

# Renewable Energy Scenarios as a Key for Sustainable Rural Area Applications in Turkey

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## Abstract

In order to reduce dependency on petroleum fuels, Turkey, a country located in Southeastern Europe and Southwestern Asia, in search of new energy sources like the other countries. Modern energy services can be considered as renewable energy technologies (RETs) which are sustainable and abundant in the country. However considering the total cost of RET production, renewable energy sources can be used not to replace the fossil fuels, but to supply energy requirement in rural areas, in order to decrease the imported energy resources that place a big burden on the economy. In this study, the renewable energy resources in Turkey were comparatively expressed, regards to the potential and current use. This paper was aimed to provide an overview of worldwide examples and projects for the use of renewable energy technologies that can also be applied in Turkey, which has a proportion of rural population, to increase the access to modern energy services in rural areas in the country. For these purposes, the rural and nationwide renewable energy productions were compared and the limitations and prospects were also discussed.

**Keywords:** Renewable energy resources; Rural energy; Turkey; Sustainable development; Bioenergy; Energy policies

## Introduction

The Republic of Turkey, located in Southeastern Europe and Southwestern Asia and it has an area of about 783,562 sq km and a population of over 70 million [1]. Energy demand per person is growing due to the fast urbanization and economic development however, much of the energy generated and consumed would not be sustained. Energy production, transmission, distribution and consumption should be focused on the minimum pollution to environment [2]. However the most common energy sources are fossil fuels (Figure 1) which are the reason for air pollution, the reducing of ozone layer and the emission of greenhouse gases. Keeping in mind the drawbacks of fossil energy, alternative renewable energy sources which include hydro, solar, wind, geothermal and biological have become crucial.

In order to reduce dependency on fossil fuels, the European Union (EU) attributes great importance to renewable energy. EU concentrates its efforts to ensure the renewable energy to be 20% of the overall energy portfolio by the year 2020 [3]. As a candidate of the EU, in Turkey, authorities focus on the new arrangements and regulations concerning the utilization of renewable energy in the facilities for electrical energy [4,5]. As a result of these arrangements, total installed capacity in Turkey reached to 50.003 MW at the early stages of 2011 [6]. Though Turkey is more dependent on the natural gas than any other countries, the natural was decreased by 10.11% in 3 years. Contrary to these, energy production via hydro energy was increased by 35.96% in three years and energy from other sources (solar, geothermal, wind and bioenergy) is greater 28.6 times in 2011 than 2008 (Figure 1).

According to Ministry of Energy and Natural Resources (MENR), considering the renewable sources, Turkey's hydropower is generally has the most economical potential; however the technical potential of wind energy is 48% higher than technical potential of hydroenergy which is 80.000 MW (Table 1). Because the geological structure of Turkey is volcanic and there are approximately 600 hot water sources with a temperature up to 100°C, the country is considered very rich in terms of geothermal energy with a technical potential of 1500 MW [7]. Moreover, bioenergy has an important share among other renewable energy sources (Table 1).

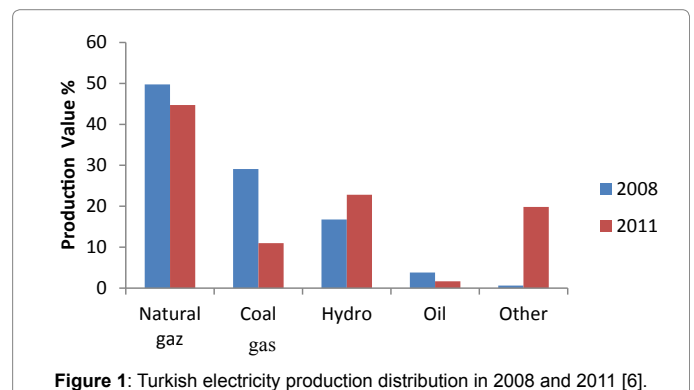


Figure 1: Turkish electricity production distribution in 2008 and 2011 [6].

Recently the energy production of these renewable sources is also increased dramatically. As shown in (Figure 2), hydro energy is the most produced renewable energy source which is 84.47% higher than geothermal energy; similarly, solar energy generation is 34.38% higher than wind energy which is only 4.8% by the end of 2012. It is worth to mention that, biomass based energy in the chart is consisted of wood, biofuel production and usage of the dung of animals.

The main motivation of this paper is to provide an overview of worldwide examples and projects for the use of renewable energy technologies that can also be applied in Turkey, which has a proportion of rural population of 29.0 percent in 2010, to increase the access to modern energy services in rural areas in the country. This paper also provides an overview of the energy situation and energy production in Turkey regards to the potential and current use of the renewable

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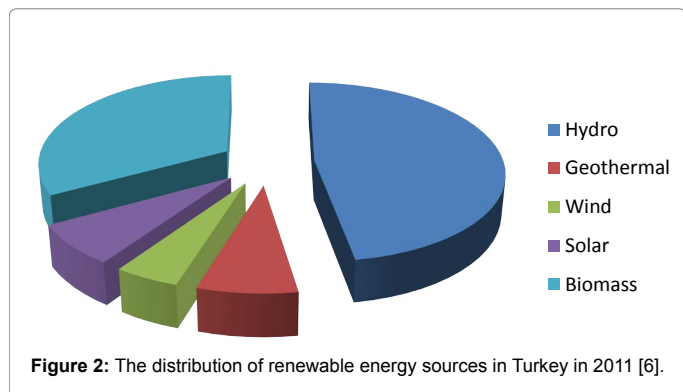
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Type of energy	Technical potential (MW)	Economical potential (MW)	Installed capacity (MW)
Hydropower	54000	42000	14.553
Wind	80000	20000	802.8
Geothermal	1500	600	77.2
Wastes (biogas+biomass)	-	-	81.2
Solar	56000	-	1

**Table 1:** Potential of renewable energy sources in Turkey and the situation by the end of 2009 [7].



**Figure 2:** The distribution of renewable energy sources in Turkey in 2011 [6].

energy sources including hydro, wind, solar, geothermal and biomass energy. For these purpose, all previous data are collected and evaluated. Reserves and several applications of each renewable energy resource will be explained in the following sections separately.

### Renewable energy potential in Turkey

In order to develop a case scenario in rural areas, one should consider the potential (technical, economic, as well as market) of renewable energy sources. Technical potential is characterized by hypothetical generation if 100% of input energy is converted to output for all the technologies involved in power generation. The economic potential scenario considers only those technologies that are cost-effective. The achievable market potential includes an increasing fraction of the total market potential over time. This potential is a function of the time allowed, the type of programs and institutions involved, and the technical-economic cost-effectiveness threshold. In this study, we considered all the three scenarios for each energy source.

### Hydropower

Hydroelectric power plants are the mostly preferred energy sources, because they are environment-friendly and have a lower potential risk. Thus, hydropower is currently the largest of the renewable energy resources in worldwide [8,9].

The technically hydroelectric potential in Turkey is 140 GWh/year. The installed hydropower is 14.417 MW which is 38% of the total potential since 2009. Turkey has 25 economically feasible hydropower plants for electricity production distributed into 14 river basins which are placed in the mountainous areas. Turkey's largest hydropower plants were constructed on the Euphrates River, namely: Ataturk (2400 MW), Karakaya (1800 MW) and Keban (1330 MW). Moreover, the Black Sea region, has a considerable hydropower potential with various flow rates of rivers [10]. Sectoral studies have showed that small-scale hydropower (less than 20 MW) is underdeveloped in Turkey [11]. There have been new arrangements to increase the number of sectoral studies since 2010 and various new projects are being developed in Turkey.

### Wind energy

Wind energy is formed when masses of air with differing temperatures and pressures switch places. The movement of air in the form of wind carries kinetic energy and a wind turbine converts this kinetic energy into electricity [12]. 1 to 2% of the energy that reaches the earth from the sun is transformed to wind energy and considering its potential, global wind energy capacity will increase from an annual 8 billion Euros to 80 billion Euros by 2020. Wind energy is topic of key interest in Turkey, parallel to its increasing potential in worldwide and among other renewable resources, wind is considered as the most appropriate and most accessible power source in the last 4 years [13]. Turkey has the highest share in technical wind energy potential with 166 TW/yr and 83 GW between European countries [7] and it is assumed that in regions with an annual average wind speed of 7.5 m/s, a total potential of at least 48.000 MW is possible to make potentially economical investments over present prices.

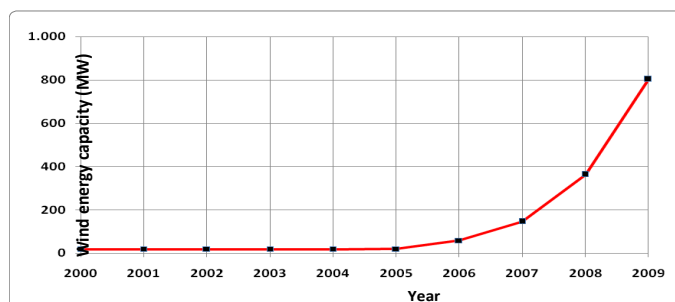
Turkey Wind Energy Potential Atlas showed that Turkey has a annual wind speed of 8.5 m/s and higher. Considering its potential, the main target of Turkey's MENR Strategic Plan for the renewable energy resources is to enhance the usage of wind energy in the electricity energy production up to 30% of its potential. Thus, the wind energy installed capacity was approached to 800 MW in late 2009 (Figure 3). The second target of MENR is to increase the wind plant installed capacity by 2015 [7].

As a result of wind speed, the most attractive regions in Turkey for wind energy applications are the Marmara which is followed by the southeast Anatolian and the Aegean regions (Table 2). All these 3 regions are considered as appropriate for wind power generation, since the wind speed overlaps 3 m/s in these areas [14]. The monthly wind speed values are 11.4-13.7 m/s in Nurdagi, 8.7-11.0 m/s in Belen, 7.2-10.3 m/s in Kocadag and 6.5-10.0 m/s in Akhisar in summer [7].

Volume is likely to grow speedily, as plans have been submitted for a further 600 MW of individual installations. Installed wind capacity is presumed to grow 1000 MW per year since 2009, reaching more than 5 GW by 2015. Turkey awaits to install up to 20 GW by 2023, by 30% of its electricity generation from renewable sources by that date [15]. In order to attain this target, however, new upgrades and developments are required to provide for large scale applications.

### Solar energy

Turkey has a suitable potential for the utilization of solar energy, as it lies in a sunny belt between 36°C and 42°N latitudes [12]. Turkey's yearly average total solar radiation varies from a min of 1.120 kWh/m<sup>2</sup> year in the Black Sea Region with 1971 h of sunshine a year to a max of 1.460 kWh/m<sup>2</sup> year in South East Region with 2993 h of sunshine



**Figure 3:** Development of wind energy installed capacity in Turkey by 2000-2009 (MW) [7].

Region	Wind power potential (MW)	Annual average wind density (W/m <sup>2</sup> )	Annual average wind speed (m/s)
Marmara	43.917	51.9	3.3
Aegean	16.150	23.5	2.6
Black Sea	14.312	21.4	2.5
Mediterranean	11.214	21.3	2.4
Central Anatolia	10.904	20.1	2.5
South-eastern-Anatolia	4703	29.3	2.7
Eastern Anatolia	2974	13.2	2.1

Table 2: Technical wind energy potential of various regions of Turkey [14].

a year [15]. Regards to solar radiation and sunshine duration in a day Southeast Anatolia has 23% and 34% more than Black Sea Region of Turkey (Table 3). The average solar radiation is 309.6 cal/cm<sup>2</sup>/d and the average sunshine duration is 7.2 h/d country wide [16]. Particularly, the southeast Anatolia and the Mediterranean regions are prosperous for solar energy use [15]. Although it has an important potential, currently solar power is used mainly for domestic thermal hot water production in the country which is the most commonly used among the three applications of solar energy (i.e. photovoltaic, thermoelectricity and thermal). Annual thermal energy production via solar energy from solar collectors was doubled from 1998 to 2007 [10]. Utilization of flat-plate solar collectors were increased as domestic water heating [17].

The second most common used application of solar energy is photovoltaic (PV) systems which have a significantly large market, since the country is very applicable for insolation and available for solar farms [15]. The primary application areas comprise telecom stations, signaling purposes, forest monitoring stations, fire observation stations, lighthouses and highway emergency systems [18]. Solar energy is produced depending on the PV type and area in Turkey. Monocrystalline and polycrystalline silicon usage is significantly higher than amorphous silicon [15]. Despite this enormous potential for solar energy, its usage in electricity generation is almost negligible due to the fact that solar panels only use a variety of experimental and basic applications.

### Geothermal energy

Turkey has substantial potential for geothermal energy production, hold one-eighth of the global geothermal potential [17] with an approximate 31.500 MW of geothermal energy, hence the country is located along the Alpine-Himalayan belt [10]. This amount of energy is mostly generated in the Western Anatolia with 77.9% share of all regions.

Significant developments in geothermal energy production are observed in the country since 1990 [18-20] and especially since the last decade. According to General Directorate of Mineral Research and Exploration of Turkey (MTA), the amount of geothermal fields increased from 170 in 2005 to 187 in 2008 and five of this newly discovered geothermal sites are feasible for electricity production [21]. By 2009, Turkey's total installed capacity was indicated as 827 MWt [22] and only 13% of the geothermal capacity has been developed for utilization by the MTA. The installed potential presently being used in residential and thermal installation heating is 76.78%, while an installed potential of 23.22% is being used for greenhouse heating of total capacity. Moreover, the total direct use of geothermal energy in Turkey is 1229 MWt with the installed capacity of 402 MWt is being used for thermal tourism purpose [10]. The planned amount of electricity production from geothermal energy and direct use by the end of 2013 which was prepared by Turkey's Prime Ministry in the name of the Ninth Development Plan (2007-2013) is shown in (Table 4) [10,23]. As

As a source of biomass energy production, several agricultural wastes are accessible in Turkey [30]. As seen in (Table 7), Turkey has an important potential of wheat straw which is almost 66.07% of total bioenergy sources. These agricultural wastes can also be transformed to ethanol, biodiesel, hydrogen-and-methane-rich gaseous products by the hydrolysis methods and these products are considered to be the best fuel for electricity production [26,31-33].

Region	Solar radiation (cal/cm <sup>2</sup> /d)	Sunshine duration (h/d)
South-eastern Anatolia	344.8	8.2
Mediterranean	328.3	8.1
Eastern Anatolia	322.4	7.3
Central Anatolia	310.3	7.2
Aegean	308.0	7.5
Marmara	275.9	6.6
Black Sea	264.5	5.4

Table 3: Solar radiation and sunshine duration in various regions of Turkey [16].

Usage	Capacity	
	February 2005	The end of 2013
Electricity generations	94000 GWh	350000 GWh
Residence heating	635 MWt	4000 MWt
Thermal tourism	402 MWt	1100 MWt
Greenhouse heating	192 MWt	1700 MWt
Cooling	-	300 MWt
Drying	-	500 MWt
Fishery + other usage	-	400 MWt
Total direct use	1229 MWt	8000 MWt

Table 4: Actual geothermal use in 2005 and predictions in 2013 in Turkey [10,23].

seen in Table 4, the total direct use planned for 2013 is significantly higher compared to the values in 2005, indicating that the Turkish government is planning to increase geothermal energy investments and incentives. Moreover, in the 2010-2014 strategic plan, it was targeted to increased up the installed capacity for the geothermal plant to 300 MW until 2015, which has been 77.2 MW as of 2009 [7].

### Bioenergy

Bioenergy is broadly detailed as all sort of fuel whose components were obtained utilizing biomass, such as biodiesel, bioethanol, biogas [24,25]. Similar to worldwide Turkey's biomass sources are mainly forests and bush, farm and urban trees, agricultural wastes (for instance leaves, plant stems, saw dust, bagasse, nutshell, and rice husks), and domestic residues (such as rubbish and sewage) [26], however, dry agriculture residue and woody materials can be defined as the best sources for biomass potential [27]. Biomass energy of these sources generates far less air emissions than fossil fuels, diminishes the amount of residues sent to landfills, downgrades the dependence on foreign oil, initiate thousands of jobs and help regenerate rural communities [26,28]. Due to these advantages, biomass has been considered as the best source for renewable energy in worldwide for the last 20 years. In Turkey, new strategies are being planned along with the reported studies since 1990s parallel to these approaches in worldwide and biomass energy production also enhanced in the last decade in the country. Only 41.26% of total biomass potential which is 16920 ktOE (Table 5) was used for biomass energy production in 1998 and it was increased by 6.19% in 2010 [29]. Moreover the projected biomass potential is predicted to be 8205 ktOE (Table 6) and biomass energy production will be increased by 10.67 % by the end of 2030 in Turkey [27].

Type of biomass	Energy potential (ktoe)
Dry agricultural residue	4560
Moist agricultural residue	250
Animal waste	2350
Forestry and wood processing residue	4300
Municipality wastes and human extra	1300
Firewood	4160

Table 5: Total recoverable bioenergy potential in Turkey in 1998 [29].

Year	Total biomass energy production (ktoe)
1999	7017
2000	6982
2005	7260
2010	7414
2015	7320
2020	7520
2025	7810
2030	8205
Total	52.511

Table 6: Biomass energy production from 1999 to 2030 (ktoe) [27].

Bioethanol can be produced from sugar beet and residues, potato, molasses, wheat straw, corn and corncobs [26,34]. More recently, lignocellulosic biomaterials are used through hydrolysis of cellulose into simple sugars and subsequent bioconversion to ethanol [35].

Biodiesel is another bioenergy product gained from oleaginous seeds such as canola, safflower, sunflower and microalgae [34]. Being environmentally friendly, ready availability, renewability, higher combustion efficiency, lower sulfur and aromatic content [36] and higher biodegradability [37] constitute the biggest advantage of using biodiesel. However, the number of biodiesel refinery plant was decreased in the last decade in Turkey. By 2006, amount of biodiesel planting is 54,000 decare in 6.6 million decare oily seed planting and 12,600 tones (0.45%) in 2.8 million tones oily seed production in the country [34]. In 2011, approximately 12 thousand tons of biodiesel was produced by a biodiesel license holder and 10 thousand tons were sold to distributor license holders. Besides, providing via import established 40% of the total of the distributor license holders. It is believed that the amount in the fuel distribution market has a trend to decrease. The total market share of the companies was 80% in 2009, 76.8% in 2010 and 74.5% in 2011 [3].

Biogas, produced from organic substrates after anaerobic fermentation and accounts for mostly methane and carbon dioxide and lower amounts of hydrogen sulfide, hydrogen, nitrogen, carbon monoxide mixtures and this gas mixture can be used directly in gas turbines and fuel cells to produce electricity with less environmental pollution than fossil fuel. As a result of its advantages, biogas production studies are highly increased in Turkey. Biogas manufacturing only from animal residues is calculated to be 2.2-3.9 billion m<sup>3</sup> in the country [34].

In Turkey, the most of biomass energy is consumed in residences for cooking and heating purposes. Wood is the main heating fuel and approximately 8.67% of residences use wood substituted for coal in heating purpose in Turkey [10]. Production cost of 1 kWh energy is 12.86% higher in biomass than coal as power sources [3,38]. According to these benefits, government is also planning to introduce bioenergy production in near future.

Figure 4 shows the cost-effectiveness of today's renewable technologies. However, the cost ranges are wide and very site-specific. Generally, hydropower is still the cheapest way to generate electricity. It

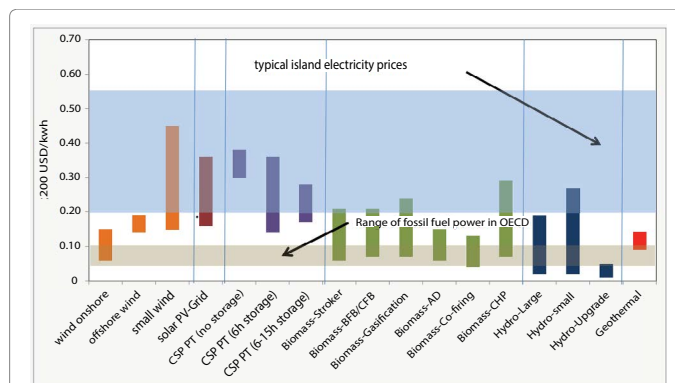


Figure 4: The cost of renewable power generation. The figure assumes the cost of capital is 10%. The bands reflect ranges of typical investment costs (excluding transmission and distribution) and capacity factors. PT = parabolic trough, ST = solar tower, BFB/CFB = bubbling fluidised bed/circulating fluidised bed, AD = anaerobic digester, CHP = combined heat and power.

is also important to note that distributed renewable technologies, such as rooftop solar PV and small wind, can provide new capacity without the need for additional transmission and distribution investment and therefore cannot be directly compared with large utility-scale renewable solutions. Although many cost factors are technical (e.g. wind turbine design) or resource-related (e.g. wind speeds), the cost of capital can depend more on external factors such as a lack of experience in financing renewable projects of a particular type in a country. Addressing the real or perceived risks of renewable projects can have a large impact on cost of electricity of renewable energy. For instance, the cost of electricity of a wind farm project is around 60% higher when the cost of capital is 14.5%, rather than 5.5%. Different renewable power generation technologies can be combined in mini-grids to electrify isolated villages and extend existing grid networks. The complementary nature of different renewable options, sometimes deployed in combination with electricity storage, can help reduce the overall variability of supply to low levels and provide low-cost, local electrification solutions. However, a major challenge to the economics of these electrification projects is the high cost of capital, which can be two to three times higher in developing countries than in developed ones.

### Scenarios / Case Studies in Rural Areas

Renewable energy technology (RET) comprises the virtuals of energy services that are controlled by renewable sources for heating, space conditioning and liquid pumping. RETs have great unrealized capacity to fit the energy demands of rural associations in a sustainable way to decrease energy poverty. The global nature of RETs allows them to be matched with the specific needs of different rural areas and constitute examples for different countries.

Regards to one of the main bottlenecks of the renewable energy which is the integration of the small scale systems with the main power streams, a good idea is to utilize renewable energy systems for built in place applications. This way the constructed power will be consumed in the micro community like in rural areas where it is built. Main focus of these technologies for rural areas will be wind, small-scale hydropower, solar, geothermal and biomass energy.

Wind energy presents several advantages specific to rural communities as well. Agricultural areas generally have open land which can serve as a well-suited wind power generation. For example, in Cadillac, Michigan, a power supply cooperative serve more than

220,000 residences and businesses in rural portions of Michigan's Lower Peninsula and the facility has a plate capacity of 52.8 MW [39]. This confirms that Turkey with its significant amount of wind capacity, wind power can provide electrical energy in rural areas. Most regions in Turkey have unrealized potential, although the growth possibilities in the western region are plentiful.

Small-scale hydropower plants are also used to produce electricity and can differ in different size in rural areas. Many small-scale hydro systems have a main energy-carrying medium which is the natural flow of water [40]. As one of the most suitable and applicable rural energy sources [41], small scale hydro powers perform a major role in the advance of agricultural modernization and rural electrification in Turkey.

Besides hydro and wind energy, solar energy is also commonly used in rural areas. For example, GEDAP which has been projected by the government of Ghana, aimed to supply all educational buildings and other organizations to be run with solar PV systems to render up to 10,000 households with basic electricity. Ghana endorses both on-grid and off-grid electrification alternatives that accompany each other. Also in the country, the off-grid solar systems are sustained at the rates ranging from 25% to 50% [42].

Additionally, solar energy protect environment and induce the economical growth in rural areas. The photovoltaic systems can reduce CO<sub>2</sub> emission significantly [43]. Hence, as a result, they are inexpensive, secured and less depending on the environment; solar PV systems can be built in rural areas in the eastern of Turkey.

With the increasing demand of hydrogen production, the investigators are in the search of founding alternative hydrogen sources. Considering the utilization of renewable sources for hydrogen production, geothermal resources appear to be an applicable and suitable option where thermo-chemical water splitting is applied in a serial process of the decomposition of water into hydrogen and oxygen using heat. Numerous countries like Iceland, Japan and USA, take advantage of their geothermal resources for the enhancement of hydrogen energy based economy. Hachijo Island in Japan is considered as a main prototype for other areas worldwide, where hydrogen is produced from geothermal energy. Another inspiring example is the coaction between France and Iceland for considering the possibilities of generating hydrogen with high temperature steam electrolysis (HTSE), a process which needs 18% less energy input compared to conventional electrolysis, paired with a geothermal reservoir. The final aim of this project is to generate hydrogen by HTSE paired with a geothermal reservoir in the Icelandic context where superheated water could be supplied at 200°C from geothermal sources [44]. To envisage the production potential, Arnason and Sigfusson reported that the Bjarnarflag geothermal field in Northern Iceland, is able to furnish approximately 50 tonnes of H<sub>2</sub> annually [45].

Among the renewable energy sources, biomass energy is considered as the most applicable source in rural areas [46], and therefore it has been studied more than others. For this purpose Gautam et al. [47] studied the biogas production in Nepal. Most of household biogas plants in Nepal supported by the Biogas Support Partnership (BSP) uphold by Netherlands, Germany and Nepal [47]. BSP provides financing sponsorship to enhance cookery and illuminating using biogas [48]. The biogas facilities supported by BSP transform animal dung, human wastes and other biomass into biogas [47]. Figure 5 shows the flow diagram of a typical biogas plant in Nepal [49]. The size of the digester can be varied 4-20 m<sup>3</sup>. Daily amount of animal wastes extends

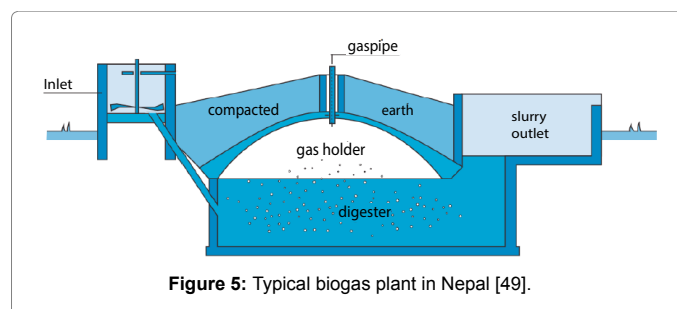


Figure 5: Typical biogas plant in Nepal [49].

6 kg per m<sup>3</sup> of the facility. Prior to feeding the animal dung should be merged with water to make the slurry homogeneous. After leaving the outlet, it will go to a compost unit and half of the generated gas will be used for cookery and illuminating.

Biofuel production was also studied in Iran from microalgae. Najafati et al. [50] emphasized that algae from Urmia salt lake in Iran has increased its biofuel capacity using algae. They suggested that using CO<sub>2</sub> and salt from the sea nearby the country, they can produce more oil than corn or soybean by microalgae in closed or opened photobioreactors in large scale [50]. The government of the country is also planning to produce biofuel using wood which constitutes 10.5% of Iran's land area, in order to supply the energy consumption in rural areas [51]. In the light of the fact that biofuel is much feasible and easier to distribute in rural and poor areas [52], it can be used as a main energy source in the rural areas of Turkey.

As another example of biomass energy production, the rural areas in China were also investigated. Mortimer and Grant [53] showed that, wheat and cassava can be provided regionally, bioethanol production would decrease the CO<sub>2</sub> emission up to 96%. Similarly in Turkey, wheat and corn can be used to produce bioethanol in order to reduce CO<sub>2</sub> emission with the amount of 20100 and 4600 kiloton, respectively [54].

In order to evaluate the cost efficiency of biomass energy, Gwuvuya et al. [55] investigated the costs of energy production from primary energy sources of wood in rural Ethiopia, and the economic capacity of biogas. They concluded that, households in rural areas in the country mostly gather their own fuel from surrounding. Thus, households could save money and energy, and have their own fertilizer in agricultural production. This situation leads a costly benefit approach of biogas plants and presents important benefits for householders who collect their own energy sources [55].

## Prospects and Limitations

With its young generation, increasing energy requirements, rapidly growing urbanization and its economic enhancement, Turkey has been one of the hot spots for power industries of the world for the last two decades. Unfortunately Turkey is intemperately dependent on high-priced imported energy reservoirs that puts a big undesirable weight on the economy and air pollution is becoming a major environmental issue. In this regard, renewable energy resources occur to be the one of the most feasible, applicable and effective solutions for environmentally-friendly and renewable energy in Turkey. Moreover, renewable energy demand is mostly supplied by hydropower and biomass. The interest of wind energy is also increasing in production of electricity. Turkey's geothermal energy has also a significant potential, but only a few of them is considered to be applicable to use as an alternative energy [56].

Besides the fact that these alternative energy sources have a great potential to serve as an environmental-friendly, sustainable and

abundant future, using these technologies relied on centuries ago based on the direct utilization [57]. For example wind energy was used for floating the boats from one coast to another in Egypt 500 years ago. Windmill or watermill was used for grain milling all around the world for centuries. Moreover solar energy was used to dry vegetables or fruits. As an example considering Turkey, sun drying is still a local method to dry grapes, tomatoes, peppers and fig. And dried dung was burned for heating the mains in the villages in Turkey. However by the agricultural activities blended with the technological approach, these natural sources that were directly used, are now important for enhanced purposes. Therefore this energy sources were converted into heat or electrical energy to provide energy requirements.

In this respect, scientists and government are in the search of new applications and projects. The number of projects and applications listed in Table 8 are likely to increase year by year with the increasing support of government especially in rural areas. In the light of local resources focusing on biogas, hydropower, solar, wind and geothermal energy systems, local plans will target economic and social development with nationwide research, development, and application strategy integrated with the national macro plans on governmental basis.

A schematic energy production concept in a rural area is illustrated in (Figure 6). In order to make it self-sufficient; wind, solar, hydro, geothermal and bio-based energy productions were represented for a concept rural area. The key is to select the potential sources according to the area. For example, in case of being in the west of Turkey, wind energy can be considered as the best energy resource for heating or electricity (Figure 7). Moreover, if the area is in the southeast Anatolia or the Mediterranean regions, energy of the mains can be supplied with solar energy, utilizing PV systems or solar collectors. Also for the rural areas with livestock potential like having cattle farms, the fertilizers can be send to the biogas plant for heating or electricity purposes of the hospitals, houses and schools. The waste of other agricultural activities (corn cob, wheat straw, sunflower stalk, etc.) can be used as substrate for bioethanol or biodiesel production which can be used as alternative green fuels. In case of being near a river, a micro hydropower plant can be set and conducted to grids in order to supply electricity to the mains, considering annual rainfall in Turkey varies between 220 mm to 2500 mm, and most of the hydro power plants are in the regions receiving an average annual rainfall of more than 500 mm. This case shows that a rural area can become self-sufficient in the mean of energy production by using renewable energy sources.

However, it is not easy to run a big nationwide energy plant in terms of various process bottlenecks like social impact, environmental

Biomass	Annual production (million tons)
Wheat straw	26
Wood/woody materials	12
Cocoon shell	1
Hazelnut shell	0.35
Total	39.35

Table 7: Turkey's main agricultural biomass production in 2002 [26].

Type of renewable energy	Number of projects	Installed capacity of investment (MW)	% Completed projects of capacity
Hydropower	80	2957	40.95
Wind	8	267	89.89
Geothermal	2	58	100
Biomass	5	78.7	40.66

Table 8: An economic analysis of renewable energy project held in Turkey by 2015 [61].

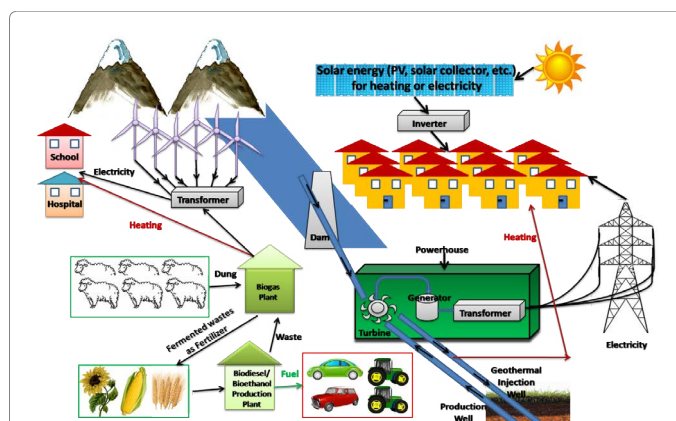


Figure 6: A concept for energy production and consumption by sustainable energy technologies in a rural area.



Figure 7: Distribution of hydro power, solar energy, geothermal fields having temperatures greater than 100°C and wind energy potential in Turkey.

concerns, feasibility, management and controlling (Table 9). Considering the investment and operation, cost of a nationwide plant is more than a rural plant due to the necessity of land, process related infra structure, construction, labor and distribution lines. Moreover, the accessibility and transporting of the raw materials will be difficult and allowing of the usage of local raw material will also attribute to the micro economy. Although RETs are environmentally friendly, sustainable and renewable, they are not considered to replace the fossil fuels. In case of biofuel production, the major drawback is the cost of production and the difficulty of competing with fossil fuels under current market conditions for the foreseeable future. On the other hand there is a dichotomy between the cost of fuel and the revenue because the cost depends on the market dynamics worldwide. In a comparative study of the cost effectiveness of biofuels and petroleum fuels, Lundquist et al [58]. concluded that biofuel production as a byproduct of wastewater treatment is more feasible and resulted in a cost of production that was about a third of 2010 petroleum oil prices in US regards to both the capital and annual operating costs. Considering a rural area wastewater treatment, this process is not just economically feasible, but also helps the management of wastewater which for a safer and more environmentally friendly than discharging to sewer system. However the production of oil and biogas without wastewater treatment cost 15% higher than treatment process in the same conditions and the authors emphasized that oil would need to be sold for \$332/barrel and electricity for \$0.72/kWh, respectively [58]. In order to study the economical analysis of biodiesel production by microalgal technology, Chisti [59] determined that the price of crude oil was about \$100

	Cost	Accessibility to raw material	Competition to fossil fuels	Awareness	Effect on micro economy	Control and processing	Sustainability	Safety
Rural area	+	+	+/-	+	+	+	+	+
Nationwide	-	-	+/-	+	+	-	-	-

**Table 9:** The comparison of renewable energy production plants that built in rural areas and nationwide. The markers of (+) and (-) defines the possibility and the challenges of each column, respectively.

per barrel and microalgal biomass with an oil content of 55% would supposed to be produced at less than about \$340/ton to compete with petroleum diesel. It was also indicated that the price of algal biomass production needed to decline by a factor of approximately 9 [59]. However as fossil fuels are not abundant and will be run out sooner or later in a few decades, the RETs can be considered as an alternative energy source for only rural environment to help these areas become self-sufficient. Also, the directives of European Commission underlines that the usage of biofuels decrease the emissions of greenhouse gases by up to 40% compared to its petroleum based counterparts [60].

Furthermore, as RETs get into rural areas, social awareness will rise. Local village populations will be educated for renewable energy production and employed in such plants. This situation will also lead the local people to establish new foundations and develop new ideas for a better energy production process in terms of cost, performance or yield which will also increase micro economy as well (Table 9). Likewise, a nationwide RET plant will result in such a positive effect, but on the other hand controlling, sustainability and safety problems will become prominent as it will be hard to control from one point. For such case, it will be mandatory to build more control centers but in such case, required plant area will become larger and cost will increase. Moreover the sustainability of energy or electricity and subsequently, personal or environmental safety will diminish [61].

While the projects related to sustainable and renewable energy sources led to significant reductions of greenhouse gases and enhancing the air quality, it also had a number of socio-economic and environmental benefits such as, improving the local infrastructure in the project region by mending the streets and building a bridge, planting of trees in the project area, indirectly diminishing emissions of petroleum fuels like SO<sub>2</sub>, helping to enhance the regional and national energy demand and to decrease dependency on fossil fuels. Furthermore, as RETs get into rural areas, social awareness will rise Local village populations will be educated for renewable energy production and employed in such plants: employing qualified and unqualified workers during the construction of the facility and creating permanent jobs for the operation and maintenance. This situation will also lead the local people to establish new foundations and develop new ideas for a better energy generation process in terms of cost, performance or yield which will also increase micro economy as well (Table 9). Likewise, a nationwide RET plant will result in such a positive effect, but on the other hand controlling, sustainability and safety problems will become prominent as it will be hard to control from one point. For such case, it will be mandatory to build more control centers but in such case, required plant area will become larger and cost will increase. Moreover personal or environmental safety will be diminished.

Long-term supply of cheap and renewable feedstocks are critical to the rural economy for biomass power plants. Substrate costs can be almost zero for some wastes, for example those produced onsite at industrial installations like black liquor at pulp and paper mills. Indeed, several times their usage saves disposal charge. Costs can be reduced by easily collecting agricultural wastes and transporting over short distances. However, if higher distances are involved, costs will be higher, as well. Expenses for these substrates may significantly surpass costs in markets if costs are exhibited relative to the occasion cost of

competing fuels and this uncertainty can increase project risks and thus financing costs.

## Conclusion

Approach to advanced energy services and rural development are unavoidably linked. This modern energy services can be considered as renewable energy technologies which are sustainable and abundant in Turkey. Due to the fact that energy demand increase day by day to run small energy systems integrated with the resources of the rural areas will have a positive effect to depressurize the economic concerns. However considering the total cost of RET production, renewable energy sources can be used not to replace the petroleum fuels in Turkey, but to supply energy requirement in rural areas, in order to decrease the imported energy resources that has a expanded effect on the economy. As a result of this strategy, not just the rural economy will be developed, but also local employment and social awareness will be increased. Also the sources or wastes will be converted in to value-added products and energy which can help the rural area to become self-sufficient.

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