Transboundary Air Pollution in the Jakarta, Banten, and West Java provinces

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August 2020

Centre for Research on Energy and Clean Air

CREA is an independent research organisation focused on revealing the trends, causes, and health impacts, as well as the solutions to air pollution.

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Key messages

- Transboundary pollution in the surrounding provinces of Banten and West Java are major contributors to air pollution in Jakarta City. Jakarta's "airshed" - the area where emissions affect its air quality - extends far beyond its borders, regularly including Tangerang, Bogor, Depok, Bekasi, Puncak and Cianjur, and even extending as far as Sumatera Selatan, Lampung, and Central Java. (*See pp. 10-18*)

- Air pollutant emissions both in Jakarta and in surrounding provinces have been increasing, worsening Jakarta's air quality and hampering clean air efforts (*See pp. 5-7, 19-22*). PM2.5 monitoring in Jakarta recorded 101 days with "unhealthy" air quality in 2018 and 172 in 2019. Even with COVID-19, air quality in the city did not significantly improve (*See p. 8).* Satellite images show that the Suralaya power plants in Banten were operating and emitting as usual during COVID restrictions. Winds brought their pollution into Jakarta, which may have contributed to Jakarta's PM2.5 remaining high despite major reductions in local traffic and urban activity.

- Meteorological factors like wind trajectories affect the dispersion of pollutants like NO, SO2 and PM2.5. In the dry months of May to October, when overall pollution levels in the city are highest, sources from coal-fired power and industrial plants to the east of Jakarta (from Bekasi, Karawang, Purwakarta all the way to Bandung) have more impact on air quality. In the wet months (December to March), sources to the west - specifically the Banten Suralaya power plants - are larger contributors. (*See pp. 10-15*)

- There are 136 registered industrial facilities (including power plants) in highly-emitting sectors in Jakarta and within a 100km radius of the city borders. 16 are located in DKI Jakarta; 62 in West Java, 56 in Banten, one in Central Java and the last in Sumatera Selatan (*See p. 12*). Clusters of these industrial facilities coincide with the NOx and SO2 hotspots of Java. NOx and SO2 oxidize in the atmosphere to form large amounts of secondary PM2.5, which can be carried on winds to surrounding areas more than 100km away (*See pp. 10-12, 16-19).* Atmospheric modeling of the worst pollution days in Jakarta shows wind trajectories passing through these NOx and SO2 hotspots in Banten and West Java, contributing to all three types of air pollution in the city. (*See p. 12, 14*)

- Emissions inventories for Banten, West Java and Jakarta show that Banten and West Java have much higher (double or even quadruple) emissions of PM2.5, SO2 and NOx than Jakarta, in large part due to industries and power plants (*See pp. 16-17*).

- Transboundary pollution is imposing major health and economic costs on Jakartans. Coal-fired power plants (CFPPs) within 100km of the city are responsible for an estimated 2,500 premature deaths in the Jabodetabek area. Transboundary pollution is also responsible for other negative health impacts related to immunity, respiratory and cardiovascular systems. The annual cost of transboundary pollution from CFPPs is estimated at IDR 5.1 trillion per year in Jabodetabek, or IDR 180,000 per person per year. *(See pp. 21-22)*

- Policies and frameworks to limit emissions from these sources have been insufficient. These must be strengthened and implemented to protect the health and wellbeing of Indonesia's citizens. (*See pp. 19-23*)

About CREA

The Centre for Research on Energy and Clean Air (CREA) is a new independent research organisation focused on revealing the trends, causes, and health impacts, as well as the solutions to air pollution. CREA uses scientific data, research and evidence to support the efforts of governments, companies and campaigning organizations worldwide in their efforts to move towards clean energy and clean air, believing that effective research and communication are the key to successful policies, investment decisions and advocacy efforts. CREA was founded in December 2019 in Helsinki and has staff in several Asian and European countries.

This report was prepared at the request of Earthjustice and the Indonesian Centre for Environmental Law (ICEL), and is the cumulative work of the following:

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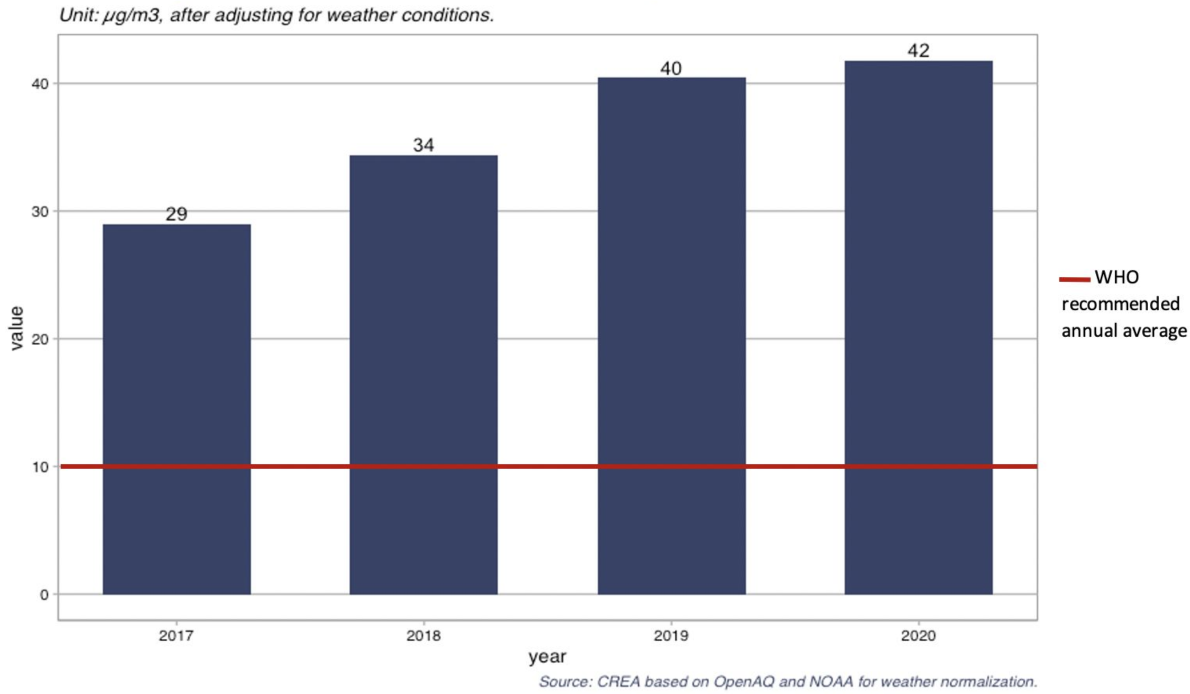
Overview

Air pollution is a serious problem in Jakarta. Rapid industrialization and urbanization has led to a continuous rise in air pollution. It has reached a point where air pollution exceeds the recommended concentrations of the World Health Organization (WHO) (*Figure 1*) three-fold, resulting in worsening impacts on public health. A 2010 study by Indonesia University found that nearly 60 percent of Jakarta's residents suffer from respiratory illnesses associated with poor air quality (Haryanto 2017). Meanwhile, the number of known emitters like coal-fired power plants, transport vehicles, and manufacturing facilities has increased. The production and consumption of coal, oil and gas from these sources emit huge amounts of pollutants into the atmosphere, which impacts the air quality of surrounding areas for hundreds of kilometers downwind.

Figure 1: Average PM2.5 levels in Jakarta, Indonesia[1]



While Indonesia has ambitious renewable energy targets, the country is simultaneously increasing its fossil fuel use (UNEP 2015). Currently, it has the most coal-fired power plants (CFPP) in Southeast Asia with a total of 74. Since 2010, electricity generation from such plants has more than doubled (Greenstone et al 2019). Indonesia also has plans for additional 31,200 MW of coal generation capacity, 20% of which will be located within a 100 km radius of Jakarta, and will have air quality impacts equal to adding 10 million more cars to Jakarta (Lowy Institute 2019).[2] Air quality could become much worse if adequate safeguards are not in place. A Harvard study found

[1] The WHO recommends a 10 µg/m3 annual mean for PM2.5. Annual PM2.5 has risen to four times what the WHO recommends and considers healthy.
[2] This includes plants whose status is under construction, permitting, or announced. Global Coal Plant Tracker, 2019.

that those planned coal plants would cause an additional 2,600 people to die prematurely each year (Koplitz et al. 2017).

The regulations on emissions have remained lenient with limited enforcement of regulations for industries. In addition, Indonesia's lax ambient (outdoor) air quality standards do not adequately control the accumulation of pollution from all sources. While the WHO says exposure to fine particulate matter (PM2.5) of more than 25 µg/m3 over a 24-hour period is already dangerous to human health, the National Ambient Air Quality Standard (NAAQS) has a limit of 65 µg/m3.
The aim of this study is to examine transboundary emissions from industrial facilities and power plants in western Java and their impacts to air quality and human health.

Major Air Pollutants

Fossil fuel-burning power and industrial plants produce emissions while operating, and these emissions contain toxic air pollutants. Pollutants - including but not limited to NOx, SO2, particulate matter (PM), and mercury (Hg) - spread in the atmosphere and cause harm to human health, including stroke, heart disease, asthma, respiratory infections, and chronic obstructive pulmonary disease (WHO 2016). Impaired health conditions lead to increased hospital visits and premature death.

Not only are pollutants emitted directly from the source, but they also interact in the atmosphere and create new pollutants. NOx gases are emitted whenever fossil fuels are burned, due to the very high temperatures (SEPA). Similarly, SO2 is formed during fuel combustion in power plants and industrial facilities (US EPA 2019).

PM2.5 - emitted directly from sources (primary) such as vehicles, heavy equipment, forest fires, and other burning activities, or formed in the atmosphere (secondary) - can remain airborne for long periods and travel hundreds of miles. Secondary formation of PM2.5 and ozone occurs when NOx reacts with other compounds in the atmosphere, generally downwind and/or some distance from the original emission sources (US EPA 2016). Short- or long-term exposure to the particles can cause adverse cardiovascular effects. Because PM2.5 can get deep into the lungs, it has also been linked to respiratory effects, including the exacerbation of asthma and the impairment of lung development.

Mercury, a neurotoxic heavy metal, is another pollutant emitted from coal plants and that is easily transported in the atmosphere. It can even travel around the globe, depositing in very remote regions (UN Environment 2019). Mercury emissions from power plants lacking adequate air pollution control devices, such as those around Jakarta, are readily deposited in the region around the power plant, creating mercury deposition hotspots[3] (see e.g. Sullivan et al 2006).

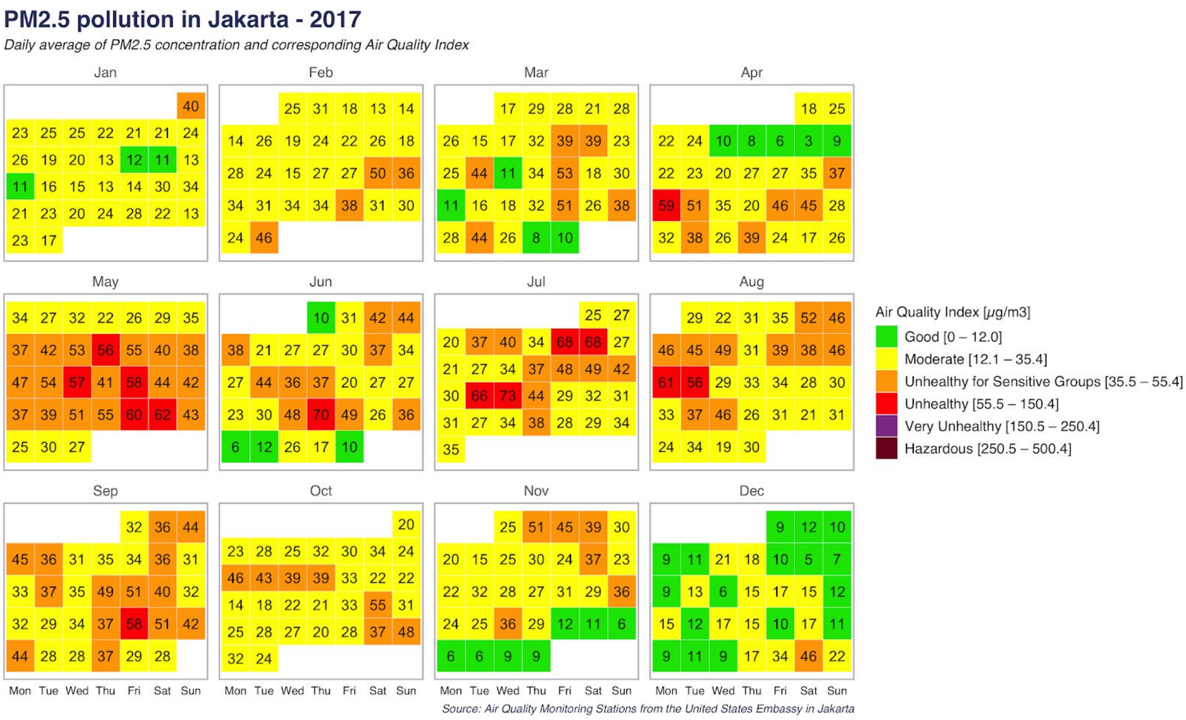
[3] The equipment used to control SO2, wet flue gas desulfurization devices, are effective at removing the locally deposited, divalent mercury from the flue gas.

State of Air Quality in Jakarta

Air quality monitoring of PM2.5 by the US Embassy in Jakarta shows that the city only saw 40 days of "good" air quality in 2017, mostly in the months of January, November and December. 2018 had only 25 "good" days, in contrast to the 101 recorded days of air quality within a range considered "unhealthy". In 2019, the number of unhealthy days increased to 172 - over 50% of the year. Early 2020 monitoring shows that even with the disruption caused by COVID-19, air quality from March to May remained within moderate to unhealthy levels (*See Figure 2*).

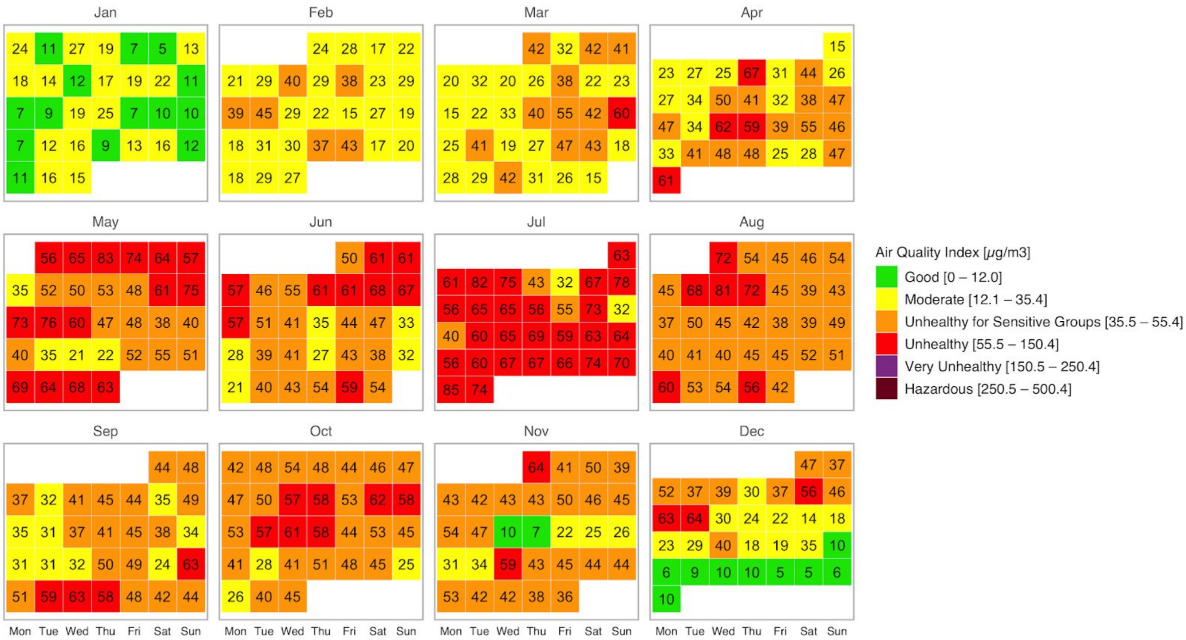
The dry season (May to October) sees the most number of unhealthy air quality days. The rainy season (November to March) provides some respite but overall air quality in 2018 and 2019 show that for most of the year PM2.5 are at levels that are unhealthy to sensitive groups, and for the first time in the past four years, not a single day in 2020 has had good quality air.

Figure 2: Daily average of PM2.5 concentrations in Jakarta from 2017 to 2020



PM2.5 pollution in Jakarta - 2018

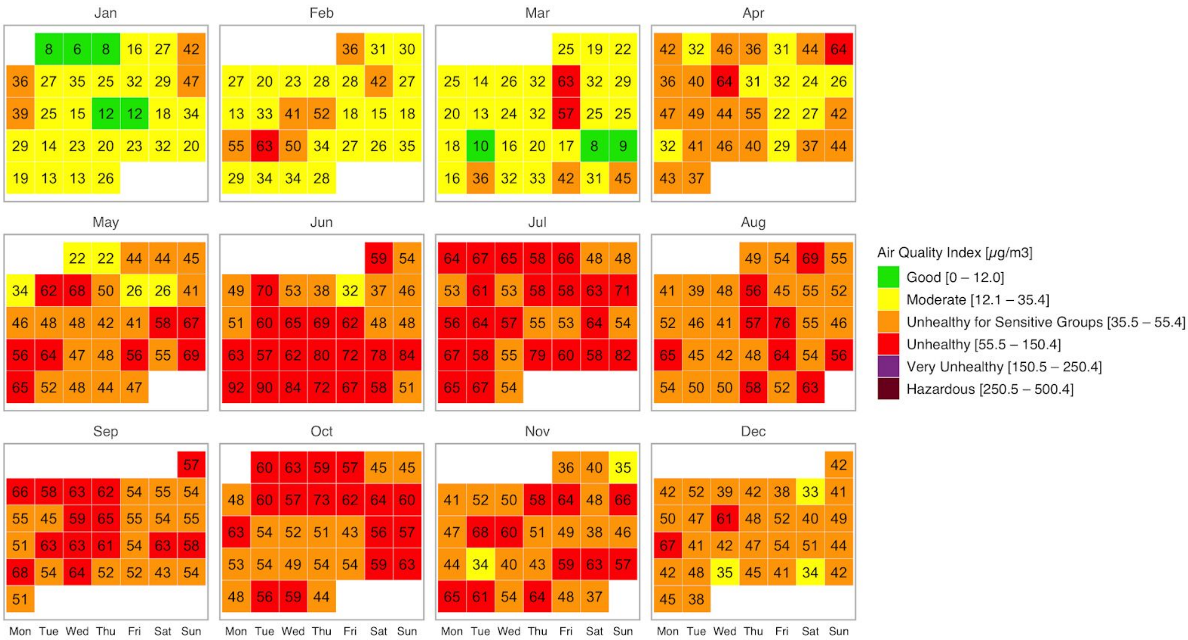
Daily average of PM2.5 concentration and corresponding Air Quality Index



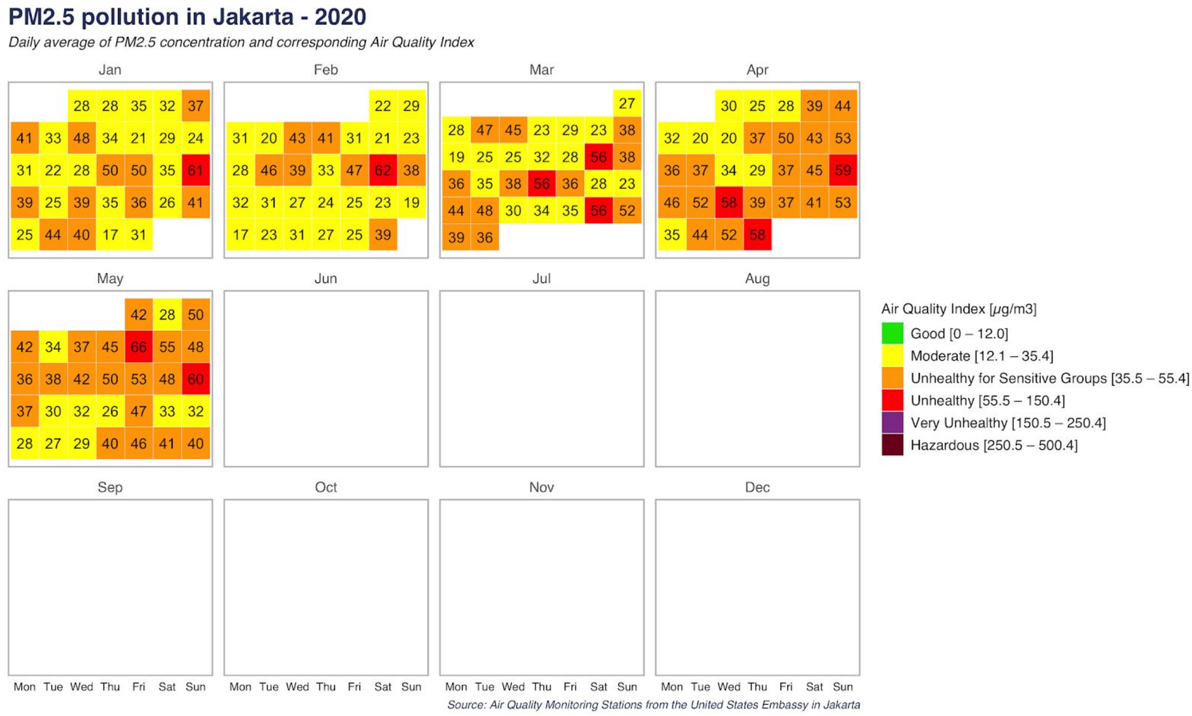
Source: Air Quality Monitoring Stations from the United States Embassy in Jakarta

PM2.5 pollution in Jakarta - 2019

Daily average of PM2.5 concentration and corresponding Air Quality Index



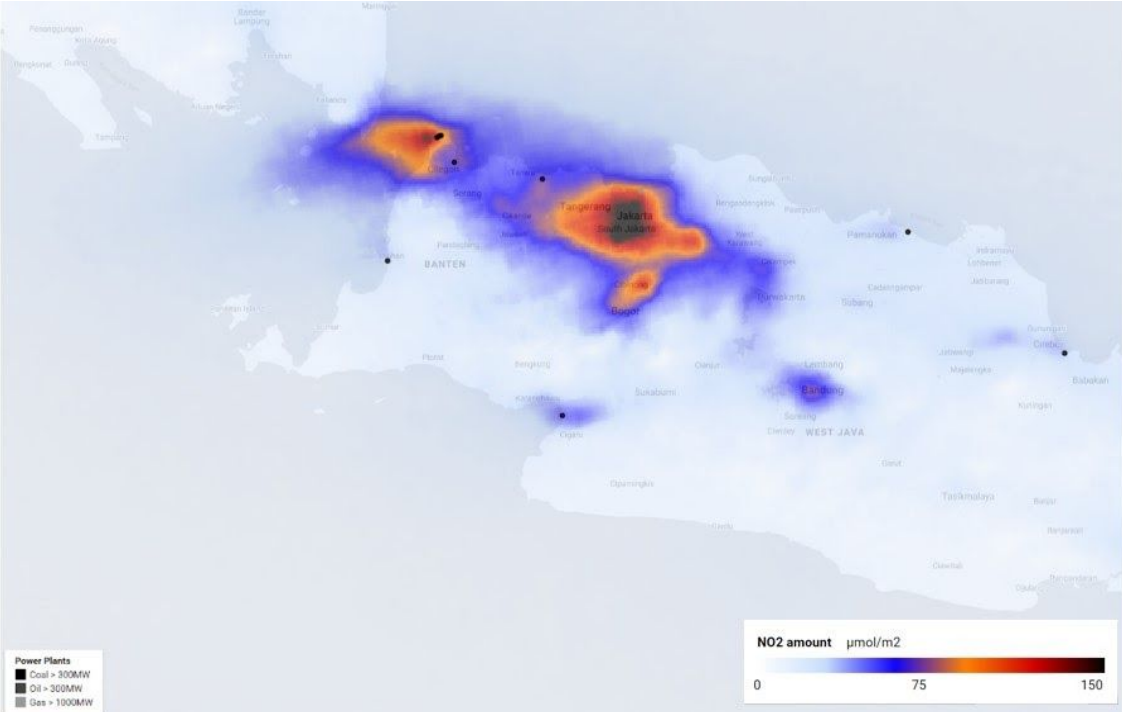
Source: Air Quality Monitoring Stations from the United States Embassy in Jakarta



Source: Air Quality Monitoring Stations from the United States Embassy in Jakarta

In addition to PM2.5, satellite-based imaging shows that Jakarta and parts of Banten and West Java are major ambient NO2 hotspots (*Figure 3*). Over the past decade, NO2 levels increased in Banten, West Java and southern Lampung. There was also a big increase in NO2 further away in Jepara due to coal expansion. This indicates an increasing trend in fossil fuel use and emissions outside Jakarta, which also means an increased transboundary impact on air quality in Jakarta. NO2 levels are an indicator of increased fossil fuel emissions of both NOx and PM2.5, as the same emissions sources produce both types of emissions. (NOx emissions contribute to PM2.5 formation, because some NOx is converted into PM2.5 particles (nitrates) before reaching the city.) This has contributed to the worsening measurements of ambient PM2.5 concentrations in Jakarta (*Figure 2*), as secondary PM2.5 circulates with meteorological conditions resulting in their long range transfer. Together with pollution from local sources, this can result in episodes of higher pollution.

Figure 3: NO2 Hotspots over Jakarta, Banten and West Java



SOURCE: CREA based on TROPOMI Satellite data

Related Literature

Regulations for industrial emissions have remained lenient although the country has implemented stricter standards on other emission sources such as the transport sector. Jakarta has faced several situations where traffic has eased but air pollution has not significantly dropped, leading to the conclusion that controlling emissions from transportation is not enough.

An in-depth study on the effects of sea and land breezes shows how air pollutants are transferred by these winds into Jakarta (Sofyan et al. 2008). The results of the study indicate that before daily land and sea breezes, NO2 and SO2 concentrations are highest in the emission-source areas in central Jakarta and coastal industries. Sea breeze increases the concentration of the pollutants in the city by transporting them from the coast to southern Jakarta and into the mountainous area beyond.

CREA analyses on the impact of COVID-19 around the world found that unlike many other countries, the work-from-home and Pembatasan Sosial Berskala Besar (PSBB) in Indonesia did not improve air quality despite a decrease in urban activity. Atmospheric NO2 in Jakarta, Banten and West Java decreased in comparison to 2019 levels due to a slowdown in emissions from major NO2 sources like transport and industry (*See Appendix*). However, PM2.5 concentrations in Jakarta increased from late March to early June. PM2.5 travels farther than NO2 and can pollute farther away from its original source, suggesting that transboundary pollution from outside the city was a factor in the lack of change in PM2.5. TROPOMI Satellite images showed that the Suralaya power plants in Banten were operating and emitting as usual. Wind trajectories on April 12, 2020 - when PM2.5 in Jakarta spiked - showed that air was traveling in a north-east direction, passing across or close to the Suralaya plants and carrying pollution to Jakarta, preventing PM2.5 in the city from dropping substantially.

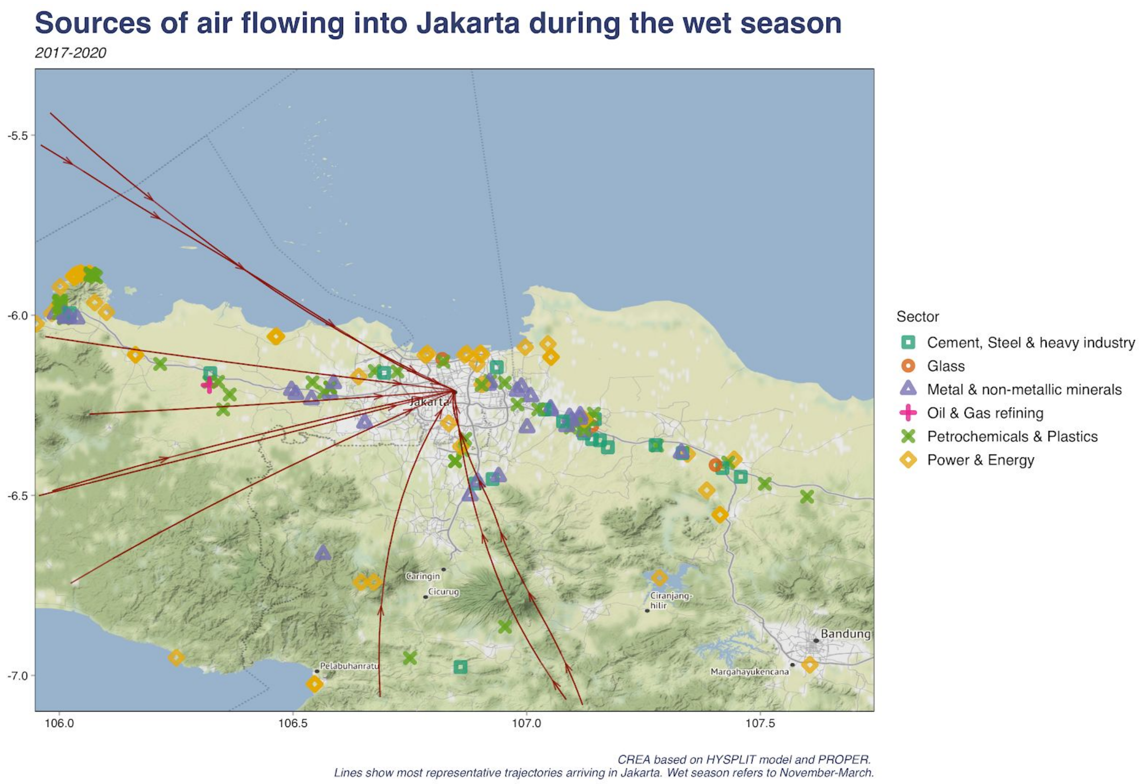
Modeling transboundary pollution from the source

Meteorology plays a role in the build up of air pollution

Meteorological conditions in western Java are a factor in the transboundary movement of pollutants. Wind speed, temperature, humidity and rainfall can affect the concentration and dispersion of air pollution away from its original source.

We used the HYSPLIT model developed by the U.S. NOAA, driven by weather data from 2017 to 2020, to generate the distinct patterns of air flow and wind trajectories for Indonesia's two seasons (*Figure 4*). HYSPLIT modeling is at a receptor height of 10 meters - a level where pollution is "well-mixed" and thus, transported and easily inhalable by humans. The modeling shows that in the seven months of the wet season (November to May), winds come from both northeast and southeast directions, bringing emissions from sources in South Sumatra, Lampung, Banten, and Bogor in West Java. In the dry season (June to October), wind trajectories are more frequently coming from West Java, indicating that emissions sources in the east and southeast of Jakarta - as far away as Cirebon and Bandung - have a greater impact on air quality in the dry season. Satellite-based analysis shows that emissions in these provinces have been increasing over the years, which will have increased Jakarta's pollution, as well as local pollution levels (*See Appendix*). Controlling these emissions sources is essential for improving air quality in the Jakarta region.

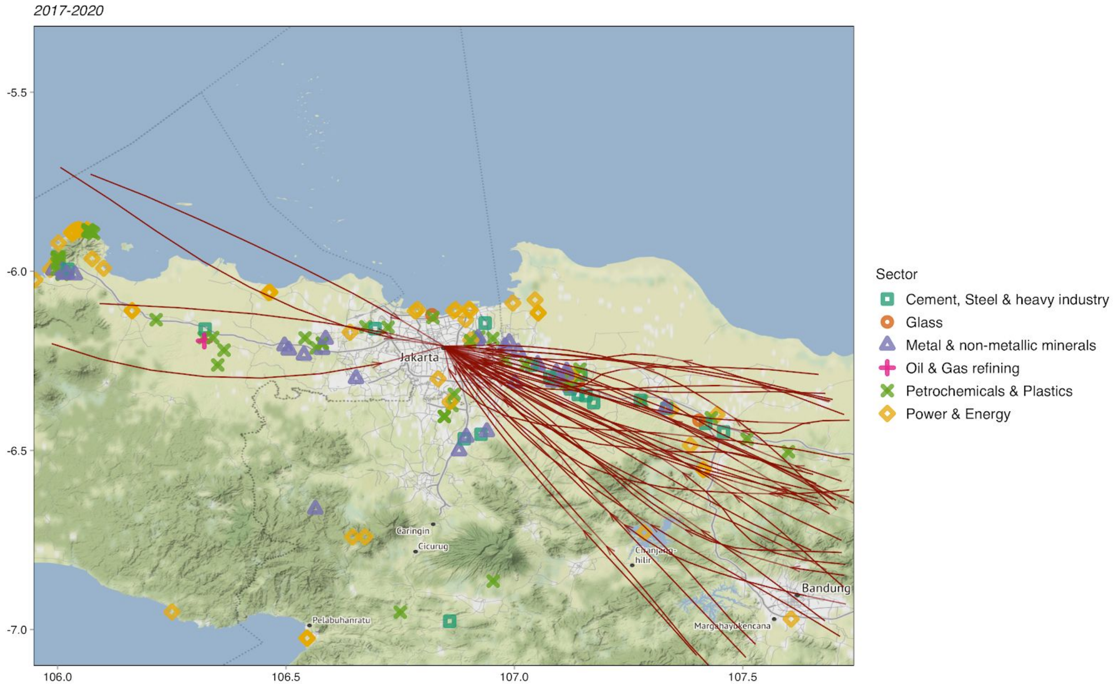
Figure 4: Most representative wind trajectories that reached Jakarta during the wet and dry seasons (2017-2020)



To further illustrate that wind trajectories are a factor in transboundary pollution, we modeled the individual wind trajectories on some of the days with the worst air pollution readings in Jakarta (when PM2.5 was over 80 µg/m3). *Figure 5* shows the wind trajectories that entered Jakarta during these peak pollution days between 2017 and 2020. These winds brought in pollutants from industries in Suralaya and Tangerang in Banten, as well as from industries in West Java, starting from the cluster of facilities on the eastern border of Jakarta and extending to West Karawang, Purwakarta, and Bandung.

Figure 5: Wind trajectories flowing into Jakarta during 'pollution peaks' (2017-2020)

Power plants and industrial facilities 100 km from Jakarta

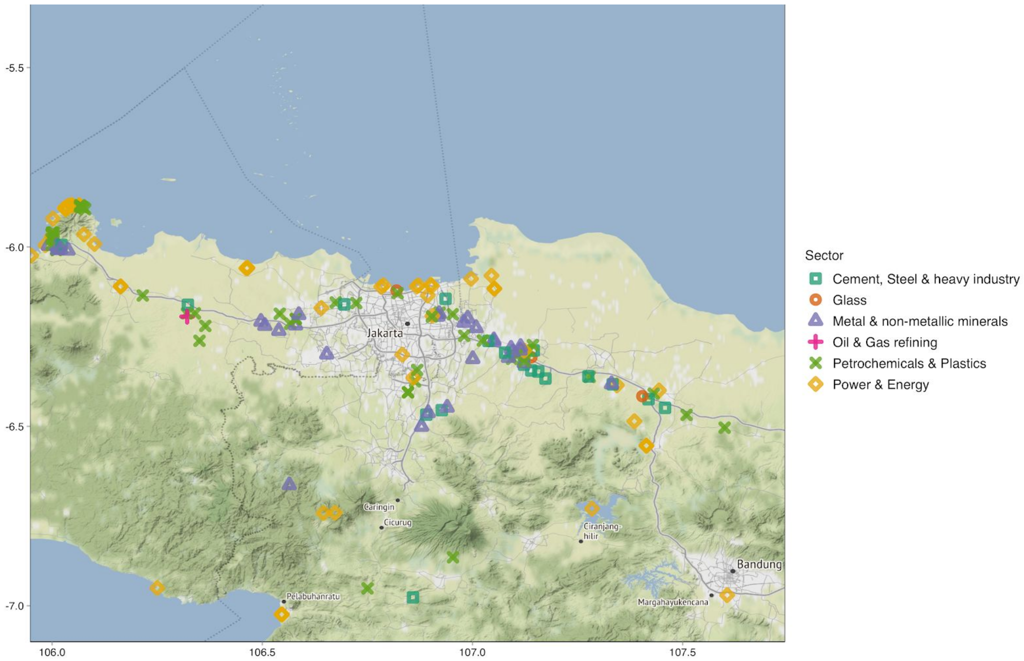


CREA based HYSPLIT modeling and PROPER 2019

Power plants & industrial facilities in western Java

A tally of facilities from the 2019 Program for Pollution Control Evaluation and Rating (PROPER) shows that a total of 418 industrial facilities are found within a 100 km radius of the greater Jakarta area. Of these facilities, 136 are in highly emitting sectors like cement and steel, glass, oil and gas refining, power and energy (which includes CFPPs), metals, and petrochemicals and plastics (*Figure 6*). 86 percent of these highly emitting facilities operate outside of Jakarta's borders; there are 62 facilities in West Java, 56 in Banten, 1 in Central Java and 1 in Sumatera Selatan which fall within 100 km of Jakarta.

Figure 6: Distribution of power and industrial plants in Jakarta and within 100km of the city



Source: CREA based on PROPER.

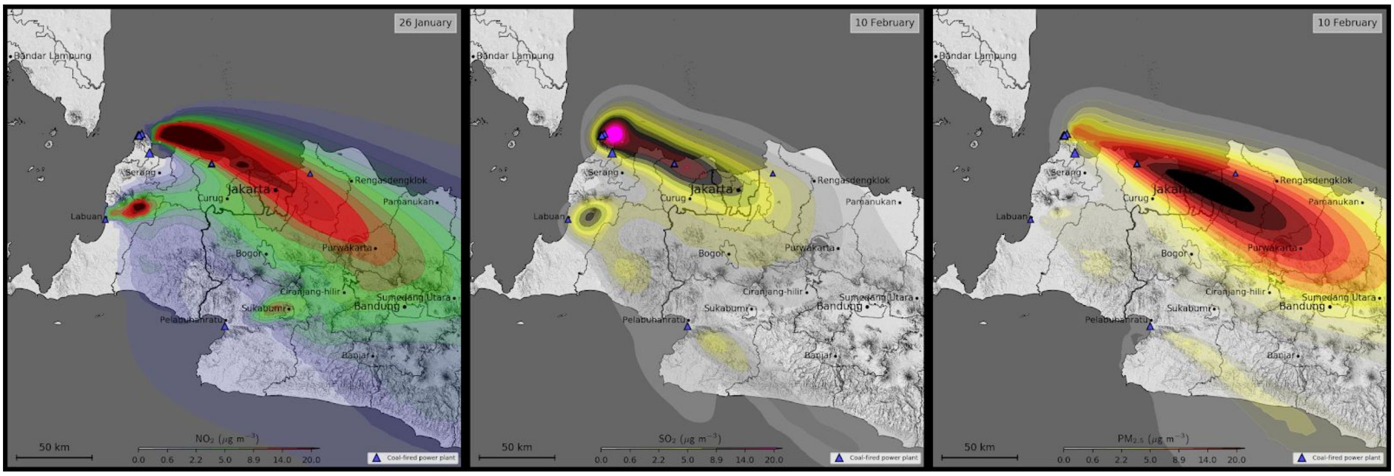
The cluster of power plants and industries that run along northern Java are hotspots for SO2 and NO2 emissions - both indicators of fossil fuel pollution. They also overlap with the areas where industrial facilities are located (*refer to both Figure 3 and Figure 6*).

Concentration & Distribution range of pollutants

To assess the contribution of large point sources to air pollution in Jakarta, we carried out detailed atmospheric modeling of pollutant dispersion from the coal-fired power plants surrounding the city. We developed 3-dimensional meteorological data for every hour of the modeling year (2014), including wind speeds, directions, humidity, temperature, atmospheric stability and other relevant variables using the TAPM meteorological model developed by Australia's national science agency CSIRO. We then used the CALPUFF dispersion model, the most widely used long-range model in the world, to simulate the pollution from the coal-fired power plants. The model tracks ground-level pollution dispersion, chemical transformation and deposition in the atmosphere to assess the impact of the modeled sources on air quality across the modeling area.

TAPM/CALPUFF modeling of surface-concentrations of pollutants emitted from coal-fired power plants shows that large emissions sources up to 100km away from Jakarta have a significant impact on the city's air quality. Figure 7 shows examples of the worst-case pollution dispersion in Jakarta, when air masses arrived in the city from the Suralaya industrial zone, where five large CFPPs are located. PM2.5 pollutant concentration (*right-most in Figure 7*) caused by the coal plants in this case is higher in DKI Jakarta than in Banten. This is partly due to the transformation of large SO2 and NOx emissions from coal plants in Banten - where the two pollutants are most highly concentrated (*center and left-most images in Figure 7*) - into secondary PM2.5 downwind and closer to Jakarta.

Figure 7: NO2, SO2 and PM2.5 concentrations over Jakarta on the "worst days" of pollution



We also used TAPM/CALPUFF to model emissions of the three pollutants from the six coal-fired power plants within 100km of Jakarta averaged for each month to demonstrate differences in the dispersion and concentrations of pollutants (*Figure 8-10*). The concentration of pollution in the northernmost area of Banten, where the Suralaya plants are located, remains consistently high, and contributes to air pollution in Jakarta in all months, with highest impacts from December through April.

Figure 8: Monthly Average of NO2 concentrations from coal-fired power plants

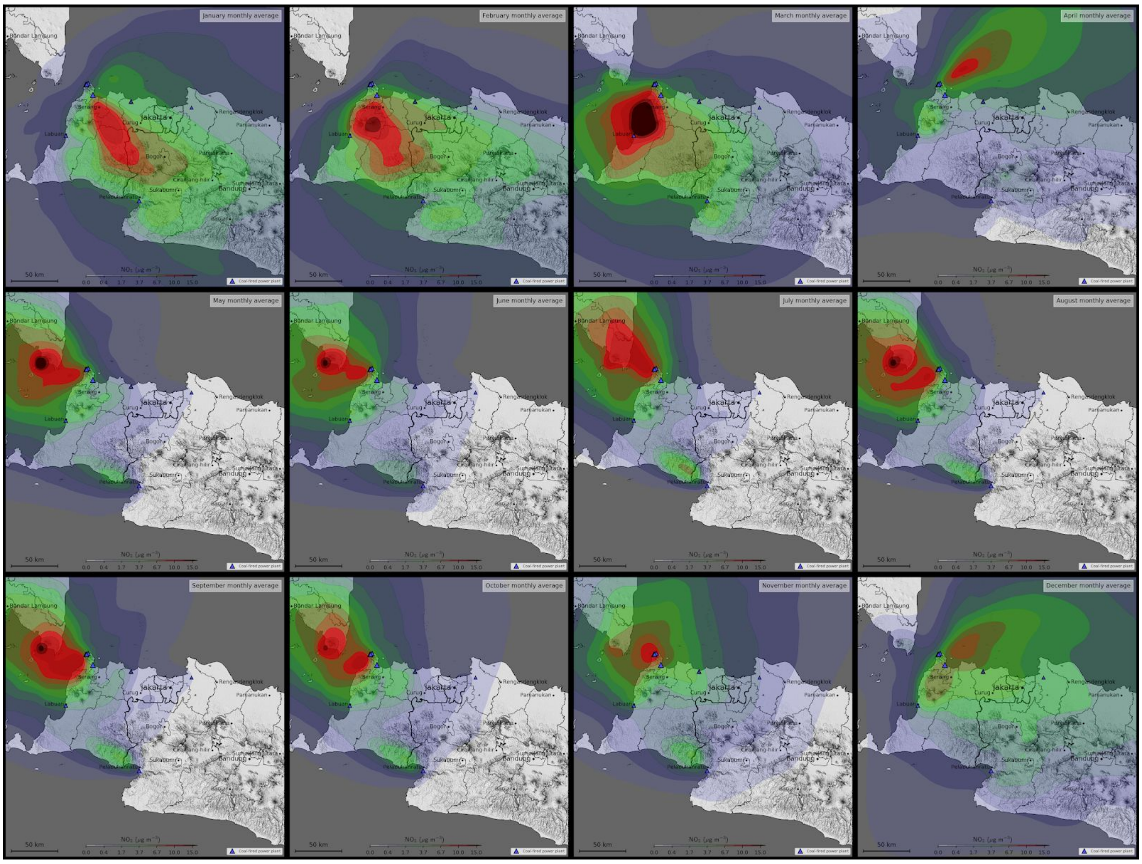


Figure 9: Monthly Average of SO2 concentrations from coal-fired power plants

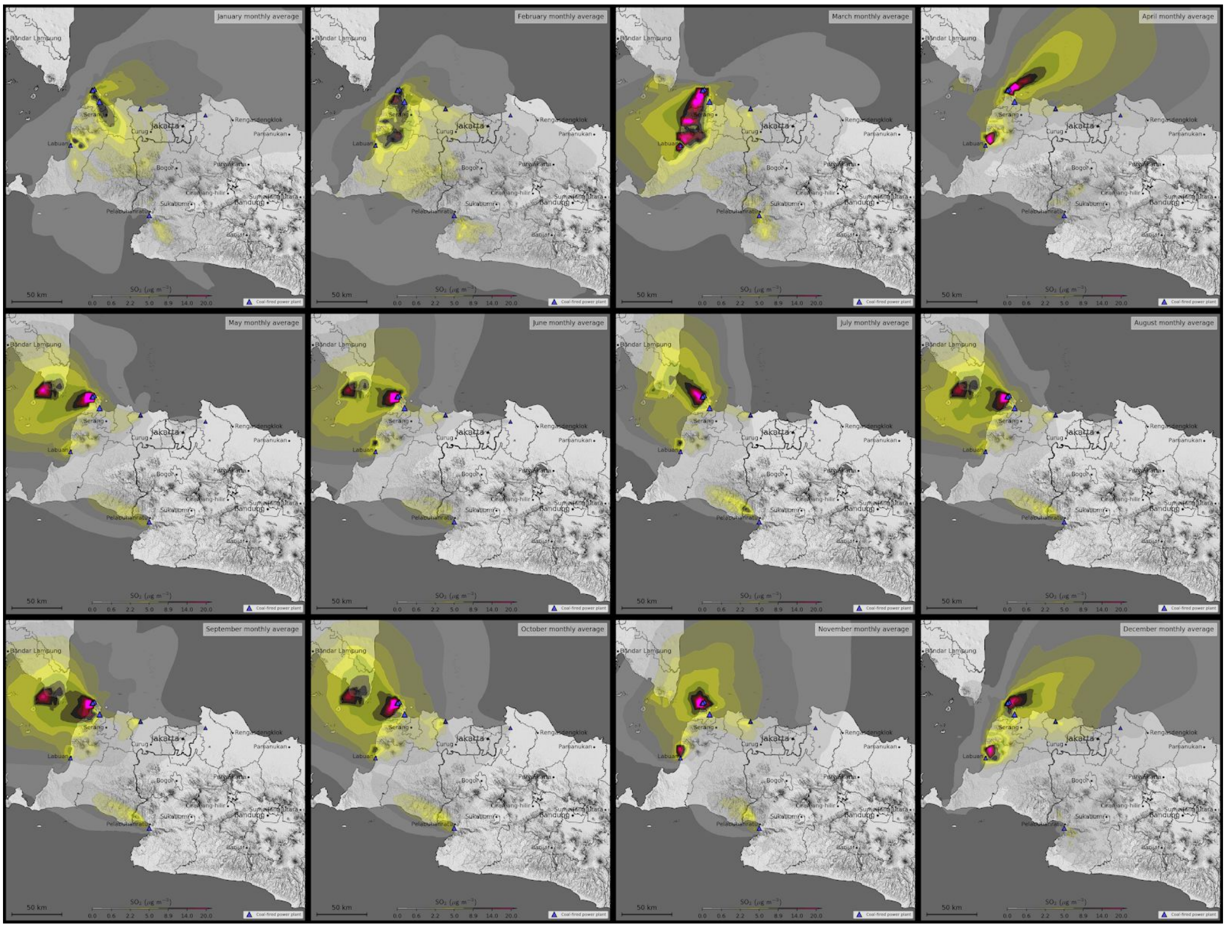
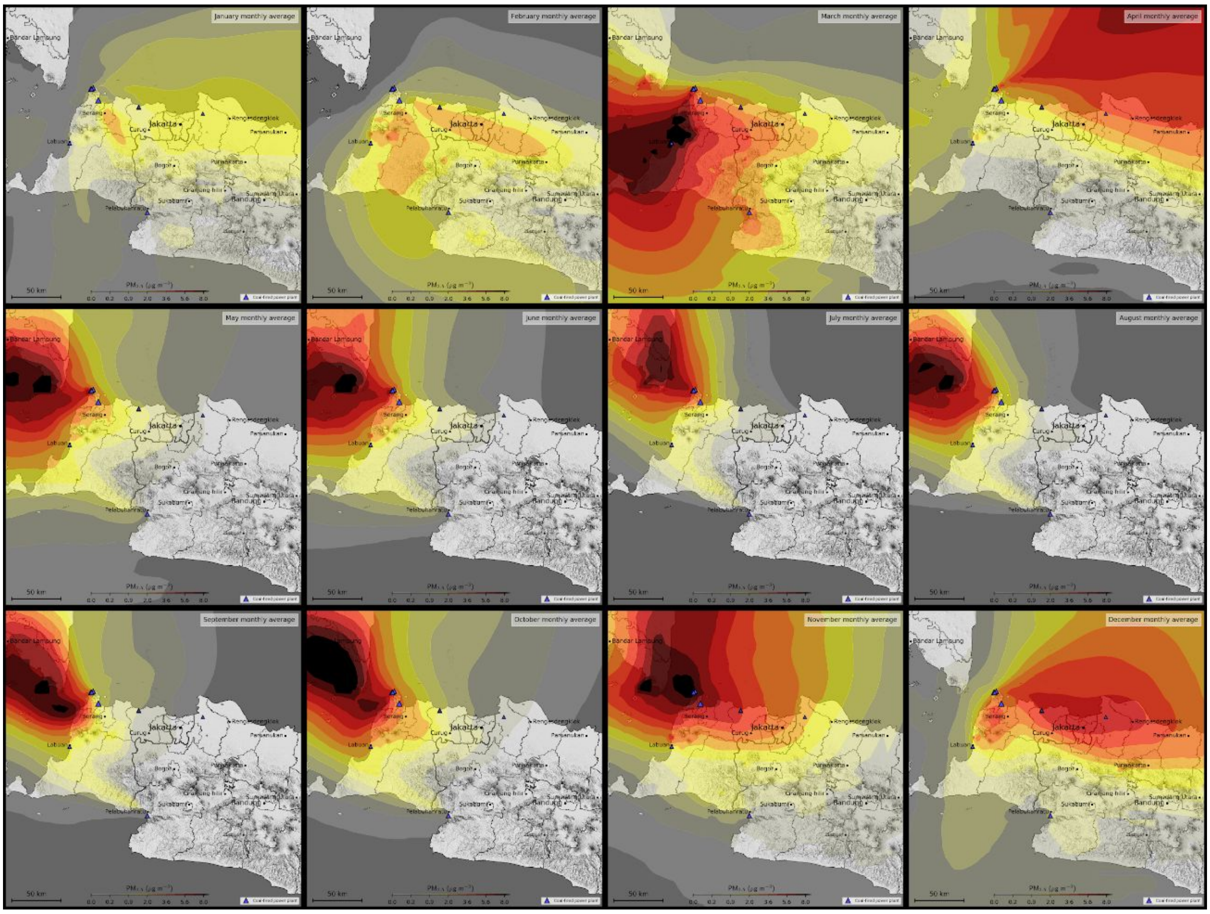


Figure 10: Monthly Average of PM2.5 concentrations from coal-fired power plants



Emission sources in the areas affecting Jakarta’s air quality

The figures above make it clear that Jakarta’s “airshed” - the area within which air is frequently confined or channeled, and thus the area where emissions affect Jakarta’s air quality - extends far outside the city’s borders to include Banten, West Java, Sumatera Selatan, Lampung, and Central Java. Because of their proximity, the Kabupatens of Serang, Tengerang, Kota Cilegon and Kota Tangerang in Banten, as well as Kota Depok, Kab. Bekasi and Kab. Karawang in West Java all fall within the airshed and regularly contribute to transboundary pollution into Jakarta. Many other Kabupatens located more than 100km from Jakarta's border are also part of the airshed (*Figures 8-10*), but their contributions to transboundary pollution have not yet been analyzed in detail.

This is in line with experiences in other countries and cities. For example, in New Delhi, India, air quality measures target the “National Capital Region” which extends 300 km outside the city, while for Beijing and Shanghai in China, the “National Key Control Regions” designated around these cities extend up to 500 km away.

Analysis of emissions in Java, based on the EDGAR 5.0 emissions inventory for 2015, prepared by the European Union Joint Research Committee, shows that Central Java, West Java and Banten each have much higher air pollutant emissions than the Greater Jakarta area (*methodology in the Appendix*). In terms of emitting sectors, energy (power plants), industry, road transport, agriculture and residential fuel use are all important sources of pollution. The emissions inventory by province and sector in *Figure 11* show that the provinces of West Java, Banten, and Central Java have the highest emissions among the provinces found within Jakarta's airshed; higher than Jakarta itself. The extent to which each province contributes to transboundary air pollution in Jakarta has not yet been analyzed.

Figure 11: Air pollutant emissions around Jakarta by province (2015)

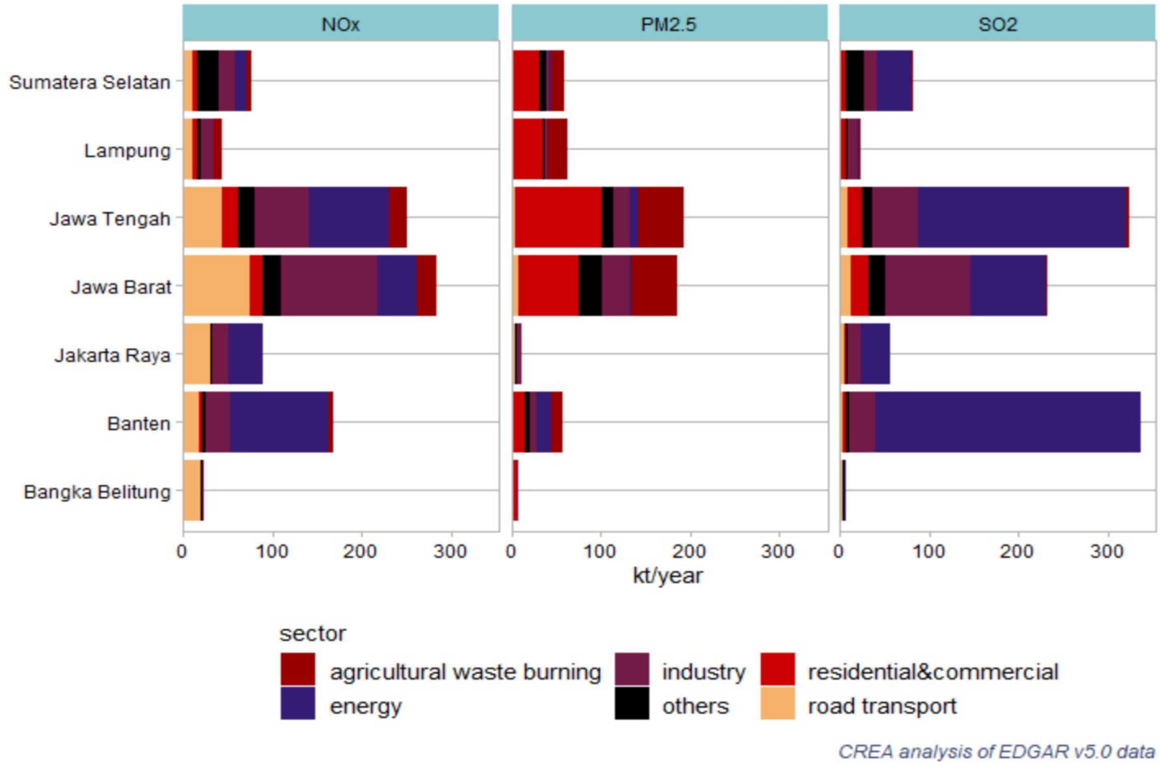
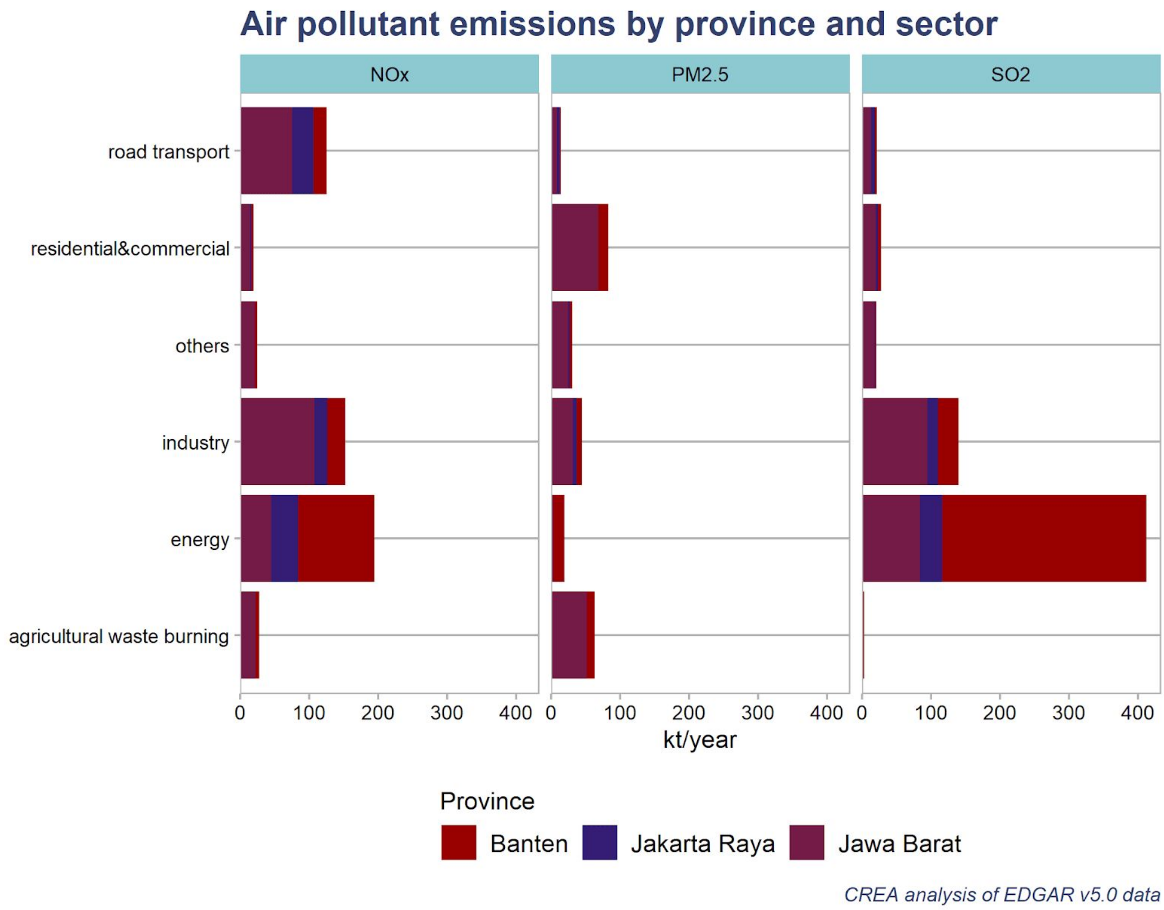


Figure 12 is a combined emissions inventories of Jakarta, West Java and Banten that shows the amount of pollutants from each sector. SO2 and NOx emissions from the energy and industrial sectors are highest, while primary PM 2.5 is more heavily emitted from agricultural burning and the residential and commercial sectors. It is important to note that these emission inventories do not calculate how large amounts of SO2 and NOx in the atmosphere transform into "secondary" PM2.5 and ozone. While industrial and energy sources of primary PM2.5 are small, large amounts of secondary PM2.5 can be very significant, especially as wind trajectories carry them from one province to another, as shown in the sections above. Thus, it is important to address all sources of pollution that may impact Jakarta, particularly from the industry and energy sources in Banten and West Java.

Figure 12: Air pollutant emissions by sector in Jakarta, West Java and Banten (2015)



While EDGAR data shows how emissions by province and sector contribute to the regional airshed, it is not a replacement for local emissions inventories, which provide specificity to the sources of pollution and their contributions to a smaller geographic area. Emissions inventories conducted at a city level across the three provinces should be part of air quality management plans.

Estimated risk of air pollution without regulations on emissions

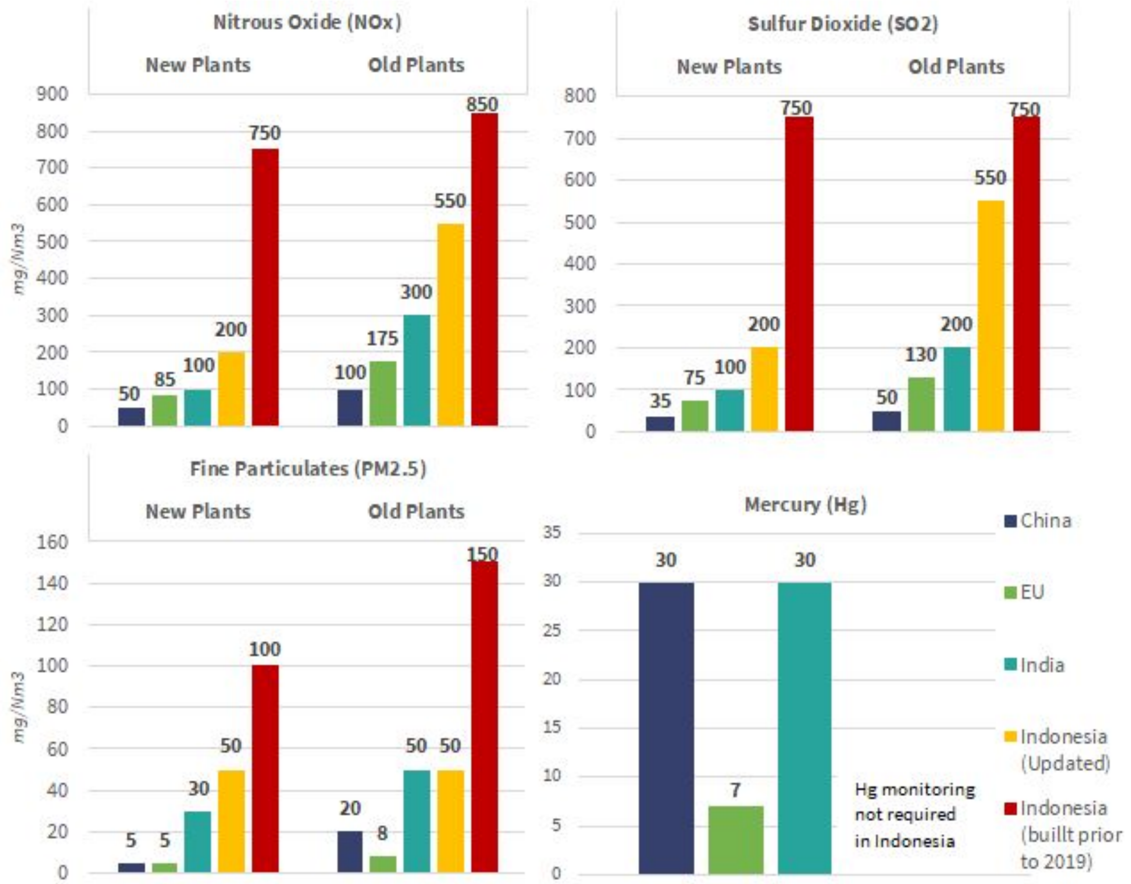
According to Indonesia's National Energy Council, the country has a projected 5% average annual growth rate in national energy demand under a business-as-usual scenario, where demand in 2050 is almost four times that of 2019 (Indonesia Energy Outlook, 2019). Despite plans to increase renewable energy, an increase in fossil fuel supply and consumption is expected in order to meet projected demand in the energy, transportation, industrial, and commercial sectors. Unless stronger standards and policies are introduced and enforced, the already unhealthy air quality will continue to worsen.

There are 7600 megawatts (MW) of operating coal-fired capacity within 100km of Jakarta's borders, with another 6000 MW in development. This is more than any other national capital airshed in the world, and currently the highest stationary source of emissions (*Figure 13*). In addition, the air pollutant emissions standards applied to these plants are very weak, allowing 10-20 times more air pollution than the recommended standards (e.g. in China, the European Union, Japan or South Korea). More than half of current capacity within 100 km of Jakarta is in the Banten Suralaya power plant complex, the most polluting industrial complex in all of Southeast Asia based on satellite measurements (NASA 2020).

Emissions Standards for thermal power plants

In 2019, the MoEF issued new emission standards that substantially strengthened the limits for "new" coal-fired power plants, but the ministry has stated that these new plant limits won't be applied to the new projects coming up around Jakarta since they already have power purchase agreements or permits. In addition, old plants can emit levels of NOx and SO2 of up to 550 milligrams per cubic metre (mg/Nm3) - which are significantly higher than standards of most other major coal consuming countries, and not limiting enough to incentivize retrofitting of such plants with effective pollution controls. The enormous planned expansion of coal-fired power generation, combined with the failure to require compliance with new plant emission limits, is a distinct threat to the air quality of Jakarta.

Figure 13: Comparison of Indonesia's operating and new emission standards for thermal power plants to China, India, and the European Union



Economic & Health Costs of air pollution from surrounding coal plants on Jakarta

The energy sector is the largest source of SO2 and NOx pollutant emissions in the provinces surrounding Jakarta - although not the only source (*Figures 11 and 12 above*). To illustrate the importance of transboundary pollution, we present a further analysis of the health and economic impacts of this sector.

Dangerous air pollution from power plants in Banten and West Java is made worse by weak emissions standards, severely impacting both the health of Jakartans and the city's economy. Coal-fired power plants expose people to toxic particles (some microscopic like PM2.5), ozone (from NOx) and heavy metals like mercury. In addition to the direct effects on human health, exposure to such particles indirectly impacts healthcare systems, economic productivity, and social welfare. With the COVID-19 pandemic, such stresses on the country's systems will only worsen. New studies show links between long term exposure to poor air quality and vulnerability to the virus (CREA, 2020; Harvard, 2020).

CREA modeled the health impacts of the coal power plants surrounding Jakarta, following the methodology of the Harvard study "Burden of Disease from Rising Coal-Fired Power Plant Emissions in Southeast Asia", updated to the current situation of operating coal-fired power plants (This model does not include PLTU Jawa 7 Unit 1, which began operations in December 2019. *See Appendix for list of plants included*). The air quality modeling was done with the CALMET-CALPUFF modeling system that allows higher local resolution than the original study. We found that transboundary air pollution from coal-fired power plants alone is responsible for an estimated 2500 air pollution-related deaths in Jabodetabek annually.[4] This transboundary pollution is also responsible for other negative health impacts, including new cases of asthma, asthma emergency visits, preterm births, increased prevalence of disabilities related to stroke, respiratory diseases and diabetes, as well as increased sick leaves.

Table 1: Estimated health impact of transboundary air pollution from operating coal-fired power plants on Jabodetabek *(excluding PLTU Jawa-7)*, using 2019 standards.

Health effects		Operating	95% confidence interval
PM2.5 deaths	Lower respiratory infections (infants)	40	(10-90)
	Lung cancer	60	(20-90)
	Other cardiovascular diseases	170	(100-230)

[4] Jabodetabek includes the city of Jakarta and the surrounding regions of Tangerang, Bogor, Depok, Bekasi, Puncak, and Cianjur.

	Ischemic heart disease	480	(310-650)
	Stroke	550	(340-760)
	Other respiratory diseases	60	(40-80)
	Chronic obstructive pulmonary disease	80	(50-110)
	PM2.5 Total	1430	(870-2020)
NO2 deaths	All causes	1020	(590-2180)
Total premature deaths		**2450**	**(1260-3470)**

The economic costs of these health impacts on Jabodetabek were assessed following the methodology of the CREA report "Quantifying the Economic Costs of Air Pollution from Fossil Fuels". Currently, transboundary pollution from coal power plants causes estimated annual costs of IDR 5.1 trillion in Jabodetabek. This is currently equivalent to IDR 180,000 per person per year in the city.

Table 2: Estimated economic cost of transboundary air pollution from operating coal-fired power plants on Jabodetabek *(excluding PLTU Jawa-7)*, using 2019 emissions standards.

Outcome	Number of cases	Cost (IDR billion)
asthma emergency room visits	1,772 (1,180 - 2,427)	1.6 (1 - 2.1)
new cases of asthma in children	3,180 (1,485 - 4,013)	51 (24 - 65)
preterm births	718 (416 - 746)	264 (153 - 275)
work absence (sick leave days, million)	0.65 (0.56 - 0.73)	191 (166 - 215)
years lived with disability	9,616 (7,678 - 11,275)	1,040 (830 - 1219)
years of life lost	24,953 (18,432 - 34,855)	3,528 (2,606 - 4,927)
total economic cost		**5,076 (3,781 - 6,703)**

Recommendations

Air pollution is a manageable problem. Prioritizing the necessary measures to protect Indonesian citizens' right to clean air will require the appropriate policies to regulate and monitor both ambient air quality and pollution from major sources. These policies must be accompanied by enforcement mechanisms to hold large polluters accountable whilst protecting Indonesia's environment and citizens. Considerable efforts have been made to establish a national energy plan, which must be supported by reforms to the country's air quality management system. This should include:

- **Revising the National Ambient Air Quality Standard to meet the WHO guidelines for healthy air quality.** This requires time-bound targets to reduce pollutants like PM, NOx, and SO2 at both the national and provincial level.
    - To ensure accuracy of information about air quality and compliance with environmental standards, the government must also improve monitoring networks both within Jakarta and in all major cities. Monitoring stations should measure for emissions in real-time, and data from these stations should be readily available to the public. The data should also be reported electronically across different levels of government (e.g. city, province and central) to prevent data manipulation.
- **Enforcing the updated 2019 emissions standards on all planned thermal power plants** (Figure 13), **including ones currently under construction to ensure that plants can still be retrofitted to fit stricter and safer emissions standards.**
    - To ensure compliance, such facilities should also be responsible for installing continuous emission monitoring systems (CEMS) for all major pollutants (e.g. PM2.5, PM10, SO2, NOx, ozone and carbon monoxide). This will also allow regulators and monitoring bodies to track whether such standards are sufficiently mitigating emissions.
- **Updating the emissions standards for other polluting industries based on industry-specific "Best Available Technology" to minimize their environmental and health impacts.** Jakarta already has stricter controls on air pollution sources, but as this analysis shows, emissions from sources outside of the city greatly affect Jakarta air quality and public health. Working with neighboring jurisdictions and the national government to monitor and reduce pollution outside city borders will ensure that efforts in one municipality are not undermined by lack of effective pollution reduction elsewhere.
    - All power plants and industrial facilities in Jakarta's multi-province airshed contribute to pollution in Jakarta. Given the cross-province reach of stationary source emissions in western Java, the provinces of Jakarta, Banten and West Java should collaborate on setting emissions control targets. This can begin with a baseline emissions inventory analysis to analyze cumulative air pollution from various sources across the region.

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Appendix

Data for modeled coal power plants

Table A1: Operating and planned coal-fired power plants within 100 km of Central Jakarta

Plant	Latitude	Longitude	Units	Capacity (MW)	Status
PLTU Suralaya	-5.89274	106.0308	8	4025	Operating
PLTU Labuan Unit 1-2	-6.39212	105.8285	2	600	Operating
PLTU Lontar Unit 1-3	-6.05941	106.4619	3	945	Operating
PLTU Babelan Unit 1-2	-6.11607	107.052	2	280	Operating
PLTU Banten Unit 1 (Lestari Banten Energi)	-5.88297	106.0459	1	670	Operating
PLTU Pelabuhan Ratu	-7.0242	106.5464	3	1050	Operating
PLTU Jawa 7 Unit 1	-5.99691	106.0917	1	1000	Operating *(but not included in modeling)*
PLTU Jawa 7 Unit 2	-5.99691	106.0917	1	1000	Construction
PLTU Lontar Expansion	-6.05941	106.4619	1	315	Construction
PLTU Jawa 9	-5.89384	106.0227	-	1000	Financing
PLTU Jawa 10	-5.89384	106.0227	-	1000	Financing
PLTU Banten Unit 2	-5.88297	106.0459	-	660	Planned
PLTU Jawa 5	-5.89274	106.0308	-	1000	Planned

Table A2: Estimated air pollutant emissions from operating power plants (CALPUFF Modeling Input)

Units	Thermal Efficiency	Flue Gas Concentration (mg/Nm^3)	Annual Emissions (Tonnes)					
			SO_2	NOx	PM	PM10	PM2.5	Hg *(kg)*
PLTU Suralaya - Banten 1-4	Subcritical pulverized combustion (34% efficiency)	SO2: 550 NOx: 550 Dust: 100	18,806	18,806	3,419	2,308	1,026	90
PLTU Suralaya - Banten 5-7			21,157	21,157	3,847	2,596	1,154	101
PLTU Suralaya - Banten 8	Subcritical (37%)		8,016	8,016	1,457	984	437	38

PLTU Labuan Unit 1-2	Sub-critical circulating fluidized (37%)		7,695	7,695	1,399	944	420	37
PLTU Lontar Unit 1-3	Subcritical (38%)		11,801	11,801	2,146	1,448	644	56
PLTU Babelan Unit 1-2	Subcritical (38%)		3,497	3,497	636	429	191	17
PLTU Banten Unit 1 (Lestari Banten Energi)	Supercritical (38%)		8,367	8,367	1,521	1,027	456	40
PLTU Pelabuhan Ratu	Subcritical (38%)		13,113	13,113	2,384	1,609	715	63

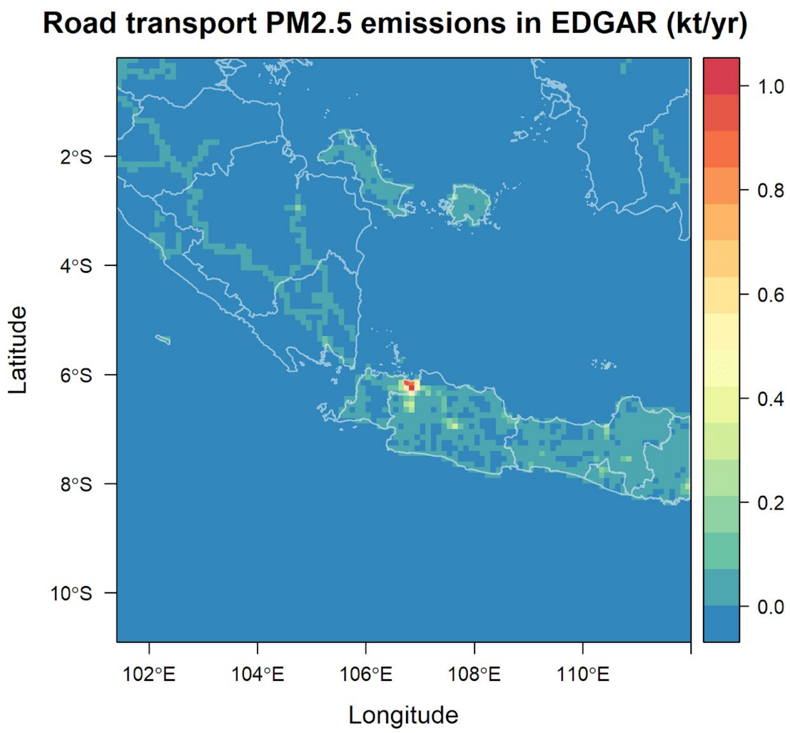
Table A3: Basic Plant Data (CALPUFF Modeling Input)

Plants	Stack Height (m)	Stack Inner Diameter (m)	Flue Gas Velocity (m/s)	Flue Gas Temperature (C)
PLTU Suralaya - Banten 1-4	200	5.5	21.5	72
PLTU Suralaya - Banten 5-7	275	6.5	-	-
PLTU Suralaya - Banten 8	275	-	-	-
PLTU Labuan Unit 1-2	215	7.5	-	94.85
PLTU Lontar Unit 1-3	127	4.6	25	131
PLTU Babelan Unit 1-2	235	6.3	17.4	90
PLTU Banten Unit 1 (Lestari Banten Energi)	235	6.3	17.4	90
PLTU Pelabuhan Ratu	235	6.3	17.4	90

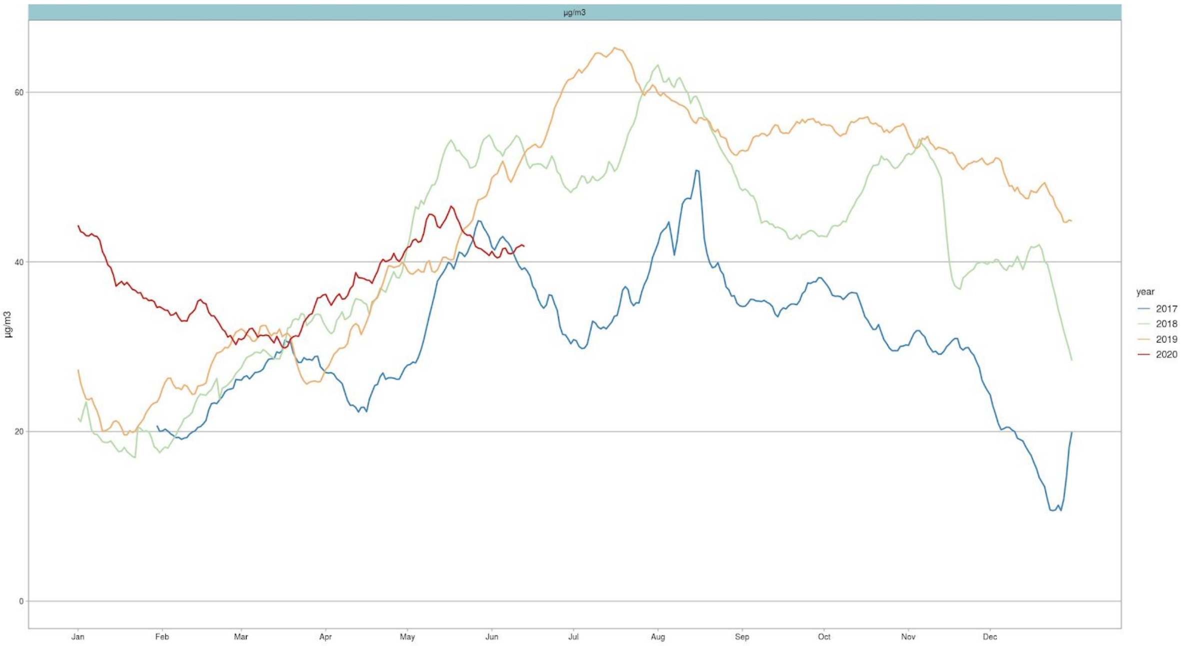
Methodology of EDGAR 5.0

The Emissions Database for Global Atmospheric Research (EDGAR v5), used to generate findings on the emissions sources in Jakarta's airshed, provides data on past and present day (1970-2015) anthropogenic emissions of air pollutants by country and sector on a spatial 0.1 degree by 0.1 degree grid. The emissions inventories found in Figures 11 and 12 feature emissions - not ambient concentrations - for three major pollutants available with EDGAR. These emissions are calculated using a technology-based emission factor approach, checked for abatement measures and quality controlled. This is applied consistently across all countries on an annual basis. In addition, EDGAR uses a geographical database built using spatial proxies to plot the location of energy and manufacturing facilities, road networks, shipping routes, human and animal population density, and agricultural land use, which can vary and change significantly over time. This gives us the ability to aggregate approximate emissions down to the city level, and disaggregate by pollutant and sector. EDGAR relies on various proxies to allocate emissions from the national level. Where they are not available, it relies on population density. As a result, some emissions for sectors like industry - though very often significantly high emitter - can be overestimated over urban areas with large populations. However, in combining the emissions of Banten, West Java and DKI Jakarta in Figure 12, we are able to better understand how facilities even outside the 100km focus of this study emit, and therefore become a factor in Jakarta's airshed and the city's overall air pollution.

Example of EDGAR emissions data: road transport emissions

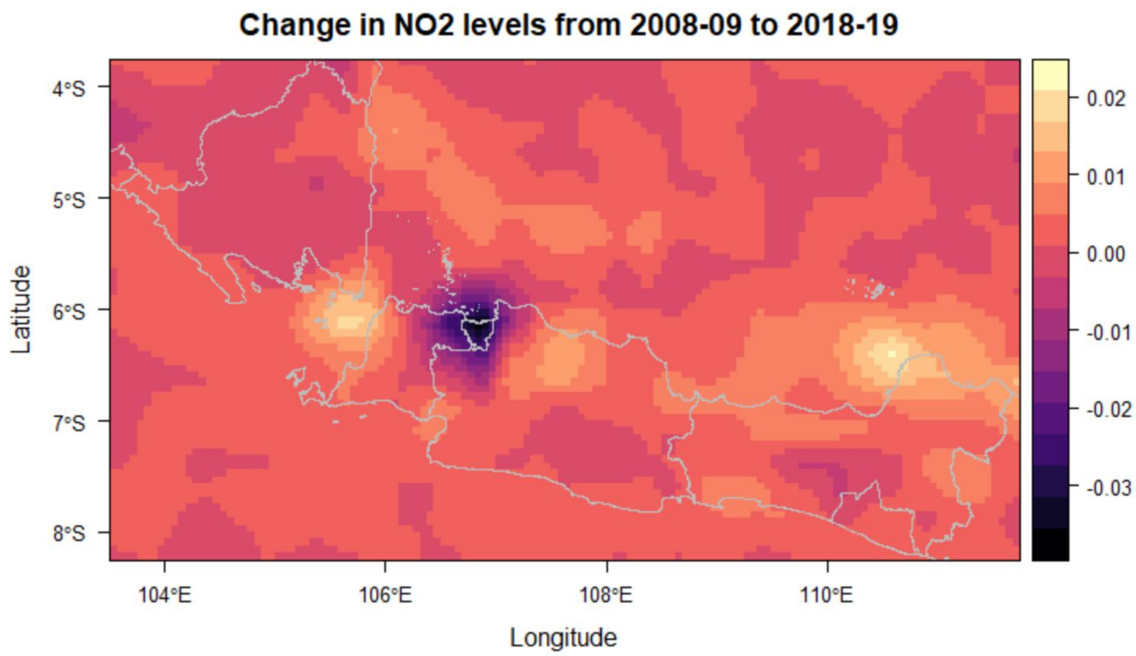


30-day running average of daily PM2.5 concentrations in Jakarta, Indonesia
Unit: µg/m3



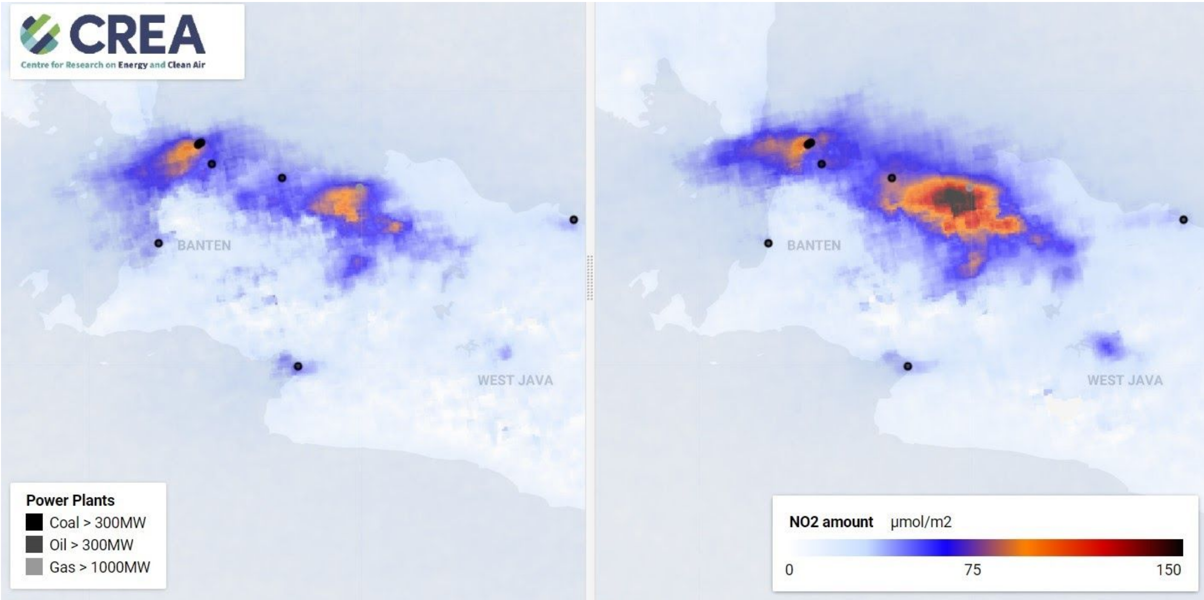
SOURCE: CREA Analysis of US Embassy monitoring stations in Jakarta, accessed through OpenAQ

Change in NO2 levels over the last decade
Unit: Dobson Unit (DU)



SOURCE: CREA Analysis of [NASA OMI Daily Data]

Atmospheric NO2 from 12 March to 4 June 2020 (left) vs 2019 (right) during COVID-19 WFH and PSBB show a decrease in NO2 over Jakarta, Banten and West Java and no change in Suralaya



Source: CREA Analysis of TROPOMI Sentinel-5P Satellite data