Air quality and health impacts of new coal-fired power plants in the Tokyo-Chiba and Osaka-Hyogo regions

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Contents

Summary

Ambient air pollution is the largest environmental health threat in the world and in Japan, with the Global Burden of Disease project estimating that approximately 180 premature deaths per day were caused by ambient air pollution exposure in Japan in 2013[1]. Furthermore, the number of deaths increased by an estimated 40% from 1990 to 2013, as population aging, epidemiological change and urbanization increased susceptibility of the population to health impacts of air pollution.

Yet Japan is planning a major expansion in coal-fired power generation, one of the important sources of air pollutants, with the potential to significantly increase air pollution emissions from the power sector. While new power plants generally emit less air pollutants per unit of electricity than older ones, due to higher thermal efficiency and more efficient emissions control devices, their flue gases still contain high concentrations of SO2, NOx and particle pollution. Furthermore, investment in new coal-fired generating capacity would lock the emissions in for decades. Among advanced economies, Japan stands out as one of the few countries that are still planning new coal-fired power plants, and as the one with by far the largest plans among the handful that still do.

Many of the power plants are planned in the vicinity of very large population centers, which amplifies their potential health impacts. This paper presents two case studies on the air quality and health impacts of the planned power plants around Tokyo and Chiba, and around Osaka and Hyogo. 10 projects with 7500MW of capacity are planned within 200 kilometers of Tokyo, while 15 projects with 6500MW of capacity are planned around Osaka and Hyogo.

Air pollutant emissions from these power plants were projected, using information on pollution concentrations in flue gases from the project proponents themselves, whenever possible. The emission levels used as the basis for the study are significantly below the maximum levels allowed in Japanese legislation.

The potential air quality impacts of the pollution emissions from the planned power plants were then studied using the CALPUFF air pollution modeling system[2] recommended by the U.S. EPA for assessing long range transport of pollutants and their impacts. The health impacts of the modeled air pollutant exposure resulting from the emissions were assessed following World Health Organization recommendations.

The projected health impacts of the new coal-fired power plants around Tokyo and Chiba, in addition to health impacts of current air pollution levels, are 260 premature deaths per year (95% confidence interval 140 to 370), and 30 low birth weight births, if all proposed plants are built and operated. Of the premature deaths, 180 are due to exposure to PM2.5 and 80 due to exposure to NO2. Over a typical operating life of 40 years, this would imply a total of 6,000-15,000 premature deaths and 1,200 low birthweight births.

The new coal-fired power plants around Osaka and Hyogo would be projected to cause 200 premature deaths per year (95% confidence interval 100 to 208), and 20 low birthweight births, if all proposed plants

[1] Institute for Health Metrics and Evaluation (IHME). GBD Compare. Seattle, WA: IHME, University of Washington, 2015. Available from http://vizhub.healthdata.org/gbd-compare.
[2] U.S. EPA: Preferred/Recommended Models. https://www3.epa.gov/ttn/scram/dispersion_prefrec.htm#calpuff

are built and operated. Of the premature deaths, 130 are due to exposure to PM2.5 and 70 due to exposure to NO2. If the plants operate for 40 years, this would translate to 4,000-11,000 premature deaths and 800 low birthweight births.

The impacts were modeled over a 1500km x 1500km domain covering most of Japan and the Korean peninsula, with the immediate vicinity of the plants covered at higher spatial resolution. There are approximately 210 million people living within this domain.

The emissions from the power plants elevate the levels of toxic particles and NO2 in the air over the entire large areas extending several hundred kilometers from the power plant location and beyond. SO2, NOx and dust emissions all contribute to toxic PM2.5 particle levels, increasing the risk of diseases such as stroke, lung cancer, heart and respiratory diseases in adults, as well as respiratory symptoms in children. Direct exposure to NO2 increases the risk of death from a number of chronic diseases and can exacerbate respiratory symptoms in people with pre-existing conditions. Importantly, the CALPUFF modeling system is capable of simulating the chemical transformation of SO2 and NOx emissions into secondary PM2.5 pollution in the atmosphere, a very important impact pathway that is usually neglected in Environmental Impact Assessments and regulatory processes.

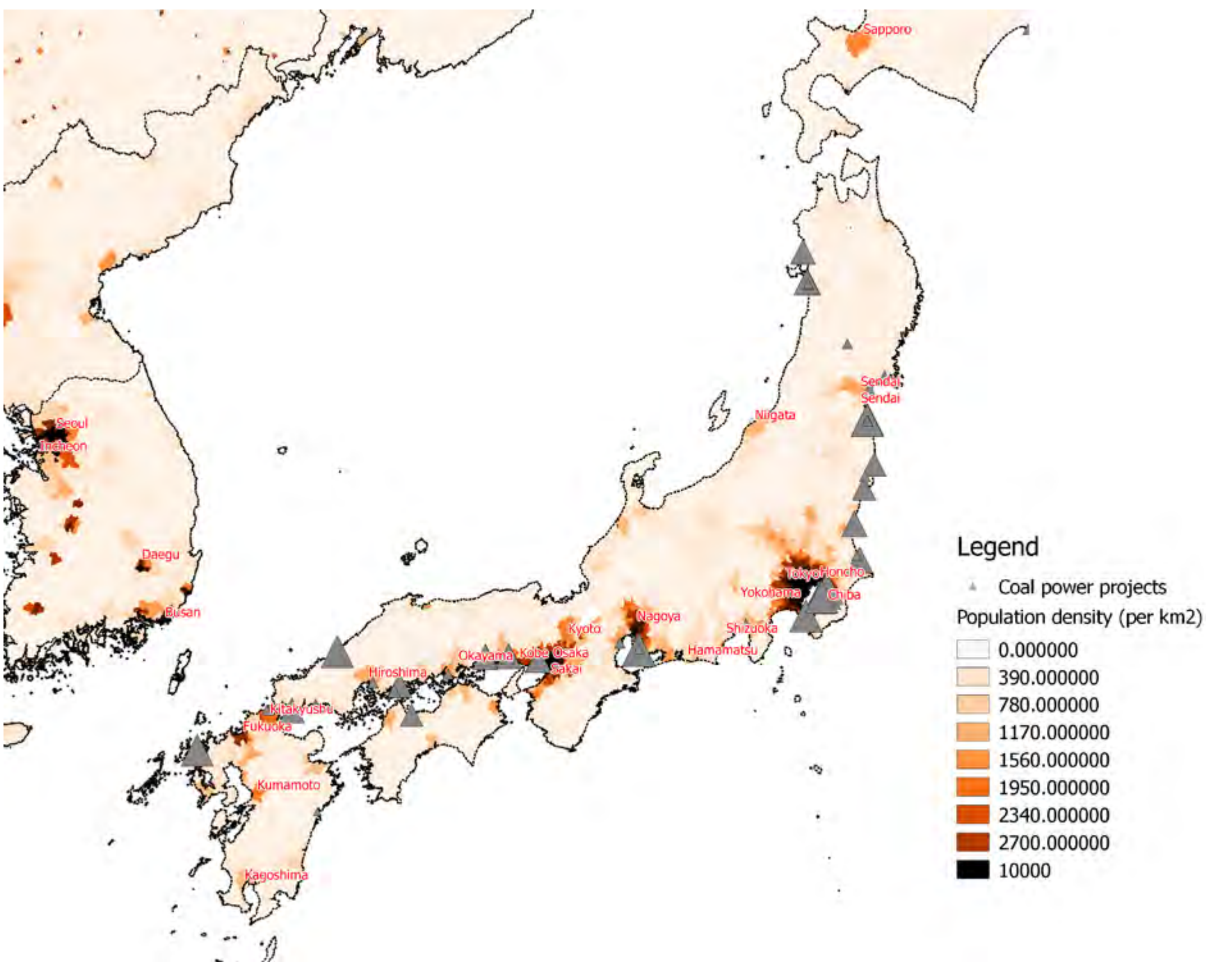

Figure 1. *Map of coal power projects and population density*

Studied new coal power plants

Power plants in the neighborhood of two Japan's largest population centers were selected for case studies. Nested modeling domains were set up to cover all of the new power plants included in each case study at a horizontal resolution of at least 10x10km, and the main population center at a resolution of 5x5km.

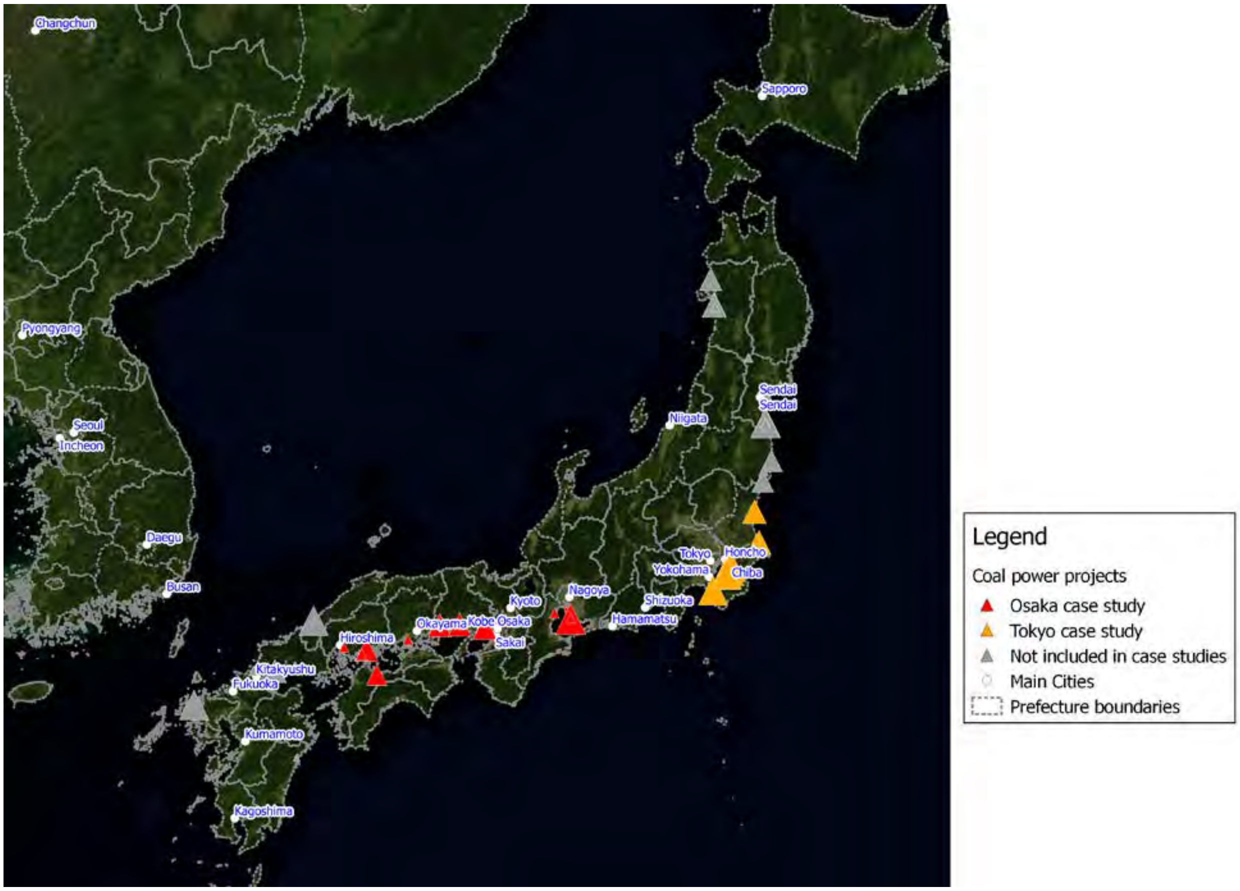

Figure 2. *Map of coal-fired power plant projects in Japan and inclusion in case studies*

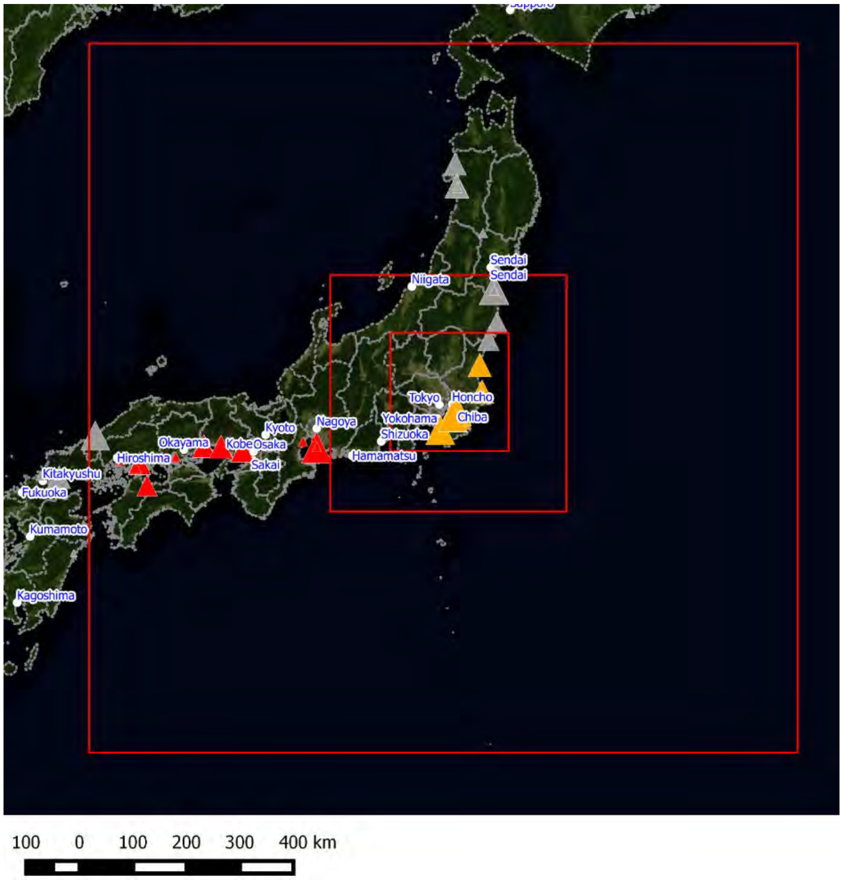

Figure 3. *Calpuff nested modeling domain for the Tokyo-Chiba case study (in red).*

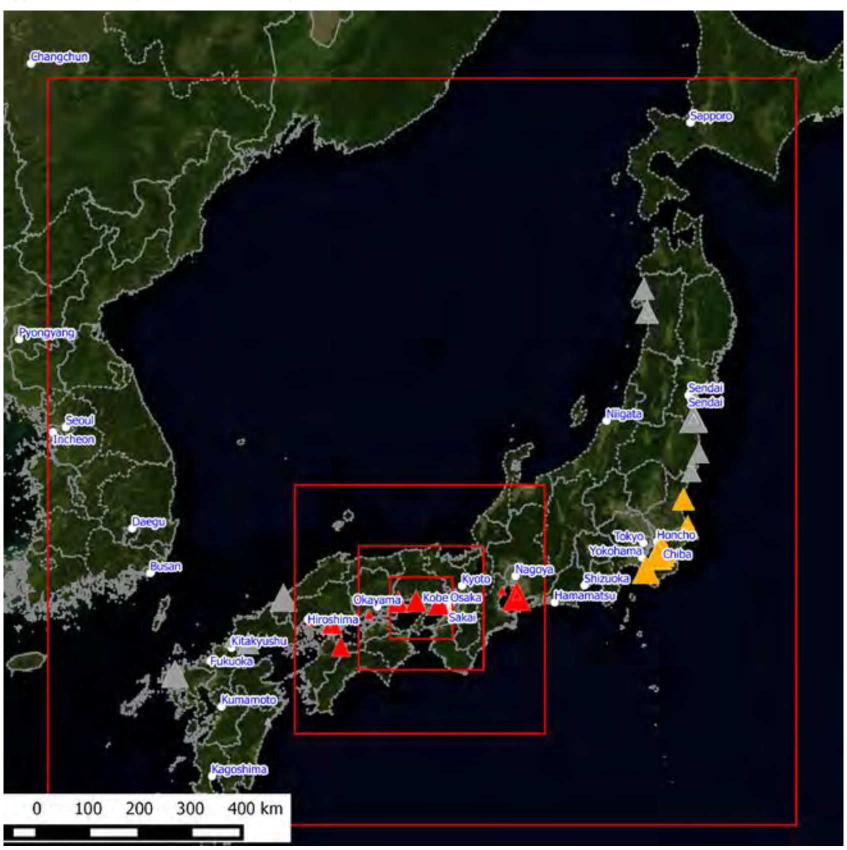

Figure 4. *Calpuff nested modeling domain for the Osaka-Hyogo case study (in red).*

Projecting air pollutant emissions from the proposed power plants

The first step in assessing the health impacts of coal-fired power plants is estimating the emissions of harmful pollutants. Coal combustion always generates very large amounts of the major air pollutants – SO2, NOx and dust. New coal-fired power plants have to meet emission limits set by regulators, requiring the installation of emission control devices that remove much of the pollution from the flue gas, but removing all of it is not physically, let alone economically, possible. Air pollutant emissions from the proposed power plants were projected using data on pollutant concentrations in plant flue gases from the project proponents themselves, as far as possible.

The following basic information on the coal-fired power plant projects in the study areas was obtained from Japan Coal Plant Tracker maintained by Kiko Network.

Table 1. Basic data on the projects included in the case studies.

Area	Plant name	Company / Operator	Lat	Lon	Capacity (MW)	Planned operation	Status	Technology type
Tokyo-Chiba case study								
Chiba	Ichihara	Ichihara Thermal Power Generation godo kaisha	35.51	140.05	1000	2024	Assessment processing	Ultra-supercritical (USC)
Ibaraki	Kashima No.2	Kashima Power	35.94	140.67	650	July 2020	Assessment processing	Ultra-supercritical (USC)
Chiba	Chiba Sodegaura No.2 (tentative)	Chiba Sodegaura Energy	35.47	139.98	1000	2026	Assessment processing	Ultra-supercritical (USC)
Chiba	Chiba Sodegaura No.1 (tentative)	Chiba Sodegaura Energy	35.45	139.97	1000	2025	Assessment processing	Ultra-supercritical (USC)
Ibaraki	Hitachinaka Kyodo No.1	Hitachinaka Generation	36.44	140.61	650	1H of 2021	Assessment processing	Ultra-supercritical (USC)
Chiba	Unknown	Chugoku Electric Power	35.58	140.09	1000	around 2020	Planning (without official announcement)	Unknown
Kanagawa	Yokosuka Power Plant	Tokyo Electric Power	35.21	139.72	1000	2020	Planning (without official announcement)	Ultra-supercritical (USC)
Chiba	Unknown	Kansai Electric Power	35.46	140.00	1000	Unknown	Planning (without official announcement)	Unknown
Ibaraki	Unknown	Kamisu Power	36.00	140.62	100	2018	Planning (without official announcement)	Unknown
Shizuoka	Suzukawa Energy Center	Suzukawa Energy Center	35.14	138.71	100	Sep. 2016	Under construction	Pulverized Coal-fired (PC) boiler
Osaka-Hyogo case study								
Aichi	Taketoyo No.5	Chubu Electric Power	34.82	136.92	1070	March 2022	Assessment processing	Ultra-supercritical (USC)
Hiroshima	Takehara New No.1	J-Power	34.34	132.96	600	June 2020	Under construction	Ultra-supercritical (USC)
Ehime	Saijo New No.1	Shikoku Electric Power	33.93	133.17	500	FY 2022	Assessment processing	Ultra-supercritical (USC)
Hiroshima	Osaki Cool Gen	Osaki Cool Gen	34.26	132.87	166	March 2017	Under construction	Integrated gasification combined cycle (IGCC)
Mie	Unknown	MC Kawajiri Energy Service	34.93	136.61	112	2019	Assessment processing	Pulverized Coal-fired (PC) boiler
Hiroshima	Kaita biomass blend firing power station	Hiroshima Gas	34.36	132.52	112	2019	Assessment processing	Circulating fluidized bed (CFB) boiler
Aichi	Nagoya No.2	Nakayama Nagoya Kyodo Hatsuden	34.84	136.93	110	2nd half of 2016 FY	Under construction	Steam generation (steam turbine)

Okayama	Mizushima Energy Center	Mizushima Energy Center	34.50	133.76	110	Summer 2017	Under construction	Unknown
Aichi	Unknown	Meinan Kyodo Energy Corporation	34.99	136.84	31	Jan. 2018	Planning (with official announcement)	Pulverized Coal-fired (PC) boiler
Hyogo	Ako No.1	Kansai Electric Power	34.74	134.38	600	2020	Assessment progressing	Supercritical (SC)
Hyogo	Ako No.2	Kansai Electric Power	34.74	134.37	600	2020	Assessment progressing	Supercritical (SC)
Hyogo	Takasago New-No.1	J-Power	34.75	134.76	600	FY 2021	Assessment processing	Ultra-supercritical (USC)
Hyogo	Takasago New-No.2	J-Power	34.75	134.76	600	FY 2027	Assessment processing	Ultra-supercritical (USC)
Hyogo	Kobe Works New-No.2	Kobe Steel, Ltd.	34.71	135.25	650	FY 2022	Assessment processing	Ultra-supercritical (USC)
Hyogo	Kobe Works New-No.1	Kobe Steel, Ltd.	34.71	135.25	650	FY 2021	Assessment processing	Ultra-supercritical (USC)

The CALPUFF modeling system requires information on the location of the emission source, the emission volume of each pollutant, and the characteristics of the smokestack affecting the rise of the plume (stack height and diameter, flue gas temperature and velocity). These data were not consistently available, but the following relevant information was compiled by Kiko Network from project documents and other public sources.

Table 2. Data used to estimate air pollutant emissions and source characteristics.

Plant name	CO2 emisssion (k-tonne-CO2/year)	CO2 emission rate (g-CO2 / kWh)	SOX emission concentration (ppm)	NOX emission concentration (ppm)	Dust emission concentration(mg/m3)	Stack height (m)	Chimney Diameter(m)	Gas Temperature(℃)	Gas velocity (m/s)
Tokyo-Chiba case study									
Ichihara	6000		25	15	5	180	7	90	30
Kashima No.2	3439	767	25	15	5	180		90	30
Chiba Sodegaura No.2 (tentative)	6000		22	15	5	200	7.25	90	30
Chiba Sodegaura No.1 (tentative)	6000		22	15	5	200	7.25	90	30
Hitachinaka Kyodo No.1	3900		22	15	5	180		90	31.5
Unknown (Kansai Electric Power)	6000		21.0625	19.125	6.461538				
Yokosuka Power Plant	6000		21.0625	19.125	6.461538				
Unknown (Chugoku Electric Power)	6000		21.0625	19.125	6.461538				
Unknown (Ibaraki, Kamisu)	600		19	40	10				
Suzukawa Energy Center	600		19	40	10				
Osaka-Hyogo case study									
Taketoyo No.5	6420		25	15	6.461538				
Takehara New No.1	3160	766	18	20	7	200		90	35.9
Saijo New No.1	3000		21.0625	19.125	6.461538				
Osaki Cool Gen	706	692	8	5	3				
Unknown (MC Kawajiri)	672		19	40	10				

Kaita biomass blend firing power station	672		19	40	10				
Nagoya No.2	660		19	40	10				
Mizushima Energy Center	660		19	40	10				
Unknown (Meinan Kyodo Energy)	187		19	40	10				
Ako No.1	3350	800	19	16	8				
Ako No.2	3350	800	19	16	8				
Takasago New-No.1	3600		18	22	8	180		70	20
Takasago New-No.2	3600		18	22	8	180		70	20
Kobe Works New-No.2	3900		13	20	5	150		90	30
Kobe Works New-No.1	3900		13	20	5	150		90	30

When needed data was not available, the median value for units of similar size and technology was used instead. Using these assumptions when needed, annual air pollutant emissions were calculated by estimating normalized flue gas volume from CO2 emissions and allowed stack emission concentrations.

Table 3. Emission and stack characteristics data used for the study.

Unit name	**SOx as SO2, t/a**	**NOx as NO2, t/a**	**PM10, t/a**	**PM2.5, t/a**	**Chimney height(m)**	**Chimney Diameter (m)**	**Gas Temperature (℃)**	**Gas velocity(m/s)**
Taketoyo No.5	1673.5	704.5	147.8	73.9	180.0	7.0	90.0	30.0
Takehara New No.1	730.0	569.1	78.8	39.4	200.0	7.0	90.0	35.9
Saijo New No.1	658.8	419.7	69.1	34.5	180.0	7.0	90.0	30.0
Osaki Cool Gen	243.3	170.7	7.5	3.8	80.0	6.5	120.0	31.0
MC Kawajiri / Yokkaichi city, Miye pref.	133.1	196.6	23.9	12.0	80.0	6.5	51.0	20.0
Kaita biomass blend firing power station	133.1	196.6	23.9	12.0	80.0	6.5	51.0	20.0
Nagoya No.2	130.7	193.1	23.5	11.8	80.0	6.5	51.0	20.0
Mizushima Energy Center	130.7	193.1	23.5	11.8	80.0	6.5	51.0	20.0
Meinan Kyodo Energy / Chita city, Aichi pref.	37.0	54.7	6.7	3.3	80.0	6.5	51.0	20.0
Ako No.1	663.7	392.1	95.5	47.7	180.0	7.0	90.0	30.0
Ako No.2	663.7	392.1	95.5	47.7	180.0	7.0	90.0	30.0
Takasago New-No.1	750.3	640.3	102.6	51.3	180.0	7.0	70.0	20.0
Takasago New-No.2	750.3	640.3	102.6	51.3	180.0	7.0	70.0	20.0
Kobe Works New-No.2	527.3	597.6	69.5	34.7	150.0	7.0	90.0	30.0
Kobe Works New-No.1	527.3	597.6	69.5	34.7	150.0	7.0	90.0	30.0
Ichihara	1480.4	654.5	106.9	53.5	180.0	7.0	90.0	30.0
Kashima No.2	1014.0	469.5	61.3	30.6	180.0	7.0	90.0	30.0
Chiba Sodegaura No.2 (tentative)	1419.5	711.4	106.9	53.5	200.0	7.3	90.0	30.0
Chiba Sodegaura No.1 (tentative)	1419.5	711.4	106.9	53.5	200.0	7.3	90.0	30.0
Hitachinaka Kyodo No.1	892.3	441.1	69.5	34.7	180.0	7.0	90.0	31.5

Chugoku Electric Power, JFE Steel, Tokyo Gas / Chiba city, Chiba pref.	1317.7	839.5	138.2	69.1	180.0	7.0	90.0	30.0
Yokosuka	1317.7	839.5	138.2	69.1	180.0	7.0	90.0	30.0
Kansai Electric Power / Chiba pref.	1317.7	839.5	138.2	69.1	180.0	7.0	90.0	30.0
Marubeni, Kansai Electric Power / Kamisu, Ibaraki pref.	118.9	175.6	21.4	10.7	80.0	6.5	51.0	20.0
Suzukawa Energy Center	118.9	175.6	21.4	10.7	80.0	6.5	51.0	20.0
Osaka case study total	**7753.0**	**5958.4**	**940.1**	**470.0**				
Tokyo case study total	**10416.4**	**5857.6**	**908.7**	**454.3**				

Due to the relatively low stack emission concentrations specified for the projects, all dust emissions were assumed to be smaller than 10 microns in diameter (PM10) and 50% smaller than 2.5 microns (PM2.5), in line with U.S. EPA AP-42 default values for high-performance baghouses. The emissions were assumed to take place uniformly throughout the year, in the absence of more detailed operating data.

These emission data were used as the basis of modeling the plants' air quality impacts using the CALPUFF modeling system.

Results

Air quality impacts: Tokyo–Chiba case study

The studied facilities would affect air quality most significantly in central and northern Chiba, southern Ibaraki and the Tokyo metropolitan area. Under worst-case conditions, the emissions from the power plants could increase daily PM2.5 levels by over 20% and NO2 levels by over 10% compared with annual average. The cities with largest projected increases in daily PM2.5 levels are Chiba city, Funabashi city, Sagamihara city, Yokohama city and the Tokyo metropolitan area; for NO2, Chiba city is most affected.

Most significant impacts take place during summer months.

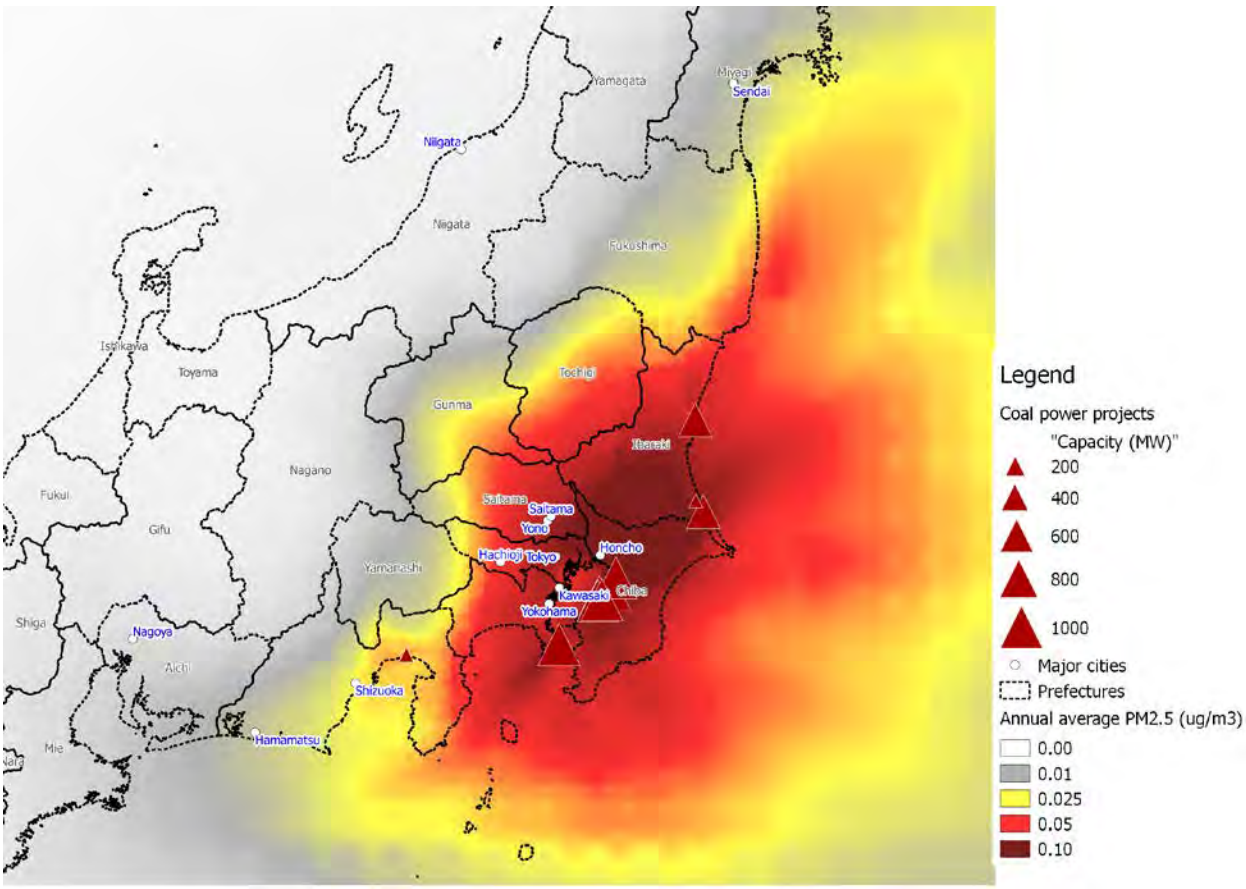

Figure 3. Projected increase in annual average PM2.5 concentration due to emissions from the studied coal-fired power plant projects (µg/m3)

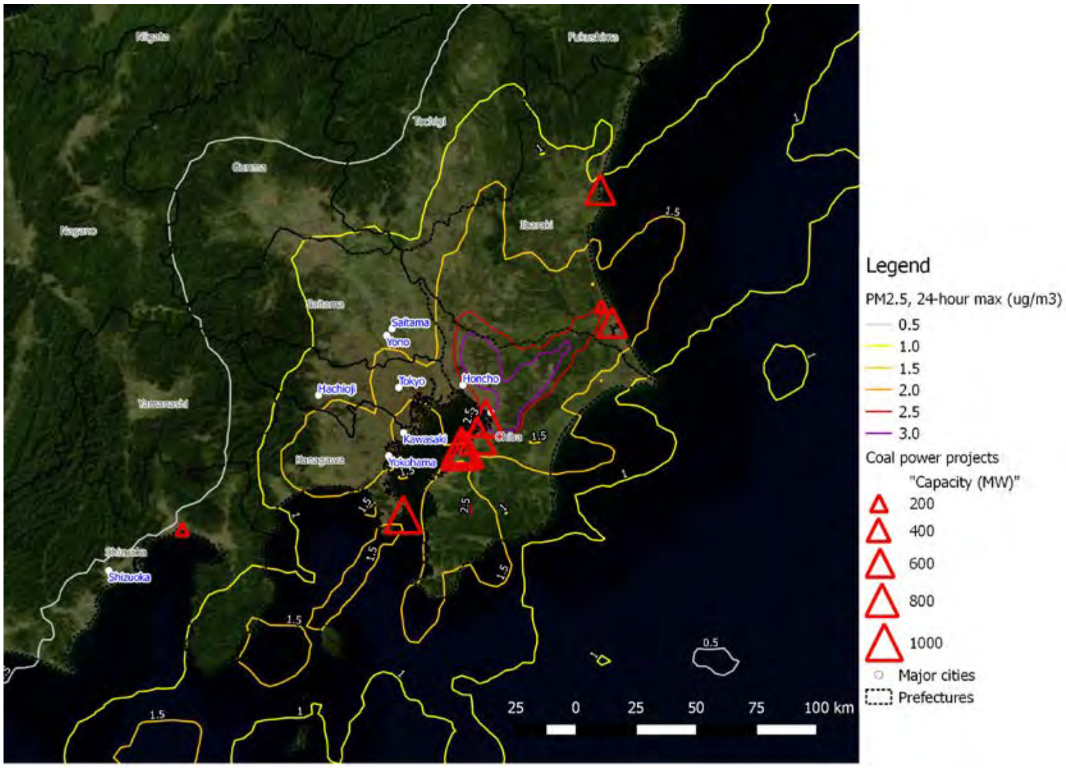

Figure 4. Projected maximum increase in 24-hour average PM2.5 concentration due to emissions from the studied coal-fired power plant projects (µg/m3)

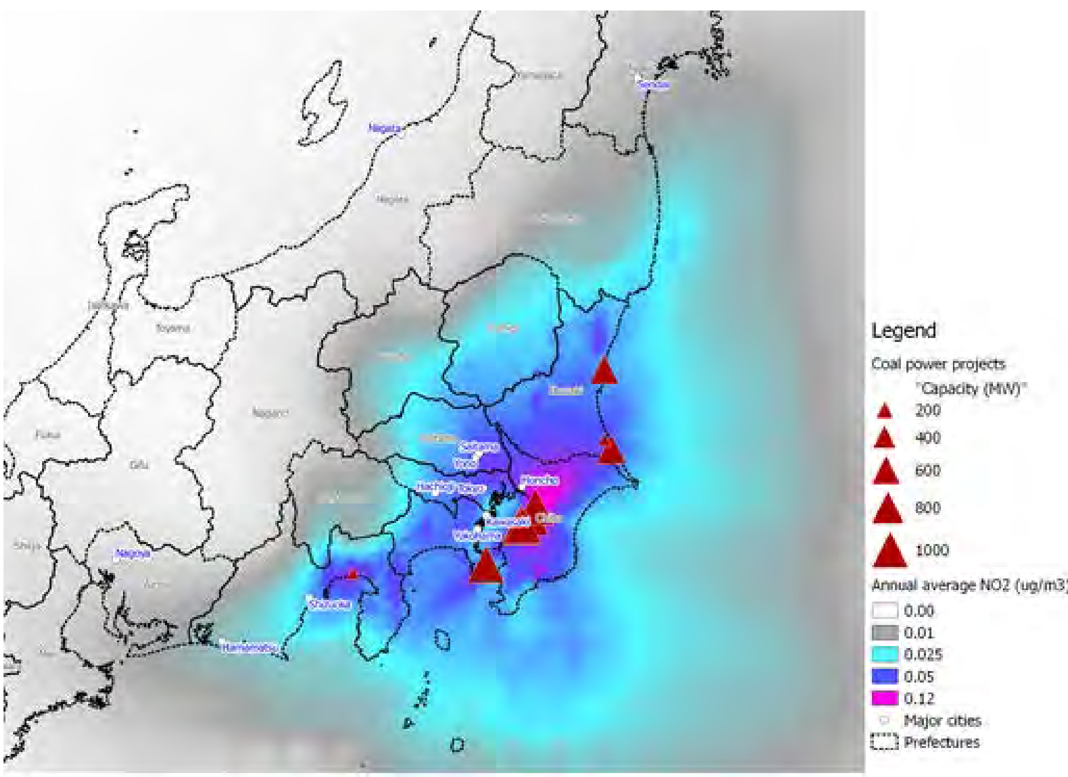

Figure 5. Projected increase in annual average NO2 concentration due to emissions from the studied coal-fired power plant projects (µg/m3)

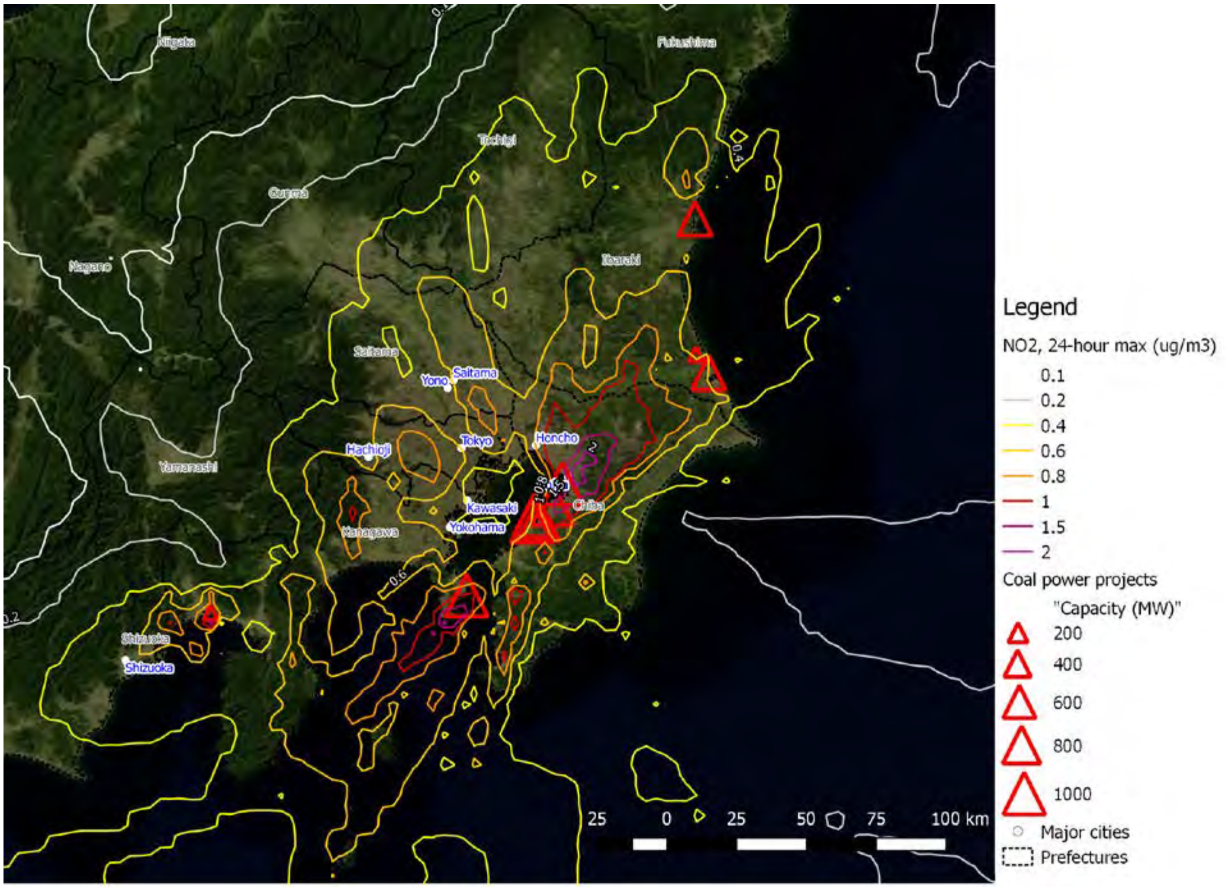

Figure 6. Projected maximum increase in 24-hour average NO2 concentration due to emissions from the studied coal-fired power plant projects (µg/m3)

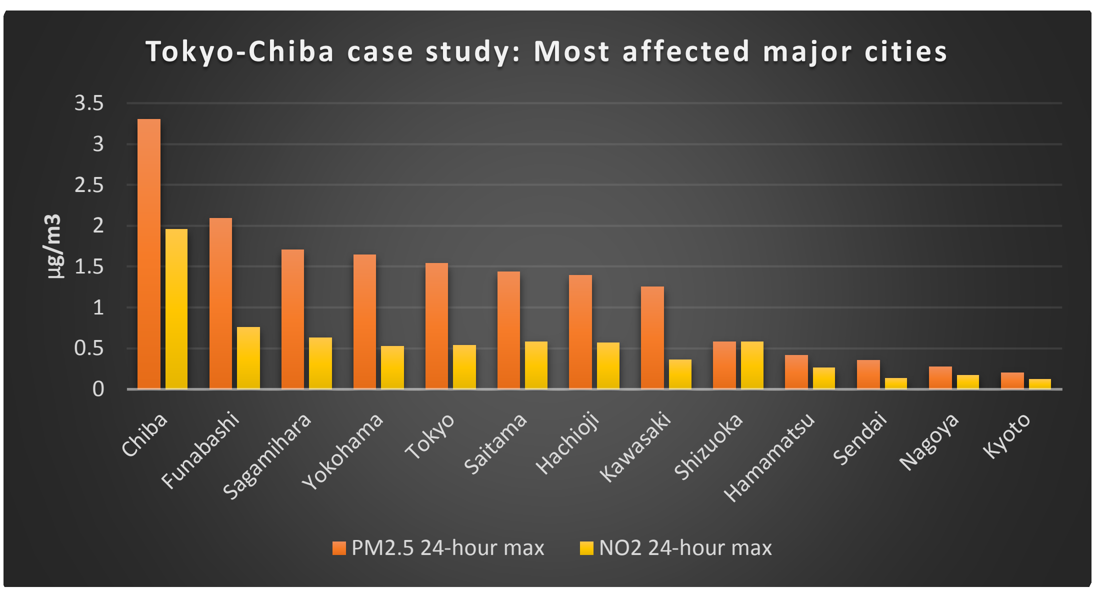

Figure 7. Projected maximum increase in 24-hour concentrations due to emissions from the studied coal-fired power plant projects.

A significant part of the total population exposure to pollution and of the resulting health impacts takes place due to long-range transport of the pollution across central and western Japan.

Air quality impacts: Osaka- Hyogo case study

The studied facilities would affect air quality most significantly in the Osaka-Kobe area and the Nagoya area. Under worst-case conditions, the emissions from the power plants could increase daily PM2.5 levels by 5% and NO2 levels by 20% compared with annual average. The cities with largest projected increases in daily PM2.5 levels are Higashiosaka, Osaka, Kobe, Sakai, Kyoto and Nagoya; for NO2, Kobe is most affected.

Most significant impacts take place during summer months.

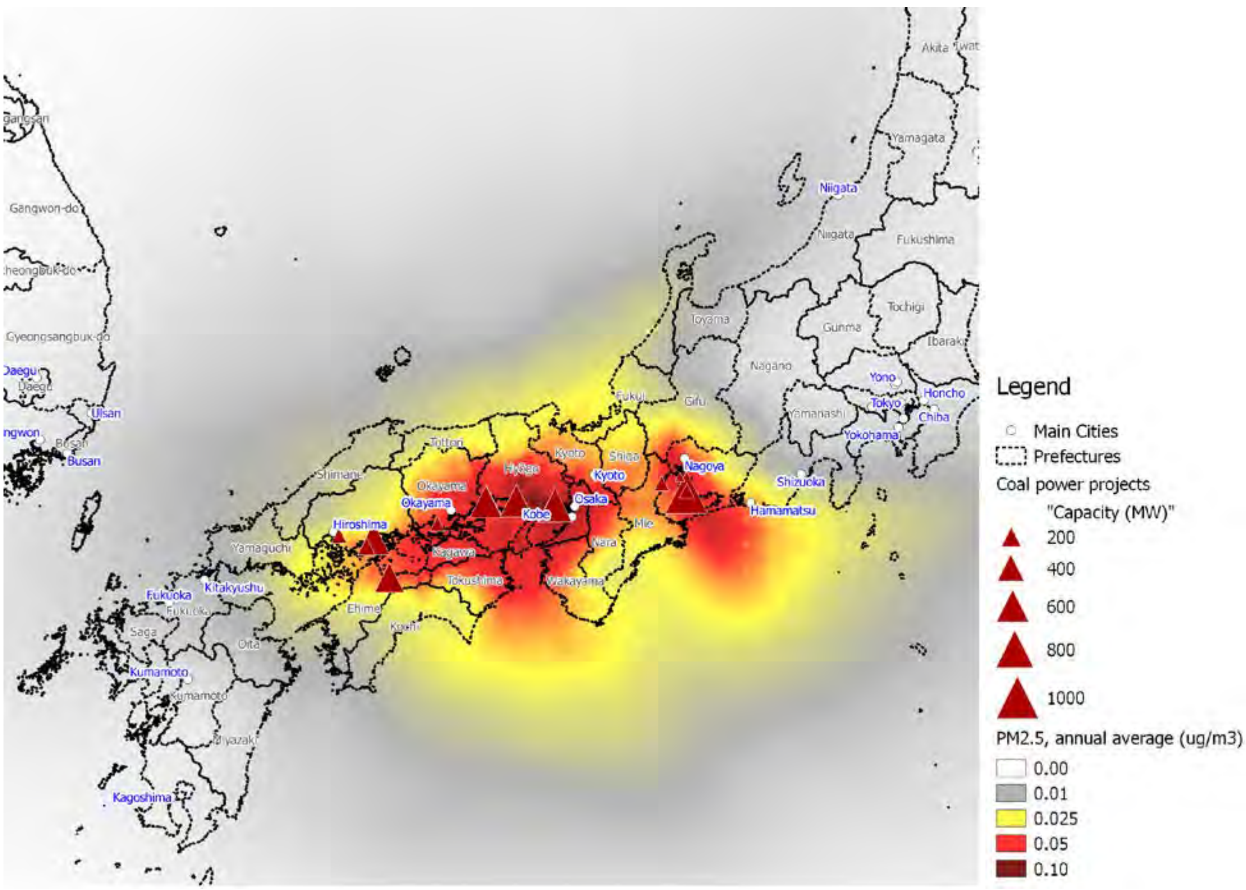

Figure 8. Projected increase in annual average PM2.5 concentrations due to emissions from the studied coal-fired power plant projects (µg/m3)

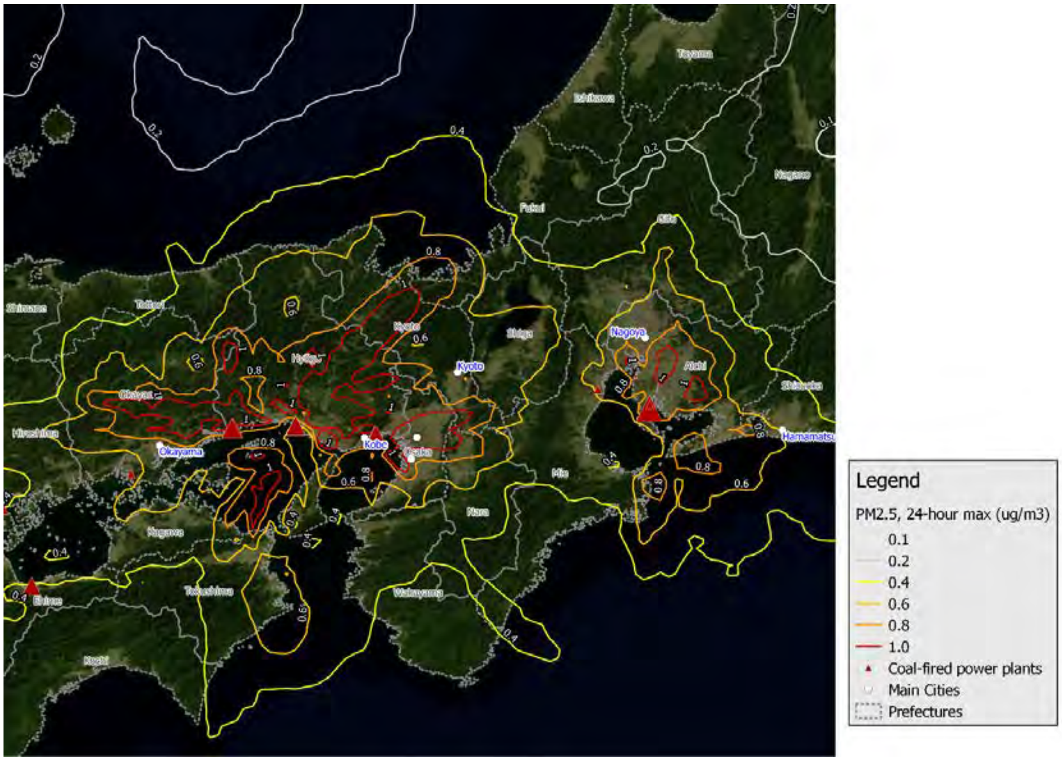

Figure 9. Projected maximum increase in 24-hour average PM2.5 concentration due to emissions from the studied coal-fired power plant projects (µg/m3)

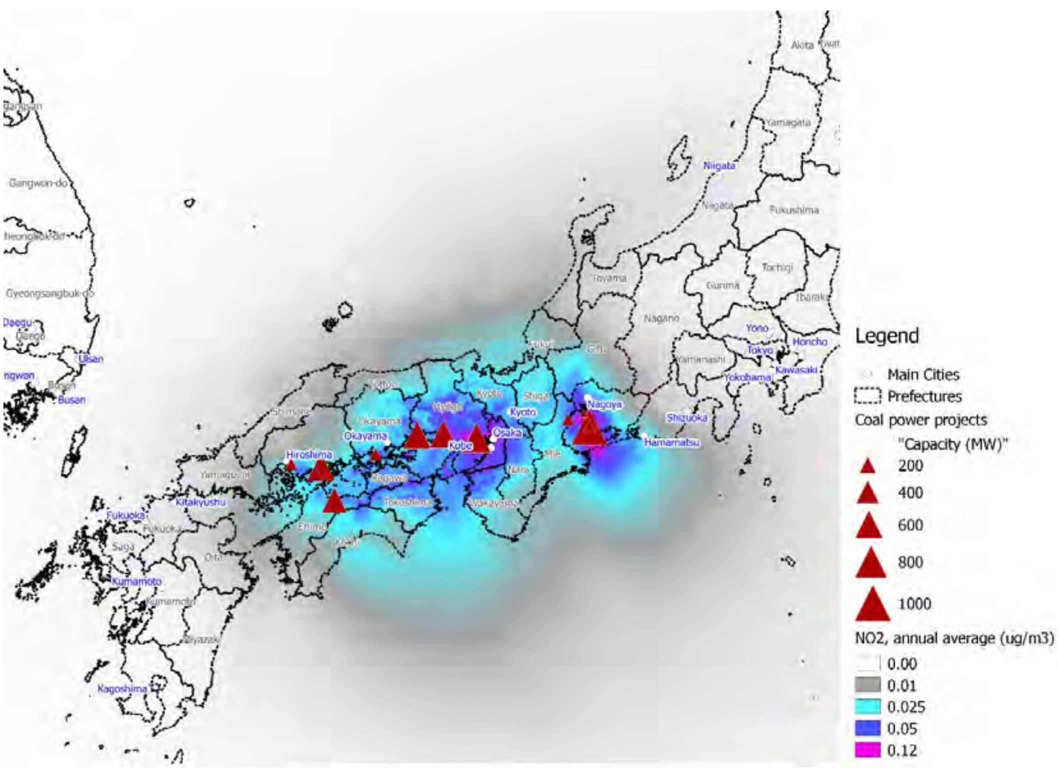

Figure 10. Projected increase in annual average NO2 concentration due to emissions from the studied coal-fired power plant projects (µg/m3)

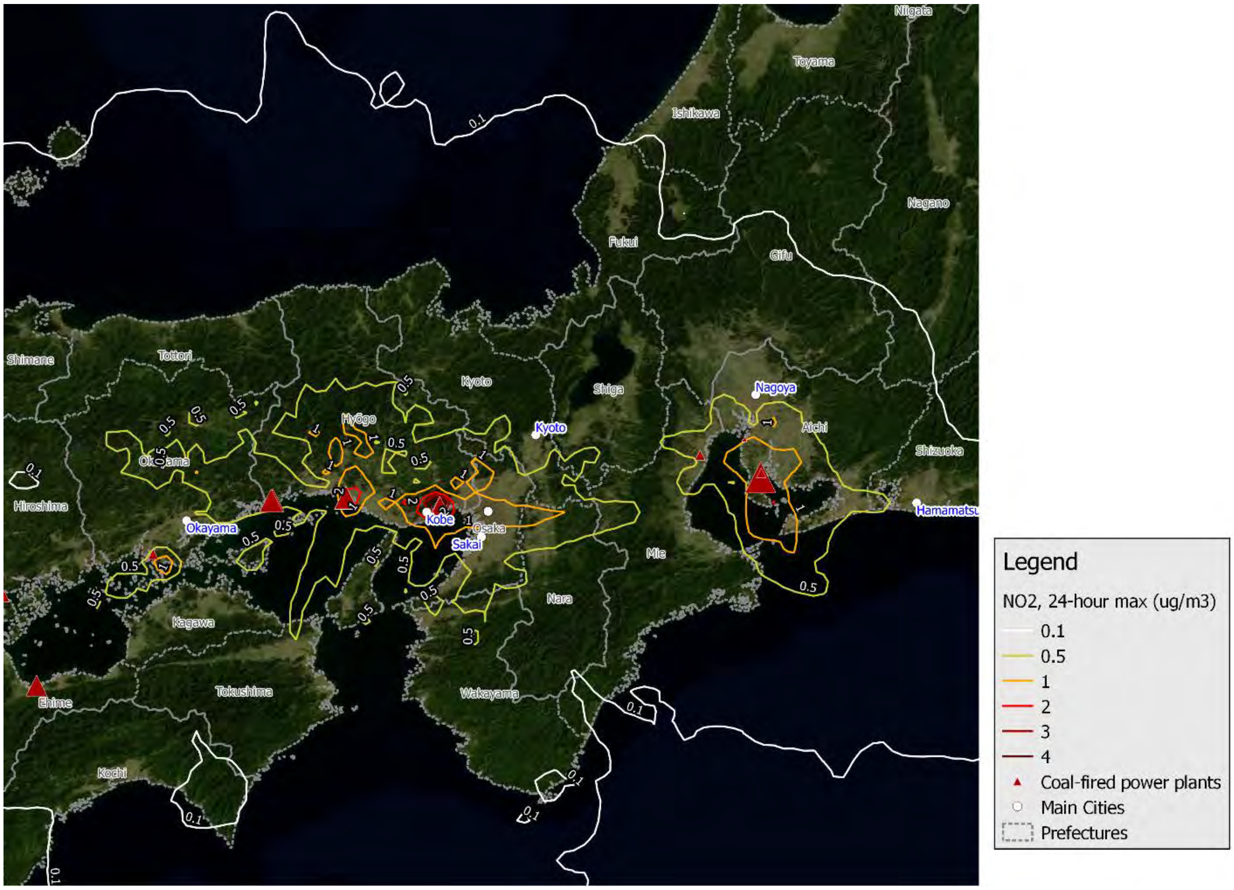

Figure 11. Projected maximum increase in 24-hour average NO2 concentration due to emissions from the studied coal-fired power plant projects (µg/m3)

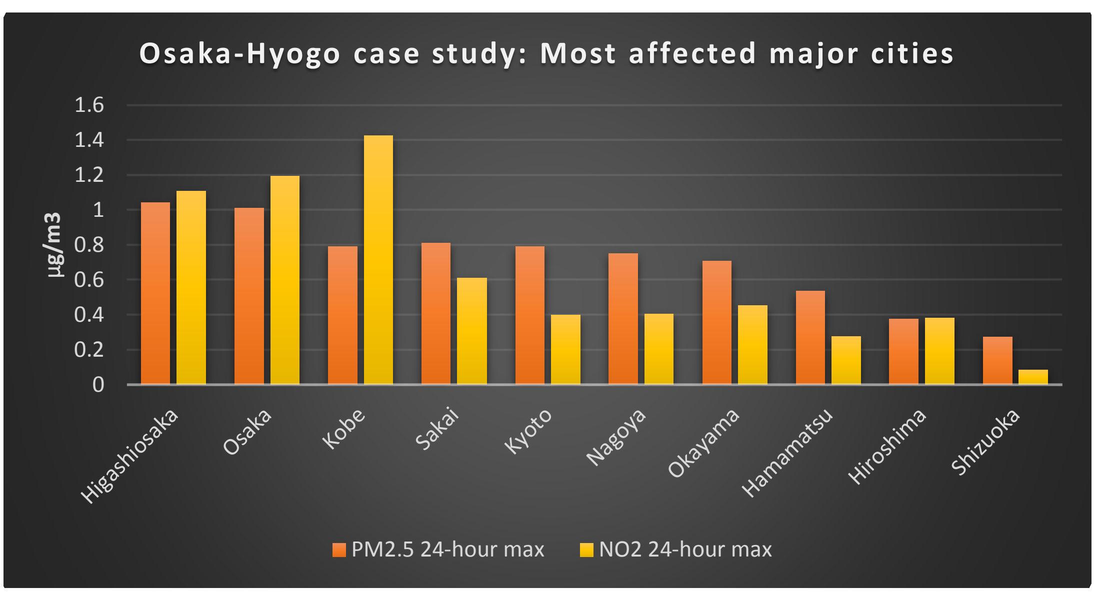

Figure 12. Projected maximum increase in 24-hour concentrations due to emissions from the studied coal-fired power plant projects.

Health impacts

The health impacts resulting from the increase in PM2.5 concentrations were evaluated by assessing the resulting population exposure, based on high-resolution gridded population data for 2010 from NASA SEDAC[3], and then applying the relationship between air pollution levels and risk of death from various causes established by Krewski et al (2009) [4]. For NO2, the updated WHO recommendations for health impact assessment were followed,[5] and required data for current mortality[6] was obtained from WHO databases. For low birth weight births, the concentration-risk relationship was taken from Dadwand et al (2013)[7] and the data on current percentage of low-birthweight births from World Bank data[8].

The projected health impacts from the proposed coal-fired power plants in the Tokyo-Chiba region and the Osaka-Hyogo region respectively are 260 and 200 premature deaths per year of operation. The projected increase in the amount of low birthweight births would be 30 and 20 births per year, respectively. If the proposed plants are built, they will potentially be operated for 40-50 years. Over a 40-year period, the health impacts would amount to approximately 10,000 and 8,000 premature deaths, respectively.

Table 4. Projected annual premature deaths attributable to emissions from the studied power plants, cases per year.

Cause	Tokyo-Chiba case study	Confidence interval	Osaka-Hyogo case study	Confidence interval
Exposure to PM2.5				
Lung cancer	29	(12-46)	21	(9-33)
Ischemic heart disease	54	(35-73)	39	(25-53)
Stroke	32	(19-44)	23	(14-32)
Other cardiovascular diseases	37	(23-51)	26	(16-36)
Chronic obstructive pulmonary disease	7	(4-10)	5	(3-7)
Other respiratory diseases	24	(15-34)	17	(11-24)
Exposure to PM2.5 total	183	(109-258)	131	(78-185)
Exposure to NO2				
All causes	115	(45-166)	102	(39-146)
Total	**260**	**(138-368)**	**199**	**(104-282)**

[3] http://sedac.ciesin.columbia.edu/data/set/gpw-v3-population-count-future-estimates
[4] Krewski D et al 2009: Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality. HEI Research Report 140. Health Effects Institute, Boston, MA.
[5] http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/health-aspects-of-air-pollution-and-review-of-eu-policies-the-revihaap-and-hrapie-projects
[6] http://www.who.int/healthinfo/global_burden_disease/estimates/en/index1.html
[7] "Maternal Exposure to Particulate Air Pollution and Term Birth Weight: A Multi-Country Evaluation of Effect and Heterogeneity". Environmental Health Perspectives. http://ehp.niehs.nih.gov/pdf-files/2013/Feb/ehp.1205575.pdf
[8] http://data.worldbank.org/indicator/SH.STA.BRTW.ZS

Table 5. Projected low birth weight births attributable to emissions from the studied power plants, cases per year.

	Tokyo-Chiba case study	Confidence interval	Osaka-Hyogo case study	Confidence interval
Low birth weight births	30	(9-52)	21	(7-37)

Conclusions and policy recommendations

New coal-fired power plants would be an important source of air pollutant emissions, despite improved thermal efficiency and advanced emission controls. The case studies demonstrate that planned power plants in the Tokyo-Chiba and Osaka-Hyogo regions have potential for causing severe and previously unassessed health impacts because of the very large planned capacity and exacerbated by the proximity to large population centers.

- The air quality and health impacts of the proposed power plants are highly cumulative, with air quality in e.g. Osaka, Chiba or Tokyo affected by multiple projects at the same time, along with existing pollution sources. It is essential that a cumulative impact assessment be carried out, instead of treating the projects separately.
- Building new coal-fired power plants would lock Japan into the highest-emitting power generation option, both in terms of toxic air pollutants and CO2, for decades to come. Over the operating life of the power plants, the air pollutant emissions alone would have the potential to cause tens of thousands of premature deaths. The long-term health impacts should be fully assessed and factored in when making decisions about power generation investments.
- Air pollutant emissions from all large pollution sources should be disclosed in real-time and on annual basis, like the U.S. already does.

Materials and methods

Atmospheric dispersion modeling for the case studies was carried out using version 7 (June 2015) of the CALPUFF modeling system. CALPUFF is an advanced non-steady-state meteorological and air quality modeling system adopted by the U.S. Environmental Protection Agency (USEPA) in its Guideline on Air Quality Models as the preferred model for assessing long range transport of pollutants and their impacts.

The TAPM modeling system, developed by Australia’s national science agency CSIRO, was used to generate the hourly three-dimensional weather fields required by CALPUFF. TAPM uses as its inputs global weather data provided for the modeling system by CSIRO. TAPM outputs were converted into formats accepted by CALPUFF’s meteorological preprocessor, CALMET, using the CALTAPM utility, and the meteorological data were then prepared for CALPUFF execution using CALMET. CALMET generates a set of time-varying micrometeorological parameters (hourly 3-dimensional temperature fields, and hourly gridded stability class, surface friction velocity, mixing height, Monin-Obukhov length, convective velocity scale, air density, short-wave solar radiation, surface relative humidity and temperature, precipitation code, and precipitation rate) for input to CALPUFF.

Terrain height and land-use data were also prepared using the TAPM system and global datasets made available by CSIRO. A set of concentric nested grids with 50x50 grid cells, 30km, 10km and 5km horizontal resolutions and 35 vertical levels, centered on each of the major population centres, was used for the TAPM simulations. A separate simulation was carried out for a 30x30km grid positioned to cover most of Japan, and the output from this run was used as the outmost domain for CALPUFF simulations, to provide better coverage of the main population centres likely to be affected.

A full calendar year CALPUFF simulation was carried out for all the operating facilities for 2013. The ISORROPIA II chemistry module of the CALPUFF model requires data on background concentrations of species affecting secondary inorganic aerosol formation. Hourly ozone measurements obtained from the websites of Chiba and Hyogo prefectural governments were imported into the model. For ammonia and H2O2, appropriate measured values could not be obtained and monthly average background concentrations were retrieved from Geos-Chem simulations carried out at Harvard University.

The CALPUFF results were reprocessed using the POSTUTIL utility to repartition different nitrogen species (NO, NO2, NO3 and HNO3) based on background ammonia concentrations.

The health impacts resulting from the increase in PM2.5 concentrations were evaluated by assessing the resulting population exposure, based on high-resolution gridded population data for 2010 from NASA SEDAC[9], and then applying the updated WHO recommendations for health impact assessment[10] in order to project the resulting premature deaths. Required country-level data for current mortality[11] was obtained from WHO databases.

These health impact estimates include the effects of direct NO2 exposure, in line with new WHO recommendations. The central and low estimates only include 67% of the health impact projected based on a single-pollutant risk model because of possible overlap with PM2.5 health impacts identified by the WHO. Only NO2 exposure to urban population was included in the impact estimates, because of the 20μg/m3 threshold for chronic health risk included in the WHO recommendations –urban populations are likely to be exposed to average NO2 concentrations above this limit. The assessment of health impacts from the coal-fired power plants is based on the findings of the largest study ever carried out on the chronic health impacts of air pollution, the American Cancer Society study that tracked the medical histories and residence records of 1.2 million Americans for 18 years, and showed significant differences in the health risks between cities with different pollution levels[12].

[9] http://sedac.ciesin.columbia.edu/data/set/gpw-v3-population-count-future-estimates
[10] http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/health-aspects-of-air-pollution-and-review-of-eu-policies-the-revihaap-and-hrapie-projects
[11] http://www.who.int/healthinfo/global_burden_disease/estimates/en/index1.html
[12] Krewski et al 2009: Evaluating the Effects of Ambient Air Pollution on Life Expectancy. New England Journal of Medicine, 2009; Vol. 360, pp 413-415.

Table 6. Concentration-response relationships for premature deaths

– increase in risk for a 10µg/m3 increase in concentration. Central and low values for NO2 are scaled down by 1/3 to remove possible overlap with PM2.5 impacts. [13]

Risk ratio for 10µg/m^3 increase in PM2.5 exposure	Central	95% CI, low	95% CI, high	Reference
Cardiopulmonary diseases	1.128	1.077	1.182	Krewski et al 2009
Ischemic heart disease	1.287	1.177	1.407	Krewski et al 2009
Lung cancer	1.142	1.057	1.234	Krewski et al 2009
Low birth weight	1.100	1.030	1.180	Dadwand et al (2013)[14]

Risk ratio for 10µg/m^3 increase in NO2 exposure	Central	95% CI, low	95% CI, high	Reference
Respiratory diseases	1.037	1.021	1.08	WHO 2013 [15]

Asian populations are becoming more susceptible to the health impacts of air pollution due to aging, lifestyle changes, urbanization, and improvements in health care. For projections of future health impacts, the results take into account projected population growth and change in rates of death from different causes, based on WHO Global Burden of Disease for 2030[16].

[13] Krewski D et al 2009: Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality. HEI Research Report 140. Health Effects Institute, Boston, MA.

[14] "Maternal Exposure to Particulate Air Pollution and Term Birth Weight: A Multi-Country Evaluation of Effect and Heterogeneity". Environmental Health Perspectives. http://ehp.niehs.nih.gov/pdf-files/2013/Feb/ehp.1205575.pdf

[15] http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/health-aspects-of-air-pollution-and-review-of-eu-policies-the-revihaap-and-hrapie-projects

[16] http://www.who.int/healthinfo/global_burden_disease/projections/en/