INTERNATIONAL GAS UNION
UNION INTERNATIONALE DU GAZ

Case Studies in Improving Urban Air Quality

2019

CONTENTS

PREFACE

This is the fourth edition of the Clean Air report series by the International Gas Union (IGU).

The previous editions included cases from North and South America, Europe and Asia, featuring lessons on how jurisdictions can effectively tackle the greatest urgent environmental threat to health by cleaning up polluted urban air.

This year's edition builds on the tradition of showcasing cities, regions and countries around the globe taking on the air pollution challenge and improving the quality of life and health of their residents. As in the previous reports, the initiatives presented in this edition demonstrate the complexity of the issue yet again, and highlight the need to take an economy-wide, multi-stakeholder comprehensive approach to solving it.

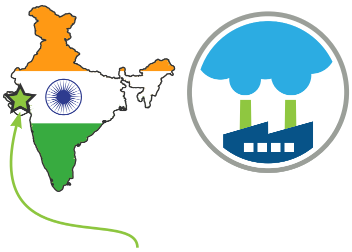
Air pollution is a complex problem, which often implicates socio-economic issues, and the solutions are not always easy to implement, but as this report series sets out to demonstrate, the benefits and long-term social and economic welfare gains outweigh the short-term challenges. With prudent policies and appropriate engagement, clean air is attainable and one major common tool is switching from polluting fuels to natural gas. This switch can deliver clean air immediately, as natural gas burns cleanly and is largely free of common air pollutants.

KEY FINDINGS

The 2019 Air Quality report is a tour across the globe, with cases from three very distinct regions addressing air pollution challenges, across different sectors (industry, power, and transport).

It starts in India, with the most severe example of air pollution, set in the context of a growing economy and evolving regulations. Then, UK presents a case where air quality regulations have been evolving since the 1950's, and a recent move to establish a CO_2 market brought on a further reduction in air pollution, as well as GHG's. Finally, Bogotá is a case where ongoing progress in the development of a public transit system also helped to meet several city development objectives, including improving the quality of its air, and now the city is taking it a step further by bringing in new natural gas-powered buses into the fleet.

MORBI, INDIA



The city of **MORBI** in the Gujarat region of India achieved a dramatic reduction of air pollution and environmental contamination, thanks to switching from coal to natural gas in its ceramic industry.

LESSONS:

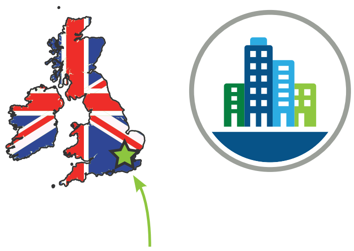
Morbi is an example of how switching to natural gas in industry can effectively and immediately help to eliminate air and environmental pollution in industrial processes.

The policy lesson here is about overcoming challenges with compliance, once standards are in place.

In the case of Morbi, it took regulatory oversight and legal follow-through with decisive action by a national tribunal, in collaboration with the state authorities, to achieve positive results.

In addition, having access to the natural gas distribution network made the switch possible, and immediately resulted in significant reductions of pollutant levels.

LONDON, UK



The city of **LONDON** and the UK's rapid switch from coal to gas produced significant benefits in both CO_2 emissions and air quality, thanks to effective carbon pricing.

LESSONS:

London showcases the importance of air quality regulations in industrializing regions.

Its first Clean Air Act was the result of a tragic and deadly industrial pollution event in the 1950's.

Thereafter, policy action to regulate industrial and domestic pollution sources played a critical role in improving London's air. Switching from coal to natural gas played a major role in meeting the new clean air standards and eliminating the hazardous coal pollution.

There is also a recent lesson that prudently designed carbon pricing policy can deliver on both, climate and clean air goals.

BOGOTÁ, COLOMBIA

The city of **BOGOTÁ** is continuing to make progress in its efforts to improve the quality of air on its streets, through strong investment in public transit and gas-powered transportation.

LESSONS:

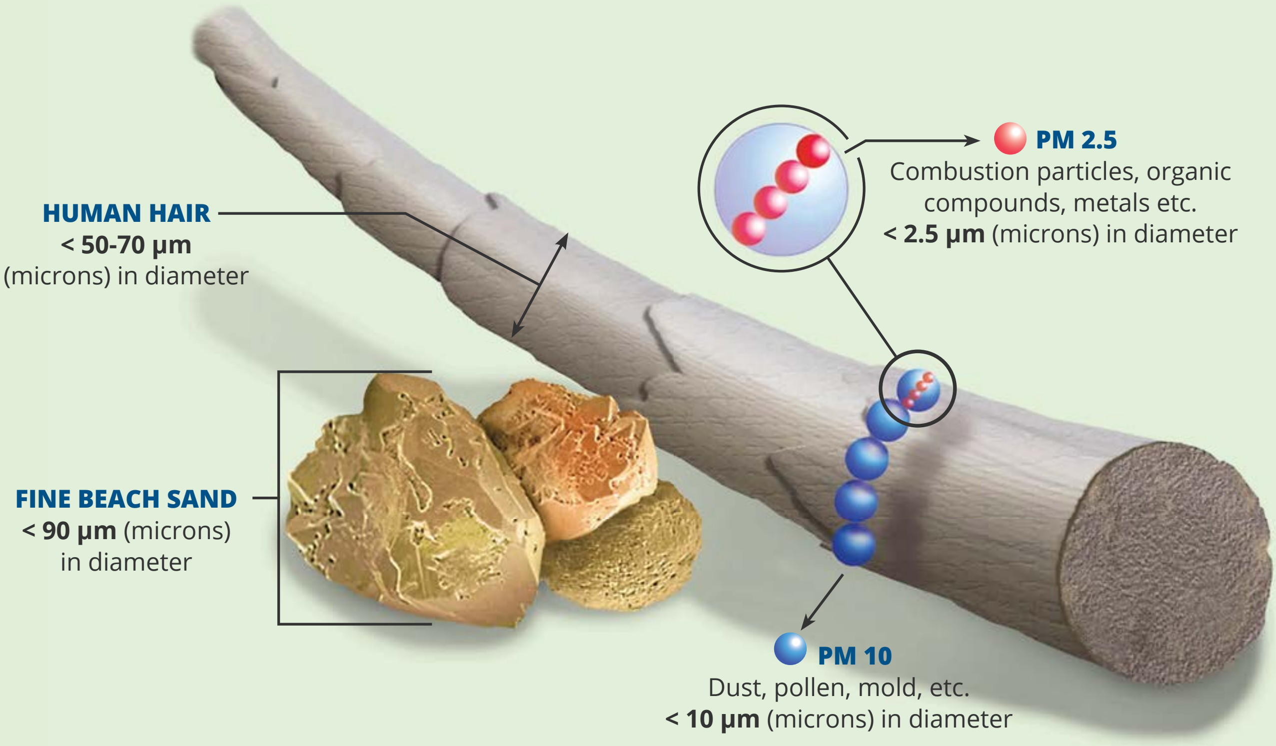
The story of Bogotá showcases that smart city planning, investment in public transit, and mobility emissions standards, bring about a notable improvement in urban air quality.

The rollout of a centralized rapid bus network, and the subsequent reduction in traffic and congestion, resulted in a sustained downward trend in the levels of pollutants on Bogota's streets.

At present, the city is taking further steps to clean up its air by upgrading the bus fleet with natural gas-powered buses.

COMMON AIR POLLUTANTS AND THEIR HEALTH IMPACTS

Fig 1: An illustration of Particulate Matter Size



The major components of air pollution are a combination of gases and dust particles (particulate matter, or "PM") that have detrimental human health and environmental consequences. Health impacts include lung disease, cardiac disease, cancer, and more.

Outdoor air pollution has a variety of human and natural sources, but the most significant human contributor to outdoor air pollution is the combustion of fuels – primarily fossil fuels.

A few of the main components of air pollution[1]:

- **PARTICULATE (PM)**
- **SULPHUR DIOXIDE (SO2)**
- **NITROGEN DIOXIDE (NO2)**

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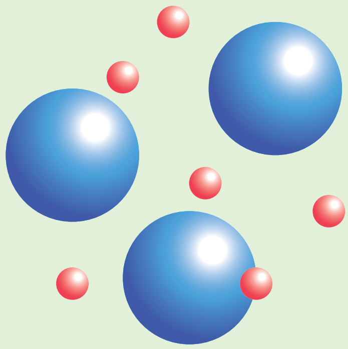
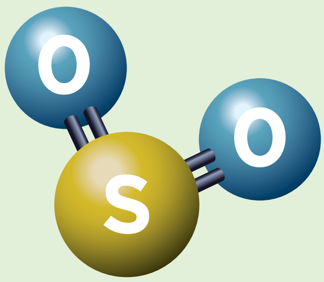
[1] Information for this overview of air pollutants is drawn from the World Health Organization, http://www.who.int/mediacentre/factsheets/fs313/en; and the U.S. Environmental Protection Agency, http://www.epa.gov/air/urbanair

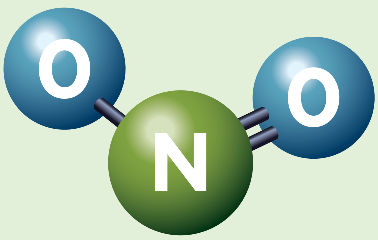


PARTICULATE MATTER (PM): PM consists of sulfate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. The most health-damaging particles are those with a diameter of 10 microns or less (PM_{10}), especially fine particles of 2.5 microns or less ($PM_{2.5}$). PM is generated from human and natural sources, with PM_{10} and above often coming from dust generated in the environment. Combustion of fossil fuels, particularly coal, fuel oil, and diesel, are a significant source of $PM_{2.5}$.

There is a close relationship between exposure to high levels of PM and impacts on human health. Long-term exposure to $PM_{2.5}$ is associated with increased mortality due to lung and cardiac issues. The WHO has recognized PM matter as a carcinogen since 2013.[2] Exposure to PM has health impacts even at very low levels.



SULPHUR DIOXIDE (SO2): SO_2 is produced from burning fossil fuels (coal and oil) that contain sulphur. It is one of a group of sulphur oxides that are highly reactive gases.[3] SO_2 has harmful health effects and is a major contributor to the formation of acid rain. SO_2 can impact the respiratory system, impair lung function, and cause eye irritation. Studies have found that hospital admissions for cardiac events and mortality increase on days of high SO_2 concentration.



NITROGEN DIOXIDE (NO2): NO_2 is one of several nitrogen oxides (NO_X) produced during combustion processes, particular higher temperature combustion associated with burning fossil fuels. NO_X are harmful pollutants that have direct health consequences in humans and contribute to the formation of ground-level ozone and acid rain. NO_2 is linked to reduced lung function and respiratory issues in asthmatic children.

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[2] World Health Organisation. Oct. 17, 2013. "*IARC: Outdoor Air Pollution a Leading Environmental Cause of Cancer Deaths,*" available at: *http://www.iarc.fr/en/media-centre/iarcnews/pdf/pr221_E.pdf*.

[3] Both SO_2 and NO_2 are considered indicators of the presence of the other sulphur oxides and nitrogen oxides, respectively. Rather than set standards for each of the separate gas individually, regulatory bodies typically set standards just for SO_2 and NO_2. Reports of emissions and concentrations of pollutants in the air are sometimes done just for SO_2 or NO_2, and other times are done for the broader group of SO_X and NO_X

1. INTRODUCTION

On June 5th 2019, the United Nations (UN) chose air pollution to be the focus of its World's Environment Day[4] to raise awareness on an urgent environmental and health issue that is growing in relevance around the world, especially in urban areas.

The World Health Organisation (WHO) continues to sound alarm about the pressing problem of air pollution, which kills 7 million every year and costs economies trillions of dollars in health, welfare and productivity losses, while 90% of world population breathe polluted air[5].

Key Findings from the 2018 WHO Report on Global Pollution[6]

- Over the past 6 years, ambient air pollution levels have remained high and approximatively stable, with declining concentrations in some parts of Europe and in the Americas.
- The highest ambient air pollution levels are in the Eastern Mediterranean Region and in South-East Asia, with annual mean levels often exceeding more than 5 times WHO limits, followed by low and middle-income cities in Africa and the Western Pacific.
- Africa and some of the Western Pacific have a serious lack of air pollution data. For Africa, the database now contains PM measurements for more than twice as many cities as previous versions, however data was identified for only 8 of 47 countries in the region.
- Europe has the highest number of places reporting data.
- In general, ambient air pollution levels are lowest in high-income countries, particularly in Europe, the Americas and the Western Pacific. In cities of high-income countries in Europe, air pollution has been shown to lower average life expectancy by anywhere between 2 and 24 months, depending on pollution levels.

Fig 2: WHO Air Quality Guidelines

$PM_{2.5}$ (fine Particulate Matter)	10 µg/m³	*annual mean*
	25 µg/m³	*24-hour mean*
PM_{10} (coarse Particulate Matter)	20 µg/m³	*annual mean*
	50 µg/m³	*24-hour mean*
NO_2 (Nitrogen Oxide)	40 µg/m³	*annual mean*
	200 µg/m³	*1-hour mean*
SO_2 (Sulphur Oxide)	20 µg/m³	*24-hour mean*
	500 µg/m³	*10-minute mean*

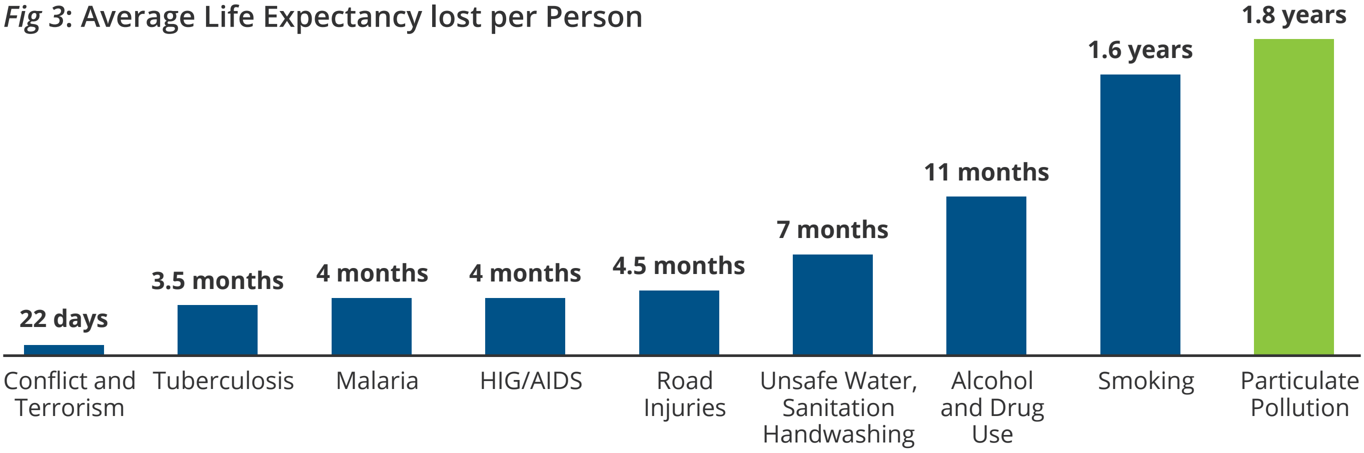
4 United Nations Framework Convention on Climate Change (UNFCC). "Clean Air is a Human Right - UN Special Rapporteur". June 04, 2019 https://unfccc.int/news/clean-air-is-a-human-right-un-special-rapporteur=

5 United Nations Environment Program (UNEP). "*Global Environment Outlook (2019). Healthy Planet. Healthy People*" https://wedocs.unep.org/bitstream/handle/20.500.11822/27539/GEO6_2019.pdf?sequence=1&isAllowed=y; and The World Bank and Institute for Health Metrics and Evaluation (IHME). "The Cost of Air Pollution. Strengthening the Economic Case for Action". 2016. http://documents.worldbank.org/curated/en/781521473177013155/pdf/108141-REVISED-Cost-of-PollutionWebCORRECTEDfile.pdf

6 World Health Organization. "9 out of 10 people worldwide breathe polluted air, but more countries are taking action". May 02, 2019. https://www.who.int/news-room/detail/02-05-2018-9-out-of-10-people-worldwide-breathe-polluted-air-but-more-countries-are-taking-action

According to research by the Institute for Health Metrics and Evaluation, pollution reduces global average life expectancy by 1.8 years per person, which puts it ahead of smoking and road accidents[7]

Fig 3: Average Life Expectancy lost per Person



Source: AQLI Report2018[8]

While air pollution is a universal threat, its greatest burden falls on the most vulnerable. Low and mid-level income countries suffer the greatest consequences of air pollution, with children and the elderly being the most susceptible to disease[9] . In many of these countries, population is affected by a double burden, both from ambient and household pollution[10] . Household air quality (indoor) still represents a large part of the deaths attributable to air pollution (3.8 million deaths in 2016).[11]

The UN made the fight for cleaner air one of the top priorities in the Sustainable Development Goals (SDGs), with the aim of reducing "the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination" by 2030[12].

In March this year, the Special Rapporteur to the Human Rights Council of the UN presented a report[13] making the case for recognizing clean air as a human right, and stating that air pollution has negative impacts "on the enjoyment of many human rights, in particular the right to life and the right to health, in particular by vulnerable groups".

The report also encourages public authorities, as well as businesses, to take action in the fight for cleaner air by, for example, replacing "solid fuels and kerosene with cleaner energy"[14], like natural gas.

In order to achieve this goal though, there needs to be cooperation from industries, pressure from citizens, and decisive action by local and national authorities. The case studies that will be presented in this report will reflect on some of those efforts and their impact on improving air quality and public health.

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7 Institute for Health Metrics and Evaluation (IHME). "State of Global Air 2019". 2019.

8 Air Quality Life Index (AQLI). "*Introducing the Air Quality Life Index*". November 2018. https://aqli.epic.uchicago.edu/wp-content/uploads/2018/11/AQLI-Report.111918-2.pdf

9 World Health Organization (WHO). "9 out of 10 people worldwide breathe polluted air, but more countries are taking action". May 02, 2019. https://www.who.int/news-room/detail/02-05-2018-9-out-of-10-people-worldwide-breathe-polluted-air-but-more-countries-are-taking-action

10 Institute for Health Metrics and Evaluation (IHME). "*State of Global Air 2019*". 2019. https://www.stateofglobalair.org/sites/default/files/soga_2019_report.pdf

11 World Health Organisation (WHO) https://www.who.int/news-room/detail/02-05-2018-9-out-of-10-people-worldwide-breathe-polluted-air-but-more-countries-are-taking-action

12 Specifically, Indicator 3.9.1 refers to "mortality rate attributed to household and ambient air pollution".

13 United Nations Human Rights Council. "*Issue of human rights obligations relating to the enjoyment of a safe, clean, healthy and sustainable environment. Report of the Special Rapporteur*". March 22, 2019 http://srenvironment.org/sites/default/files/Reports/2019/UN%20HRC%20Right%20to%20clean%20air.pdf

14 Ibidem

2.1 CASE STUDY: MORBI

Moving Industry from Coal to Gas to Rapidly Improve Air Quality

National Green Tribunal, Government of India:

"Purpose of economic development in any region is to provide opportunities for the improved living by removing poverty and unemployment. While industrial development invariably creates more jobs in any region, such development has to be sustainable and compliant with the norms of environment..."[15]

The problem of air pollution in India is radical – 1.24 million people died from it in 2017, which put poor air quality as the cause of 12.5% of all deaths that year.[16]

While the government has been battling pollution for some time, it began to escalate its efforts very recently. On January 10, 2019, the Government of India declared a "war against pollution" and launched the National Clean Air Programme (NCAP)[17], with a target to reduce particulate pollution (PM_{10} and $PM_{2.5}$) by 20-30 % from 2017 levels in 102 cities, by 2024[18].

In order to accomplish this ambitious goal, the government plans to deploy a number of measures, including investments in renewable energy and a move to a "gas-based" economy, planning to more than double the share of natural gas in its energy mix from 6% to 15% by 2022[19].

In the next three years[20], the government plans to extend the City Gas Distribution (CGD) network to connect households to the gas grid. The program, which is now in the 10th round of bidding, aims to extend the natural gas grid connections to reach 70% of India's population, from 20% in 2014[21].

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15 National Green Tribunal. Order from 06.03.2019. *Original Application No. 20/2017 (WZ) (M. A. No. 344/2017 & M. A. No. 91/2018) and other connected matters DV&AS.* http://www.indiaenvironmentportal.org.in/files/file/coal-based-gasifiers-Morbi-NGT-Order.pdf.

16 India State-Level Disease Burden Initiative Air Pollution Collaborators. The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: the Global Burden of Disease Study 2017. The Lancet Planetary Health. 2019(3)1. https://www.sciencedirect.com/science/article/pii/S2542519618302614?via%3Dihub#fn1

17 The Indian Express. "National Clean Air Programme to combat pollution launched, to be rolled out in 102 cities". Juanuary 10, 2019. https://indianexpress.com/article/india/national-clean-air-programme-launch-air-pollution-5532409/

18 Air Quality Life Index (AQLI). "India's 'War Against Pollution': An Opportunity for Longer Lives". 2019. https://aqli.epic.uchicago.edu/wp-content/uploads/2019/01/India-Report_GlobalSite_v03-nobleeds.pdf

19 Ministry of Petroleum & Natural Gas. "Prime Minister lays Foundation Stones of City Gas Distribution Projects under the 9th CGD bidding Round; 10th bidding round launched". November 22, 2018. https://pib.gov.in/newsite/PrintRelease.aspx?relid=185911

20 The Hindu. "*70% of population to have city gas in 3 years*". November 22, 2018. https://www.thehindubusinessline.com/news/modi-lays-foundation-stone-for-city-gas-work-in-122-districts/article25566727.ece

21 Ministry of Petroleum & Natural Gas. "*Prime Minister lays Foundation Stones of City Gas Distribution Projects under the 9th CGD bidding Round; 10th bidding round launched*". November 22, 2018. https://pib.gov.in/newsite/PrintRelease.aspx?relid=185911

The CGD network extension will enable access to natural gas, to allow switching away from the highly polluting fuels that are in use today, including conventional biomass, coal and oil-based fuels[22]. However, it should be noted that access alone does not always automatically result in fuel switching, and the story about Gujarat's Morbi-Wankaner industrial area is case in point.[23] This heavily industrial zone was connected to the natural gas pipeline network, but until recent regulatory action, continued to use coal and tar, which led to severe environment and public health implications.[24]

INDUSTRIAL FUEL SWITCH IN THE MORBI CERAMICS INDUSTRY

The IGU extends special Thanks to the Gujarat Pollution Control Board, for providing information to support this case study.

Excerpt from the case summary, by the Gujarat Pollution Control Board (GPCB)

Morbi, is a mid-sized city of Gujarat known for its contribution in the global ceramic sector, with a total of 900 ceramic manufacturing units[25], which contribute significantly to the region's economy.

However, use of coal gas in the manufacturing of the ceramic tiles was making ambient air quality of the area very poor causing problems to the citizens of the area and regulators of the state.

Hon. National Green Tribunal in its order in March, 2019 banned the use of gasification technology in the ceramic units of Morbi-Wankaner area and ordered Gujarat Pollution Control Board to close down all the coal gasifiers of this area.

Due to this, all the ceramic units of the area switched over to the Piped Natural Gas immediately for, which the supply and network was already available to them.

Use of Natural Gas as fuel in the rotary kiln in ceramic industries has created a win-win situation for all the stakeholders. Now, ceramic units in the area are convinced and adopted the Natural Gas as cleaner fuel considering its advantages of less pollution and safety aspects over coal gasifier. Regulator and Government are also benefiting, as less monitoring and regulation will be required in this area considering improved air quality. Local residents in the area will benefit at a large due to positive health impacts considering improved breathing air quality.

Source: Gujarat Pollution Control Board, 2019

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22 Air Quality Life Index (AQLI). "*India's 'War Against Pollution': An Opportunity for Longer Lives*". 2019. https://aqli.epic.uchicago.edu/wp-content/uploads/2019/01/India-Report_GlobalSite_v03-nobleeds.pdf

23 The state of Gujarat, in the north-western region of India has had one of the most developed natural gas markets in the country. Its gas dristribution network already extends to about 90% of consumers and is about reach full coverage; it also has access to domestic supply and two LNG importing terminals, and its strong industrial base make for a desirable market. (Gujarat infrastructure Development Board. http://www.gidb.org/gas-current-scenario)

24 National Green Tribunal. Order from 06.03.2019. *Original Application No. 20/2017 (WZ) (M. A. No. 344/2017 & M. A. No. 91/2018) and other connected matters DV&AS*. http://www.indiaenvironmentportal.org.in/files/file/coal-based-gasifiers-Morbi-NGT-Order.pdf.

25 Source: Gujarat Pollution Control Board and Pathak, Maulik. "NGT orders shutdown of coal gasifiers at Morbi ceramic cluster". March 07, 2019. ttp://timesofindia.indiatimes.com/articleshow/68295471.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

Ceramic tile manufacturing is a very energy and heat-intensive process. Morbi's manufacturers have traditionally relied on coal gasification, a highly polluting technology, to fuel their production. Using coal was cheaper than natural gas, with widespread avoidance of environmental regulations, and the costs were passed on to the society via environmental and health hazards.

The issue of non-compliance was first raised in 2013, and it took a series of investigations and legal action by local, state and national authorities to resolve it. As a result, in March of 2019, the National Green Tribunal ordered to shut down all coal gasifiers in Morbi, and switch to natural gas or LNG, unless another technology would be shown to meet the environmental criteria in the future.[26]

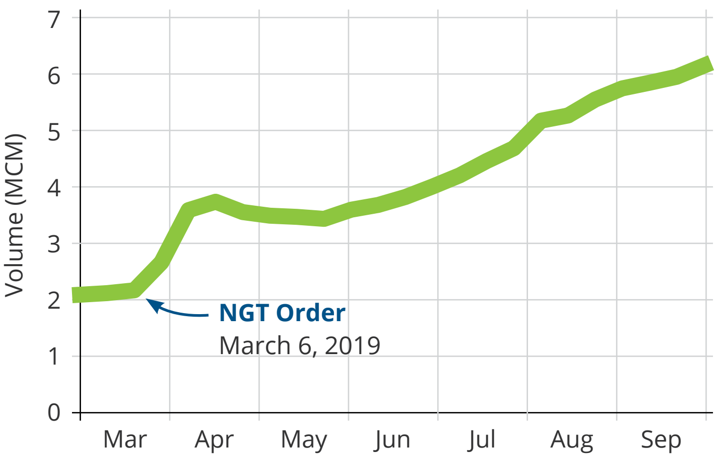
The NGT decision came as a result of a recommendation made by an expert committee that was tasked to investigate the situation. The panel found that "coal gasification is a dangerous process" that generated highly carcinogenic waste on the scale of 8,000 kg per day. The committee found high and alarming levels of particulate matter pollution and contaminated water.[27]

The Committee also recommended that industries "may opt for PNG (Piped Natural Gas)" which "may be used to avoid any environmental issues/damage which are being created due to mismanagement, illegal disposal of tar and wastewater generated from existing gasifiers".[28]

The switch was facilitated by the existing pipeline infrastructure and supply in the region[29], although a new 4.5 km pipeline has been recently commissioned to solve the problems for lack of pressure due to the sudden surge in demand after NGT's order[30].

A month after NGT's order, gas consumption in Morbi nearly doubled, from 2 million cubic meters (mcm) a day to almost 4, and it is expected to reach the 8 mcm in the near future[31]. At the same time, coal consumption dropped by 900 MT/Day, with the associated decrease in heavy vehicle movement, and the saving of 2,250 thousand litres fresh water per day[32].

Fig 4: Natural Gas Consumption after NGT Order (MCM)



Pollutant level changes in June-August 2019, relative to 2017

75%	↓	$PM_{2.5}$
72%	↓	PM_{10}
85%	↓	SO_2

Source: Guajarat Pollution Control Board

[26] National Green Tribunal Order. "*Babubhai Ramubhai Saini vs Gujarat Pollution Control Board & Ors. Item Nos. 03 to 21*". March 06, 2019. http://www.indiaenvironmentportal.org.in/files/file/coal-based-gasifiers-Morbi-NGT-Order.pdf

[27] Amongst findings of the commission: "The general ambiance of Morbi-Wakaner industrial cluster is smell of half burnt coal, VOC, SO_2, and poor visibility due to dust and smog... It was observed that most of the storm water drains in the industrial area are carrying condensate wastewater.. Many low lying areas along the road and nearby abandoned mines contain condensate wastewater, which is deposed of illegally." Ibid.

[28] Ibidem

[29] As noted in the Expert Committee Report to the Tribunal: "Natural gas grid /pipe connections are already established in area and most of industries are having connections." National Green Tribunal (NGT). "*Babubhai Ramubhai Saini vs Gujarat Pollution Control Board & Ors. Item Nos. 03 to 21*". March 06, 2019. http://www.indiaenvironmentportal.org.in/files/file/coal-based-gasifiers-Morbi-NGT-Order.pdf

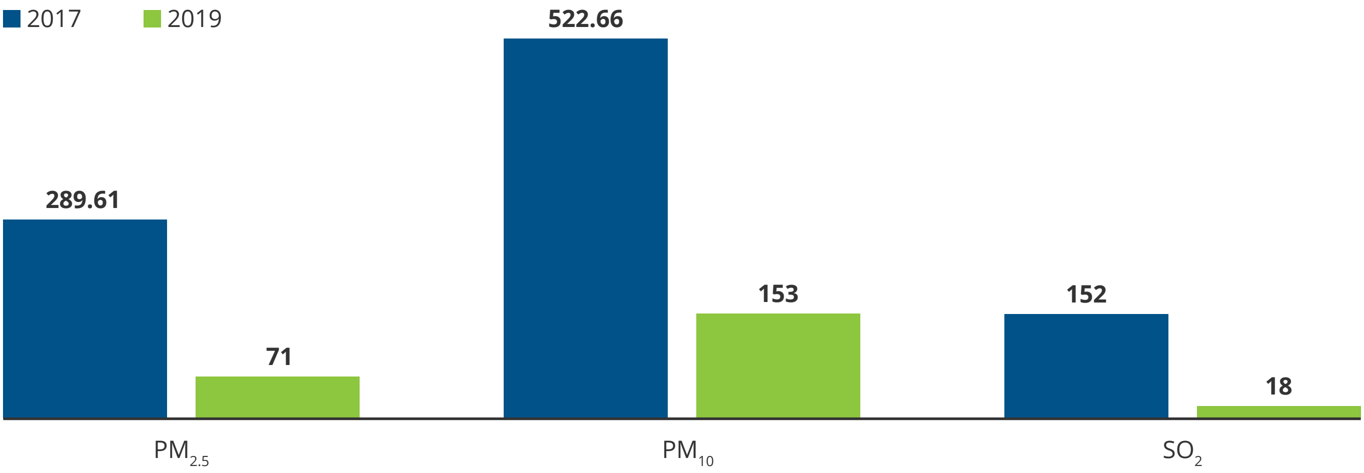
[30] The National Network. "*New pipeline commissioned for Morbi ceramic units*". May 08, 2019 http://timesofindia.indiatimes.com/articleshow/69224530.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

[31] Pathak, Maulik and Damor, Kalpesh. "*GAIL eyes GSPC LNG's Morbi stronghold*". May 06, 2019 http://timesofindia.indiatimes.com/articleshow/69192422.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

[32] Source: Gujarat Pollution Control Board

The switch to natural gas brought immediate results and translated into significantly improved d air quality readings, with a 75% reduction in $PM_{2.5}$ levels, 72% reduction in PM_{10}, and an 85% reduction in SO_2. In addition to the air quality improvement, there were significant other environmental benefits, including reduced water consumption and avoided emissions from reduced coal truckloads, as shown in the table below[33].

Fig 5: Improvement in Air Quality, due to change over from Coal-gas to Natural Gas (μg/m³)



Sources: Hon. NGT Committee, "*Report on technological & environmental issues related to coal gasifier in ceramic industries of Morbi-Wankaner area, Gujarat*"; GPCB Monitoring Data

Other Benefits from Switching to Natural Gas

Parameter	Total Consumption in area	Positive impacts due to use of NG as a fuel
Reduction in coal consumption	900 MT/Day	Reduced truck movement- less vehicular emission, prevention of fugitive emission due to storage and handling of the coal
Tarry waste	900 MT/Day	No generation of Tarry waste now so no transportation and disposal
Wastewater management	3150 KL/Day	No wastewater generation now due to use of NG as a fuel so no energy utilization for disposal of wastewater
Water Consumption	2250 KL/Day	Reduced Consumption of fresh water which can cater to the town of @16,000 Population
Improved public perception	Low smog conditions, improved water sources, etc	Image of the industry in the public has improved due to improved ambient air quality and cleanliness in the area.

Source: GPCB, Case Summary, 2019

[33] Source: Gujarat Pollution Control Board, 2019

Fig 6: GPCB Comparison of the Coal Gas Based Gasifier Technology and Natural Gas Kiln

Parameter	Coal gas based Gasifier Technology	Natural Gas based Kiln
Generation of Air Pollutants like PM, SO_2, VOC, CO	Yes, Significant	No
Waste Water generation which is having High Pollutants	Yes, Significant	No. No wastewater is generated when the NG is used as fuel in the Kiln
Toxic Tarry waste generation	Yes, Significant	No Tarry waste generation
Treatment Cost for the Wastewater	Yes, Significant	No , as there is no wastewater generation
Treatment Cost for Air Pollution Prevention at Source	Yes, Significant	No, as the NG is the cleaner fuel
Cost for the disposal of Hazardous Waste	Yes, Significant	No, as there is no hazardous waste generation from the use of NG
Impact on Air Environment	Significant Negative Impact	Insignificant Negative Impact
Impact on Water Environment	Significant Negative Impact	No Negative Impact
Impact on Land Environment	Significant Negative Impact	No Negative Impact.

Source: GPCB, Case Summary, 2019

2.2 CASE STUDY: LONDON

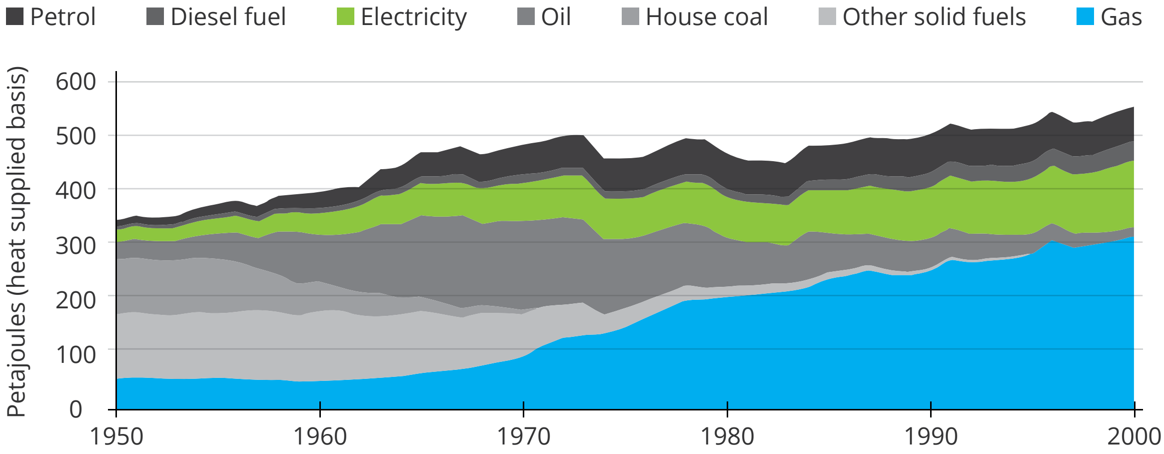
Coal-to-Gas Switch under a Carbon Market Design Approach

A LOOK BACK: KILLER FOG

London had its first tragic lesson on the importance of clean air more than half a century ago, when a dense yellow fog – mostly pollution from coal use – was trapped in the city by an anticyclone in 1952. The episode, that became known as the “London Killer Fog” or the “Great Smog”, caused more than 12,000 deaths[34]. Shortly thereafter, the 1956 Clean Air Act was enacted, and that was one of the world’s first major clean air policies. It introduced social, economic, and technological changes to help reduce smoke and SO_2 emissions[35], including relocation of power stations, changes in sources of household heating, and the creation of “smokeless” zones.

The new measures dramatically reduced the use of coal inside homes, which went from 28% in 1952 to zero, by the start of 1970s, replaced largely by natural gas and electricity, especially since 1965[36]. As a result, SO_2 concentrations generated from household heating were significantly reduced[37], from more than 400 μg/m³ to less than 50 μg/.m³.[38]

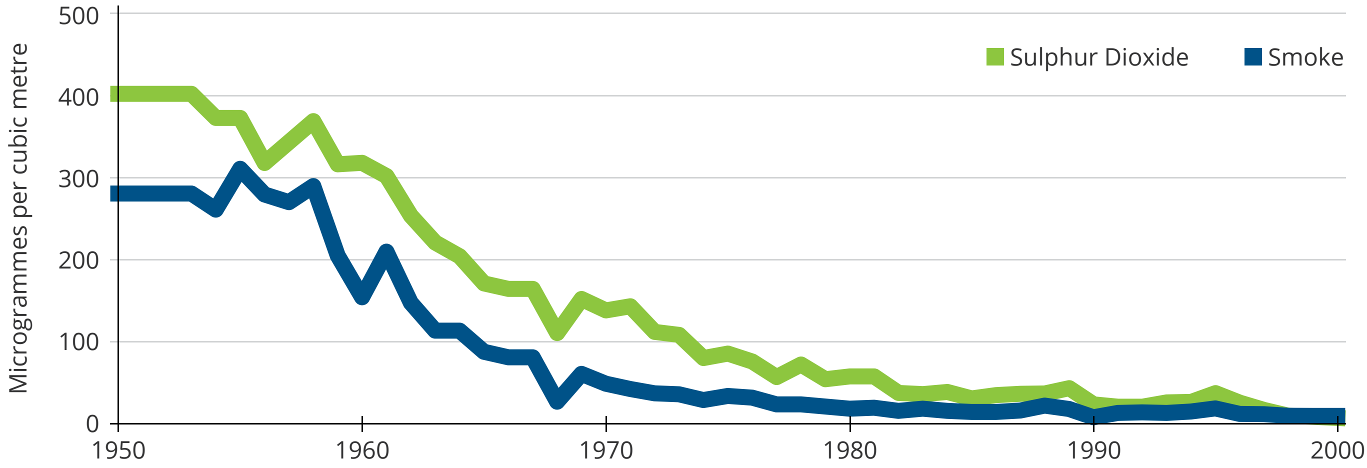
Fig 7: Energy use in London 1950-2000



Source: Greater London Authority, 2002[39]

[34] Bell, M. and Davis, D. “*Reassessment of the Lethal London Fog of 1952: Novel Indicators of Acute and Chronic Consequences of Acute Exposure to Air Pollution*”. Environmental Health Perspectives. Volume 109. Supplement 3. June 2001.
[35] Zhang, D et al. “*Tackling Air Pollution in China—What do We Learn from the Great Smog of 1950s in London*”. Sustainability 2014.6. 2014
[36] “Natural gas was discovered in abundance in the North Sea in 1965, and in 1967 a national programme began to convert boilers and other gas burning equipment to use natural gas in place of town gas”. Greater London Authority. “50 years on. The struggle for air quality in London since the great smog of December 1952”. December 2002. https://cleanair.london/app/uploads/CAL-217-Great-Smog-by-GLA-20021.pdf
[37] Zhang, D et al. “*Tackling Air Pollution in China—What do We Learn from the Great Smog of 1950s in London*”. Sustainability 2014.6. 2014
[38] Greater London Authority. “50 years on. The struggle for air quality in London since the great smog of December 1952”. December 2002. https://cleanair.london/app/uploads/CAL-217-Great-Smog-by-GLA-20021.pdf
[39] Ibidem

Fig 8: Avg. Smoke and Sulphur Dioxide Concentrations in London (1950 to 2000)



Source: GLA[40]

THE ROLE OF NATURAL GAS IN REDUCING EMISSIONS OF LOCAL POLLUTANTS TODAY

While traffic and the resulting NO_2 emissions remain a major concern for London's air quality, until recently, coal-fired power generation was also a major contributor of pollution. In 2012, one year prior to the introduction of the carbon pricing policy, coal-fired power plants caused 51% of all the UK's SO_2 emissions and 22% of NO_x emissions.[40] Thus, the recent rapid fuel switch to natural gas has had a positive impact on the quality of air in the UK, as well as its GHG emissions profile.

The fact that the switch in the UK was a direct result of the government's carbon market policy, rather than pollution control, highlights the strong relationship between air quality and climate goals, and complementarity of measures to address both.

A Look on Carbon Pricing Policies

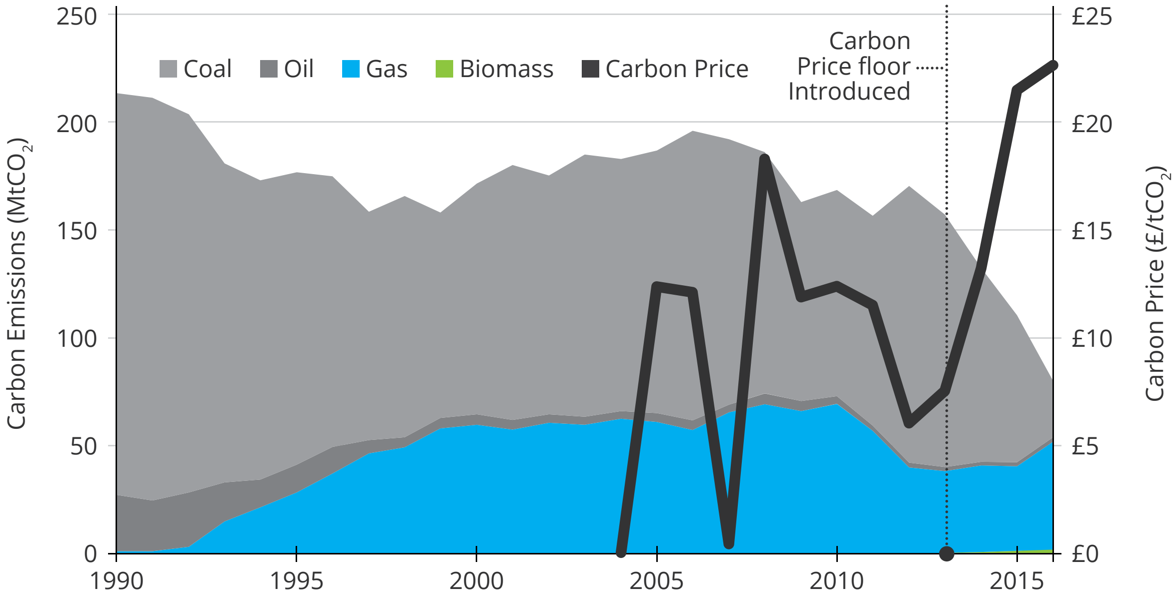
Carbon pricing is one of the most effective policy tools for incorporating the environmental externality cost of CO_2 emissions. It is also effective at closing the gap between the cost of natural gas and coal, but only at sufficient levels. For example, in the UK, the carbon price floor of £18 per tonne was sufficient to drive most coal power generation out of the market. Beyond Europe and North America, governments are increasingly adopting new carbon pricing measures. China's national emissions trading scheme, covering for nearly 40% of global emissions, will include some form of carbon price in 2020. However, in many cases the price of carbon is often not yet sufficient to prompt significant fuel switching.

The Carbon Price Support program, also known as a carbon price floor, came into effect in April 2013, and rose annually, so that in April 2015, it doubled from about £9/tonne of CO_2 to £18/tonne. It is currently frozen at this level until 2021[41].

[40] Ibidem
[41] Sandbag. "*Why does the UK Carbon Price Support matter?*". November 2016. https://sandbag.org.uk/wp-content/uploads/2016/11/Why_the_Carbon_Price_Support_matters_Nov_2016.pdf

Analysis from the London School of Economics and Aurora suggests that the Carbon Price Support caused coal generation to drop by 73% between 2013 and 2017, with the associated benefits in the reduction of air pollutants.[42] In particular, pricing carbon raised the price of electricity from the more carbon-intensive coal and allowed gas to replace it as a baseload generation source. The fact that there was existing gas infrastructure has also made the rapid switch possible[43].

Fig 9: Power Sector CO_2 Emissions by Fuel Source



Source: Wilson, G. and Staffell Iain

This has had a direct impact on total GHG, reducing the total UK CO_2 emissions by 18% in just four years, and as an additional benefit, brought on air quality improvements, by removing the NO_x and SO_x emissions from coal.[44]

According to the Department for Environment and Rural Affairs:

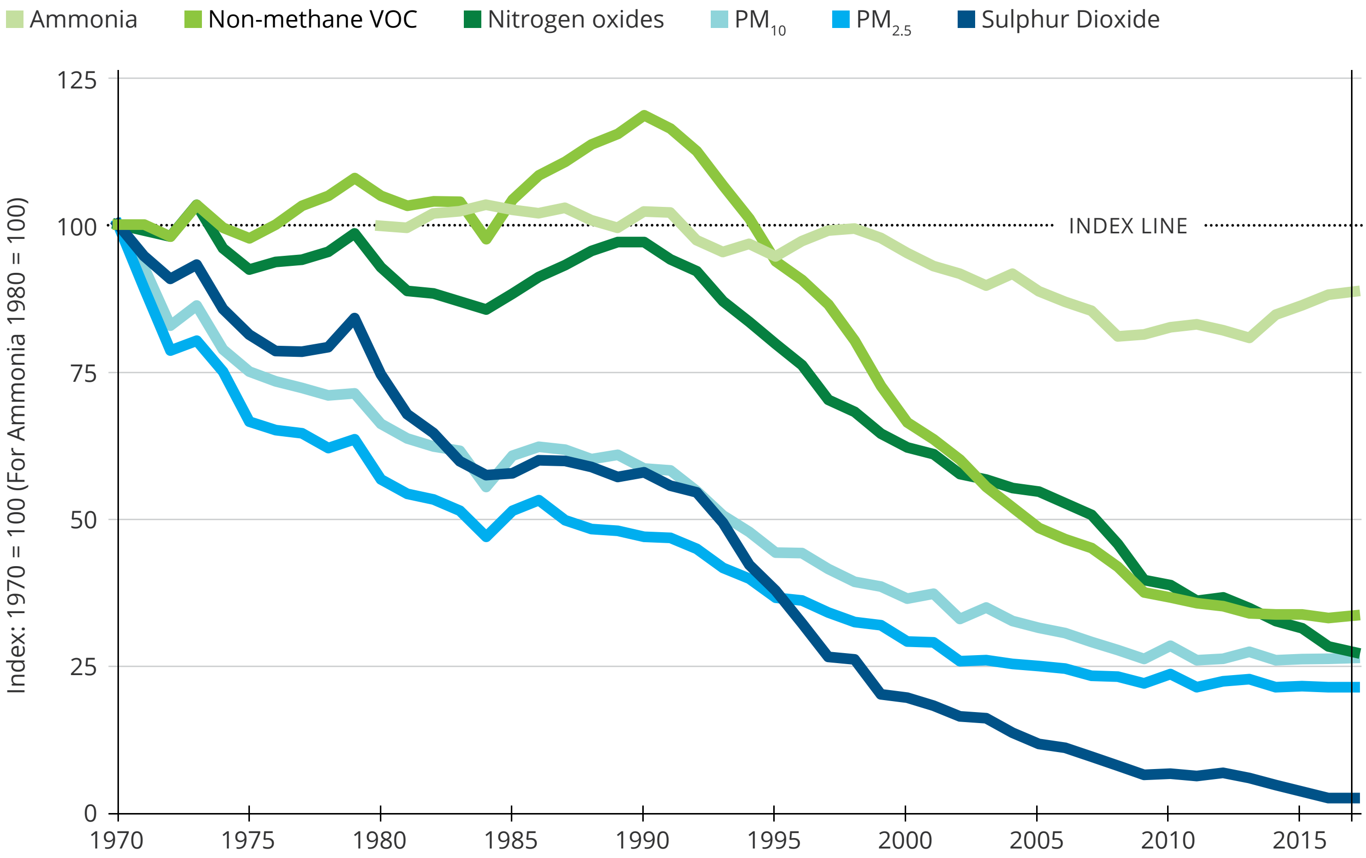
- Emissions of sulphur dioxide decreased by 1.6 per cent from 2016 to 2017, dropping to the lowest level in the time series. This was driven by a decline in coal use in power stations, continuing a long-term decrease in emissions from this source.
- NO_x emissions from power stations and industrial combustion plants have reduced significantly, reflecting a long-term trend away from the use of coal and oil in favour of natural gas and renewable energy sources.
- There was a decrease in NO_x emissions in 2017 by 3.4 per cent compared to 2016. This is a smaller annual decrease than the long-term trend, since emissions have fallen by an average of 4.6 per cent per year between 1990 and 2017. This trend was driven by a decline in coal use in power stations and modernisation of the road transport fleet.
- Road transport accounted for 32 per cent of emissions of nitrogen oxides in 2017.[45]

[42] Grantham Research Institute on Climate Change and the Environment. "*Global lessons for the UK in carbon taxes*". The London School of Economics and the University of Leeds. August, 2019. http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2019/07/GRI_Global-lessons-in-carbon-taxes-for-the-UK_policy-brief.pdf

[43] Wilson, G. and Staffell Iain. "*Rapid fuel switching from coal to natural gas through effective carbon pricing*". Centre for Environmental Policy, Imperial College London. 2018. https://spiral.imperial.ac.uk/bitstream/10044/1/57116/2/NENERGY-17061065B-FINAL.pdf

[44] Sandbag. "*Why does the UK Carbon Price Support matter?*". November 2016. https://sandbag.org.uk/wp-content/uploads/2016/11/Why_the_Carbon_Price_Support_matters_Nov_2016.pdf

Fig 10: **Annual Emission Trends in the UK: 1970 - 2017**



Source: Department for Environment and Rural Affairs[45]

The Department for Environment also states that "emissions reductions from the energy production and manufacturing sectors have been the strongest drivers for the long-term trend of decreasing emissions, by switching fuel use from coal to gas and the fitting of flue gas desulphurization in the remaining coal-fired plants in the power sector"[46].

Further research shows that "the fall in coal generation (...) was filled entirely by natural gas: coal output fell 46 TWh and gas output increased 43 TWh, while zero-carbon renewables changed by less than 1 TWh due to underlying weather conditions". Moreover, this was a quick change, saving 25 million tonnes of CO_2 in a single year; renewable energy helped to achieve a further reduction, yet at a somewhat slower pace, as it took six years to grow from 4% to 19% of Britain's generation with a saving of approximately 22 $MTCO_2$.[47]

While Carbon pricing has aided air quality improvement and delivered significant overall emissions reduction, the London example shows that a comprehensive policy approach is important for maintaining clean air. In this context, it is necessary to maintain market mechanisms that ensure a cleaner power production, while at the same time, continue to roll out measures, like Ultra Low Emission Zones, to make transportation in the city sustainable. The results and effectiveness of these initiatives will have to be monitored in the future.

[45] Department for Environment and Rural Affairs. "*Emissions of air pollutants in the UK, 1990-2017*". February, 15 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/778483/Emissions_of_air_pollutants_1990_2017.pdf

[46] Ibidem

[47] Wilson, G. and Staffell Iain. "*Rapid fuel switching from coal to natural gas through effective carbon pricing*". Centre for Environmental Policy, Imperial College London. 2018. https://spiral.imperial.ac.uk/bitstream/10044/1/57116/2/NENERGY-17061065B-FINAL.pdf

2.3 CASE STUDY: BOGOTÁ

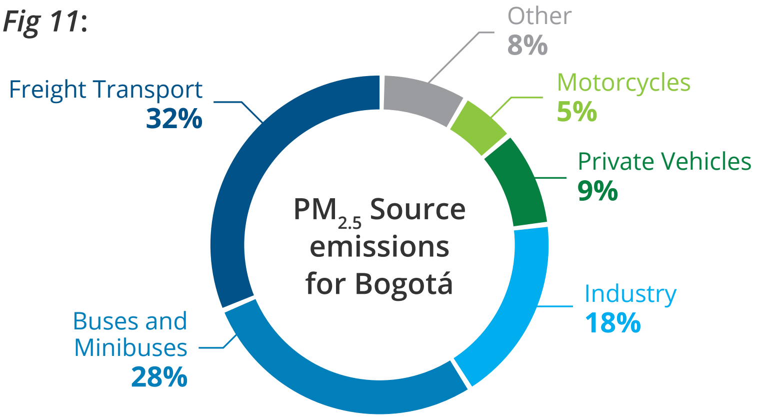
An Overhaul of the Public Transportation System

In February 2019, Bogotá suffered a severe pollution episode,[48] due to unfavourable atmospheric conditions that, yet again, raised the alarm about air quality in the capital city of Colombia. It forced the city government to declare an emergency situation, temporarily limiting traffic, especially in the heavier affected zones, in the southwest of the city, and permanently restricting heavy duty diesel powered trucks during rush hours. It took four days to reduce the high PM_{10} levels from 72 µg/m³ to 32 mg m³.[49] The episode reopened the debate around the causes of poor air quality in Bogotá.

Experts agree that[50] mobility is one of the main causes of pollution, particularly the diesel-powered public buses and heavy vehicle transportation fleet[51]. Other causes include emissions coming from industrial activity powered by coal, poor maintenance of road pavement, or waste burning.[52] The former contribute to 44% of the polluting emissions, while the latter are responsible for 56%. Out of the moving sources, 43.6% corresponds to heavy transportation vehicles and 23.6% to public transportation.[53]

Particle concentrations are also not homogeneously distributed. PM_{10} and $PM_{2.5}$ concentrations tend to be higher in the western and southwestern part of the city[54], where most of the routes for heavier vehicles are located[55]. PM_{10} also fluctuates within a day in these zones, as reported by RMCAB[56], with higher concentrations in the mornings and evenings, when residents commute to work.

Fig 11:



Source: Secretaría Distrital de Ambiente, 2017

[48] Semana. "*¿Qué se está haciendo con los vehículos más contaminantes en Bogotá?*". February 22, 2019. https://www.semana.com/nacion/articulo/que-es-lo-que-mas-contamina-a-Bogotá/602267

[49] Ibidem

[50] Téllez Oliveros, V. "*Opinión: El aire de Bogotá más allá de la emergencia ambiental*". February 22 2019. https://www.elespectador.com/noticias/Bogotá/opinion-el-aire-de-Bogotá-mas-alla-de-la-emergencia-ambiental-articulo-841011

[51] Rojas, Nestor Y. "*Aire y problemas ambientales de Bogotá*". Universidad Nacional de Colombia. 2007. https://Bogotá.gov.co/sites/default/files/inline-files/aire_y_problemas_ambientales_de_Bogotá.pdf

[52] Agencia Anadolu. "*¿Qué necesita Bogotá para mejorar la calidad del aire?*". February 25, 2019. https://www.elespectador.com/noticias/Bogotá/que-necesita-Bogotá-para-mejorar-la-calidad-del-aire-articulo-841785

[53] Semana. "*¿Qué se está haciendo con los vehículos más contaminantes en Bogotá?*". February 22, 2019. https://www.semana.com/nacion/articulo/que-es-lo-que-mas-contamina-a-Bogotá/602267

[54] Red de Monitoreo de Calidad del Aire de Bogotá (RMCAB). "*Informe anual de calidad del aire de Bogotá. 2016*". 2017

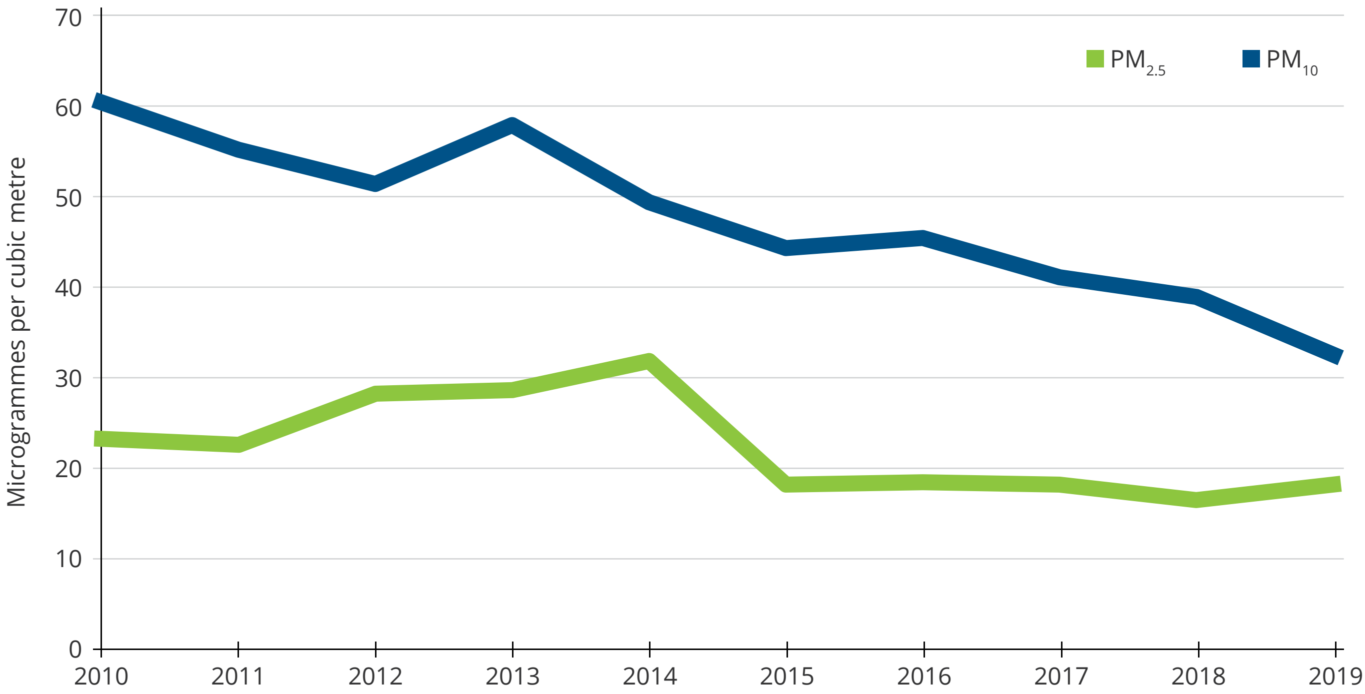
[55] https://www.elespectador.com/noticias/Bogotá/que-necesita-Bogotá-para-mejorar-la-calidad-del-aire-articulo-841785

[56] Agencia Anadolu. "*¿Qué necesita Bogotá para mejorar la calidad del aire?*". February 25, 2019. https://www.elespectador.com/noticias/Bogotá/que-necesita-Bogotá-para-mejorar-la-calidad-del-aire-articulo-841785

It should be noted that Bogotá has generally been on a positive trend in management of its air pollution, as can be seen from the reduced levels of PM_{10} and $PM_{2.5}$ in recent years[57]. Even though the annual averages exceed the ones recommended by the WHO,[58] it is close to meeting local standards set by the RMCAB (Bogotá's Air Quality Monitoring Network), which are 50 µg/m³ and 25 µg/m³ for PM_{10} and $PM_{2.5}$ respectively[59].

On average, 2019 will still be a positive year for PM_{10} measurements, as the current projected average (32.6 µg/m³) is below 2018 (38.9 µg/m³) and 2017 (41.4 µg/m³).[60]

Fig 12: Average PM levels in Bogotá (2010-2019)

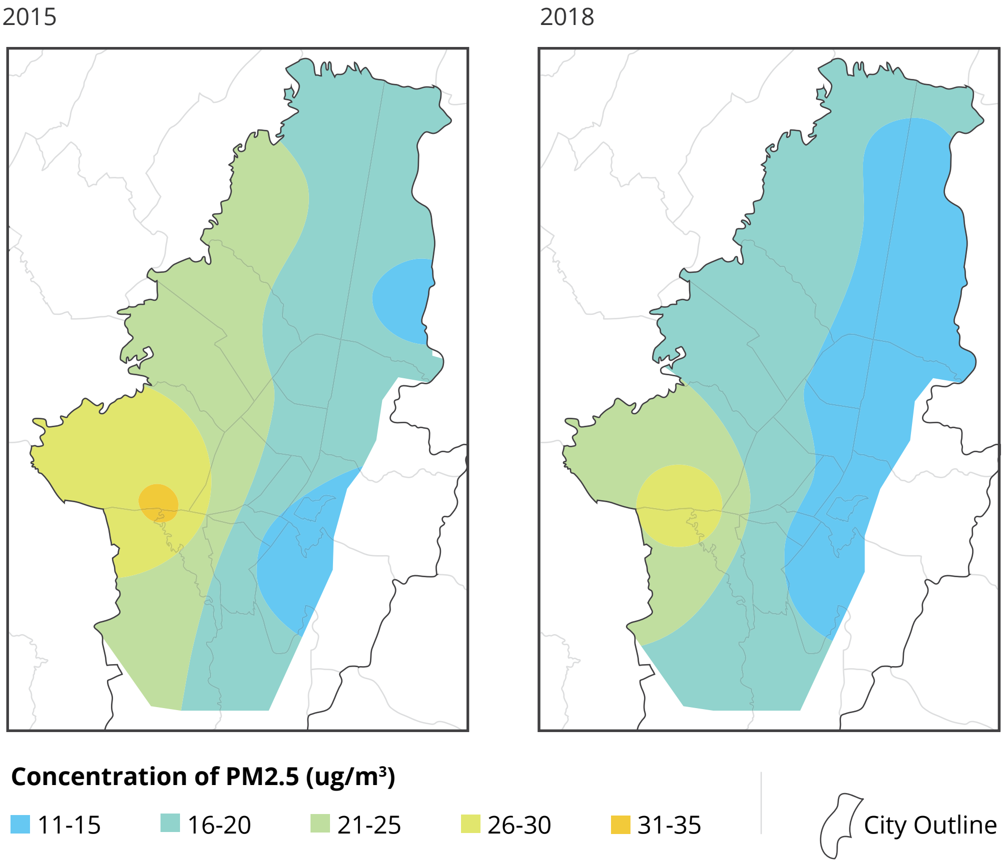


Source: RMCAB data[61]

One large contributor to the improvement has been the city's bus rapid transport system (BRT) – Transmilenio – the largest in the world today. The system development first started in early 2000's, and it helped resolve the growing issues of traffic congestions resulting in drops of both emissions and air pollution, by reducing the number of vehicles on the roads, and replacing old buses with newer and more efficient ones.[62]

[57] Red de Monitoreo de Calidad del Aire de Bogotá (RMCAB), 2019. https://gobernanzadelaire.uniandes.edu.co/?page_id=164
[58] Garcia, S. and Carranza, D. "*¿Qué respiran y de dónde proviene la contaminación en Bogotá?*". Semana Sostenible. August 08, 2018"https://sostnibilidad.semana.com/medio-ambiente/articulo/calidad-del-aire-Bogotá-contaminacion-que-respiran-y-de-donde-proviene-la-contaminacion-en-Bogotá/41330
[59] Red de Monitoreo de Calidad del Aire de Bogotá (RMCAB). "*Informe anual de calidad del aire de Bogotá. 2018*". 2019
[60] Red de Monitoreo de Calidad del Aire de Bogotá (RMCAB), 2019. https://gobernanzadelaire.uniandes.edu.co/?page_id=164
[61] Ibid.
[62] Bogotá slashed pollution and road deaths with one simple tool: a bus. https://apolitical.co/solution_article/Bogotá-slashed-pollution-and-road-deaths-with-one-simple-tool-a-bus/.

Fig 13: Geographical Distribution of $PM_{2.5}$ Emissions in in Bogotá



However, the BRT buses operated on diesel, which still produces large volumes of pollutants. Recognizing this problem, the city authorities made it a priority to improve the BRT fleet with cleaner vehicles.

To accomplish this, the city of Bogotá and Transmilenio are renewing 70% (1,400 vehicles) of its fleet: 53% (a total of 741 units) to EuroVI compressed natural gas (CNG) vehicles, and the rest will be powered by Euro V standard diesel engines with particulate filters that will absorb 75% of particulate emissions[63] . These efforts have already started and there are currently 200 CNG Euro VI buses in operation in Bogotá. The switch will be completed in May 2020.

Because natural gas does not contain Sulphur and has much lower NO_x emissions, the switch allows to minimize air pollution significantly and immediately. The new Euro VI CNG buses will cut PM emissions threefold, from 0.030 to 0.010 (g/kW-hr), and emissions of NO_x fivefold – from 2.0 to 0.4.[64] As the rollout is still in progress, the final outcomes of the switch are not available yet, but the city plans to monitor, measure and report the results, after its completion.

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[63] Téllez Oliveros, V. "Opinión: El aire de Bogotá más allá de la emergencia ambiental". February 22 2019. https://www.elespectador.com/noticias/Bogotá/opinion-el-aire-de-Bogotá-mas-alla-de-la-emergencia-ambiental-articulo-841011

[64] The International Council on Clean Transportation. "CNG Bus Emissions Roadmap: from Euro III to Euro VI". 2009 https://theicct.org/sites/default/files/publications/CNGbuses_dec09.pdf

Natural Gas Powered Transportation Creates Significant Long-Term Environmental Benefits

The increasing use of natural gas in transportation is contributing to significant long-term cost savings, while greatly improving air quality.

As a transportation fuel, natural gas can reduce greenhouse gas emissions by 20%, when compared with gasoline.

Natural gas offers great improvement in air quality, due to its nearly zero PM emissions and low NO_x emissions, that are major contributors to a growing issue of urban smog.

For example, natural gas fuelled vehicles emit up to 95% less PM and up to 70% less NO_x, compared with the European emission standards.

NOX
Nitrogen oxides by 75 to 95%

CO_2
Carbon dioxide by up to 20%

NMOG
Non-methane organic gas by 50 to 75%

CO
Carbon monoxide by 70 to 90%

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