



Dynamics of energy utilization patterns in Turkey for sustainable development

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Abstract

Turkey has a very young population, high annual population growth rate, rapid urbanization and high economic growth rate. Turkey's population has reached about 86 million in 2015. The country has faced with growing demand for energy during last two decades and primary energy demand is projected to reach 273 Mtoe in 2020. But primary energy supply met about 26% of energy demand in 2015. Increasing import dependency highlights the energy security problem for the country and also poses important burden on economy. Energy import increased nearly six folds for last two decades with 10% annual average growth rate. The share of energy in total import has exceeded 25% in recent years. Increasing GHG emissions is another issue has substantially increased due to energy utilization. Therefore, energy dependency and emissions entails investment in renewables such as wind, biomass, hydro and solar to both reducing energy dependency and GHG emissions. The study shows that renewables has more potential for energy security in Turkey.

Keywords: Energy utilization dynamics; sustainable development; energy policies; Turkey

1. Introduction

Turkey has been rapidly growing country for decades and gross national product of country has grown at an average annual rate of 6% since 1990 [1]. Turkey's energy demand has also risen rapidly as a result of economic growth and development as shown in Table 1. Turkey has an economy challenging by a growing demand for energy while its self-sufficiency rate in domestic fossil energy sources are very low [2].

Total primary energy production met about 26% of the total primary energy demand in 2015 (see Table 2). On the other hand, Turkey is heavily dependent on expensive energy imports which impose significant burden on the economy [3]. As a result of increasing energy consumption, air pollution has

been causing severe environmental issues in the country. Furthermore, to meet criteria of Kyoto Protocol, consumption pattern needs to be modified [1]. In this regard, promoting renewable energy resources seem to be one of the effective energy policies in Turkey which also entails substantial investments [4].

The aim of this article is to analyze the dynamics of the energy consumption patterns in Turkey and evaluate the impacts of energy demand patterns change both on energy sector and whole economy. Furthermore, this paper aims to contribute the national energy sources management and policy decision by analyzing the energy demand patterns change and its macroeconomic consequences.

Table 1. Population, economy and energy in Turkey, 1990-2020.

Year	Population	GDP per capita (US \$)	GDP, at current prices (billion US \$)	Energy utilized (Mtoe)
1990	55,075,345	3,859.54	202.40	40.65
1995	59,756,215	5,693.56	223.86	63.74
2000	64,259,456	7,149.45	265.34	82.56
2005	67,903,463	8,005.84	482.78	93.46
2010	72,698,876	9,392.45	729.24	106.68
2015	78,741,234	10,456.56	965.86	152.86
2020	83,245,568	15,654.24	1,468.56	280.34

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2. Global energy consumption

Global primary energy consumption increased by just 1.0% in 2015 and well below its ten year average of 1.9%. Consumption growth was below the ten year average for all regions except Europe & Eurasia; emerging economies accounted for 97% of the increase in global consumption. OECD consumption experienced a small increase, with growth in Europe offsetting declines in the US and Japan [5]. Chinese consumption slowed further, but still recorded the world's largest increment in primary energy consumption for the fifteenth consecutive year [6].

Russia recorded the largest volumetric decline in primary energy consumption. By fuel, only oil and nuclear power grew at above-average rates, with oil gaining global market share. Renewables in power generation continued to grow robustly, to nearly 3% of global primary energy consumption, while coal consumption recorded the largest percentage decline on record. Figure 1 shows global primary energy consumption as a million tons of oil equivalent (Mtoe) [5].

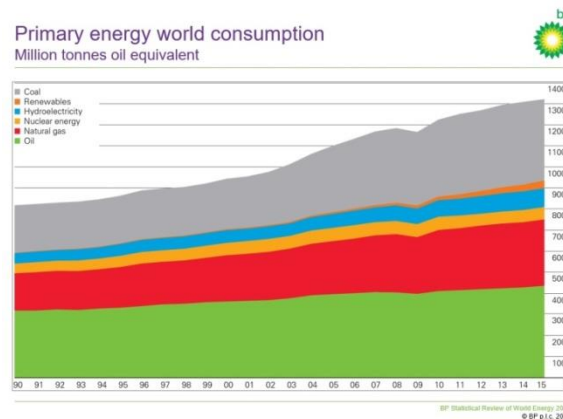


Figure 1. Global primary energy consumption (Mtoe).

As shown in Figure 2, oil remained the world's leading fuel, accounting for 32% of global energy consumption [5]. Emerging economies now account for 58.1% of global energy consumption [6]. Chinese consumption growth slowed to just 1.5%, while India recorded another robust increase in consumption. OECD consumption increased slightly, compared with an average annual decline of 0.3% over the past decade [5]. Global oil consumption grew by 1.9 million barrels per day. The relative strength of consumption was driven by the OECD countries.

Growth was well above recent historical averages in the US and the EU, while Japan recorded the largest decline in oil consumption. Outside of the OECD, net oil importing countries recorded significant increases: China once again accounted for the largest increment to demand, while India surpassed Japan as the world's third-largest oil consumer. But this was offset by slower growth in oil producers, such that oil demand growth in the non-OECD was below its recent historical average [5, 6].

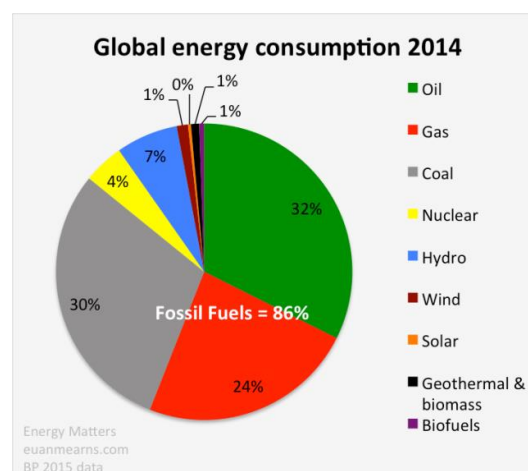


Figure 2. Percentage of global energy consumption in 2014.

World natural gas consumption grew by 1.7% in 2015, a significant increase from the very weak growth seen in 2014 but still below the ten year average of 2.3%. As with oil, consumption growth was below average outside the OECD but above average in the OECD countries. Among emerging economies, Iran and China recorded the largest increments to consumption, even though growth in China was sluggish compared with a ten year average growth of 15.1%. Meanwhile, Russia recorded the largest volumetric decline, followed by the Ukraine. Among OECD countries, the US accounted for the largest growth increment, while EU consumption rebounded after a large decline in 2014. Globally, natural gas accounted for 23.8% of primary energy consumption [5].

Global coal consumption fell by 1.8% in 2015, well below the ten year average annual growth of 2.1% and the largest percentage. All of the net decline was accounted for by the US and China, partially offset by modest increases in India and Indonesia. Global coal production fell by 4%, with large declines in the US, Indonesia, and China. Coal's share of global primary energy consumption fell to 29%, the lowest share since 2005 [5].

Global nuclear output grew by 1.3%, with China accounting for virtually all of the increase. China has passed South Korea to become the fourth-largest supplier of nuclear power. Elsewhere, increases in Russia and South Korea offset declines in Sweden and Belgium. EU output fell to the lowest level since

1992. Nuclear power accounted for 4.4% of global primary energy consumption [5, 6].

Global hydroelectric output grew by a below average 1%, compared with a ten year average of 3%. China remains by far the world's largest producer of hydroelectricity; as with nuclear power, China accounted for all of the net global increase, even though growth in percentage terms was less than half the recent historical average. Elsewhere, growth in Turkey and Scandinavia was offset by drought conditions in Italy, Spain and Portugal and Brazil. Hydroelectric output accounted for 6.8% of global primary energy consumption [5].

Renewables in power generation continued to increase in 2015, reaching 2.8% of global energy consumption. Renewable used in power generation grew by 15.2%, slightly below the ten year average growth of 15.9% but a record increment was roughly equal to all of the increase in global power generation. Renewables accounted for 6.7% of global power generation. China and Germany recorded the largest increments in renewables in power generation. Globally, wind energy remains the largest source of renewable electricity, with Germany recording the largest growth increment [6]. In 2015, solar power generation grew by 32.6% accounting for the largest increases. China overtook Germany and the US to become the world's top generator of solar energy. Global biofuels production grew by just 0.9%, well below the ten year average of 14.3% [5].

3. Economic drivers for energy demand in Turkey

3.1. Energy supply and demand

Energy supply in Turkey has been on an upward trend for the last four decades to meet the rapidly increasing energy needs of the fast growing economy. Turkey's total primary energy supply (TPES) was 152.9 million tons of oil-equivalent (Mtoe) in 2014 (see Table 2). Turkey is highly dependent on oil and gas imports as only 24.8% of

energy supply is met by domestic production. TPES is the lowest among IEA members with 1.7 tons of oil-equivalent (toe) per capita in 2014, in comparison to the IEA average of 4.5 toe per capita. In relation to GDP, the energy intensity is much higher and Turkey is ranked around the IEA average [4].

Table 2. Total energy production and consumption in Turkey (Mtoe)

Energy Sources	Production		Consumption	
	2014	2020	2014	2020
Coal and Lignite	26.15	32.36	39.70	107.57
Oil	1.13	0.49	51.17	71.89
Gas	0.17	0.14	49.58	74.51
Hydropower	5.34	10.00	5.34	10.00
Geothermal	0.98	1.71	0.97	1.71
Wood and Biomass	5.12	4.96	5.12	4.96
Solar/Wind/Other	1.05	2.27	1.05	2.27
TOTAL	39.94	52.23	152.93	273.21

Total fossil fuel consumption is reached to 140.6 Mtoe in 2014 and natural gas, coal and oil each covered a third of TPES in the country's energy utilization. Over the past decade, natural gas and coal supply increased by 72.1% and 56.2%, respectively, while oil supply increased by 35.8% during that period, stood at 39 Mtoe, rising from 28.7 Mtoe in 2005, mainly because of a 68.7% increase of consumption in transport [7, 8].

Conversely, in 2015, Turkey's domestic energy production only covered 39.94 Mtoe or 26% of TPES; 36.1% of domestic energy was produced from fossil fuels, notably coal (41.8%, mostly lignite), oil (8.3%) and natural gas (1%) [9]. Renewable sources constituted 48.9% of all domestic energy production, with biomass providing 10.1%, hydro 17.9%, geothermal 14.8%, solar 3% and wind 3.1%. According to the government, it is estimated that TPES will double to reach 274 Mtoe by 2020 [7, 8].

Energy from renewable sources represented 12.1% of TPES, and came from biofuels and waste (2.5%), hydro (4.4%), geothermal (3.7%), solar (0.7%) and wind (0.8%). The share of renewable energy has been volatile over the past ten years, largely reflecting varying levels of hydro basins. Most of the increase in energy demand was met by conventional energy sources. Turkey has experienced strong growth in its total installed renewable power capacity which increasing from 15.5 GW to 28 GW from 2009 to 2014. Turkey has no production or consumption of nuclear energy at present [4, 7]. Growing energy needs have been met by a higher use of gas and oil. Given their limited domestic availability, oil and natural gas supply is almost entirely covered by imports. Turkey's energy mix is dominated by fossil fuels which represent 87.6% of TPES in 2015, slightly lowered from the share of 88.1% in 2005 [8].

Total final consumption (TFC) of Turkey amounted to 85.8 Mtoe in 2014 [4]. It represented around 70.6% of TPES, the remainder being power generation and other energy industries. Driven by economic growth, final consumption of energy has also increased in all sectors, by 35.8% since 2000 [7]. Oil consumption accounted for 32.6% of TFC in 2014, followed by natural gas (32.4%), and coal (26%). Natural gas has been replacing oil use in heating and electricity generation, while geothermal and solar increased marginally, and biofuel use contracted [18-24]. The initial growth of natural gas consumption was led by the power sector, but

residential consumption increased with the expansion of the domestic gas distribution network. In addition, geothermal energy is used in all sectors as direct-use heating, mostly for district heating and partially for individual space heating, domestic hot water supply, greenhouse heating, industrial processes and electricity generation [18].

The industry sector is the largest consumer of energy in Turkey, with 36.1% of TFC in 2014 and its energy use has increased by 20% since 2000. Coal use dropped by 38.5% and has been replaced mainly by gas, which increased by 207.1%. Households accounted for 22.3% of TFC, with 19.1 Mtoe, while energy use in the commercial and public services amounted to 15.1 Mtoe. While energy demand in households has increased by 5.8% since 2004, demand in the commercial sector grew by 105.4%, more than in any other sector. Energy use in transport accounts for 24% of TFC or 20.6 Mtoe. According to the government projections, it is estimated that TFC will more than double and reach 170.3 Mtoe by 2020 [4, 7, 8].

3.2. Economic drivers

Turkey is situated at the meeting point of the Asia, Europe and Africa. Turkey has adjacent to regions pose over 70 % of the world's proven oil and gas reserves. Moreover Turkey sits on major international waterways. Therefore Turkey is an important transit state for world energy resources [7, 8]. Turkey's size 779,452 km² and Turkey's population was about 73 million in 2010. Moreover fast migration from rural regions to industrial and/or tourism regions has continued and fast growing urbanization is leading more energy consumption. Turkey is rapidly growing economy and it's GDP has increased an exceptional rate (see Figure 3). Turkey is 17th largest economy expanded on average by 4.7 % per year [4].

Turkey's GDP is expected to grow at a rate 3 % in 2016 and 5 % in 2018 [9]. Turkey is also expected to fastest medium-long term growth in energy demand [4, 7, 8]. The total energy consumption is expected to reach 273 Mtoe by the year 2020. But, Turkey's energy consumption per capita is still relatively low compared to developed countries [2]. In this regard, Turkey adopted a strategy consists of a privatization and integration into EU and global economy [1]. In this context, some efforts for sustainable energy, energy efficiency and environmental issues have been observed in Turkey [4].

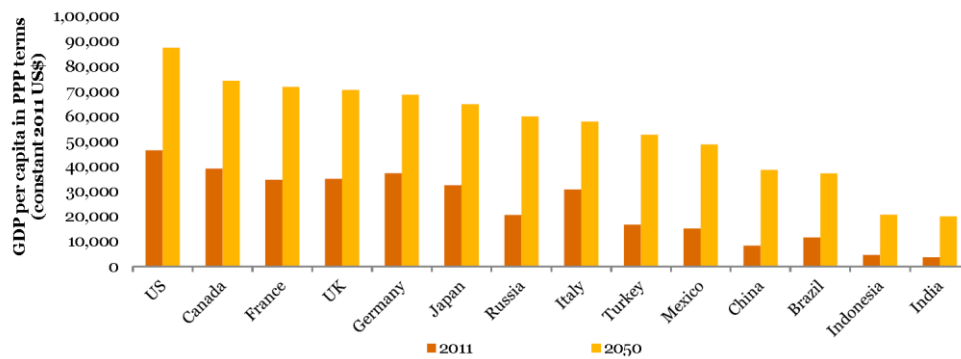


Figure 3. Gross Domestic Product (GDP) per capita for selected countries.

4. Dynamics of energy patterns in Turkey

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Energy consumption of Turkey has grown substantially since the beginning of the 1980s. Turkey's energy consumption is rapidly growing, but it's domestic fossil energy sources such as oil and natural gas are relatively low. According to the

Ministry of Energy and Natural Resources (MENR), primary energy demand is projected to reach 270 million toe in 2020, revealing 100% increase as compared to the current figure [4, 5 6].

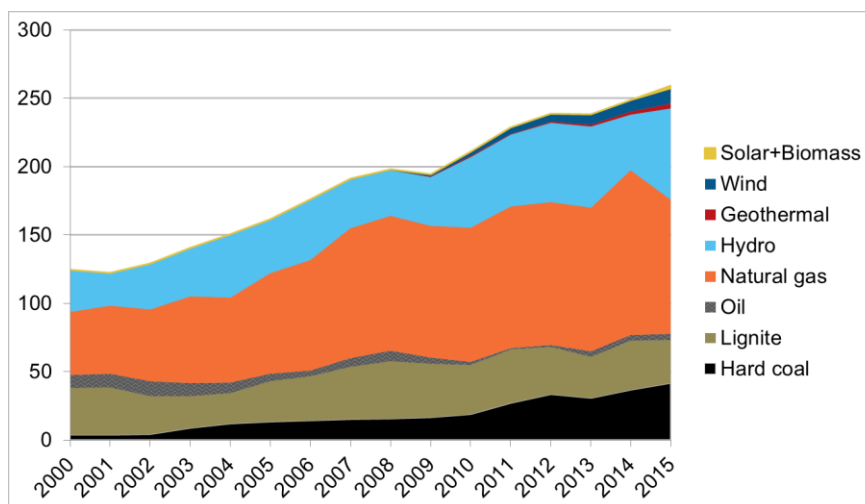


Figure 4. Power generation by energy source in Turkey (TWh).

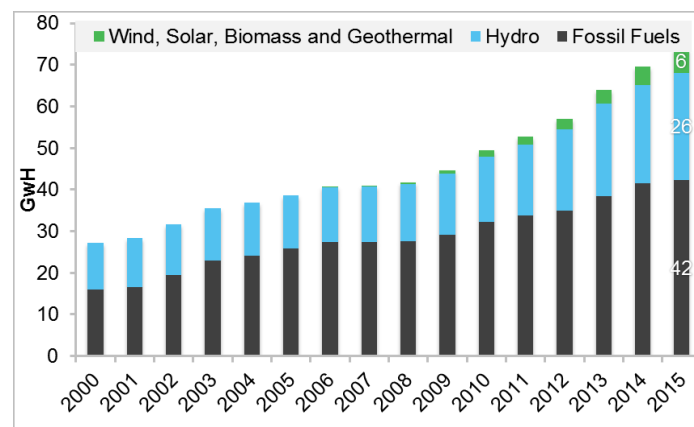


Figure 5. Turkey's Installed capacity (GWH).

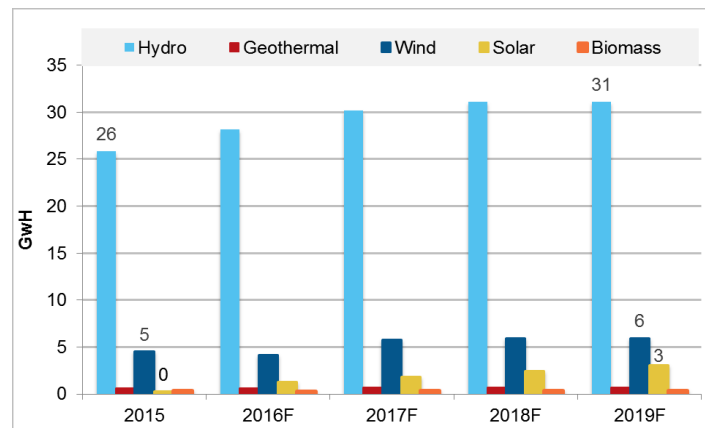


Figure 6. Expected installed capacity by renewables (GW).

According to the MENR statistics (2014), oil, natural gas and coal consist of the bulk of the primary energy consumption in Turkey. Although the consumption of oil has been increasing for the several decades, because of the natural gas, this rate was started to decrease. In Turkey, about 90% of oil supply is being imported. But oil is still the dominant energy source in Turkey. In the past three decades oil's shares were 45.5 %, 41.1 % and 34.1 % for 1990, 2000 and 2014 respectively. Turkey oil consumption was 51.17 Mtoe in 2014 [8]. Turkey's oil production in 2014 met only 1.9 of total in consumption [4]. The oil deficit between production and final consumption was met by imported oil from Saudi Arabia, Libya, Iran, Iraq, Russia, Syria and Algeria [4, 7, 8].

Turkey is a transforming country, so energy usage has shifted towards to manufacture sector and cycle and energy sector [7, 8]. While the manufacture sector share in total energy consumption was 34.5 % in 1990, this share nearly doubled in 2014. Moreover share of the cycle and energy sector increased more than two folds from 1990 to 2014. The shares of cycle and energy sector were 16.1 % and 32.4 % for 1990 and 2014 respectively. Shares in total energy demand for households, transportation, agriculture and out of energy were 29.1%, 20.4 %, 6.2 % and 5.8 % respectively [4, 7, 8, 9].

Natural gas consumption has risen substantially in recent years in Turkey. The shares for natural gas in energy consumption for 1980, 1990 and 2014 were 5.9%, 17.5% and 32.4 % respectively. Natural gas

has been particularly important in the power sector which has risen to tenfold from 1990 to 2014. Gas usage is expected to continue to increase rapidly in all sectors for medium and long term. Turkish natural gas is anticipated to increase rapidly over the next years with the most important consumers expected to be natural gas fired electric power plants and industrial users. Natural gas has been imported mainly from Russia, Algeria, Iran and Nigeria. Turkey produces only a small amount of natural gas and therefore natural gas imports have increased rapidly [8, 9]. Coal has been a major fuel source in energy consumption in Turkey after the oil and natural gas since 1980s. The share of coal (hard coal plus lignite) in consumption was 19 % in 1990 and increased to 26 % in 2014. Around 85% of domestic lignite is used for generating electricity in 2014. Power generation, industry and household usage accounted 46, 44 and 9% respectively in 2014 [4, 7, 8, 9].

There has been also rapid increase in electricity consumption. It has grown 9-10% per year during the last two decades and electricity demand reached 254.62 GWh in 2014 [4]. Although significant increase realized in electricity consumption per capita in 2014 (3120 kWh/yr), it is still under the EU average (6500 kWh/yr) [16]. Electricity consumption increase is expected to continue over the next two decades [17]. Besides natural gas, another fast growing source for electricity is coal. Demand projections up to 2020 indicate that annual average increase in demand will be 6 [18].

5. Implications of energy consumption pattern in Turkey

Total primary energy production met about 28% of total primary energy demand in 2014 and Turkey has no significant oil and natural gas reserves. So the first

inevitable result of energy consumption in Turkey is energy security issue. Turkey is highly dependent on imported primary energy sources. Energy import by

the sectoral break down is presented in Table 3. The highest dependency rate with 93.3% is in natural gas. Dependency rate for oil and hard coal are 92 % and 91 % respectively. It is projected that the production will decrease and meet the 23 % of total energy demand in 2020 which was 28% in 2014. This

energy import dependency poses important burden on economy. The oil and natural gas import is expected to substantially increase over the next decade. The natural gas share in total import is expected to be 33 % in 2020 [4, 7-9].

Table 3. Energy import of Turkey (Million US Dollars,\$)

Energy sources	1995	2000	2005	2010	2014
Hard coal	616.4	676.3	1784.2	2518.5	8346.8
Petroleum	3895.8	5642.8	11580.1	16921.2	24686.3
Natural gas	1268.6	3079.2	7654.9	11185.2	21678.8
Total energy import	5780.8	9530.3	21019.2	30624.9	54711.9
Energy import share (%)	13.5	17.5	20.1	20.7	22.6

Turkey's total energy import has increased nearly six folds for last two decades and reached to 54712 million US Dollar in 2014. Energy import bill has nearly grown with annual average 10%. The energy import share in total energy import also increased during last two decades and constitutes about 20 % of the country total import. Because of the high import dependency rate, the government has developed an energy policy aimed at diversifying energy sources and suppliers and attracting private capital in Turkey [21]. Hence domestic energy sources especially renewable become strategically important [4, 7-12].

Although Turkey has no large oil and natural gas reserves, it has promising significant energy sources like lignite, hydropower and geothermal (see Table 4) [7, 8]. Turkey has also the great remaining potential for hydro. It is stated that Turkey's hydropower potential can meet 33-46 % of electricity demand in 2020. Based on the electricity supply and demand projections, it has been targeted that the share of the nuclear power plants in electricity production will be 5% by the 2020. An intergovernmental agreement was signed between Turkey and Russia for the construction a nuclear power plant in Mersin-Akkuyu [4, 7-9].

Table 4. Clean energy resources in Turkey (1000 TOE/year)

	2000	2005	2010	2014
Total energy demand	77624	85340	101510	152934
Total energy production	26808	23626	27279	39950
Supply by renewables	10149	10131	9604	12426
Biomass and waste	6546	5332	5023	4864
Wind energy	3	5	31	46
Solar energy	262	385	420	964
Hydropower	2655	3402	3083	4864
Geothermal energy	684	1007	1048	1214
Renewables share (%)	13.07	11.87	9.46	12.49

In the context of the energy diversification issue in Turkey, alternative energy sources such as biofuels became an important focus in recent years. Furthermore, as a candidate country, Turkey will have to adopt the bio-energy and bio-fuels directives of EU in case of membership. Turkey has potential for ethanol based biofuels [17]. According to the MENR, the renewable energy share in electricity generation is growing year by year as shown in Figs. 4-6 and planned to be 40 % in 2030 [17-26].

Turkey is a Party to United Nations Framework Convention on Climate Change (UNFCCC) and a

Party to Kyoto Protocol in 2009. However, as developing economy with low emission per capita, Turkey has preferred not to determine quantitative overall target to limit emissions. Although Turkey has no legal compulsory commitment, she has been working on further developing it's post 2012 approach and determining it's commitment. For example it has set a unilateral quantitative target for CO₂ emissions from energy sector as determined in it's 2009 National Climate Change Strategy report [29]. Both biofuels targets and greenhouse emission commitments will bring important implications in agriculture, industry and household sector. There has

been increasing effort in energy production from biomass, but, unfortunately official statistics are not available to evaluate its contribution to energy supply and GHG emission reduction [27-29].

Turkey's energy-related CO₂ emissions have been increasing steadily, and CO₂ emissions from fuel combustion were 339 million tons of CO₂ equivalent in 2014 as shown in Table 5. The largest CO₂ emitter in Turkey is power generation, accounting for 43%

of the total. Transport and industry account for 19.8% and 14.6%, respectively, while households and the commercial and public services sector emit 9.1% and 9.7% of the total, in that order. Other energy industries account for the remaining 3.7%. Much of the increase in total emissions is driven by the power generation sector. Compared to 1990, emissions were 294.8% higher in 2014, with the share of total emissions increasing from 26.3% [29].

Table 5. GHG by sectors in Turkey, 1990-2014 (million tons CO₂ equivalent)

Sectors	1990	1995	2000	2005	2010	2014
Energy	132.1	160.1	214.4	252.7	286.0	339.1
Industry	23.1	27.0	28.4	37.8	51.8	62.8
Agriculture	41.2	39.8	39.6	37.9	39.3	49.5
Waste	10.9	12.2	14.4	16.9	18.1	16.1
Total	207.3	239.0	296.8	345.2	395.3	467.5

Most of the CO₂ emissions from fuel combustion relate to coal use, namely 43%. Coal is used across the economy, mainly in power generation and industry, both being large emitting sectors. Emissions from natural gas represent 30.5%, mainly from power generation. Those from oil, mainly used in the transport sector, account for 26.5%. Compared to

1990, emissions from natural gas grew by 1 388.3%, increasing from a low share of 4.9% of the total. Emissions from coal doubled, while emissions from oil were up by 32.8%. In 1990, oil was the dominant fuel with 48.2% of total emissions, while emissions from coal accounted for 46.9%. In many ways, natural gas has helped to reduce emissions from coal.

6. Conclusions

Turkey has no large oil and natural gas reserves and hence Turkey is dependent on imported energy sources that constitutes big burden on the economy. Turkey has potential for further growth in energy demand as a result of social and economic development. Growing energy consumption combined with the insufficient primary energy sources negatively effects not only the foreign trade balance and greenhouse emissions but also energy security. These issues constitute dilemma for energy policy in Turkey. Turkey has to develop the usage of solar and wind energies because the potential for these energies is good. Ensuring the sufficient energy supply for economic development should be the government's main target. Turkey has potential about 25% for the efficient energy usage. In this context, government should stimulate the efficient energy using in the country and prepare additional regulations for the renewable energy strategies. Environmental concern has risen because of the high value GHG especially emitted from energy sector.

In the medium-term outlook to 2023, the year marking the 100th anniversary of the Republic of Turkey and the target deadline, the government aims to have 30% of renewable energy in its electricity mix. In 2015, the share stood at 32.3%. In 2014, the country had about 28 GW of renewable energy capacity. The Turkish government expects Turkey to expand its renewable energy capacity by 12 GW during the period 2014 to 2020 in the main case and by a maximum of 13.2 GW in the accelerated case. Thereby Turkey would achieve at least 40 GW in 2020. Assuming a lower growth in electricity demand in the coming decade, and new measures adopted by the government, Turkey can increase the share of RES. Turkey's renewable energy medium-term outlook is positive. With that in mind, the government may want to adopt a new target for the period beyond 2023 towards 2030. This would also provide for a longer term outlook for renewable energy in Turkey, beyond the medium-term.

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