DOUBLE STANDARD

二重基準

A DEADLY DOUBLE STANDARD

How Japan's financing of highly polluting overseas coal plants endangers public health

GREENPEACE

Contents

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Executive summary

Japan is the only G7 country still actively building new coal-fired power plants at home and abroad, and is the second biggest public investor in overseas coal-fired power plant projects among the G20 countries through its public finance agencies (PFAs). Coal is the single worst contributor to global climate change, responsible for almost half the world's carbon dioxide emissions.[1,2] In addition, burning coal releases high amounts of dangerous air pollutants that are known to be responsible for premature deaths by causing a range of severe diseases.[3,4] Most overseas coal power projects supported by Japan employ emission control techniques far inferior to those required at home. In effect, Japan is operating a deadly double standard: Financing coal-fired power plants overseas that create air pollution at levels that would not be acceptable in Japan.

The double standard in emission limits for dangerous air pollutants allows Japanese-financed coal power plants to emit up to 13 times more nitrogen oxides (NO_x), 33 times more sulfur dioxide (SO_2) and 40 times more dust pollution than those built in Japan. This report reveals the deadly consequences of that double standard, in terms of premature deaths caused by air pollution, and evaluates how many of those deaths could be avoided if the projects funded by Japan overseas applied the same emission limits as the new coal power plants in Japan.

The impact of Japan's double standard in emission limits is evaluated by comparing the number of premature deaths caused in two different scenarios:

- **Scenario 1:** Predicted coal-fired power plant emissions based on the application of current local emission limits and actual or projected plant utilization.
- **Scenario 2:** Predicted coal-fired power plant emissions if median Japanese emission limits from coal power plants that were permitted or under assessment or planning since January 2012 were applied.

Despite the complexity of Japan's national standards for emissions from coal-fired power plants, emission limits set in environmental permits for new power plant projects are strict. We carried out detailed atmospheric modeling and health impact assessments for 17 coal power plants financed by Japanese PFAs overseas during the period January 2013 to May 2019, located in the top five invested countries: Indonesia, Vietnam, Bangladesh, Morocco and India.[5]

Our results indicate that if the median Japanese emission limits were applied – not just in Japan but to all coal power plants financed by Japanese PFAs outside of Japan – an estimated 5,000 to 15,000 premature deaths would be avoided each year. Over the typical 30-year operation period of such power plants, this amounts to between 148,000 and 410,000 avoidable premature deaths resulting from the 17 coal power plants financed by Japanese PFAs and operating under poor emission limits. Most of the deaths would occur in

India, Indonesia, Vietnam and Bangladesh, countries where dangerous air pollution is already a problem. Japanese investments in coal power are making it even harder for these countries to reduce air pollution and meet public health standards.

All countries need to shift immediately away from coal and toward renewable energy sources to avoid catastrophic climate change and prevent the health impacts of coal emissions, including premature death. Countries must work together towards a carbon-neutral economy, and Japan should play a leadership role in doing so. In contrast to the unethical and deadly double standard that Japan is applying to coal power projects overseas – causing illness, premature death and climate change – Japan's PFAs should support renewable energy solutions instead. Renewable energy and energy efficiency are getting cheaper than building new coal-fired power plants, and rather than exacerbating air pollution and climate change, they provide a solution.

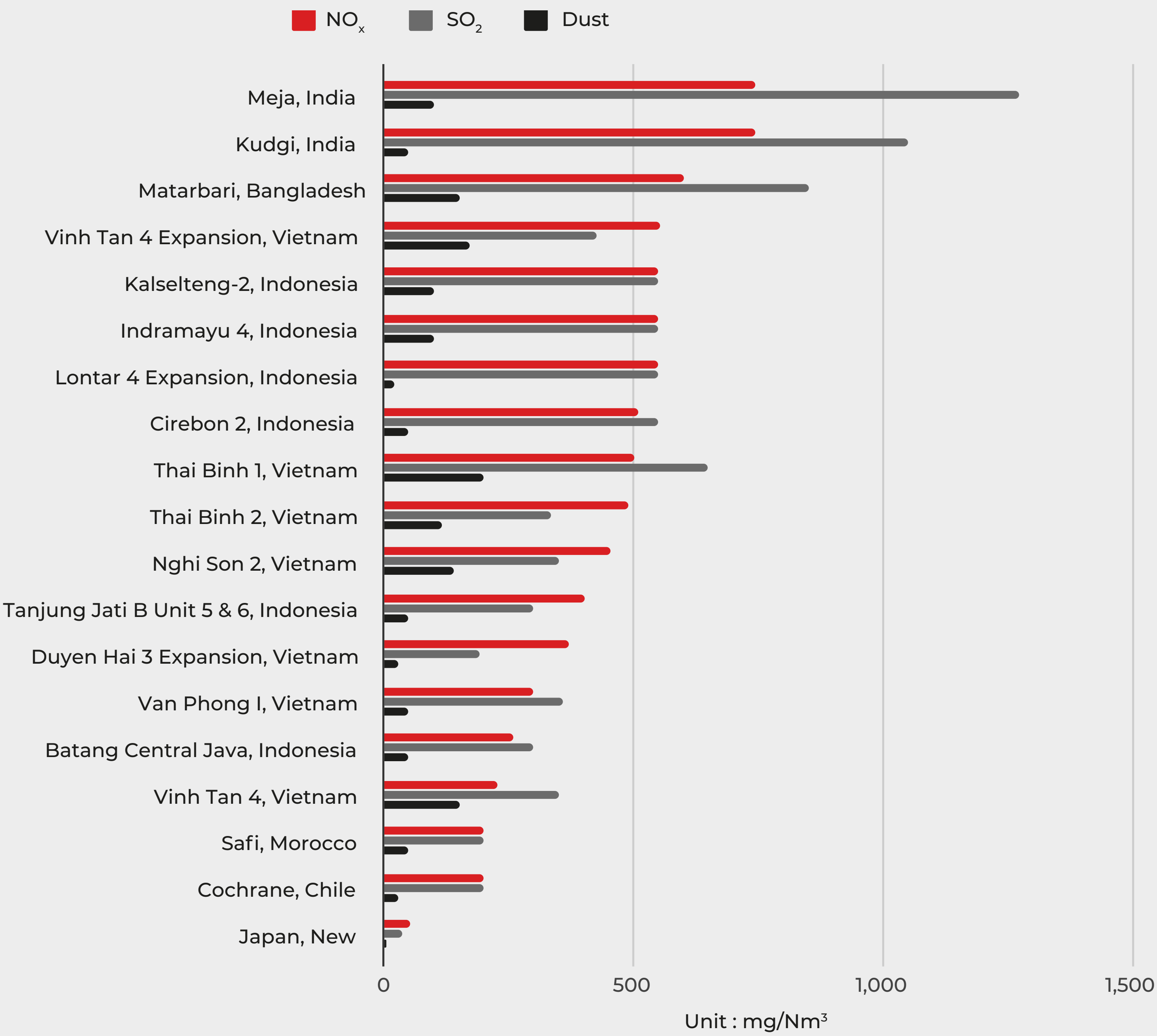
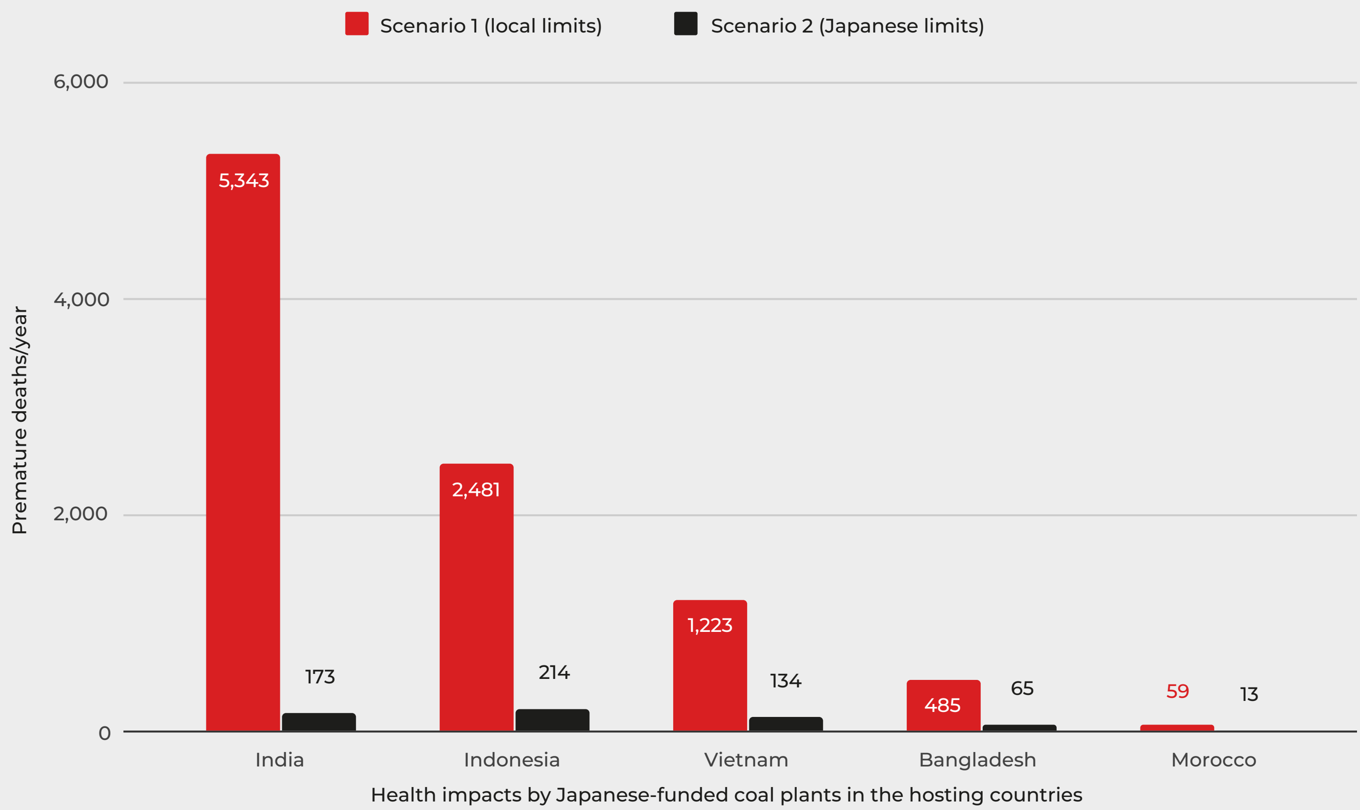


Figure: Emission limits for air pollutants NO_x, SO_2 and dust for Japanese coal power plants[6] compared to Japanese-financed coal power plants in other countries.



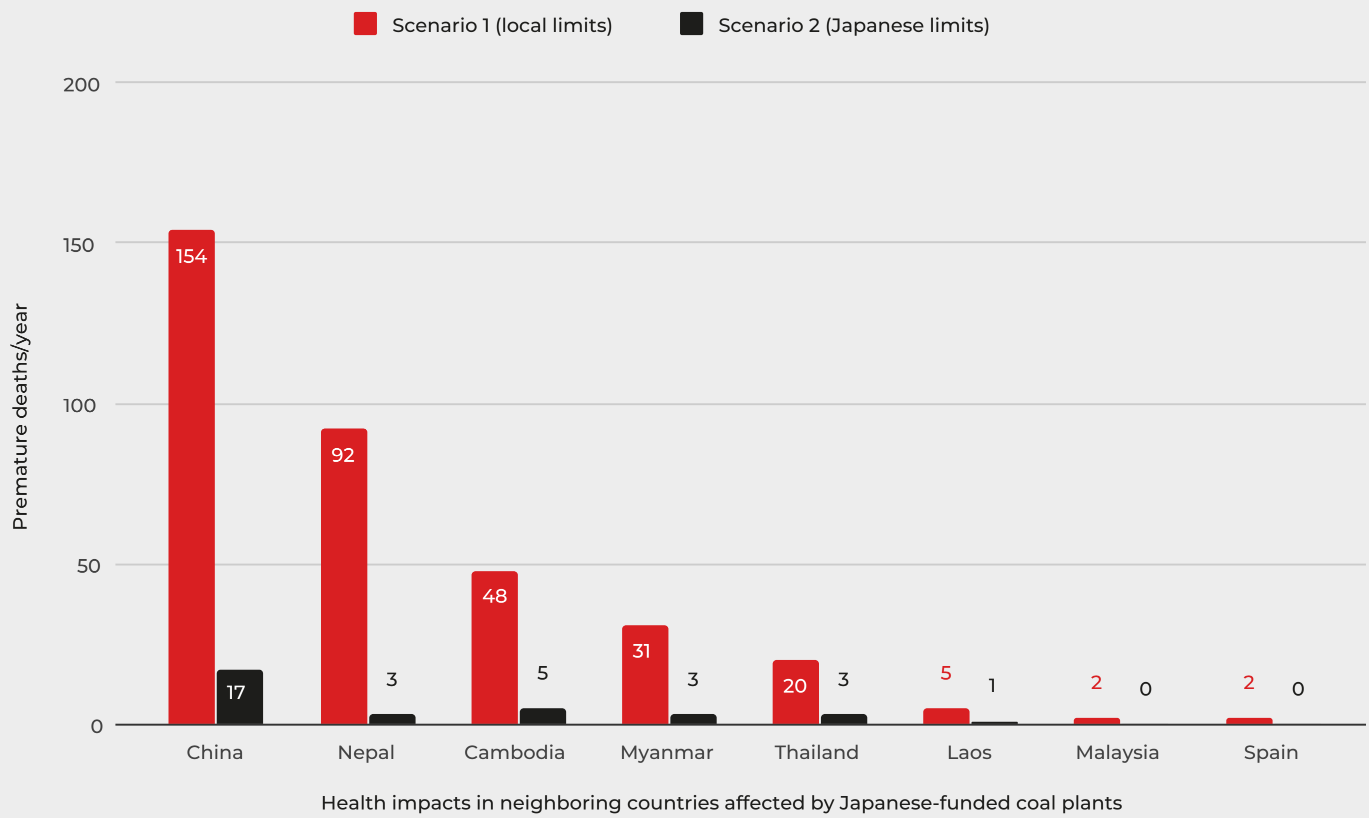


Figure: Projected number of premature deaths per year in the hosting/neighboring countries due to Japanese PFA-financed coal power plants operated under local emission limits (red) vs. operated in line with Japanese emission limits (black). Uncertainty range is about 50% (exact values are shown in the result section).

The Japanese Government must immediately stop its PFAs from investing in overseas coal power plants for which emission limits do not meet the limits applied to coal power plants in Japan. By ending this deadly double standard, hundreds of thousands of lives could be saved.

Following international trends, Japan's private banks, insurance companies and trading houses have already started taking the first steps to limit their investments in coal power plant projects. However, Japan's PFAs still invest heavily in coal-fired power plants in other countries. Japanese Government must take urgent action to end this and ensure its PFAs move to fund renewable solutions rather than coal.

Additionally, the Japanese Government must immediately stop its PFAs from investing in overseas coal power plants for which emission limits do not meet the limits applied to coal power plants in Japan. By ending this deadly double standard, hundreds of thousands of lives could be saved.

At the same time, the governments in the host countries of these coal projects should protect their citizens' right to a safe and healthy environment, by significantly strengthening their emission standards for already existing coal power plants, while undertaking an energy transition from coal to renewable energy in their countries. This change in policies and investments must be accelerated now, for human and environmental health, and to safeguard the future of our planet.

Figure: Locations of Japanese PFA-financed coal power projects overseas, from January 2013 to May 2019.

Introduction

Air pollution is estimated to cause over 7 million premature deaths across the world each year and is responsible for many non-communicable diseases globally.[7] Premature deaths from air pollution cost the world's economy nearly 225 billion USD in 2013 in lost labour income alone.[8] While air pollutants arise from various sources, fossil fuels are a major contributor, and burning coal for power generation is one of the biggest contributors to air pollution globally.[9] Air pollution from coal plants is a significant issue for many countries in Southeast Asia, projected to cause 70,000 premature deaths annually by 2030.[10]

Coal-fired power plants (CFPPs) emit toxic SO_2, NO_x and particulate matter, which exposes people to $PM_{2.5}$ and NO_2 pollution. The impacts of air pollution on public health are often not sufficiently considered by financiers of coal-fired power plants. Such investments are often promoted as serving development needs, without showing the full picture.

Global coal demand increased by 0.7% in 2018 after a brief decline between 2013 and 2016. This recent increase is due to higher demand in Asia, which has outpaced declines in other parts of the world.[11] After China and India, Southeast Asia is one of the key regions where the demand for coal is growing.

According to the International Energy Agency (IEA), coal consumption in Southeast Asia increased substantially in Indonesia and Vietnam in 2018. Increasing electricity demand and a heavy reliance on coal for electric power generation in these countries has resulted in their coal-fired power generation increasing faster than their overall growth in power generation.[12]

An increase in coal power generation poses a risk to health by degrading air quality. Air quality in Bangladesh, India and Indonesia already ranks as some of the most unhealthy in the world. Adding more pollution from the construction of new coal plants will further increase pollution in these areas, and make it more difficult and expensive to reach acceptable ambient air quality standards.[13]

In addition to contributing to the problem of air pollution, coal-fired power is the single worst contributor to global climate change. Many nations are working to phase out coal in order to meet their commitments under the Paris Agreement to keep global temperature rise within 1.5°C to 2°C.

Countries in the Organization for Economic Cooperation and Development (OECD) must phase out coal by 2030, and the rest of the world by 2050, to avert the worst consequences of climate change.[14] However, while many countries move to phase out coal, others are both financing and building coal-fired power plants, even in countries that are highly vulnerable to extreme weather and climate change.

Air pollution is estimated to cause over 7 million premature deaths across the world each year and is responsible for many non-communicable diseases globally.

This report analyzes how Japan, the only remaining G7 country still actively building new coal power plants and one of the largest funders of coal in the Asia region, is set to continue funding dirty coal.

Public finance agencies (PFAs) from China, Japan and South Korea are accountable for most of the public financing of overseas coal power.[15] These three countries alone have financed, or committed to finance, coal power with 53 billion USD of loans and other public financing between 2013 and 2018. This is close to 88% of the total overseas coal financing of all G20 countries.[16,17]

This report analyzes how Japan, the only remaining G7 country still actively building new coal power plants, and one of the largest funders of coal in the Asia region, is set to continue funding dirty coal. This reckless investment would impact upon millions of lives by contributing to devastating regional health impacts from polluted air, and the acceleration of global climate change.

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Coal power projects funded by Japan’s public finance agencies

Japan is among the world’s top financiers of overseas coal projects through both public and private investments. Between January 2013 and May 2019, financing[18] of overseas coal-fired power plants by Japan’s PFAs amounted to 16.7 billion USD, for a capacity of 21 gigawatts (GW). The majority of public financing by Japan during this period was in South and Southeast Asia, particularly Indonesia (42%), Vietnam (20%) and Bangladesh (18%) (Figure 1).

The main funders were Japan Bank for International Cooperation (JBIC), Nippon Export and Investment Insurance (NEXI) and Japan International Cooperation Agency (JICA) (Figure 2). For certain projects, this public financing was followed by substantial additional financing from Japan’s three largest private banks – Mitsubishi UFJ Financial Group (MUFG), Mizuho Financial Group, and Sumitomo Mitsui Banking Corporation (SMBC).[21] A list of all 18 existing and planned coal power projects financed by Japanese PFAs is given in Table 1.

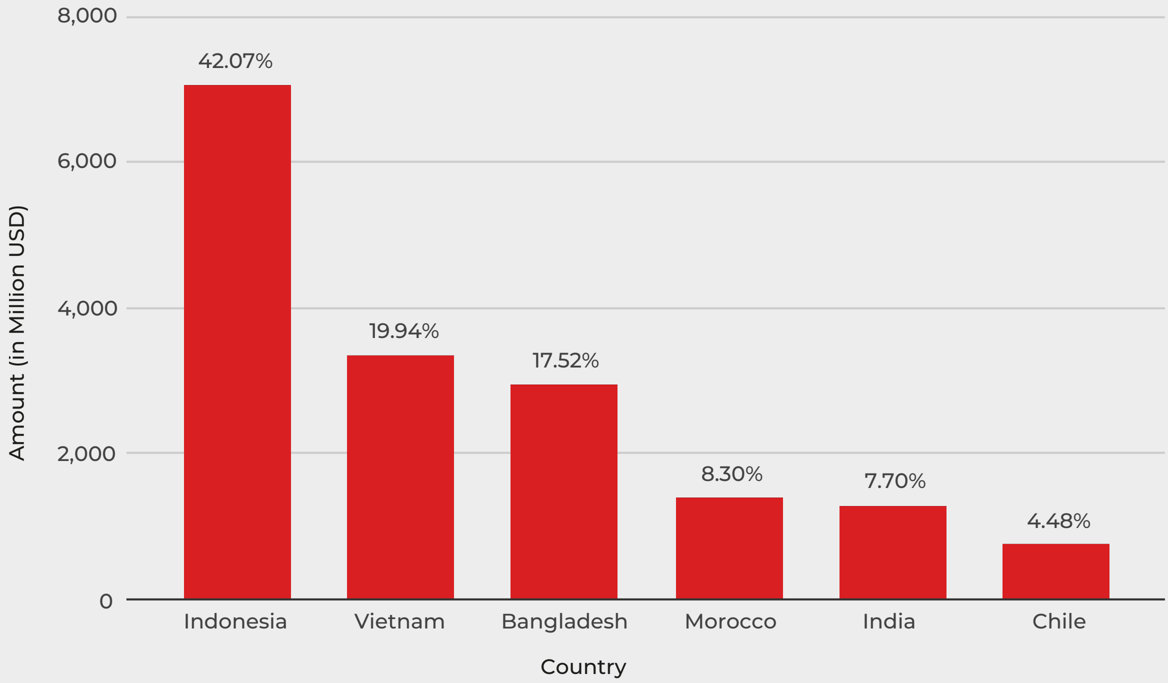

Figure 1: Japanese public finance agencies’ overseas coal financing by country (2013-2019).[19,20]

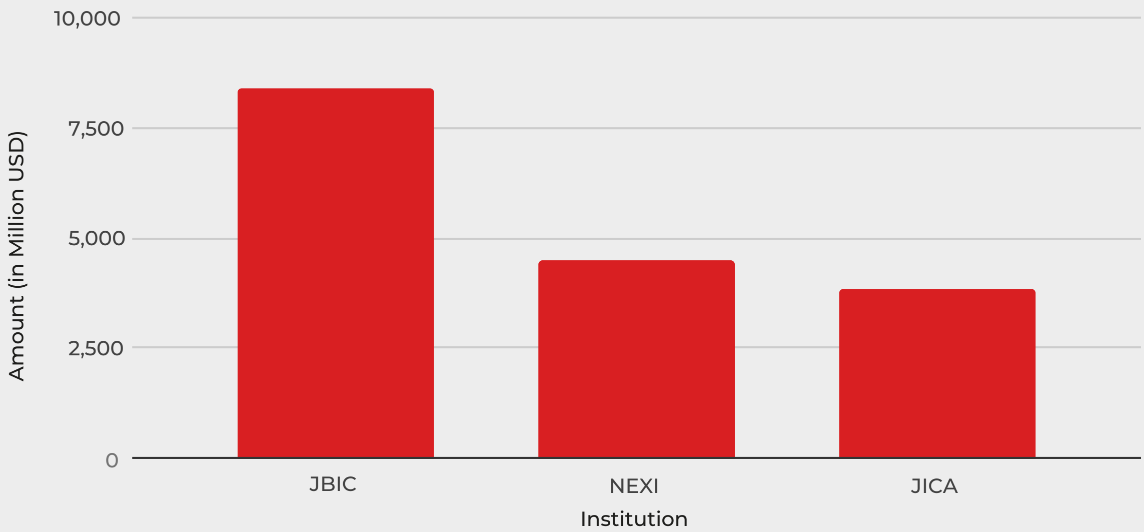

Figure 2: Japanese public finance agencies’ overseas coal financing by institution (2013-2019).

Funding institution	Recipient country	Project name	Full capacity (MW)	Amount (in USD)	Year of financial close
JICA	Indonesia	Indramayu Coal-Fired Power Plant Project Unit 4*	1000	18,371,826	2013
NEXI	Vietnam	Thai Binh 2 Coal Power Plant	1,200	56,000,000	2013
JBIC				85,000,000	2013
JBIC	Chile	Cochrane Coal-Fired Power Project	472	500,000,000	2013
NEXI				250,000,000	2013
NEXI	Vietnam	Vinh Tan 4 Coal-Fired Thermal Power Plant	1,200	135,000,000	2014
JBIC				202,000,000	2014
JBIC	India	Meja Supercritical Coal-Fired Power Plant	1,320	89,063,400	2014
NEXI				851,375,600	2014
JBIC	India	Kudgi Super Thermal Power Project	2,400	210,000,000	2014
NEXI				140,000,000	2014
NEXI	Morocco	Safi Coal-Fired Power Plant	1,386	483,630,308	2014
				906,675,800	2014
JBIC	Vietnam	Duyen Hai Plant 3 Expansion	1,905	409,910,000	2015
NEXI				274,000,000	2015
JICA	Vietnam	Thai Binh 1 Coal Plant & Transmission	600	78,412,530	2015
JICA				307,397,176	2015
JICA				500,000,000	2016
JBIC	Indonesia	Lontar Coal-Fired Power Plant Unit 4 Expansion	315	189,300,000	2016
NEXI				127,000,000	2016
JBIC	Indonesia	Batang Central Java Power Plant	2000	2,052,000,000	2016
NEXI	Indonesia	Tanjung Jati B Units 5 & 6	2000	1,678,000,000	2017
JBIC				1,678,000,000	2017
JBIC	Indonesia	Cirebon 2 Coal-Fired Power Plant	1,000	730,800,000	2017
NEXI				487,200,000	2017
NEXI	Vietnam	Vinh Tan 4 Coal Plant Expansion	600	33,800,000	2017
JBIC				50,000,000	2017
JBIC	Indonesia	Kalselteng 2 Coal-Fired Power Plant Units 5 & 6	200	89,000,000	2017
JBIC	Vietnam	Nghi Son 2 Coal-Fired Power Plant	1,200	560,000,000	2018
JICA	Bangladesh	Matarbari Coal-Fired Power Generation Hub**	1,200	401,374,186	2014
JICA				372,005,343	2016
JICA				107,685,757	2017
JICA				655,904,157	2018
JICA				1,399,914,843	2019
JBIC	Vietnam	Van Phong 1 Coal Plant	1,320	650,000,000	2019
		Total	**21,318**	**16,758,820,925**	

Table 1: Japanese public finance agencies' funding for overseas coal power projects (Jan 2013 - May 2019).

The Japanese PFA-funded project list is based on NRDC Consolidated Coal Finance Database and List of Coal Power Investments by JBIC, NEXI and JICA (source: JACSES).
* Loan for engineering service.
** For this project, JICA has provided its support phase by phase.

Japan's contradictory policies on coal

In recent years, Japan's Prime Minister Abe Shinzo has made several statements promising leadership on sustainable development and climate action, in both domestic and international fora.[22,23] The Japanese Government has also been an active proponent of so-called "quality infrastructure", aiming to elevate considerations such as environmental sustainability in infrastructure projects in developing countries.[24] However, clear contradictions remain, as Japan is still both expanding its own coal power plant domestically and exporting the technology overseas.

Domestically, the Japanese Government is aiming to reduce the proportion of coal in its energy mix from 32.3% in 2017[25] to 26% by 2030, according to the National Strategic Energy Plan ("Basic Energy Plan") published in July 2018.[26] However, new coal power plants are still under development in Japan.

In 2018, a total of 117 coal power plant units, with 44 GW capacity, were in operation in Japan. As of June 2019, 25 new coal power plants, with approximately 14.9 GW capacity, were under construction, assessment or planning.[27,28] The number of projects in the pipeline has decreased in recent years; in 2018 and 2019, several projects were cancelled. In the majority of cases, the operators have explained their withdrawal as a change in the business environment including decreasing power demand, uncertainty about the projects' ability to make sufficient economic returns, and increasing environmental expectations.[29,30,31]

Private financial institutions in Japan have recently started to restrict future investments in coal-fired power plants. In 2018, private insurance company Dai-ichi Life Insurance pledged to divest from overseas coal projects, and Nippon Life Insurance Co. has announced it will reject loans and investments in new coal-fired power plants in Japan and abroad.[32] Japan's three largest banks (MUFG, Mizuho, and SMBC) have all taken initial steps to restrict financing for new coal-fired power plants, albeit with loopholes and exclusions that need to be addressed.[33]

Support for action on climate change is also emerging at a local government level. For example, in May 2019 the Tokyo Metropolitan Government endorsed a joint Communique as part of a group of mayors from G20 countries. The Communique, among other issues, called for decarbonizing the energy mix, with targets of 100% renewable electricity by 2030, and 100% renewable energy by 2050.[34]

These announcements signal at least the start of a change of direction on coal in Japan. However, recent developments still fall far short of what's needed from OECD countries, including the need for Japan to phase out coal by 2030 to achieve the 1.5°C goal of the Paris Agreement.[35] Moreover, Japan's PFAs, as well as some private financial institutions, are still investing in overseas coal projects, negating the environmental gains from domestic coal plant cancellations and other positive trends.

A deadly double standard: Financing air pollution

Japan's financing of overseas coal projects through PFAs contrasts with its emerging, though still limited, steps away from coal power at home. A particularly clear divide can be seen in Japan's attitude to combating air pollutant emissions from coal power generation. Domestically, Japan is applying strong emission limits on new coal plants to reduce air pollution within the country. However, Japanese funded coal projects overseas are applying emission limits for air pollutants that are orders of magnitude poorer than would be required within Japan.

Japan's public financing of overseas coal power projects is normally following the OECD Sector Understanding on Export Credits for Coal-Fired Electricity Generation Projects (CFSU). This understanding limits support to coal plants utilizing ultra-supercritical (USC) technology; or in the case of the poorest countries, supercritical (SC) or subcritical (SUBC) plants smaller than 500MW or 300MW of capacity respectively.[36]

Regardless, even high efficiency coal plants using ultra-supercritical technology are major sources of air pollutants, and the gains in efficiency from ultra-supercritical technology are far from enough to protect public health.[37] This will be described further in page 31 of this report.

A deadly double standard in emission limits for coal power plants

Japan's domestic emission standards for coal-fired power plants under the Air Pollution Control Act[38] vary based on factors including power plant location, sulfur content of fuel, and smokestack height. Japan's system of regulation leaves a lot of discretion to local environmental regulators, who generally prescribe emission limits that are much stricter than the national standards in the environmental permits for existing power plants and new projects. Because of reliance on local regulators' judgement, we use data on actual permit conditions rather than minimum national standards to establish what new coal-fired power plants are allowed to emit in Japan.

The median emission limits of 26 coal power units which are ≥ 200MW that have been proposed or have started construction and operation in Japan since 2012 are 54 mg/Nm^3 for nitrogen oxides (NO_x), 38 mg/Nm^3 for sulfur dioxide (SO_2) and 5 mg/Nm^3 for dust, according to the respective projects' Environmental Impact Assessments (EIAs).[39,40] Some of the more recent projects have stricter limits, for

Through its PFA financing of highly polluting coal power plants overseas Japan is effectively exporting pollution, causing illness, death, environmental degradation and climate change.

example Yokosuka coal-fired power plant in Kanagawa Prefecture, which has two 650 MW units in pre-construction as of July 2019, has flue gas concentration limits of 40 mg/Nm^3 for NO_x, 28 mg/Nm^3 for SO_2 and 5 mg/m^3 for dust.

In contrast, overseas coal power plant projects that are supported by Japan's PFAs are applying far more lenient emission limits on air pollutants. We present here an analysis of the environmental and human health impacts of overseas coal-fired power plant projects financed by Japan's PFAs.

A comparison of these emission limits to median limits for Japan's domestic coal power plants is shown in Figures 3-5. For example, compared to Japanese limits, the Nghi Son 2 coal-fired power plant project in Vietnam, which JBIC decided to support in 2018, is allowed to emit almost 10 times more air pollution, with emission limits of 455, 350 and 140 mg/Nm^3 for NO_x, SO_2 and dust, respectively. Even worse are the emission limits of the Indramayu plant in Indonesia, which JICA decided to financially support in 2013. Emission limits for this plant are 550, 550 and 100 mg/Nm^3 for NO_x, SO_2 and dust, respectively 10 times poorer for NO_x, 14 times poorer for SO_2 and 30 times poorer for dust than Japan's domestic limits. At the highest, the emission limits in overseas projects come up to 13 times more nitrogen oxides (NO_x), 33 times more sulfur dioxide (SO_2) and 40 times more dust pollution.

Emissions from coal power plants elevate the levels of particulate matter and gaseous pollutants in the air over a large area spanning hundreds of kilometers, putting populations downwind at risk and impeding the ability of cities and regions to meet their air quality standards enacted to protect public health. Even a one ug/m^3 increase in $PM_{2.5}$ concentration could cause an exceedance of air quality standards when combined with pollution from other human-made or natural sources. This may require costly mitigation measures to be put in place by the affected jurisdiction. This pollution increases the risk of diseases such as stroke, lung cancer, heart and respiratory illness in adults, as well as respiratory infections in children.[41]

These air pollution impacts lead to premature deaths in the affected populations. In addition, emissions from coal plants cause acid rain, which can damage or destroy forests, crops, soils, waterways and wildlife as well as fallout of toxic heavy metals such as arsenic, nickel, chrome, lead and mercury.

Air pollution increases the risk of diseases such as stroke, lung cancer, heart and respiratory illness in adults, as well as respiratory infections in children.

Although countries are primarily responsible for regulating air pollution from coal power plants through their own national emission standards, Japan shares responsibility for coal plants it finances in countries with poor emission standards, and must align those projects with its domestic emission limits. Japan has developed technology to reduce emissions, and there is no excuse for allowing lower standards in PFA-financed coal power projects overseas. The current difference in emissions levels and impacts represents an unethical and deadly double standard. As a political and economic leader within the G7 and the OECD countries, Japan must be consistent in applying the same standards to both domestic and overseas projects.

Not only does this deadly double standard impact upon the health of people and the environment in recipient countries, it also damages Japan's reputation. Through its PFA financing of highly polluting coal power plants overseas Japan is effectively exporting pollution, causing illness, death, environmental degradation and climate change.

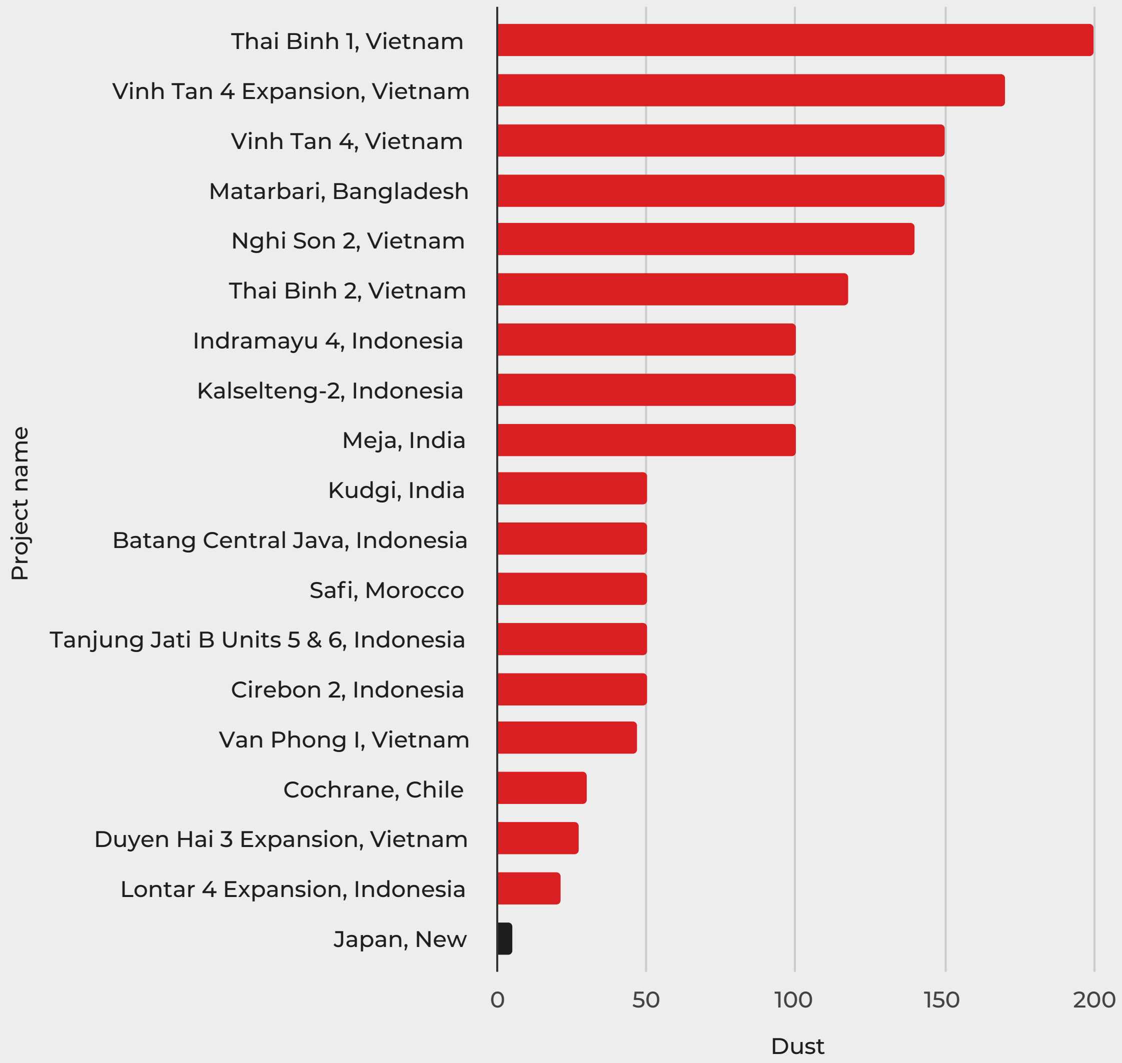

Figure 3: Emission limits for dust: Japan median since 2012[42] vs. overseas projects with Japanese financing (mg/Nm^3).

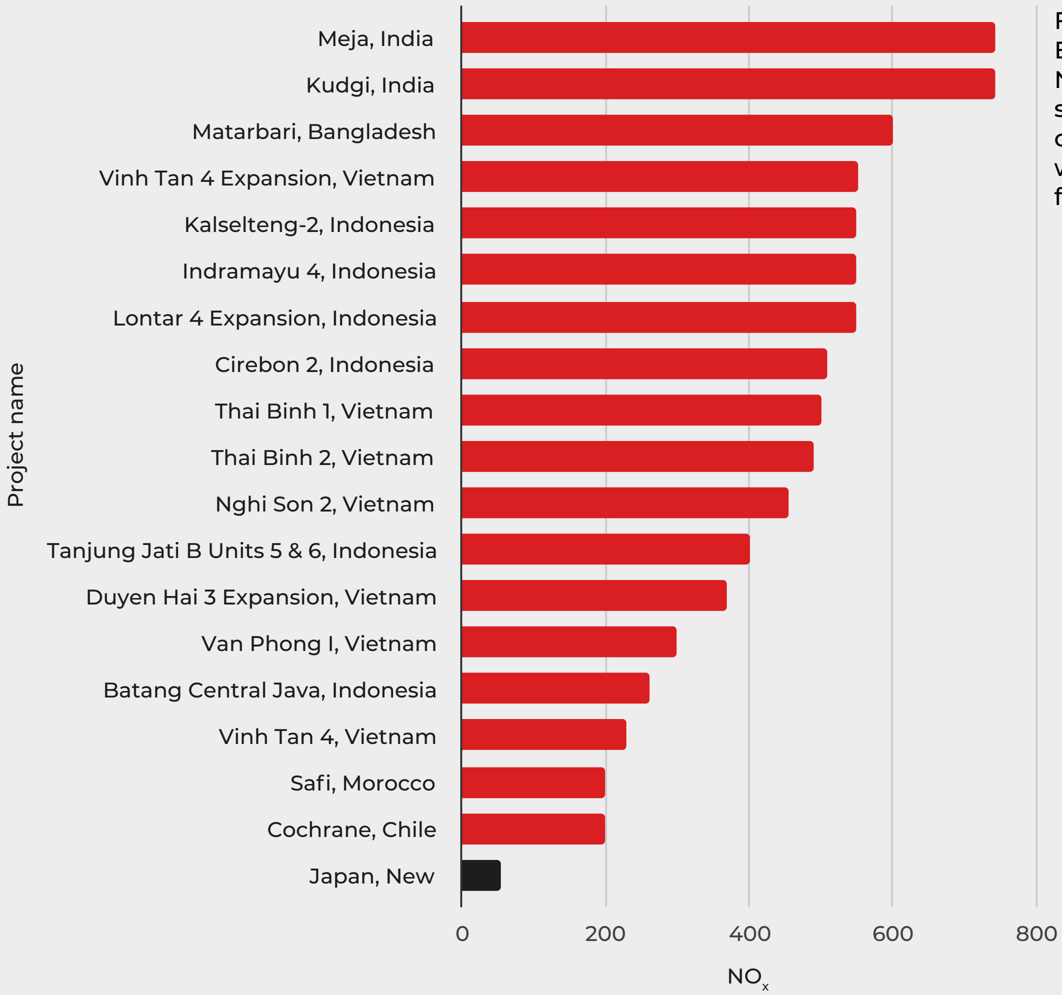

Figure 4: Emission limits for NO_x: Japan median since 2012[43] vs. overseas projects with Japanese financing (mg/Nm_3).

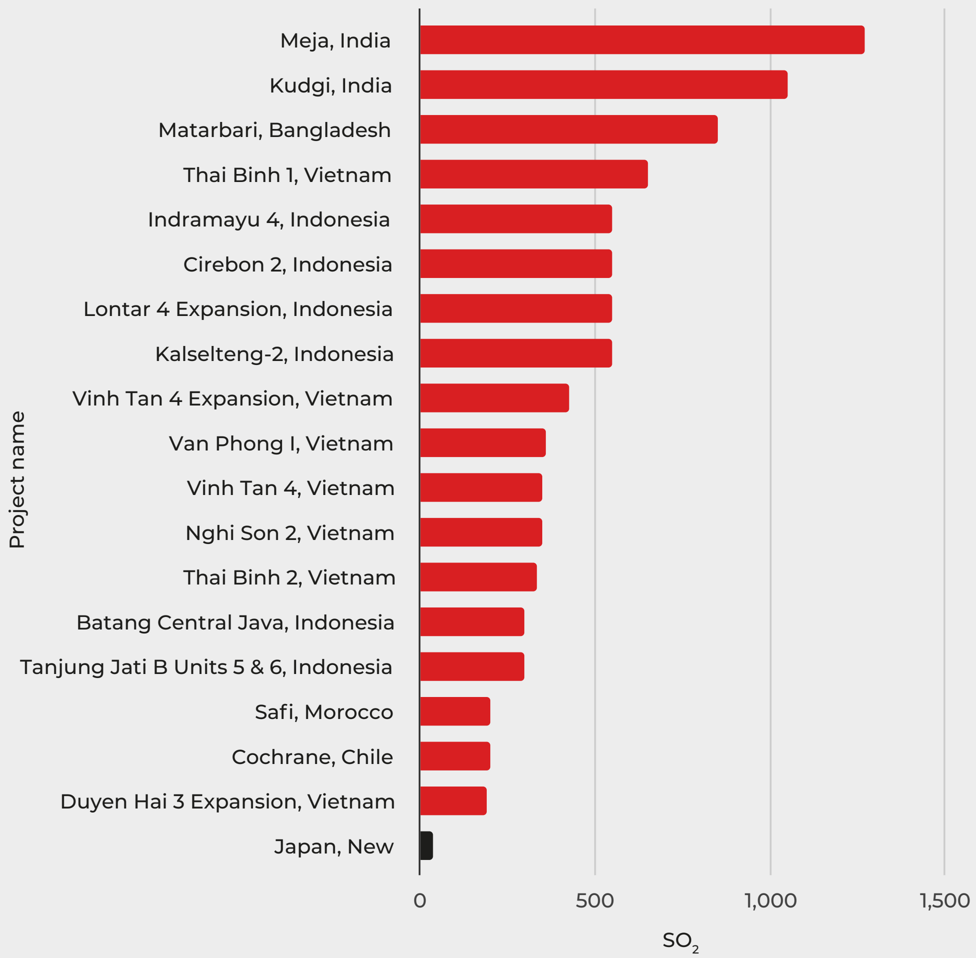

Figure 5: Emission limits for SO_2: Japan median since 2012[44] vs overseas projects with Japanese financing (mg/Nm^3).

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Country	Project name	Emission limit (mg/Nm³)			Boiler efficiency
		NO_x	SO_2	Dust	
Japan	Japan median limit since 2012	54	38	5	USC
Bangladesh	Matarbari Coal-Fired Power Generation Hub	600	850	150	USC
Chile	Cochrane Coal-Fired Power Project	200	200	30	SUBC
India	Kudgi Super Thermal Power Project	743.6	1051	50	SC
India	Meja Supercritical Coal-Fired Power Plant	743.6	1270.3	99.9	SC
Indonesia	Lontar Coal-Fired Power Plant Unit 4 Expansion	550**	550**	21.5	USC
Indonesia	Indramayu Coal-Fired Power Plant Project Unit 4	550*	550*	100*	SC
Indonesia	Kalselteng 2 Coal-Fired Power Plant Units 5 & 6	550*	550*	100*	SUBC
Indonesia	Cirebon 2 Coal-Fired Power Plant	509	550***	50	USC
Indonesia	Tanjung Jati B Units 5 & 6	400	300	50	USC
Indonesia	Batang Central Java Power Plant	260	300	50	USC
Morocco	Safi Coal-Fired Power Plant	200	200	50	USC
Vietnam	Thai Binh 1 Coal Plant & Transmission	650	500	200	SUBC
Vietnam	Vinh Tan 4 Coal Plant Expansion	553	425	170	USC
Vietnam	Thai Binh 2 Coal Power Plant	490.8	335.7	117.2	SC
Vietnam	Nghi Son 2 Coal-Fired Power Plant	455	350	140	SC
Vietnam	Duyen Hai Plant 3 Expansion	368.56	191.57	27.2	SC
Vietnam	Van Phong 1 Coal Plant	300	360	47	SC
Vietnam	Vinh Tan-4 Coal-Fired Thermal Power Plant	228	350	150	SC

Table 2: Emission limits on coal power plants: Japan domestic vs recipient countries.

– All data is extracted from the relevant project EIAs and the Global Coal Plant Tracker.[45]
– USC (Ultra-supercritical) / SC (Supercritical) / SUBC (Subcritical).
* Emission limits for Indramayu and Kalselteng 2 CFPP are not available in the EIAs, so figures are based on the newly enacted (23 April 2019) emission standards for coal power plants in Indonesia, which specify limits of 550 each (for NO_x and SO_2) and 100 (dust) for plants operating or constructed before the regulation was enacted.
** Based on the EIA, the NO_x and SO_2 emission limits for the expansion of Lontar CFPP Unit 4 exceed the newly enacted emission standards. It can be assumed that this CFPP will follow the new standard.
*** Based on the EIA, the SO_2 emissions from Cirebon 2 CFPP exceeds the newly enacted emission standards. It can be assumed that this CFPP will follow the new standard.

Modeling the emissions and health impacts from this double standard

In order to quantitatively assess the impacts of Japan's double standard on air quality and resulting impacts to human health, the dispersion of air pollutants emitted by existing and proposed coal-fired power plants has been modeled. Emission data used in the modeling were extracted from each project's EIAs or estimated based on publicly available data, including countries' national emission standards and the Global Coal Plant Tracker database[46] where EIA data were not available. A detailed technical description of the model is provided in the Appendix.

The model simulation predicts near-surface pollutant concentrations over the course of one calendar year. It has been run for the 17 coal power plants distributed across the top five countries of Japanese investment: Bangladesh, Morocco, India, Indonesia and Vietnam (Figure 6). In order to measure the impact of the double standard, the model has been run for two different scenarios for each of these 17 different plants:

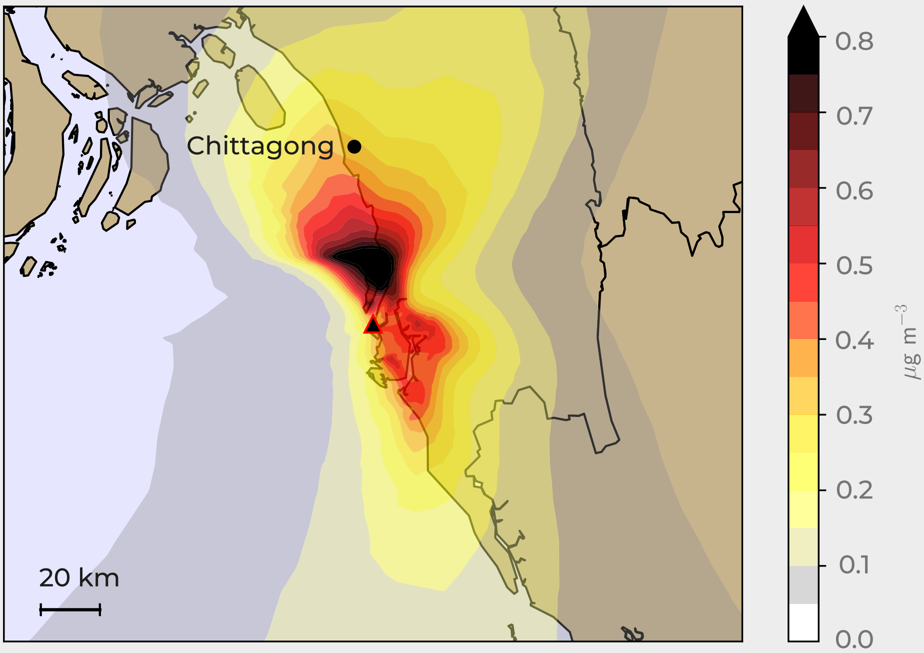
- **Scenario 1:** Predicted coal-fired power plant emissions based on actual emission limits and actual or projected plant utilization.
- **Scenario 2:** Predicted coal-fired power plant emissions if median Japanese emission limits were applied.

Figure 6: Locations of existing and planned coal-fired power plants financed by Japanese PFAs between January 2013 and May 2019 in foreign countries.

1. Pollutant concentration

The World Health Organization (WHO) publish and update Air Quality Guidelines (AQG) that set limits for air pollutants and recommend targets for reducing air pollution.[47] If local emission limits are applied to Japanese PFA-financed power plants, rather than stricter Japanese limits, WHO guidelines are likely to be breached in most of the recipient countries.

Matarbari: annual mean $PM_{2.5}$ concentration



Cirebon 2: annual mean SO_2 concentration

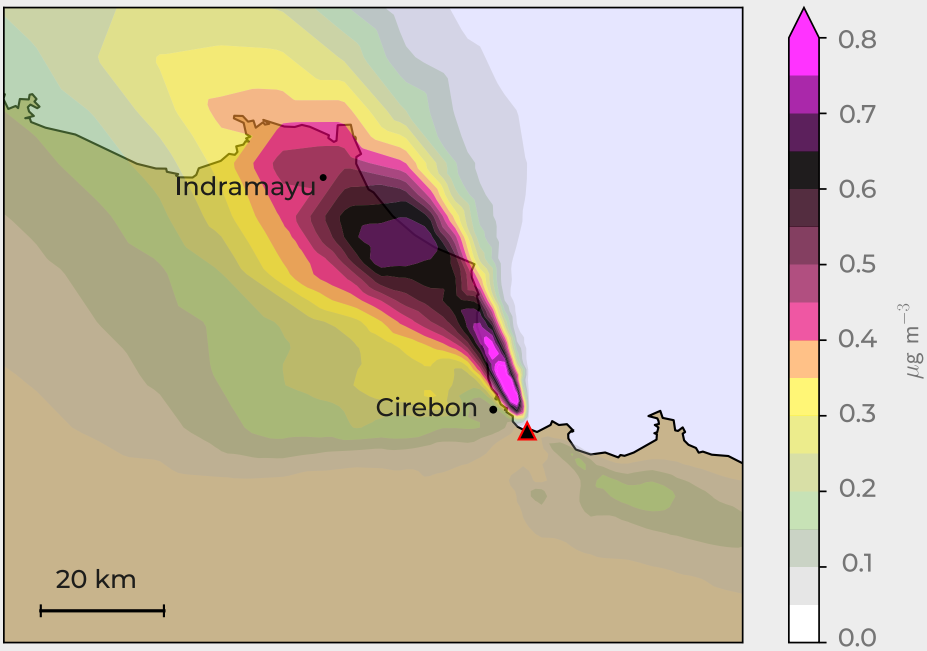
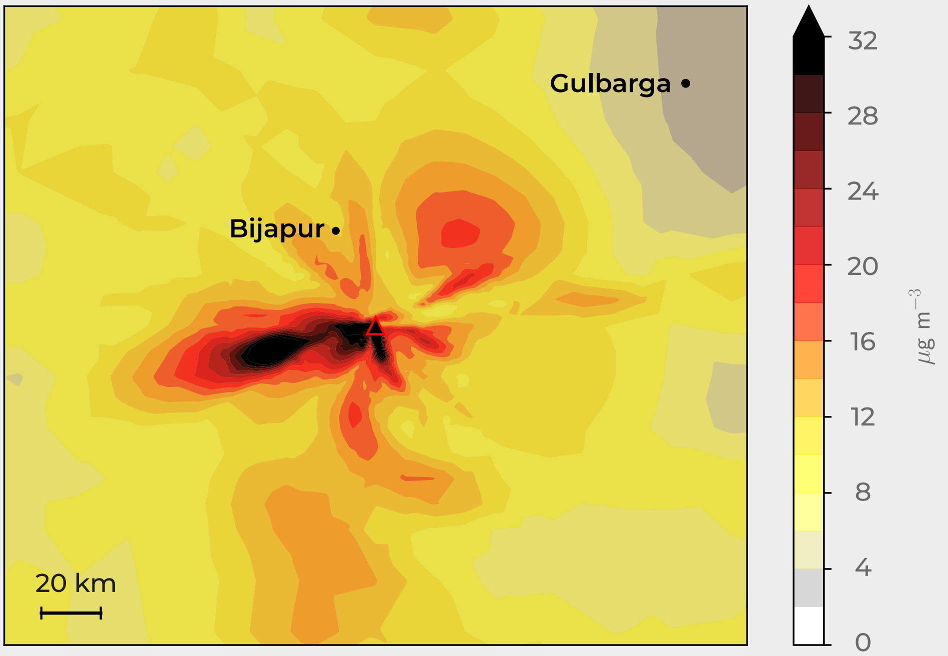


Figure 7: Top: Annual average Scenario 1 concentrations of $PM_{2.5}$ at Matarbari 1 (Bangladesh). Bottom: SO_2 at Cirebon 2 (Indonesia) in $\mu g/m^3$. The studied plants are marked as a black-red triangle.

Figure 7 shows the projected annual average $PM_{2.5}$ and SO_2 pollution from the Matarbari 1 and Cirebon 2 coal-fired power plants respectively, under Scenario 1 (local emission limits). During unfavourable meteorological conditions, higher pollutant concentrations are attained for short time periods, as shown by the highest 24-hour $PM_{2.5}$ pollution from Kudgi power plant and the 1-hour maximum concentration for NO_2 at the Meja SC power plant (Figure 8).

Kudgi: highest 24hr mean $PM_{2.5}$ concentration



Thai Binh 2: highest 1hr mean NO_2 concentration

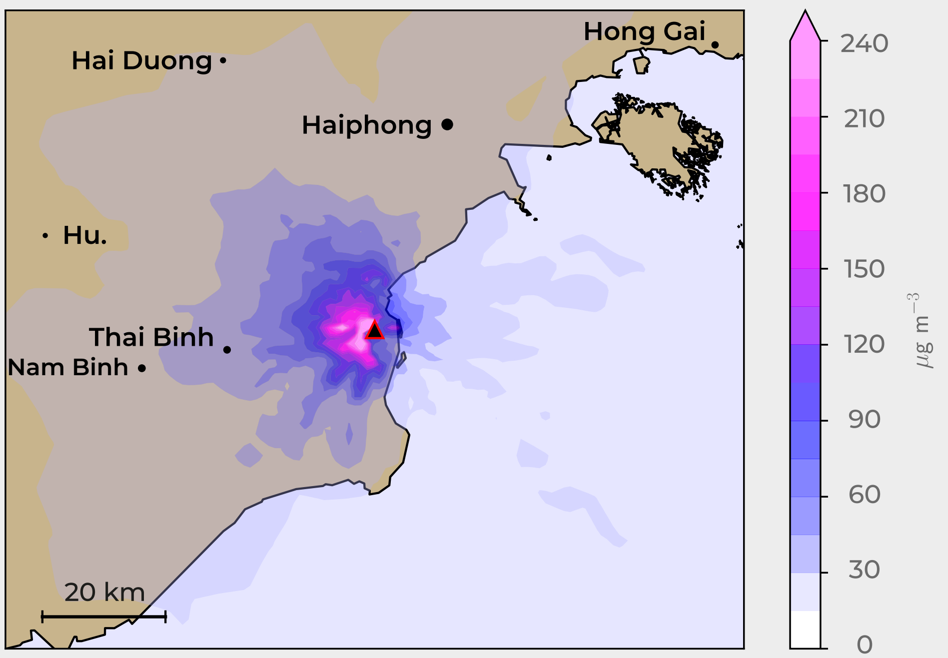


Figure 8: Top: Maximum 24-hour $PM_{2.5}$ concentration for Kudgi (India) in Scenario 1 (the WHO air quality guideline is 25 μg/m³). Bottom: Maximum 1-hour mean NO_2 concentration for Thai Binh-2 (Vietnam) in Scenario 1 (the WHO AQG is 200 μg/m³).

The model focused on the guidelines from the WHO AQG, related to the three main air pollutants emitted from burning coal. Tables 4-6 show the maximum predicted 1-hour NO_2 and 24-hour $PM_{2.5}$ and SO_2 average concentrations for each of the power plants. In the modeling result, WHO AQG (Table 3) are breached in many cases.

	NO_2		SO_2		$PM_{2.5}$	
	Annual	1-hour	24-hour	10-minute	Annual	24-hour
Air Quality Guideline (µg/m³)	40	200	20	500	10	25

Table 3: WHO guidelines for average air pollutant concentrations in different time intervals.

	Maximum 24-hour $PM_{2.5}$ concentration (µg/m³)			Maximum 24-hour $PM_{2.5}$ concentration (µg/m³)	
	Scenario 1 (local limits)	Scenario 2 (Japanese limits)		Scenario 1 (local limits)	Scenario 2 (Japanese limits)
WHO guideline	25	25	WHO guideline	25	25
Batang Central (IDN)	32.6*	4.0	Nghi Son 2 (VNM)	12	1.1
Cirebon 2 (IDN)	9.7	0.4	Safi (MAR)	5.3	1.0
Duyen Hai 3 Exp. (VNM)	2.2	0.4	Tanjung Jati B 5&6 (IDN)	9.5	1.1
Indramayu 4 (IDN)	7.2	0.5	Thai Binh 1 (VNM)	4.2	0.6
Kalselteng 2 5&6 (IDN)	6.4	0.4	Thai Binh 2 (VNM)	11.4	1.1
Kudgi (IND)	77.2	2.4	Van Phong 1 (VNM)	10.3	1.3
Lontar 4 Exp. (IDN)	4.0	0.3	Vinh Tan 4 (VNM)	15.8	1.1
Matarbari (BGD)	25.8*	2.5	Vinh Tan 4 Exp. (VNM)	6.6	0.5
Meja (IND)	27.2*	0.6			

Table 4: Modeled maximum 24-hour contribution to $PM_{2.5}$ concentration. Figures in **bold red** indicate where WHO air pollution guidelines are modeled to be exceeded. Those marked by * occur only in unpopulated areas (e. g. above ocean).

	Maximum 1-hour NO_2 contribution (µg/m³)			Maximum 1-hour NO_2 contribution (µg/m³)	
	Scenario 1 (local limits)	Scenario 2 (Japanese limits)		Scenario 1 (local limits)	Scenario 2 (Japanese limits)
WHO guideline	200	200	WHO guideline	200	200
Batang Central (IDN)	941	197	Nghi Son 2 (VNM)	400	49
Cirebon Unit 2 (IDN)	220	21	Safi (MAR)	195	56
Duyen Hai 3 Exp. (VNM)	112	17	Tanjung Jati B 5&6 (IDN)	280	35
Indramayu 4 (IDN)	268	26	Thai Binh 1 (VNM)	202	21
Kalselteng 2 5&6 (IDN)	149	15	Thai Binh 2 (VNM)	407	43
Kudgi (IND)	783	46	Van Phong 1 (VNM)	332	50
Lontar 4 Exp. (IDN)	179	18	Vinh Tan 4 (VNM)	364	68
Matarbari (BGD)	940	219*	Vinh Tan 4 Exp. (VNM)	311	31
Meja (IND)	654	37			

Table 5: Modeled maximum 1-hour contribution to NO_2 concentration. Figures in **bold red** indicate where WHO air pollution guidelines are model to be exceeded. Those marked by * occur only in unpopulated areas (e. g. above ocean).

	Maximum 24-hour SO_2 contribution (µg/m³)			Maximum 24-hour SO_2 contribution (µg/m³)	
	Scenario 1 (local limits)	Scenario 2 (Japanese limits)		Scenario 1 (local limits)	Scenario 2 (Japanese limits)
WHO guideline	20	20	WHO guideline	20	20
Batang Central (IDN)	132.6	16.6	Nghi Son 2 (VNM)	32.4	3.5
Cirebon 2 (IDN)	25.4	1.1	Safi (MAR)	20.0*	4.0
Duyen Hai 3 Exp. (VNM)	9.2	1.8	Tanjung Jati B 5&6 (IDN)	25.3	3.0
Indramayu 4 (IDN)	18.4	1.3	Thai Binh 1 (VNM)	15.7	2.3
Kalselteng 2 5&6 (IDN)	30.7	2.1	Thai Binh 2 (VNM)	34.7	3.7
Kudgi (IND)	127.4	3.7	Van Phong I (VNM)	62.3	7.5
Lontar 4 Exp. (IDN)	14.3	1.0	Vinh Tan 4 (VNM)	83.1	3.0
Matarbari (BGD)	277.2	25	Vinh Tan 4 Exp. (VNM)	37.2	3.3
Meja (IND)	128.3	2.9			

Table 6: Modeled maximum 24-hour contribution to SO_2 concentration. Figures in **bold red** indicate where WHO air pollution guidelines are modeled to be exceeded. Those marked by * occur only in unpopulated areas (e. g. above ocean).

Under Scenario 1, applying local emission limits, four WHO AQG considered in the study are projected to be violated by one or more power plants; NO_2 1-hour, $PM_{2.5}$ 24-hour and SO_2 10-minute and 24-hour guidelines (Tables 4-6).[48] Figures 9-11 show the number of people exposed to air pollution at dangerous levels that exceed the WHO guidelines under Scenario 1, and for comparison, under Scenario 2 (if Japanese emission limits were applied).

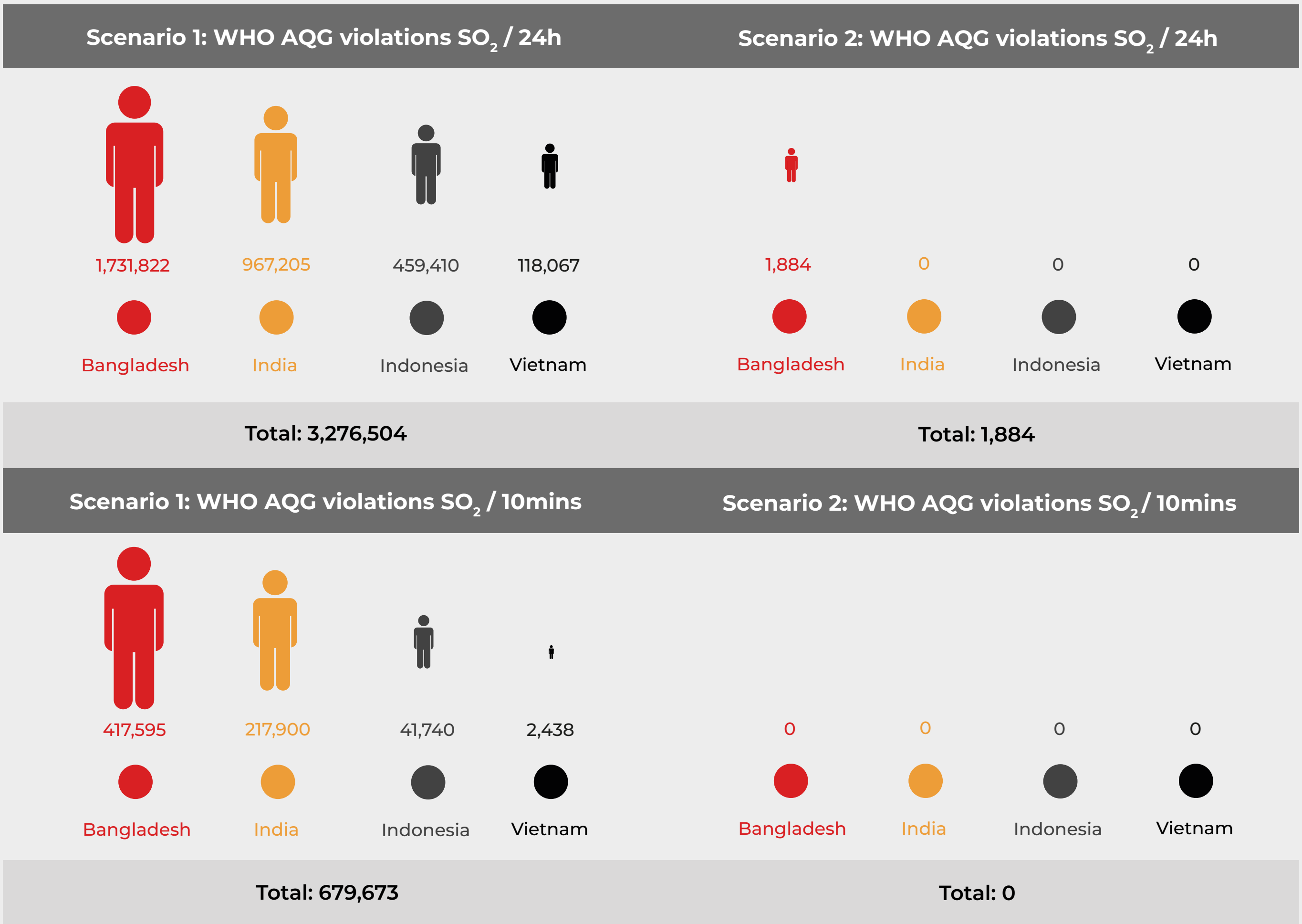


Figure 9: Modeled numbers of people exposed to SO_2 at levels exceeding WHO AQG for 24-hour mean (above) and 10-minute mean concentrations (below). Scenario 1 (actual emissions) / Scenario 2 (Japanese regulation, zero for 10-minute guideline).

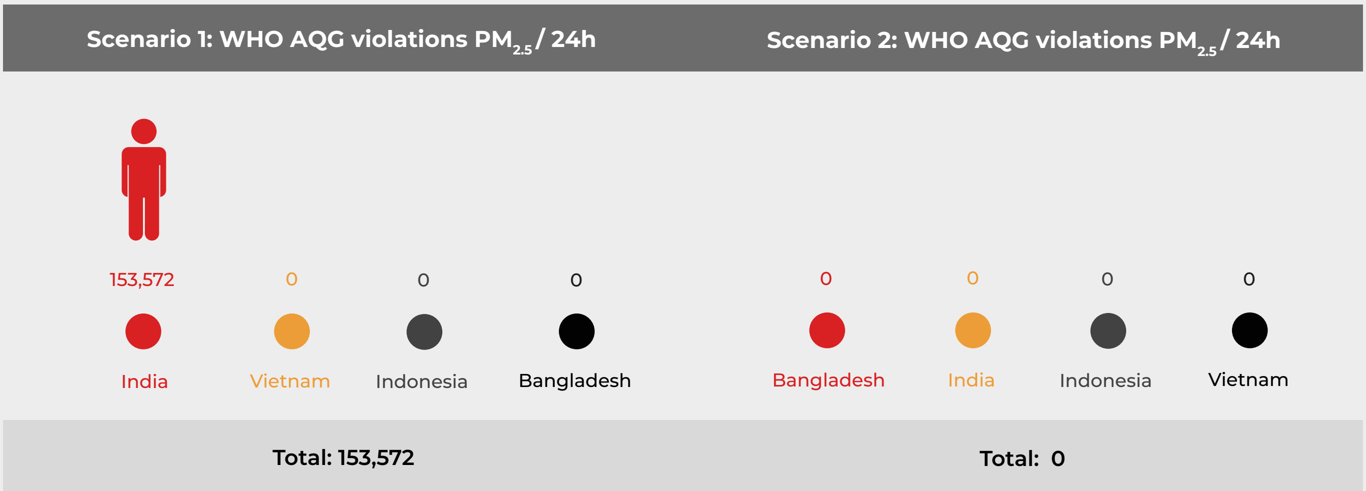


Figure 10: Modeled numbers of people exposed to $PM_{2.5}$ levels exceeding WHO AQG for 24-hour mean under Scenario 1 (left) and Scenario 2 (right).

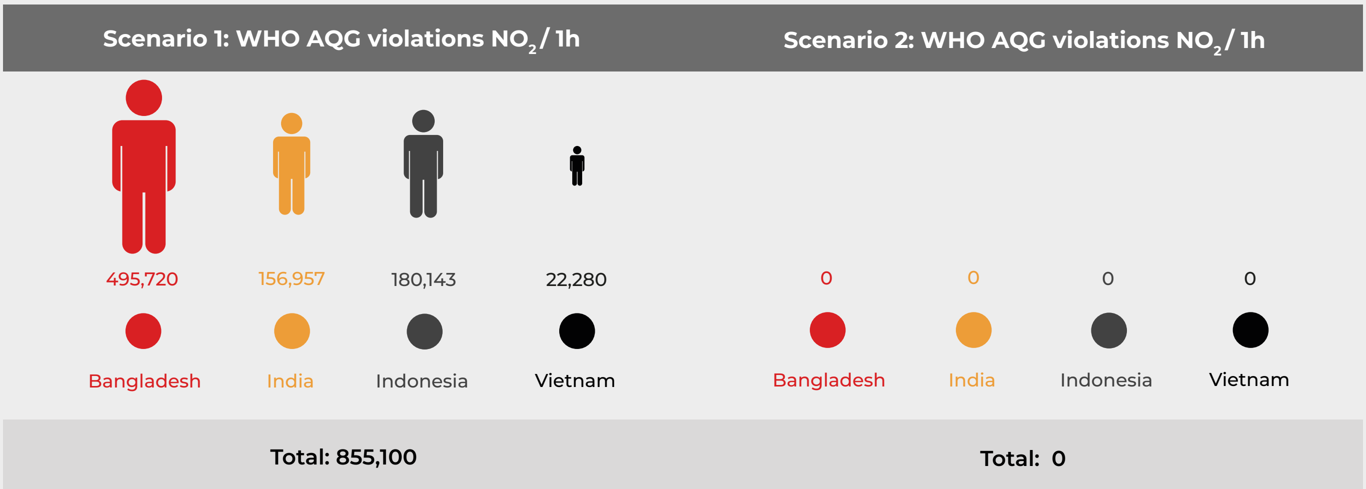


Figure 11: Modeled numbers of people exposed to NO_2 levels exceeding WHO air quality guidelines (AQG) for 1-hour mean under Scenario 1 (left) and Scenario 2 (right).

Under Scenario 1, 13 of the 17 Japanese PFA-financed overseas coal power plants are projected to breach the WHO guidelines for 24-hour average SO_2 concentrations (20 µg/m³), with close to 3.3 million people affected by guideline violations across Bangladesh, India, Indonesia and Vietnam. Around 700,000 people are projected to be exposed to SO_2 concentrations exceeding the 10-minute AQG (500 µg/m³) under this scenario, with a similar distribution across the four affected countries. In both cases, more than half of those affected are in Bangladesh.

A total of around 855,000 people are projected to be exposed to levels of NO_2 considered to be dangerous by the WHO from 13 of the power plants exceeding the 1-hour average NO_2 AQG, again with more than half of the affected people in Bangladesh. Meanwhile, $PM_{2.5}$ guidelines are projected to be exceeded by emissions from the Kudgi plant, putting 150,000 people in India at risk.

Most of this air pollution would be avoided if Japanese emission limits were applied to the power plants. If this was done, as modeled in Scenario 2, the number of people projected to be exposed to exceeding WHO guidelines would drop by 99.96% – to less than a thousandth of the projected number exposed under Scenario 1. If Japanese emission limits were applied at the 17 power plants, only Matarbari (Bangladesh) would violate WHO AQGs, exceeding both the 24-hour SO_2 and 1-hour NO_2 guidelines. Being located in a lightly populated area, the SO_2 24-hour exceedance would impact under 2,000 people, while the NO_2 1-hour exceedance would not affect any population.

2. Impacts on human health

Exposure to air pollution carries a substantial risk of respiratory and other diseases, especially for vulnerable groups such as children, elderly people, and people with pre-existing respiratory ailments. Applying a widely used health impact assessment method[49,50,51] (see Appendix), we estimated the additional number of annual premature deaths due to the pollution from the power plants supported by Japanese PFAs.

The model indicates that the additional pollution from the coal-fired power plants, if all of them are built and operated, would be responsible for 5,286 to 14,620 premature deaths per year (Table 7). Half of the total premature deaths are projected to occur in India, a quarter in Indonesia, and an eighth in Vietnam. The remaining 482 to 1,332 annual deaths are shared among Bangladesh and Morocco and 8 third-party countries: China, Nepal, Cambodia, Myanmar, Thailand, Laos, Malaysia and Spain which do not have Japanese-financed coal-fired power plants, but are impacted by air pollutants from such plants in neighboring countries. Applying Japanese emission limits would decrease the total number of premature deaths by 94% to 326-937 annually. Table 8 shows the projected premature deaths per year broken up by cause. Three out of four of these fatalities are caused by $PM_{2.5}$ pollution.

	Scenario 1 (local limits)			Scenario 2 (Japanese limits)			Scenario 1 – 2
Country	Central estimate	Low estimate	High estimate	Central estimate	Low estimate	High estimate	Difference (central estimate)
India	5,343	2,878	7,807	173	91	254	5,170
Indonesia	2,481	1,313	3,649	214	111	317	2,267
Vietnam	1,223	613	1,832	134	66	202	1,089
Bangladesh	485	250	720	65	32	99	420
China	154	82	226	17	8	25	137
Nepal	92	47	137	3	1	5	89
Morocco	59	32	86	13	7	19	46
Cambodia	48	21	74	5	2	8	43
Thailand	20	9	32	3	1	4	17
Myanmar	31	14	48	3	1	5	28
Laos	5	2	8	1	0	1	4
Malaysia	2	1	4	0	0	1	2
Spain	2	1	3	0	0	1	2
Total	**9,945**	**5,286**	**14,620**	**631**	**326**	**937**	**9,314**

Table 7: Modeled number of premature deaths per year due to air pollution under Scenario 1 and Scenario 2, and the number of premature deaths that could be avoided by applying Japanese emission limits. Note: Low and high estimates show the bounds of the 95% confidence intervals.

Pollutant	Cause	Scenario 1 (local limits)			Scenario 2 (Japanese limits)			Difference		
		Central estimate	Low estimate	High estimate	Central estimate	Low estimate	High estimate	Central estimate	Low estimate	High estimate
$PM_{2.5}$	Lung cancer	241	97	385	16	7	26	224	90	358
	Lower respiratory infections	514	0	1,046	21	0	44	493	0	1,002
	Ischemic heart disease	3,878	2,484	5,273	177	113	241	3,701	2,370	5,032
	Stroke	1,415	859	1,970	84	51	117	1,331	808	1,854
	Diabetes	302	38	566	16	2	30	286	36	536
	Chronic obstructive pulmonary disease	982	576	1,388	39	23	55	943	553	1,333
	Total	7,332	4,054	10,628	353	196	513	6,978	3,857	10,115
NO_2	**All causes**	2,613	1,234	3,993	278	131	425	2,335	1,103	3,568
All	**Total**	**9,945**	**5,286**	**14,620**	**631**	**326**	**937**	**9,314**	**4,960**	**13,683**

Table 8: Projected premature deaths per year caused by emissions from the studied power plants, under Scenarios 1 and 2, and the number of premature deaths that could be avoided by applying Japanese emission limits. Note: Low and high estimates show the bounds of the 95% confidence intervals.

3. Summary: The death toll of Japan's double standard

Modeling performed by Greenpeace has determined the likely air quality and health impacts of overseas coal-fired power plants supported by Japanese PFA investment. It is estimated that the 17 plants operating according to existing local emission limits (Scenario 1) will cause in total between 5,000 and 15,000 premature deaths per year (Table 8), amounting to an expected 158,000 to 439,000 premature deaths over the power plants' average 30-year lifespan. These figures do not take into account future population growth, which would further increase the premature death toll.

Furthermore, the model does not take into account background pollution from sources other than the power plants.[52] As this would add to the pollution from the power plants, it is thus likely that the actual number of people exposed to dangerous pollution levels, and the resulting premature death toll, is even higher.

Photo (left): © Greenpeace / Peter Caton

The highest premature death tolls are in India and Indonesia, followed by Vietnam and Bangladesh. Neighboring countries affected by cross-boundary pollution, namely Cambodia, China, Laos, Malaysia, Myanmar, Nepal, Spain, and Thailand, are modeled to suffer a total of 177 to 532 premature deaths per year as a result of the emissions (Figure 13).

It is estimated that the 17 plants supported by Japanese PFA investment will cause in total between 5,000 and 15,000 premature deaths per year.

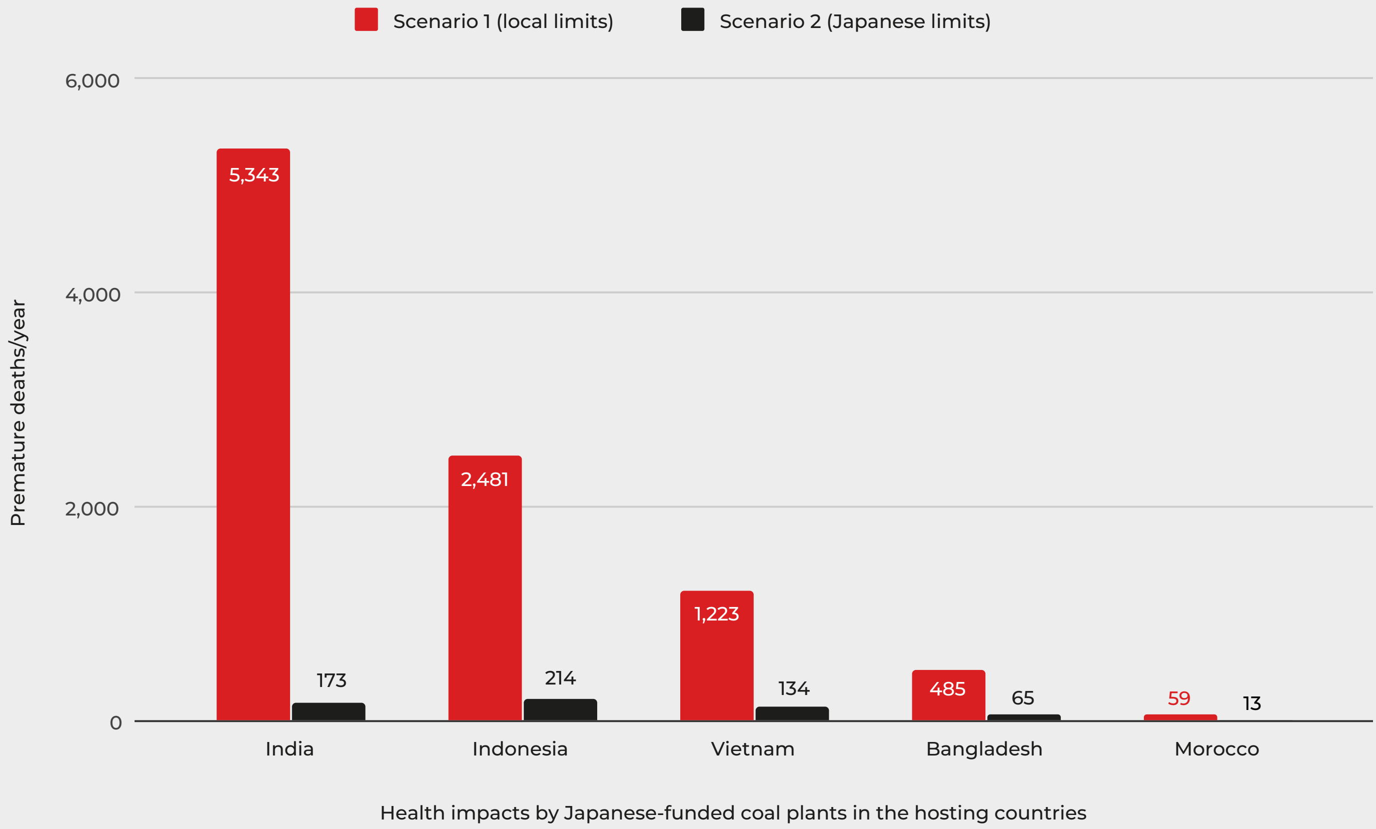


Figure 12: Number of modeled annual premature deaths due to Japanese PFA-financed coal power plants in host countries for Scenario 1 (red) and Scenario 2 (black). (Uncertainties are about 50%, see Table 7).

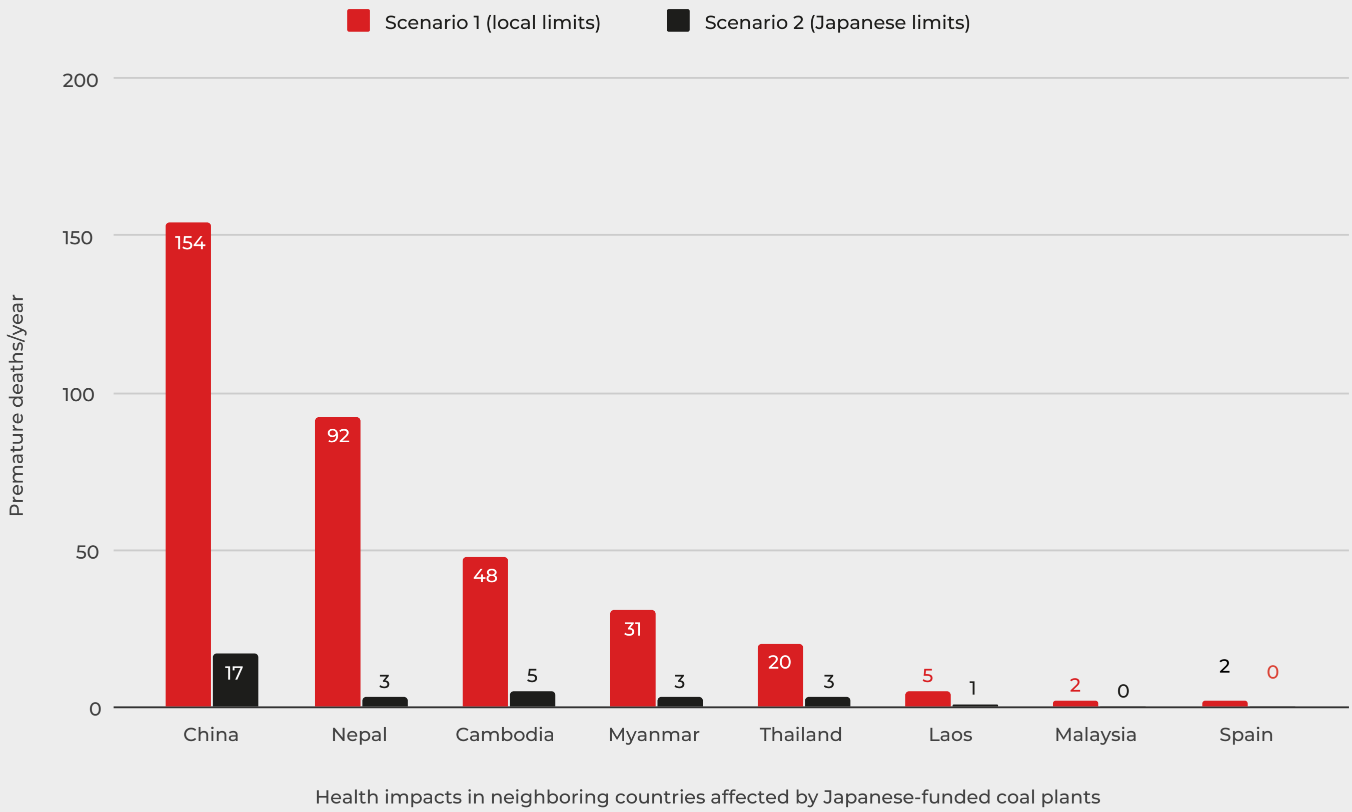


Figure 13: Number of modeled annual premature deaths in third-party countries (neighboring the host countries) due to Japanese PFA-financed coal power plants for Scenario 1 (red) and Scenario 2 (black). (Uncertainties are about 50%, see Table 7).

The power plants in these countries operate with emission limits that are considerably less stringent than those imposed in Japan. If the double standard in emission limits was removed and all plants operated within Japanese median emission limits, around 94% of these annual premature deaths could be avoided. In total 148,000 to 410,000 premature deaths could be avoided if all 17 Japanese PFA-financed power plants operated to Japanese limits over their 30-year average operation time (Figure 13).

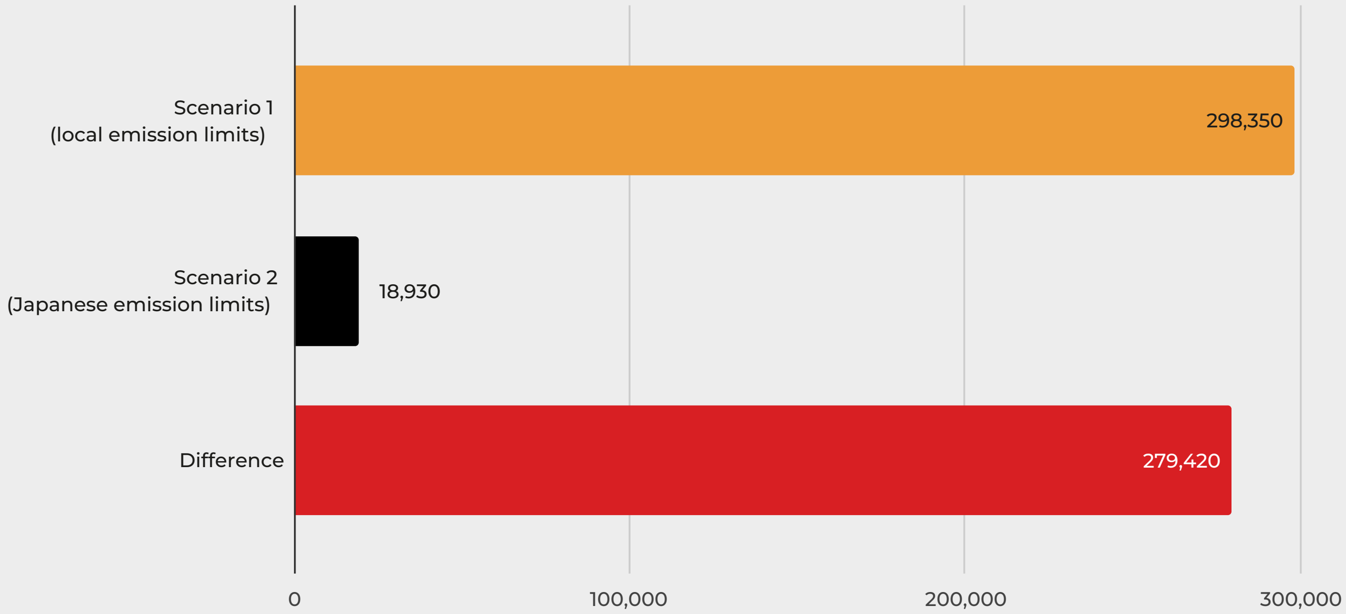


Figure 14: Modeled total premature deaths due to Japanese PFA-financed coal power plants over their 30-year average lifespans. Uncertainty intervals are about 50% (not shown).

Scenario 1 (local emission limits) / Scenario 2 (Japanese median emission limits) / Difference (the premature deaths that would be prevented if the overseas coal power plants were required to meet Japanese limits).

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Even "advanced technology" coal plants are deadly

The coal industry and some power utilities have been claiming that advanced technology, like high efficiency boilers, would dramatically reduce pollution. Moreover, the Japanese Government and the coal industry are promoting integrated coal gasification combined cycle (IGCC) technology, claiming it will provide exceptional advances in environmental performance.[53] This is leading some decision-makers and PFAs to mistakenly believe that by choosing modern ultra-supercritical and IGCC technology for a coal power plant, air pollutant and carbon dioxide emissions can be substantially mitigated. Japan's largest banks (MUFG, Mizuho, SMBC) have also endorsed the mythology of advanced technology. Although these plants are more efficient than those using older technology, they are significant polluters, even when strict emission limits are applied.

A coal-fired power plant equipped with an ultra-supercritical boiler can reduce air pollutant emissions by approximately 10-15% compared to a power plant with a sub-critical boiler. Furthermore, current specifications for IGCC power plants are unable to reduce air pollution emissions any further than ultra-supercritical technology under the median standard conditions for new coal-fired power plants in Japan[54,55,56] (Figure 15). In contrast, wind, solar PV, solar thermal power, geothermal, hydropower and other renewable energy technologies do not emit air pollution during operations. The only way to eliminate the thousands of deaths associated with coal burning is to phase out these dirty power plants in favour of clean and modern renewable energy sources.

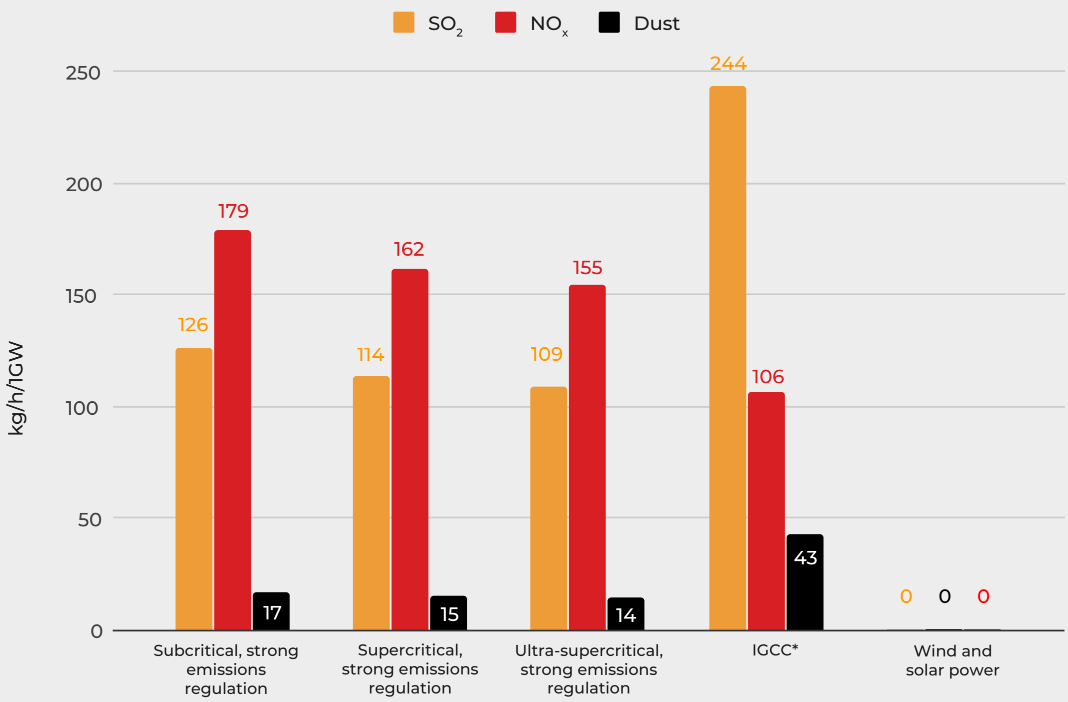

Figure 15: Air pollution (SO_2, NO_x, dust) emissions from 1,000 MW coal plants, IGCC power plants and renewable energy (unit: kg/h/1GW).

*Based on reported emission rates at the proposed Hirono and Nakoso IGCC projects.

Japan's public finance agencies would save lives by supporting renewable energy, not coal

Japanese PFAs (JBIC, NEXI and JICA) argue that financing overseas coal power plants is a way to contribute to recipient countries' development. However, as shown in this report, Japan's support for overseas coal-fired power plants that operate to emission limits considerably lower than Japanese emission limits creates a deadly double standard.

Japan's PFAs are financing coal-fired power plants that are predicted through modeling to cause thousands of premature deaths and cause serious health impacts to citizens of recipient countries, and ultimately put the whole planet at risk by contributing to climate change. The Japanese Government must take urgent action to end this and ensure its PFAs move to fund renewable solutions rather than coal.

Additionally, the Japanese Government must immediately stop its PFAs from investing in overseas coal power plants for which emission limits do not meet the limits applied to coal power plants in Japan. By ending this deadly double standard, hundreds of thousands of lives could be saved.

At the same time, the governments in the host countries of these coal projects should protect their citizens' right to a safe and healthy environment, by significantly strengthening their emission standards for already existing coal power plants, while undertaking an energy transition from coal to renewable energy in their countries. This change in policies and investments must be accelerated now, for human and environmental health, and to safeguard the future of our planet.

The Japanese Government must take urgent action to ensure its PFAs move to fund renewable solutions rather than coal.

Peer reviewer profile

© Regulatory Assistance Project

Christopher A. James

Former Environmental Protection Agency (EPA) regulator and state air quality director

Christopher A. James advises regulators and advocates on how to reduce greenhouse gases and toxic pollutants to meet existing and new air standards, improve water quality, and protect consumers. His projects span the areas of air quality, energy efficiency, distributed resources, demand response, and linking energy and the environment in air quality and energy planning processes.

Recent projects include working with environmental advocates and health professionals in Eastern Europe and Southeast Asia to improve emission standards for power plants. Mr. James has also worked with Chinese air quality officials since 2008 to develop and implement plans to improve air quality, strengthen China's air law and develop a comprehensive environmental permitting system.

Mr. James has 35 years' experience working on air quality, covering nearly every facet of this topic, from developing ambient monitoring networks, emissions inventories and control measures, to implementing and enforcing such measures. He champions multi-pollutant air quality planning and qualifying energy efficiency as both a reliability resource and air quality control measures.

Mr. James was Director of Air Planning and Manager of Climate Change and Energy Programs for the Connecticut Department of Environmental Protection (DEP), where he served as staff lead for the state's participation in the Regional Greenhouse Gas Initiative. Mr. James was also the DEP representative to the Connecticut Energy Conservation Management Board, which provided advice and oversight to utility energy efficiency programs.

Mr. James also worked in the Seattle regional office of the EPA, where he received two "gold medals" for his work to enforce air quality regulations. Mr. James also worked in the private sector for Synapse Energy Economics and for consultants to the utility and biomass energy industries.

He holds a bachelor's degree in Mechanical Engineering from the Worcester Polytechnic Institute.

Glossary of technical terms and acronyms

PFA	*public finance agency*
public finance agency	Finance agency owned by the national government. In this report, it largely refers to the following three institutions of the Japanese Government. Public finance agency Japan Bank for International Cooperation (JBIC), public insurance corporation Nippon Export and Investment Insurance (NEXI) and official development assistance agency Japan International Cooperation Agency (JICA).
WHO	*World Health Organization*
AQG	*air quality guidelines* (of the World Health Organization)
air quality guideline	A guideline for the *pollutant concentration*, issued by the WHO. Pollutant concentrations above the guideline value are deemed to be harmful to human health. For levels below guideline concentrations, it is not clear whether, or to what extent, human health is put at risk.
CFPP	*coal-fired power plant*
exceedance	A period of time when the concentration of an air pollutant is greater than the appropriate *air quality guideline*.
confidence interval	Our health assessment model uses empirical data such as population numbers, background death rates and others. The true values of these variables are not known with infinite precision. This implies that no model study can give results with absolute certainty. Instead, we provide a range (interval), which most likely contains the *true* value. In this work, we use the 95% confidence interval. That means that with 95% probability, reality is somewhere inside the confidence interval and with 5% chance it is actually outside this interval (above or below). The value which has the highest probability to be the true value is called the *central estimate*. It is somewhere inside the confidence interval. The bounds of the confidence interval are called *low* and *high estimate*. Synonyms: 95%-confidence interval (in this work), “between x and y”
central estimate	see *confidence interval*
low estimate	see *confidence interval*
high estimate	see *confidence interval*
emission concentration	The actual concentration of some *pollutant* in the *flue gas* of a power plant (e.g. 425 mg/Nm^3 or 200 ppm). It can be above the *emission limit* for this power plant (i.e. breaking some law) or below (i.e. complying with the law). Unlike the *pollutant concentration*, it is measured inside the *flue gas* and not at ground level outside the power plant. Related (but not synonym): *emission rate* Not to be confused with: *pollutant concentration*
emission rate	The amount of a pollutant that is emitted per unit time by a specific power plant (e.g. 100 kg/hour). In some cases, this is used instead of the *emission concentration* as a measure of how polluting the coal-fired power plant is. Related (but not synonym): *emission concentration*
emission limit	The maximum allowed *emission concentration* (or sometimes *emission rate*) for a specific plant. It can be prescribed by national standards, environmental permit conditions (which can be based on national standard but can also be looser or stricter) or some other legal regulation. Related (but not synonym): *emission standard*
emission standard	A nationally (or super-nationally) regulated maximum limit on *emission concentration* (or sometimes *emission rate*). It may be distinct from the *emission limit* of a specific plant, which can differ from the national standard. Related (but not synonym): *emission limit*

air pollutant	An unwanted substance found in the air in the form of a solid particle, a liquid droplet or a gas. The substance may be hazardous, harmful to human health if inhaled or damaging to the environment. Prominent examples are $PM_{2.5}$, the NO_x group and SO_2. Synonym (here): *pollutant*
pollutant concentration	The actual concentration of some pollutant at any location (close to or far away from a power plant). This is the concentration that the local population is exposed to, which means that the impact on public health is determined by this value. The pollutant concentration can above the *air quality guideline* (i. e. violating it) or below (i. e. complying with it). Not to be confused with: *emission concentration*
maximum 24-hour concentration	The highest measured or modeled *pollutant concentration*, when averaging over 24-hour periods. This is not a regulation or a guideline, but an event that really occurs (or is modeled to occur). Correspondingly for other time periods (1 hour, 10 minutes). Not to be confused with: *air quality guideline, emission limit*
flue gas	The gas that exits the power plant via its stacks.
FGD	*flue gas desulfurization*
flue gas desulfurization	Technology that removes SO_2 from a power plant's *flue gas* before it is emitted to the atmosphere.
subcritical	Conventional coal-fired power plants operate at boiler conditions that are physically described as *subcritical*. The water used by the generator to drive the turbine is boiled to generate steam which drives the turbines. The turbine water is not elevated to *supercritical* temperature and pressure. Subcritical CFPPs have a thermal efficiency of <35%. Note: In this context, the term *critical* does not indicate a "crisis" or an "out-of-control point", as it does in every-day language. Related (but not synonym): *supercritical, ultra-supercritical*
supercritical	When operating at *supercritical* conditions, the boiler water is at temperature and pressure so high that it assumes an exotic physical state: it is no longer distinguishable whether it is a gas or a liquid. *Supercritical* coal-fired power plants achieve higher thermal efficiency by operating at pressures of 22-25 MPa and temperatures of 540-580°C. *Supercritical* CFPPs have a thermal efficiency of 35-40%. Related (but not synonym): *subcritical, ultra-supercritical*
ultra-supercritical	*Ultra-supercritical* coal-fired power plants operate at even higher temperatures than *supercritical* plants. They achieve higher thermal efficiency by operating at pressures of 22-25 MPa and temperatures of 580-620°C. *Ultra-supercritical* CFPPs have a thermal efficiency of 45-52%. Related (but not synonym): *subcritical, supercritical*
IGCC	*Integrated coal gasification combined cycle*
integrated coal gasification combined cycle	In IGCC, a gasifier turns coal into a high pressure gas called *syngas*. The design uses a combined cycle where a gas turbine is driven by the combusted syngas, and the exhaust gases are used to generate steam which drives a steam turbine. IGCC plants aim to achieve a thermal efficiency of 45-50%.
MPa	*Megapascal* (unit of pressure). The pressure of the atmosphere is 0.1 MPa.
NO	**Nitrogen monoxide.** A trace gas that is produced in all combustion processes. it converts from and to NO_2. Synonym: *nitric oxide*
NO_2	**Nitrogen dioxide**. A trace gas that is produced in all combustion processes. It converts from and to NO. The amount of NO_2 in the atmosphere is commonly used as a proxy to assess the health impact of the whole NO_x group.
NO_x	**Nitrogen oxides.** A generic term for NO and NO_2, a group of trace gases that are harmful to human health.

SO_2	**Sulfur dioxide.** Sulfur dioxide is a trace gas produced by industrial processing of materials that contain sulfur, including coal burning in power plants and processing of some mineral ores. About 99% of the sulfur dioxide in air comes from human sources. Sulfur dioxide reacts with other substances to form harmful compounds, such as sulfuric acid (H_2SO_4), sulfurous acid (H_2SO_3) and sulfate particles and it is therefore a cause of acid rain and particulate matter pollution (→ $PM_{2.5}$).
dust	**Solid airborne particles.** In CFPP *flue gas*, this is mainly fly ash. A subclass of dust is $PM_{2.5}$.
$PM_{2.5}$	**Fine particulate matter.** Solid particles with aerodynamic diameter of less than 2.5μm (i. e. small dust particles). They are so small that they can pass from the lungs into the bloodstream, affecting the entire cardiovascular system and causing a range of health impacts. Due to their small size, the particles stay airborne for a long time and can travel hundreds or thousands of kilometers. Fossil fuel combustion emits $PM_{2.5}$ directly, as fly ash and other unburned particles, and contributes to $PM_{2.5}$ indirectly through emissions of gaseous pollutants (particularly SO_2 and NO_x) which form $PM_{2.5}$ in the atmosphere. $PM_{2.5}$ is harmful to human health and thus an air pollutant.
mg	**Milligram.** A thousandth of a gram (about the mass of a small ant).
mg/Nm³	**Milligram per normalised cubic meter.** The mass of a substance in milligrams, in one cubic meter of a gas. Gases expand or contract greatly with changing temperature and pressure. The *flue gas* of a power plant is much hotter than normal ambient temperature at the Earth's surface. To make the pollutant concentration inside the flue gas comparable, units are converted to what its concentration would be under temperature and pressure that is normal at the Earth's surface.
ppm	**Parts per million.** A description of concentration: the number of parts out of 1 million that are a certain substance. Can refer to mass or volume.
μg	**Microgram.** A millionth of a gram (about the mass of an ant's antennae).
μm	**Micrometer.** A thousandth of a millimeter.

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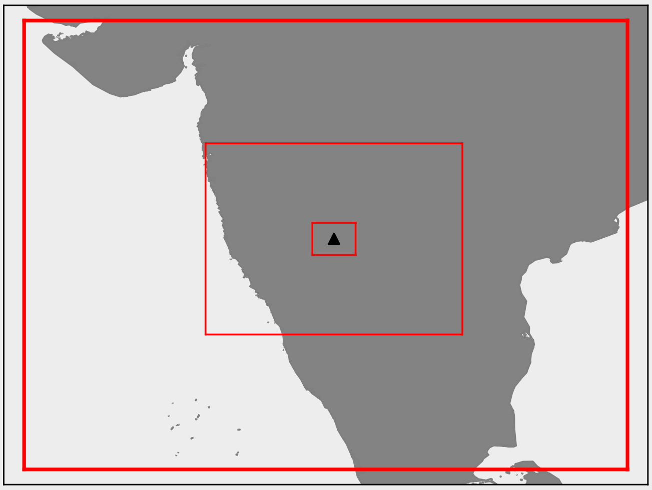
The designations employed and the presentation of the material on maps showing political borders contained in this report do not imply the expression of any opinion whatsoever concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Appendix: Methodolgy of health impacts modeling



Method overview

The impacts of the coal-fired power plants are derived using a combined approach that uses an atmospheric dispersion modeling system to estimate pollutant concentrations and demographic data to estimate health effects. The atmospheric dispersion model consists of two major components:

1. The pollution model

As a first step, a numerical weather model is used to simulate the regional meteorological conditions around each power plant. It is combined with a chemistry model to study the propagation of the power plant emissions to its environment.

a **Meteorology model.** The meteorology around the power plant is modeled using version 3 of the *The Air Pollution Model* (TAPM).[58] Although TAPM includes the ability to model pollutant dispersion, only the meteorology component of TAPM is used. TAPM is run on three nested domains centred around each power plant or cluster of closely located power plants. The model domains have 37x37 grid cells with spatial resolutions of 40 km, 10 km and 2.5 km, respectively, getting finer towards the center (Figure A.1). Boundary conditions are derived from the Global Analysis and Prediction System (GASP) model of the Australian Bureau of Meteorology[59]. In each TAPM simulation, the model has a nine day spin up period covering the last nine days of 2017. TAPM is then run for the whole year of 2018, to provide data for the analysis.

b **Atmospheric chemistry-transport model.** The dispersion, chemical transformation and deposition of the power plant emissions of NO_x, SO_2 and primary $PM_{2.5}$ is modeled by the *CALPUFF* model (version 7).[60] As we are solely focusing on the impacts from the power plant, no other emission sources are included in the model. Background concentrations of O_3, NH_3 and H_2O_2 are included for use by the chemistry module.[61] Both emission scenarios (Scenario 1, actual emission limits vs. Scenario 2, Japanese median limits) are modeled. The model outputs a time series of near-surface concentrations of the pollutants for analysis at gridded receptor locations across the model domains.

Figure A.1 (above): For each power plant, a numerical weather model with three nested domains (red boxes) around the source (black triangle, here Kudgi) is run.

Emission data sources

The pollutant emission rates and flue gas release characteristics used for the modeling are based, as far as possible, on data disclosed by project proponents. The following data was collected from environmental impact assessments, environmental permits, feasibility studies and other documents related to the projects, when available:

- Annual emissions volumes (AEV)
- Emissions rates at full operation (ER)
- Pollutant concentrations in flue gas (CFG)
- Flue gas volume flow (FGV)
- Plant net thermal efficiency (EFF), electric capacity (CAP) and steam condition (subcritical/supercritical/ultra-supercritical)
- Projected plant load factor (PLF)
- Coal type
- Stack height and inner diameter
- Flue gas release temperature and velocity
- Stack location

To assess both short-term maximum air quality impact, annual pollutant exposure and health impact, data on both AEV and ER is required. When either AEV or ER was unavailable, the missing parameter was calculated from:

$$ER = AEV / PLF,$$

effectively assuming that CFG is constant throughout plant operation, a conservative assumption with respect to projected maximum short term air quality impact. When both ER and AEV were unavailable, ER was calculated as:

$$ER = FGV * CFG.$$

When FGV was unavailable, it was estimated as:

$$FGV = CAP / EFF * SFGV,$$

where SFGV is specific flue gas volume per unit thermal input (Nm^3/GJ) estimated for the type of coal used by the power plant.

When project-specific CFG information was unavailable, the plant was assumed to follow national emission standards in the country.

To estimate SFGV values based on net calorific value, moisture and ash content of coal, the empirical formula A.5N on p. 85 of European standard EN 12952-15 was used. Coal characteristics were obtained from project documents when available, and otherwise from closest corresponding samples in the USGS World Coal Quality Inventory.[62] Average values for Kalimantan coal were used for projects importing unspecified seaborne sub-bituminous coal; average values for Australian coal were used for projects importing unspecified seaborne bituminous coal, and averages for Sumatran coal for projects using unspecified domestic seaborne coal in Indonesia. For the Kalselteng 2 lignite project, coal properties were taken from an academic paper containing the chemical analysis of lignite from the region.[63]

Once AEV and ER were obtained for all projects, the atmospheric model was run for a full calendar year at the full-operation emissions rates, and the resulting ground-level pollutant concentration fields were used as such for assessing maximum short-term air quality impact. For the purposes of health impact assessment, the average concentrations were scaled down by the plant's projected load factor, effectively spreading the plant's annual emissions volume evenly throughout the year.

When data on coal type and plant location were not available, these data were taken from the Global Coal Plant Tracker.[64] For stack height and inner diameter, flue gas release temperature and velocity, EFF and PLF, the median value for comparable projects was used to fill in missing data. When specific information on thermal efficiency was not provided but the plant steam condition was known, net thermal efficiency of 38%, 41% and 44% was assumed for subcritical, supercritical and ultra-supercritical plants respectively.

2. Health impact assessment

The results of the pollution model (step 1) are used to assess the number of people exposed to concentrations that violate the WHO guidelines and to estimate the impact of this pollution on the health of the local human population.

a **Exposure to guideline level exceedances.** Using global population data with 1 km resolution, we assessed the number of people living in areas that exceed WHO guidelines. There are guidelines that refer to average concentration and others that refer to maximum concentrations within a certain time interval. For those referring to average concentrations, we used the temporal mean of the full year of analysis time. For the maximum concentrations, we calculated for each of the chemical model receptors individually the maximum value of the appropriate temporal running mean.

b **Health impact.** The number of fatalities caused by the excess pollution have been assessed using empirical values of *relative risks* relating to various causes of premature deaths to increases in pollutant concentrations. The relative risk r expresses how much more likely an individual is to die prematurely if they are exposed to a certain excess pollution than if they were not exposed:

$$m_x / m_0 = r, \quad (1)$$

where m_x is the mortality (number of deaths per number of inhabitants) under the increased pollution Δx, and m_0 is the mortality in absence of the excess pollution. In state-of-the-art epidemiological models, r depends exponentially on x for $m_x << 1$:[65,66]

$$r = \exp(c\,\Delta x), \quad (2)$$

with c being a constant called *concentration response factor.* Combining Eqs. (1) and (2) gives:

$$m_x = m_0 \exp(c\,\Delta x).$$

Since the number of deaths is the population number P times the mortality, the number of people dying under the higher pollutant concentration is:

$$d_x = P\,m_0 \exp(c\,\Delta x).$$

The number of deaths attributable to the excess pollution is:

$$\Delta d = d_x - d_0 = P\,m_0\,[\exp(c\,\Delta x) - 1].$$

Values for r in the scientific literature may be broken down to different death causes or be a total for one substance.

Data sources for the health impact assessment

- **Population.** We used the 1 km resolution global population data for 2010 from Socioeconomic Data and Applications Center (SEDAC).[67]
- **Country boundaries** are taken as defined in version 3.6 (May 2018) of the Database of Global Administrative Areas (GADM).[68]
- **Concentration response factors (CRFs).** We used the CRFs listed in Tab. A.1. CRFs have been computed from relative risks given in WHO (2013)[69] for NO_2, Pope et al. (2015)[70] for $PM_{2.5}$-*diabetes* and Krewski et al. (2009)[71] for all other $PM_{2.5}$. The same values are used for all countries and all age groups.[72]
- **Background mortality** is taken from the Institute for Health Metrics and Evaluation (IHME) Global Burden of Disease Study 2017.[73] The data set provides values per death cause per country. The numbers for the countries and causes in this report are listed in Tab. A.2.

Allocation of death cause names from the CRFs to background death rates is shown in Table A.3.

	NO_2		$PM_{2.5}$	
	relative risk at 10 μg m^{-3} increase	CRF (10^{-3} μg^{-1} m^3)	relative risk at 10 μg m^{-3} increase	CRF (10^{-3} μg^{-1} m^3)
All causes	1.055 (1.021-1.080)	5.354 (2.078-7.696)	-	-
Lower respiratory infections	-	-	1.128 (1.077-1.182)	11.33 (2.96-26.24)
Lung cancer	-	-	1.142 (1.057-1.234)	13.28 (5.54-21.03)
Chronic obstructive pulmonary disease	-	-	1.13 (1.02-1.26)	12.04 (7.42-16.72)
Diabetes	-	-	1.128 (1.077-1.182)	11.33 (2.96-26.24)
Stroke	-	-	1.128 (1.077-1.182)	11.33 (2.96-26.24)
Ischemic heart disease	-	-	1.12 (1.03-1.30)	25.23 (16.30-34.15)

Table A.1: Concentration response factors for NO_2 and $PM_{2.5}$ derived from relative risks for a standard increase of 10 μg/m^3. The CRFs have been computed from the relative risks using Eq. (2). Brackets show 95% confidence intervals. For NO_2, there is no data on specific death causes (thus, only the aggregated health impact of all causes is assessed for this pollutant).

	All	LRI	LC	COPD	Diabetes	Stroke
Bangladesh	5652 (5198-6138)	245 (209-294)	161 (139-186)	412 (366-468)	159 (134-187)	1030 (933-1138)
Cambodia	6318 (5823-6893)	612 (541-694)	139 (117-165)	189 (159-220)	93 (76-109)	866 (784-969)
China	7400 (7187-7619)	127 (119-155)	490 (468-510)	684 (655-757)	78 (74-83)	1494 (1446-1547)
India	7178 (7049-7311)	368 (333-389)	61 (57-65)	694 (574-779)	135 (121-147)	526 (496-551)
Indonesia	6363 (6090-6661)	170 (154-181)	144 (124-168)	259 (221-291)	236 (209-265)	1195 (1125-1271)
Laos	6536 (5934-7222)	539 (437-664)	124 (100-150)	236 (190-287)	108 (88-132)	849 (736-969)
Malaysia	5389 (5041-5772)	773 (513-884)	154 (133-176)	157 (136-203)	48 (43-54)	579 (526-638)
Mongolia	6523 (6051-7019)	203 (167-252)	156 (136-175)	64 (56-79)	10 (8-12)	1006 (917-1103)
Morocco	6219 (5402-7075)	165 (139-211)	125 (99-156)	141 (114-175)	159 (122-198)	765 (618-916)
Myanmar	7765 (7060-8435)	428 (372-482)	155 (136-174)	736 (508-872)	314 (262-373)	673 (600-737)
Nepal	6114 (5562-6610)	311 (259-365)	78 (51-108)	601 (491-767)	121 (90-151)	462 (390-536)
Spain	8979 (8630-9326)	279 (260-299)	486 (454-522)	620 (576-668)	159 (148-171)	698 (651-760)
Thailand	6616 (6086-7129)	512 (329-595)	276 (246-311)	225 (198-276)	166 (146-194)	610 (551-685)
Vietnam	6306 (5801-6932)	189 (164-234)	370 (317-432)	294 (249-338)	177 (152-205)	1161 (1060-1293)

Table A.2: Background death rates for the countries in this report from the 2017 IHME Global Burden of Disease dataset. Annual deaths per million with 95% confidence ranges. Death causes are abbreviated as in Table A.3.

CRF	Background death rate
All causes (all)	All causes
Lower respiratory infections (LRI)	Lower respiratory infections
Lung cancer (LC)	Tracheal, bronchus, and lung cancer
Chronic obstructive pulmonary disease (COPD)	Chronic obstructive pulmonary disease
Diabetes	Diabetes mellitus type 2
Stroke	Stroke
Ischemic heart disease (IHD)	Ischemic heart disease

Table A.3: Translation dictionary between death cause names in the CRF sources and in the background death rate data.

Health impact per power plant

Figure A.2 shows the projected annual number of total premature deaths for each power plant. The contribution of individual causes is shown in Figure A.3.

	Scenario 1 (local limits)			Scenario 2 (Japanese limits)			Difference		
Unit	**Central**	**Low**	**High**	**Central**	**Low**	**High**	**Central**	**Low**	**High**
Kalselteng 2	26	13	38	2	1	3	23	12	35
Van Phong	99	49	150	14	7	21	85	42	129
Thai Binh 1	179	89	269	20	10	30	159	79	239
Thai Binh 2	310	157	464	32	16	48	278	141	416
Tanjung Jati-B 5&6	319	166	472	38	20	57	281	146	415
Safi	60	33	88	13	7	20	47	26	68
Nghi Son 2	285	144	427	32	16	47	254	128	380
Meja SC	3,340	1,798	4,889	101	53	149	3,239	1,745	4,739
Matarbari 1	506	261	751	73	36	109	433	224	642
Kudgi	2,106	1,146	3,070	70	38	103	2,036	1,109	2,967
Indramayu-4	785	413	1,158	64	33	94	721	380	1,063
Lontar 4 Exp.	269	140	399	23	12	34	247	129	365
Duyen Hai 3 Exp.	72	36	108	13	6	19	59	29	90
Batang Central	277	148	406	42	22	61	235	126	345
Vinh Tan 4	328	169	489	34	17	51	295	152	438
Vinh Tan 4 Exp	178	90	266	16	8	23	162	82	243
Cirebon 2	806	436	1,176	46	24	68	759	411	1,108
SUM	**9,945**	**5,286**	**14,620**	**631**	**326**	**938**	**9,314**	**4,960**	**13,683**

Table A.4: Modeled number of total premature deaths due to excess pollution per source for Scenarios with 95% confidence intervals (same data as Figure A.2).

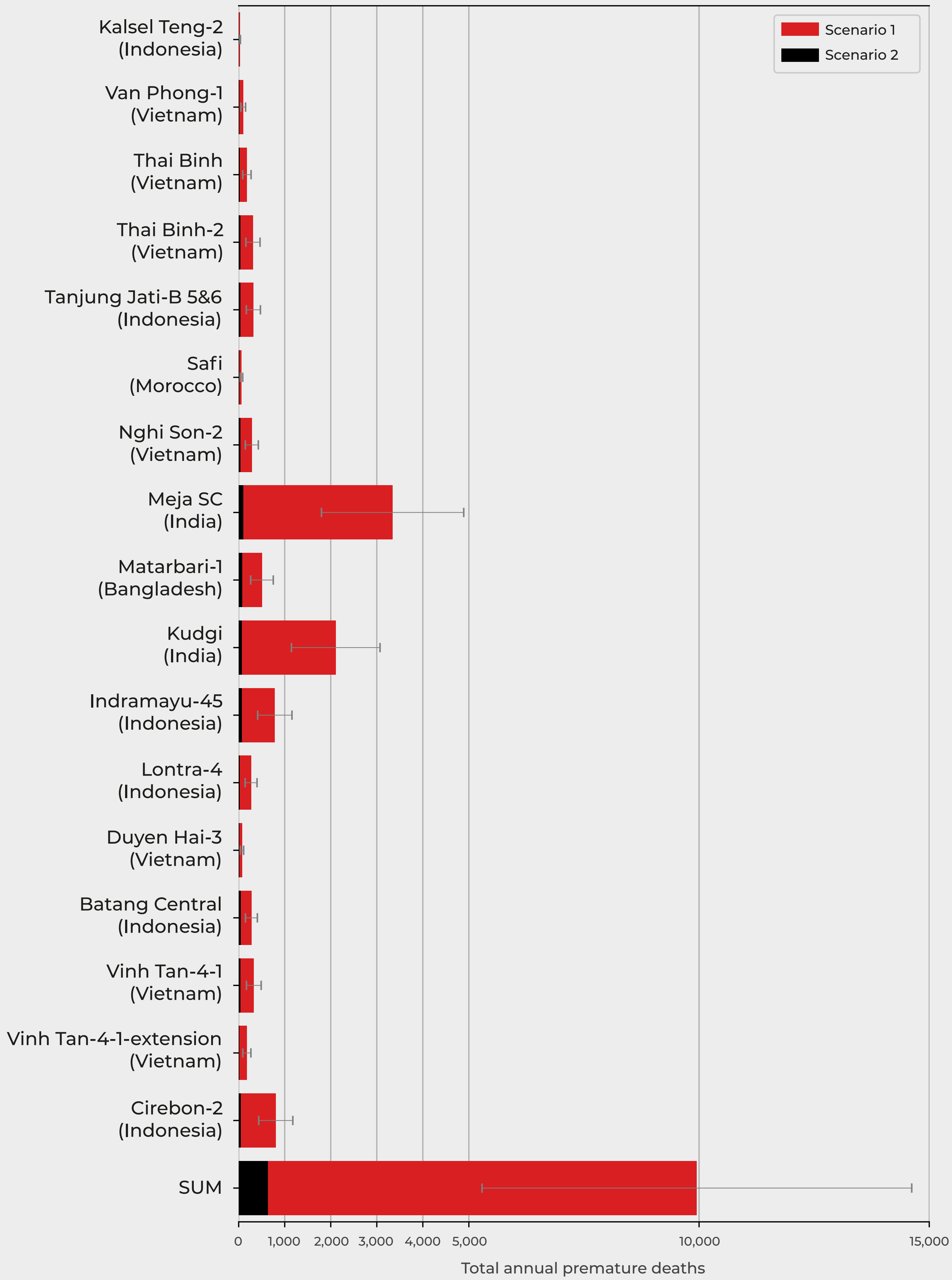


Figure A.2: Modeled number of total premature deaths due to excess pollution per power plant for Scenario 1 (red bars) and Scenario 2 (black bars). Whisker lines show 95% confidence intervals for Scenario 1.

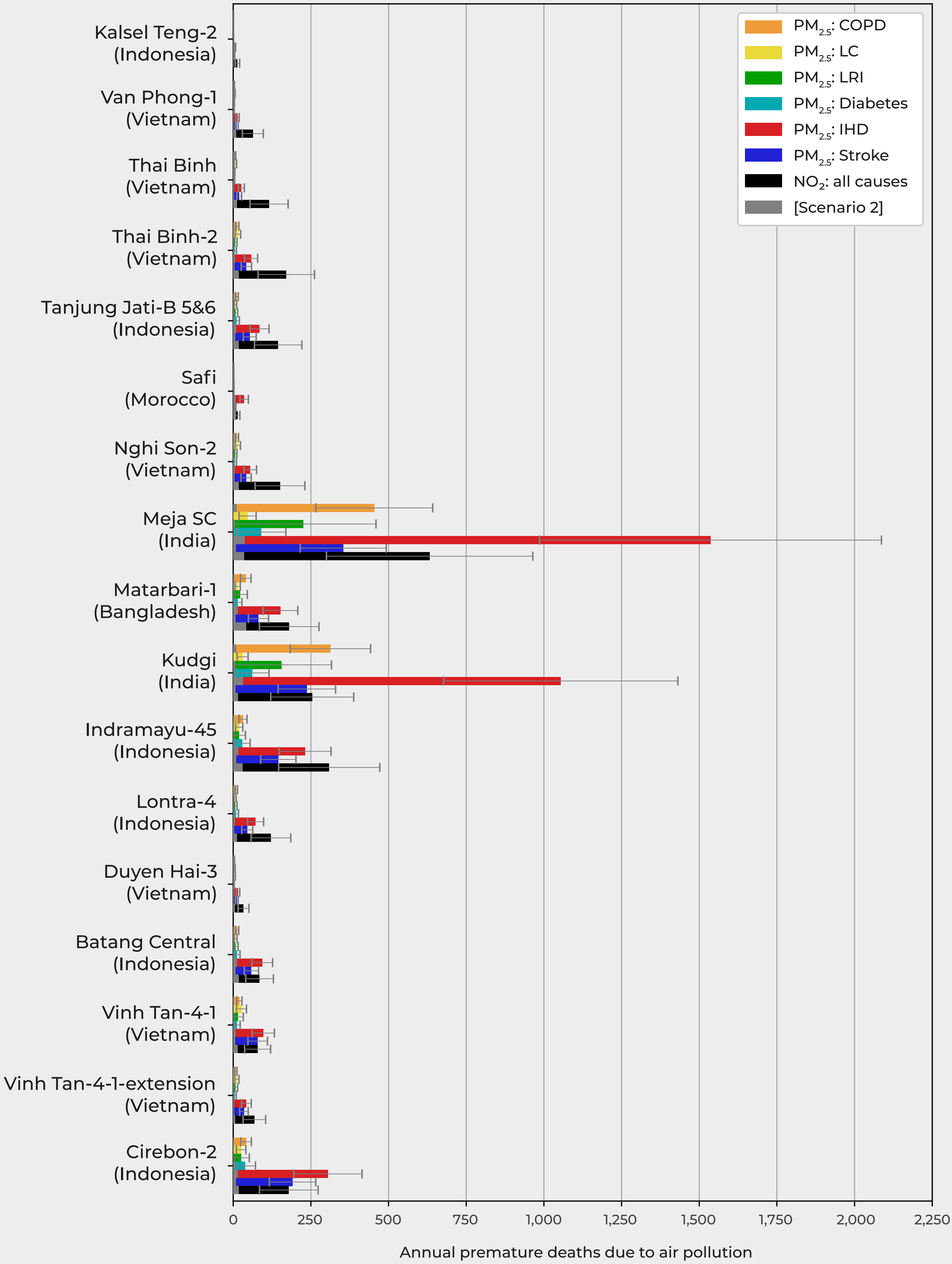


Figure A.3: Modeled number of premature deaths due to excess pollution per power plant broken down per death cause for Scenario 1 (colored and black bars) and Scenario 2 (grey bars). Whisker lines show 95% confidence intervals for Scenario 1.

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