and evolving methodology.

In this paper, a preliminary analysis is performed on the relevant statistical data of land transportation in Turkey. Then, the reference energy system of land transportation for Turkey is developed. According to statistics and RES, data obtained from the Turkish Statistical Institute (TurkStat) is entered into MARKAL-Answer software and the Base Scenario is prepared. In this way, all data is seen as a summary table. This will hopefully establish a foundation for further analyses in the transport sector in Turkey (Şener and Sulukan 2016).

2.8 Energy–Economy–Ecology–Engineering (4E) Integrated Approach for GHG Inventories

Energy is a very effective factor for the economic and social improvement of a country. Nonetheless, energy resources, energy conversion/processes or demand technologies are complicated and need to use an algorithm to optimize the energy system. Because that is the best way to get energy-efficient and clean solutions that may provide sustainability and mitigate climate change effects. It is possible for countries to achieve the purpose of sustainable development in terms of economic and environmental constraints through realistic and long-term strategic plans that combine and optimize their global and unique conditions. When performing a comprehensive analysis with realistic parameters, the current situation and the potential for the future can be taken into account. MARKet ALLocation (MARKAL) is a model manufacturer that is currently being developed and is currently being used by universities, government agencies, non-governmental organizations, energy services, and consulting companies. The Energy Technology Systems Analysis Program (ETSAP) is the implementation agreement of the International Energy Agency (IEA), which acts as a consortium of member country teams. It also invites teams that actively cooperate to build a consistent multi-country analytical capability related to energy, economy, environment, and engineering (4E).

This study sums up the progress of a MARKAL model for Turkey and the beginning predictions proceeding from the BAU predictions from 2005 to 2025. If the Turkish MARKAL model is analyzed in more detail, the basic demands to analyze for an effective energy policy road map of Turkey can be created. These can be achieved by creating and running additional alternative scenarios against the BAU scenario as follows:

- Supporting the financial decision mechanisms for renewable energy system investments,
- Accelerate the integration of renewable energy among the heating/cooling and transportation sector for meeting national targets,
- Improve alternative plans for increasing efficiency in thermal power capacity or technologies used in end-use sectors that influence the energy generation, consumption, and GHG emission levels,
- Creating potential candidate generator examinations to acquire yearly investment levels and power load rates of electricity,
- Boosting alternative capabilities of hydro, wind, solar and wave power sources of the national energy system is analyzed in terms of possible effects,
- Benefit from combined heat and power facilities also called co-generation across all sectors, particularly power plants and industrial sub-sectors,
- Analyzing upcoming nuclear power plants' effects in the energy system,
- Analyzing CO_2 reduction scenarios to determine a road map in terms of ecological aspects.

Currently utilized conventional energy resources manage Turkey's energy grid and the present energy mix involves no externalities for fossil fuels, as the energy technologies have progressed to be mainly based on fossil fuels since the industrial revolution. Demand technologies rely almost exclusively on the use of fossil fuels which bring about ecological pollution. However, management is the most significant component for deciding a useful path for decreasing the consumption of polluting harmful energy resources to reduce global warming effects and sustain society. There is a consensus among decision-makers, engineers, local authorities and non-governmental organizations on the choice of energy and technology to support environmental planning by experts with energy modeling capabilities. Additionally, it should identify relevant aspects of an energy system such as energy economy, environmental impacts, energy production and ethical responsibilities (Sulukan et al. 2017a).

2.9 Reference Energy System Development for Turkish Residential Sector

Another energy analysis and modelling of demand technologies via ANSWER-MARKAL software have been carried out by this study which focused on the Turkish residential sector. Some basic assumptions were made during data entry and model building processes. The energy decision support model can be complicated to the extent that the available data allows. Though, an initial phase of modelling is constituting the base scenario that belongs to demands technologies in the residential sector of Turkey has been completed. The next step will be to run the base scenario model and obtain the results of the BAU scenario. The next step after running the base scenario is establishing various alternative scenarios such as one with a fully renewable energy source and another with fossil fuel use set to zero, and so on.

Additionally, actions to achieve energy-efficiency and energy-saving ought to be able to bring into the model as input. The primary aim of this study is to have a projection of the next five decades and to help forward-looking alternative scenarios that will be progressed over time. These results will be used to minimize the total cost of the system by providing technical support to the decision-makers in the residential sector (Mutluel and Sulukan 2017) (Fig. 1).

2.10 Technical Efficiency Improvement Scenario Analysis for Conversion Technologies in Turkey

The results of the technical efficiency improvement option in especially conversion technologies can be analyzed through the technical efficiency improvement scenario. It is analyzed if there is a 1% increase in the technical efficiency of currently active energy production. When there is a 1% increase in technical efficiencies, the influences of the scenario occur in the efficiencies and investment costs of conversion technologies, beginning from 2015. For a 1% progress in energy efficiency, the investment costs of conversion technologies are estimated to be an additional cost of $2/kW. The investment costs of the TECH-1 scenario are calculated by adding $2/kW for each technology. After the main data are entered into the model assuming basic assumptions, this model runs against the BAU with the TECH1 Scenario. As a result, fossil fuel imports and export levels are the same in the Base and TECH-1 scenarios. According to the TECH-1 scenario, fossil fuel exportation halts during the 2010–2025 period. Final energy and use of final energy levels are the same in these two scenarios. Mining activities increased 55% and total primary energy decreased 6% in TECH1 Scenario.

Domestic fuel margin steps up 3.43% on average while annual total costs of TECH-1 diminish 3.77% on average. Fuel and net import cost diminished by 15.61% and 18.09%, on average. While the undiscounted total system cost diminished by 8.10%, the total discounted system cost diminished by 1.6% as can be seen in the

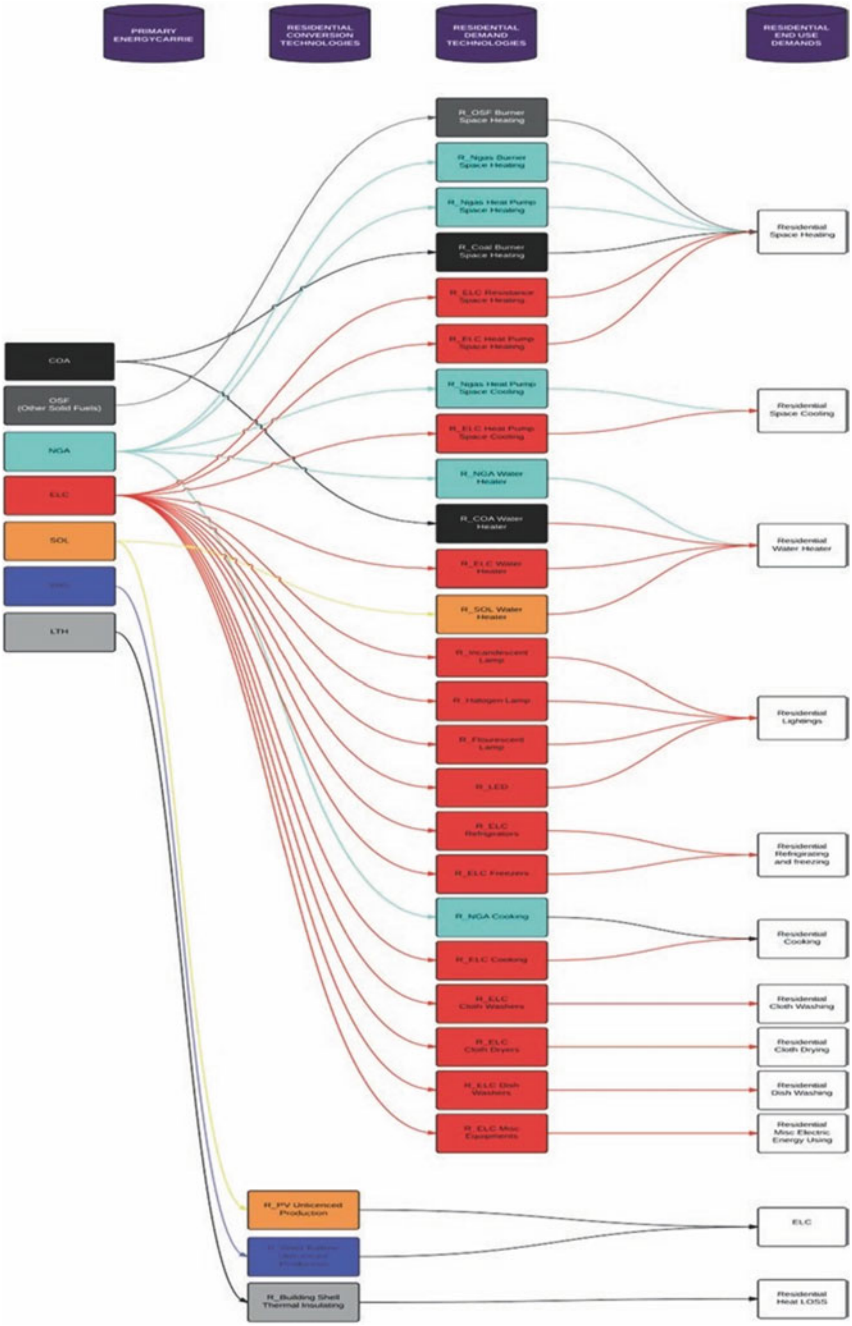

Fig. 1 Reference energy system of the residential sector in Turkey (Mutluel and Sulukan 2017)

TECH1 Scenario in this cost summary. Domestic fuel costs step up as the system prefers more domestic fuel rather than imports. Thus, import costs additionally somewhat decline. A small development has a positive effect on the national economy by creating a chain effect on the whole system (Sulukan et al. 2017b).

2.11 Analysis of Demand-Side Management Option with Cogeneration Implementations in Turkish Energy System by MARKAL Model

As stated in the official reports previously published, the main motivation of this study was the optimistic assumption of the demand side to activate the cogeneration potential and to manage it in a more efficient manner. Demand levels are assumed to decrease by 15% in industry and by 10% in the residential sector to show the possible effects of improving the use of expanding cogeneration, especially in industry. In addition to demand reduction precautions in these sectors, it is expected that cogeneration type facilities will be used to grow the share of cogeneration in total electricity production, which is expected to reach 16% in 2025 from 4% at the end of 2005. Thus, 16% of total electricity production would originate from combined heat and power in 2025.

If you compared with base scenario demand levels, the demand level is decreased by 13.9% in 2020 and by 25.9% in 2025. The total efficiency of combined heat and power generation is taken as 85%, whose 55% is for heat and 30% is for electricity production. It is also accepted that all new combined heat and power plant capacities will be ignited by natural gas.

Emission mitigations and cost-effectiveness of alternative scenarios were evaluated by comparing scenarios. Some economic and ecological values were calculated such as total economic cost, cost increase, net energy import cost, net energy added value, total CO_2 emission, emission increase and cost reduction (%) through alternative scenarios and Base Scenario values. While these modeling studies, the DSM scenario is considered as a cost-effective and climate-friendly application. At the rate of 43%, CO_2 reduction is achieved with this scenario. As a result of such measures, implementation will bring an additional cost to the country's economy in the first stage, but it will bring advantages both economically and environmentally in the long term. This idea will strengthen the position of our country in the international community in terms of determining the sustainable development target together with the IPCC process (Sulukan et al. 2017c).

2.12 A Native Energy Decision Model for Turkey

Turkey's Reference Energy System has been created over time and constantly improved throughout the study period involving the present and predicted resources, fuels, and technologies. Lastly, 28 energy carriers, 29 resource technologies, 11 process and 20 conversion technologies, 139 end-user (demand) technologies, 30 demands in five sectors, 11 emission components, 11 tax/subsidies, and 12 global items (i.e., annual discount rate, GDP in first year, fraction of year for season, time of day) have been determined in suitable positions according to MARKAL hierarchy and characterized with value by using ANSWER user interface (Fig. 2).

The menu-driven user interface of ANSWER makes it easy to adjust the data input and structuring of the MARKAL model. Demonstration cases with default data are also provided. This interface not only organizes file processing and execution but also includes result processing menus for both table and graphical display. However, the components and structure of the RES can be developed depending on economic, technological or environmental requirements for further analysis with future requirements (Sulukan et al. 2017d).

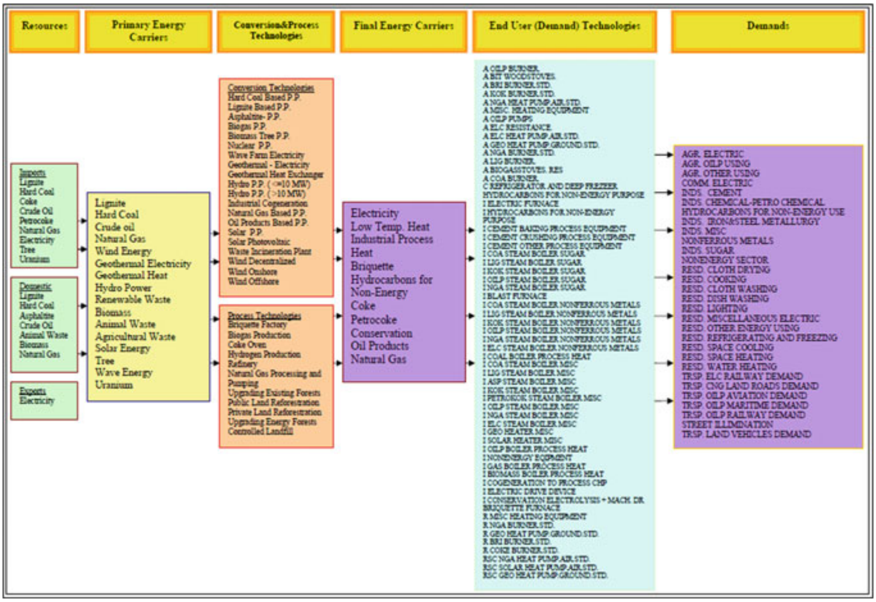

Fig. 2 Generalized RES of Turkey energy system (Sulukan et al. 2017)

2.13 Analyzing Cost-Effective Renewable Energy Contribution Options for Turkey

The scenario which is aimed to meet the energy demand in Turkey via using all renewable energy sources is named Renewable Scenario (REN100). Possible renewable energy potentials have become the upper limit on the activities in the model. All costs are given in US dollars in 2005. In particular, the estimation of demand and associated capacity has been one of the assumptions that it is proportional to Turkey's economic growth estimated by the World Bank. It is assumed that the total hydro-energy potential in the country is renewable by applying an upper limit in the scenario, ignoring the size or capacity of the dams.

Second, storage, hydrogen production, and forestry which are renewable process technologies have been determined to limit the maximum level of renewable use with existing technologies. So, allowing the model to be used even more than the reserves of the country and determining the fixed fossil fuel boundaries on which the technologies are based, turns towards a positive result as a model output. In this case, the model gives an "optimal" result, in the end, it is possible to observe a significant increase in the use of a renewable but on the contrary, there is a decline in fossil fuel use. The overall demand in the system is optimized and the overall system cost of energy is drastically reduced due to excessive exports of fossil fuel products and the generation of abundant renewable electricity. After this progression, if it is restricted to use one of the fossil fuels (e.g., coal) entirely in the energy system by setting the bounds "zero" on fossil-based and the end-use (demand) technologies, the energy carriers used in the model preferred by the end-use technologies give rise to "infeasible" result.

This means that unless there are subsidies, taxes, certain limitations or innovations in end-use technologies, the marketing system does not change direction. In order to prepare a more realistic scenario that will yield a viable result with positive input, each assumption must be carefully selected and applied one by one, showing a clear response of the model for each trial. As an illustration, setting a limit on the burden imposed by reference fossil energy technologies would be a good starting point for the reducing options, as long as the model gives optimal results, by setting it to zero at times other than the reference year. Reserves are selected as the upper limits determined at the resource level. The bounds on activities and capacities of renewable technologies are set free to allow the system to use them independently. Limits on the capacities of demand technologies that use electricity have been allowed, for example, to use renewable electricity instead of diesel in railway transport. In this case, while the whole system stops importing fossil fuels including crude oil and NGA, the increase in domestic lignite and coal usage sets up. The system does not produce any briquettes. The fact that hard coal and crude oil are the essential components of the country's energy mix until the market possesses the transportation technologies using hydrogen and alternative fuel production as hydrogen is concluded by the model.

As progress, hydrogen fuel turned out from renewable electricity and hydrogen using in end-use technologies has been introduced. It is suggested that the wave power plant will generate electricity by 2020. All potential energy resources are ready for use. Good security points are provided for domestic mining resources. It does not allow the model value to be entered to indicate wind and solar energy security. The system runs under these conditions and gives optimum results.

The model notes that the use of fossil resources has declined significantly, and that no nuclear energy is necessary to sustain the energy system with respect to conversion technologies. It is clear that renewable use is extremely high when it is a model that is allowed to use all the renewable electricity potential, regardless of whether the energy type is expensive or cheap or has other characteristics. Therefore, in REN100 Scenario, it is not possible to generate electricity from any of the asphaltites, natural gas, petroleum products, lignite and hard coal plants since the country's renewable potential is used. The model refrains from using fossil energy in electricity generation. In this case, renewable energy sources provide total electricity production. As an important indicator of dependence on foreign resources, in the REN100 Scenario; total fossil energy carrier imports decreased by 100% and total domestic fossil energy carrier supply decreased by 94.4%.

To illustrate the impact of end-use technologies on all energy systems, it should be noted that different changes in demand technology investment costs can be analyzed under different scenarios. According to the BAU results, the country's total primary energy rose from PJ 3861.6 in 2005 to PJ 7705.5 in 2025, up by 128.9% during the 20-year analysis period under the main economic assumptions. In the REN100 Scenario, this increase is seen as 90.1%. The use of renewable energy changes this view by a 97.2% increase in the BAU Scenario and provides 100% renewable electricity generation during the scenario with 892.3% in the REN100 Scenario. All these parameters can be modified or applied by the user like other scenarios on the model, relying on the leading indicators of the economy. Carbon dioxide emission levels are also affected due to increasing renewable energy use and decreasing fossil fuel use among the sources used as energy carriers. The BAU scenario foresees that CO_2 emissions will increase from 236.8 Mt in 2005 to 479.9 Mt in 2025, resulting in an increase of 131.6% in the total analysis period. The change in Carbon dioxide emissions decreased by 64.4% in the REN100 Scenario. The use of imported fossil fuels has led to an increase in the level of security by 6.3% (Sağlam et al. 2017a).

2.14 An Alternative Carbon Dioxide Emission Estimation for Turkey

Estimates were made using the CO_2 emission rate methodology according to the calculation method based on fuel use described in the IPCC rules (Sağlam 2010). Approach of the fuel analysis made up of calculations grounded on aggregate of results of multiplications of the quantity of fuel consumption and the fuel characteristic information containing heat content, carbon content oxidation factor, CO_2's molecular weight (44), C's molecular weight (12), conversion factor from kg to tons (1/907.2) in base scenarios of transportation, residential, agricultural and industrial sectors. While CO_2 emission is calculated, default fuel-specific emission factors (kT/PJ or kilotons/petajoule) multiplied with the quantity of fuel type on volume/mass/energy basis (PJ or petajoule) and addition the results (kT/year) for all type of fuels and this method called as a generalized approach. In this model, greenhouse gas emissions are predicted from all sources contains imports and exports, presuming they are consumed as any kind of fuels such as gas, solid or liquid and forestry effect over the system is assessed in the alternative scenarios. An example of estimating carbon dioxide emissions from sample fuel consumption in technology is compared with the results of fuel analysis and generalized approaches. The MARKAL model allows using different methods to calculate the total quantity of emissions produced from all sources (sources and technologies) in each period. However, the cross-check of methodologies is significant to confirm the correctness of the CO_2 emission estimate.

The base scenario also named as business as usual or BAU is consists of a series of information about Turkish energy and emission to develop policies on how to mitigate carbon dioxide emissions. The base scenario is also used to assess the relationship among the economic growth, energy consumption and GHG emissions of Turkey by comparing with other scenarios. Therefore, we create and run various scenarios with a base scenario and add detailed and appropriate energy sources on a sectoral basis, conducting detailed analyzes in terms of economic composition change, carbon density and energy density change. In this study, the period between 2005 and 2025 was analyzed.

The model indicates carbon dioxide emission projection as five-year periods in which TUIK information is added to the results of the base scenario. Here, especially to predict demand, domestic fossil fuel reserves and the consequent capacity, as envisaged by the World Bank, it is assumed that every sector in Turkey is directly proportional to the 3.3% economic growth. Estimates of long-term carbon dioxide emissions from energy-related use increased the rate of 183.49% from 183.59 kT to 479.95 kT between the years 1990 and 2025. The fulfilled period of carbon dioxide projections which is related to energy provides clues about the economic growth rate of a country. We foresee that in 2010, 293979.36 kT of CO_2 emissions will be released and if we compare it with the TUIK data, we can see the similarity between these values. TUIK is declared 299.11 kT CO_2 in 2009. This means one may be impressed with this study which made in 2005 and foresee the economic growth of Turkey in energy demand between 2005 and 2010 is not much more than 3.3%.

The carbon dioxide ratio of the electricity produced in Turkish power plants was calculated. From 2000 to 2025 the increase in the emission rate was 153.21%. The increase in carbon emissions from electricity generation is lower than the increase in emissions from other activities in the country, as shown in Fig. 3.

If there isn't comprehensive information associated with the process, conversion or combustion in plants or other end-use technologies such as trucks, steam boilers,

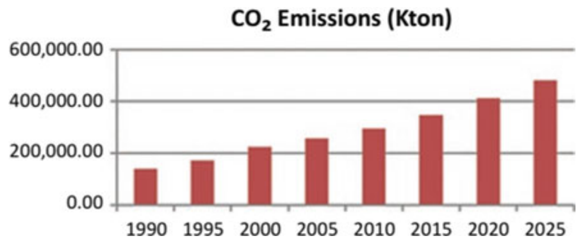

Fig. 3 CO_2 emission projections between 1990 and 2025 (Sağlam et al. 2017b)

stoves, etc., the quantity of the CO_2 by using default carbon factors can be calculated from the combustion of the resources at the beginning (generalized approach). Emission coefficient/activity (ENV_ACT) has been set to zero in the Scenarios, while the carbon dioxide emission factor is being used as an emission coefficient/resource activity (ENV_SEP) in this study. This is more accurate than what I have achieved in my previous studies. In the model, the carbon coefficients in the BAU scenario are adjusted according to the consumption given in the balances and emission stocks from each activity in 2000 and 2005. The worth of carbon dioxide coefficients acquired for each technology in 2005 was used in the period between 2010 and 2025. In the GEMIS and TCR scenarios, carbon dioxide emissions are predicted in resource technologies, which means before burning in conversion or end-use technologies. Intergovernmental Global Emission Model of Integrated Systems (GEMIS) and The Climate Registry (TCR) General Reporting Protocol provide all GHG emission factors for all sectors and technologies. In the GEMIS and TCR scenarios, the results are 4.9% and 5.1% higher than the BAU ‘results in general terms, respectively. Different results are obtained with Fuel Analysis Approach for sample products extracted from the RES system and imported to RES system.

As a result; the operational data of technologies are the most significant part of trustworthy statistics, some of which are based on assumptions or estimates. Even Though it requires hard work to improve emission coefficients for fuel combustion technologies used in Turkey, they should be calculated for each of the fuels used in the Turkish sectors according to the measurement and scientific methods. Because they must be trustworthy both in tracking the actual CO_2 emission and in creating the emission inventories (Sağlam et al. 2017b).

2.15 An Analysis of Centennial Wind Power Targets of Turkey

Wind power has become one of the cost-effective options for improving the energy mix, while the wind farm installations reach higher shares by new capacity additions in Turkey, similar to many other countries, in order to support the sustainable development targets. Various methodologies are implemented and applied for planning and optimizing the energy systems of countries, taking into consideration the energy, economy, and ecology aspects as a whole. The objective of this paper is to demonstrate the implications of the “2023 energy targets” policy in terms of wind power. A futuristic scenario was tailored and applied to a comprehensive energy model for the energy system of Turkey.

The official wind energy vision and goal of Turkey were analyzed by applying a scenario based on 20,000 MW wind power capacity installation by the year 2023. The results indicated that, if applied, this action will increase the share of wind power utilization to the level of 16% in the total renewables while the installed wind capacity will reach 18%. Finally, the total cost of this strategic target which doubles the installed capacity and electricity generation by wind power, including the respective investment costs and subsidization results, was calculated as $24.78 billion on the analysis horizon (Sulukan 2018).

2.16 A Model-Based Analysis of End-Use Energy Efficiency for Çanakkale, Turkey

The energy-saving potential can increase the share of renewable energy in the energy mix and accelerate to become more economical by opening to new markets. This paper primarily focuses on the importance of energy efficiency in the transition of 100% renewable energy in cities.

In this study; a detailed energy network, namely Reference Energy System is developed for Çanakkale to identify the components and the interrelations between the energy supply, demand, and energy technologies as a holistic approach. This framework also aims to analyze end-use efficiency in electricity consumption in Çanakkale and will allow us to make inferences for large-scale situations from a broader perspective. It is crucial to increase end-use efficiency in order to meet or even reduce the rising energy demand and then plan a sustainable, environmentally friendly energy system (Bakirci et al. 2018).

2.17 Urban Scaled Reference Energy System Development with a Sectoral Focus

This study aims to analyze and determine the potential of the marble sector, which is a significant part of the energy model developed for Burdur, Turkey. Burdur, the selected city as the analysis domain, is located in the West Mediterranean region of Turkey.

Burdur province makes most of its revenue from the marble sector, because of the rich marble veins and region-specific marble types. Other than the marble, Burdur also makes income from livestock breeding, agriculture, and dairy products. As a result, high capacity marble quarries also attract local and foreign companies to

Burdur province and stimulate the establishment of various marble processing plants. The marble sector in Burdur is analyzed in the energy system structure perspective as two main segments; quarrying and processing of the marble. The entire equipment and machinery inventory were determined from a middle-sized marble quarry and processing plant. Reference Energy System is based on the year 2016, extending to 2031 by Answer-TIMES energy-economy-ecology model generator. The energy demand of the sector in the years 2021–2026–2031 was calculated and the Burdur-TIMES model is designed and developed on the urban scale, based on rich energy technology and sector-based data (Beşikçi et al. 2018a).

2.18 Reference Energy System Analysis of a Generic Ship

With the ever increase of population and technology development, energy consumption and demand have increased in diminishing sources worldwide. Therefore, energy system analysis has been an important topic to control energy consumption against limited sources in the last decade. In light of climate change, governments and organizations have been released new environmental regulations on energy consumption and emissions in the maritime sector to reduce the effects of climate change.

In this study, energy consumption characteristics and energy demand segments of a generic ship were evaluated by the energy system analysis approach and a RES is developed. On this basis, data-driven and technology-rich RES will be available to help prospective analyses on a base scenario. Furthermore, the respective energy model of a generic ship will be ready to be developed and analyzed, taking into account technical, economic and ecological constraints (Sulukan et al. 2018).

2.19 An Analysis of Centennial Solar Power Target of Burdur Province

Solar photovoltaic has recently become a significant energy conversion technology in all of the renewable alternatives. Like other countries, rising solar share in the renewable market supports sustainable development targets in Turkey. To achieve this development, Answer-TIMES optimizes possibly the best solutions among the other energy modelling methods due to the energy-economy-ecology aspects.

In this paper, 2023 renewable energy targets Turkey is discussed. In this perspective, 5000 MW installed capacity target of Turkey has been implemented to Burdur province by the share of solar PV installed capacity. Results show that, after 47.35 MW addition to current solar power plant installations, total electricity generation from solar PV peaks to 49% and triples the solar-based electricity production (Beşikçi et al. 2018b).

2.20 Calculating the Levelized Cost of Electricity by an Urban Scaled Simulation Approach

Countries are working to define and track pathways decreasing CO_2 emissions since the Kyoto Protocol has been signed in 1992. Paris Agreement in 2015 fortified renewable energy strongly; and as a result, the US and Europe had to step ahead in renewable energy roadmaps. In the renewable energy transition process, the cost of annually generated energy has great importance. On the other hand, as a small representative of a country, cities have more than one energy generation plant. Various fuel-based plants and energy generation technologies (from renewables to fossil-fuelled plants) make the calculation of the unit cost of energy generation more complex.

Manisa is an important city in the Aegean Region of Turkey, rich in energy generation technologies from renewable to lignite plants presents with a wide opportunity for assessment of energy production costs. However, alternative energy cost calculation methods exist in the literature such as ESA and LCOE, with different limitations and assumptions. In this study, a code on the MATLAB environment is prepared to simulate the Manisa electricity generation grid to determine the amount of electricity production for each power plant. The outputs of the simulation are used in the cost calculation process on the MS Excel sheets using a modified version of the LCOE methodology for the base year 2016.

The same simulation has been applied to the EnergyPLAN environment as an additional study to verify the results of the MATLAB code and provide a basis for discussion on the amount of energy and respective equivalent CO_2 emissions by these two platforms (Köker et al. 2019).

2.21 Transition to a Low Carbon Future in Maritime Fleet for Climate Change

Climate change is a recent important issue for transportation sub-sectors and the environmentalists have been working to combat climate change for decades. As 90% of the world-trade carried out by maritime transport; ships play a crucial role in the transport and trade vehicles. Approximately, 2.5% of the global GHG are caused by the ships and it has been ever-increasing, depending on the expanding maritime transport demand. Reducing the maritime-based GHG is a global challenge task, determined by the International Maritime Organization (IMO).

Nowadays; a number of measures to reduce carbon footprint and respective course of actions are recently being discussed and developed globally. IMO encourages shipping industry to minimize the carbon footprint by fostering energy-efficient onboard technologies, as the global top decision-maker. In this study, the current technology configuration on a chemical tanker ship has been modelled by LEAP (Long-range

Energy Alternatives Planning System), one of the widely used energy decision support tools. Then we focused on reducing greenhouse gas emissions with an alternative scenario according to IMO regulations and future technology developments. The results show that reducing the ship based GHG is possible and that is sure to give us a more secure future, in a cleaner atmosphere (Sarı et al. 2019).

2.22 An Urban Techno-Economic Hydrogen Penetration Scenario Analysis for Burdur, Turkey

Turkey's existing power generation infrastructure and the mixture of energy are analyzed, and two alternative scenarios based on hydrogen are implemented on Burdur's TIMES model in this paper in order to have an estimate of any environmental or economic outcomes for the years of 2016–2031. Building an advanced RES, determination of how energy carriers and the related technologies are connected and illustration of the existing energy system of Burdur was provided. Then, relevant data, which involves technologies of fuel cell driven land vehicles that are combined with demand-side of land transportation, was used to enounce this structure.

In this paper, hydrogen's applicability as an alternative bearer of energy in the fuel mixture for producing electricity in Burdur was examined to attain a continual economic growth, to enhance safety of energy through reducing relevant environmental emissions and to demonstrate the potential impacts of implementation of hydrogen supply chain and various fuel cell end-use technologies from the viewpoint of an energy modeling on city level.

The city of Burdur has been chosen as the target city to resolve hydrogen technologies' demand for land transport passengers. After putting hydrogen cars in practice in 2020; calculation showed that a total of 43.44 kT CO_2 emission can be ruled out by only 0.09 PJ of hydrogen car activity in Burdur, focusing on the 8% of the base scenario's total emission in the time period of the analysis. Lastly, hydrogen has been considered a secure and clean alternative in order to expand the mixture of energy on Burdur's existing energy generation system (Beşikçi et al. 2019).

3 Conclusion

Energy system analysis studies at Marmara University, Turkey via reference energy system concept firstly appeared in 2005. The Reference Energy System of Turkey was established and the effects of GHG reduction strategies on Turkish energy and economy systems analyzed through MARKAL which is a comprehensive energy decision support tool, have been used to create the energy database of Turkey for the period 2000–2025.

Since 2010, a number of studies have been carried out jointly in this field at Marmara University and National Defence University. Analyses of different energy systems have been done, but these studies are not only limited to regional energy analysis; also, for sectors, vehicles, buildings and so on. Besides these efforts, data mining has been used in the energy sector aiming to make a positive contribution to the energy profile of the country by increasing energy efficiency (Zorlu et al. 2019).

In the studies, the designated energy model has been created through reference energy system approach and decision support tools have been utilized to maximize the synergy between Energy–Economy–Ecology–Engineering (4E) to achieve a cleaner and more reliable future.

Disclaimer
The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied of Turkish Armed Forces, Turkish Naval Forces, National Defence University, Marmara University, and any affiliated organization or government.

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