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Energy Related Environmental Profile in Turkey-Green House Gas Emissions

Greenhouse Gas Emissions

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***Abstract*— Greenhouse gases (GHG) like carbon and methane in the atmosphere have increased to an unprecedented level in the past two centuries. Likewise, greenhouse gas emissions in Turkey of 207,8 mtCO2e (million tons of CO2 equivalent) in 1990 level reached 467.6 mtCO2e in 2014. In the 1990-2014 period, total emissions increased by 125%. The CO2 equivalent emission per capita in 1990 was calculated as 3.77 ton/person, which is calculated as 6,08 ton/person in 2014. The highest portion of total CO2 emissions was originated from energy sector with 86.1%. The remaining 13.7% was originated from industrial processes and product use and 0.2% with agricultural activities and waste in 2015. The highest portion of CH4 emissions was originated from agricultural activities with 59.3% while 28.8% was from waste, 11.8% was from energy and 0.1% was from industrial processes and product use. While 78.4% of N2O emission was from agricultural activities, 11.2% of that was from energy, 6.1% was from waste and 4.3% was from industrial processes and product use.**

Keywords*— Greenhouse gases, GHC, climate change, renewables, carbondioxide, energy, emission.

I. INTRODUCTION

Greenhouse gases (GHG) like carbon and methane in the atmosphere have increased to an unprecedented level in the past two centuries. The atmospheric global CO_2 concentration, which averaged 280 ppm before industrialization and never exceeded 300 ppm, exceeded 350 ppm in the 1980s and now exceeds 400 ppm. The 4th Assessment Report, published by the United Nations Intergovernmental Panel on Climate Change (IPCC) in 2007, points out that global CO_2 intensity has to be kept below 450 ppm in order to kept climate balances in an irreversible manner. However, when the report was published, the carbon concentration of 383 ppm seems to have already increased by 20 units [1].

Paris Treaty states that all developed and developing countries should take measures to reduce emissions in line with the understanding of "common but differentiated responsibilities and relative capabilities and capabilities". However, Kyoto Protocol set concrete targets for developed countries to reduce emissions while no setting reduction targets for the developing countries. Turkey will increasingly have to participate in the global tendency to reduce the carbon intensity of the economy. All sectors that provide significant sources of carbon emissions will be transformed in the coming period, renewable resources will be more important in the primary energy mix, energy efficiency will be increased rapidly, and new emission adjustments will be made in high emissions industries and transportation due to less carbon emissions.

In particular, energy efficiency will play a major role in reducing emissions, as it is worldwide and as laid down in the analysis of the International Energy Agency. It is also important to move to a system where renewable energy resources are used with a higher share and more widely, as is the case globally.

Turkish lignite constitutes a significant part of our energy resources and are used for thermal power generation, domestic heating and industrial purposes and cause serious environmental problems due to its low calorific value. While Turkey has a high potential for renewable energy sources such as solar energy, geothermal energy, wind energy and biomass, more hydraulic energy investments have been supported, but their ecological and socio-economic impacts have not been considered enough.

This study investigates Turkish total energy demand, import, consumption, production, generated electricity and mainly focuses on GHG emissions.

II. TURKEY'S ENERGY PROFILE

A. Total energy demand

In the last decade Turkey has been ranked second after China in terms of natural gas and electricity demand growth, and projections also indicate that the demand growth trend will continue. Approximately 25% of the total energy demand is provided by domestic resources and the rest by imports. It is

estimated that the total primary energy demand will reach 218 Mtoe from the current 125 Mtoe level by 2023. Turkey's total electricity demand has increased rapidly, reaching 264 TWh in 2015 (Fig.1). According to the estimates of the Ministry of Energy and Natural Resources, Turkey's final electricity demand is expected to reach 416 TWh in 2023. Primary energy demand is currently provided by natural gas with 35%, coal (28,5%), petroleum (27%), hydro-power (7%) and other renewable resources (2.5%) [2].

The net effect of Turkey's dynamic economic development, rapid population growth and monetary instability is that Turkey's energy demand increases rapidly every year, but the investment necessary to meet the increasing demand does not occur at the desired rate. Turkey's primary energy reserves are not enough to meet the energy demand. Turkey is a country that imports more than 74% of its total energy consumption from imported fuels.

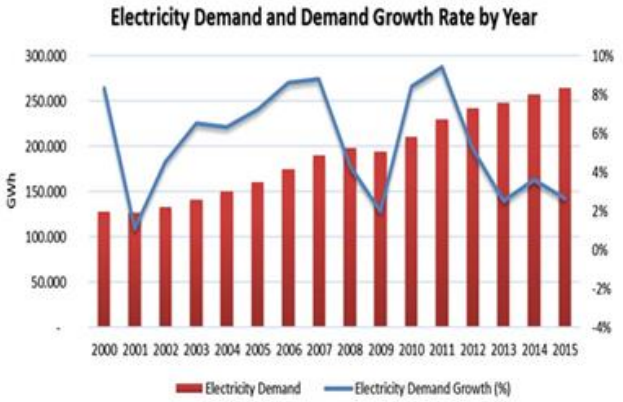

Fig. 1. *Electricity demand and demand growth rate by year*

B. Total imports

Fig.2a gives national gas imports by source. Turkey imported about 99% of the natural gas from Russia (55.3%), Iran (16.2%), Azerbaijan (12.7%), Algeria (8.1%) and Nigeria (2.6%) [2].

Similarly, as given in Fig.2b, Turkey imports 89% of its oil supply from Iraq (45.6%), Iran (22.4%), Russia (12.4%), Saudi Arabia (9.6%), Colombia (3.5%), Kazakhstan (2,6%) and Nigeria (2,1%) [2].

C. Electricity generation

In 2015, as Figure 3a reveals 37.8% of total electricity production was obtained from natural gas followed by coal (28.4%), hydro (25.8%), wind (4.4%), geothermal (1.3%) fuel oil, diesel and naphtha (1.6%) and biogas (0.6%) [3].

D. Power capacity

At the end of 2015, 35.4% of Turkey's installed power capacity is of hydro power (Figure 3b), 28.7% natural gas, 21.3% coal, 6.2% wind, 5.9% are multi-fueled, 0.8% geothermal and 1.7% is from other sources and reach almost 74.000 MW ([3].

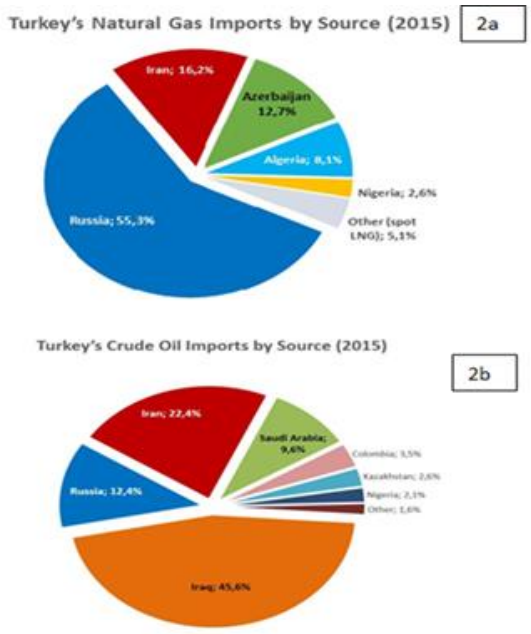

Fig. 2. *Turkey's gas imports by source (a), Turkey's crude oil imports by source (b).*

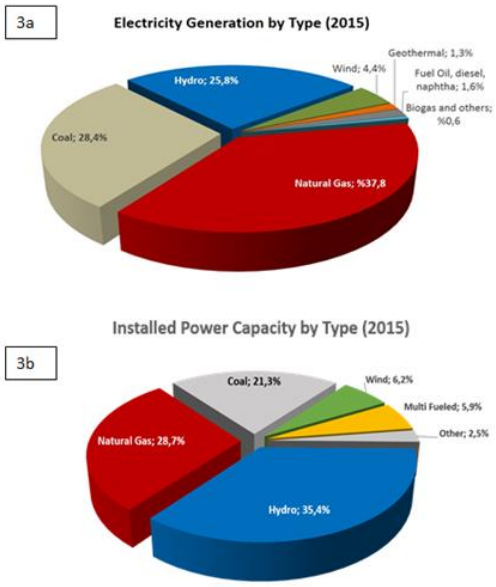

Fig. 3. *Electricity generation by type (a), installed power capacity by type (b).*

E. Total energy production

As Table 1 shows, the largest share of Turkey's energy production is coal and lignite. 20.69 Mtoe in 2005 shows that this trend is continuing to increase with the rise to 26.15 Mtoe in 2010. Estimates made by Ministry of Energy and Natural Resources indicate that this value will rise to 35.13 Mtoe in 2030. Leadership among renewable energy sources is hydropower energy with 4.16 Mtoe. While the energy obtained from hydropower in 2005 was 4.16 Mtoe, it increased to 5.34 in 2010 and is expected to be 10 Mtoe in 2030 [4].

TABLE I. TOTAL FINAL ENERGY PRODUCTION IN TURKEY (MTOE)

Energy Sources	Years			
	2005	***2010***	***2020***	***2030***
Coal and lignite	20.69	26.15	32.36	35.13
Oil	1.66	1.13	0.49	0.17
Gas	0.16	0.17	0.14	0.10
Nuclear	-	-	7.30	14.60
Hydropower	4.16	5.34	10.00	10.00
Geothermal	0.70	0.98	1.71	3.64
Solar/wind/other	0.22	1.05	2.27	4.28
Total production	27.59	34.77	54.27	71.68

F. Total energy consumption

Table 2 gives total final energy consumption in 2005, 2010, 2020 and 2030 [4] and Fig.4 represents total energy consumption between 1990 and 2014.

Import dependency is a vital issue for turkey. In 2005, the total energy production was 27.59 Mtoe, while the energy consumption was 95.25 Mtoe. According to estimates, energy consumption is expected to be 71.68 Mtoe in 2030, compared with 459.49 Mtoe energy consumption.

TABLE II. TOTAL FINAL ENERGY CONSUMPTION IN TURKEY (MTOE)

Energy Sources	Years			
	2005	***2010***	***2020***	***2030***
Coal and lignite	35.46	39.70	107.57	198.34
Oil	34.60	51.17	71.89	102.38
Gas	19.40	49.58	74.51	126.25
Nuclear	-	-	7.30	14.60
Hydropower	4.16	5.34	10.00	10.00
Geothermal	1.89	0.97	1.71	3.64
Solar/wind/other	0.22	1.05	2.27	4.28
Total production	95.28	147.81	275.25	459.49

III. GHG EMISSIONS

As can be seen from Table 3 greenhouse gas emissions in Turkey of 207,8 mtCO_2e (million tons of CO_2 equivalent) in 1990 level reached 467.6 mtCO_2e in 2014 [5]. In the 1990-2014 period, total emissions increased by 125%. This represents an increase of 28.7 Mt, or 6.5%, in emissions compared to 2013, and an increase of 125% above 1990 levels (Table 3).

The CO_2 equivalent emission per capita in 1990 was calculated as 3.77 ton/person, which is calculated as 6,08 ton/person in 2014. Total greenhouse gas emissions as CO_2 eq. increased by 122% in 2015 compared to the emissions in 1990. CO_2 equivalent emissions per capita were 6.07 tonnes in 2015, while it was 3.88 tonnes in 1990 (Fig.4).

TABLE III. GREENHOUSE GAS EMISSIONS (1990-2014) (MTOE) [5]

Energy Sources	Years							
	1990	***1995***	***2000***	***2005***	***2010***	***2012***	***2013***	***2014***
Total (Mt CO2 eq)	207.8	239	296.8	345.2	395.3	447.5	438.8	467.6
Change compared to 1990 (%)	-	15	42.9	66.2	90.2	115.4	11.2	125.0

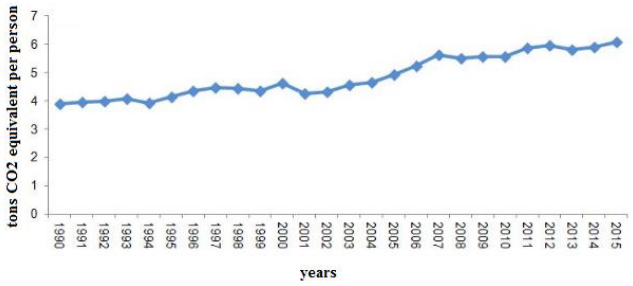

Fig. 4. *Greenhouse gases per person (1990-2015) [6]*

In overall 2014 emissions excluding LULUCF (Land Use, Land Use Change and Forestry), the energy sector had the largest portion with 72.5%. The energy sector was followed by the IPPU with 13.4%, the agricultural activities with 10.6% and the waste with 3.5%. Total GHG emissions in 2014 increased by 6.5% compared to year 2013, and 125% to 1990 (Table 4).

54.4% of CH4 emissions were from agricultural activities, 25% from waste, 20.5% from energy, 0.2% from industrial operations and product use. The largest share of N_2O emissions was agricultural activities. 75.9% of N_2O emissions were resulted from agricultural activities, 8.3% from energy, 8% from waste, and 7.8% from industrial operations and product use.

TABLE IV. OVERVIEW OF GHG EMISSIONS (1990-2014) [5]

MtCO2 eq.	Years							
	1990	***1995***	***2000***	***2005***	***2010***	***2012***	***2013***	***2014***
CO2 emissions including LULUCF	116.5	148.6	196.3	235.4	273.2	312.6	296.5	322.3
CO2 emissions excluding LULUCF	146.8	178.8	232.5	279.1	320.4	363.1	355	382.2
CH4	43.8	43.9	44.8	44.6	51.4	58	56.2	57.1
N2O	16.5	15.8	18.4	19	19.6	21.1	23.2	23.3
Total (including LULUCF)	177.5	208.9	260.6	301.5	348.1	396.9	380.4	407.7
Total (excluding LULUCF)	207.8	239	296.8	345.2	395.3	447.5	438.8	467.6

As can be seen from Table 4, Turkey's total GHG emissions, including the LULUCF sector, were 407.7 Mt CO_2 eq. in 2014. Thus, LULUCF included total emissions increased 7.2% as compared to 2013 emissions. There is a 129.6% increase from 1990 to 2014. Total GHG emissions as CO_2 eq. for the year 2014 were 467.6 Mt (excluding LULUCF).

In overall 2014 emissions, the energy sector had the largest portion with 72.5%. The energy sector was followed by the sectors of IPPU with 13.4%, the agriculture with 10.6% and the waste with 3.5%. GHG emissions by sectors are given in Table 5.

As shown in Table 5 emissions from energy increased by 9.4% to 339.1 Mt CO_2 eq. in 2014 as compared to 2013. However, there is 156% increase as compared to 1990. Emissions in the IPPU sector decreased to 62.8 Mt CO_2 eq. in 2014 which is 0.6% lower than the emissions in 2013. Emissions in the agriculture and waste sectors were 49.5 and 16.1 Mt CO_2 eq. respectively in 2014 [5].

Table V. GREENHOUSE GAS EMISSIONS BY SECTORS ($MtCO_2$ eq.1990-2014)

Year	Energy	Industrial process	Agriculture	Waste	Total (excluding LULUCF)
1990	132.5	23.1	41.2	10.9	207.8
1991	136.6	24.4	41.9	11.2	214.1
1992	142.6	24.7	42.1	11.4	220.8
1993	150.5	25.5	43.0	11.7	230.6
1994	147.0	25.5	40.3	11.9	224.7
1995	160.1	27.0	39.8	12.2	239.0
1996	175.2	28	40.8	12.6	256.7
1997	188.1	29.6	39.1	13.1	269.9
1998	187.7	29.8	40.8	13.4	271.8
1999	187.4	28.7	41.3	13.9	271.4
2000	214.4	28.4	39.6	14.4	296.8
2001	198.3	28.6	37.0	14.9	278.8
2002	206.0	30	35.7	15.4	287.1
2003	219.1	31.6	37.1	15.8	303.7
2004	229.2	34.3	37.0	16.4	316.9
2005	252.7	37.8	37.9	16.9	345.2
2006	275.2	39.8	38.9	17.4	371.3
2007	306.1	41.1	38.5	17.7	403.4
2008	295.3	43.5	36.5	17.8	393.1
2009	280.9	45.8	38.0	17.9	382.5
2010	286.0	51.8	39.3	18.1	395.3
2011	298.2	58.2	41.1	18.4	415.9
2012	321.3	62.4	45.8	18.0	447.5
2013	310.0	62.2	49.3	16.2	438.8
2014	339.1	62.8	49.5	16.1	467.6

The highest portion of total CO2 emissions originated from energy sector with 85.2%. The remaining 14.6% originated from IPPU and 0.2% from agriculture in 2014. CO_2 emissions from energy increased 9.4% compared to 2013 while increased 161.2% as compared to 1990. CO_2 emissions from industrial processes decreased 1% compared to 2013 and increased 158% as compared to 1990. The largest portion of CH_4 emissions originated from agriculture activities with 54.3% while 25% from waste, and 20.7% from energy and industrial processes. CH_4 emissions from agriculture increased 0.9% compared to 2013. It increased 12.6% as compared to 1990. CH_4 emissions from waste decreased 1.1% compared to 2013. However, it increased 48.6% as compared to 1990 depending on increase in the amount of managed waste. While 75.9% of N_2O emission was from agricultural activities, 8.3% was from energy, 8% was from waste and 7.8% was from IPPU. There is a 0.3% increase and 41% increase in total N_2O emissions as compared to 2013 and 1990 respectively.

IV. DISCUSSION AND CONCLUSION

Turkey's demand for energy and electricity is increasing rapidly. Since 1990, energy consumption has increased at an annual average rate of 4.3%. As would be expected, the rapid expansion of energy production and consumption has brought with it a wide range of environmental issues at the local, regional, and global levels. With respect to global environmental issues, Turkey's carbon dioxide (CO_2) emissions have grown along with its energy consumption.

Paris Treaty states that all developed and developing countries should take measures to reduce emissions in line with the understanding of "common but differentiated responsibilities and relative capabilities and capabilities". However, Kyoto Protocol set concrete targets for developed countries to reduce emissions while no setting reduction targets for the developing countries. Turkey will increasingly have to participate in the global tendency to reduce the carbon intensity of the economy. All sectors that provide significant sources of carbon emissions will be

transformed in the coming period, renewable resources will be more important in the primary energy mix, energy efficiency will be increased rapidly, and new emission adjustments will be made in high emissions industries and transportation due to less carbon emissions.

In particular, energy efficiency will play a major role in reducing emissions, as it is worldwide and as laid down in the analysis of the International Energy Agency. It is also important to move to a system where renewable energy resources are used with a higher share and more widely, as is the case globally. In the Turkish electricity sector, approximately two-thirds of the capacity increase over the last three years has been provided by renewable energy sources and this increase is expected to continue.

The highest portion of total CO_2 emissions was originated from energy sector with 86.1%. The remaining 13.7% was originated from industrial processes and product use and 0.2% with agricultural activities and waste in 2015.

The highest portion of CH_4 emissions was originated from agricultural activities with 59.3% while 28.8% was from waste, 11.8% was from energy and 0.1% was from industrial processes and product use.

While 78.4% of N_2O emission was from agricultural activities, 11.2% of that was from energy, 6.1% was from waste and 4.3% was from industrial processes and product use.

In order to reduce total GHG emissions the government of Turkey needs to:

- Focus on the energy efficiency, by strengthening energy efficiency measures in the industrial sector and by encouraging energy efficiency in buildings,
- Step up efforts to increase efficiency in coal mining,
- Encourage the rehabilitation of the thermal power plants to increase their efficiency,
- Diversify energy supplies and avoiding dependence on a single source or country,
- Increase share of renewable sources in energy supply system
- Ensure energy security of supply, Minimize losses in energy production, transmission, distribution, and consumption,
- Water and energy waste is unfortunately widespread in Turkey. Energy saving will prevent the establishment of power plants that cause greenhouse gases
- The accumulation of population in certain regions in Turkey increases vulnerability to natural disasters. With proper policies, more regular distribution of the population from the city scale to the country scale should be encouraged.
- The city heat island effect will deteriorate the city's living conditions when it occurs together with global warming. For this reason urbanization should be planned to minimize the effect of city heat island.
- The infrastructure of cities should be developed to allow re- use of water.
- Turkey uses most of the available water in agricultural irrigation. Water-saving irrigation techniques should be supported and encouraged to reduce the amount spent for agricultural irrigation. Turkey should increase the use of water-saving irrigation techniques.

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