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Investigation of usage of 100% renewable energy in building sector in Turkey

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Abstract

Renewable energy plays a critical role to satisfy rising energy demands and to achieve low-carbon economy. Renewable energy policy has become a focus of national policy formulation and legislation. The government has promulgated more than a dozen national policies to promote the utilization of renewable energy in buildings. However, Turkey is still at the early stage compared to the developed countries. Share of renewable energy usage in the TPES was determined 9.58% (includes hydropower) in the year of 2014. According to result of this study, usage of 100% renewable energy is impossible in building sector in Turkey

Key words: energy; renewable energy, usage; building sector

1. Introduction

During the last two decades, the rapid growth of Turkey economy has created a massive demand for energy. In 2014, the total energy production was 5163.47 PJ tripled than 2009.31 PJ in 1990. The annual increase rate of energy consumption is about 5.8% during the same period, reaching 5163.47 PJ in 2014. On the other hand, natural gas dominates the energy consumption structure of Turkey, accounting for as high as 36% of the total energy consumption in 2014. As a result, Turkey has become a net energy importer. Furthermore, the highly energy intensive economy and strong GDP growth in Turkey will inevitably drive the continuous growth of the energy demand. These present key challenges to Turkey to balance between rising energy demands and potential environmental issues. Renewable energy (RE) helps to mitigate the tension between the energy demands and public concerns on environmental pollution. In recent years, the renewable energy capacity expands dramatically around the World and more than 85 countries have adopted renewable policy targets by 2010 [1]. Renewable energy plays a critical role in achieving low carbon economy, especially for Turkey. The abundant reserve of RE sources will help Turkey to reduce the high intensity of carbon dioxide emission per unit of GDP. Energy consumption from renewable energy resources will account for 20 % of total energy consumption by 2023. With the rapid growth of economy, the building sector has become one of the biggest contributors towards energy consumption and greenhouse gas emission. According to the statistics of the U.S. Energy Information Administration, the buildings sector accounts for some 20% of the total energy consumption around the world [2]. In Turkey, the residential building sector consumed 1253 PJ, accounting for 35% of the national overall energy consumption. This consumption will even increase further in the future. In the past two decades, the annual increase rate of building energy consumption in Turkey is more than 10%. To achieve low carbon economy, Turkey has devoted to utilize renewable energy in buildings. Various types of energy consumption in buildings, such as cooling, heating, hot water, and lighting as well as house hold appliance energy consumption can be supplied by renewable energy systems. Similarly, the utilization of renewable energy also features in sustainability reporting of leading

international construction companies. This study aims to investigate the utilization of renewable energy in buildings in Turkey by reviewing the energy consumption in buildings as well as analysing the relevant policies, regulations and strategic plans in Turkey.

Table 1. Energy inputs in Turkey in 2014

Populations	Total energy consumption	Total energy production	Renewable energy production	Per/capita for total energy consumption	Per/capita for renewable energy production
	(PJ)	(PJ)	(PJ)	(GJ/cap)	(GJ/cap)
77 780 418	5163.47	1228.48	494.91	66.39	6.36

Turkey, with a population of 77 780 418 and with dwelling units of 21 275 220 on 800,000 km² of land, is located between 35°50' and 42°06' north latitudes and 25°40' and 44°48' east longitudes. Most of Turkey is in Asia. The far northwestern part of the country is in Europe and is separated from the rest of the country by the Dardanelles and Bosphorous Straits and the Sea of Marmara [3-4]. The values of populations, total and renewable energy production and consumption 2014 are summarized in Table 1. while energy inputs for 2014 according to energy carriers are illustrated in Table 2.

Table 2. Consumption of total energy and usage of residential-commercial sector in 2014

	Total energy consumption		Residential-Commercial sector consumption		
	Energy consumption (PJ)	Share of the total consumption (%)	Energy consumption (PJ)	Share of the RCS (%)	Share of the total consumption%
Hard Coal	802.27	15.54	143.20	11.51	2.77
Lignite	567.55	10.99	26.40	2.12	0.51
Asphaltite	13.86	0.27	2.80	0.23	0.05
Petroleum	1319.29	25.55	36.91	2.97	0.71
Natural Gas	1854.39	35.91	470.99	37.87	9.12
Wood	90.36	1.75	90.36	7.27	1.75
Bio – Mass	44.00	0.85	41.65	3.35	0.81
Hydropower/Electric	146.14	2.83	364.18	29.28	7.05
Biofuel	2.80	0.05	0.00	0.00	0.00
Geothermal (heat)	147.30	2.85	45.23	3.64	0.88
Solar	33.57	0.65	21.86	1.76	0.42
Wind	30.63	0.59	0.00	0.00	0.00
Petrocoke	101.15	1.96	0.00	0.00	0.00
Coke	10.15	0.20	0.00	0.00	0.00
Total	5163.47	100.00	1243.57	100.00	24.09

As can be seen in these tables, total energy input to the Turkish sector were determined as 5163.47 PJ in 2014. Of total energy input, 35.05% was produced in 2000 []. It was also determined that 25.05% of total energy input produced in 2014, respectively while the rest obtained by imports.

In 2014, 34.47% of Turkey's total end-use energy was consumed by the residential-commercial sector as shown in Fig 1. The other sectors were determined as listed; the industrial sector, with 32.45%; the transportation sector, with 28.34%; the agricultural sector, with 6.6%; and out of energy, with 5.1%. In this year, in terms of consumption of the 13 largest energy sources, natural gas had the largest share, with 34.99%, followed by petroleum, with 26.22%.

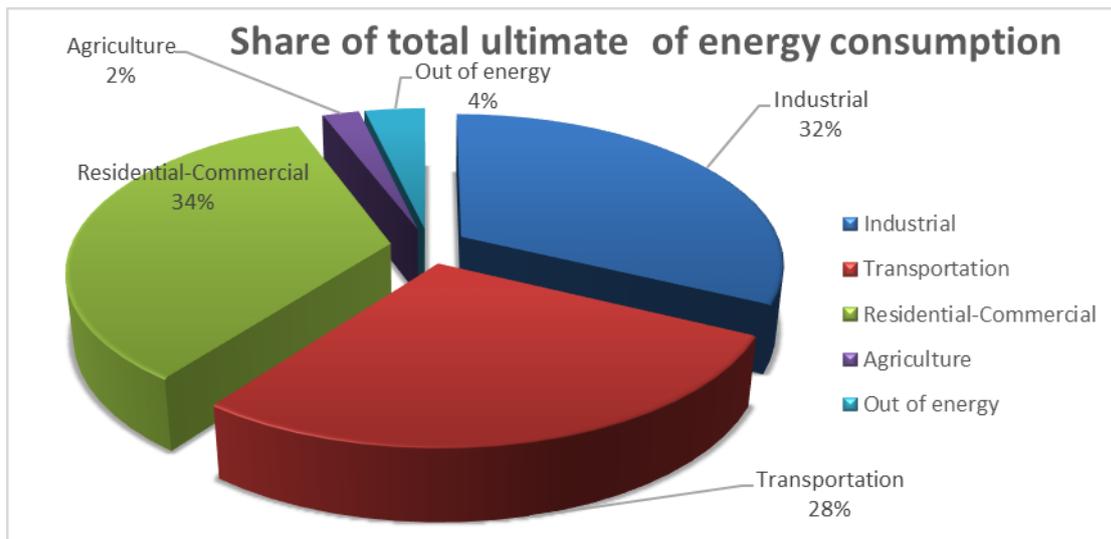


Fig. 1. Share of the end use energy according to sectors

2. Energy Consumption and Renewable Energy in Buildings

2.1. Energy Consumption in the Residential-Commercial Sector

Buildings generally fall into two sectors, i.e. residential and commercial. The US Energy Information Administration predicted that the energy consumption in residential sector and commercial sector will increase 1.1% and 1.5% annually, respectively, from 2008 to 2035. The commercial energy consumption and residential energy consumption together see a rapid growth from 2000. The trend of energy consumption showed consumption showed that, as the living standard of people improved, together with a rapid development of tertiary industry, the rapid growth trend of energy consumption in buildings will continue and the percentage of building energy consumption in national overall energy consumption may increase even further

The building sector is one of the main protagonists in environmental problems because of the exploitation of non-renewable resources, the use of soil and the energy consumption during the whole life cycle of a building. The negative effects on the environment include both resource consumption and pollution; in the building sector, the latter factor causes the largest impact. In 2000, it was estimated that 45% of the energy produced in Europe was used

in the building sector and 50% of air pollution was caused by this sector [5]. Same as, building energy consumption accounts for one-third of the total energy consumption in Turkey and the demand is increasing parallel to the World. Over the last decade policymakers, as elsewhere, have increasingly recognized the potential of the sector to contribute towards reductions in energy consumption and CO₂ emissions (Kavgic,2010). Therefore, reducing energy use for space heating and cooling in buildings is a key measure to energy conservation.

In recent years, energy performance study of buildings has been widely used for the design, simulation and performance evaluation of buildings. In evaluating the energy performance of buildings, energy performance analysis method has been widely used, while studies on energy performance. Building energy simulation has been playing an increasingly significant role not only in building design, but also in operation, diagnostics, commissioning and evaluation of buildings in the last two decades. It can help designers compare various design options and lead them to energy-efficient designs in manner of cost-effectiveness. Building energy simulation can also help facility managers and engineers identify energy saving potentials and evaluate the energy performance and cost-effectiveness of ECMs (energy saving measures) to be implemented.

On the other hand, Turkey is revising its legislations on building energy performance as foreseen in Directive 2002/92/EC, through the European Union accession process. The national standard, TS 825, “Thermal insulation requirements for buildings” which came into force at 2000, is revised in 2008. “Energy Efficiency Law” is released in February 2007; urging industry, transportation and building sectors to take measures on reduction in energy consumption. Finally “Building Energy Performance Regulation” came into force in December 2009. Thus, there has been a growing interest in the evaluation of the heating and cooling energy demand for buildings.

2.2. Utilization of Renewable Energy

Common renewable energy resources include solar energy; wind energy, biomass energy, geothermal energy, and ocean energy, featured with recycle ability and low level of environmental pollution [6-9].

The RE consumption in the world increased from 74.5 million tce in 2000 to 230.6 million tce in 2010 with an annual increase rate of 12%. As for Turkey, the renewable energy consumption has gained a rapid growth since the PRC Law of Renewable Energy went into effect in January 2006. For instance, the renewable energy consumption for Turkey accounted for 7.6% of the total world renewable energy consumption in 2010 and the consumption has increased 16 times in the past decade [10]. According to the annual report of the United Nations Environment Program, Turkey has exceeded the United States to become the country that made the most investments in renewable energy area in 2009. The limited reserves of conventional energy resources have gradually become the bottle neck for economic development while the greenhouse gas emission is another issue associated with conventional energy sources [11,12]. Renewable energy, such as solar energy and wind energy with no greenhouse gas emission during power generation process, can be utilized in buildings to provide a solution to the problem [13]. For instance, solar water heater can save 10–15%

energy consumption and solar heating system can create 45% energy saving in buildings [14]. The utilization of solar desiccant cooling system in institutional building can help to achieve 60% of energy related cost saving and significant reduction of greenhouse gas emission [15]. Similarly, utilizing renewable energy has become an important part of the design and development of green buildings [16,17]. There is great potential to utilize solar energy, wind, geothermal energy and biomass in buildings and the technology is relatively mature. The utilization of solar energy has received increasingly level of attention worldwide, within exhaustible source and no greenhouse gas emission and it can be utilized in photovoltaic systems, solar thermal water heating and hybrid photovoltaic thermal solar systems, etc [18-19]. Wind energy is mainly utilized for power generation, especially in the high rise buildings. Geothermal energy is another vast clean energy source, stored in the interior of the earth. The heat pump technology is drawing rising attention and it has an enormous application potential in buildings [20,21]. At present, the available biomass contains crop straw, firewood, livestock manure, industrial organic waste and municipal solid waste, etc. They can be utilized for heating through direct combustion or chemical conversion [22,23]. For instance, biogas can be generated from livestock manure through biochemical conversion.

3. Analysis of Energy Utilization in the Turkish Residential-Commercial Sector

The TRCS includes space heating, water heating, cooking and electrical appliances for energy consumption. In the following subsections, the utilization of energy in the TRCS in the years of 2014 is analyzed. The specific applications for energy consumptions were determined for 2014. In 2000, of Turkey's end use energy, 33% was used by the residential sector. Table 2 illustrates the use of energy as well as the shares of the resources in this sector for the year of 2014. Share of the energy utilization in the residential-commercial modes is as follows: space heating with 43%, water heating with 27%, cooking 12% and electrical appliances with 18% in studied years, respectively. These values are determined for 2014. Table 2 shows energy utilization values for the year studied in the TRCS. The highest contributions came from natural gas with 37.87%, electric with 29.28, renewable resources (includes wood) with 16.20 in the 2014. In this case, the result of development of economic in studied country. Unfortunately, natural gas usage has continuously increased in the TRCS for space heating, water heating and cooking purposes in several cities. In addition, utilization of renewable energy is spread in the TRCS, especially from sunlight for water heating, from geothermal for water heating and space heating and from bio waste for general usage.

3.1. Usage of Renewable Energy in Turkish Residential-Commercial Sector

The share of RE in Turkey's **total primary energy supply** (TPES) in 2014 was 494.91 PJ, with the majority of total RE supply from geothermal, biomass and animal products, mostly solid biomass (wood), solar and some biofuels energy. In addition, wind with 2.49%, hydro electricity provided 11.89% of country's electricity production. The relative importance of renewables in TPES continues to decline as domestic coal production and natural gas imports rise steadily to satisfy rising electricity demand. However, there is a significant room for expanding RE use in Turkey, which has a large resource base of biomass, geothermal, solar

and wind energy as well as hydropower.

Table 3. Renewable energy inputs Turkey in 2014

Renewable energy sources	Produced (PJ)	Renewable energy production (%)	Share of renewable energy in the total production (%)	Share of renewable energy in the total consumption (%)
Wood	90.36	18.26	7.36	1.75
Biomass	44.00	8.89	3.58	0.85
Hydro-power	146.11	29.52	11.89	2.83
Biofuels	2.93	0.59	0.24	0.06
Geothermal	147.30	29.76	11.99	2.85
Solar	33.57	6.78	2.73	0.65
Wind	30.63	6.19	2.49	0.59
Total	494.91	100.00	40.29	9.58

In 2014, of TRESs, 39.34% was used by the residential-commercial sector. The share of the conversion and industrial sectors were 52.97 and 3.37%, respectively, while the transportation sector and agriculture sector were determined as 2.93%, 4.73%, respectively, as illustrated in Table 4.

Table 4. Usage of renewable energy according to sectors

	RC sector	Share of RE	Industrial sector	Share of RE	Utility sector	Share of RE	Transportation sector	Share of RE	Agriculture sector	Share of RE	Total
	PJ	%	PJ	%	PJ	%	PJ	%	PJ	%	PJ
Wood	90.36	18.26	*	*	*	*	*	*	*	*	90.36
Biomass	44.00	8.89	*	*	*	*	*	*	*	*	44.00
Hydro-power		*		*	146.11	29.52		*		*	146.11
Biofuels		*		*		*	2.93	0.59		*	2.93
Geothermal	38.48	7.78		*	85.44	17.26		*	23.39	4.73	147.30
Solar	21.86	4.42	11.71	2.36610		*		*		*	33.57
Wind		*		*	30.63	6.19		*		*	30.63
Total	194.70	39.34	11.71	2.37	262.2	52.97	2.93	0.59	23.39	4.73	494.91

In the following subsections, the utilization of renewables energy in the TRCS during 2014 is analyzed. Table 5 shows usage renewable energy in the TRCS and its subsectors.

3.3.1. Space heating

Based on the values obtained from Turkey's population census, the fuel preferences of dwelling units for space heating were determined for each province, while energy consumptions in residences were predicted according to geographical regions and selected

provinces in 1998 in Turkey [47]. The distribution of heating systems according to their utilization ratios in 1998 was as follows: district heating at 2.50%, central heating at 5.30%, individual heating at 4.30%, stove at 84.10% and others 3.80%.

Table 5. Utilization of Renewable energy in the TRCS and its subsectors

Residential - Commercial							
Energy sources	Space heating		Water heating		Cooking		Total
	<i>PJ</i>		<i>PJ</i>		<i>PJ</i>		<i>PJ</i>
Wood	56.66		33.08		0.63		90.36
Biomass	19.80		8.81		15.40		44.00
Hydro-power	*		*		*		
Biofuels	*		*		*		
Geothermal	17.32		21.16		*		38.48
Solar	*		20.76		1.09		21.86
Wind	*		*		*		
Total	77.78	90.00	68.80	40.00	48.12	70.00	194.70

According to usage of renewable energy this sector. The contribution of geothermal energy to the TRCS was 17.32 PJ for space heating in 2014. However, it is expected that geothermal usage will continue to increase to 190.50 PJ in 2020 in direct use of geothermal energy for heating [42].

3.3.2. Water heating

In 2014, 32% of all direct fuel use was for water heating. The distribution of residences according to their types of heating systems in 2014 was as follows: stove with 16%, solar collector with 14%, thermo siphon type heater with 11%, gas or LPG fuelled water heater with 43%, combined heater with 11% and central hot water system 5% [47]. These figures indicate that a small part of Turkey's solar energy potential is used for water heating although Turkey has a huge solar energy potential.

3.3.3. Cooking

In cooking activities, various fuels such as natural gas, city gas, LPG, wood, etc. are used. 20% of all direct fuel use was for cooking.

4. Policy analysis of renewable energy in TRCS

Turkey has substantial renewable energy potential. Renewables make the second-largest contribution to domestic energy production and consumption after coal. However commercial use of renewable energy in Turkey excluding large-scale hydropower has not developed in proportion to its large resource base. Renewable energy use has been dominated by large hydro and biomass (mostly wood and animal wastes). The huge potential of Turkey in renewables like wind, solar, and geothermal has not been used efficiently until recently.

In the event that Turkey continues pursuing the same policy it is more likely that renewable shares will continue decreasing rather than increasing. Just as, total share of renewable in TPES has declined depending on mainly decreasing biomass use and the

growing role of natural gas in the system. It has been estimated that the share of renewable energy will decrease to % 9 of TPES in 2020. In addition, Turkey's highly supply-oriented energy policy dominated with emphasis placed on ensuring additional energy supply to meet the growing demand while the sustainability criteria remained a lower priority

It is still under discussion in the Turkish National General Assembly Turkey is also now at the stage of setting targets for renewable energy development.

The Higher Board of Planning adopted the "Electric Energy Market and Supply Security Strategy Paper"³³ in May 2009. In this Strategy Paper the long term primary target is "to ensure that the share of renewable resources in electricity generation is increased up to at least 30% by 2023." This strategy document was published as a general road map to increase the share of renewable energy in electricity generation. Within the framework of the Strategy Paper, long term efforts will take into consideration the following targets by 2023:

Ensure that available technically and economically hydro-electric • potential is fully utilized.

- Increase installed wind energy power to 20.000 MW.
- Commission all geothermal potential of 600 MW that is currently considered as suitable for electric production.
- Generalize the use of solar energy for generating energy and ensure maximum utilization of country potential.
- Follow and implement closely technological advances in the use of solar energy for electricity generation.
- Amend accordingly the Law No. 5346 to encourage generation of electricity using solar energy.
- Prepare and produce plans that will take into account the potential changes in utilization potentials of other renewable energy resources based on technological and legislative developments and in case of increases utilization of such resources share of fossil fuels and particularly of imported resource will be reduced accordingly.

Near-term targets are the following:

The hydroelectricity plans of 5.000 MW under construction will be completed by 2023.

The wind plant installed capacity will be increased up to 10.000 MW by 2023.

The installed capacity for the geothermal plant will be increased up to 300 MW by 2015.

4.1. Major barriers

The research and practice on integration of renewable energy in buildings is not adequate in Turkey and the immature technology is one of key barriers for the further development. Other barriers include the lack of complete national standards and industrial standards of related technologies and products; and lack of security architecture of products and facilities [18]. For example under a strict national production standards system the solar water heater in Australia can guarantee 12- year or even 20-year working life. Whilst in Turkey the product quality is comparatively poorer and the maintenance cost is higher which gradually a barrier for the development becomes. The high initial cost of renewable energy development compared to the conventional energy is another significant barrier. The imported equipment from overseas cost around 60% higher than those purchased locally. This limits the extensive utilization of renewable energy. Usually the grid companies are required to pay a higher price for electricity generated from renewable energy than that from coal- fired generation and as a result the profit is much lower [7]. Although solar water heater is very popular in Turkey the inadequate supply chain has significantly restricted the application of solar PV in buildings in Turkey. Over 90% raw materials for solar PV are imported whereas over 95% products are exported . As a result the profit level of the solar PV industry in Turkey is comparatively low whereas the associated greenhouse gas emissions are considerably high. Furthermore the Turkey solar PV industry needs further rigid policy supports. Although related policies have been

promulgated by the government substantial supports are far from adequate. The utilization of wind energy in buildings is at the initial stage. Many theoretical and experimental works are exploratory rather than providing an accurate description of the technology [24,25].

4.2. Development plan for renewable energy in buildings in Turkey

The Turkish government has recognized the significance of utilization of renewable energy in buildings and has developed a strategic plan accordingly. In 2006 the government promulgated the Medium and Long-term Development Plan for Renewable Energy. Goals were established to promote industrialization development in wind energy generation, biomass generation and solar energy generation aiming to increase the proportion of renewable energy in overall energy consumption to 10% and 15% in 2015 and 2020, respectively. According to this strategic plan the amount of renewable energy utilized in buildings will dramatically increase. These strategies and ambitious goals are further endorsed in the recently released Strategic Twelfth Five- Year Plan for Renewable Energy Development. These renewable energies resources are: biogas, solar PV, solar water heater and geothermal.

5. Conclusions

Renewable energy plays a critical role to satisfy rising energy demands and to achieve low-carbon economy. Renewable energy policy has become a focus of national policy formulation and legislation. The government has promulgated more than a dozen national policies to promote the utilization of renewable energy in buildings. However, Turkey is still at the early stage compared to the developed countries. Share of renewable energy usage in the TPES was determined 9.58% (includes hydropower) in the year of 2014. According to result of this study, usage of 100% renewable energy is impossible in building sector in Turkey.

- The utilization of renewable energy in buildings has been an important way to promote the development of renewable energy.
- Turkey is rich in renewable energy sources where different types of renewable energy develop rapidly, especially in buildings.
- The immature technologies lack of comprehensive product standards, inadequate supply chain and high cost are major barriers to the further development of renewable energy in buildings.
- A more rigid policy system is required and further research works are encouraged to facilitate the utilization of the renewable energies in buildings.
- It is worth noting that even though a number of strategic plans have been released to promote the utilization of renewable energy in buildings wind energy seems out of the radar as the current focus is placed on large scale wind farm developments that have connected to the power grid.

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