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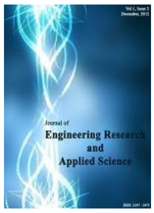

Air polluted emissions from coal-fired power plants and their human health effects in Turkey

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Abstract

Air pollution is an important risk factor for health in Turkey and the quality of the air we breathe is even more important for a mega city like Istanbul, having the busiest traffic flow and highest population in Turkey. It is still difficult to gather adequate and verified data on air pollution in Turkey. From the evidence available, Turkey emerges as a country with one of the highest rates of premature deaths due to air pollution. In 2021, 78,924 people in Turkey died prematurely from ambient PM and Covid-19 pandemic. This study shows that for the past 40 years, coal has been reshaping the provinces of Muğla, Çanakkale, Afşin-Elbistan, Zonguldak, Bolu, Ankara, Kocaeli, Bursa, Sıvas, Kütahya, Manisa and Adana in several regions of Turkey. This geographical transformation has brought with it heavy ecological, social and economic burdens. Air pollution in major cities, including from coal-fired power plants, is a serious concern. Thermal power plants in Turkey are subject to the Industrial Air Pollution Control Regulation, which sets limit values for air pollutants such as SO2, CO, NOX and particulate matter. The government's decision to not grant extra time to existing privatised and public thermal power plants that were exempted from securing environmental permits until the end of 2020 was a step in the right direction.

Keywords: Air pollution; human health; coal utilization; electric generation; Turkey.

1. Introduction

Access to energy for cooking, heating, transport, and productive activities is essential to human health [1]. Access to electricity is also critical to improving health service delivery, strengthening health systems, and achieving universal health coverage. As the World Health Organization (WHO) observes, "energy access in health facilities is a critical enabler of access to many medical technologies, and thus to health services access. Yet 1.3 billion people around the world lack access to electricity and the potential it offers for improving the social and environmental conditions that support better health [2]. At the same time, the generation, distribution, and consumption of energy can have marked adverse impacts on health [3]. In particular, the exploitation of fossil fuels for energy generation has serious implications for human health through its contribution to both local pollution and global climate change. These health impacts accrue into a heavy and largely unaccounted-for economic burden borne by communities, governments, and health systems [4].

On November 2021, political leaders from across the world will come together in Glasgow at the so-called COP26 meeting, to discuss and agree the urgent measures necessary to avoid severely damaging global warming. Obviously, significant and immediate reductions to polluted emissions will be highest on the agenda [5]. So, two specific targets are apparent: (1) to reduce emissions by 50% of their 1990 value by 2030; and (2) to reduce them further to net-zero by mid-century. Here, we look at the challenges they will face, the risks of failure and the opportunities presented by the transition to a sustainable future [6-10].

Humans have been emitting greenhouse gases, and in particular carbon dioxide (CO_2), at an industrial scale and at increasing rates since the Industrial Revolution in the mid-19th century [11]. Atmospheric CO_2 is particularly troubling, not because it is the most potent greenhouse gas but because it can remain in high concentrations for long periods. So, as we incrementally add more CO_2 into the atmosphere, its gross value increases gradually and inevitably. Its atmospheric concentration today is around 415 parts per million (ppm) [12]. That might not sound like a lot, but it was only about 280 ppm in 1950, and since

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the 1960s we have added 100 ppm worth of CO_2. As a consequence, the world has warmed by over 1^{o}C since 1850 [13]. The last time the world experienced over 400 ppm of CO_2 was more than 3.5 million years ago, when the climate was far warmer than now [14-16].

Air pollution causes a range of negative health impacts such as chronic respiratory diseases, hospitalizations, preterm births and other health effects [1]. These lead to increased health care costs; economic productivity loss due to sickness and inability to work. In this study we investigate the environmental and health impacts of coal utilization, the macroeconomic and environmental effects of Turkey's existing coal subsidies using an applied general equilibrium model of the computable general equilibrium variety. Also we calculate greenhouse gas emissions due to coal-fired power plants and their socio-economic effects. The result shows that high risks for coal-fired power plants on human-health and economical condition of Turkey.

2. Air pollution

Air pollution is the contamination of air and burning fossil fuels releases gases and chemicals into the air. Air pollution does not only contribute to climate change but is also exacerbated by it. By trapping the earth's heat in the atmosphere, greenhouse gases lead to warmer temperatures and all the hallmarks of climate change [1-8]. There are various substances that pollute the air. The most important are nitrogen dioxide (NO_2), particulate matter (PM_{10} and $PM_{2,5}$), carbon dioxide (CO_2), sulfur dioxide (SO_2) and ozone (O_3). On the other hand, CO_2, a greenhouse gas, is the main pollutant that is warming earth. NO_2 and SO_2 can contribute to the formation of particulate matter and ozone [1-8].

The air quality is determined by the amount of harmful substances present in the air. Our air naturally contains particulate matter and nitrogen dioxide. Road and maritime traffic, emissions from factories and industries, urban renewal, agriculture, mining operations and indoor air pollution increase these concentrations and wear them to the air pollution. In order to come up with solutions to air pollution and thereby increase the air quality, we need to understand the factors that cause the contamination of the air and risk our health [6-10].

Most of the air pollution comes from the burning of fossil fuels, such as coal, oil, natural gas and gasoline are used for domestic heating and transportation. It is obvious that coal is responsible for all four types of air pollutants. An analysis of the Turkish Ministry of Environment and Urbanism shows that 46% of the NOx emissions in Turkey is the result of energy use and production [15]. The second important source of NOx is road transport, whose contribution is 35.2%. Furthermore, it seems that 62% of SO_2 emissions comes from energy production and 23.2% from use of energy. This means that 85.6% of SO_2 emissions in Turkey can be attributed to the use and production of energy [15-18].

Manufacturing industries release large amount of carbon monoxide, hydrocarbons, organic compounds, and chemicals into the air and thereby deplete the air quality. Petroleum refineries also release hydrocarbons and various other chemicals that pollute the air and also cause land pollution. On the other hand, due to the implementation of many big infrastructure and construction projects in Istanbul, the urban renewal seems to contribute to the air pollution in the city as well [9-12]. Ammonia is a very common by product from agriculture related activities and is one of the most hazardous gases in the atmosphere. Use of insecticides, pesticides and fertilizers in agricultural activities has grown quite a lot, which cause the emission of harmful chemicals into the air. Mining is a process wherein minerals below the earth are extracted using large equipment. Household cleaning products and painting supplies emit toxic chemicals in the air [12-23].

Air pollution refers to the release of pollutants into the air that are detrimental to human health and the planet as a whole. Environment Protection Agency (EPA) determined six criteria air pollutants. These pollutants are particulate matter (PM), lead (Pb), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3). Table 1 provides the main sources of each type of air pollutant. In general, the main sources of air pollution can be classified as: vehicle and industry emissions, mining operations, agriculture and households. Most of the air pollution in Turkey comes from energy use and production, which is used for domestic heating and transportation, amongst other things [16-23].

Table 1. Pollutants and their sources

Pollutant	Main sources
SO_2	Fossil fuel burns and vehicle emissions
NO_x	High temperature combustion processes and vehicle emissions
PM	Industry, vehicle emissions, fossil fuel burns and agriculture
CO	Incomplete combustion and vehicle emissions

The most basic solution for air pollution is to end its root causes: quit coal and move away from fossil fuels, replacing them with clean, renewable energy. In the short-term, there are many intermediate solutions for air pollution. Table 2 shows the air pollution limits for selected pollutants in μg/m^3. The use of renewable energy sources, introducing cleaner fuel standards and switching to electric vehicles are only a few of the measures that can be implemented. However, all of these solutions require governments to recognize the impact of air pollution on public health and the economy, and take action accordingly [16-23].

Table 2. Air pollution limits for selected pollutants (in μg/m^3)

Pollutant	Period	WHO Air Quality Guidelines	Turkey's Regulation (2019-2023)
PM_{10}	24-hour mean	50	50
	Annual mean	20	40
$PM_{2.5}$	1-hour	25	-
	Annual mean	10	-
SO_2	1-hour	-	350
	24-hour mean	-	125
NO_2	1-hour	200	200
	Annual mean	40	40

Source: Ref. [1, 17, 18].

3. Coal-fired power plants in Turkey

Turkey has large coal resources and the Turkish coal sector produced 1.6 million tons (Mt) of hard coal and 44 Mt of lignite for power generation in 2020. Coal imports have doubled since 2005 and stood at 32 million tons in 2020, again used mostly for power generation. In total, Turkish coal-fired power plants had an installed capacity of approximately 19 613 MW at the end of 2020 (20.45% of total). Hard coal-fired power plant installed capacity was 6 500 MW (8.8%) and the installed capacity using domestic lignite was 8 700 MW (11.8%). Table 3 gives the installed power capacity in Turkey (MW). As shown in Table 3, the coal installed capacity increased from 11 950 MW in 2010 to 19 613 MW in 2020. It means that the greenhouse gas emission increasing during 2010-2020 [20-23].

Table 3. Turkey's installed power capacity (MW).

Energy Sources	Installed capacity in 2010 (MW)	Percent of Total (%)	Installed capacity in 2020 (MW)	Percent of Total (%)
Coal	11 950	24.13	19 613	20.45
Liquid Fuels	1 593	3.22	190	0.20
Natural Gas	13 302	26.86	21 600	22.53
Renew wastes	107	0.22	1 503	1.57
Multi-fuels	5 326	10.75	4 890	5.1
Hydropower	15 831	31.97	30 984	32.31
Geothermal	94.2	0.19	1 613	1.68
Wind power	1 320	2.67	8 833	9.22
Solar energy	-	-	6 668	6.95
Total	49 524	100,00	95 891	100,00

Lignite is Turkey's most important indigenous energy resource, with proven reserves of 16 billion tons [9]. Deposits are spread across the country, the most important one being the Afşin-Elbistan lignite basin of south-eastern Anatolia, near the city of Maraş where the economic reserves are estimated at around 7 billion tons [9]. The Soma basin is the second-largest lignite mining area in Turkey. Other exploited deposits are located in: Muğla province with the Yeniköy lignite facility at Ören (Milas) and the South Aegean lignite facility at Yatağan; Kütahya province with the Seyitömer lignite facility at Seyitömer and the Tunçbilek mining centre at Tavşanlı; Çanakkale province with the Çan lignite facility; Bursa province with the Bursa lignite facility at Orhaneli; and Konya province with the Ilgın lignite facility. The quality of Turkish lignite is generally very poor and only around 5.1% of existing reserves have a heat content of more than 3 000 kcal/kg [8, 9].

Yatağan, Kemerköy and Yeniköy coal power plants are operating with their 685 MW, 685 MW and 457 MW installed capacities respectively in Muğla city of Turkey. It is estimated that these three coal power plants caused 45,000 premature deaths due to air pollution since 1983, with the planned rehabilitation an additional 5,270 premature deaths would be caused in the next 10 years [8-12]. On the other hand, the Afşin-Elbistan lignite mine in Manisa is currently the biggest operating lignite mine in Turkey. It is estimated to have at least 46% of the lignite reserve in Turkey and Afşin Elbistan-A and Afşin Elbistan-B coal power plants that have 1.5 and 1.6 GW electricity capacity respectively. Soma B Coal Power and Soma Lignite Mine Soma B Coal Power Plant with a capacity of 990 MW is the 3rd biggest lignite power plant in Turkey [8-12].

The Çan-1 Lignite Power Plant, with 330 MW installed capacity, is situated in Çan town of Çanakkale city. Çan-1 coal power plant is not one of the biggest one in terms of capacity but air pollution levels, especially SO_2 emission values in the town hosting the plant is alarming mostly due to high dust and sulfur content of the lignite mined in the same area. On the other hand, Eskisehir Alpu lignite basin is defined as the 3rd largest lignite reserve in Turkey that can be used in electricity production. In Eskişehir, Yunus Emre Coal Power Plant with 315 MW installed capacity on lignite has completed construction and is in the test phase while another plant, Alpu Coal Power Plant is in the planning process [8-12].

4. Methodology for emission calculations

From the elemental analysis of the coal, the percentage of carbon, hydrogen, nitrogen, oxygen, ash, and moisture in the coal is known. Let C be the mass of the carbon, S of the sulfur, H of the hydrogen, O_2 of the oxygen, and N_2 of the nitrogen, then Oxygen required (O_{req}) to burn one kilogram (kg) of coal can be calculated as [8, 10, 12]:

$$O_{req} = C * (32/12) + H \text{ x } (16/2) + S * (32/32) – O_2 \quad (1)$$

Air mass required for O_{req} kg of oxygen
$= (O_{req}$ / mass fraction of O_2 in the air)
$= O_{req} / 0.233$ (2)

If E is the percentage of excess air used in the furnace to burn the coal, the air mass used =

$$\text{Air (used)} = (1 + E) * O_{req} / 0.233 \quad (3)$$

Knowing the air mass used to burn one kg of coal, mass of O_2 and N_2 are calculated as:
O_2 in the air used $= (1+ E) * O_{req}$ (4)

N_2 in the air used $= 0.767 * (1+ E) * O_{req} / 0.233$ (5)

Mass of CO_2, SO_2, NO, and H_2O are calculated by mass balance as
$CO_2 = C * (44/12)$ (6)
$SO_2 = S * (64/32)$ (7)

$H_2O = H * (18/2)$ (8)

Oxides of nitrogen (NOx) are nitrous oxide (N_2O), nitric oxide (NO), and nitrogen dioxide (NO_2). The formation of NOx during coal combustion is a complex process involving both homogeneous and heterogeneous reactions. Most (about 90% or higher) of the NOx emitted during combustion process is in the form of NO. Generally accepted principal reactions for ‘thermal NO’ formation are [8, 11]:

$O + N_2 = NO + N$ (9)
$N + O_2 = NO + O$ (10)
$N + OH = NO + H$ (11)

In this study we also used the following equation for calculating the emissions rate [8]:

$$ER = CAP / EFF * SFGV * FGC \quad (12)$$

Where; CAP is the electric output capacity of the power generating unit, EFF is thermal efficiency, SFGV is the specific flue gas volume of the fuel per energy unit (in Nm^3/GJ) and FGC is the pollutant concentration in flue gas [12].

For older plants equipped with SO_2 controls that are not sufficient to meet the emission standards, FGC was calculated as:

$$FGC = FGCO * (1 - CE) \quad (13)$$

FGCO is the pollutant concentration in untreated flue gas and CE is the pollutant control efficiency, or the percentage of the pollutant captured by the plant's emission control techniques. In most cases, a design efficiency of 95% was used. At plants lacking emission controls, CE is zero [8].

For most plants burning domestic lignite, fuel calorific value (NCV) as well as dust (A), moisture (M) and sulfur (S) content were available from various sources compiled by HEAL. This information was used to calculate SFGV using the following equation as [9]:

$$SFGV = [-0.06018 * (1 - A - M) + 0.25437 * (NCV + 2.4425 M)] / (NCV) \quad (14)$$

FGCO for SO_2 was calculated based on reported fuel sulfur content assuming full conversion of S into SO_2 [8]:

$$FGCO = S * 2 * NCV / SFGV \quad (15)$$

In the Eq.(4), the number of 2 is the ratio of the molar masses of SO_2 and S.

5. Results and discussions

Turkey's industrial and development targets would increase emissions to 355% above 1990 levels, or approximately 999 $MtCO_2e$, by 2030. To keep below the 1.5˚C temperature limit, Turkey's 2030 emissions would need to be around 280 $MtCO_2e$, leaving an ambition gap of 719 $MtCO_2e$. All figures exclude land use emissions. In addition to this bad situation, 32 GW of new coal power capacity is planned by the Turkish government, offsetting the closure of five coal power plants at the beginning of 2020 that failed to meet environmental protocols.

Turkey could achieve a 14% overall reduction in GHG emissions below 2017 levels by 2030 with ambitious, but realistic measures in the electricity, buildings, and transport sectors alone. With emissions consistently below those in its 2030 target, Turkey should ratify the Paris Agreement and submit a more ambitious target. Turkey's intention to secure its energy independence could be achieved through renewable energy rather than its planned increase of domestic coal production. Over 44,200 people die in Turkey every year as a result of outdoor air pollution due to stroke, heart disease, lung cancer and chronic respiratory diseases.

Turkey aims to increase the share of power generation from domestic coal and to increase domestic production by 220% from 2020 to 2030, along with increasing installed capacity using domestic coal by 12 GW over the same period. In the green economy initiative promoting Turkey's transition to a greener economy, and the admission in its Industry Strategy Plan that 'green jobs' are likely to become an engine of growth. Turkey's GHG emissions have increased by 133% (1990-2018) and the government's proposed climate targets for 2030 (21% below its BAU scenario) is not in line with a 1.5°C pathway. Projections under current policies show 2030 emissions will be below the government's modest target. In 2030, global CO_2 emissions need to be 45% below 2010 levels and reach net zero by 2050. Global energy-related CO_2 emissions must be cut by 40% below 2010 levels by 2030 and reach net zero by 2060.

Turkey's energy mix is dominated by fossil fuels and country's coal consumption has slightly decreased, it is higher than the developed countries average. Total fossil fuel demand has fallen since 2017, led by a fall in natural gas consumption. Overall energy demand has remained constant due to increased renewables. On the other hand, Turkey produced 35% of its electricity from coal in 2020. Concern over reliance on foreign energy imports has led Turkey to increase renewable energy generation and consume domestically produced coal rather than imported natural gas. If Turkey continues this approach, coal's replacement of natural gas will largely cancel out emission reductions from increased renewables.

The air pollutant emissions calculation values from large coal power plant in both Çanakkale and Muğla are given in Table 4 and 5. As shown in Table 4, PM, SO_2 and NO_x emissions from hard-coal fired power plants are greater than the lignite-fired power plants. Also, Table 4 shows that the emitted emissions from five power plants (Bekirli, Cenal, Biga, Çan-1 and Çan-2) are high according to the WHO Air Quality Standards and their environmental effects very seriously. On the other hand, Table 5 shows that the emitted emissions from Yatağan, Kemerköy and Yeniköy lignite-fired power plant are greater than the Biga, Çan-1 and Çan-2 lignite-fired power plants.

Table 4. The estimated air pollutant emissions from large coal power plants in Çanakkale

Name Power Plant	PM Emissions (tons/yr)	SO_2 Emissions (tons/yr)	NOx Emissions (tons/yr)	Capacity (MWe)	Coal type	Filters Installed
Bekirli	1 300	10 400	5 198	1 200	Hard Coal	PM SO_x NO_x
Cenal	792	5 254	5 256	1 320	Hard Coal	PM SO_x NOx
Biga	520	4 094	5 114	405	Hard Coal	PM SO_x NO_x
Çan-1	74	5 920	1 270	320	Lignite	PM SO_x NO_x
Çan-2	162	1 052	1 045	330	Lignite	PM SO_x NO_x

Table 5. The estimated air pollutant emissions from large coal power plants in Muğla

Name Power Plant	PM Emissions (tons/yr)	SO2 Emissions (tons/yr)	NOx Emissions (tons/yr)	Capacity (MWe)	Coal type	Filters Installed
Yatağan	1 178	10 148	18 410	634	Lignite	PM Sox NO
Kemerköy	340	10 024	7 912	634	Lignite	PM Sox NO
Yeniköy	280	8 490	6 218	426	Lignite	PM Sox NO

The dust emissions estimates were converted to PM_{10} using a PM_{10}:TSP ratio of 54/80 and to $PM_{2.5}$ emissions using a $PM_{2.5}$:PM_{10} ratio of 24/54, based on the U.S. EPA AP-42 default emissions factors for electrostatic precipitators at coal-fired utility boilers. Annual emissions are then calculated based on the emissions rate and annual electricity generation of the plant. There are significant uncertainties in the emissions estimates, particularly related to control efficiencies. For some older plants, there is at least anecdotal evidence that design control efficiencies are not being achieved due to poor maintenance.

Table 6 shows the estimated health impacts of air pollutant emissions from coal-fired power plants for Turkey in 2020. As shown in Table 6, we understand that the estimated results shows that the impacts of the air pollutant emissions from coal-fired power plants are high and have seriously human health effects during the Covid-19 pandemic. Table 6 also shows that an important health impacts of air pollutant emissions from coal-fired power plants are work day lost and sickness days.

Table 6. Estimated health impacts of air pollutant emissions from coal-fired power plants for Turkey in 2020.

Effect	Pollutant	Impacts
Deaths	All	4 968
Adult deaths	$PM_{2.5}$	4 470
Deaths of children up to 1 year	$PM_{2.5}$	36
Adult deaths	NO2	178
Adult deaths	Mercury	362
Preterm birth	$PM_{2.5}$	3 380
Bronchitis in children	PM_{10}	27 600
Respiratory and cardiovascular hospital admissions	$PM_{2.5}$, NO_2 And ozone	5 896
Asthmatic and bronchitis symptoms in asthmatic children	PM_{10} and NO_2	245 136
Work days lost (age 20-65 years)	$PM_{2.5}$	1 780 000
Sickness days (for the population up to 20 years, and over 65)	$PM_{2.5}$	11 800 000

Estimated economic cost of health impacts associated with air pollutant emissions from coal-fired power plants in Turkey are given in Table 7 as a million US$. As given in Table 6, the calculated values show that total economic cost of health impacts associated with air pollutant emissions from coal-fired power plants in Turkey for 2020 is 3 316 (low) and 6176 (high) US$. These calculated values gives an important results such as "Coal Dirty and No-Healthy". Table 8 also shows the risk ratios used for the health impact assessment for a 10 μg/m^3 change in annual average pollutant concentration.

Table 7. Estimated economic cost of health impacts associated with air pollutant emissions from coal-fired power plants in Turkey in 2020 (million US$).

Effect	Pollutant	Low	High
Deaths	All	3 124	6 462
Adult deaths	$PM_{2.5}$	2 786	5 168
Deaths of children up to 1 year	$PM_{2.5}$	34	104
Adult deaths	NO_2	240	546
Preterm birth	$PM_{2.5}$	40	80
Bronchitis in children	PM_{10}	2	8
Work days lost (age 20-65 years)		14	20
Sickness days (age 20 years, and over 65)		200	250
Total cost in million US$		3 316	6 176
Total cost in million TRY		27 834	51 654

Table 8. Risk ratios (RRs) used for the health impact assessment, for a 10μg/m^3 change in annual average pollutant concentration (95% confidence interval)

Effect	**Pollutant**	**Risk ratios (Low)**	**Risk ratios (Middle)**	**Risk ratios (High)**
Bronchitis in children, PM_{10}	PM_{10}	0.96	1.06	1.20
Asthma symptoms in asthmatic children, PM_{10}	PM_{10}	1.04	1.03	1.08
Incidence of chronic bronchitis in adults, PM_{10}	PM_{10}	1.02	1.12	1.20
Long-term mortality, all causes	$PM_{2.5}$	1.02	1.08	1.12
Cardiovascular hospital admissions	$PM_{2.5}$	1.00	1.02	1.04
Respiratory hospital admissions	$PM_{2.5}$	0.96	1.21	1.06
Restricted activity days	$PM_{2.5}$	1.02	1.06	1.08
Work days lost (age 20-65)	$PM_{2.5}$	1.01	1.05	1.08
Bronchitic symptoms in asthmatic children	NO_2	1.00	1.03	1.09
Respiratory hospital admissions	NO_2	1.01	1.02	1.04
Long term mortality, all causes	NO_2	1.02	1.06	1.10
Preterm birth	$PM_{2.5}$	1.12	1.20	1.18

Figure 1 shows a comparison of emissions from residential or commercial combustion of different heating fuels. As shown in Figure 1, coal has highest emissions values for NOx, SO_x, $PM_{2.5}$ and CO_2. The second most harmful fuel is No.1 oil after the coal. It means that coal dirty and no-healthy. Coal has same emissions values for four greenhouse gas emisions.

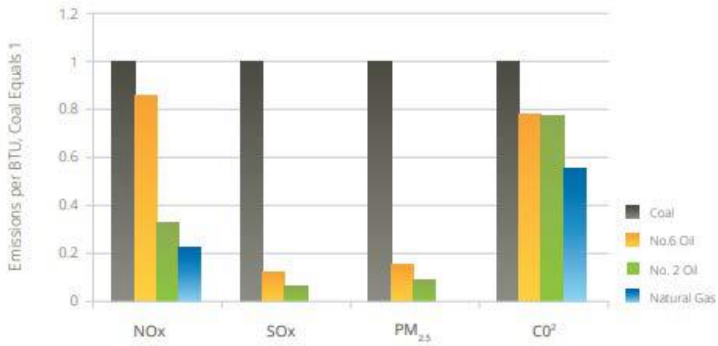

Figure 1.Emissions from residential combustion of different heating fuels [9].

Figure 2 shows the map of coal-fired thermal power plants and supporting coal deposits in Turkey. Figure 3 also shows estimated regional greenhouse gas emissions per capita as a ton carbon dioxide equivalent (tCO_2e) in 2018. Greenhouse gas (GHG) emissions per capita generated in most Turkish large regions are below 10 tCO_2e per capita. Only Southern Marmara – West, Western Black Sea – West and Mediterranean region - East have higher emissions per capita than the OECD average of 11.5 tCO_2e per capita. Estimated emissions per capita in Southern Marmara – West are almost five times higher than in Istanbul.

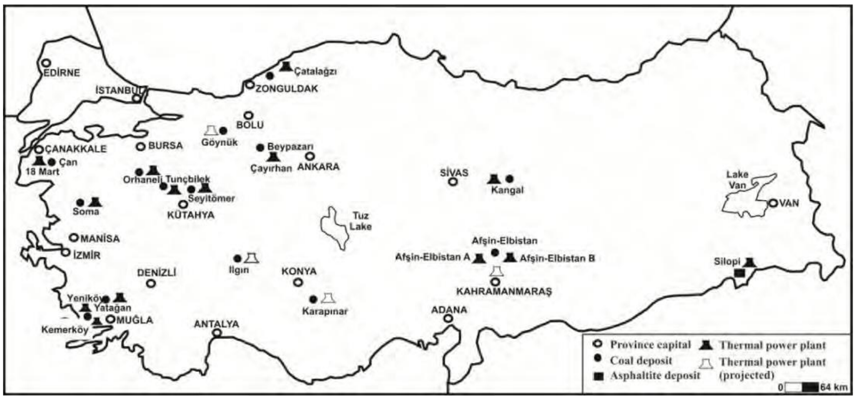

Figure 2 – Coal-fired thermal power plants and supporting coal deposits in Turkey

Figure 3. Estimated regional greenhouse gas emissions per capita (tCO2e) in 2018.

Figure 4 shows Turkey's estimated emissions amount of million tons CO_2 equivalent in 2018. As shown in Figure 4, the biggest city of İstanbul in Turkey emits 60 million tons of CO_2-eq emissions. Because the amount of CO_2 emissions depend on the fuel used for heating, industry and transportation. Figure 5 also shows Turkey's total CO_2 emissions ($MtCO_2$-eq) and per capita CO_2 emissions (tCO_2-eq/per capita). The amounts of CO_2-eq emissions are growing year by year. On the other hand, Turkey's total CO_2 emissions by industrial sectors are shown in Figure 6 during the years.

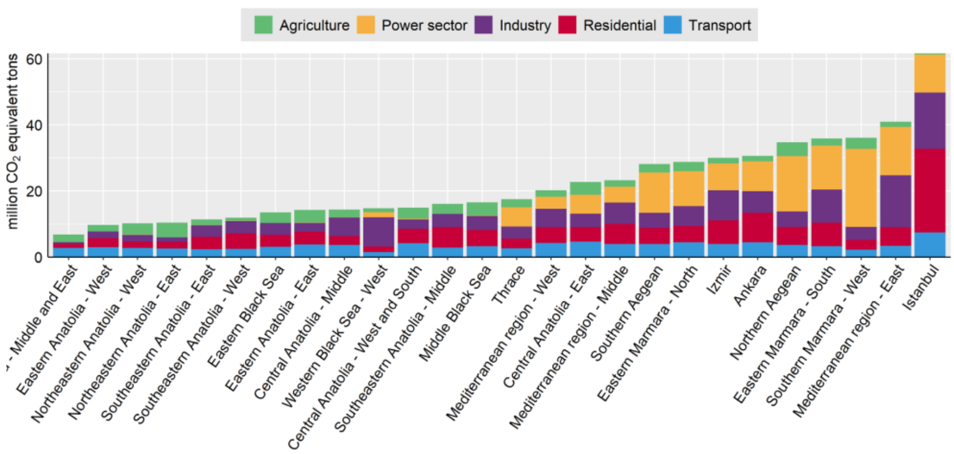

Figure 4. Turkey's estimated emissions million tons CO_2 equivalent in 2018.

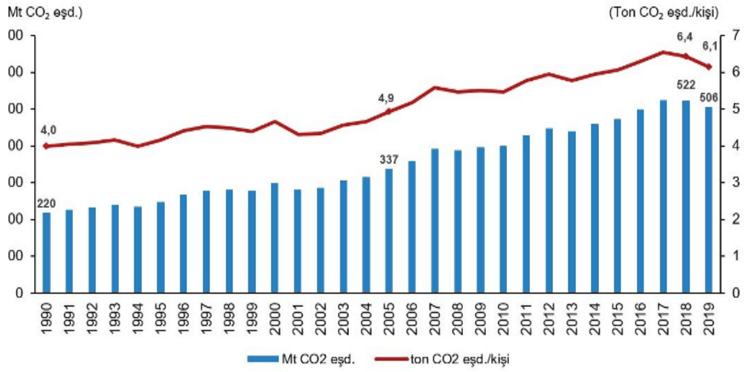

Figure 5. Turkey's total CO_2 emissions (Mt CO_2-e) and per capita emissions (tCO_2-e/per capita).

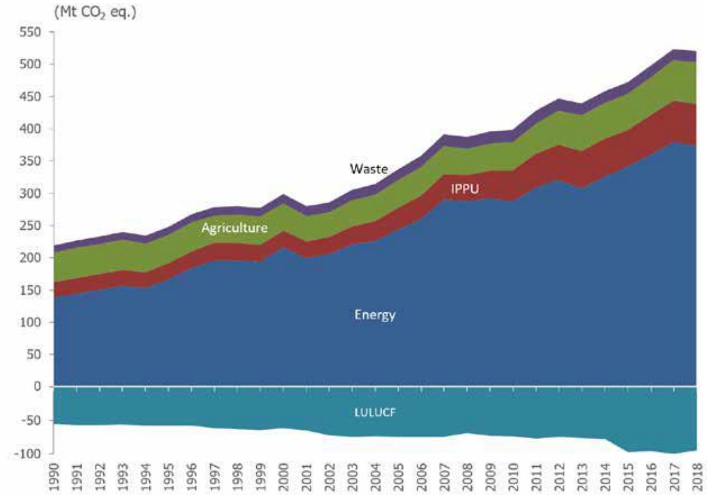

Figure 6. Turkey's total CO_2 emissions (Mt CO_2 eq) by sector between 1990-2018.

6. Conclusions

Under the Paris Agreement, governments have committed to limiting temperature increase to well below 2°C above pre-industrial levels and pursuing efforts to limit it to 1.5°C. Emissions from coal-fired thermal power plants are influenced by many factors and depend on the chemical composition of coal and the coal usage per unit of electricity. It means that, CO_2 and SO_2 emissions are influenced by the chemical composition while NO emissions are influenced by the excess air used during combustion and the coal usage. The Ministry of Environment and Urbanization in Turkey has different measures to monitor and prevent air pollution in Turkey. The government is regularly performing environmental audits in facilities and motor vehicles. Fines are imposed on businesses that violate the environment law and cause air pollution. Furthermore, regular inspections are carried out to prevent air pollution caused by heating. The government gives attention to periodic cleaning of boilers, prevention of heat losses by isolating the heating installations and maintenance and cleaning of the entire heating system. Air pollution in major cities, including from coal-fired power plants, is a serious concern. Thermal power plants in Turkey are subject to the Industrial Air Pollution Control Regulation, which sets limit values for air pollutants such as SO_2, CO, NO_X and particulate matter. The government's decision to not grant extra time to existing privatized and public thermal power plants that were exempted from securing environmental permits until the end of 2020 was a step in the right direction.

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