SHURA
Energy Transition Center

Methodology and detailed results:
The external cost of fossil fuel use in power generation, heating and road transport in Turkey

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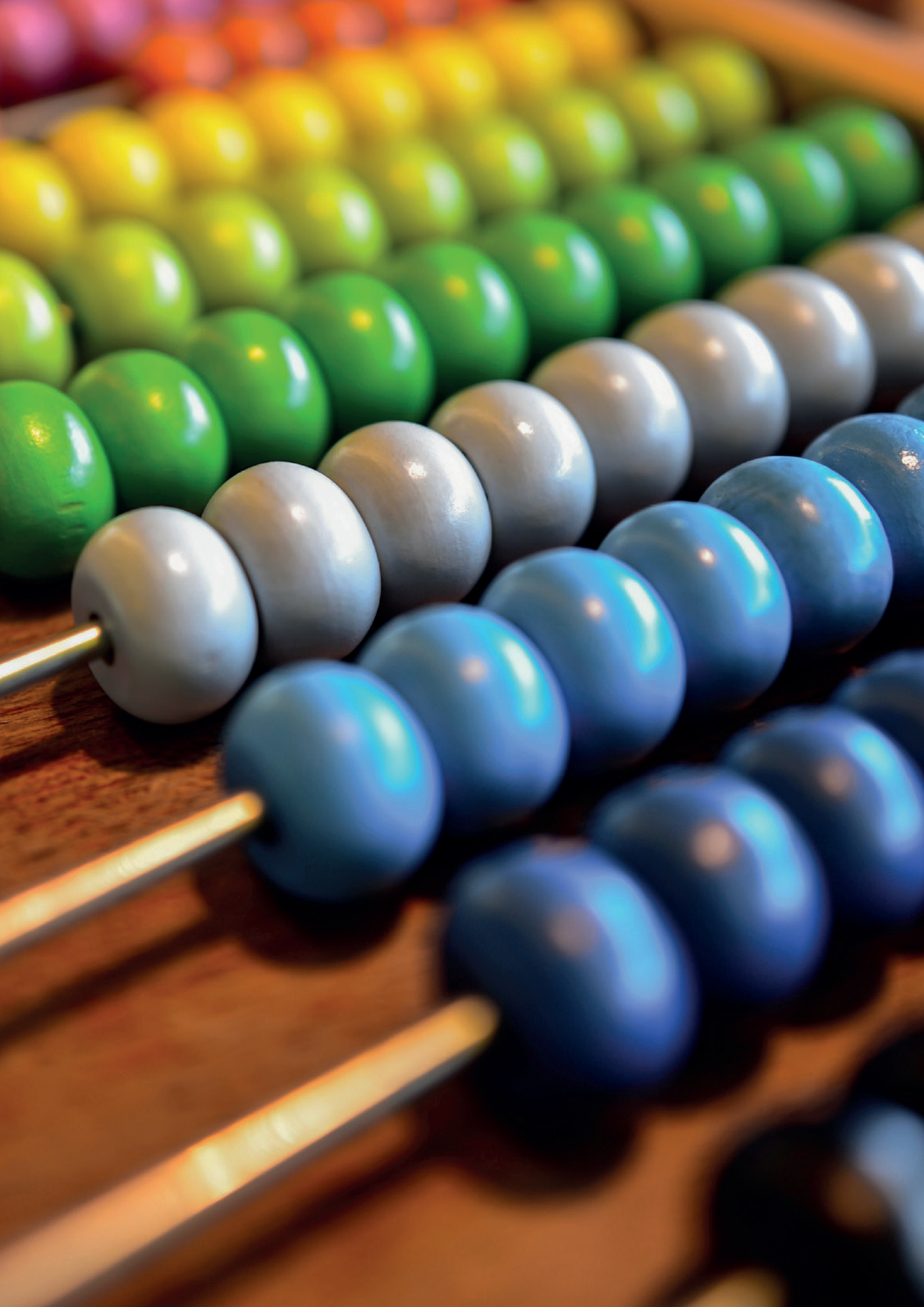


1. Introduction

In the first section of the report, the methodology and data sources used to estimate the emissions and externalities of major air pollutants and GHG mainly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) generated due to fossil fuel use and industry related processes in power, buildings, road transport, petroleum refining and major industrial sectors including cement, iron and steel, textile and leather and ceramic industries are presented. The second section presents findings that are more detailed than shown in the main report.

+8.76
65.32
-12.14
55.01
11.08

2. Methodology and Data Sources

The methodology and the data sources used to estimate the emissions and externalities of the air pollutants and GHGs are presented in this section of the report. The major sectors included in the analyses are chosen based on their fossil fuel consumption intensity shown in Table 1. As can be seen in this table, the sector with the highest fossil fuel energy consumption is the electricity generation (power) sector, followed by road transport, petroleum refining, industry, and building sectors. The industries included in the analyses in this report are cement, iron and steel production, textile and leather production, ceramic production, and food industries.

Table 1: *Sectoral fossil fuel consumption in 2018 reported in General Energy Balance Table, ktoe*

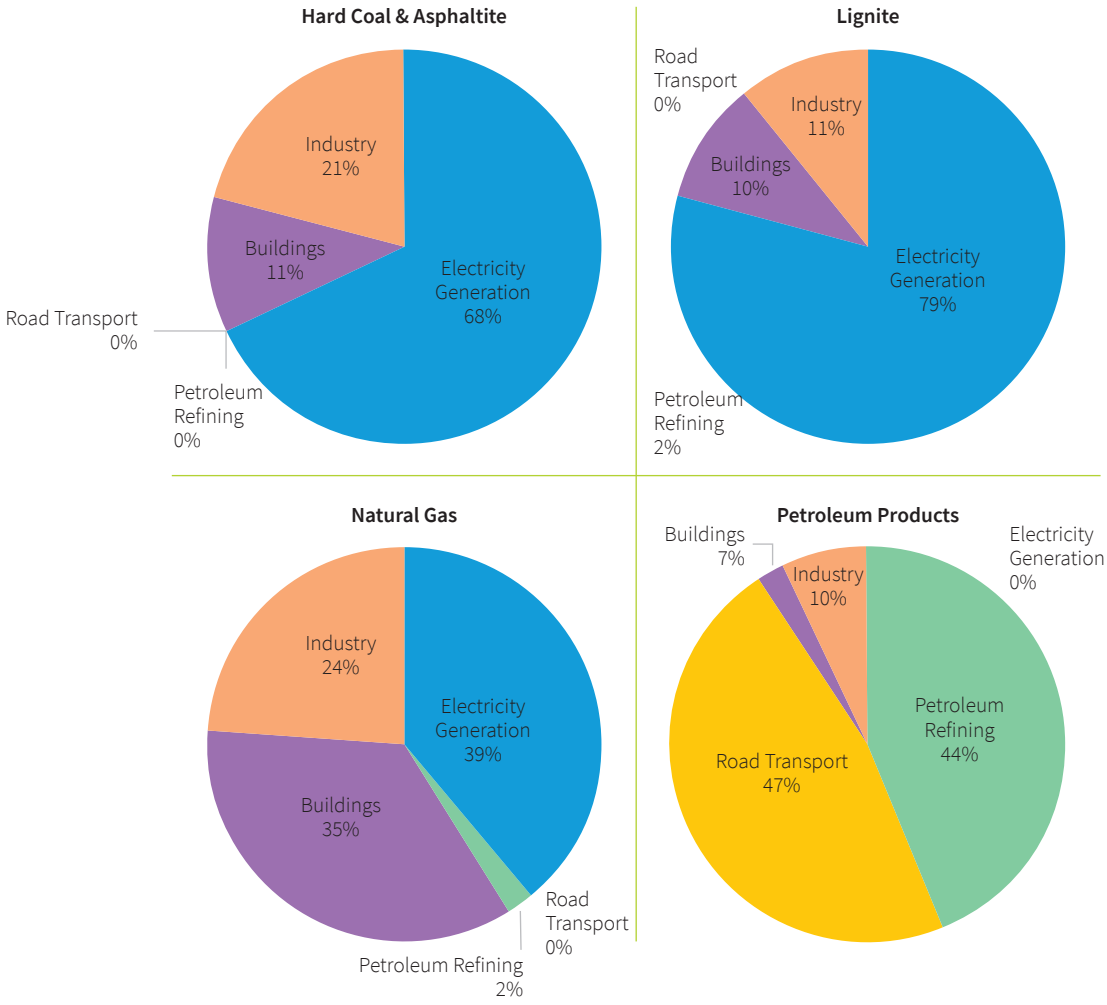
Sectors	Hard Coal/ Asphaltite	Lignite	Coke	Natural Gas	Petroleum Products	Total
Power Generation	13,814	11,645	-	15,031	144	40,633
Petroleum Refining	-	-	-	753	24,815	25,568
Road Transport	-	-	-	76	26,052	26,128
Buildings	2,444	1,452	-	13,712	1,017	18,626
Industry	4,138	1,677	3,229	9,434	3,767	22,245
Cement Industry	1,982	439	-	176	3,389	5,986
Iron & Steel Prod.	1,264	-	3,145	1,171	7	5,587
Textile and Leather	103	502	-	1005	4	1,614
Ceramic	24	118	-	885	41	1,068
Food	180	336	42	1,006	20	1,584

Source: Enerji İşleri Genel Müdürlüğü, 2019

The consumption distribution of these sectors for each fuel type is given in Figure 1. While the power sector accounts for the largest shares of hard coal, lignite, and natural gas consumption, petroleum refining and road transport have high shares of liquid fuel consumption[1].

[1] Over 90% of the petroleum consumed in refineries is actually conversion of crude oil into petroleum products. The actual amount taken into account is the amount combusted for the production/conversion process.

Figure 1: *Consumption distribution of sectors on fuel type basis in 2018*



2.1 Emission Estimations

The emission estimation calculations are performed using available data, including annual production and/or energy consumption of the plants and the available and reliable emission factors for the major air pollutants and GHGs. The GHG and air pollutant emissions are determined using Equation 1 given below.

$$Ep = EFp * A \qquad (Equ.\ 1)$$

where;

E: annual amount of emissions of the pollutant p (kg/year)

EF: emission factor (kg pollutant/kg of fuel consumed, kg pollutant/kJ of fuel consumed, kg pollutant/m^3 of fuel consumed or kg pollutant/kg of goods produced)

A: activity (kg of fuel consumed/year, kJ of fuel consumed/year, m^3 of fuel consumed/year, or kg of goods produced/year)

p: pollutant (SO_x, NO_x, PM, NMVOC, NH_3, and other pollutants; and GHGs such as CO_2, N_2O, and CH_4)

For sectors for which the plant-based data and/or plant location data could not be obtained, the regional distribution is based on the regional gross domestic product (GDP), industrial GDP or population distributions, where available, as presented in Table 2. The sectors for which regional GDP, industrial GDP, or population shares are used for the allocation of regional distribution are specified in the related sections. At the time of calculations, GDP by provinces was not released by TurkStat for 2018. Therefore, 2017 GDP and population data were used for regional distribution.

Table 2: *Regional GDP, industrial GDP, and population distribution (TÜİK, 2019)*

Region	GDP (TL)	%	Industrial GDP (TL)	%	Population	%
Aegean	388,492,757,266	13%	123,762,829,986	14%	10,383,963	13%
Black Sea	210,569,245,296	7%	52,095,630,662	6%	7,782,736	10%
Central Anatolia	508,805,725,945	16%	140,333,918,774	15%	12,895,988	16%
Eastern Anatolia	116,275,514,448	4%	20,806,936,908	2%	5,962,666	7%
Marmara	1,405,515,661,220	45%	446,659,432,275	49%	24,816,023	31%
Mediterranean	307,856,544,790	10%	75,864,908,251	8%	10,303,984	13%
South Eastern Anatolia	169,021,302,480	5%	46,295,617,500	5%	8,665,165	11%
Total	3,106,536,751,445		905,819,274,355		80,810,525	

2.1.1 Power Sector

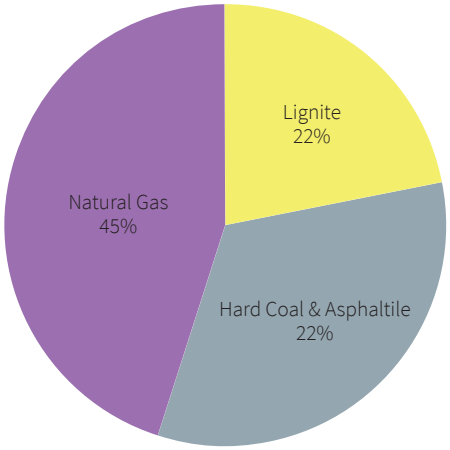
This study covers the emissions from 262 power plants currently operating, of which 220 are natural gas fueled, 26 are lignite fueled, 15 are hard coal fueled, and one is asphaltite fueled. The data for these plants are obtained from Enerji Atlası and TEİAŞ (Enerji Atlası, n.d.; TEİAŞ, n.d.). Data regarding the hourly electricity generated at each of these 262 power plants in 2018 is gathered from EPİAŞ (EPİAŞ Şeffaflık Platformu, n.d.). The plant-based hourly generation data are then summed up on fuel type basis to obtain total annual electricity generated from each fossil fuel type. 2018 power generation totals for each fuel type on plant basis are then compared with the official fuel type generation figures reported by TEİAŞ (TEİAŞ, n.d.). As can be seen in Table 3, the difference between these two figures are negligible for each fuel type, showing that the plant-based power data gathered from EPIAŞ is reliable.

Table 3: *Comparison of 2018 Power generation data from EPIAS and TEİAS*

	2018 Generation from EPIAS, MWh	2018 Generation TEIAS, MWh	Difference (%)
Lignite	44,700,646	44,838,338	0.3 %
Hard Coal & Asphaltite	66,981,327	66,633,044	0.5%
Natural Gas	90,231,872	90,522,202	0.3%

The generation of about 50 natural gas power plants (mostly with capacities < 10 MW) could not be obtained from EPİAŞ; thus, their annual generation is estimated assuming these plants have annual operational capacities of 20% and thermal efficiencies of 20%. The total installed capacity of such plants is less than 2.5% of total natural gas-fueled power generation capacity. Through these analyses, the shares of fossil fuels used in the power sector are determined and presented in Figure 2. As can be seen, natural gas has the highest share, followed by hard coal and lignite fueled power plants.

Figure 2: *The share of fossil fuels in power generation*

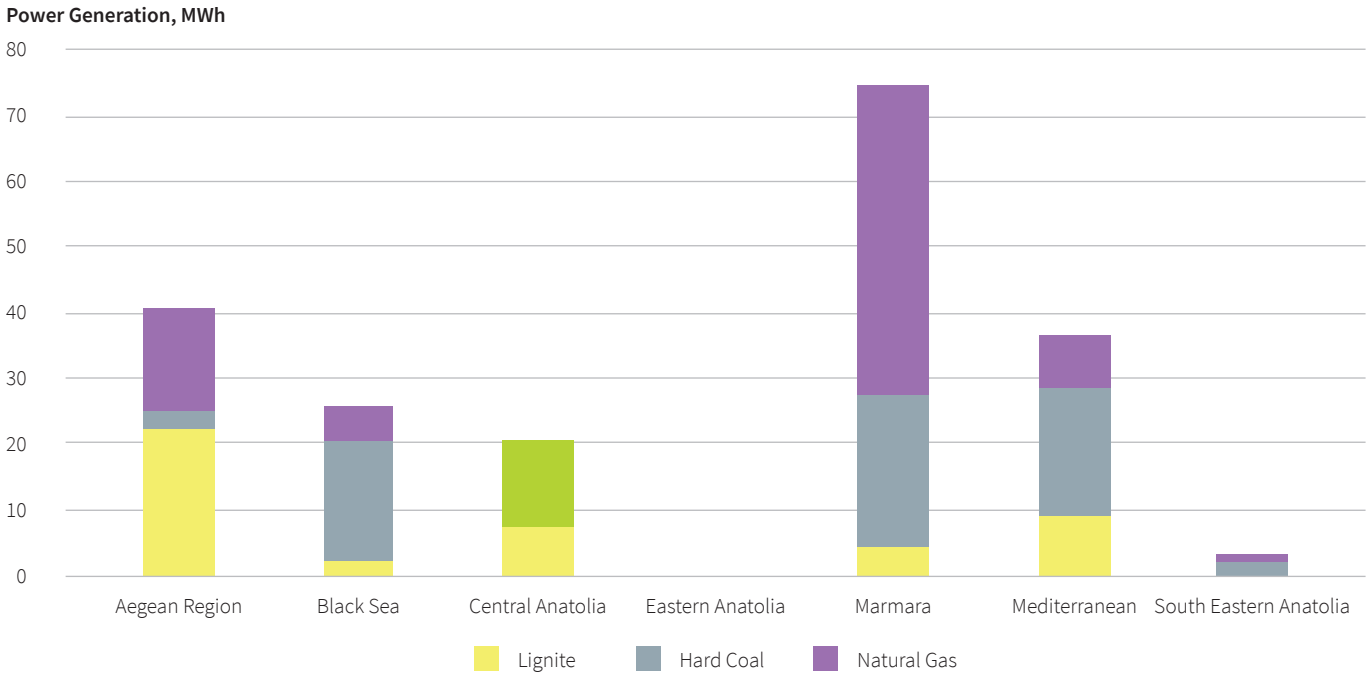


The location, fuel properties (low heating value - LHV), ash, sulphur, humidity, carbon content etc.), and technology of the plants are obtained from various open sources. Using the location data, 2018 power generation by region and fuel type is shown in Table 4 and Figure 3. As can be seen from the table and the figure, more than one third of the electricity was generated in the Marmara Region in 2018, and almost half of the total electricity in the region was from natural gas fueled power plants. The data also show that there is no fossil fuel power plant in Eastern Anatolia Region, and the share of fossil fuel power generation in South Eastern Anatolia Region is only 2% of the total generation.

Table 4: *Distribution of power generation by region and fuel type in 2018, MWh*

Region	Hard Coal	Lignite	Natural Gas	Asphaltite	Total	Share (%)
Aegean	2,673,957	22,467,261	15,464,561	-	40,605,779	20%
Black Sea	18,389,682	1,837,628	5,644,695	-	25,872,005	13%
Central Anatolia	-	7,288,648	13,408,257	-	20,696,905	10%
Eastern Anatolia	-	-	-	-	-	
Marmara	23,392,869	4,274,578	47,085,685	-	74,753,131	37%
Mediterranean	19,848,834	8,832,532	7,981,065	-	36,662,430	18%
South Eastern Anatolia	-	-	937,940	2,327,702	3,265,642	2%
Total	64,305,342	44,700,646	90,522,202	2,327,702	201,855,892	100%
Share (%)	32%	22%	45%	1%		100%

Figure 3: *Regional distribution of power generation by fossil fueled power plants (MWh)*



The thermal efficiencies of the power plants are assumed to be between 29-38% for lignite fueled, 28-44% for hard coal fueled, and 20-55% for natural gas fueled power plants based on the information gathered from various sources (Bülent and Kılıçarslan, 2014; Dinçer, 2018; Erdoğan et al., 2001; Vardar and Yumurtaci, 2010). The coal and lignite properties, such as LHV, ash and sulphur contents, used at power plants are also gathered from various sources (Aytaç, 2018; Başaran, 2018; Baz, et al., 2018; Bülent and Kılıçarslan, 2014; Ilgar, 2008; İlhan, 2012; Sitti, et al., 2016; Steel Exporters' Association, 2018; Vardar and Yumurtaci, 2010). Using the power generation, thermal efficiency and LHV of the fuel, the mass of the fuel consumed at each power plant is calculated through the below equation.

$$m = \frac{W_e}{\eta^* LHV} \qquad \textit{(Equ. 2)}$$

where;
m: annual mass of fossil fuel consumption (kg)
We: annual power generation (kWh or MJ)
η: thermal efficiency of the power plant
LHV: heating value of the fossil fuel (kWh/kg or MJ/kg)

Similarly, the annual volume of the natural gas consumed at the natural gas power plants are calculated by dividing the annual electricity generation by the efficiency and the LHV of the natural gas which is taken as 8250 kcal/m^3.

The emissions of the major air pollutants and GHGs are then determined by using the mass, volume, or energy of the fuel consumed by each power plant and the emission factors obtained from various sources based on uncontrolled combustion as presented in Table 5 for lignite, Table 6 for hard coal, and Table 7 for natural gas fueled power plants. As can be seen in Table 5, the range of the emission factor for CO_2 is between 90900 kg/TJ and 115000 kg/TJ for lignite fueled power plants. A similar

range is presented for hard coal as seen in Table 6. In this study, coal with low LHV is assumed to have a higher emission factor than the ones with higher LHVs. Thus, the CO_2 emission factors for coal are distributed based on this assumption.

Table 5: *Emission factors for lignite fueled power plants*

Pollutants/GHGs	Range	Unit	Reference	Remarks
CH_4	1.0	kg/TJ	IPCC (Gómez et al., 2006)	
CO	0.0681 – 0.1135	kg/ton	AP 42 (Environmental Protection Agency, n.d.)	Varies based on the technology
CO_2	90,900 – 115,000	kg/TJ	IPCC (Gómez et al., 2006)	Varies based on the LHV of the lignite
N_2O	1.5	kg/TJ	IPCC (Gómez et al., 2006)	
NMVOC	0.01362 – 0.01816	kg/ton	AP 42 (Environmental Protection Agency, n.d.)	Varies based on the technology
NO_x	1.634 – 5.902	kg/ton	AP 42 (Environmental Protection Agency, n.d.)	Varies based on the technology
PM	43.993 – 104.193	kg/ton	AP 42 (Environmental Protection Agency, n.d.)	Varies based on the technology and the ash content of the fuel
PM_{10}	22	kg/ton	Alyuz (Alyüz, 2012)	
$PM_{2.5}$	3.28	kg/ton	Alyuz (Alyüz, 2012)	
SO_x	2.724 – 61.290	kg/ton	AP 42 (Environmental Protection Agency, n.d.)	Varies based on the technology and the sulphur content of the fuel

Table 6: *Emission factors for hard coal fueled power plants*

Pollutants/GHGs	Range	Unit	Reference	Remarks
CH_4	1.0	kg/TJ	IPCC (Gómez et al., 2006)	
CO	0.227 – 0.274	kg/ton	AP 42 (Environmental Protection Agency, n.d.)	Varies based on the technology and type of the fuel
CO_2	94,600 – 96,100	kg/TJ	IPCC (Gómez et al., 2006)	Varies based on the LHV of the lignite
N_2O	1.5	kg/TJ	IPCC (Gómez et al., 2006)	
NMVOC	0.02724	kg/ton	AP 42 (Environmental Protection Agency, n.d.)	
NO_x	0.817 – 8.172	kg/ton	AP 42 (Environmental Protection Agency, n.d.)	Varies based on the technology and type of the fuel
PM	45.500 – 68.100	kg/ton	AP 42 (Environmental Protection Agency, n.d.)	Varies based on the technology, type, and the ash content of the fuel
PM_{10}	10.442 – 15.663	kg/ton	AP 42 (Environmental Protection Agency, n.d.)	Varies based on the technology, type, and the ash content of the fuel
$PM_{2.5}$	9	kg/ton	Alyuz (Alyüz, 2012)	
SO_x	1.317 – 19.068	kg/ton	AP 42 (Environmental Protection Agency, n.d.)	Varies based on the technology, type, and the sulphur content of the fuel

Table 7: *Emission factors for natural gas fueled power plants*

Pollutants/GHGs	Range	Unit	Reference
CH_4	1.0	kg/TJ	IPCC (Gómez et al., 2006)
CO	1,347	kg/106 sm^3	AP 42 (Environmental Protection Agency, n.d.)
CO_2	54,300 – 58,300	kg/TJ	IPCC (Gómez et al., 2006)
N_2O	0.1	kg/TJ	IPCC (Gómez et al., 2006)
NMVOC	88.181	kg/106 sm^3	AP 42 (Environmental Protection Agency, n.d.)
NO_x	2,245	kg/106 sm^3	AP 42 (Environmental Protection Agency, n.d.)
PM	121.850	kg/106 sm^3	AP 42 (Environmental Protection Agency, n.d.)
SO_x	9.620	kg/106 sm^3	AP 42 (Environmental Protection Agency, n.d.)

The emissions estimated are uncontrolled emissions, i.e. the emission generated by the fossil fuel combustion. Due to regulations, the power plants are required to limit their SO_x, NO_x, and PM emissions below the allowable limits. The percent reductions due to the use of various air pollution control equipment for each air pollutant can be found in various open sources (Environmental Protection Agency, n.d., n.d., n.d., n.d.) The typical collection efficiencies based on the pollutant, fuel type, and technology used in this study are presented in Table 8. Since the type and efficiency of the collection devices used by each operating power plant are not known, average collection efficiencies are used for all plants where fossil fuels are combusted. This, of course, adds a degree of uncertainty to the estimated emissions of the air pollutants and GHGs in this study. In coal fueled power plants using wet scrubbers to collect SO_x from the flue gas, additional CO_2 is formed during the desulphurization process. Thus, these CO_2 emissions are added to the total emissions assuming that 0.79 tons CO_2 is produced per ton SO_x removed at the wet scrubber (Alyüz, 2012). It is assumed that there are no PM collection devices at natural gas power plants since PM emissions generated at these plants are low.

Table 8: *Air pollutant collection efficiencies for major air pollutants used in this study*

Pollutants/GHGs	Combustion Technology	Control Technologies	Collection Efficiencies
NO_x	Solid and natural gas combustion	Selective non-catalytic reduction / Selective catalytic reduction	75%
PM	Solid fuel combustion	ESP/Bag filter	98%
SO_x	Solid fuel combustion	Wet Scrubber	95%

2.1.2 Transport Sector

In this study, the estimation of major pollutants and GHGs from the road transport sector including passenger cars, light commercial vehicles, heavy duty trucks, and busses are covered. These estimates for 2018 are obtained from a study conducted at Hacettepe University (Hacettepe University, 2018). The number of vehicles by categories as of 2018 covered in this study is presented in Table 9. As can be seen in this table, the majority of the vehicles in 2018 are automobiles in Turkey (Türkiye İstatistik Kurumu, 2018).

Table 9: *Number of vehicles by categories in 2018*

Vehicle Type	Number	Share (%)
Automobiles	12,354,008	72 %
Light Commercial Vehicles	3,755,580	22%
Heavy Duty Trucks	845,462	5%
Buses	218,523	1%
Total	**17,173,573**	**100%**

The emissions are calculated taking into account the fuel type of the vehicle (gasoline, diesel, LPG, and electric), vehicle engine displacement, vehicle age and standard (Conventional, Pre-Ece, Euro 1, Euro 3, Euro4, Euro5, and Euro6), and vehicle mileage for all vehicle categories. The estimated major pollutant and GHG emissions of the transportation sector based on the number of vehicles presented in Table 9 are given in Table 10.

Table 10: *2018 Emissions of the transport sector*

Pollutants/GHGs	Emissions, ton
CO	343,441
CH_4	4,847
CO_2	78,501,802
N_2O	2,518
NMVOC	47,074
NO_x	306,843
PM	11,275
PM_{10}	18,785
$PM_{2.5}$	15,262
SO_x	8,638
VOC	51,920

Since the number of vehicle ownership has a positive correlation with the population, the regional distribution of the emissions is allocated based on the population shares given in Table 2.

2.1.3 Buildings Sector

The residential and commercial building sector in Turkey consume about 31% of total energy supply as of 2018 (Enerji İşleri Genel Müdürlüğü, 2019). Pollutant emissions arising from the use of hard coal, lignite, and natural gas for space and domestic hot water heating purposes in the residential and commercial buildings are based on the types of fuel consumed in the buildings.

According to General Energy Balance Table (Enerji İşleri Genel Müdürlüğü, 2019) residential hard coal consumption is 1,813 thousand tons in 2018. This value is multiplied by the percentage of the population share of each region and the residential coal consumption is distributed regionally. Emissions are obtained by multiplying regional hard coal consumption amounts with the pollutant emission factors. These emission factors are given in the Table 11. The sulphur content of hard coal is taken as 1.5 % (Türkiye Taşkömürü Kurumu, 2018).

Table 11: *Emission factors for hard coal combustion in residential buildings*

Pollutants/GHGs	EF (kg/TJ)	References
CH_4	217	AP-42 (Environmental Protection Agency, n.d.)
CO	4600	EPA (Trozzi et al., 2009)
CO_2	94,600 – 101,000	IPPC (Intergovernmental Panel on Climate Change, 2006)
N_2O	1.5	IPPC (Intergovernmental Panel on Climate Change, 2006)
NMVOC	484	EPA (Trozzi et al., 2009)
NO_x	81	AP-42 (Environmental Protection Agency, n.d.)
PM	444	EPA (Trozzi et al., 2009)
PM_{10}	404	EPA (Trozzi et al., 2009)
$PM_{2.5}$	398	EPA (Trozzi et al., 2009)
SO_x	16	AP-42 (Environmental Protection Agency, n.d.)

According to General Energy Balance Table (Enerji İşleri Genel Müdürlüğü, 2019) commercial hard coal consumption amount is 626 thousand tons in 2018. Hard coal emission factors for commercial buildings are given in Table 12.

Table 12: *Emission factors for hard coal combustion in commercial buildings*

Pollutants/GHGs	EF (kg/TJ)	References
CH_4	300	IPCC(Intergovernmental Panel on Climate Change, 2006)
CO	931	EPA (Trozzi et al., 2009)
CO_2	94,600 – 101,000	IPPC (Intergovernmental Panel on Climate Change, 2006)
N_2O	1.5	IPPC (Intergovernmental Panel on Climate Change, 2006)
NMVOC	88.8	EPA (Trozzi et al., 2009)
NO_x	173	EPA (Trozzi et al., 2009)
PM	124	EPA (Trozzi et al., 2009)
PM_{10}	117	EPA (Trozzi et al., 2009)
$PM_{2.5}$	108	EPA (Trozzi et al., 2009)
SO_x	900	EPA (Trozzi et al., 2009)

According to General Energy Balance Table (Enerji İşleri Genel Müdürlüğü, 2019), residential lignite consumption amount is 1,186 thousand tons in 2018. As in hard coal, the lignite consumed in Turkey is distributed to regions by multiplying the percentage of population share, multiplied by emission factors, and emissions on a regional basis were found. Emission factors of pollutants for lignite combustion are given in Table 13.

Table 13: *Emission factors for lignite combustion in residential buildings*

Pollutants/GHGs	EF (kg/TJ)	References
CH_4	300	IPCC(Intergovernmental Panel on Climate Change, 2006)
CO	4600	EPA (Trozzi et al., 2009)
CO_2	90,900 – 115,000	IPPC (Intergovernmental Panel on Climate Change, 2006)
N_2O	1.5	IPPC (Intergovernmental Panel on Climate Change, 2006)
NMVOC	484	EPA (Trozzi et al., 2009)
NO_x	110	EPA (Trozzi et al., 2009)
PM	444	EPA (Trozzi et al., 2009)
PM_{10}	404	EPA (Trozzi et al., 2009)
$PM_{2.5}$	398	EPA (Trozzi et al., 2009)
SO_x	900	EPA (Trozzi et al., 2009)

According to General Energy Balance Table (Enerji İşleri Genel Müdürlüğü, 2019), commercial lignite consumption amount is 266 thousand tons in 2018. Lignite emission factors for commercial buildings are given in Table 14.

Table 14: *Emission factors for lignite combustion in commercial buildings*

Pollutants/GHGs	EF (kg/TJ)	References
CH_4	10	IPCC (Gómez et al., 2006)
CO	4600	EPA(Trozzi et al., 2009)
CO_2	90,900 – 115,000	IPCC (Gómez et al., 2006)
N_2O	1.5	IPCC (Gómez et al., 2006)
NMVOC	484	EPA (Trozzi et al., 2009)
NO_x	110	EPA (Trozzi et al., 2009)
PM	444	EPA (Trozzi et al., 2009)
PM_{10}	404	EPA (Trozzi et al., 2009)
$PM_{2.5}$	398	EPA (Trozzi et al., 2009)
SO_x	900	EPA (Trozzi et al., 2009)

The amount of natural gas consumption distributed to residential and commercial customers are obtained from EPDK (EPDK, 2019) at provincial level to determine the regional distributions, the regional consumption amounts are given in Table 15.

Table 15: *Regional natural gas consumption in commercial and residential buildings, 2018*

Region	Residential Natural Gas Consumption (Sm^3)	Commercial Natural Gas Consumption (Sm^3)
Aegean	1,047,596,135	516,757,835
Black Sea	846,431,993	224,142,302
Central Anatolia	2,484,925,124	588,613,350
Eastern Anatolia	554,118,961	65,925,529
Marmara	6,560,226,681	2,093,721,291
Mediterranean	476,531,661	404,045,413
South Eastern Anatolia	655,339,444	102,434,280
Total	12,625,170,000	3,995,640,000

Natural gas emission factors for residential and commercial buildings are given in Table 16.

Table 16: *Emission factors for natural gas combustion in commercial and residential buildings*

Pollutants/GHGs	EF (kg/TJ)	References
CH_4	5	IPCC (Gómez et al., 2006)
CO	31	EPA (Trozzi et al., 2009)
CO_2	54,300 – 58,300	IPCC (Gómez et al., 2006)
N_2O	1.02	AP-42 (Environmental Protection Agency, n.d.)
NMVOC	10.5	EPA (Trozzi et al., 2009)
NO_x	57	EPA (Trozzi et al., 2009)
SO_x	0.5	EPA (Trozzi et al., 2009)

The annual consumption amounts of the regions are multiplied by the emission factors given in Table 16, and the regional emissions are estimated.

2.1.4 Petroleum Refining

In Turkey, TUPRAS has four refineries located in Izmit, Izmir, Kırıkkale and Batman, with a total refining capacity of 28,100,000 tons/year crude oil as given in Table 17 (TÜPRAŞ, 2018). A new refinery plant, STAR Refinery Plant, is in operation since October 2018. Since operation data was not available at the time the calculations were made, the plant was not included in the analyses.

Table 17: *Location and capacity of the petroleum refineries in Turkey, 2018*

Plant Name	Region	Province	Capacity (Mil. tons/yr.)
TUPRAS İzmit Refinery	Marmara	İzmit	11
TUPRAS İzmir Refinery	Aegean	İzmir	11
TUPRAS Kırıkkale Refinery	Central Anatolia	Kırıkkale	5
TUPRAS Batman Refinery	South Eastern Anatolia	Batman	1.1

All units in petroleum refineries require process heaters that use a variety of fossil fuels to supply required heat to the system. The combustion of these fuels generates mainly CO_2, SO_x, and NO_x emissions which are then discharged to atmosphere through stacks (Choudhari, n.d.).

According to General Energy Balance Table 2018 (Enerji İşleri Genel Müdürlüğü, 2019), there are two main fossil fuel types used in petroleum refinery, namely crude oil and natural gas with consumptions of 24,815 and 753 ktoe, respectively. The consumptions of these fuels on a regional basis are determined by distributing the total amount depending on the refining capacities of the plants.

Generally, the fuel combusted to provide the process heat and steam required for the refining processes is taken as 6 to 10 percent of the total fuel input to the refinery (Gómez et al., 2006). Therefore, the amount of crude oil to be combusted is taken as 6 percent of the value given in the General Energy Balance Table 2018 (Enerji İşleri Genel Müdürlüğü, 2019). Moreover, it is considered that all the natural gas input to the petroleum refinery is used for combustion. Amounts of fuel combusted are given in Table 18.

Table 18: *Amount of fuel combusted by regions in 2018, ktoe*

Region	Amount of fuel combusted, ktoe	
	Crude Oil	Natural Gas
Marmara	615	295
Central Anatolia	279	134
Aegean	615	295
South Eastern Anatolia	61	29
Total	1570	753

Emission factors for crude oil and natural gas that are used to determine the emissions from petroleum refineries are given in Table 19 (Alyüz, 2012).

Table 19: *Emission factors of petroleum refining*

Pollutant	Emission Factor (g/GJ)	
	Crude Oil	Natural Gas
PM	20	1
SO_x	653	NA
CO	14	39
NO_x	194	88
CO_2	73,300	56,100
N_2O	1.5	0.3
NMVOC	2.3	2.6
CH_4	3.0	NA

Petroleum refining emissions are calculated by Tier 1 Method of IPCC Guideline (Gómez et al., 2006). In this method, the emission factors given in Table 19 are multiplied by the fuel consumption data. The estimated controlled emissions are calculated by considering the controlling of SO_x, PM and NO_x emissions with 95%, 98%, and 75% abatement efficiencies, respectively.

2.1.5 Industrial Sectors

Industry is an energy intensive sector and emissions from this sector will be handled within two separate cases. In the first part, process emissions, which are unique to each sector, are estimated. At the second stage, emissions due to fuel combustion are considered. In this study, electricity which is used directly by the plants via grid connection is included to electricity sector and not considered here in order to avoid double counting. Pollutants arising from the combustion of hard coal, lignite, natural gas, and petroleum products, which are presented in General Energy Balance Table, have been considered for each sector separately. Emission factors of aforesaid fuel types are presented in Table 20.

Table 20: *Emission factors by fuel type for major air pollutants and GHGs, kg/TJ*

Pollutants/ GHGs	Hard coal	Lignite	Natural	Fuel oil	Diesel	Asphaltite
CH_4	1	1	1	3	3	1
CO	17	9	39	5	15	9
CO_2	96,100	105,430	56,100	73,300	74,100	105,430
N_2O	2	2	0	1	1	2
NMVOC	2	2	3	1	1	2
NO_x	251	407	65	215	180	407
PM	5,116	8,870	4	25	3	8,812
PM_{10}	1,170	2,103		2	2	2,103
$PM_{2.5}$	672	314		1	1	314
SO_x	1,546	1,926	0	485	460	1,926

2.1.5.1 Cement Industry

There are two aspects of cement production that result in pollutants and GHG emissions. The first is the process emissions accounting for about 5% of total anthropogenic CO_2 emissions excluding land use change. The second source of emissions is the combustion of fossil fuels used for generating significant amount of energy required to heat the raw ingredients to well over 1000 °C and these are considered energy combustion emissions (Andrew, 2018).

Cement industry operates in all regions of Turkey and production rates of 2018 are shown in Table 21 (TÇMB - Turkish Cement Manufacturers' Association, n.d.). In 2018, total production decreased 10% by comparison to 2017.

Table 21: *Turkey cement industry capacity and production in 2018, tons*

	Capacity, tons/year		Capacity, tons/year		Capacity, tons/year	
	Clinker	Cement	Clinker	Cement	Clinker	Cement
Marmara	20,068,820	29,117,921	20,068,820	29,117,921	20,068,820	29,117,921
Aegean	9,444,600	13,777,960	9,444,600	13,777,960	9,444,600	13,777,960
Mediterranean	22,929,230	33,964,430	22,929,230	33,964,430	22,929,230	33,964,430
Black Sea	8,672,550	18,359,839	8,672,550	18,359,839	8,672,550	18,359,839
Central Anatolia	15,025,890	22,315,866	15,025,890	22,315,866	15,025,890	22,315,866
Eastern Anatolia	7,447,440	13,176,595	7,447,440	13,176,595	7,447,440	13,176,595
South Eastern Anatolia	6,273,830	11,164,145	6,273,830	11,164,145	6,273,830	11,164,145
Total	89,862,360	141,876,755	89,862,360	141,876,755	89,862,360	141,876,755

The cement industry, like other industrial activities, is strictly regulated by national and international legislation regarding environmental protection. Various emission reduction technologies used in the cement industry have been described in detail in the BREF document (Berdowski et al., 2016). In Turkey, different fuel types are used for cement production as listed in Table 22 (Enerji İşleri Genel Müdürlüğü, 2019). Fuel type preferences are dominated by petroleum products, followed by hard coal.

Table 22: *Energy consumption of cement production in 2018*

Fuel Type	Consumption, ktoe
Hard coal	1,982
Lignite	439
Coke	0
Petroleum products (mainly petroleum coke)	3,389
Natural gas and other gases	176

In general, the main emissions emitted from the processes of cement industries are CO, PM, and CO_2. Also, emissions such as SO_x and NO_x are strongly dependent of the type and properties of the fuel used (Alyüz, 2012). Thus, emissions based on processes (Alyüz, 2012; Berdowski et al., 2016) and fuel combustion (Alyüz, 2012) are considered separately and then summed up. For fuel combustion emissions, total emission amount is distributed according to production rates of 2018 using the emission factors presented in Table 23.

Table 23: *Process emission factors for cement industry*

Pollutants/ GHGs	Emission Factor, kg/ton clinker
CO	2.53
CO_2	421
NO_x	2.5
PM	10.15
PM_{10}	10
$PM_{2.5}$	5.5
SO_x	5.56
VOC	0.07015

2.1.5.2 Iron and Steel Production

There are two main processes to produce steel; namely, integrated and recycling processes. The integrated process is based on the production of iron from iron ore, while the recycling process uses scrap iron as the main iron-bearing raw material in electric arc furnaces. In the integrated route, the energy consumed comes from fossil fuels (mainly coal and coke) whereas the recycling route uses electricity. The recycling process consumes much less energy (about 80 %) than the integrated process. Steel is produced from either iron ore in integrated steelworks or scrap in electrical arc furnaces (SETIS, n.d.). In Turkey, 74% of the steel is produced in electrical arc furnaces and 26% is produced in integrated steelworks (Türkiye Çelik Üreticileri Derneği, 2016). The amount of steel produced in 2018 is 37.3 million tons (Çelik, 2018) and the total is distributed according to production capacities of regions (Türkiye Çelik Üreticileri Derneği, 2016) as seen in Table 24.

Table 24: *Regional steel capacity and estimated production in Turkey in 2018*

Region	Capacity, ton	Production, ton
Marmara	7.350.000	5.441.333
Aegean	11.300.000	8.365.587
Mediterranean	10.700.000	7.921.397
İsdemir	5.300.000	3.923.683
Black Sea	8.400.000	6.218.667
Kardemir	3.500.000	2.591.111
Erdemir	3.850.000	2.850.222
	50.400.000	37.312.000

The integrated process relies on the use of coke ovens, sinter plants, blast furnaces, and Basic Oxygen Furnace converters (SETIS, n.d.). In Turkey there are three integrated steel plants; Kardemir (established in 1939, in Karabuk), Erdemir (established in 1965, in Ereğli), and Isdemir (established in 1977 in Iskenderun). All of these plants have their own coke production units (Alyüz, 2012). Emission factors of coke production process is given in Table 25 and the total emission amount of the process is detailed in Appendix 1. According to 2018 General Energy Balance Table (Enerji İşleri Genel Müdürlüğü, 2019), 4319 thousand tons of coke is used in coke ovens. Consumption of each integrated plant (Kardemir, Erdemir and Isdemir) is assumed to be proportionate to its capacity.

Table 25: *Emission factors for coke production (Alyüz, 2012)*

Pollutants/ GHGs	Emission Factor, kg/ton clinker
CH_4	0.1
CO	1.88
CO_2	560
NH_3	0.01
NO_x	0.83
PM	7.97
SO_x	0.4
VOC	6.03

Process emissions of integrated steel work plants in addition to coke production are given based on their assumed production (see Table 24.). Process emissions are estimated using the emission factors given in Table 26.

Table 26: *Emission factors for integrated steelworks*

Pollutants/ GHGs	Emission Factor, kg/ton clinker
CO	37
CO_2	1,911
NO_x	0
PM	36
SO_x	1

Electrical Arc Furnaces (EAF) directly melt the materials containing iron (mainly scrap) and do not need coke. The input material for an EAF is nearly 100 percent ferrous scrap. EAFs use considerable amounts of electrical energy and cause substantial emissions. The main EAF process air pollutants are respectively CO_2, CO, PM, NO_x, So_x, and NMVOC (Alyüz, 2012).

According to the steel map obtained from Turkish Steel Producers' Association website, plants are located in four regions (Türkiye Çelik Üreticileri Derneği n.d.). In 2018, total amount of steel produced in Turkey is 37.3 million tons. The total amount has been distributed to regions in proportion with capacity to assume for production distribution. The emission factors for regional emissions are given in Table 27.

Table 27: *Process emission factors for Electrical Arc Furnaces (Alyüz, 2012)*

Pollutants/ GHGs	Emission Factor, kg/ton clinker
CO	4
CO_2	80
NMVOC	1
NO_x	25
PM	25
SO_x	0.4

2.1.5.3 Ceramic Production

The ceramic manufacturing industry in Turkey is divided into two large groups: ceramic coating production and sanitary ware production. In 2017, sanitary ware production was 352 thousand tons while ceramic coating production reached 5.47 million tons (Kocabaş and Ermurat, 2017). Ceramic plants in Turkey are mainly located in Marmara, Aegean, and Black Sea regions. Therefore, the production has been assumed according to adjusted industrial GDP percentages, considering the regions with ceramic production facilities. The regional distribution of ceramic production is given in Table 28.

Table 28: *Regional ceramic production distribution*

Region	Industrial GDP	Adjusted GDP	Ceramic Coating (million tons/yr.)	Sanitary Ware (thousand tons/yr.)
Aegean	14%	16%	0.8874	57.11
Black Sea	6%	7%	0.3735	24.04
Central Anatolia	15%	18%	1.0063	64.75
Eastern Anatolia	0%	-	-	-
Marmara	49%	59%	3.2028	206.10
Mediterranean	0%	-	-	-
South Eastern Anatolia	0%	-	-	-
Total	84%	100%	5.47	352

Emission factors for both sanitary ware and ceramic coating production are given in Table 29 (National Pollutant Inventory, n.d.).

Table 29: *Emission factors for natural gas-fired ceramic kilns for ceramic coating and sanitary*

Pollutants/ GHGs	Emission factor(kg/ton)
Fluoride	0.28
HF	0.23
VOC	0.22

Fuel-based emissions are also estimated assuming that natural gas is solely used for the processes, and hard coal and lignite are combusted at the plants for processing and other requirements. General Energy Balance Table 2018 (Enerji İşleri Genel Müdürlüğü, 2019) reveals that the amount of coal and lignite used in ceramic industry in 2018 is 1,002 and 4937 TJ respectively.

2.1.5.4 Textile and Leather Production

Textile and leather industry emissions are in higher quantities to water than air. Odour is considered as one of the major problems in textile sector. Textile plants are located in all regions of the country and division of the industry by provinces is not reliable due to limited data. Energy consumption figures based on fossil fuel type in textile and leather industries in 2018 are obtained from General Energy Balance Table 2018 data (Enerji İşleri Genel Müdürlüğü, 2019) and presented in Table 30.

Table 30: *Fossil fuel use in textile and leather production, 2018*

Fuel	Consumption, ktoe	Share, %
Natural Gas	1,005	62%
Lignite	502	31%
Hard-Coal	103	6%
Other Petroleum Products	4	0.23%
Diesel	3.04	0.19%
Gasoline	0.34	0.02%
Fuel Oil	0.10	0.01%
Petroleum Coke	0.04	0.00%

Regional share of production is assumed according to industrial GDP percentages by regions. Industrial GDP percentages given in Table 2 are used to distribute the total emissions released by textile industry fuel consumption.

2.1.5.5 Food Industry

Food industry, whose energy consumption is dominated by natural gas, accounts for 8% of total industrial energy consumption. (Enerji İşleri Genel Müdürlüğü, 2019). Production plants are spread all over Turkey and distribution of energy is based on regional GDP percentages. In this study, only emissions caused by combustion are considered and any emissions caused by processes of the food industry are ignored. Energy consumption figures by fossil fuel type in the food industry in 2018 are obtained from General Energy Balance Table 2018 (Enerji İşleri Genel Müdürlüğü, 2019) and presented in Table 31.

Table 31: *Fossil fuel use in food industry, 2018 (TUIK, 2018)*

Fuel	Consumption, ktoe	Share, %
Natural Gas	1,106	65.9%
Lignite	336	20.0%
Hard-Coal	180	10.8%
Coke	42	2.5%
Diesel	8	0.5%
Fuel Oil	4	0.2%
Petroleum Coke	2	0.1%

2.2 External Cost Estimations

This section presents the methodology used for the calculation of external costs of fossil fuels used in power generation, transportation, petroleum refining, and major fossil fuel consuming industries (cement, iron & steel, ceramics, textiles & leather, and food). First, two main studies selected to be used in this study, namely ExternE (CIEMAT, 2000) and Cost Assessment for Sustainable Energy Systems (CASES) (CASES, 2008), are compared. Then, the approach used to determine the base country to transfer the external costs and external costs per pollutant for Turkey are explained.

2.2.1 ExternE and CASES projects

ExternE Project

ExternE Project assesses the external costs based on the impacted areas shown in Figure 4 . Public health and environmental damages are considered separately in terms of mECU/kWh in the project.

Figure 4: *ExternE Project Details*

	mECU/kWh
POWER GENERATION	
Public health	
Mortality*- YOLL (VSL)	
Morbidity	
Occupational health	
Major accidents	
Crops	
Ecosystems	
Materials	
Noise	
Visual impact	
Global warming	
OTHER FUEL CYCLE STAGES	
Public health	
Occupational health	
Ecological effects	
Road damage**	
Others (road damage and congestion)	
Global warming	

*YOLL= mortality impacts based on 'years of life lost' approach,

ExternE Project evaluates the impacts for areas presented in Figure 4 for the pollutants listed in Table 32.

Table 32: *ExternE Project pollutant list*

Pollutant	Definition
SO_x	Sulphur oxide, air, total
NO_x	Nitrogen oxides, air, total
NO_x via ozone	Ammonia, air, total
PM_{10}	NMVOC, unspecified origin, air, total
CO_2	Carbon dioxide, fossil, air, total (low, mid 3%, mid 1%, Upper)

CASES Project

In terms of the assessed impacted areas, CASES Project is different from the ExternE Project. Thus, results evaluated are also different. CASES evaluates impacts imposed on the areas listed below:

- Human Health
- Loss of Biodiversity
- Crops: Regional: crops N deposition & crops O_3
- Crops: SO_x - (based on WTM model run - year 2000)
- Materials: SO_x & NO_x - (based on WTM model run - year 2000)

Additionally, the types of pollutants considered are also different from the ExternE Project. Below, is the list of pollutants considered in CASES.

NH_3	Ammonia, air, total
NMVOC	unspecified origin, air, total
NO_x	Nitrogen oxides, air, total
PPMco	Particulates, > 2.5 µm, and < 10 µm, total
$PPM_{2.5}$	Particulates, < 2.5 µm, air, total
SO_x	Sulphur dioxide, air, total

Climate Change Abatement Cost – GHG is considered separately for GHGs such as CO_2, CH_4 and N_2O. In addition to these GHGs and pollutants, radionuclides and other pollutants are also considered for target countries as listed in Table 33.

Table 33: *CASES Project pollutant list*

Impacted Area	Cases	Definition
Human Health Loss of Biodiversity Crops: Regional: crops N deposition & crops O_3 Crops: SO_x - (based on WTM model run - year 2000) Materials: SO_x&NO_x - (based on WTM model run - year 2000)	SO_x	Sulphur oxide, air, total
	NOx	Nitrogen oxides, air, total
	NH_3	Ammonia, air, total
	NMVOC	NMVOC, unspecified origin, air, total
	PPMco	Particulates, > 2.5 µm, and < 10 µm, total
	$PPM_{2.5}$	Particulates, < 2.5 µm, air, total
Climate Change - abatement costs GHG	CO_2	Carbon dioxide, fossil, air, total
	CH_4	Methane, air, total
	N_2O	Dinitrogen monoxide, air, total
Results for other pollutants generic, i.e. applicable to all countries - only human health	Cd	Cadmium, air, total
	Cd	Cadmium, ion, water, total
	Cd	Cadmium, soil, total
	As	Arsenic, air, total
	As	Arsenic, ion, water, total
	As	Arsenic, soil, total
	Ni	Nickel, air, total
	Ni	Nickel ion, water, total
	Pb	Lead, air, total
	Pb	Lead, water, total
	Pb	Lead, soil, total
	Hg	Mercury, air, total
	Hg	Mercury, water, total
	Hg	Mercury, soil, total
	Cr	Chromium, air, total
	Cr	Chromium, ion, water, total
	Cr	Chromium, soil, total
	Cr-VI	Chromium VI, water, total
	Cr-VI	Chromium VI, soil, unspecified
	Formaldehyde	Formaldehyde, air, total
Results for Radionuclides generic, i.e. applicable to all countries/time	Aerosols, radioactive, unspecified into air	Aerosols, radioactive, unspecified, low population density
	Carbon-14 into air and water	Carbon-14, low population density
	Hydrogen-3, Tritium into air and water	Hydrogen-3, Tritium, low population density
	Iodine-129 into air	Iodine-129, low population density
	Iodine-131 into air	Iodine-131, low population density
	Krypton-85 into air	Krypton-85, low population density
	Noble gases, radioactive, unspecified into air	Noble gases, radioactive, unspecified, low population density
	Radon-222 into air	Radon-222, air, total
	Thorium-230 into air	Thorium-230, low population density
	Thorium-230 into water	Thorium-230, river
	Uranium-234 into air	Uranium-234, low population density
	Uranium-234 into water	Uranium-234, river

2.2.2 Comparison of ExternE and CASES

The CASES Project considers external costs based on the technology and fuel type for each European Country in terms of ECU/kWh. The external costs per pollutant emitted by different technologies are provided only for EU27 countries in this project.
On the other hand, ExternE considers externalities in terms of ECU/kWh based on fuel type and in terms of ECU/ton of pollutant . In Table 34 below, the externalities determined by these two studies are compared according to fuel type for countries common to both.

Table 34: *Comparison of the externalities determined by ExternE and CASES Projects*

COUNTRY	NGCC Electricity Only (ECU/kWh)	NGCC* Heat & Electricity (ECU/kWh)	Coal (ECU/kWh)	Lignite (ECU/kWh)
AUSTRIA-ExternE	0.0063	0.0375		
AUSTRIA-CASES	0.0166			
BELGIUM-ExternE	0.0130		0.1030	
BELGIUM-CASES	0.0155		0.0364	
GERMANY-ExternE	0.0115		0.0297	0.0353
GERMANY-CASES	0.0165		0.0383	0.0348
DENMARK-ExternE	0.0436	0.0102		
DENMARK-CASES	0.0126			
SPAIN-ExternE	0.0109		0.0478	0.0287
SPAIN-CASES	0.0118		0.0263	0.0265
FINLAND-ExternE			0.0042	
FINLAND-CASES			0.0228	
FRANCE-ExternE	0.0254		0.0839	
FRANCE-CASES	0.0157		0.0355	
GREECE-ExternE	0.0069			0.0457
GREECE-CASES	0.0115			0.0258
IRELAND-ExternE			0.7150	
ITALY-ExternE	0.0143			
NETHERLANDS-ExternE	0.0160		0.0420	
NETHERNLANDS-CASES	0.0158		0.0370	
NORWAY-ExternE	0.0077			
PORTUGAL-ExternE	0.0145		0.0544	
PROTUGAL-CASES	0.0105		0.0325	
SWEDEN-ExternE	0.0130		0.0181	
SWEEDEN-CASES	0.0118		0.0254	
UK-ExternE		0.0110	0.0420	
UK-CASES		0.0127	0.0286	

**NGCC: Natural gas combined cycle*

As seen in Table 34, the externalities determined by these two studies present similar values for some countries such as Germany, Sweden and Netherlands; for other countries values highlighted in red in the table vary significantly.

While CASES covers all EU countries including some non-European countries such as Turkey, Brazil, India, and China, ExternE covers only the EU countries listed in Table 34. CASES considers the impacts of pollutants for human health, environment (loss of biodiversity, material, crops), radio nuclides, and GHGs. ExternE also covers public health, impacts on ozone, and materials. The main difference between two studies is the type of pollutants considered. CASES provides more detailed information by considering more pollutants. Besides, CASES project studies more technology specific information on power plants, such as fuel type, carbon capture and storage, and size of plants. In comparison, ExternE considers only fuel types and excludes different technologies.

Both of the projects are based on "Impact Pathway Approach" (Bickel and Friedrich, 2005; CASES, 2008) by accepting "willingness to pay" approach for human health impacts. Marginal external costs for classical air pollutants are calculated for CASES project with the updated EcoSenseWebV1.2 tool. To estimate external costs by transforming impacts that are expressed in different units into a common monetary unit, the ExternE methodology is adapted in CASES. The principal steps can be grouped as follows:

i. Emission: specification of the relevant technologies and pollutants emitted by a power plant at a specific site, for the whole life cycle from construction to dismantling, including fuel extraction and transportation;
ii. Dispersion: calculation of increased pollutant concentrations in all affected regions, using models of atmospheric dispersion;
iii. Impact: calculation of the cumulated exposure from the increased concentration, and calculation of impacts (damage in physical units) of this exposure using an exposure-response function;
iv. Cost: valuation of these impacts in monetary terms.

2.2.3 Base Country Selection

Since ExternE project provides data in terms of ECU/ton of pollutants both for industrial processes and combustion, this project is selected to be used for analysing the cost of damages imposed on society and environment. Income adjustment method is used to transfer and adjust external cost values determined for reference countries. This method assumes that the benefit value in the country studied can be estimated by adjusting the benefit value in the reference country by the ratio of income levels in the two countries and the income elasticity of demand for the environmental good given in equation 3 below.

$$\beta_p = \beta_s \left(\frac{Y_p}{Y_s}\right) \qquad \textit{(Equ. 3)}$$

where (β_p) is the adjusted policy-site benefit; (β_s) is the original benefit estimate in the study-site; (Y_p) and (Y_s) are the income levels; and (β) is the income elasticity of demand for the analyzed environmental good.

In order to adjust the external cost of the reference country to Turkey, GDP at Purchasing Power Parities (PPP) and nominal GDP figures obtained from World Bank (World Bank, 2020) and ExternE are used. For sensitivity analysis, CASES Project which provides results in terms of ECU/kWh of power generated, is also used to calculate externalities and results of the two projects for the same countries are compared. For Purchasing Power Standard, original values given by CASES (CASES, 2008) are used. As seen in Table 34, two projects will generate different results by fuel type for the same country. While some of the externalities estimated for each pollutant have similar results for both studies, some show drastic differences in terms of external cost calculations for the same technology and fuel type. Besides, each country has included different fuel impacts, natural gas, lignite, and hard coal have not been evaluated separately by all of them. Within this frame, Germany has been selected as the reference country for the following reasons:

- Germany is evaluated by both projects
- Both projects report similar results for the same fuel types
- Natural gas, hard coal, and lignite are evaluated separately

Thus, to avoid inconsistencies between the two projects and to be able to assess all fossil fuels, monetary value of impacts evaluated for Germany is adjusted to Turkey.

2.2.4 External Cost per Pollutant

The external costs obtained from ExternE Project have been used for adjustment to Turkey using Equ. 3. For pollutants that are not covered for Germany such as PM, CO, CH_4, and N_2O, Austria is assumed as the reference country since it is the only country that evaluates these pollutants. Additionally, for $PM_{2.5}$ and VOC via Ozone France is used. The calculated external costs for each pollutant are assumed to be the same for all regions of Turkey.

The external cost of CO_2, the main contributor of global warming, lies in a wide range for each country varying between a minimum of 3.8 ECU (€)/ton to a maximum of 139 ECU (€)/ton. Disregarding these outliers, the external cost in the majority of the countries lies in the range of 18-46 ECU (€)/ton. Thus, the midpoint of the range of 18 and 46 is assumed as the reference value to be used for the transfer of the external cost of CO_2 to Turkey.

After determining the reference country, the next step is selecting the appropriate income indicator to be used in the transfer equation; either Purchasing Power Parity (PPP) or nominal GDP. Table 35 and Table 36 show the results of the external costs assumed for Turkey based on nominal GDP and PPP (CIEMAT, 2000; World Bank, 2020). Comparison of the calculation of external costs of pollutants based on income adjustment with PPP is shown in Table 35.

Table 35: ECU (€)/ton of pollutant in terms of PPP based Unit Transfer

Country/Data/Pollutant	AUSTRIA	GERMANY	FRANCE	TURKEY
1995 PPP (current international $)	23,660	23,581	20,745	7,487
2018 PPP (current international $)	56,253	54,327	45,877	28,816
CH_4	155	0	0	49
CO	1,160	0	0	367
CO_2	7	3.8-139	18-46	10
N_2O	2,294	0	0	726
NO_x	16,800	13,173	13,650	4,657
PM	16,800	0	0	5,316
PM_{10}	0	21,610	8,033	6,861
$PM_{2.5}$	0	0	21,500	7,760
SO_x	9,000	12,233	8,433	3,884
VOC via ozone	0	0	930	336

Income adjustment method is also applied based on nominal GDP values of countries to be able to compare the consistency of the estimates. ECU (€)/ton of pollutant for Turkey is assumed as shown in Table 36.

Table 36: ECU (€)/ton of pollutant in terms of nominal GDP based Unit Transfer

Country/Data/Pollutant	AUSTRIA	GERMANY	FRANCE	TURKEY
1995 PPP GDP per capita	23,660	23,581	20,745	7,487
2018 GDP per capita	56,253	54,327	45,877	28,816
SO_x	155	0	0	49
NO_x	1,160	0	0	367
NO_x via ozone	7	3.8-139	18-46	10
PM	2,294	0	0	726
CO	16,800	13,173	13,650	4,657
CO_2	16,800	0	0	5,316
CH_4	0	21,610	8,033	6,861
N_2O	0	0	21,500	7,760
PM_{10}	9,000	12,233	8,433	3,884
$PM_{2.5}$	0	0	930	336
VOC via ozone	9,000	12,233	8,433	3,884

In the CASES Project, the costs of the pollutants by fuel type and technology are provided only for EU-27 countries based on per kWh or power generated as shown in Table 37. Purchasing Power Standard (PPS) of EU27 is given as 0.92 while it is 1.00 for Germany and 0.51 for Turkey.

Table 37: *External cost by pollutant per kWh of electricity, CASES project*

EU-27	Name	Unit	Hard Coal Fuelled Power Plant	Lignite Fuelled Power Plant	NGCC* Power Plant
CO_2	Carbon dioxide, fossil, air, total	Euro Cent	1.602	1.911	0.847
CH_4	Methane, air, total	Euro Cent	0.096	0.006	0.044
N_2O	Dinitrogen monoxide, air, total	Euro Cent	0.022	0.019	0.007
NH_3	Ammonia, air, total	Euro Cent	0.027	0.001	0.000
NMVOC	NMVOC, unspecified origin, air, total	Euro Cent	0.004	0.001	0.009
NO_x	Nitrogen oxides, air, total	Euro Cent	0.669	0.461	0.319
PPMco	Particulates, > 2.5 µm, and < 10µm, total	Euro Cent	0.004	0.003	0.001
$PPM_{2.5}$	Particulates, < 2.5 µm, air, total	Euro Cent	0.043	0.011	0.020
SO_x	Sulphur oxide, air, total	Euro Cent	0.614	0.507	0.125

**NGCC=Natural gas combined cycle*

As mentioned before, the external cost of lignite condensing power plant for Turkey is determined as 3.35 Euro Cent/kWh in CASES Project. In the same project, the external cost closest to this value belongs to Czech Republic with only 2% difference, whose PPS is also 0.51.

Based on the assumptions detailed above, external cost calculations on GDP and PPP basis as well as ExternE and CASES based calculations for power generation are as shown in Table 38.

Table 38: *Comparison of the results developed for Turkey from CASES and ExternE*

Pollutants/GHGs	ExternE GDP- ECU (€)	ExternE PPP- ECU (€)	CASES EU27- ECU (€)	CASES Germany Total- ECU (€)	CASES Czech Rep. Total- ECU (€)
CH_4	25,529	84,543	59,089,637		
CO	3,956,823	13,103,647	0		
CO_2	426,522,854	1,482,851,416	1,490,141,303		
N_2O	2,047,546	1,235,513	15,977,988		
NMVOC	311,506	1,043,259	6,510,280		
NO_x	139,142,953	483,745,062	521,621,516		
PM	144,405,989	502,042,560	0		
PM	42,599,652	141,075,503	0		
PM_{10}	55,580,371	193,230,985	0	NA	NA
$PM_{2.5}$	18,146,673	60,774,748	28,566,305		
So_x	74,067,652	257,503,958	415,357,6130		
TOTAL	906,807,546	3,136,691,193	2,537,264,642	2,859,672,511	5,452,373,025

**NA: Not Available*

As shown in Table 38, GDP based external cost transfer methodology produces irrelevant results, while PPP and PPS based calculations have similarities. Especially, external costs of NO_x and CO_2 show only a slight difference. **Thus, using PPP based unit transfer methodology is chosen for the analysis of external costs of pollutants and GHGs in this study, as presented in Table 35.**

3. Detailed results

3.1 Power Sector Emission Estimates

Table 39: *Uncontrolled regional emissions of major air pollutants and GHGs from lignite power plants, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	246	19	80	0	41	89	0	476
CO	2,674	65	794	0	219	1,092	0	4,844
CO_2	27,441,595	1,727,049	8,536,606	0	4,280,464	10,386,854	0	52,372,568
N_2O	369	28	121	0	62	134	0	714
NMVOC	428	13	127	0	39	190	0	798
NO_x	138,796	1,563	41,129	0	8,291	45,822	0	235,600
PM	1,711,346	54,436	534,453	0	91,802	610,734	0	3,002,771
PM_{10}	519,551	21,034	154,528	0	56,631	262,319	0	1,014,062
$PM_{2.5}$	77,460	3,136	23,039	0	8,443	39,109	0	151,187
SO_x	515,918	12,544	222,468	0	61,557	217,957	0	1,030,445

Table 40: *Uncontrolled regional emissions of major air pollutants and GHGs from hard coal power plants, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	23	164	0	0	216	190	24	617
CO	219	1,693	0	0	2,066	1,822	91	5,891
CO_2	2,174,282	15,596,366	0	0	20,443,579	18,031,081	2,373,014	58,618,322
N_2O	34	246	0	0	324	285	36	925
NMVOC	22	175	0	0	207	182	36	622
NO_x	6,583	43,682	0	0	27,649	35,295	1,088	114,297
PM	40,231	319,642	0	0	431,801	333,949	90,625	1,216,248
PM_{10}	9,253	73,518	0	0	99,314	76,808	20,844	279,737
$PM_{2.5}$	7,250	57,792	0	0	68,273	60,183	11,977	205,475
SO_x	8,558	75,091	0	0	37,131	46,553	54,375	221,709

Table 41: *Uncontrolled regional emissions of major air pollutants and GHGs from natural gas power plants, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	107	40	91	0	324	56	8	626
CO	4,180	1,548	3,544	0	12,650	2,198	315	24,435
CO_2	5,933,917	2,226,522	5,095,464	0	18,188,563	3,160,837	453,345	35,058,649
N_2O	11	4	9	0	32	6	1	63
NMVOC	274	101	232	0	828	144	21	1,600
NO_x	6,966	2,581	5,906	0	21,083	3,664	525	40,725
PM	378	140	321	0	1,144	199	29	2,211
SO_x	30	11	25	0	90	16	2	175

Table 42: *Uncontrolled regional total emissions of major air pollutants and GHGs from fossil fueled power plants, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	376	223	171	0	581	336	32	1,719
CO	7,073	3,307	4,338	0	14,935	5,112	406	35,170
CO_2	35,549,795	19,549,936	13,632,070	0	42,912,606	31,578,772	2,826,359	146,049,539
N_2O	414	278	130	0	418	425	37	1,702
NMVOC	724	289	359	0	1,074	517	57	3,020
NO_x	152,345	47,825	47,035	0	57,023	84,781	1,613	390,623
PM	1,751,955	374,218	534,773	0	524,748	944,882	90,654	4,221,229
PM_{10}	528,804	94,552	154,528	0	155,945	339,128	20,844	1,293,799
$PM_{2.5}$	84,710	60,928	23,039	0	76,716	99,293	11,977	356,662
SO_x	524,506	87,647	222,493	0	98,779	264,525	54,377	1,252,328

Table 43: *Controlled regional emissions of major air pollutants and GHGs from lignite power plants, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	246	19	80	0	41	89	0	476
CO	2,674	65	794	0	219	1,092	0	4,844
CO_2	27,441,595	1,727,049	8,536,606	0	4,280,464	10,386,854	0	52,372,568
N_2O	369	28	121	0	62	134	0	714
NMVOC	428	13	127	0	39	190	0	798
NO_x	34,699	391	10,282	0	2,073	11,455	0	58,900
PM	34,227	1,089	10,689	0	1,836	12,215	0	60,055
PM_{10}	10,391	421	3,091	0	1,133	5,246	0	20,281
$PM_{2.5}$	1,549	63	461	0	169	782	0	3,024
SO_x	25,796	627	11,123	0	3,078	10,898	0	51,522

Table 44: *Controlled regional emissions of major air pollutants and GHGs from hard coal power plants, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	23	164	0	0	216	190	24	617
CO	219	1,693	0	0	2,066	1,822	91	5,891
CO_2	2,174,282	15,596,366	0	0	20,443,579	18,031,081	2,373,014	58,618,322
N_2O	34	246	0	0	324	285	36	925
NMVOC	22	175	0	0	207	182	36	622
NO_x	1,646	10,920	0	0	6,912	8,824	272	28,574
PM	805	6,393	0	0	8,636	6,679	1,813	24,325
PM_{10}	185	1,470	0	0	1,986	1,536	417	5,595
$PM_{2.5}$	145	1,156	0	0	1,365	1,204	240	4,109
SO_x	428	3,755	0	0	1,857	2,328	2,719	11,085

Table 45: *Controlled regional emissions of major air pollutants and GHGs from natural gas power plants, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	107	40	91	0	324	56	8	626
CO	4,180	1,548	3,544	0	12,650	2,198	315	24,435
CO_2	5,933,917	2,226,522	5,095,464	0	18,188,563	3,160,837	453,345	35,058,649
N_2O	11	4	9	0	32	6	1	63
NMVOC	274	101	232	0	828	144	21	1,600
NO_x	1,741	645	1,477	0	5,271	916	131	10,181
PM	378	140	321	0	1,144	199	29	2,211
SO_x	30	11	25	0	90	16	2	175

Table 46: *Controlled regional total emissions of major air pollutants and GHGs from fossil fueled power plants, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	376	223	171	0	581	336	32	1,719
CO	7,073	3,307	4,338	0	14,935	5,112	406	35,170
CO_2	35,549,795	19,549,936	13,632,070	0	42,912,606	31,578,772	2,826,359	146,049,539
N_2O	414	278	130	0	418	425	37	1,702
NMVOC	724	289	359	0	1,074	517	57	3,020
NO_x	38,086	11,956	11,759	0	14,256	21,195	403	97,656
PM	35,410	7,622	11,010	0	11,617	19,093	1,841	86,591
PM_{10}	10,576	1,891	3,091	0	3,119	6,783	417	25,876
$PM_{2.5}$	1,694	1,219	461	0	1,534	1,986	240	7,133
SO_x	26,254	4,393	11,149	0	5,025	13,241	2,721	62,782

3.2 Transport Sector Emission Estimates

Table 47: *Regional road transportation emission estimates of major air pollutants and GHGs, ton*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	623	467	773	358	1,488	618	520	4,847
CO	44,131	33,076	54,807	25,341	105,467	43,791	36,827	343,441
CO_2	10,087,297	7,560,386	12,527,555	5,792,315	24,107,040	10,009,603	8,417,605	78,501,802
N_2O	324	243	402	186	773	321	270	2,518
NMVOC	6,049	4,534	7,512	3,473	14,456	6,002	5,048	47,074
NO_x	39,429	29,552	48,967	22,641	94,228	39,125	32,902	306,843
PM	1,449	1,086	1,799	832	3,462	1,438	1,209	11,275
PM_{10}	2,414	1,809	2,998	1,386	5,769	2,395	2,014	18,785
$PM_{2.5}$	1,961	1,470	2,436	1,126	4,687	1,946	1,637	15,262
SO_x	1,110	832	1,378	637	2,653	1,101	926	8,638
VOC	6,672	5,000	8,286	3,831	15,944	6,620	5,567	51,920

3.2 Transport Sector Emission Estimates

Table 48: *Emissions from the use of hard coal in residential sector, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	1,226	919	1,523	704	2,931	1,217	1,023	9,545
CO	26,015	19,498	32,308	14,938	62,171	25,814	21,709	202,454
CO_2	555,925	416,663	690,411	319,223	1,328,573	551,643	463,906	4,326,344
N_2O	8	6	11	5	20	8	7	66
NMVOC	2,737	2,052	3,399	1,572	6,541	2,716	2,284	21,302
NO_x	460	345	571	264	1,099	456	384	3,579
PM	2,511	1,882	3,118	1,442	6,001	2,492	2,095	19,541
PM_{10}	2,285	1,712	2,837	1,312	5,460	2,267	1,907	17,781
$PM_{2.5}$	2,251	1,687	2,795	1,292	5,379	2,234	1,878	17,517
SO_x	90	67	111	52	214	89	75	698

Table 49: *Emissions from the use of hard coal in commercial buildings sector, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	586	439	728	337	1,401	582	489	4,562
CO	1,819	1,363	2,259	1,045	4,348	1,805	1,518	14,157
CO_2	192,078	143,961	238,544	110,295	459,035	190,598	160,284	1,494,795
N_2O	3	2	4	2	7	3	2	23
NMVOC	174	130	215	100	415	172	145	1,350
NO_x	338	253	420	194	808	335	282	2,631
PM	242	182	301	139	579	240	202	1,886
PM_{10}	229	171	284	131	546	227	191	1,779
$PM_{2.5}$	211	158	262	121	504	209	176	1,642
SO_x	1,759	1,318	2,184	1,010	4,203	1,745	1,468	13,686

Table 50: *Emissions from the use of lignite in residential sector, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	1,126	844	1,398	646	2,690	1,117	939	8,761
CO	17,262	12,937	21,437	9,912	41,252	17,129	14,404	134,333
CO_2	379,003	284,061	470,689	217,631	905,758	376,084	316,269	2,949,496
N_2O	6	4	7	3	13	6	5	44
NMVOC	1,816	1,361	2,256	1,043	4,340	1,802	1,516	14,134
NO_x	413	309	513	237	986	410	344	3,212
PM	1,666	1,249	2,069	957	3,982	1,653	1,390	12,966
PM_{10}	1,516	1,136	1,883	871	3,623	1,504	1,265	11,798
$PM_{2.5}$	1,493	1,119	1,855	858	3,569	1,482	1,246	11,623
SO_x	3,377	2,531	4,194	1,939	8,071	3,351	2,818	26,283

Table 51: *Emissions from the use of lignite in commercial buildings sector, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	8	6	10	5	20	8	7	65
CO	783	587	972	449	1,870	777	653	6,090
CO_2	84,902	63,634	105,441	48,752	202,903	84,248	70,849	660,729
N_2O	1	1	2	1	3	1	1	10
NMVOC	75	56	93	43	178	74	62	581
NO_x	145	109	181	84	348	144	121	1,132
PM	104	78	129	60	249	103	87	811
PM_{10}	98	74	122	56	235	98	82	765
$PM_{2.5}$	91	68	113	52	217	90	76	707
SO_x	757	567	940	434	1,808	751	631	5,888

Table 52: *Emissions from the use of natural gas in residential sector, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	181	146	429	96	1,133	82	113	2,180
CO	1,122	906	2,661	593	7,025	510	702	13,519
CO_2	2,029,985	1,640,178	4,815,178	1,073,747	12,712,117	923,402	1,269,888	24,464,495
N_2O	37	30	88	19.557	232	17	23	446
NMVOC	380	307	901	201	2,379	173	238	4,579
NO_x	2,063	1,666	4,892	1,091	12,916	938	1,290	24,857
SO_x	18	15	43	10	113	8	11	218

Table 53: *Emissions from the use of natural gas in commercial buildings sector, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	89	39	102	11	362	70	18	690
CO	553	240	630	71	2,242	433	110	4,278
CO_2	1,001,350	434,333	1,140,589	127,748	4,057,120	782,941	198,493	7,742,574
N_2O	18	8	21	2	74	14	4	141
NMVOC	187	81	213	24	759	147	37	1,449
NO_x	1,017	441	1,159	130	4,122	796	202	7,867
SO_x	9	4	10	1	36	7	2	69

Table 54: *Regional total emission estimates of residential sector, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	2,533	1,909	3,350	1,446	6,754	2,416	2,076	20,486
CO	44,398	33,342	56,406	25,443	110,448	43,453	36,815	350,306
CO_2	2,964,914	2,340,903	5,976,278	1,610,601	14,946,447	1,851,129	2,050,063	31,740,336
N_2O	51	40	105	28	265	31	35	555
NMVOC	4,933	3,720	6,556	2,816	13,261	4,691	4,037	40,015
NO_x	2,935	2,321	5,976	1,592	15,002	1,804	2,019	31,649
PM	4,177	3,131	5,188	2,399	9,983	4,145	3,486	32,507
PM_{10}	3,801	2,849	4,720	2,182	9,083	3,772	3,172	29,579
$PM_{2.5}$	3,744	2,806	4,650	2,150	8,948	3,716	3,125	29,139
SO_x	3,485	2,613	4,349	2,000	8,399	3,448	2,904	27,199

Table 55: *Regional total emission estimates of residential sector, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	684	484	840	353	1,783	660	514	5,317
CO	3,155	2,190	3,861	1,565	8,460	3,014	2,281	24,526
CO_2	1,278,330	641,928	1,484,574	286,795	4,719,058	1,057,788	429,626	9,898,098
N_2O	22	11	26	5	84	18	7	174
NMVOC	436	267	522	166	1,352	393	244	3,380
NO_x	1,501	804	1,759	407	5,278	1,275	605	11,629
PM	347	260	430	199	828	344	289	2,697
PM_{10}	327	245	406	188	781	324	273	2,545
$PM_{2.5}$	302	226	375	173	721	299	252	2,349
SO_x	2,524	1,889	3,134	1,445	6,047	2,503	2,101	19,643

Table 56: *Overall regional emission estimates of residential and commercial buildings sectors, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	3,217	2,394	4,191	1,799	8,537	3,076	2,590	25,804
CO	47,553	35,532	60,268	27,008	118,908	46,468	39,096	374,832
CO_2	4,243,244	2,982,831	7,460,852	1,897,395	19,665,505	2,908,917	2,479,688	41,638,434
N_2O	74	52	131	32	349	49	42	729
NMVOC	5,369	3,987	7,078	2,982	14,614	5,084	4,282	43,395
NO_x	4,436	3,124	7,736	2,000	20,279	3,079	2,624	43,278
PM	4,524	3,390	5,618	2,598	10,811	4,489	3,775	35,204
PM_{10}	4,128	3,094	5,126	2,370	9,865	4,096	3,445	32,123
$PM_{2.5}$	4,046	3,033	5,025	2,323	9,670	4,015	3,376	31,488
SO_x	6,009	4,502	7,482	3,446	14,446	5,951	5,005	46,841

3.4 Petroleum Refining Emission Estimates

Table 57: *Uncontrolled regional emission estimates of petroleum refining, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	66	0	30	0	66	0	7	169
CO	789	0	358	0	789	0	79	2,015
CO_2	2,307,832	0	1,049,015	0	2,307,832	0	230,783	5,895,463
N_2O	37	0	17	0	37	0	4	95
NMVOC	83	0	38	0	83	0	8	211
NO_x	5,362	0	2,437	0	5,362	0	536	13,698
PM	452	0	205	0	452	0	45	1,154
SO_x	14,394	0	6,543	0	14,394	0	1,439	36,770

Table 58: *Controlled regional emission estimates of petroleum refining, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	66	0	30	0	66	0	7	169
CO	789	0	358	0	789	0	79	2,015
CO_2	2,307,832	0	1,049,015	0	2,307,832	0	230,783	5,895,463
N_2O	37	0	17	0	37	0	4	95
NMVOC	83	0	38	0	83	0	8	211
NO_x	1,341	0	609	0	1,341	0	134	3,424
PM	9	0	4	0	9	0	1	23
SO_x	720	0	327	0	720	0	72	1,839

3.5 Cement Industry Emission Estimates

Table 59: *Uncontrolled process emissions released by cement production, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CO	15,750	20,219	31,270	12,860	47,701	49,746	11,923	189,469
CO_2	2,481,766	3,802,367	5,452,715	2,619,999	8,247,529	7,127,807	2,209,442	31,941,623
NO_x	15,564	19,979	30,900	12,708	47,135	49,156	11,782	187,223
PM	59,834	91,672	131,461	63,166	198,842	171,846	53,268	770,089
PM_{10}	58,949	90,318	129,518	62,233	195,903	169,307	52,481	758,708
$PM_{2.5}$	32,422	49,675	71,235	34,228	107,747	93,119	28,864	417,290
SO_x	34,613	44,433	68,721	28,262	104,829	109,322	26,203	416,383
VOC	437	561	867	357	1323	1379	331	5,253

Table 60: *Cement industry fuel combustion based uncontrolled emissions, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	117	179	257	123	389	336	104	1,505
CO	576	883	1,266	608	1,915	1,655	513	7,418
CO_2	1,871,317	2,867,085	4,111,492	1,975,549	6,218,855	5,374,555	1,665,978	24,084,831
N_2O	28	43	62	30	94	81	25	363
NMVOC	125	191	274	132	414	358	111	1,604
NO_x	3,315	5,080	7,284	3,500	11,018	9,522	2,952	42,672
PM	45,965	70,424	100,991	48,525	152,754	132,015	40,921	591,596
PM_{10}	11,540	17,681	25,356	12,183	38,352	33,145	10,274	148,531
$PM_{2.5}$	5,365	8,220	11,787	5,664	17,829	15,408	4,776	69,048
SO_x	14,045	21,518	30,858	14,827	46,674	40,338	12,504	180,763

Table 61: *Uncontrolled regional major air pollutant and GHG emission estimates of cement industry (combustion + processes), tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	117	179	257	123	389	336	104	1,505
CO	16,326	21,102	32,536	13,468	49,616	51,401	12,436	196,887
CO_2	4,353,083	6,669,452	9,564,207	4,595,548	14,466,384	12,502,362	3,875,420	56,026,454
N_2O	28	43	62	30	94	81	25	363
NMVOC	125	191	274	132	414	358	111	1,604
NO_x	18,879	25,059	38,184	16,208	58,153	58,678	14,734	229,895
PM	105,799	162,096	232,452	111,691	351,596	303,861	94,189	1,361,685
PM_{10}	70,489	107,999	154,874	74,416	234,255	202,452	62,755	907,239
$PM_{2.5}$	37,787	57,895	83,022	39,892	125,576	108,527	33,640	486,338
SO_x	48,658	65,951	99,579	43,089	151,503	149,660	38,707	597,146
VOC	437	561	867	357	1,323	1,379	331	5,253

Table 62: *Controlled fuel combustion based regional major air pollutant and GHG emission estimates of cement industry, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	117	179	257	123	389	336	104	1,505
CO	576	883	1,266	608	1,915	1,655	513	7,418
CO_2	1,871,317	2,867,085	4,111,492	1,975,549	6,218,855	5,374,555	1,665,978	24,084,831
N_2O	28	43	62	30	94	81	25	363
NMVOC	125	191	274	132	414	358	111	1,604
NO_x	829	1,270	1,821	875	2,755	2,381	738	10,668
PM	919	1,408	2,020	971	3,055	2,640	818	11,832
PM_{10}	211	323	464	223	701	606	188	2,716
$PM_{2.5}$	96	147	210	101	318	275	85	1,231
SO_x	636	975	1,398	672	2,114	1,827	566	8,188

Table 63: *Controlled process based regional major air pollutant and GHG emission estimates of cement industry, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CO	15,750	20,219	31,270	12,860	47,701	49,746	11,923	189,469
CO_2	2,481,766	3,802,367	5,452,715	2,619,999	8,247,529	7,127,807	2,209,442	31,941,623
N_2O	3,891	4,995	7,725	3,177	11,784	12,289	2,945	46,806
NMVOC	1,197	1,833	2,629	1,263	3,977	3,437	1,065	15,402
NO_x	1,179	1,806	2,590	1,245	3,918	3,386	1,050	15,174
PM	648	993	1,425	685	2,155	1,862	577	8,346
PM_{10}	1,731	2,222	3,436	1,413	5,241	5,466	1,310	20,819
$PM_{2.5}$	437	561	867	357	1,323	1,379	331	5,253
SO_x	48,658	65,951	99,579	43,089	151,503	149,660	38,707	597,146
VOC	437	561	867	357	1,323	1,379	331	5,253

Table 64: *Controlled total regional major air pollutant and GHG emission estimates of cement industry (combustion + processes), tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	117	179	257	123	389	336	104	1,505
CO	16,327	21,102	32,537	13,469	49,616	51,401	12,436	196,888
CO_2	4,353,083	6,669,452	9,564,207	4,595,547	14,466,384	12,502,362	3,875,419	56,026,454
N_2O	28	43	62	30	94	81	25	363
NMVOC	125	191	274	132	414	358	111	1,604
NO_x	4,720	6,265	9,546	4,052	14,538	14,670	3,683	57,474
PM	2,116	3,242	4,649	2,234	7,032	6,077	1,884	27,234
PM_{10}	1,390	2,130	3,054	1,467	4,619	3,992	1,237	17,890
$PM_{2.5}$	744	1,140	1,635	786	2,473	2,137	662	9,577
SO_x	2,367	3,196	4,834	2,085	7,356	7,293	1,876	29,007
VOC	437	561	867	357	1,323	1,379	331	5,253

3.6 Iron and Steel Production Emission Estimates

Table 65: *Uncontrolled process emissions of coke production, tons*

Plant Name	PM	CO	SO_x	VOC	NH_3	CH_4	NO_x	CO_2
Kardemir	9,525	9,525	478	7,206	12	120	992	669,235
Erdemir	10,477	10,477	526	7,927	13	131	1,091	736,158
İsdemir	14,423	14,423	724	10,912	18	181	1,502	1,013,413
TOTAL	34,425	34,425	1,728	26,045	43	432	3,585	2,418,806

Table 66: *Uncontrolled process emissions of integrated steelworks, tons (Alyüz, 2012)*

Plant Name	PM	CO	SO_x	NO_x	CO_2
Kardemir	93,280	95,871	3,783	1,166	4,951,613
Erdemir	102,608	105,458	4,161	1,283	5,446,775
İsdemir	141,253	145,176	5,729	1,766	7,498,157
TOTAL	337,141	346,506	13,673	4,214	17,896,545

Table 67: *Uncontrolled regional emissions for electrical arc furnaces, tons*

Plant Name	NO_x	CO	NMVOC	SO_x	PM	CO_2
Marmara	1,034	21,765	5,006	2,177	136,033	435,307
Aegean	1,589	33,462	7,696	3,346	209,140	669,247
Mediterranean	1,505	31,686	7,288	3,169	198,035	633,712
Black Sea	1,182	24,875	5,721	2,487	155,467	497,493
TOTAL	5,310	111,788	25,711	11,179	698,675	2,235,759

Table 68: *Uncontrolled fuel-based emissions by region, tons*

Plant Name	Marmara	Aegean	Mediterranean	Black Sea	TOTAL
CH_4	15	23	33	32	103
CO	410	631	893	880	2.814
CO_2	1.146.116	1.762.056	2.494.947	2.455.963	7.859.082
N_2O	12	19	27	27	85
NMVOC	34	52	74	73	233
NO_x	2.410	3.705	5.246	5.164.902	16.524
PM	39.286	60.754	86.024	84.183	270.975
PM_{10}	9.030	13.883	19.657	19.350	61.920
$PM_{2.5}$	5.189	7.977	11.295	11.119	35.579
SO_x	11.958	18.384	26.031	25.624	81.997

Table 69: *Uncontrolled regional emission estimates of steel production (process + combustion), tons*

Plant Name	Aegean Region	Black Sea	Marmara	Mediterranean	TOTAL
CH_4	23	32	266	214	535
CO	34.093	227.083	42.178	192.178	495.533
CO_2	2.431.303	13.351.845	2.986.816	11.640.229	30.410.193
N_2O	19	26	12	27	85
NO_x	5.294	8.794	5.527	10.019	29.634
NMVOC	7.749	5.794	5.040	7.362	25.944
PM	269.537	435.538	195.321	439.230	1.339.626
PM_{10}	13.883	19.350	9.030	19.657	61.920
$PM_{2.5}$	7.977	11.119	5.189	11.295	35.579
SO_2	0	0	0	0	0
SO_x	21.731	36.056	15.138	35.652	108.577
TSP	356	496	231	504	1.588
VOC	0	0	15.133	10.912	26.045
NH_3	0	0	25	18	43

Table 70: *Controlled fuel combustion based regional emission estimates of steel production, tons*

Pollutant/GHG (ton	Aegean Region	Black Sea	Marmara	Mediterranean	TOTAL
CH_4	23	32	15	33	103
CO	631	879	410	893	2.814
CO_2	1.762.056	2.455.963	1.146.116	2.494.947	7.859.082
N_2O	19	26	12	27	85
NO_x	926	1.291	602	1.311	4.131
NMVOC	52	73	34	74	233
PM	1.208	1.684	786	1.710	5.388
PM_{10}	278	387	181	393	1.238
$PM_{2.5}$	160	222	104	226	712
SO_2	0	0	0	0	0
SO_x	919	1.281	598	1.302	4.100
TSP	7	10	5	10	32

Table 71: *Controlled process based regional emission estimates of steel production, tons*

Pollutant/GHG (ton	Aegean Region	Black Sea	Marmara	Mediterranean	TOTAL
CH_4	0	0	251	181	432
CO	33.462	226.204	41.767	191.285	492.718
CO_2	669.247	10.895.881	1.840.700	9.145.282	22.551.110
NO_x	397	908	779	1.193	3.277
NMVOC	7.696	5.721	5.006	7.288	25.711
PM	4.183	7.027	3.121	7.074	21.405
SO_x	167	522	159	481	1.329
TSP	0	0	0	0	0
VOC	0	0	15.133	10.912	26.045
NH_3	0	0	25	18	43

Table 72: *Controlled total regional emission estimates of steel production (process + combustion), tons*

Pollutant/GHG (ton	Aegean Region	Black Sea	Marmara	Mediterranean	TOTAL
CH_4	23	32	266	214	535
CO	34.093	227.083	42.178	192.178	495.533
CO_2	2.431.303	13.351.845	2.986.816	11.640.229	30.410.193
N_2O	19	26	12	27	85
NO_x	1.324	2.198	1.382	2.505	7.408
NMVOC	7.749	5.794	5.040	7.362	25.944
PM	5.391	8.711	3.906	8.785	26.793
PM_{10}	278	387	181	393	1.238
$PM_{2.5}$	160	222	104	226	712
SO_2	0	0	0	0	0
SO_x	1.087	1.803	757	1.783	5.429
TSP	7	10	5	10	32
VOC	0	0	15.133	10.912	26.045
NH_3	0	0	25	18	43

3.7 Ceramic Production Emission Estimates

Table 73: *Uncontrolled emissions caused by ceramic coating production, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
Fluoride	248	105	282	0	897	0	0	1,532
HF	204	86	231	0	737	0	0	1,258
VOC	191	80	216	0	689	0	0	1,176

Table 74: *Uncontrolled emissions caused by sanitary ware manufacturing, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
Fluoride	16	7	18	0	58	0	0	99
HF	13	6	15	0	47	0	0	81
VOC	13	5	14	0	45	0	0	77

Table 75: *Regional distribution of total uncontrolled process-based emissions of ceramic industry, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
Fluoride	264	111	300	0	954	0	0	1,630
HF	217	91	246	0	784	0	0	1,339
VOC	203	86	231	0	734	0	0	1,253

Table 76: *Regional distribution of uncontrolled fuel-based emissions, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	7	3	8	0	25	0	0	43
CO	245	103	277	0	883	0	0	1,507
CO_2	437,174	184,020	495,709	0	1,577,759	0	0	2,694,662
N_2O	2	1	2	0	7	0	0	13
NMVOC	17	7	19	0	61	0	0	104
NO_x	758	319	859	0	2,735	0	0	4,671
PM	7,957	3,349	9,023	0	28,718	0	0	49,047
PM_{10}	1,875	789	2,126	0	6,766	0	0	11,556
$PM_{2.5}$	360	152	409	0	1,301	0	0	2,222
SO_x	1,795	756	2,036	0	6,480	0	0	11,067

Table 77: *Uncontrolled regional emission estimates of ceramic industry (process + combustion), tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	7	3	8	0	25	0	0	43
CO	245	103	277	0	883	0	0	1,507
CO_2	437,174	184,020	495,709	0	1,577,759	0	0	2,694,662
Fluoride	264	111	300	0	954	0	0	1,630
HF	217	91	246	0	784	0	0	1,339
N_2O	2	1	2	0	7	0	0	13
NMVOC	17	7	19	0	61	0	0	104
NO_x	758	319	859	0	2,735	0	0	4,671
PM	7,957	3,349	9,023	0	28,718	0	0	49,047
PM_{10}	1,875	789	2,126	0	6,766	0	0	11,556
$PM_{2.5}$	360	152	409	0	1,301	0	0	2,222
SO_x	1,795	756	2,036	0	6,480	0	0	11,067
VOC	203	86	231	0	734	0	0	1,253

Table 78: *Controlled fuel combustion based regional emission estimates of ceramic industry, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	7	3	8	0	25	0	0	43
CO	245	103	277	0	883	0	0	1,507
CO_2	437,174	184,020	495,709	0	1,577,759	0	0	2,694,662
N_2O	2	1	2	0	7	0	0	13
NMVOC	17	7	19	0	61	0	0	104
NO_x	189	80	215	0	684	0	0	1,168
PM	159	67	180	0	574	0	0	981
PM_{10}	37	16	43	0	135	0	0	231
$PM_{2.5}$	7	3	8	0	26	0	0	44
SO_x	90	38	102	0	324	0	0	553

Table 79: *Controlled total regional emission estimates of ceramic industry (process + combustion), tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	7	3	8	0	25	0	0	43
CO	245	103	277	0	883	0	0	1,507
CO_2	437,174	184,020	495,709	0	1,577,759	0	0	2,694,662
Fluoride	264	111	300	0	954	0	0	1,630
HF	217	91	246	0	784	0	0	1,339
N_2O	2	1	2	0	7	0	0	13
NMVOC	17	7	19	0	61	0	0	104
NO_x	189	80	215	0	684	0	0	1,168
PM	159	67	180	0	574	0	0	981
PM_{10}	37	16	43	0	135	0	0	231
$PM_{2.5}$	7	3	8	0	26	0	0	44
SO_x	90	38	102	0	324	0	0	553
VOC	203	86	231	0	734	0	0	1,253

3.8 Textile and Leather Production Emission Estimates

Table 80: *Uncontrolled regional emission estimates of the textile industry, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	10	4	11	2	34	6	4	70
CO	253	106	287	42	912	155	95	1,849
CO_2	720,905	303,452	817,430	121,198	2,601,744	441,905	269,667	5,276,302
N_2O	7	3	8	1	24	4	2	48
NMVOC	20	9	23	3	74	12	8	149
NO_x	1,873	789	2,124	315	6,761	1,148	701	13,711
PM	32,709	13,768	37,089	5,499	118,048	20,050	12,236	239,400
PM_{10}	7,719	3,249	8,752	1,298	27,857	4,731	2,887	56,493
$PM_{2.5}$	1,534	646	1,740	258	5,538	941	574	11,231
SO_x	7,463	3,141	8,462	1,255	26,935	4,575	2,792	54,623

Table 81: *Controlled regional emission estimates of the textile industry, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	10	4	11	2	34	6	4	70
CO	253	106	287	42	912	155	95	1,849
CO_2	720,905	303,452	817,430	121,198	2,601,744	441,905	269,667	5,276,302
N_2O	7	3	8	1	24	4	2	48
NMVOC	20	9	23	3	74	12	8	149
NO_x	468	197	531	79	1,690	287	175	3,428
PM	654	275	742	110	2,361	401	245	4,788
PM_{10}	154	65	175	26	557	95	58	1,130
$PM_{2.5}$	31	13	35	5	111	19	11	225
SO_x	373	157	423	63	1,347	229	140	2,731

3.9 Food Industry Emission Estimates

Table 82: *Uncontrolled emissions of food industry due to fuel consumption, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	10	4	11	2	35	6	4	71
CO	287	121	325	48	1,036	176	107	2,101
CO_2	685,778	288,665	777,600	115,293	2,474,970	420,373	256,527	5,019,205
N_2O	6	2	6	1	20	3	2	40
NMVOC	22	9	25	4	79	13	8	160
NO_x	1,529	644	1,734	257	5,519	937	572	11,192
PM	23,596	9,932	26,755	3,967	85,157	14,464	8,826	172,698
PM_{10}	5,535	2,330	6,276	931	19,976	3,393	2,070	40,510
$PM_{2.5}$	1,458	614	1,653	245	5,262	894	545	10,670
SO_x	5,709	2,403	6,474	960	20,605	3,500	2,136	41,787

Table 83: *Controlled emissions of food industry due to fuel consumption, tons*

Pollutants / GHGs	Aegean	Black Sea	Central Anatolia	Eastern Anatolia	Marmara	Mediterranean	South Eastern Anatolia	TOTAL
CH_4	10	4	11	2	35	6	4	71
CO	287	121	325	48	1,036	176	107	2,101
CO_2	685,778	288,665	777,600	115,293	2,474,970	420,373	256,527	5,019,205
N_2O	6	2	6	1	20	3	2	40
NMVOC	22	9	25	4	79	13	8	160
NO_x	382	161	433	64	1,380	234	143	2,798
PM	472	199	535	79	1,703	289	177	3,454
PM_{10}	111	47	126	19	400	68	41	810
$PM_{2.5}$	29	12	33	5	105	18	11	213
SO_x	285	120	324	48	1,030	175	107	2,089

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Appendix 1: Iron and Steel Production Emission Estimates

Table 84: *Uncontrolled process emissions of coke production, tons*

Plant Name	PM	CO	SO_x	VOC	NH_3	CH_4	NO_x	CO_2
Kardemir	9,525	9,525	478	7,206	12	120	992	669,235
Erdemir	10,477	10,477	526	7,927	13	131	1,091	736,158
İsdemir	14,423	14,423	724	10,912	18	181	1,502	1,013,413
TOTAL	34,425	34,425	1,728	26,045	43	432	3,585	2,418,806

Table 85: *Uncontrolled process emissions of integrated steelworks, tons (Alyüz, 2012)*

Plant Name	PM	CO	SO_x	NO_x	CO_2
Kardemir	93,280	95,871	3,783	1,166	4,951,613
Erdemir	102,608	105,458	4,161	1,283	5,446,775
İsdemir	141,253	145,176	5,729	1,766	7,498,157
TOTAL	337,141	346,506	13,673	4,214	17,896,545

Table 86: *Uncontrolled regional emissions for electrical arc furnaces, tons*

Plant Name	NO_x	CO	NMVOC	SO_x	PM	CO_2
Marmara	1,034	21,765	5,006	2,177	136,033	435,307
Aegean	1,589	33,462	7,696	3,346	209,140	669,247
Mediterranean	1,505	31,686	7,288	3,169	198,035	633,712
Black Sea	1,182	24,875	5,721	2,487	155,467	497,493
TOTAL	5,310	111,788	25,711	11,179	698,675	2,235,759

Table 87: *Uncontrolled fuel-based emissions by regions, tons*

Plant Name	Marmara	Aegean	Mediterranean	Black Sea	TOTAL
CH_4	15	23	33	32	103
CO	410	631	893	880	2.814
CO_2	1.146.116	1.762.056	2.494.947	2.455.963	7.859.082
N_2O	12	19	27	27	85
NMVOC	34	52	74	73	233
NO_x	2.410	3.705	5.246	5.164.902	16.524
PM	39.286	60.754	86.024	84.183	270.975
PM_{10}	9.030	13.883	19.657	19.350	61.920
$PM_{2.5}$	5.189	7.977	11.295	11.119	35.579
SO_x	11.958	18.384	26.031	25.624	81.997

Table 88: *Uncontrolled regional emission estimates of steel production (process + combustion), tons*

Plant Name	Aegean Region	Black Sea	Marmara	Mediterranean	TOTAL
CH_4	23	32	266	214	535
CO	34.093	227.083	42.178	192.178	495.533
CO_2	2.431.303	13.351.845	2.986.816	11.640.229	30.410.193
N_2O	19	26	12	27	85
NO_x	5.294	8.794	5.527	10.019	29.634
NMVOC	7.749	5.794	5.040	7.362	25.944
PM	269.537	435.538	195.321	439.230	1.339.626
PM_{10}	13.883	19.350	9.030	19.657	61.920
$PM_{2.5}$	7.977	11.119	5.189	11.295	35.579
SO_2	0	0	0	0	0
SO_x	21.731	36.056	15.138	35.652	108.577
TSP	356	496	231	504	1.588
VOC	0	0	15.133	10.912	26.045
NH_3	0	0	25	18	43

Table 89: *Controlled fuel combustion based regional emission estimates of steel production, tons*

Pollutant/GHG (ton	Aegean Region	Black Sea	Marmara	Mediterranean	TOTAL
CH_4	23	32	15	33	103
CO	631	879	410	893	2.814
CO_2	1.762.056	2.455.963	1.146.116	2.494.947	7.859.082
N_2O	19	26	12	27	85
NO_x	926	1.291	602	1.311	4.131
NMVOC	52	73	34	74	233
PM	1.208	1.684	786	1.710	5.388
PM_{10}	278	387	181	393	1.238
$PM_{2.5}$	160	222	104	226	712
SO_2	0	0	0	0	0
SO_x	919	1.281	598	1.302	4.100
TSP	7	10	5	10	32

Table 90: *Controlled process based regional emission estimates of steel production, tons*

Pollutant/GHG (ton	Aegean Region	Black Sea	Marmara	Mediterranean	TOTAL
CH_4	0	0	251	181	432
CO	33.462	226.204	41.767	191.285	492.718
CO_2	669.247	10.895.881	1.840.700	9.145.282	22.551.110
NO_x	397	908	779	1.193	3.277
NMVOC	7.696	5.721	5.006	7.288	25.711
PM	4.183	7.027	3.121	7.074	21.405
SO_x	167	522	159	481	1.329
TSP	0	0	0	0	0
VOC	0	0	15.133	10.912	26.045
NH_3	0	0	25	18	43

Table 91: *Controlled total regional emission estimates of steel production (process + combustion), tons*

Pollutant/GHG (ton	Aegean Region	Black Sea	Marmara	Mediterranean	TOTAL
CH_4	23	32	266	214	535
CO	34.093	227.083	42.178	192.178	495.533
CO_2	2.431.303	13.351.845	2.986.816	11.640.229	30.410.193
N_2O	19	26	12	27	85
NO_x	1.324	2.198	1.382	2.505	7.408
NMVOC	7.749	5.794	5.040	7.362	25.944
PM	5.391	8.711	3.906	8.785	26.793
PM_{10}	278	387	181	393	1.238
$PM_{2.5}$	160	222	104	226	712
SO_2	0	0	0	0	0
SO_x	1.087	1.803	757	1.783	5.429
TSP	7	10	5	10	32
VOC	0	0	15.133	10.912	26.045
NH_3	0	0	25	18	43

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