



## Energy and food nexus for sustainable development in Turkey

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### Abstract

The energy–food nexus is being promoted as a conceptual tool for achieving sustainable development. Frameworks for implementing nexus thinking, however, have failed to explicitly incorporate sustainable livelihoods perspectives. This is counterintuitive given that livelihoods are key to achieving sustainable development. Turkey has young population and growing energy demand per person, and its economic development, has been one of the fast-growing power markets of the world. Turkey is heavily dependent on expensive imported energy resources that place a big burden on the economy and air pollution is becoming a great environmental concern in the country. In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions for clean and sustainable energy development in Turkey. Turkey’s geographical location has several advantages for extensive use of most of these renewable energy sources. This article discusses the current perspective of the sustainable food and energy policies in Turkey.

*Keywords:* sustainable development; energy sources; renewable energy; greenhouse gases

### 1. Introduction

The focus of this review is the integrated system that supplies energy, water, and food for use within human society. This is often called the Energy-Water-Food Nexus; we use the term Nexus for brevity. Humans have always required food and water for personal survival and have long exploited external sources of energy for cooking food, processing materials, and providing warmth and light. Since the industrial revolution, we have understood how to make heat engines to power machinery, which has vastly expanded the potential of human existence but also greatly increased our demand for energy. As long as most people lived in scattered communities, food, water, and fuel could be supplied locally, or by simple trade and barter. But with the growth of the world’s population [1] and its concentration in urban areas, which distance people from the sources of their primary energy, water, and food, the supply of these three commodities has become ever more complex and interrelated.

These interrelationships can arise from many different causes, from relatively simple interactions in the supply chains to highly complex dependencies. An example of the latter is the effect of climate change, brought about primarily by the burning of

fossil fuel, with an additional contribution from land-use change in developing new agriculture. As carbon dioxide concentrations in the atmosphere rise and weather patterns change owing to the greenhouse effect, the interaction of energy, water, and food systems is being demonstrated on a global scale [2].

The world’s population is expected to grow from the current 7 billion to perhaps 9.5 billion by 2050 [1]. As we consider how the Nexus will develop in this period, we recognize that existing arrangements are, for very many people only barely adequate. For example [3-5]:

- approximately 1.4 billion people live without access to electricity (see Table 1), and another 3.0 billion use wood or other biomass for cooking and heating, suffering air pollution, which is associated with some 4.3 million deaths each year [3];
- 1.8 billion people rely on a source of drinking water that is fecally contaminated [4];
- Approx. 795 million people do not get enough food to lead a normal active life [5].

Table 1. Number of people without access to electricity and relying on the traditional use of biomass, 2010 (million)

	<b>Number of people lacking access to electricity</b>	<b>Number of people relying on the traditional use of biomass for cooking</b>
<b>Africa</b>	587	657
<b>Sub-Saharan Africa</b>	585	653
<b>Developing Asia</b>	794	1936
<b>China</b>	8	423
<b>India</b>	400	854
<b>Other Asia</b>	386	658
<b>Latin America</b>	31	85
<b>Developing countries*</b>	1436	2676
<b>Total World**</b>	1438	2676

\*Includes Middle East countries. \*\*Includes OECD and transition economies

Meeting the demands for energy, water, and food will put further strain on both the fundamental resources and the complex supply chains that distribute the products. There have been striking successes, for example, in agricultural productivity. The Food and Agriculture Organization (FAO) points out that in the past 50 years agricultural production has grown between 2.5 and 3 times, whereas the cultivated area has grown by only 12%. But as a consequence, agriculture now accounts for 70% of all water withdrawn from aquifers, streams, and lakes. There are other impacts, like decline in soil quality [6] and loss of biodiversity [7]. More must be done to manage such issues and also to preserve the amenity and cultural heritage values of the environment [8]. Figure 1 shows a correlation between the Food Price

Index and the price of crude oil, reflecting the role of energy in fertilizer production, food production, and distribution. Figure 1 also demonstrates the increasing connection through trade between regional agricultural markets [6]. In earlier periods these markets were separate, but now prices of food and energy are seen to be linked. Those with the lowest incomes will be most likely to suffer the effects of rising food and energy prices when they are passed on as a result of international trade. As the FAO points out, though, the situation is complex, and free-trading markets that stimulate economic growth are a key success factor for reducing hunger, provided the right social policies are also in place to protect the poorest [7-13].

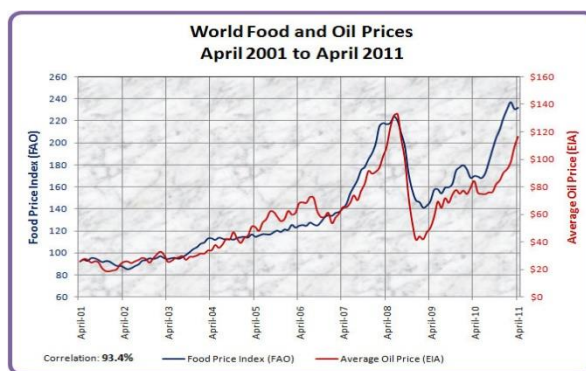


Figure 1. Food and oil prices 2001-2011. Data from FAO, 2019.

Energy sustainability is becoming a global necessity, given the pervasive use energy resources globally, the impacts on the environment of energy processes and their reach beyond local to regional and global domains, and the increasing globalization of the world's economy. Energy is directly linked to the broader concept of sustainability and affects most of civilization. That is particularly evident since energy resources drive much if not most of the world's

economic activity such as industry, transportation, residential, and commercial. Also, energy resources, whether carbon-based or renewable, are obtained from the environment, and wastes from energy processes are typically released to the environment. Finally, the services provided by energy allow for good living standards, and often support social stability as well as cultural and social development. Given the intimate ties between energy and the key

components of sustainable development, the attainment of energy sustainability is being increasingly recognized as a critical aspect of achieving sustainable development [10].

Energy sustainability is taken here not just to be concerned with sustainable energy sources, but rather to be much more comprehensive [11]. That is, energy sustainability is taken to involve the sustainable use of energy in the overall energy system. This system includes processes and technologies for the harvesting of energy sources, their conversion to useful energy forms, energy transport and storage, and the utilization of energy to provide energy services such as operating communications systems, lighting buildings and warming people in winter [12]. Thus, energy sustainability goes beyond the search for sustainable energy sources, and implies sustainable energy systems that use sustainable

energy resources, and that process, store, transport and utilize those resources sustainability [13].

Turkey announced in the development plans, the main objectives of its energy policy are to ensure sufficient, reliable and economic energy supplies in order to maintain economic and social development, to provide the growing energy demand, to reform and to liberalize the energy sector to increase productivity and efficiency and to advance transparency. The main difficulties are the increasing demand and the import dependence. The events because of the global climate change caused to take into account the environmental concerns in all stages of energy chain. Turkey is taking steps to respond to the threat of climate change. The present study is discussed the energy and food nexus for sustainable development in Turkey

## 2. Energy use for food production

Agricultural productivity has increased with increased use of energy from a variety of sources. Increasing use of inputs to production agriculture of fertilizer, irrigation and pesticides all require commensurate increases in the use of energy [3-5]. Mechanization of agricultural tasks increases human productivity and improves the timeliness and quality of many operations and also relies on energy inputs. Increasingly the energy for all of these inputs to the agricultural production system has been derived from

fossil fuels, particularly in the developed countries and increasingly in the developing countries [4]. The requirements of fossil fuel-based energy sources for post farm operations including processing, transportation, storage, wholesale and retail distribution and home storage and cooking far exceed production energy requirements in developed production systems [3-7]. Table 2 shows global production some agricultural grain cereals as a million tons.

Table 2. Global production some agricultural products between 2015-2017 average (Million tons)

Continent/Region	Cereal	Wheat	Maize	Barley	Sorghum	Rice	Total Oilcrops
Asia	1 184.8	326.1	356.2	20.6	8.7	454.4	131.1
Africa	177.1	26.5	77.0	6.2	26.8	21.3	20.3
Central America	43.2	3.7	31.3	0.9	5.4	1.8	2.0
South America	192.1	25.3	136.8	5.1	5.8	16.7	185.4
North America	503.0	85.4	381.0	12.4	12.2	6.3	146.0
Europe	510.2	260.2	110.3	90.4	1.1	2.5	68.7
Oceania	41.0	25.5	0.6	10.9	1.7	0.4	5.1
Developing countries	1 538.4	352.6	586.5	27.4	46.5	485.8	338.9
Developed countries	1 112.9	400.0	506.7	119.1	15.1	17.7	219.6
Total World	2 651.4	752.7	1 093.2	146.5	61.6	503.4	558.5

The energy requirements for production agriculture, less than 3% of global energy use, represent a small portion of the demand for fossil fuels, but are a critically important input to the food, feed and fiber production system. Interest in reducing the dependence on fossil fuel for agricultural production increased dramatically just after the oil embargo of 1973. Many studies were undertaken to quantify the

relationships involved in energy flows in various farming systems [3]. Research and demonstration projects focused on reducing dependence on fossil fuel by conservation and replacing fossil fuel resources with solar energy and other renewable alternative sources [3-6]. Figure 2 also shows variable global renewable sources.

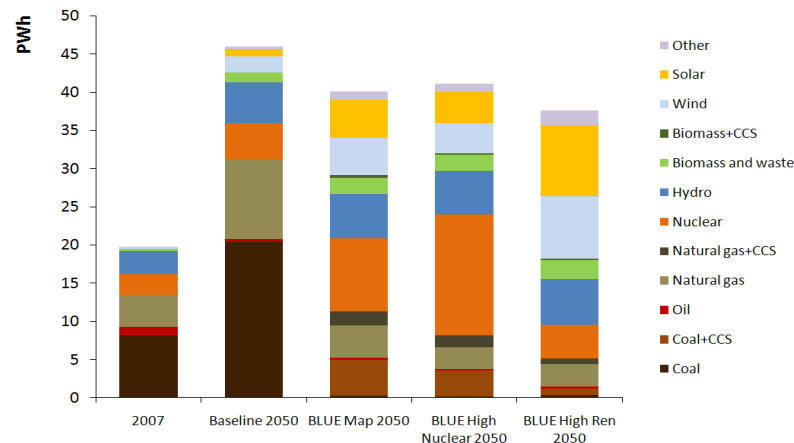


Figure 2. Variable global renewables according to the some scenarios in 2050.

Many renewable energy strategies such as solar thermal energy systems and electrical generation systems such as photovoltaic, wind and small-scale hydro can make a contribution to on-farm as well as off-farm applications. In addition there are possibilities to generate on-farm energy requirements from on-farm sources such as agricultural wastes and other biomass derived energy sources that are particularly effective fossil fuel replacement strategies as the resource is near the place of application [1-8].

### 2.1 Agriculture and alternative energy

In order to provide mankind's need for food energy resources must be available to agriculture in a form that is suitable for the application and in sufficient amount for the task. As food production is a very high priority activity relative to many other uses of fossil fuel energy it is rational for society to bear the costs required. However, as the price and scarcity of fossil fuel supplies increase it is prudent and will become essential to look for opportunities to meet the needs of production agriculture from renewable resources [6]. In this regard there have been substantial efforts to understand the energy requirements for agriculture and the patterns of use as well as programs to develop and apply alternative energy Technologies [3-7].

To meet energy requirements for agricultural production there are a number of technologies that have been studied and in many cases implemented. In some cases the energy requirements of the farm family and/or others living on the farm may be

### 2.2. Alternative energy sources for on farm use

Historically production agriculture was completely dependent upon non fossil-fuel-based energy sources. Hunter-gatherer societies and some cropping systems

Beyond the use of farm derived energy sources to meet on-farm energy requirements there are additional opportunities for agriculture to contribute to off-farm energy needs, particularly through biomass derived fuels. Biogas from anaerobic digestion and liquid fuels including ethanol and biodiesel can meet a substantial portion of global energy requirements on a sustainable basis. In order for this to occur the technologies developed must be based on consideration of all aspects of the production and utilization systems [9-12].

integrated with the systems being used to provide energy for production. An important aspect of most alternative energy sources is their distributed nature. Wind, solar energy, small-scale hydro systems and biomass based energy supplies all are localized resources. Wind, solar and hydro systems that can be developed and used at the local level will generally be economically competitive with fossil fuel sooner than applications that have to provide energy to distant needs [10-14].

Beyond meeting the need for on-farm energy requirements there is also potential for agriculture to provide energy sources for other societal needs. One example is the production of ethanol for use as a fuel or fuel additive. It is generally accepted that biomass derived energy, such as ethanol; biodiesel and biogas are particularly attractive agricultural based energy sources that can be transported and used off-farm as well as on-farm [14-18].

depend only on human energy. The use of animal power for production agriculture shifts work from humans to animals but requires feed for the animals,

which may be provided primarily from forage crops that can be produced on land that is better suited to forage crops than human food crops. Hydropower has been utilized as an energy source for grain milling, sawmills and other energy requirements [3]. Wind power has been extensively relied on for water pumping and milling also. Early mechanization relied on steam power both for tractors and stationary power units for grain threshing and other operations. Biomass byproducts such as straw could be used as a fuel source as well as wood and later coal [8]. The use of biomass of any sort to provide energy for agricultural production has largely been supplanted by the ready availability of low-cost, easy to handle fossil fuel, primarily petroleum and natural gas [2-4].

Wind power has historically been widely utilized for water pumping and is still found to be a practical energy source for this purpose in many locations. As the potential power that can be derived from wind varies with the cube of the wind speed the likely availability of adequate wind at the location and time it is required is a key element in the practicality of wind systems. Water pumping remains one of the most likely applications for wind power as there is the potential to store the water and as the pumping system can be driven directly by the wind machine. When the wind power resource is not completely reliable a hybrid system including another power supply can be used. However, in this case the energy cost savings alone must justify the investment in the wind generation system. So as long as fossil fuel based energy is available at relatively low cost it will generally be simpler and probably more economical to use only that energy source and not make the equipment investment necessary to utilize the renewable resource for part of the work [1-18].

In general there is an advantage when the mechanical power from the wind can be used directly without conversion to electricity and when storage of the energy is not required or is already an integral part of the system. Wind generated electricity is becoming and will continue to become increasingly competitive with fossil fuel powered electricity generation in some areas, particularly where the power can be used on site and directly. While there are power losses in the conversion of mechanical power to electricity and conversion from electrical power to the final application the versatility of electrical power is often a compelling advantage. Also, if the point of application is near the electrical power distribution grid there is the option to use the grid system to purchase additional power when needed and to which surplus power can be sold when wind supply exceeds

demand [3-7].

The direct use of solar energy on farms can meet many needs. Traditionally many agricultural crops have been dried using only solar energy but often fossil fuels are used to heat air for crop drying to reduce losses and to increase reliability and product quality. In the analysis discussed earlier, of the 1.39 kcal of energy required in the field to produce a kcal of food, 0.09 kcal of energy is used for drying. A modern crop drying system that uses fossil fuel to heat the drying air and purchased electricity to operate fans can be replaced or supplemented by solar collectors for the heat input and/or a photovoltaic source for the electricity for the fans. A hybrid collector of photovoltaic cells incorporated in an air heater array is one example. In some cases it is possible to incorporate the solar collector air-heating component in various farm buildings in such a way as to significantly reduce the investment cost in the system [3-5; 8-12; 13-18].

In addition to crop drying there are other requirements for heat at modest temperatures that can be met with solar thermal collectors. Some animal housing units require heating and, as with solar drying systems, if it is possible to incorporate the solar thermal collection system in the structure itself system economics can be optimized. Some food processing operations require process heat can be provided with solar collection systems, whether the processing is on-farm or at an industrial processing site off-farm. On the other hand, solar thermal energy is particularly suited to applications where hot water requirements are met by temperatures under 100°C and the food processing industry uses hot water for many processing applications and for space heating of facilities. One study on the technical and economic feasibility of solar energy indicates that 20% of the energy requirement of the food processing industry could be met with solar energy [19-24].

There is need for domestic energy requirements for on-farm residences including energy for space heating, water heating and food preparation. All of these needs can be met in whole or part with solar energy. Refrigeration needs for cold storage for farm production and for the residences can be met with solar thermal collectors powering absorption refrigeration systems. The technologies required for most of these applications and the economic barriers to their adoption are generally similar for onfarm applications and domestic residential applications. An important consideration in solar thermal systems

is the relationship between system economics and the needed operating temperature of the system. In general for solar thermal collectors the efficiency of the collector decreases as operating temperature increases as most losses in the system are directly related to the difference in operating and ambient temperature [25-32].

Greenhouse production of seedlings, vegetables and ornamentals is a particularly highly productive yet energy intensive agricultural production system. Energy is required for heating the greenhouse in cold weather and often for mechanical ventilation systems as well as for operating equipment and cold storage for the crops. Increasing costs of both ventilation systems and electricity to power the fans have led to renewed interest in natural ventilation systems but space heating is also needed in many locations. One of these, developed at Rutgers University utilized a floor storage/heat distribution system for the water heated in external collectors and a movable curtain system for insulation to reduce heat loss. The initial emphasis in the development of both the floor heating and movable curtain systems was to provide energy savings [32-43].

Curtain materials have been developed that provide appropriate levels of daytime shade and are deployed during high light periods to reduce heat stress on the crop as well as

energy conservation on cold nights. Floor and bench heating systems have been found to benefit many crops as the grower can independently control the root zone and plant canopy temperatures. Benefits of root zone heating include better plant growth for some crops, improved disease control due to warmer and drier conditions under the plant canopy and increased energy savings in cases where warmer soil allows for cooler air temperature above the crop. These concepts have been widely applied in greenhouses worldwide even though the relatively low cost of fossil fuels have essentially eliminated the desire for the solar collectors to provide the heat. This case is an example of the integration of systems of crop production and energy management that develop synergies, which produce multiple benefits [42, 43].

The International Energy Agency's (IEA) World Energy Outlook (WEO) Report [19] indicates that the world production of energy from traditional renewable resources in 2016 was 64 EJ. Traditional renewable resources in this context represent fuelwood, crop residues and biomass left from industrial sources such as papermaking. Over half of

this is in Asia, mostly India and China. In this region the traditional renewable energy resource is about 8.7 times the energy input to production agriculture. While some of this energy may be utilized in support of production agriculture, most of it is used for other applications. Cooking and heating are significant consumers of this resource as are some forms of agricultural product processing such as sugar refining makes extensive use of bagasse. Many sugar-refining operations use bagasse as a fuel source for generation of electricity needed at the plant and process heat. As this has traditionally been used as much as a method of getting rid of the large amount of waste [19].

On-farm biogas plants utilize manure and other wet plant or food waste materials to generate methane can be used for cooking, heating, process heat or electrical generation. While there is an economy of scale in the use of biogas generators, there have been many workable designs developed for very small-scale applications, even for single-family use, particularly in China and India [3-7]. These countries the trend is to progress from traditional small-scale family biogas plants to more efficient community. Large livestock facilities are attractive sites for biogas generation, particularly when the cropland supporting the livestock operation is close by, making the transport of the sludge left at the end of the biogas generation process to the fields easy. In such an integrated system the biogas generation basically harvests much of the potential energy in the waste while most of the plant nutrients remain in the sludge and can be recycled to the productive fields [9-19].

Systems integration in on-farm energy programs is and will become an increasingly important concept. The more effectively an alternative energy resource can be implemented and the greater the utilization of the energy produced the more economically attractive and sustainable the technology will become. A biogas plant where the energy in the gas is used productively and the nutrients are returned to plant production is a more attractive application than if the sludge is not recycled. If the biogas is used to power an electrical generator, either with a piston engine or turbine, it is beneficial to find a use for the waste heat. In temperate climates it is often found necessary to heat the digester in cold weather so this is an obvious application of the waste heat. Another byproduct of biogas utilization is the carbon dioxide in the exhaust, which could be used to promote plant growth in controlled environment agriculture if any contaminants deleterious to plant growth are removed [8-12; 42; 43].

As an example, the author had an undergraduate student design team conceptualize and analyze materials and energy balances for a particular communal farm in Poland, with a variety of activities. The large farm produced a variety of field and horticultural crops, had a large swine operation utilizing feed grown on the farm, a small food processing plant, some greenhouses producing vegetables year round and a coal fired power plant producing electricity and heat for the processing plant and greenhouses. Manure disposal had become a large problem and the rapidly rising cost of coal was an issue. A system was developed based on plug flow biogas generators located under the benches in the greenhouse. In cold weather the reject heat from the engine on the electrical generator was used to heat the biogas digester, which in turn provided the heat needed for the greenhouses. The heat transfer systems were designed so that the operating temperature of the biogas generator, near the optimum for that process, would match the heat needs for the structure. In summer and fall much of the reject heat would be available for the processing operations. The carbon dioxide in the engine exhaust could be cleaned for use in the greenhouse and the sludge returned to the fields [3].

The starting point of the analysis was to utilize all of the reported 60 cubic meters per day manure production in the biogas digester. The students utilized data from the literature on the composition of swine manure and found six references on gas production for this amount of manure between 990-2763 m<sup>3</sup> gas per day. They designed the volume of the digesters based on a 15-day retention time. From this starting point they studied the heat transfer from the engine coolant circulating in piping in the digester and the subsequent transfer of this heat into the greenhouse and thence from the greenhouse to the external environment. While this design approach can be used to size system components that provide a workable solution, system optimization will require a simulation approach to evaluate the overall system performance of proposed designs throughout the year [3, 7, 9, 11, 13, 15, 17].

A modeling approach could be used to combine the

### 2.3. Agricultural energy sources for off farm use

As noted above, there is an economy of scale that can be achieved in some of the production facilities that convert agricultural products into useable energy resources. Therefore, when energy resources are produced in larger, community based or industrial scale settings, the products can be made available to

concepts described in the student project utilizing biogas generation from the manure and the integrated system modeling of Rotz, which includes a materials balance on nutrients. Adding in the systems to generate and utilize energy on the farm could add the features of balancing energy production and needs as well as carbon balance to the nutrient balance [24]. The sizing of the capacities of the various system components and the management strategies employed can be evaluated in terms of the farm's economic viability and sustainability. While modeling research has been frequently applied to optimizing farm economics and the concepts of energy sustainability is needed.

In addition to direct burning to recover energy from dry biomass waste material gasification is an attractive technology for some applications as the gas can be used to operate an engine as well as be utilized in direct burning applications. Economies of scale favor larger, community based systems as opposed to small and therefore much of the application of energy derived from gasification of biomass may ultimately be utilized off-farm [11, 13, 19].

Liquid fuels for farm operations can also be derived from crops. Ethanol derived from small-scale farm based plants is one option that can replace or supplement gasoline. While there have been limited attempts to develop small scale ethanol production facilities the economies of scale substantially favor larger, centralized plants. As is the case with biogas production, the energy product is only hydrocarbon and all of the nutrients remain in the byproduct, which is generally used for livestock feed. When this is the case the animal will extract some of the nutrients and energy. The energy and nutrients remaining in the manure can then be recovered in a biogas generator as discussed above. Plant based oils can be utilized as a replacement for diesel fuel in engines. As is the case with ethanol production, the residual plant material can be utilized as livestock feed. Again, the economies of scale in the processing operation favor large production facilities [3, 6, 10, 12, 14, 20, 24-27].

other segments of society besides production agriculture. The suitability of alternative energy resources to particular applications depend significantly upon the relationship between the location of the resource relative to the needed application and the timing of the need relative to the

availability. Distributed resources such as solar energy and wind are particularly useful when they can be applied directly on-farm and there is no need to move the energy resource. When solar or wind are used to generate electricity on the farm and the farm is served by the grid the transportation problem is mitigated assuming pricing policies are favorable [23]. However, for the most significant farm produced energy resources that are based on some form of biomass, the conversion process generally favors larger processing facilities so the application of the derived energy resource may well be appropriate for off-farm application, as well as on-farm use [24-27].

While there may well be significant opportunities for agricultural enterprises to feed electricity to a national or regional grid that is produced from photovoltaic or wind systems on the farm, a very large potential resource is biomass production for energy as well as feed and fiber. The total biomass resource is large in relationship to all of man's current energy needs. The energy content of the annual production of biomass on a global scale is well over ten times the total annual production of fossil fuels. Biomass productivity per unit land area is substantially greater on agricultural land than non-farm areas so there is significant global potential to further increase the total production of plant material produced for food, feed energy or a combination. For this productivity to continue indefinitely on a sustainable basis the recycling of nutrients and effective use of water are essential [24-27; 42; 43].

A potentially important aspect of turning to biomass as an energy source to replace fossil fuel is the recycling rather than the mining of carbon. The carbon from the atmosphere to which the carbon is replaced when the biomass derived fuel is used. A variety of biomass energy production scenarios from the standpoint of carbon mitigation as a climate change solution. Agricultural waste is an obvious choice as an energy source, particularly when considering the climate change issue. As noted earlier, in the United States food production system for each kcal of food produced there are 3.9 kcal residing in crop residue, 5.1 kcal in animal manure and 0.2 kcal in processing waste. These waste streams have a potential energy over five times the total on-farm energy requirement [1-7; 9-14; 24-27; 42, 43].

There are a variety of technologies available for harvesting the energy in agricultural wastes. The most appropriate technology for any given situation

will vary depending on the characteristics of the waste material, the desired energy application and environmental considerations including the desirability of recycling the nutrients in the waste. Direct burning to fire a boiler or provide process heat is an appropriate option in some situations. In general, dry waste materials are more appropriate for direct burning than wetter wastes, such as manure, unless the waste can be dried before burning [9-12; 16-19].

Gasification is an appropriate alternative application, particularly if the end use is to an engine to provide mechanical or electrical power as producer gas can be utilized directly in a spark ignition engine or as a replacement for 80 to 85% of the diesel fuel in a compression ignition engine. Gasification efficiency can be 60 to 70% for woody material. For higher moisture wastes such as manures, anaerobic digestion may be the most appropriate conversion process. Sustainability characteristics of anaerobic digestion and gasification processes for several types of manures. He calculates the net energy production from 100 tonnes of fresh cattle manure to be 33.64 Giga Calori (Gcal) by anaerobic digestion and 13.51 Gcal by gasification. Net energy production from 100 tons of poultry manure which has a higher solids content initially with air drying before gasification would produce 54.36 Gcal by anaerobic digestion and 71.42 Gcal by gasification [9-14; 16-19; 42; 43].

In addition to extracting energy from waste streams there is significant potential to grow crops specifically for energy production. The IEA's WEO [19] projections shows that total world wide energy supplies from crops grown specifically for energy can increase from current levels of 45 EJ per year to a total of 441 EJ per year by 2050. This analysis is based on looking at projections of population, arable land required to meet food needs and the remaining land available for energy crops. Liquid fuels for use in engines are important for many applications and ethanol and biodiesel are particularly useful forms of energy potential in this regard. As noted earlier, ethanol produced from sugar cane can utilize the bagasse as the major processing energy source and with an efficient system can be a net exporter of electrical energy [10-12; 17-19].

Production of ethanol from cereal crops such as maize is of great interest in many developed countries and there have been many studies focused on the net energy production. Ethanol is an attractive liquid fuel that can supplement or replace gasoline in internal combustion engines. While some studies

have show a negative net energy production in the past a recent comprehensive study by Hopwood et al [12] note that the net energy value of ethanol production from corn has been increasing since the early studies of 1970 due in large part to increases in both corn yields and processing efficiency. Their study indicates a net energy output/input ratio

averaging 1.34 and up to 1.53 for the best-case scenario. This study indicates that only 17% if the input energy is from liquid fuels such as gasoline and diesel with the rest of the energy inputs coming from other feedstocks. Thus the liquid fuel output/input ratio is 6.4.

### 3. Effective energy use in Turkey for sustainability

#### 3.1. Energy policies for sustainability

The total length of Turkish electricity distribution system is 994324 km as end of the year 2016. Transmission system has been designed appropriate to European standards by considering population density, location of supply resources and geographical conditions and the line losses around 3% which is at the level of international performances. In 2016, the Turkey's total transmission losses is about 6415 GWh [28-41].

The electricity losses come from the transmission and distribution systems. The loss in the transmission line of Turkey is about 3.4%. However, the

distribution loss is considerably high at 15%. It is expected that the distribution losses will be reduced. By mid-2009, this has been improved in Turkey so much that, there were 130 operating cogeneration plants with a total capacity of 3440 MW<sub>e</sub>, and 176 cogeneration plants representing another 12,784 MW<sub>e</sub> [45, 46]. The total installed cogeneration capacity was expected to reach up to 88760 MW<sub>e</sub> by 2012. That means it will represent about 20 % of Turkey's total installed electricity generating capacity [28, 29, 30]. Table 3 shows Turkey's energy situation in 2016.

Table 3. Turkey's energy situation in 2016 (ktoe)

Energy source	Production	Consumption
Hard coal	722	23 597
Lignite	14 013	13 556
Asphaltite	725	796
Oil	2 700	42 204
Natural gas	303	38 338
Hydropower	5 782	5 782
Geothermal	6 034	6 034
Bioenergy	2 843	2 843
Wind	1 334	1 334
Solar	917	917
<b>Total</b>	<b>35 374</b>	<b>136 230</b>

ktoe: kilo tons of oil equivalent

Renewable energy supply in Turkey is dominated by hydropower and biomass, but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating [28]. As a result, the composition of renewable energy supply has changed and wind power is beginning to claim market share (see Figs. 3-6). As a contributor of air pollution and deforestation, the share of biomass in the renewable energy share is expected to decrease with the expansion of other renewable energy sources [33-41]. Table 4 also shows Turkey's renewable energy potential.

Turkey spent a total of US\$ 130 million (2009 prices and exchange rates) on government energy RD&D between 1980 and 2009. In this period, 16.6% of its

total energy research and development (R&D) budget (US\$ 22.4 million) was allocated to renewable energy [28]. Government R&D expenditures for renewables followed the general trend in overall energy R&D expenditures, rising in the late 1980s and falling in the early 1990s [30]. Among the renewable technologies, geothermal received the most sustained funding over the past two decades and the highest level of funding, equivalent to US\$7.3 million or 37% of the renewables R&D expenditures between 1980 and 2009 [28]. The Turkish government's approach to the deployment of renewables reflects its priorities to develop indigenous and renewable resources in conjunction with the expansion of privately owned and operated power generation from renewable sources as shown

in Figs. 3-6 [28-30].

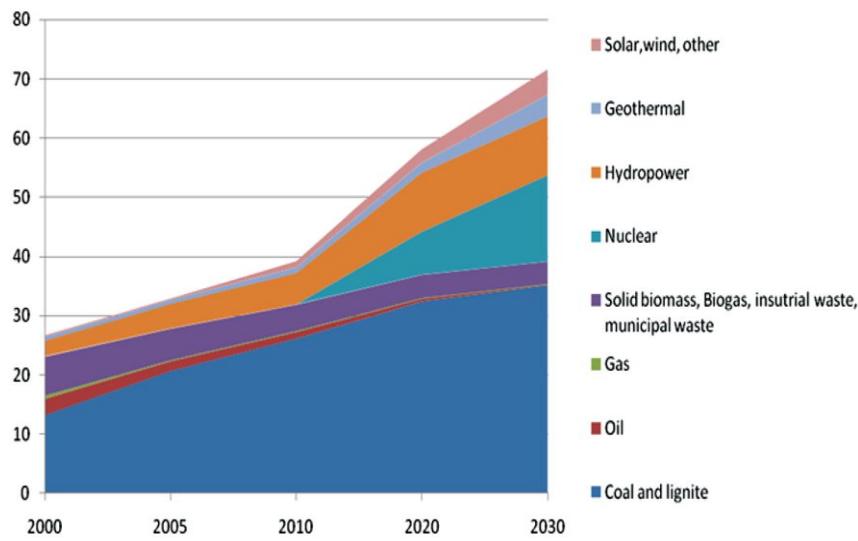


Figure 3. Present and future total final energy production in Turkey, Mtoe.

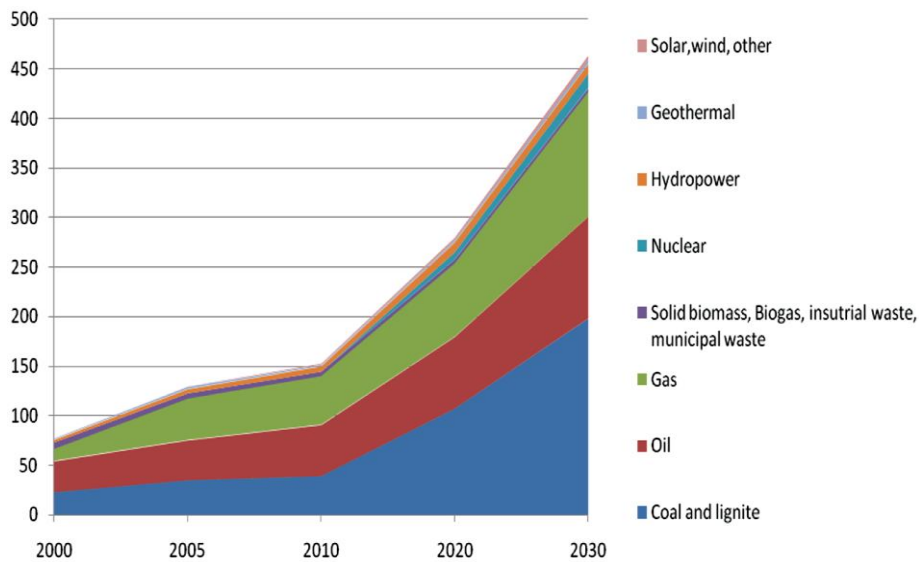


Figure 4. Present and future total final energy consumption in Turkey, Mtoe.

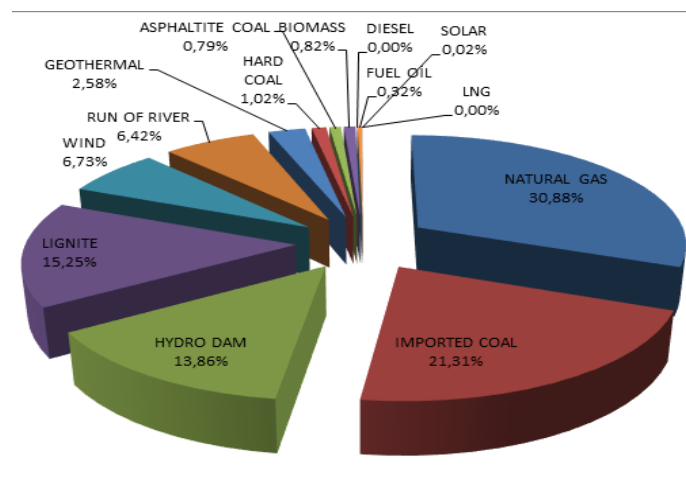


Figure 5. The Distribution of Licensed Electricity Generation by Sources in 2018 (%).

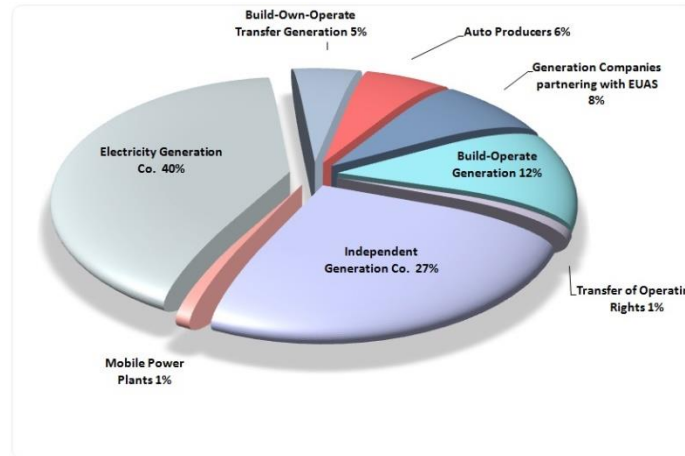


Figure 6. The distribution of installed capacity by electric utilities in Turkey (2016)

Table 4. Turkey’s renewable energy potential

Energy type	Usage purpose	Technical	Economical
Solar energy	Electric (billion kWh)	6 105	<b>305</b>
	Thermal (mtoe)	500	<b>25</b>
Hydropower	Electric (billion kWh)	215	<b>124.5</b>
Wind energy (land) Wind energy (off shore)	Electric (billion kWh)	110	<b>50</b>
	Electric (billion kWh)	180	-
Wave energy	Electric (billion kWh)	18	-
Geothermal energy	Electric (109 kWh)	-	<b>1.4</b>
	Thermal (mtoe)	7 500	<b>2 843</b>
Biomass energy	<b>Total (mtoe)</b>	<b>50</b>	<b>32</b>

Turkey is to be recipient of a US\$202 million renewable energy loan provided by the World Bank to be disbursed as loans via financial intermediaries to interested investors in building renewable energy sourced electricity generation [31]. These loans are expected to finance 30-40% of associated capital

### 3.2. Energy efficiency

The industrial sector accounted for 35% of total final energy consumption and for 46% of electricity consumption in 2009, while the agriculture, household and services sectors together accounted for 40% of final energy consumption and 46% of electricity consumption [28]. Although all four sectors have important potential for energy conservation, industry has been targeted as a priority area for energy conservation programs owing to the projected rapid expansion of industrial energy demand [28-30].

According to estimates of the MENR, Turkey has an energy conservation potential equal to 12–14 Mtoe/year, and therefore, \$4.2 billion could be saved through conservation measures in three main end-use sectors [29]. Within the industrial sector, iron and

costs. The aim of the Renewable Energy Program is to increase privately owned and operated power generation from renewables sources within a market-based framework, which is being implemented in accordance with the Electricity Market Law and the Electricity Sector Reform Strategy [28-32].

steel manufacturing and cement production are by far the largest energy users [30]. However, the petrochemical industry, the fertilizer industry, the textile industry, ceramic products and paper manufacturing, as well as sugar production, are also major users. According to the MENR, potential for conservation in these sectors ranges from 25% to 35% in the country [28-30].

In the residential/commercial sector, more than 70% of the energy consumed is used for heating. Energy use per unit of building area could be reduced by nearly half through the application to all buildings of the new Heat Insulation Standards on building envelopes, issued in 2000 [28, 29]. While existing buildings require 200–250 kWh/m<sup>2</sup>, the new standards could bring requirements down to 100–150

kWh/m<sup>2</sup> [30]. At current rates of building stock turnover, the estimated energy efficiency gains could take several decades to materialize. In addition, major efficiency improvements are also possible in power generation by increasing power plant size from the existing average of 150–340 MW by requiring higher efficiency specifications for new plants and by increasing the use of cogeneration, especially in industry.

Turkey has dynamic economic development and rapid population growth. It also has macro-economic, and especially monetary, instability [28]. The net effect of these factors is that Turkey's energy demand has grown rapidly almost every year and is expected to continue growing. The domestic share of total energy consumption is 37%, and between the years 2008 and 2020, the cost for needed energy will be approximately 66 billion US\$ [29]. The government has been planning for 81% of this amount as an investment [30]. Considering the country's economic conditions, Turkey must come up the plan which reduces the share of fossil fuels, increases energy production, and changes the course of long-term energy plans into very effective and applicable solutions [28, 29, 30, 31].

According to the studies conducted by Turkish State Statistics Institute (DIE) in 2002 and 2005, on the

#### 4. Conclusions

Interest in theNexus is growing. Driven by increasing global population and urbanization, and with lifestyles based on greater material consumption, concern about energy water and food provision is rising up in many agendas. The interdependence of theNexus supply chains and the competition for increasingly scarce resources introduce complex questions of priorities, trade-offs, and strategy. The timescale of change is typically a few decades—of disruptive climate change, of population growth and lifestyle change, of resource depletion, for achieving political consensus and striking international agreements, for establishing new institutions, and for building new infrastructure and developing new markets. Governments and intergovernmental agencies with responsibility for infrastructure and development are interested, as are a wide variety of stakeholders. Many companies now realize that Nexus issues offer both a threat and an opportunity and must be taken into account. The numbers of conferences and publications are increasing. Our review covers mainly scientific progress, but social science approaches, which we mention briefly, are

basis of the results obtained from about 1350 of these manufacturers, their total energy consumption of the places of employment, constitute 75% of the industrial energy consumption of Turkey [28-30]. In case of industrial sector, the iron and steel sectors consumes 36% of the total energy consumption. In this sector, when the cost of the energy is investigated, this share breaks down into 48% in the iron and steel sector, 35% in the ceramics industry and 57% in the cement industry. On the basis of the cost of the energy, the share of the metal and soil industry, out of the total value of Turkey ranges from 10% to 56% [28].

The Turkish residential–commercial sector includes space heating, water heating, cooking and electrical appliances for energy consumption [28]. The highest contributions came from renewable resources with 35%, fuel with 38% and electric with 25% in 2009, respectively [29]. In 2008, the highest contributions came from wood with 4.58 Mtoe, while the share of this resource in this breakdown is expected to continue to decrease at approximately 3–5% per year and to reach 3.4 Mtoe in 2020. This is due to the economic development in Turkey. However, natural gas utilization has continuously increased in the Turkish residential–commercial sector for space heating, water heating and cooking purposes in several cities [30, 33, 35, 37, 39].

also producing valuable insights.

Turkey is heavily dependent on expensive imported energy resources that place a big burden on the economy and air pollution is becoming a great environmental concern in the country. In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions for clean and sustainable energy development in Turkey. Turkey has substantial reserves of renewable energy sources, including hydropower, biomass, wind, geothermal and solar energy potential. In order to use renewable energy effectively in the country, the governments and private companies should be supported to these clean resources.

The energy and food policy objectives of Turkey essentially require diversifying the natural resources. The Turkish food sector continues to grow in 2018. Discount retail chains with compact stores remain the growth driver, both in number of stores and sales volumes. The organized retail sector is split evenly between traditional small grocery stores and modern

retail chains. The young and growing population provides opportunities for growth and new product introductions. Turkey has a welldeveloped food processing sector that is producing good quality food items for the Turkish market, and European suppliers are also dominant in imported retail food. In Turkey, energy sources, to use domestic energy resources, to increase efficiency in electricity generation and consumption and to create an environment-friendly power system. Turkey is a developing country with a young and urbanizing population and its energy use is still comparatively low. However, it has experienced considerable growth in energy demand in the last three decades and this trend is expected to continue in the medium to long term. Ensuring sufficient energy supply to a growing economy remains the government's main energy policy concern.

Recent energy data indicate that Turkey is a net energy importer country, depending on such imports for 73% of its energy needs. This high rate of energy dependence has been the main driving force behind the formulation and implementation of new policies

to commission local and renewable energy resources. In this respect, Turkey announced the National Energy and Mining Strategy in 2017 which identified security of supply, localization, and predictable market conditions as the main pillars to follow in energy sector. Under the Strategy, ensuring localization and reducing import dependence through utilization of domestic resources stands as a top priority for Turkey which is ambitious to generate 2/3 of its electricity from local and renewable resources by 2023.

Turkey has a substantial amount of renewable energy potential, and utilization of this potential has been on the rise over the last decade. As of the end of 2018, hydro, wind and solar resources constitute the vast majority of the country's renewable energy resources, accounting respectively for 28,291 MW, 7,005 MW and 5,068 MW of the total installed capacity of more than 88,526 MW. However; biomass/biogas and geothermal energy resources are also expected to comprise a considerable portion with the rapid growth in utilization of these resources in the market.

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