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Investigation of a NO_x emission from coal power plants in Texas, United States and its impact on the environment

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ABSTRACT

Texas is the largest state by area in the US after Alaska, and one of the top states in the production and consumption of electricity with many coal-fired plants. Coal-fired power plants emit greater than 70% of pollutants in the energy sector. When coal is burned to produce electricity, nitrogen oxides (NO_x) are released into the air, one of the main pollutants that threaten human health and lead to a large number of premature deaths. The key to effective air quality management is the strict compliance of all plants with emission standards. However, not all Texas coal plants have the environmental equipment to lower pollutant emissions. Nitrogen dioxide (NO₂) observations from the Tropospheric Monitoring Instrument (TROPOMI) were used to evaluate the emissions for Texas power plants. Data from both the Emissions and Generation Resource Integrated Database (EGRID) and the Emissions Database for Global Atmospheric Research (EDGAR) were used to examine emissions. It was found that NO_x emissions for Texas power plants range from 1.53 kt/year to 10.99 kt/year, with the Martin Lake, Limestone and Fayette Power Project stations being the top emitters. WA Parish and Martin Lake stations have the strongest NO_x fluxes, with both exhibiting significant seasonal variability. Comparisons of bottom-up inventories for EDGAR and EGRID show a high correlation ($r=0.956$) and a low root mean square error (0.766). A more reasonable control policy would lead to much reduced NO_x emissions.

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1. Introduction

Texas leads the United States in total residential energy consumption. Coal is one of three main energy sources used in the production of electricity. Coal-fired power plants, currently account for about a third of global electricity production. They represent one of the main sources of pollutant emissions in the global power industry (Tain XL et al., 2022).

The most harmful emissions from burning coal are sulfur dioxide (SO₂), nitrogen oxides (NO_x), carbon monoxide (CO), particulate matter (PM) and greenhouse gases, as well as ash (Tong D et al., 2018; Kumar A et al., 2022; Uddin MS and Czajkowski KP, 2022). Other important emissions include

heavy metals, hydrogen fluoride, halides, unburned hydrocarbon particles, and non-methane volatile organic compounds (NMVOCs).

Nitrogen oxides (NO_x=NO+NO₂) are major air pollutants in large urban and industrial agglomerations (de Foy B and Schauer JJ, 2022). They result mainly from the combustion of fuels in all types of motor vehicles and from electricity generation (Yu Q et al., 2021). NO_x plays an important role in tropospheric photochemistry as precursors of tropospheric ozone (O₃) and nitrate aerosols (Cichowicz R et al., 2020). In all combustion processes, nitrogen monoxide (NO) is primarily emitted, which is then further oxidized in air to NO₂ (Ibusuki T and Takeuchi K, 1994). Nitric acid can be formed from NO₂, which accounts for up to a third of the total acids involved in the formation of acid rain (Liu Y et al., 2021). Under the influence of sunlight, NO_x reacts with dangerous photooxidants, including O₃ and the more toxic peroxyacetyl nitrate (Laufs S et al., 2010). The absorption of solar radiation by NO₂ and O₃, as well as its scattering by aerosols, have a direct effect on the radiation balance of the atmosphere (Li J

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et al., 2022). Aerosols also affect the radiation balance by changing cloud albedo and cloud lifetime (Rap A et al., 2013; Liu LX et al., 2020; Wang C et al., 2021).

Nitrogen dioxide (NO₂) is an important trace gas component that is involved in anthropogenic ozone generation and destruction cycles. Chemical transformations of NO₂ in the upper-atmosphere are important factors in the dynamics of the atmosphere and energy transfer processes. NO₂ has well-defined absorption bands in the 405–465 nm wavelength range which, in the presence of even insignificant amounts, makes it possible to confidently measure NO₂ using differential optical absorption spectroscopy (DOAS) (van Geffen JHGM et al., 2015).

Previous studies conducted in different regions of the world examined emissions of various types of pollutants including greenhouse gases from coal power generation and associated changes in air quality (Oberschelp C et al., 2019; Strasert B et al., 2019) and the impact on human health (Kim C et al., 2020). Epidemiological studies have provided evidence that prolonged exposure to NO₂ can cause respiratory distress by attacking mucous membranes, leading to bronchitis and emphysema (Dons E et al., 2018; Kim C et al., 2020). Residents of large, industrial cities are at particular risk of NO₂ poisoning since NO₂ is an important trace gas component that is involved in the anthropogenic ozone generation and destruction cycles. In these cities, the concentration of a toxic substance most often exceeds the permissible limits.

An increase in the share of coal in the fuel balance for power plants without the implementation of measures to reduce pollutant emissions can lead to an increase in the negative effects of coal-fired power plants on the environment. Therefore, it is important to analyze the impact of coal-fired power plants on the environment and determine the effectiveness of mitigation methods for reducing their harmful effects. When analyzing the possibilities for energy development of a country or region, it is important to use methodological approaches that allow a comprehensive assessment of the advantages and disadvantages of various generating technologies. This paper investigates the impact of selective catalytic reduction (SCR), a pollution control device, on NO_x emissions from coal-fired power plants in Texas. Data from bottom-up inventories and satellite remote sensing are used resulting in an integrated approach to assess the amount of NO_x emissions from coal-fired plants.

2. Data and methods

The TROPospheric Monitoring Instrument (TROPOMI) is the main instrument of the Sentinel-5 Precursor (Sentinel-5P) satellite, launched by the European Space Agency in October 2017. The main purpose of this radiometer is to monitor the content of aerosols and various gases in the ultraviolet (UV), UV-visible (UV-VIS), near-infrared (NIR) and short-wavelength infrared (SWIR) spectral regions. The spatial resolution is 3.5×7 km² (increased to 3.5×5.6 km² on 6

August 2019) with swath across-track of about 2600 km. The TROPOMI NO₂ retrieval algorithm utilizes the bands of the ultraviolet-near infrared spectrometer (405–465 nm). This research used the NO₂ Level 2 data product with a qa_value greater than 0.75. According to van Geffen JHGM et al. (2019), a qa_value ≥ 0.75 does not contain clouds (cloud radiance fraction <0.5), snow/ice, errors or problematic readings. The tropospheric NO₂ column from the TROPOMI Level 2 data were obtained from the Sentinel-5P Pre-Operations Data Hub.

The Emissions Database for the Global Atmospheric Research (EDGAR) version 6.1 is a global air pollutant emission inventory providing global emissions for greenhouse gases, air pollutants, and aerosols with high spatial resolutions of 0.1°×0.1° (Crippa M et al., 2018). The source sectors provided are energy, aviation, industry, ground transport, agriculture, waste, and other anthropogenic sources.

The Emissions and Generation Resource Integrated Database (EGRID) is published by the US Environmental Protection Agency (EPA) (EPA, 2022a). It contains information about the characteristics of almost every power plant or boiler in the country, and focuses on the measured emissions from each. EGRID collects data on CO₂, NO_x, SO₂, N₂O, CH₄ and mercury emissions.

The National Electric Energy Data System (NEEDS) v6 by EPA contains information on all generating installations in the country (EPA, 2022b). This data includes basic geographic data, operational data, air emissions data and installed environmental equipment data.

Air temperature, wind speed and direction were obtained from NASA's Prediction of Worldwide Energy Resources (POWER) reanalysis. These data are available on a daily and monthly time scale with a spatial coverage of 0.5°×0.5°. The advantage of NASA-POWER data is in the wide spatial coverage. As a result, various kinds of solar and meteorological data for the study area can be obtained at high spatial resolutions.

3. Results and discussion

Texas is a large state with rich energy resources. It is the country's leader in energy production. In 2020, it generated almost 25% (473.37 GWh) of all energy produced in the country while having only about 9% of US population. Texas' rich natural resources, including natural gas, oil, coal, and wind, are readily available to power plants. The rich natural resources of Texas are distributed in much of the state. Due to its location and climatic conditions, Texas is also one of the leaders in the number of renewable energy sources, ranking among the top states in wind and solar power generation.

Initially, power plants produced electricity mainly from coal or hydroelectric power. However, while the state still generates electricity from coal, electricity generation is gradually shifting to natural gas as well as renewable sources. Through a combination of conditions, all types of energy production are present in Texas. The total generating capacity

of the state in megawatts (MW) is 209807.8 MW, of which coal, natural gas and renewable energy (including solar, wind and hydropower energy) account for more than 90%. Of the total energy capacity, 50.4% is from natural gas, 28.2% is renewable and 14.9% is from coal. For electricity production in 2020, 51.2% (242.48 GWh) of Texas' electricity was generated by natural gas-fired power plants. Coal-fired power plants were at 16.9% (80.22 GWh) and renewable sources accounted for 21.5% (102 GWh, including wind at 92.4 GWh, solar at 8.55 GWh and hydro power with 1.05 GWh). However, although coal plants do not dominate the state's electricity generation, they are one of the main sources of emissions for various types of pollutants into the atmosphere.

Fig. 1 shows the 15 coal-fired power plants in Texas as of August 2021. Three of the state's active coal-fired power plants are scheduled to close: Pirkey in 2023, JT Deely in 2024 and Coletto Creek in 2027. The state is home to some of the country's largest coal-fired power plants, WA Parish (4008.4 MW), Martin Lake (3179.6 MW) and Oak Grove (1795.4 MW), which are also the largest emitters of air pollutants. The pollutions from these power plants have a huge impact on the environment.

In 2020, the most climate-polluting coal-fired power plants in Texas accounted for more than 70% of global warming and overall air pollution-related emissions from the state's energy sector, despite the fact that these plants generated only 16.9% of the state's total electricity. In 2020, the most polluting coal-fired power plants in Texas accounted for more than 70% of the state's energy sector global warming and overall air pollution-related emissions, despite

the fact that these plants generated only 16.9% of the state's total electricity. Air pollution from coal-fired power plants is mainly associated with emissions of flue gases generated by the combustion of fossil fuels in power plant boilers. Moreover, coal-fired power plants account for more than 80% (Table 1) of the total emissions in the energy sector of such greenhouse gases as methane (CH₄) and nitrous oxide (N₂O). More than 97% of SO₂ emissions also come from coal-fired plants, a major source of anthropogenic SO₂ emissions, contributing to the formation of acid rain.

When fuel is burned at coal plants, combustion byproducts are generated. Pollutants emissions from power plant affect the biosphere of the area where the enterprise is located, undergo various transformations and interactions, and are also deposited, washed away by precipitation, and enter the soil and water bodies. The main components formed as a result of coal combustion are dust particles of various compositions, SO₂, NO_x, fluoride compounds, metal oxides, and gaseous products of incomplete combustion of fuel. Their entry into the air causes great damage to all the main components of the biosphere, as well as to enterprises, urban facilities, transport and the population of cities. The presence of dust particles and SO₂ is due to the content of mineral impurities in the fuel, and the presence of NO_x is due to the partial oxidation of air nitrogen in a high-temperature flame.

Satellite systems are currently actively used to monitor regional tropospheric vertical column densities (VCD) of NO₂ (Hilboll A et al., 2013; Prunet P et al., 2020; Beirle S et al., 2021; Marais E et al., 2021). This data allows for the study of the characteristic features of tropospheric NO₂ content and its

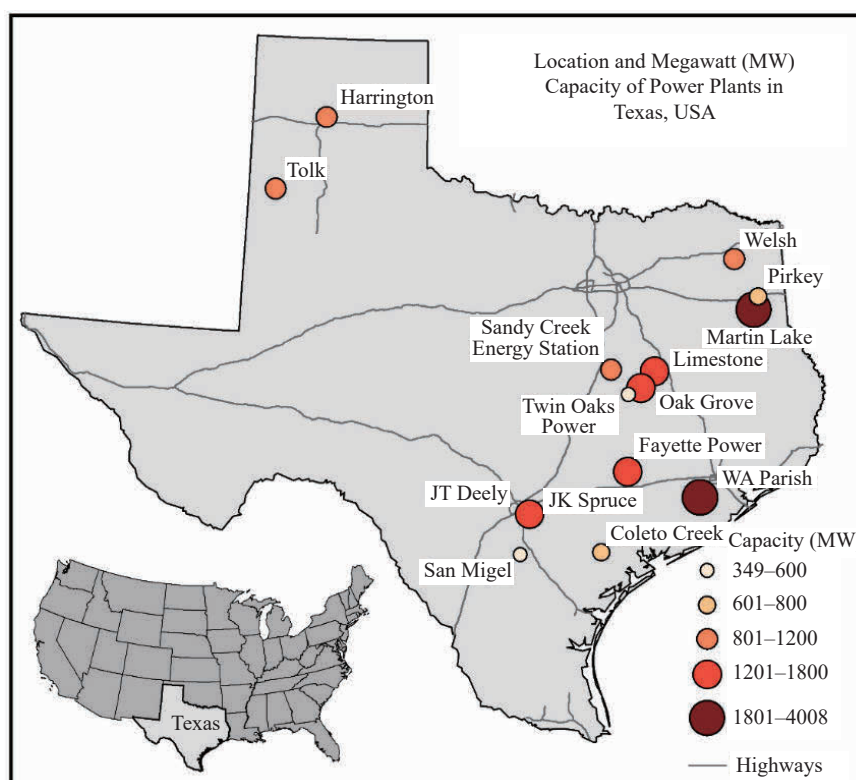


Fig. 1. Location and capacity in MW of power plants in Texas, USA.

Table 1. US electric power sector air pollutants emissions by source (share of total in %).

Source	NO _x	SO ₂	CO ₂	CH ₄	N ₂ O
Coal	43.9	97.6	45.4	83.2	87.2
Natural gas	55	0.6	53.7	15.8	11.4
Petroleum	0.3	0.7	0.1	0.04	0.05
Other	0.8	1.1	0.8	1	1.3

space-time evolution. With its high spatial resolution and high signal-to-noise ratio, TROPOMI allows the distinct identification of various NO₂ plumes from specific sources such as coal-fired power plants, city centers and industrial areas. However, the accuracy of TROPOMI NO₂ retrieval may be affected by other factors, such as the presence of clouds and other sources of NO₂ emissions (industrial facilities and high traffic) in the vicinity of the station itself (Liu F et al., 2020).

Fig. 2 shows population density for Texas and the spatial distribution of columnar NO₂ from May 1, 2018 to May 1, 2021. High NO₂ VCDs are observed over the largest cities in the state (Houston, San Antonio, Austin, Dallas, etc.), where

the transport sector is an important source of emissions (Tirumalachetty S et al., 2013; Brozynski MT and Leibowicz BD, 2018; Demetillo MAG et al., 2020) and various types of industries are present. TROPOMI NO₂ VCDs ranged from 80 μmol/m² over Austin to over 140 μmol/m² over Houston and Dallas, with values ranging from 60 μmol/m² to 70 μmol/m² for most of the state. There is a clear relationship between population density and NO₂ ($r=0.75$ with a significant level of 95%), indicating that the higher the population density, the higher the NO₂ values. NO₂ hotspots are also apparent over coal-fired power plants. NO₂ hotspots are also apparent over coal-fired power plants, which is also confirmed by the high correlation between power plant locations and enhanced NO₂ VCD ($r=0.69$ with a significance level of 95%).

Data obtained from US EPA EGRID for 2018 were used to estimate NO₂ emissions for each station. EGRID data is a source of information on the environmental performance of nearly all electricity generated in the US. Fig.3a provides detailed information on NO_x emissions and generating capacity for each station. The figure shows that plant emissions range from 1.53 kt/year at Sandy Creek Energy

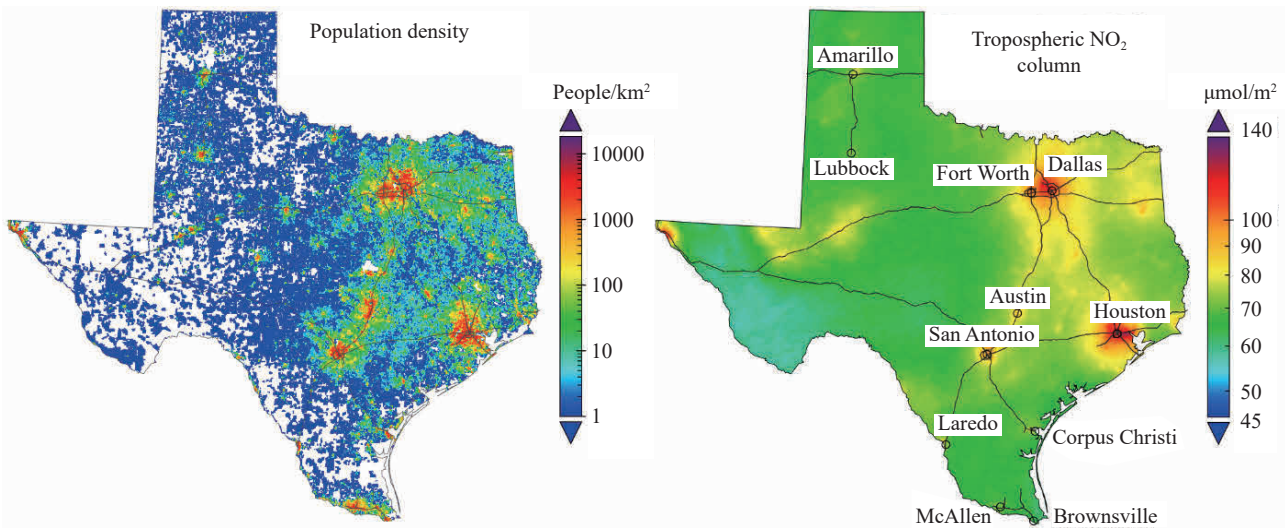


Fig. 2. Population density and TROPOMI NO₂ VCDs over Texas.

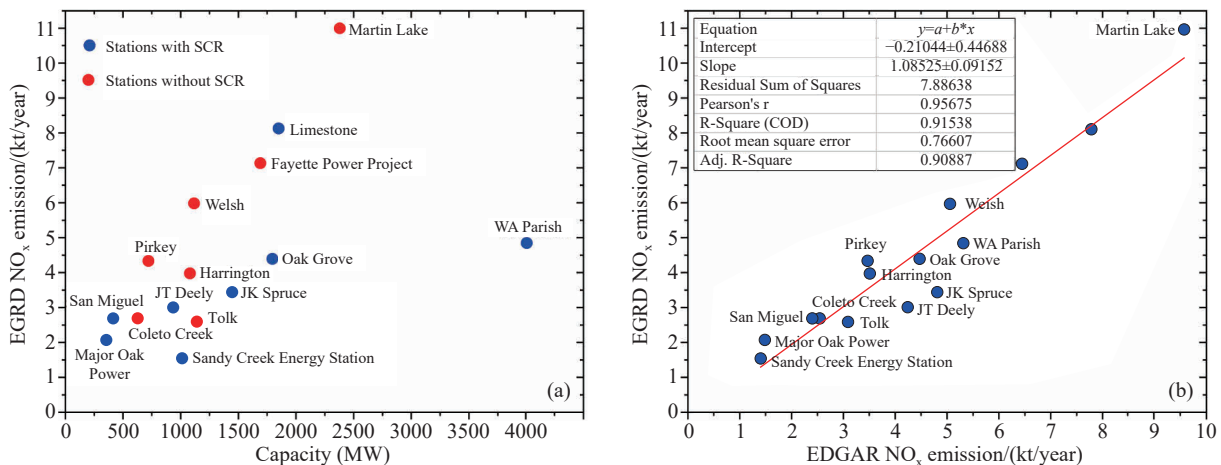


Fig. 3. EGRID NO_x emission and comparison between EGRID and EDGAR emissions for 2018.

Station to 10.99 kt/year at Martin Lake, with Limestone (8.13 kt/year) and Fayette Power Project (7.13 kt/year) leading in NO_x emissions. At the same time, it can be noted that the larger the capacity of the installations, the greater the NO_x emissions. This is due to the large consumption of coal at these installations and, consequently, large emissions.

An important factor to reduce NO_x emissions is the availability of appropriate environmental equipment such as selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR). In coal-fired power plants, SCR is used to convert NO_x using a catalyst into nitrogen (N₂) and water (H₂O), thus reducing emissions of NO_x. Meanwhile, SNCR has a similar technology that works by injecting reagents at high temperature without the need for a catalyst (van Caneghem J et al., 2016).

Nearly half of the stations, including Martin Lake, Welsh, Fayette Power Project, Harrington, Tolk, Pirkey and Coletto Creek, lack NO_x emission control equipment, subsequently having higher emissions compared to plants that are so equipped. Note that emissions from individual stations do not directly correlate to the power generated. So, NO_x emissions are not the same for plants with similar capacities. For example, NO_x emissions at Sandy Creek Energy Station (1.53 kt) were more than 2.5 times less than at Harrington Station (3.98 kt), although these stations have almost the same capacity of 1008MW and 1080MW, respectively. The reason for this difference in emissions may be the installed SCR at Sandy Creek Energy Station and the lack of one at Harrington Station. Other reasons for differences in NO_x emissions may be related to the age of the stations, their level of maintenance, different performance efficiency of the burner and installed capacity of the various stations compared to other installations of the same category (Strasert B et al., 2019; Saw GK et al., 2021).

To further examine NO_x emissions, the Emissions Database for Global Atmospheric Research (EDGAR) data was used. This database includes emissions of various gases

from all anthropogenic sectors (such as energy, industry, aviation, ground transport, etc.), with the exception of forestry, land use change and land. However, in order to avoid distortion of the received data, a mutual check of the EGRID and EDGAR data is first carried out. Comparison of the bottom-up inventories, EDGAR and EGRID, show a high correlation ($r=0.956$) and low root mean square error (0.766) (Fig. 3b).

NO_x emission fluxes from each power plant were quantified by using EDGAR data (Table 2). As expected, emission fluxes increased from a plant with lower plant capacities to more powerful plants. The highest emission fluxes were at WA Parish and Martin Lake, which were 7.208 μg/(m²/s) and 5.717 μg/(m²/s), respectively. Due to its large population, Texas leads the nation in total residential energy consumption.

Winter and summer had the highest NO_x emission fluxes. This may be due to the generation of large amounts of electricity by power plants resulting from the population's need for electricity to heat or cool homes (Abel D et al., 2017). Autumn and spring are intermediate periods between winter and summer, so NO_x emission fluxes are noticeably lower than in winter. In summer to run air conditioners, many stations generate more electricity resulting in stronger NO_x emission fluxes than in spring and autumn. In many respects, changes in NO_x emission can be associated with the peculiarities of the climate. Texas varies from humid and subtropical climates along the coast, where most of the state's population lives, to semi-arid in the high plains of central and western Texas, and arid in the mountainous west of the state (Jiang X and Yang ZL, 2012). Sub-zero temperatures often occur on the sparsely populated high plains in winter, while summer temperatures often exceed 32°C in the most densely populated parts of the state. Therefore, the use of energy for cooling in summer and heating in winter is very high, affecting electricity generation and, consequently, emissions.

The concentration of harmful substances in lower layers

Table 2. Seasonal and annual variability in EDGAR NO_x emission fluxes (unit: μg/(m²/s)) by the coal-fired power stations in Texas in 2018.

Plant Name	Winter	Spring	Summer	Autumn	Annual
Limestone	2.469	1.844	2.145	2.157	2.154
WA Parish	8.453	6.190	6.918	7.270	7.208
Sandy Creek Energy Station	0.608	0.456	0.530	0.532	0.531
Welsh	4.060	3.000	3.205	3.536	3.450
Martin Lake	6.716	4.975	5.315	5.863	5.717
Fayette Power Project	4.104	3.031	3.239	3.573	3.487
Oak Grove	–	–	–	–	–
San Miguel	1.303	0.962	1.027	1.134	1.107
Harrington	3.031	2.249	2.411	2.625	2.579
Tolk	2.603	1.926	2.051	2.264	2.211
Major Oak Power	0.906	0.667	0.713	0.788	0.769
JK Spruce	0.749	0.657	0.874	0.760	0.760
Pirkey (2023)*	1.458	1.086	1.162	1.281	1.247
JT Deely (2024)*	–	–	–	–	–
Coletto Creek (2027)*	0.886	0.669	0.779	0.782	0.779

Note: * The plants are planned for closure.

of the atmosphere depends not only on the volume of harmful emissions but also on the climatic and meteorological conditions of the area, as well as on the design of power plant stacks. With emissions of harmful substances into the atmosphere under normal conditions, the level of their concentration depends on the design of the chimney, primarily on its height (Guttikunda SK and Jawahar P, 2014; Nassar R et al., 2017). While tall stacks are expensive to construct, the cost of stacks is significantly lower than flue gas treatment facilities. However, at present, the construction of high chimneys is not recognized as a general method for protecting the air basin, since harmful emissions from high stacks are dispersed over very long distances.

The negative impact of power plants on large areas of the country can have a variety of adverse consequences, including acid rain, deterioration of air quality in remote areas as a result of emissions superimposed on increased anthropogenic and natural concentrations of harmful substances (Eckelman MJ and Sherman J, 2016; Oberschelp C et al., 2019). In this regard, priority is currently given to methods that minimize emissions of harmful substances into the atmosphere, after which it is possible to select the appropriate stack height.

TROPOMI satellite data show (see Fig. 4) that the NO₂ VCD was higher in winter and fall than in summer and spring across much of the state, despite NO_x being high in summer due to the heavy demand from air conditioning. The higher

NO₂ VCD in winter was due to the longer NO₂ lifetime in cold weather, associated with slower photolysis rates. Photolysis occurs in the atmosphere as part of a sequence of reactions in which primary pollutants interact to form secondary pollutants. When NO_x is released during warm weather, it is converted to other chemical compounds faster than in winter. In addition, the proportion of NO_x in the form of NO₂ is variable, mainly due to relatively high levels of O₃ and sunlight (Zhou X et al., 2003). It was found that around power plants, the content of NO₂ VCD is higher by 15%–20% in winter than in summer.

Terrain orography, wind speed and direction can significantly affect spatiotemporal variations in NO₂ (Yu Z and Li X, 2022). As wind speed increases, NO₂ decreases due to faster dissipation (Pirjola L et al., 2006). For example, the Martin Lake station, located in East Texas in a relatively flat area, has an average wind speed of about 3 m/s (10.8 km/h). An increase in wind speed to more than 7 m/s (25.2 km/h) leads to a decrease in NO₂ by 40%–50%. Harrington Station, located near Amarillo in north Texas on relatively more elevated and uneven terrain, is characterized by higher wind speeds of around 5.2 m/s (18.72 km/h). An increase in wind speed here to more than 7 m/s leads to a much larger decrease in NO₂ by 60%–75%. This indicates a strong relationship between NO₂ concentrations and wind speed. Similar results have been found in urban areas in the US (Goldberg DL et al.,

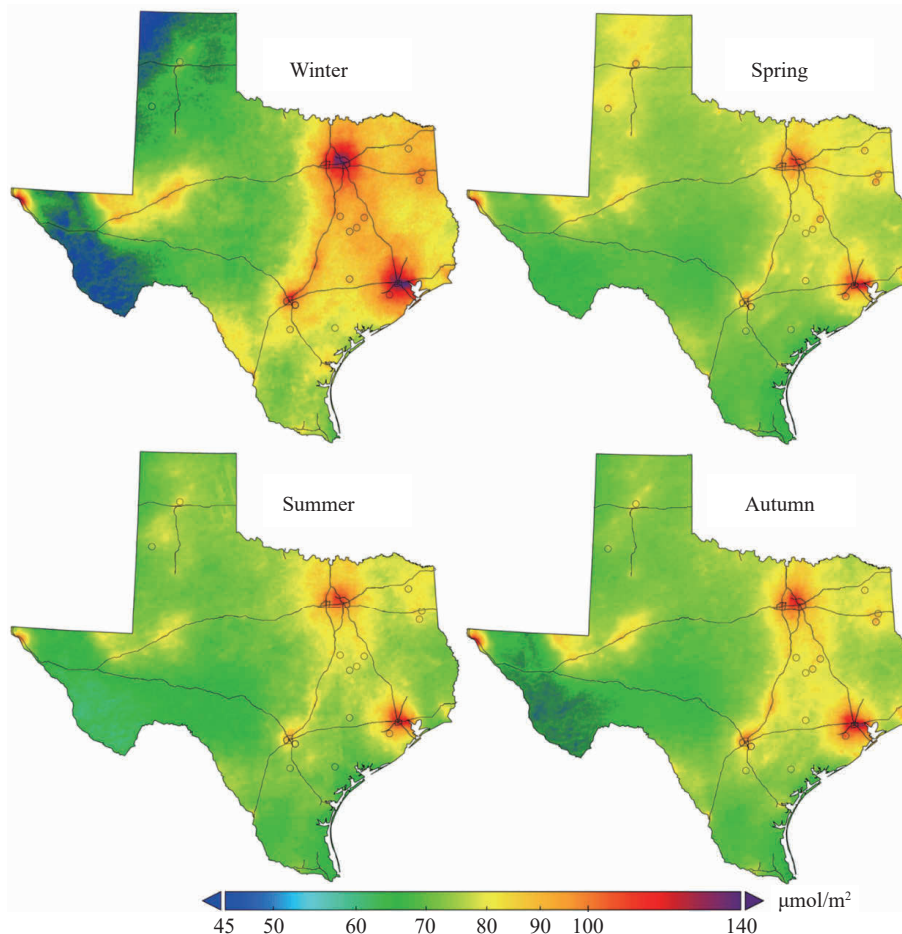


Fig. 4. Seasonal mean distribution of TROPOMI NO₂ VCDs ($\mu\text{mol}/\text{m}^2$) over Texas during period from May 2018 to May 2021.

2020).

As for the direction of the wind, southerly winds prevail, bringing warm, moist air from the Gulf of Mexico. Therefore, air upwind will not affect NO₂ levels in the vicinity of power plants, but areas downwind of a power plant can have significantly high NO₂ levels. For example, WA Parish stations southwest of Houston and JK Spruce and JT Deely southeast of San Antonio significantly affect air quality in these cities which are downwind of the stations. Many pollutants released into the air by coal-fired power plants affect local air quality but can also be transported across national borders and throughout the country by prevailing winds (Levy JI and Spengler JD, 2002).

Over the past few decades, the introduction of new emission control technologies has contributed to continuous reductions in pollution from US coal-fired power plants (Gilbert AQ and Sovacool BK, 2017; Filonchuk M and Peterson P, 2023). However, in March 2020, Texas proposed a State Implementation Plan (SIP; Docket No. 2020-0071-SIP) revision requesting that the EPA revise the SIP regarding planned startup and shutdown emissions for certain electric generating units. This affects 30 electric generating units at eight coal-fired power plants. According to the proposal, the control of emissions at these plants will only be in effect when

the plants are fully operational and not under maintenance, startup and plant shutdown. According to NEEDS v621 data, most stations have installed appropriate environmental equipment to control NO_x, SO₂, PM and mercury emissions, including scrubbers, selective catalytic reduction, activated carbon injection and other equipment (Table 3).

In October 2022, the US EPA authorized the Texas Commission on Environmental Quality (TCEQ) to exempt the state's largest coal-fired power plants, including Martin Lake, Limestone, San Miguel, Pirkey, Harrington, Fayette Power Project, from restrictions imposed by state and federal laws for PM_{2.5} and PM₁₀ emissions. The changes will allow these coal-fired power plants to bypass pollution controls during maintenance, startup and plant shutdown. This results in these plants exceeding the emission limits set by Texas.

To reduce emissions at coal-fired power plants, air pollution controls are needed to reduce particulate emissions during maintenance, start-up or shutdown. This TCEQ decision has resulted in some plants increasing their PM emissions. Thus, the Martin Lake coal plant increased its particulate matter emissions from 853 to 3000 pounds per hour, Limestone plant emissions went from 236 to 8000 pounds per hour, and San Miguel from 437.5 to 1803 pounds per hour (EIP, 2022). This influences total emissions and air

Table 3. Main characteristics of stations and installed environmental equipment.

Plant Name	Unit number	Online Year	Wet/Dry Scrubber	NO _x Comb Control	NO _x Post-Comb Control	PM Control	Mercury Controls
Limestone	2	1985, 1986	Wet Scrubber	LNC3 OFA	SNCR	ESPC	ACI
WA Parish	4	1977, 1978 1980, 1982	Wet Scrubber (1/4)	LNB+OFA LNB LNC3+NH3	SCR	B	ACI
Sandy Creek Energy Station	1	2013	Dry Scrubber	LNB+OFA	SCR	B	ACI
Welsh	2	1977, 1982		LNBO		ESPH+B	ACI
Martin Lake	3	1977, 1978, 1979	Wet Scrubber	LNC2		ESPC	ACI
Fayette Power Project	3	1979, 1980, 1988	Wet Scrubber	LNC3		ESPC	ACI
Oak Grove (TX)	2	2010, 2011	Wet Scrubber	LNC2+NH3 LNB+NH3+OFA	SCR	B	ACI
San Miguel	1	1982	Wet Scrubber	LNB+OFA	SNCR	ESPC	ACI
Harrington	3	1976, 1978, 1980		LNC2+OFA LNC3+OFA		ESPC B	ACI
Tolk	2	1982, 1985		LNC2+OFA		B	ACI
Major Oak Power	2	1990, 1991	Reagent Injection	ROFA	SNCR	B	ACI
JK Spruce	2	1992, 2010	Wet Scrubber	LNC3 AA+LNB	SCR	B	ACI
Pirkey	1	1985	Wet Scrubber	LNB+LNBO+OFA		ESPC	ACI
JT Deely	2	1977, 1977		LNC3	SCR	B	ACI
Coletto Creek	1	1980	Wet Scrubber	LNC3		B	ACI

Note: AA+LNB – Advanced Overfire Air + Low NO_x Burner Technology; LNB – Low NO_x Burner Technology; LNB+LNBO+OFA – Low NO_x Burner Technology + Low NO_x Burner Technology w/ Overfire Air + Overfire Air; LNB+NH₃+OFA – Low NO_x Burner Technology w/ Separated OFA + Ammonia Injection + Overfire Air; LNB+OFA – Low NO_x Burner Technology + Overfire Air; LNBO – Low NO_x Burner Technology w/ Overfire Air; LNC2 – Low NO_x Burner Technology w/ Separated OFA; LNC2+NH₃ – Low NO_x Burner Technology w/ Separated OFA + Ammonia Injection; LNC2+OFA – Low NO_x Burner Technology w/ Separated OFA + Overfire Air; LNC3 – Low NO_x Burner Technology w/ Closed-coupled/Separated OFA; LNC₃+NH₃ – Low NO_x Burner Technology w/ Closed-coupled/Separated OFA + Ammonia Injection; LNC₃+OFA – Low NO_x Burner Technology w/ Closed-coupled/Separated OFA + Overfire Air LNCB – Low NO_x Cell Burner; OFA – Overfire Air; ROFA – Rotating Opposed Fired Air; ESPC – Electrostatic precipitator, cold side; ESPH+B – Electrostatic precipitator, hot side + Baghouse; B – Baghouse; SCR – Selective Catalytic Reduction; SNCR – Selective Non-catalytic Reduction; ACI – Activated Carbon Injection.

quality at each facility.

Improving the environment, not only in the US but throughout the world, is largely dependent on improved air quality. A significant portion of the emissions are from coal-fired generation. Switching obsolete coal-fired stations to natural gas will not only allow for cleaner air but will also increase the efficiency of the stations. It can reduce CO₂ emissions by 30% (Grant D et al., 2021). The introduction of carbon capture technologies can cut emissions by almost half.

Power generation with natural gas is many times less harmful to the environment (EIA, 2022). While emissions are much lower when gas is used, SO₂, CO₂, NO₂ are still produced. Gas generation is also more efficient: The operating costs for obtaining energy from burning gas are much lower than from coal. Gas-fired power plants are thus considered more environmentally friendly, technologically advanced and energy efficient than coal-fired ones (Ali Abdelkareem M et al., 2021; Tian X et al., 2022). This leads to the trend in developed countries towards the gradual decommissioning of coal-fired power plants. The current higher price of natural gas is slowing the transition to its use as the main fuel in electricity generation. Thus, renewable energy sources can play an important role in increasing energy security.

4. Conclusions

The transition to more environmentally friendly raw materials such as natural gas, as well as renewable sources, has resulted in less reliance on coal. Only 14.9% of Texas electricity comes from coal-fired power plants. In 2020, coal-fired power plants generated only 80.22 GWh (16.9%) of the total 473.37 GWh. Nevertheless, this small share still accounts for more than 80% of CH₄ and N₂O emissions, more than 97% of SO₂ emissions and 40% of CO₂ and NO_x emissions from the energy sector.

EGRID data showed that the leaders in NO_x emissions were some of the largest coal-fired power plants in the country – Martin Lake (10.99 kt) and Limestone (8.13 kt). An important reason for the large amount of NO_x emissions may be the age of the plant, the level of its maintenance and the use of environmental equipment. Not all Texas coal-fired power plants are equipped with NO_x emission control equipment, such as SCR or SNCR. The presence of this equipment leads to major reductions in NO_x emissions for a particular plant.

The local impact of emissions from coal-fired power plants is not limited to short-lived pollutants. Long-lived contaminants from metals such as nickel, lead, arsenic, cadmium and chromium may be present in the immediate vicinity of the source. Thus, the potential exposure to these pollutants may be increased in areas surrounding coal-fired power plants, which can subsequently have a significant negative impact on the health of the population that lives in close proximity to the source of pollution. Therefore, it is proposed that future studies be directed to the study of heavy metal emissions and their impact on air quality near coal-fired

power plants and their impact on regional air quality.

To make environmentally sound decisions, it is necessary to analyze not only the technology of electricity generation as a source of pollution but also to take into account the entire technological chain of electricity generation by evaluating the whole operating cycle of a particular technology. The assessment of the impact of various types of power plants on the environment should be carried out while taking into account the operating cycle of this technology. The analysis of the operating cycle of a generating plant includes an assessment of the costs and environmental effects from the extraction and manufacture of fuel, the manufacture of power plant systems and equipment, and the final disposal of waste. This can further help in deciding between competing technologies for generating electricity.

CRedit authorship contribution statement

Mikalai Filonchik conceived of the presented idea and wrote the main manuscript text. Michael P. Peterson prepared all the figures. All authors discussed the results and contributed to the final manuscript.

Declaration of competing interest

The authors declare no conflicts of interest.

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