Action plan on improving air quality in BMO – metropolitan centre

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1. Literature review of the phenomenon

General information on air pollution

The first study, which deal with the air pollution, was Fumifugium; or the Inconveniencie of the Aer and Smoak of London Dissipated. This was written by John Evelyn in 1661. He made a study of the effects of coal smoke on health, plant life and buildings. (Love clean air South London, 2014) But what is the air pollution? We hear a lot of information about it, but many people do not know what is it? Definition of air pollution: Air pollution is a mixture of solid particles and gases in the air. (Medline Plus, 2016) The definition also reads that varios components contribute to issue of the air pollution. The following paragraph will discuss these components.

The present-day atmosphere is quite different from the natural atmosphere that existed before the Industrial Revolution, in terms of chemical composition. The chemical composition of the pre-industrial (i.e., before the 18th century), natural global atmosphere is compared to current compositions in Table 1:

Table 1: Atmospheric Chemical Compositions

Gas	Symbol	Percent by volume (Current Atmosphere)	Ppm (Natural Atmosphere)
Nitrogen	N_2	78,1	
Oxygen	O_2	20,9	
Argon	Ar	0,92	
Neon	Ne		18,2
Helium	He		5,2
Krypton	Kr		1,14
Xenon	Xe		0,09
Carbon dioxide	CO_2		280,0
Methane	CH_4		0,750
Nitrous oxide	N_2O		0,270
Water Vapor	H_2O	Variable (0,004 to 4)	

Source: Daly, A. and P. Zannetti. (2007). An Introduction to Air Pollution- Definitions, Classifications, and History

In this table we see that the natural components are nitrogen, oxygen, and argon. But there are more components, in the few lines we will talk about these components, and that, how they got in the air. These components are also responsible for air pollution.

Air pollutants:

- Carbon Dioxide (CO_2)

  - Carbon dioxide is produced in the combustion of fuels, and the main sources are road transport, power generation and any other combustion processes. Whilst ambient levels do not have any direct health effects there is a growing concern about its contribution to climate change. (Love clean air South London, 2014)
- Nitrogen Dioxide (NO_2)
  - Nitrogen dioxide is formed during the combustion of fuels and is probably the most widespread pollutant. In the combustion process, nitric oxide (NO) in initially formed and combines with oxygen in the air to form nitrogen dioxide. (Love clean air South London, 2014)
- Sulphur Dioxide (SO_2)
  - Sulphur dioxide has serious impacts upon human health. The concentration of sulphur dioxide in the atmosphere can also influence the survival of plants and animals. Sulphur dioxide emissions can lead to acid rain and atmospheric particulates. It is mainly produced by large power stations burning fossil fuels. Since the amendment of the Clean Air Act in 1968 sulphur dioxide concentrations have reduced significantly. (Love clean air South London, 2014)
- Ozone (O_3)
  - Although the naturally occurring ozone in the upper atmosphere forms a protective layer around the Earth, ground level ozone is harmful to health. Ozone occurs more in the summer when there are high temperatures, calm winds, and plenty of sunlight. It is usually higher in rural areas than in cities.
  - Ground level or "bad" ozone is not emitted directly into the air but is created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight. Emissions from industrial facilities, vehicle exhausts and chemical solvents are some of the major sources of NOx and VOC. (Love clean air South London, 2014)
- Ammonia (NH_3)
  - Ammonia (NH_3) is a highly reactive and soluble alkaline gas. It originates from both natural and anthropogenic sources, with the main source being agriculture, e.g., manures, slurries, and fertiliser application. (Air pollution information system, 2016)

- Particulate matter (PM)
    - Particulate matter is the term for particles found in the air, including dust, dirt, soot, smoke, and liquid droplets. Large concentrations of particulate matter are typically emitted by sources such as diesel vehicles and coal-fired power plants.
    - There are two sizes of PM:
        - PM 10: Particles less than 10 micrometres in diameter. It poses a health concern because they can be inhaled into and accumulate in the respiratory system.
        - PM2,5: Particles less than 2,5 micrometres in diameter. It poses the greatest healt risks, because of their small size. (Brise, 2021)

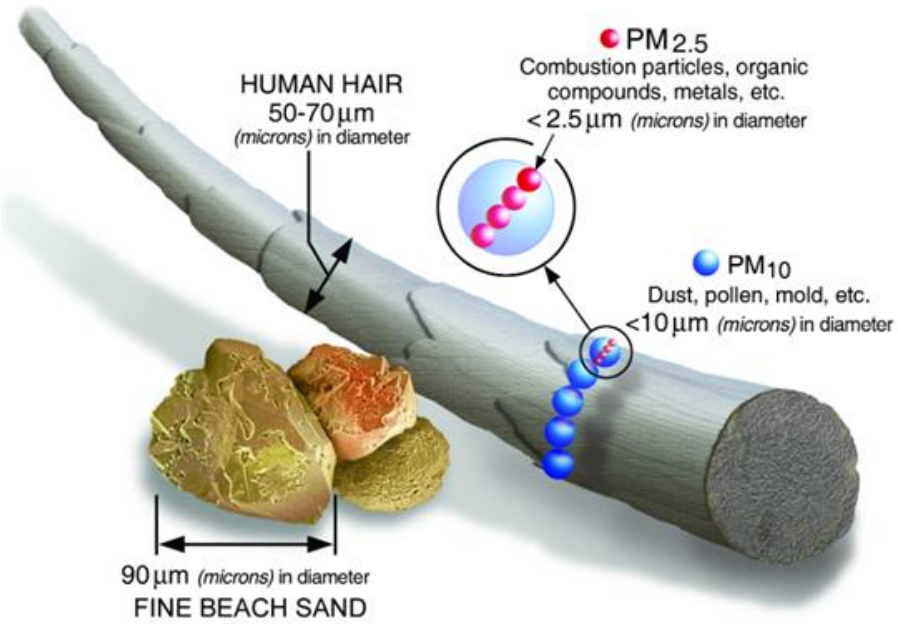


Figure 1: Comparison of hair and PM size.
Source: https://www.brisecare.com/202102-what-is-pm-and-what-are-the-harmful-effects-to-health/

In this figure, we can compare to our hair size with PM size. We can see that, our hair is 50-70 micrometre in diameter and the PM2,5 is approximately 1/30th the average width of a human hair. The fine particles can lodge deeply into the lungs, these are very bad our health(World Health Organization, 2019).

The following will be a discussion of how these air pollutants get into the air. There are various sources of air pollution, both anthropogenic and of natural origin:

1. Natural air pollution: this includes air pollution caused by natural disasters or natural processes, such as forest fires or volcanic eruptions.

2. Anthropogenic: this includes industrial, agricultural and transport. So, it comes from the residential.

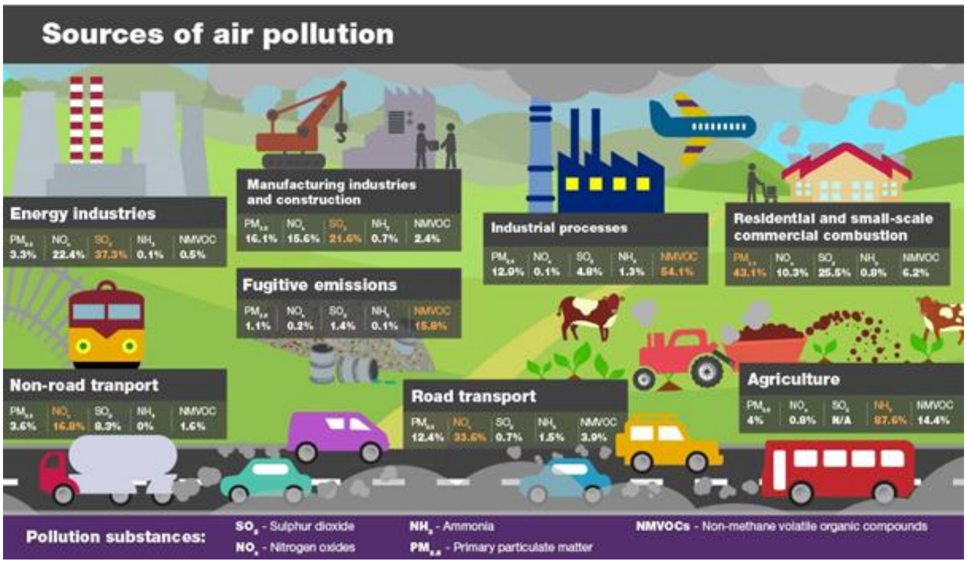


Figure 2: Sources of air pollution (https://www.gov.uk/government/publications/air-pollution-applying-all-our-health/air-pollution-applying-all-our-health)

This figure presents, which sources of air pollutants emit the highest percentage. 33,6% of NO_2 comes from the road transport and 16,8% comes from the non-road transport. A high percentage of sulphur dioxide comes from energy industries (37,3%) and manufacturing industries and construction (21,6%). The ammonia (NH_3) only comes from the agriculture. It has been mentioned before that air pollution has a detrimental effect on our health. The following paragraph will be discussing these effects.

The health effects of pollutants will depend on many factors as to the level of harm an individual is exposed to. This includes the dose, duration, how an individual comes into contact with pollutant, in addition to factors such as age, sex, diet, family traits, lifestyle and state of health. Air pollution can affect the eyes, nose and throat, the heart and associated blood vessels and the lungs and respiratory system (Office for Health Improvement & Disparities, 2022).

Air pollution is easy for everyone to notice, they can experience it on their own. Most of us have a probably experienced physical symptoms, most notably in large, busy cities, such as tearing eyes, coughing, or wheezing, when this was most likely due to air pollution. Polluted air can cause respiratory irritation or breathing difficulties even in healthy people while exercising or doing leisure activities (légszennyezés.hu, 2014).

We can group the effects of air pollution based on how long their effects are.

1. Short-term health effects (over hours or days) include wheezing and shortness of breath, pneumonia, bronchitis, various irritations.
2. Long-term health effects (years or lifetimes) include cardiovascular diseases, respiratory diseases, and lung cancer.

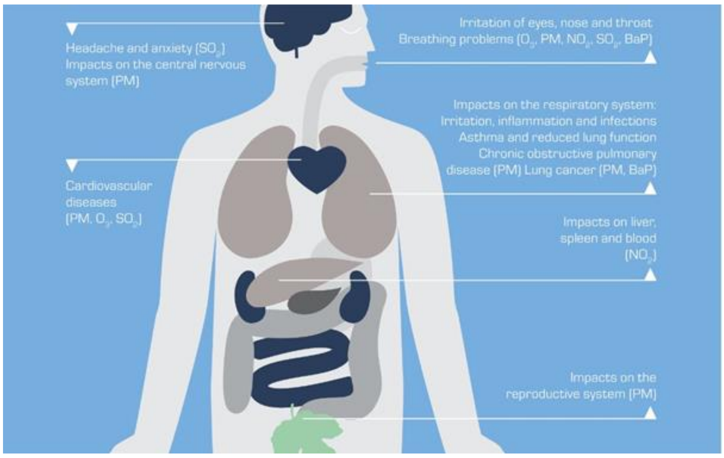


Figure 3 Health impacts of air pollution (https://www.eea.europa.eu/signals/signals-2013/infographics/health-impacts-of-air-pollution/view)

The figure shows which organs have the effect of different pollutants. For example, sulphur dioxide (SO_2) has an impact on headache and anxiety and cardiovascular diseases.

There are some other problems, which the air pollution cause. For example, dementia, cognitive decline or affecting early life leading to various birth outcomes (low birth weight and developmental problems) (Office for Health Improvement & Disparities, 2022).

It has been mentioned earlier that a number of factors affect the health impact of air pollution. We say that air pollution affects people throughout their lifetime. The previous concept is well proven by the next figure.

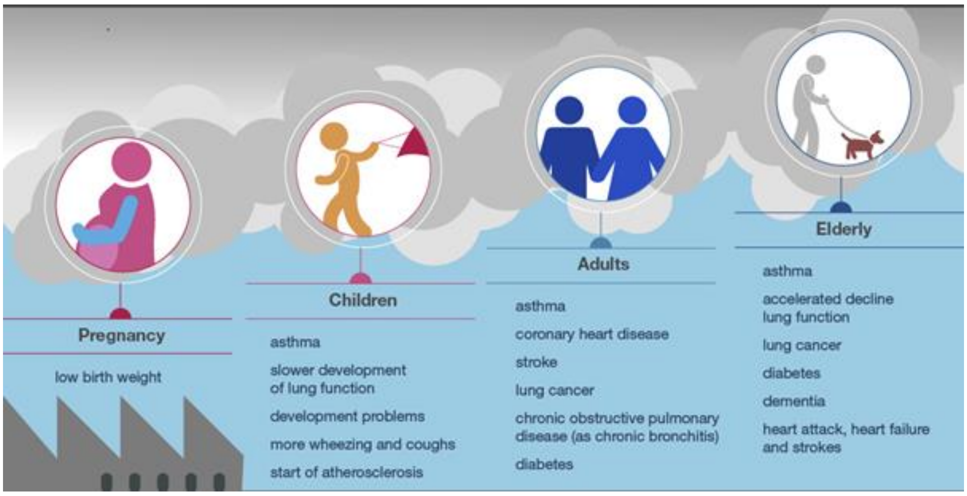


Figure 4: Air pollution affects people throughout their lifetime.
Source: https://www.gov.uk/government/publications/air-pollution-applying-all-our-health/air-pollution-applying-all-our-health

Children often have asthma or other respiratory system diseases. While in adults it can already affect the circulatory system. In the elderly, more serious problems may also occur, such as stroke.

It is not only anthropogenies air pollutants that affect our health, but also natural factors. Nowadays, natural disasters, including wildfires, are occurring more and more often.

In 2021, Russia faced one of the worst bushfire seasons. The fires raging in Siberia were larger than the fires in Greece, Turkey, Italy, the United States and Canada combined. The area burned by the wildfire can be estimated at roughly 200,000 square kilometers. The smoke pollution in Russia led to the closure of airports and roads and the evacuation of people living in the affected areas. Most of the forests exposed to fire in Siberia are located in the far north. Here, trees grow very slowly, are very sensitive, and if they burn, the impact on the environment is enormous. Global warming researchers believe that fires of this magnitude could make our ever-warming planet even hotter due to the enormous carbon dioxide emissions from the flames (The Washington Post, 2021).

The health effects of bushfire smoke can range from eye and respiratory irritation to more serious disorders, including reduced lung function, worsening asthma and heart failure, and premature death. Children, pregnant women, and the elderly are particularly vulnerable to smoke exposure. It is known that due to emissions from wildfires, people exposed to the smoke are increasingly visiting hospitals and clinics (United States Environmental Protection Agency, 2022).

What are the most current findings in the field of study?

Up to this section, the main information sheets have been presented as general. In the next section, the exact data will be presented.

In 2021, the Eu Clean Air Forum made the following findings: Over the past few years, estimates point to up to 400 000 premature deaths duo to air pollution annually across the EU. According to the latest findings of the European Environment Agency, in 2019, particulate matter (PM2,5) alone was responsible for 307 000 premature deaths. This marks a steady decrease since the year 2005 and shows that clean air policies deliver successes. Nevertheless, more than half of these deaths could have been avoided if EU Member States had reached the WHO's new air quality guideline level of 5 µg/m^3(Eu Clean Air Forum, 2022).

We can make a categorises air quality as:

- **good** for levels of fine particulate matter that do not exceed the annual guideline value of the World Health Organization of 5 µg/m^3
- **fair** for levels above 5 and not exceeding 10 µg/m^3
- **moderate** for levels above 10 and not exceeding 15 µg/m^3
- **poor** for levels above 15 and not exceeding 25 µg/m^3
- **very poor** for levels at and above the European limit value of 25 µg/m^3 (European Enviroment Agency, 2021)

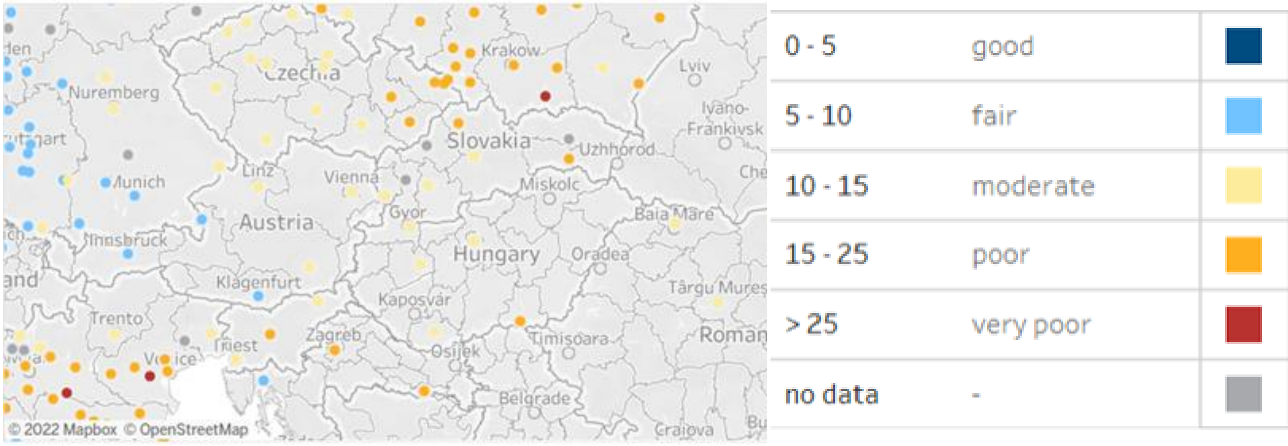


Figure 5: In 2020 and 2021, the level of fine particles in the air in European cities
Sources: https://www.eea.europa.eu/themes/air/urban-air-quality/european-city-air-quality-viewer

The figure shows the PM 2,5 annual mean concentration, µg/m^3. The colour signalling corresponds to the air quality categories mentioned earlier. You can also see in the picture that Brno and Pécs fall into the moderate category. The exact value for both cities is 13 µg/m^3 (European Enviroment Agency, 2021).

In 2021, the EU Clean Air Forum made some other decisions: As part of the European Green Deal, the EU's Pollution Control Action Plan aims to achieve its objective. Exposure to fine particulate matter means a 55% reduction in deaths by 2030. According to EEA's analysis, the EU is currently on track to reach the target, as the number of these deaths has decreased by about a third from 2005 to 2019 (European Enviroment Agency, 2021).

What can we do about air pollution?

Combating air pollution is everyone's responsibility. We all must deal with this problem. There must also be a concerted, joint effort by the government, cities, and individuals to protect our health.

To national governments: reduce emissions and set national standards that meet WHO air quality guidelines. Invest in research and education around clean air and pollution – they are an essential tool.

To cities and local communities: Public policies across sectors must factor in public health from the beginning, followed up with sufficient data and tools to assess them.

To individuals: Continue to stand up for your right to healthy and sustainable environments. Hold your governments accountable.

It is everyone's responsibility to think about how you live and consume, what sustainable decisions you make that will affect you and your children in the future (World Health Organization, 2019).

2. Urban literature review

Definition of metropolitan centre and hinterland

In the following few paragraphs, we will determine what the metropolitan area is, as well as what the centre is and what is the hinterland. Later, we will discuss the problems they carry.

Metropolitan is a term used to describe a relatively large urban area, both of the size of area, population, and the scale of economic and social activity. While the etymology, said metropolitan (noun) or metropolis (adjective) is derived from the Ancient Greek language, which the word meter means mother, and the word polis means city (UKessays, 2017).

In general, the metropolitan can also be defined as a large residential centre that consists of a large city and some in the surrounding area with one or more major cities that serve as a point of contact (hub) to the towns in the surrounding areas. A metropolitan area is an agglomeration of several settlements, settlements should not be the city, but the overall form a unity in nature activities and lead to the city centre (a large city that is the core) that can be seen from the flow of labour and commercial activities (UKessays, 2017).

As we can see many different definitions of their existence in the metropolitan area. Each other’s definition used by the OECD and the EU that is determined by the metropolitan area as a Functional Urban Area (FUA). They conclude that there is a functional and economic relationship between the area. According to the 2019 data, the population lives at least 50%

Functional Urban Area (FUA), which is about 250 000 inhabitants. This area consists of more densely populated urban cores and less populated areas that are functionally connected to the centre (European Committee of The Regions, 2019).

As mentioned above, metropolitan areas are made up of several units. The figure below shows the different areas in the metropolitan area. In the next few lines, these will be characterized.

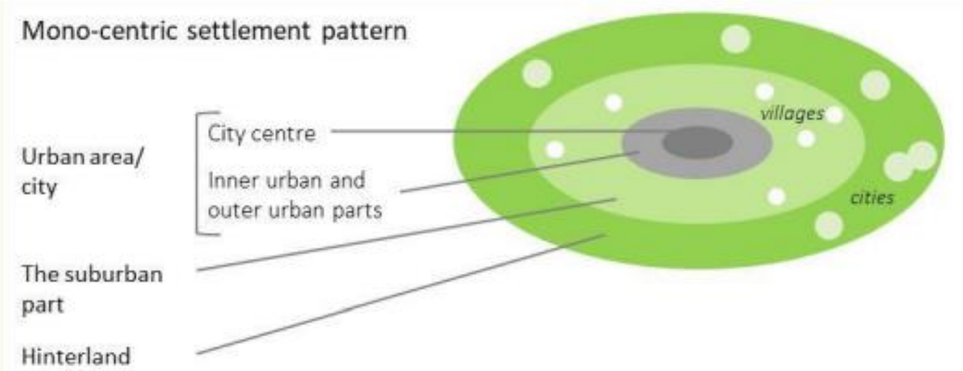


Figure 6: Parts of a metropolitan area
Source: European Committee of The Regions, 2019

Urban area/ City: You can also call it a built-up area. An area with a high population density and infrastructure of built environment. Today, the majority of the population lives in these areas. This is due to the process of urbanization, which we will discuss later. The city is a constantly densely populated place, the inhabitants of which are engaged in non-agricultural tasks. The city has extensive housing, transport, and communication systems. On the other hand, in many cases it is the centre of cultural and historical scenes.

Suburban part: The word suburb is made from two different word that originated in the Latin language. The word sub means under, and the word urbs means city. (Cook, 2021) Suburban areas are lower density areas that separate residential and commercial areas from one another. They are either part of a city or urban area or exist as a separate residential community within commuting distance of a city. As cars became the dominant way for people to get to work, suburbs grew.

Hinterland: The hinterland includes rural areas surrounding the peri-urban area as well as small and medium sized towns with potentials for linkages to the bigger urban centre. In reality, there is no sharp boundary between the areas, it is gradually shifting between urban and rural areas. These areas are more open, there is more green space. (European Committee of The Regions, 2019)

Differences between suburbanization, suburb, and relevant urban structures

The migration of people between the different areas is influenced by several factors. Metropolitan regions provide more job opportunities and access to individual services more easily. While rural areas have fewer job opportunities, fewer educational opportunities, and access to various services. However, if you look at the negative side of big cities, higher land prices, less green and recreational areas, and much higher pollution. Different concepts have evolved for the flow of population from one area to another. They will be described below (European Committee of The Regions, 2019).

<u>Urbanisation:</u>

Urbanization (or urbanisation) refers to the population shift from rural to urban areas, the corresponding decrease in the proportion of people living in rural areas, and the ways in which societies adapt to this change. It is predominantly the process by which towns and cities are formed and become larger as more people begin living and working in central areas. (Wikipedia, 2022) More than half of the world's population now lives in urban areas.

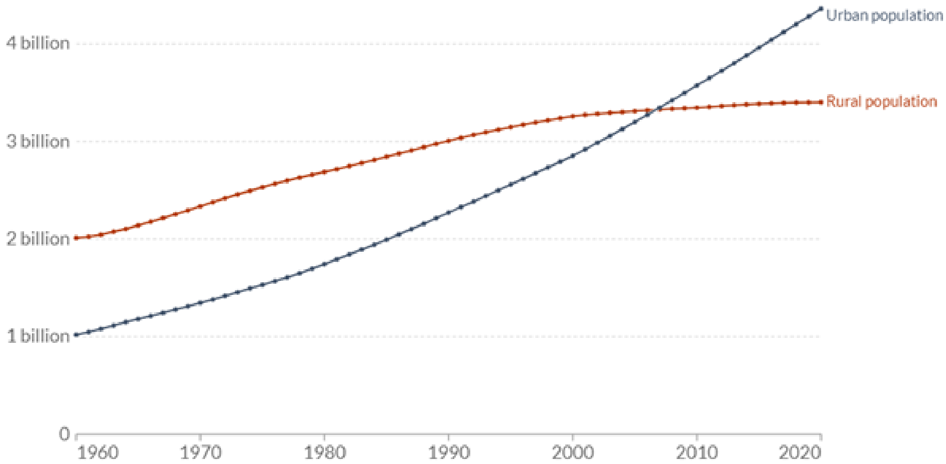


Figure 7: Number of people living in urban and rural areas World
Source : https://ourworldindata.org/urbanization#how-urban-is-the-world

This figure presents, how the urban population change in the few years. We can see, that in 2007 the rural and urban population was similar. However, by 2050, mora than two-third of the world will live in urban areas by 2050. So, while in 2016 only 54% of the world's population lived in cities, by 2050 it will rise to 68% (Our World in Data, 2019).

<u>Counter-urbanisation:</u>

Counter-urbanisation is the opposite trend to rural-urban migration. This concept refers to the migration of people from the metropolitan region to rural areas in the hinterland, keeping loose ties to the metropolitan region. The reasons for counter-urbanisation can be as diverse as new rural job opportunities, low land prices enabling more affordable space for residential use or the individual attractiveness of a rural lifestyle. Counter-urbanisation is often combined with commuting and/or home office work. Even if this phenomenon is minor, it could be an upcoming trend due to changing lifestyles and the opportunity of re-locating work in home-based office (European Committee of The Regions, 2019).

Suburbanization:

Suburbanization is the opposite of the process of urbanization. In the case, the population moves from the core city to the suburbs. Earth prices are cheaper here and there are more green areas. About these areas, people commute to work daily or work from home. As more and more people migrate to these areas and commute to work, surroundings of urban cores are growing, land take is increasing and the originally rural municipalities become part of the suburban belt around the core cities leading to the (unwanted) effect of urban sprawl (European Committee of The Regions, 2019).

Problem of metropolisation

One of the problems during the suburbanization is urban sprawl. Urban sprawl refers to the expansion of poorly planned, low-density, auto-dependent development, which spreads out over large amounts of land, putting long distances between homes, stores, and work and creating a high segregation between residential and commercial uses with harmful impacts on the people living in these areas and the ecosystems and wildlife that have been displaced. Although some would argue that urban sprawl has its benefits, such as creating local economic growth, urban sprawl has many negative consequences for residents and the environment, such as higher water and air pollution, increased traffic fatalities and jams, loss of agricultural capacity, increased car dependency, higher taxes, increased runoff into rivers and lakes, harmful effects on human health, including higher rates of obesity, high blood pressure, hypertension and chronic diseases, increased flooding, decrease in social capital and loss of natural habitats, wildlife and open space. One of negative effects is air pollution. Urban sprawl increases car and truck traffic by creating longer and more frequent commutes, which leads to a major increase in air pollution and ground-level smog. Vehicles are the number one cause of air pollution in many urban areas with serious implications for public, wildlife, and ecosystem health (EverythingConnets, 2013).

Another problem is urban heat island (UHI). It means that, the metropolitan area is warmer than the rural areas surrounding it. The heat island effect develops when urban and suburban areas lose land surface and naturally occurring vegetation, heat can no longer easily escape. Tall buildings, concrete, and asphalt trap heat and contribute to the warming effect. Waste heat from energy use is another source of additional heat. Other contributing factors include local weather, seasonal changes, time of day, and geographic location (Green Ribbon, 2013).

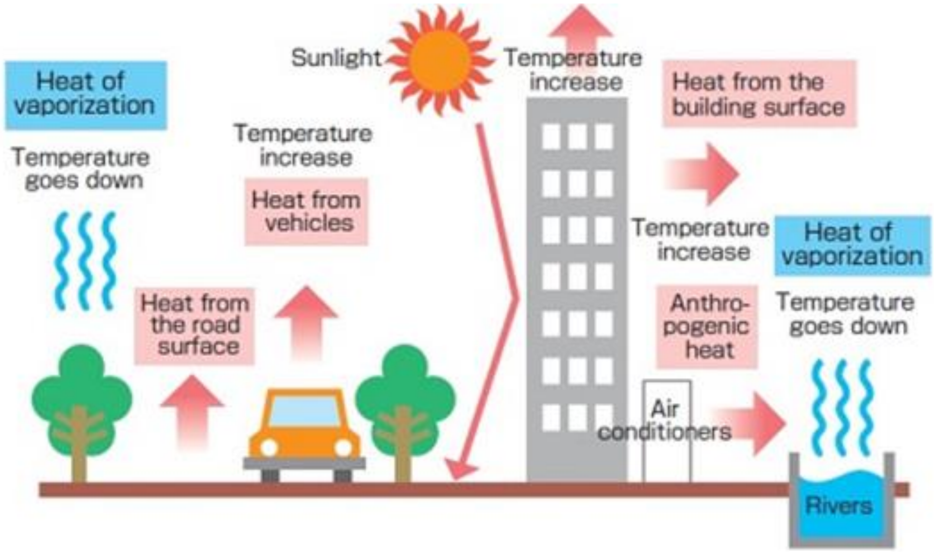


Figure 8: How the heat island phenomenon occurs
Sources: http://www.gardinergreenribbon.com/heat-island-effect/

In this figure we can see that, which components are responsible for the heat island. The vehicles, the road surface, the building surface, and air conditioners are responsible for the temperature increase.

Although we tend to think of heat islands as a modern ecological problem, scientists first noted this issue as early as the 1800s. Any area (rural, urban, or otherwise) can experience the heat island effect, but urban areas are typically of more concern since they represent a more serious threat to local climate warming. For smaller cities, heat islands are less noticeable. For a large city of one million people, the average temperature can be anywhere from around 1°C to 12°C warmer than the surrounding area (Green Ribbon, 2013).

The last problem, what we must introduce is smog. Smog is air pollution that reduces visibility. The term "smog" was first used in the early 1900s to describe a mix of smoke and fog. The smoke usually came from burning coal. Smog was common in industrial areas and remains a familiar sight in cities today. Today, most of the smog we see is photochemical smog. Photochemical smog is produced when sunlight reacts with nitrogen oxides and at least one volatile organic compound (VOC) in the atmosphere. Nitrogen oxides come from car exhaust, coal power plants, and factory emissions. VOCs are released from gasoline, paints, and many cleaning solvents. When sunlight hits these chemicals, they form airborne particles and ground-level ozone or smog. Smog is common in big cities with lot of industry and traffic (National Geographic, 2022).

We can do it to reduce smog by changing a few behaviors, such as:

- Drive less. Walk, bike, carpool and use public transport.
- Avoid gas-powered yard equipment, like lawn mowers. Use electric appliances instead.

Avoid products that release high levels of VOCs. For example, use low-VOC paints.

3. Institutional and self-government review

Review of institutional frameworks

This section aims to give explicit information on the action plan on improving air quality in three selected European countries - France, Germany, and Hungary. Again, the rationale for selecting these three (3) countries remains that they are the participating countries of the education programme from which this working paper is developed, thus, the scope remains within these countries.

In summary, what will be covered include the actions taken in each of these countries, the effects or influence of these actions and their recorded success (or failure), how sustainable are the actions, and the advantages as well as disadvantages of each action.

3.1 Germany

3.1.1 Introduction

The German air pollution history can be traced back to the Post-World War II era where the operations of the then German Democratic Republic (GDR or the East Germany) had its primary energy source from burning domestic lignite, an operation which characterized the area with high sulphur dioxide and particulate matter emissions (Breeze Technologies, 2021). And because environmental issues such as air pollution is borderless, the then Federal Republic of Germany (West Germany) was also affected by the pollutants. In the quest to protect further air pollution, several government actions were taken with more protection attention coming from the West. The West particularly engaged declaration of smog alerts, populace warning, industrial production cutbacks, and driving bans as some of their measures while the East did nothing. The only attempt to jointly address air pollution was in the late 1972, however, this attempt was stopped at the creation of the German Environment Agency (Umweltbundesamt - UBA) by the West in July 1974. The West also took further steps to address the air pollution matters by enacting the Large Combustion Plants Ordinance in 1983 and founding the Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit - BMU). The implication of these actions includes rapid fall in air pollution in the West due to the reduction in Sulphur dioxide and establishing a framework for a cleaner and healthier Germany after reunification. (See: (Breeze Technologies, 2021)). A comparison graph of the sulphur dioxide emissions in the years before the reunification for the East (characterized by Leipzig/ Halle/ Weissenfels/ Bitterfeld) and the West (characterized by the Ruhr District) can be seen in Figure.9 below:

Figure 9: Sulphur Dioxide concentrations (on an annual average)

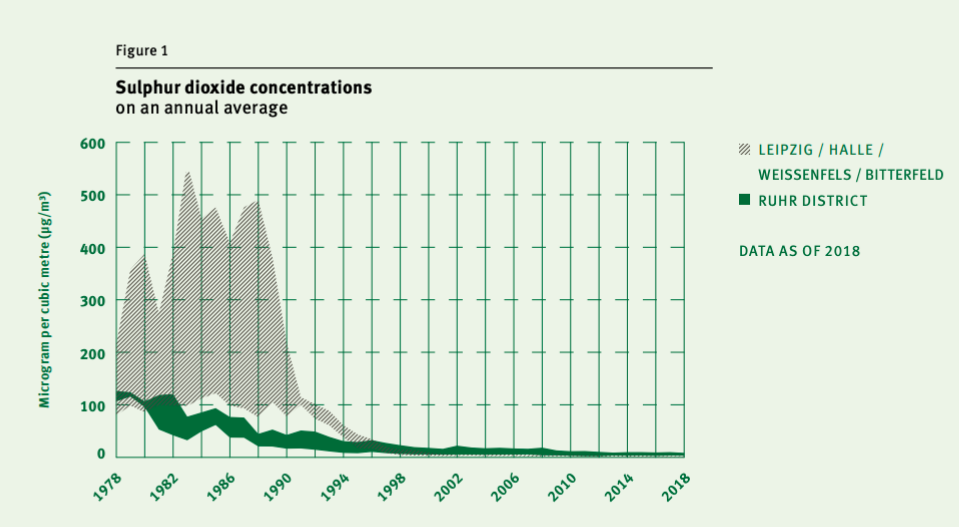


Image Source: https://www.umweltbundesamt.de/en/publikationen/what-matters-2-2020-30-years-german-unity

Figure 10 presents periods following the reunification of the East and West Germany up to 2000, the air pollutant concentrations differ in both regions, however, there was an overall significant drop in Sulphur dioxide emissions by 60% and an 82% reduction in particulate matter emissions that were due to two major factors: (a) low demand for products and energy and; (b) the closure and the rehabilitation of power stations and industrial plants ((Breeze Technologies, 2021)

Figure 10:

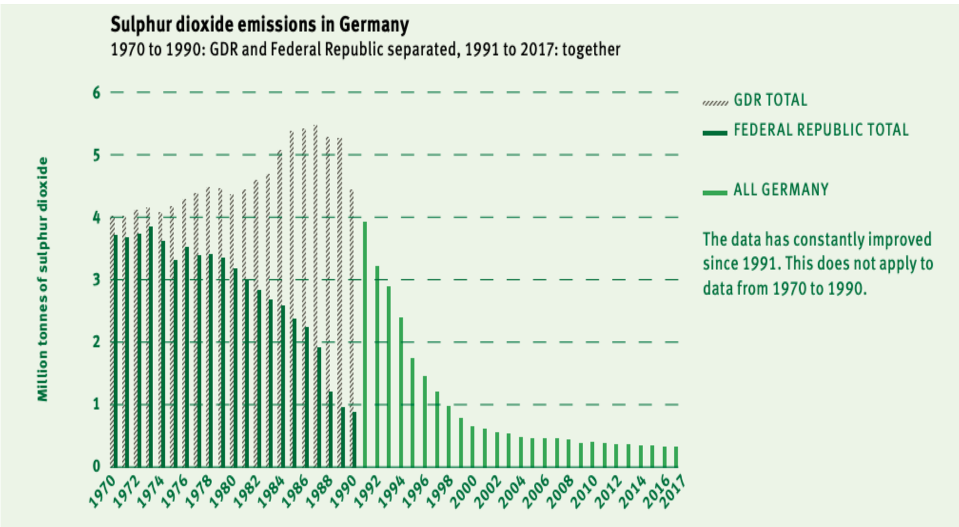


Image Source: https://www.umweltbundesamt.de/en/publikationen/what-matters-2-2020-30-years-german-unity

The immediate section below covers a brief of air pollution and the German actions taken against air pollution since the early 20s (the reason for considering from the early 20s remains the fact that these actions serve as a progress on older ones)

3.1.2 Overview of the German response to air pollution

Majority of German air pollutants today are nitrogen dioxide particulate matters (Breeze Technologies, 2021). (European Environment Agency, 2021) presented the percentage of German urban population that are exposed to air pollutant concentrations beyond the EU standards and the health impacts of these pollutants in Germany as compared to the impact in the EU (see Table 2 & 3, respectively).

Table 2:

Exposure - Germany

The table below shows the percentage of urban population exposed to concentrations above EU standards for selected air pollutants such as PM10, PM2.5, O3, NO2 and BaP for the years 2015-2019.

		2015	2016	2017	2018	2019
BaP	annual mean	0.0	0.0	0.0	0.0	0.0
NO2	annual mean	5.2	5.2	4.5	4.0	2.2
O3	percentile 93.15	37.3	2.7	0.7	74.3	33.7
PM2.5	annual mean	0.0	0.0	0.0	0.0	0.0
PM10	annual mean	0.0	0.0	0.0	0.0	0.0
	percentile 90.41	0.3	0.1	0.1	0.0	0.0

Table source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/germany

Table 3:

Health impacts

Country	Population (x1000)	Annual mean (PM2.5)	Premature Deaths (PM2.5)	Annual mean (NO2)	Premature Deaths (NO2)	Somo35 (O3)	Premature Deaths (O3)
Germany	83,019	10.10	53,801	17.50	5,996	4,612	3,353
EU27	441,984	11.59	306,725	14.82	40,444	4,343	16,801
Total	622,882	12.48	414,949	15.62	66,412	4,578	20,852

Table source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/germany

The facts presented above in combination with the three main "triggers" made Germany to intensify the policies put in place to control air pollution (Huck, et al., 2021). These triggers include;

- Widespread damage to health, effects due to smog, nature and acid rain caused by air pollution
- The growing opposition to the country's growing reliance on nuclear energy, and;

1. The shock of the two oil crises, in 1973 and 1979. (see: (Weidner & Mez, 2008))

With nitrogen oxide emissions being one of the main concerns, the targeted sectors to achieve its reduction were the transport sectors and the stationary installations (BMUB, Internetseite des Bundesumweltministeriums, 2017 & (Wehrmann, 2019)). According to (IQAir, 2022), the main sources of air pollution in Germany are anthropogenic. Thus, in addition to emissions from road traffic, emissions from power stations, industrial processes, heating with fossil fuels, agriculture and waste treatment constitute the main sources of air pollution in Germany (See: (IQAir, 2022))

In general, the German government considered four pillars in developing the strategies to control air pollution. These include;

1. Defining air quality standards
2. Determining emission limit values based on state-of-the-art technology
3. Regulating products
1. Defining emission reduction commitments (see: (BMUB, Internetseite des Bundesumweltministeriums, 2017) & Breeze Technologies, 2021))

Based on these pillars, the framework for addressing air pollution - put differently, to achieve improved air quality - was developed. This is discussed in section 3.1.3 below.

3.1.3 Review of Institutional Framework on Improving Air Quality in Germany

Starting this section with some facts and figure will give more insight to the discussion under this sub-heading. The German Partnership for Sustainable Mobility (2015) gave the following facts and figures on Transport in Germany as follows:

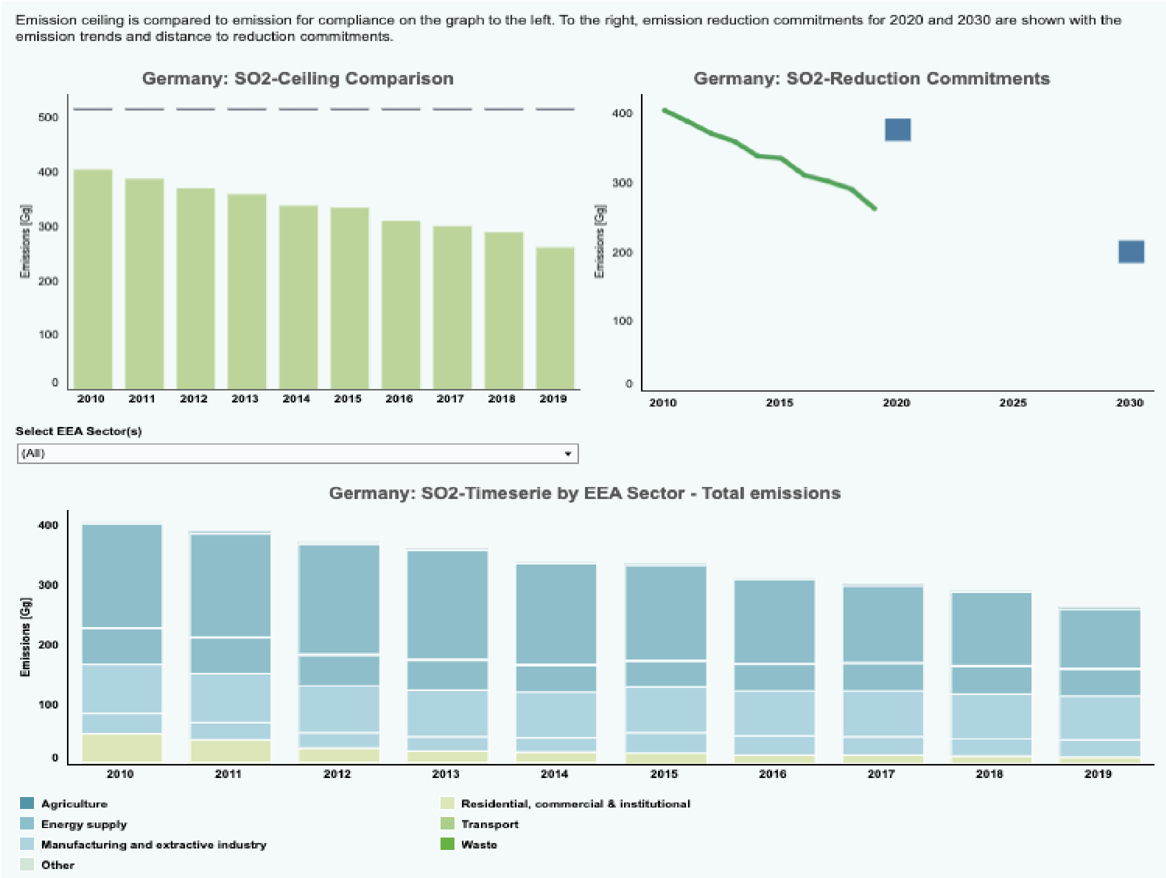
- In 2015, more than 42 million cars (equivalent to 541cars per 1000 inhabitants) were registered in Germany.
- About 70 percent of freight traffic volumes are carried on the road, followed by rail with a share of 17 per cent.
- Lorry toll rates in Germany vary between €0.14 and €0.29 per km depending on environmental performance.
- In Münster about 38 percent of all trips are done by bike; the average cycling share in German urban areas is over 10 per cent.
- A single trip by public transport costs €2.70 in Berlin and Munich and €3.10 in Hamburg.
- Pollutant emissions from transport were reduced significantly in the last 20 years: carbon monoxide (CO) by 90 per cent, polycyclic aromatic hydrocarbons (PAH) by 90 per cent, benzene by more than 95 per cent, nitrogen oxides by 90 per cent and particulate matter by 70 per cent.

In recent times, a comparison of the facts and figures provided by The German Partnership for Sustainable Mobility (2015) shows the following:

- The total number of cars registered in Germany as of 1 January 2022 increased to over 48.5 million cars (Bekker, 2022)
- In 2021, total quantities of products carried by rail transport and road transport were 357,564 and 3,107,972 in 1000 tonnes, respectively. (Goods Transport - German Federal Statistical Office, 2022)
- Forecast values for each air pollutant as presented by (European Environment Agency, 2021) are shown in Figure 11. Also, Table 4 shows the period when Germany met some of the pollutant emission ceilings set by the EU.

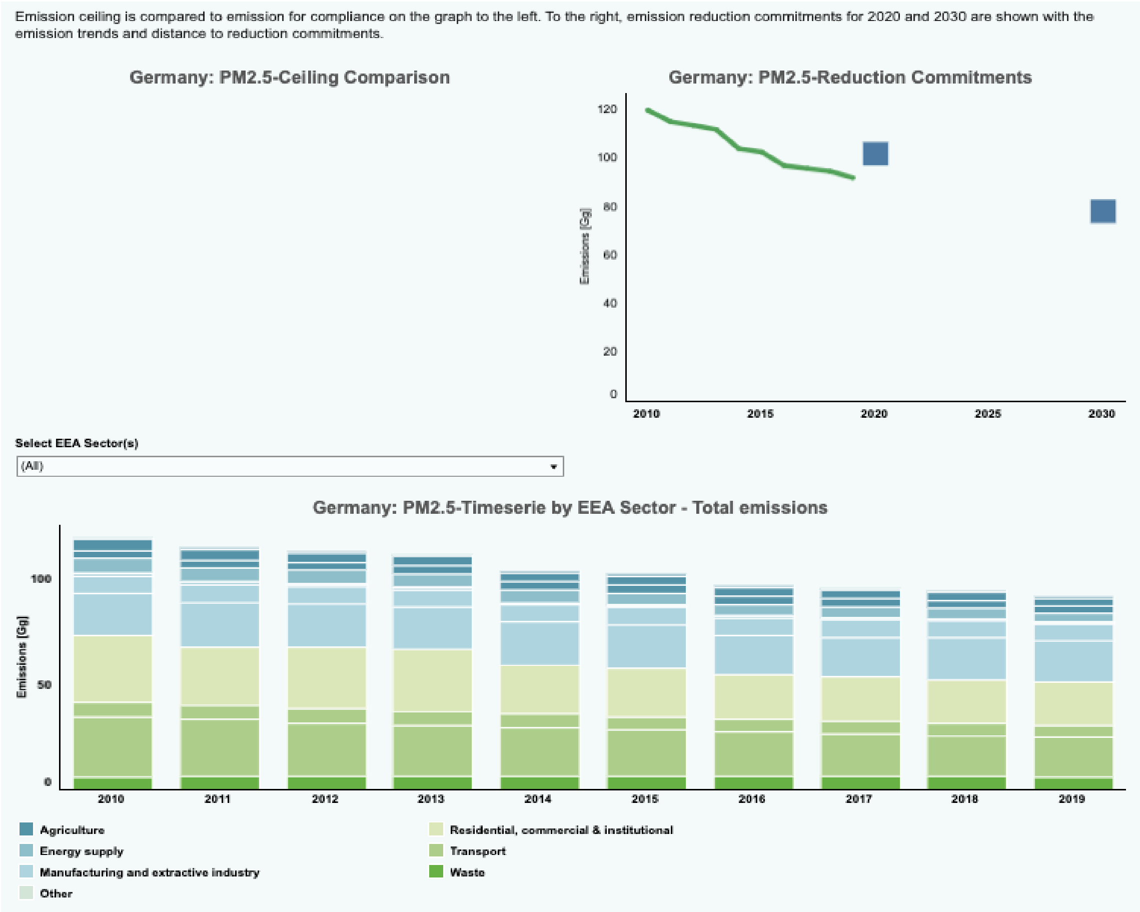
Figure 11: German Air pollutant emissions trends and comparison with the EU emission ceilings|| sector-by-sector emissions

Figure 11a: Sulphur dioxide (SO_2)



Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/germany

Figure 11b: PM2.5



Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/germany

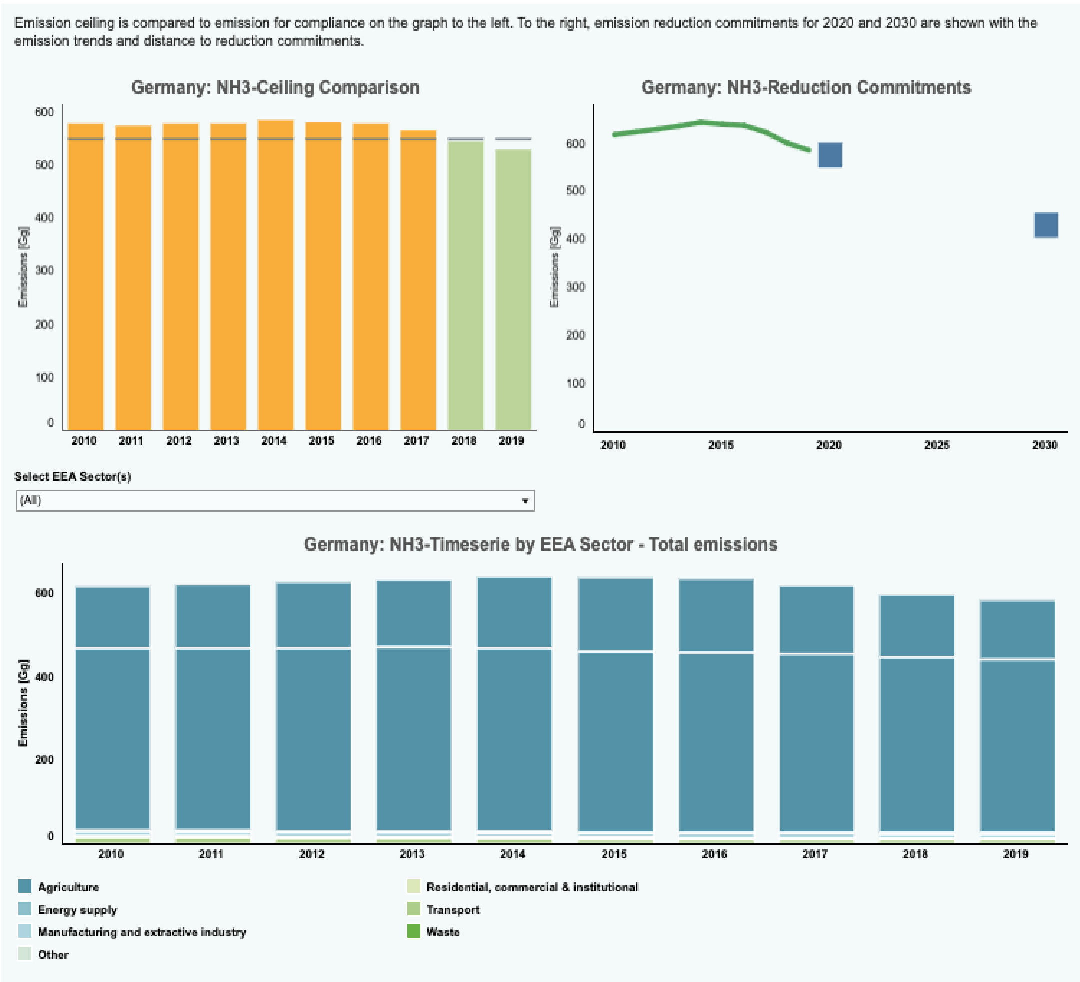
Figure 11c: Nitrogen Oxide (NO_x)

Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/germany

Figure 11d: non-methane volatile organic compound (NMVOC)

Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/germany

Figure 11e: Ammonia (NH3)



Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/germany

Table 4: Germany meeting the EU emissions ceilings

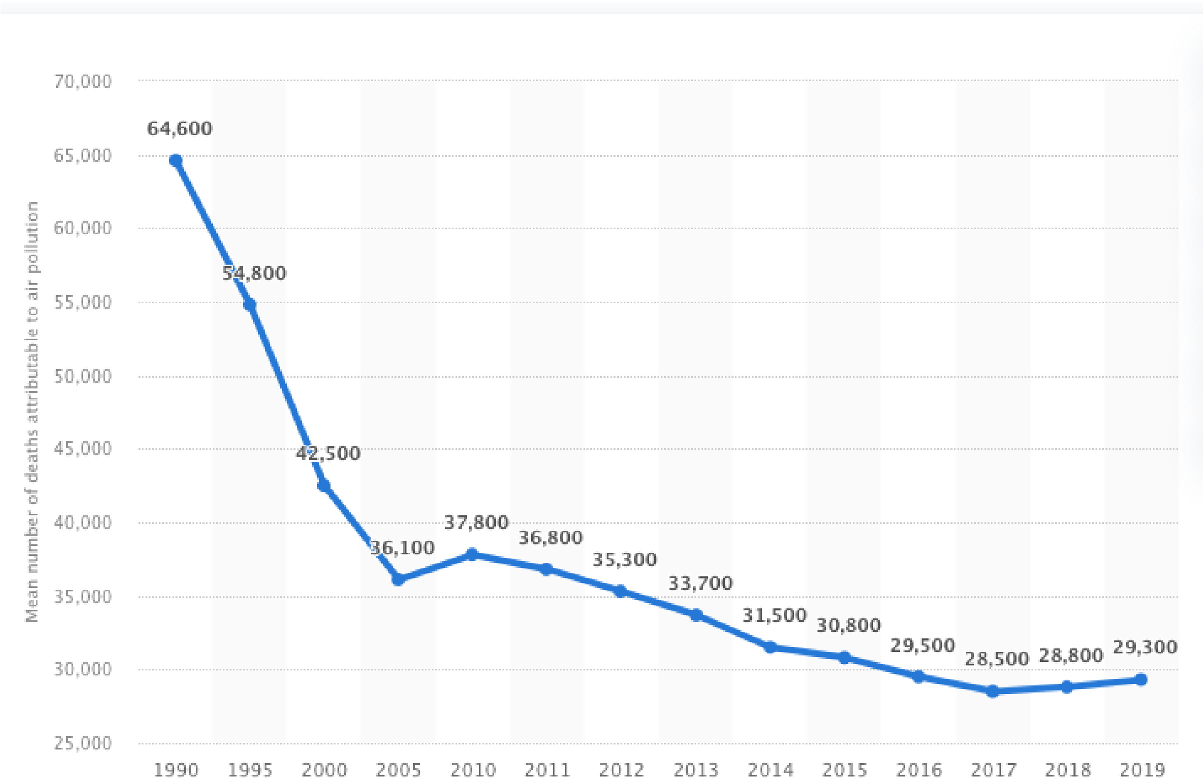
Meeting emission ceilings										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NH3	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓
NMVOC	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓
NOx	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓
SO2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/germany

Checking some of the future facts and figures as well as the graphical representations of German air pollutants give the impression that the German operates an improving framework concerning improving air quality.

Only from a few decades ago has Germany started to experience reduction in air pollution (German Partnership for Sustainable Mobility, 2015). Figure 12 shows the decline in the death attributed to air pollution in Germany as presented by (Tiseo, 2022). In general, improving air quality in Germany follows the success implementation of technologies (such as flue-gas desulfurization, electrostatic precipitators, and catalytic converters), cooperation on an international level (to tackle the long-distance transport ability of pollutants), the use of post-combustion patent (to focus on SO2 and NOx pollutants), dedication to using database that tracks patents and their effects on the environment (e.g. European Patent Office (EPO)), and their policies as regards air quality (see (Anderson, 17), (German Partnership for Sustainable Mobility, 2015)).

Figure 12: Number of Death attributed to Air Pollution in Germany



Source: Statista, 2022

The framework with which the German State improves Air Quality is discussed in detail as given by (German Partnership for Sustainable Mobility, 2015). It follows the following important headings;

1. *Policies for Healthy Environment:* the policies cover four main areas which include;
    a. the German Government's policy in the transport sector (as well as in stationary installations) and the agriculture sector to address additional air pollutants that still poses great threats from the activities of these sectors, that is, nitrogen oxides and ammonia, respectively. The approach used to formulate and implement these policies are to lay down the standards of environmental quality, product regulation, setting emission thresholds, and giving emission reduction requirements based on the capacities of the best available technology.
    b. Provision of important policy instruments for clean air. These instruments include the Federal Emission Control Act and Implementation Ordinances, The Technical Instructions on Air Quality Control (TA luft), Amendment to

Ordinance on Small Firing Installations (1. BImSchV), Implementation of the directive on industrial emissions, and Transboundary air pollution control policy.

   i. *Federal Emission Control Act and Implementation Ordinances*: To prevent harmful effects caused by air pollution, noise, vibration, and similar phenomena.
   ii. *TA Luft*: For citizen and environment protection from unacceptably high pollutant emissions from installations
   iii. *1. BlmSchV*: To reduce particulate matter emissions from small firing installations e.g., stoves and tiled stoves.
   iv. *Directives on industrial emissions*: To achieve the targets on air improvement.
   v. *Transboundary air pollution control policy*: To have air pollution control measures that work both at European and International levels.

c. Vehicle emission standards in Germany and the EU: this set of policies set limits for emissions of carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and particulates, and over the years, the limit gets tightened. Although the standards are set at EU levels, Germany is dedicated to meeting the standards set. (See: The International Council on Clean Transportation)
d. The Right for Clean Air: following the EU law on the recognition of the right for clean air, organisations such as The German Environmental Aid (Deutsche Umwelthilfe) with other European NGOs have over time advocated for improved air quality, campaigns on human health and climate impacts of air pollutions have been undertaken to push more the right for clean air.

2. *Clean Air Management:* this summarises how the German system monitors and targets air pollution through adequate planning procedures. Generally, three perspectives which include the administrational, technical-professional and municipal are crucial in the planning processes. The planning processes include:
   a. Measurement of Air Pollution: in Germany, the German Federal Environment Agency and Germany's Lander (federal states) handle the air monitoring network. Aspects focused on include the measurement of local air pollution, measurements of current pollution situation, and acquiring information of measuring sites.
   b. Database: these two responsible agencies record air quality data several times in a day to closely follow the current concentrations of air pollutants in Germany.
   c. Linking emissions calculation with transport demand data at street level: this is done using the Handbook of Emission Factors for Road Transport (HBEFA) which helps to present emission factors per kilometre derived from a wide range of parameters to choose from.
   d. Modelling air pollutant and Greenhouse gas emission: this shift focus away from large scale measurement of transport emissions through the use of rough estimates to having internal and external emission models that are useful to

calculate important air pollutants and greenhouse gases emissions both at the local (i.e., road section and intersection) and system (e.g. national transport system) levels. Important tools used in this respect include software for modelling at macro level (e.g., VISUM, IMMISem) and software for simulating at micro levels such as PTV VISSIM. While the former ensures reliable and proper calculation of emission and the impacts on local environments, the latter is used to evaluate emissions based on the simulation of single vehicles and applying related measurements for vehicles that are of different modes.

   e. Air pollutant concentration level modelling: this is done to know the current level of pollution concentrations that the people as well as the environment are exposed to which is useful for reporting and carrying out impact assessment of adopted air quality strategies.
   f. Creating plans for clean air in cities: air quality plans are done at the municipal level in Germany and compiled in all cities. In the case of big cities, the plan is prepared by the municipality and the state environmental agency supervises and controls the process. It is also important to note that air quality plans are prepared every five years.

3. *Taking Action:* some effective measures taken by the municipalities, private business and civil society to improve air quality include;
   a. Creating Low Emission Zones in Germany: as vehicle traffic has been identified as a major factor of air pollution by increasing the level of particulate matter in urban areas, many cities in Germany have designated low emission zones (LEZ). LEZ are urban areas where emission limit values are often exceeded thus, only low emission vehicles are allowed. Currently 69 German cities have LEZs, and 4 cities have Diesel ban (Hummel, 2022). Usually there are some city characteristics that qualify a place to be a low emission zone e.g., a place near the city rail ring. Vehicles are categorised into four groups depending on their emission rate and windscreen stickers with different colours are used to differentiate the categories. Permission of any category to the low emission zone remains with the local authorities.
   b. Campaign against the use of diesel without filter: this campaign was done majorly to equip all diesel vehicles and machines with diesel particle filters to ensure human health and climate protection. The campaign involved the joint participation of German organizations like Deutsche Umwelthilfe, Verehsclub Deutschland, BUND and NABU cooperate with European partner NGOs. A couple of the solutions provided is the use of buses with particle filters and Selective Catalytic Reduction (SCR) system, to enhance the share of bicycle traffic, among others.
   c. Joint forces for clean air in the city of Bonn: the air quality plan basically help to reduce the high nitrogen dioxide and particulate matter pollution in cities where the permitted limits of these substances are exceeded such as the city of Bonn.

d. Shore-to-ship electricity supply: here, the solution was to encourage the use of plug-in connection for the supply of vessels with power from a shore-based shore majorly to allow independent decision making of on-board personnel on necessary actions without power supply interruption. A good example of the local energy utilities used is the eco-power used in Lubeck.
e. Assessing the effectiveness of air quality and transport measures: this involves the assessment of the effectiveness of the measures to improve air quality. This is a quite difficult thing to do as many of the measures are due to varying meteorological conditions. However, assessments can be done based on three other approaches which include monitoring data, scenario modelling, or a mix of these approaches. Measures focused on include; Low Emission Zones (LEZ), Environmental Traffic Management (ETM), Truck transit bans, and Speed limits of 30 or 40 km/h on major roads.

4. Technology and Innovation for Clean Air: to target low emissions, some technological innovations were incorporated and some innovative technologies which are more sustainable modes were used to replace car and lorry trips e.g. innovative logistics concepts and public service vehicle fleets technologies. Importantly, there was an improved marketability of electrified vehicles as a result of the introduction of advanced vehicle electrification products. A list of some the latest technologies for hybrid cars and electric vehicles include:
    a. Vehicle sound generator to protect pedestrians
    b. Scalable and compact 12 Volt DC/DC converters for Start/Stop Vehicles
    c. High-Voltage Inverter with the Dual-Side, Liquid-Cooled Delphi Power Switch
    d. High Voltage Connection Systems for Auxiliary Modules and Devices
    e. High Voltage Power Connection Systems
    f. Battery Pack Components
    g. Chargers and Charging cables

   In addition to the introduction of these technologies, some other measures considered include;
    - Introduction of Emission Measurement Devices: the leading device in this category is the Periodical Technical Inspection developed by Maschinenbau Haldenwang GmbH to measure safety and relevant components of emissions for vehicles.
    - Exhaust-Gas After Treatment: In Germany, exhaust-gas after-treatment system for diesel usage has been supplied by HJS Emission Technology GmbH & Co KG to protect humankind and the environment from the dangerous fumes of diesel.
    - Introduction of Fuel Cell-Hybrid Buses in the Rhineland: the aim of this project was to ensure the provision of energy efficient and environmentally friendly as well as flexible public transport in order to achieve a sustainable zero-emission future. This project was adopted by the Cologne regional transport agency (RVK) in regular route service first in 2011.

- Introduction of Cargotram in Dresden: this was introduced in 2001 to replace three truck journeys on each ride.
- introduction of the world's first hydrogen fuel cell powered waste collection vehicle in Berlin: this has helped to reduce the fuel consumption during waste collection by up to 30% in 2015.
- Use of Urban Hub "Bentobox" to ensure sustainable urban freight delivery in Berlin.

BUVM means the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

3.2 FRANCE

3.2.1 Introduction

Although France is one of the countries with the leading roles in monitoring climate change and pollution levels, it ranks worse in terms of air pollution when compared to other neighbouring west European countries such as the United Kingdom, Spain, Switzerland and Germany (IQAir, 2022). France air pollution challenge seems mild in an overall context, however, some of the cities in France have some comparatively poorer air quality ratings which is characterised by high PM2.5 reading of 38.4 - 45.3 µg/m³ in 2019 in some certain period of the year, thus, posing great threats to vulnerable demographics and exposing France to impending European Commission fines. Majority of the cities that exhibit this high level of PM 2.5 are located in the northern region of France, thus, taking higher share of the sources of France air pollution problem (See: (IQAir, 2022)).

Tables 5a and 5b show the percentage of France urban population exposed to concentrations above the EU standards for some of these air pollutants (that will be discussed in detail in the following section) and the health impacts of these pollutants as presented by (European Environment Agency, 2021).

Table 5a:

Air pollution country profile

Exposure - France

The table below shows the percentage of urban population exposed to concentrations above EU standards for selected air pollutants such as PM10, PM2.5, O3, NO2 and BaP for the years 2015-2019.

		2015	2016	2017	2018	2019
BaP	annual mean	0.0	0.0	0.0	0.0	0.0
NO2	annual mean	4.6	2.7	2.5	2.5	1.9
O3	percentile 93.15	13.0	5.3	3.6	49.6	17.4
PM2.5	annual mean	0.0	0.0	0.0	0.0	0.0
PM10	annual mean	0.3	0.3	0.3	0.3	0.3
	percentile 90.41	2.6	0.3	1.2	0.4	0.9

Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/france

Table 5b:

Health impacts

Country	Population (x1000)	Annual mean (PM2.5)	Premature Deaths (PM2.5)	Annual mean (NO2)	Premature Deaths (NO2)	Somo35 (O3)	Premature Deaths (O3)
France	65,040	9.50	29,775	15.20	4,974	4,788	2,053
EU27	441,984	11.59	306,725	14.82	40,444	4,343	16,801
Total	622,882	12.48	414,949	15.62	66,412	4,578	20,852

Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/france

3.2.2 Main causes of air pollution, reasons behind their emissions and air pollution country fact sheet of France

(IQAir, 2022) give details on the classification of air pollutants in France – they are two classifications of chemicals that constitute air pollutants in France namely Primary groupings of air pollutants and secondary groupings of air pollutants.

Primary Groupings of Air Pollutants

The primary pollutants are made of up various forms of carbon and sulphur oxides that are not chemically bonded e.g. carbon monoxide (CO) and Sulphur dioxide (SO_2), and pollutants that are caused by incomplete or improper combustion of fossil fuels and other organic matter e.g., volatile organic compounds (VOCs). Lastly in this grouping, we have particulate matters PM10 and PM2.5. Primary pollutants are basically emitted directly into the atmosphere through activities such as agriculture, heating, emissions from vehicles and industrial activities.

Secondary Groupings of Air Pollutants

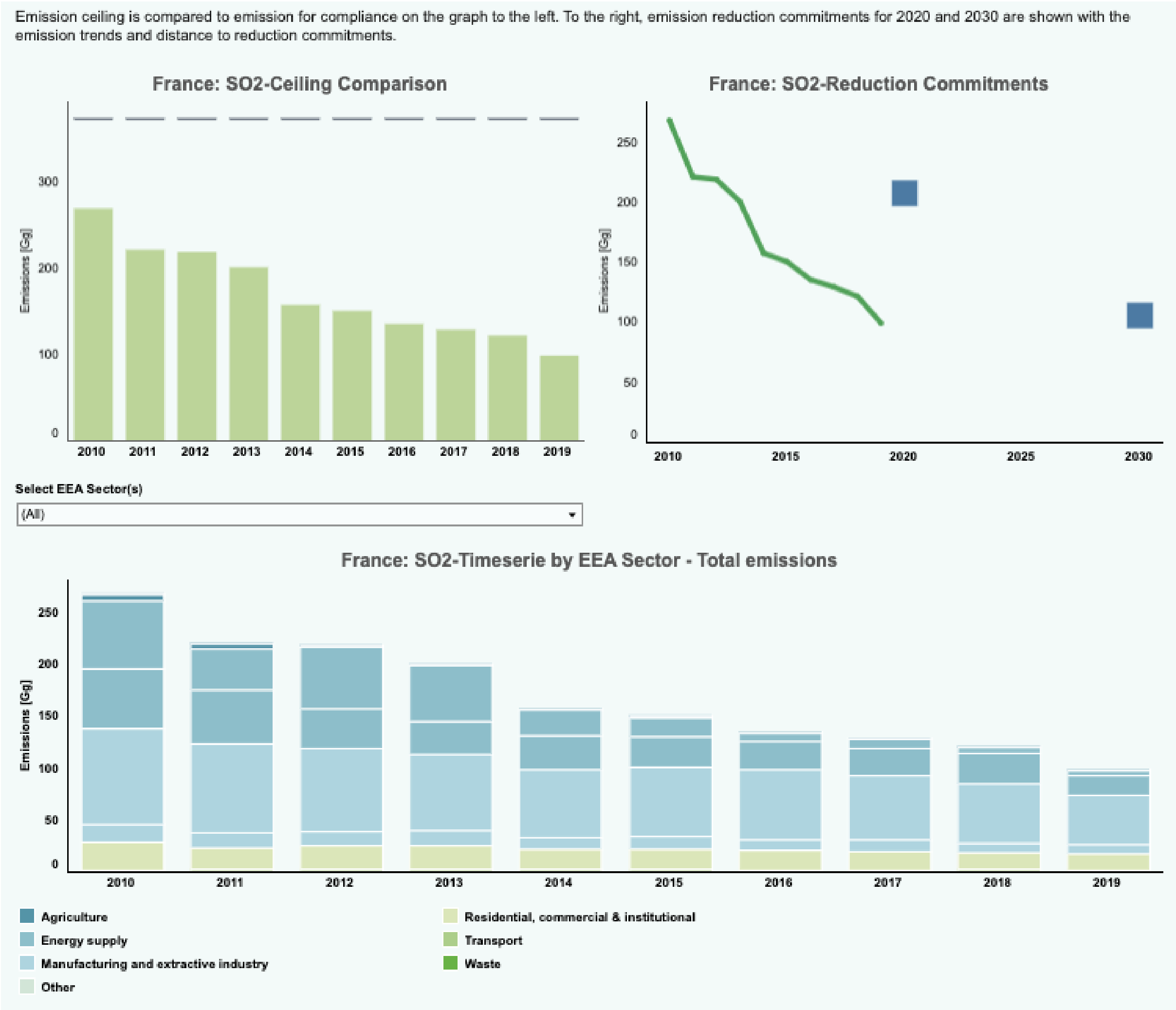
These include pollutants like nitrogen dioxide (NO_2), ozone (O_3) and other variety of secondary particles. The secondary pollutants are always as a result of chemical reactions of primary pollutants.

It is worthy to note that that some of these pollutants overlap between these two categories such as sulphur dioxide and nitrogen dioxide.

Majority of the air pollutants in France come from vehicles, heating of homes and businesses. Other sources include activities from the agricultural sector as well as industrial sector. A diagrammatic representation of these pollutants is presented under Figure 13.

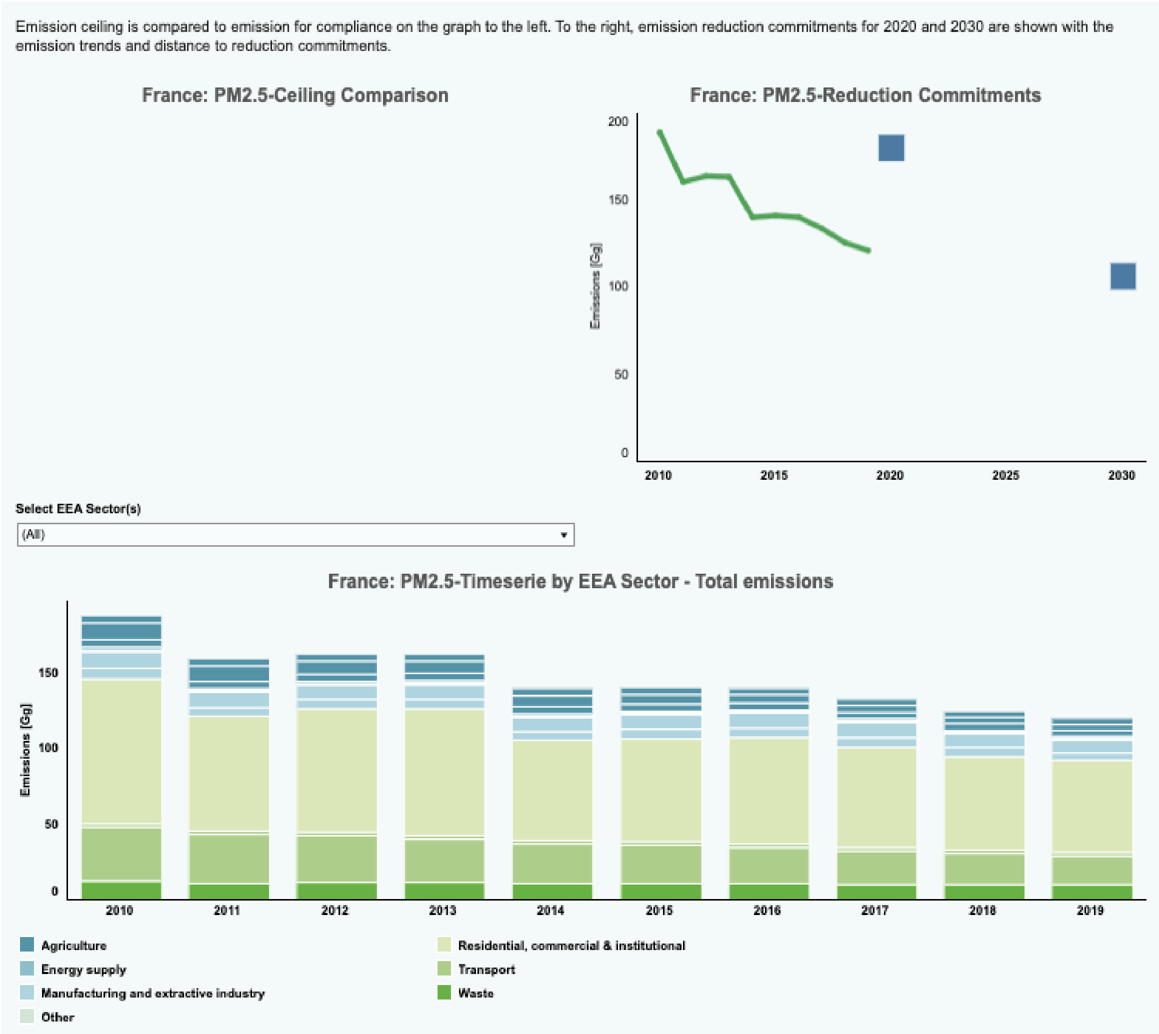
Figure 13: French Air pollutant emissions trends and comparison with the EU emission ceilings|| sector-by-sector emissions

Figure 13a: Sulphur dioxide (SO_2)



Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/france

Figure 13b: PM2.5

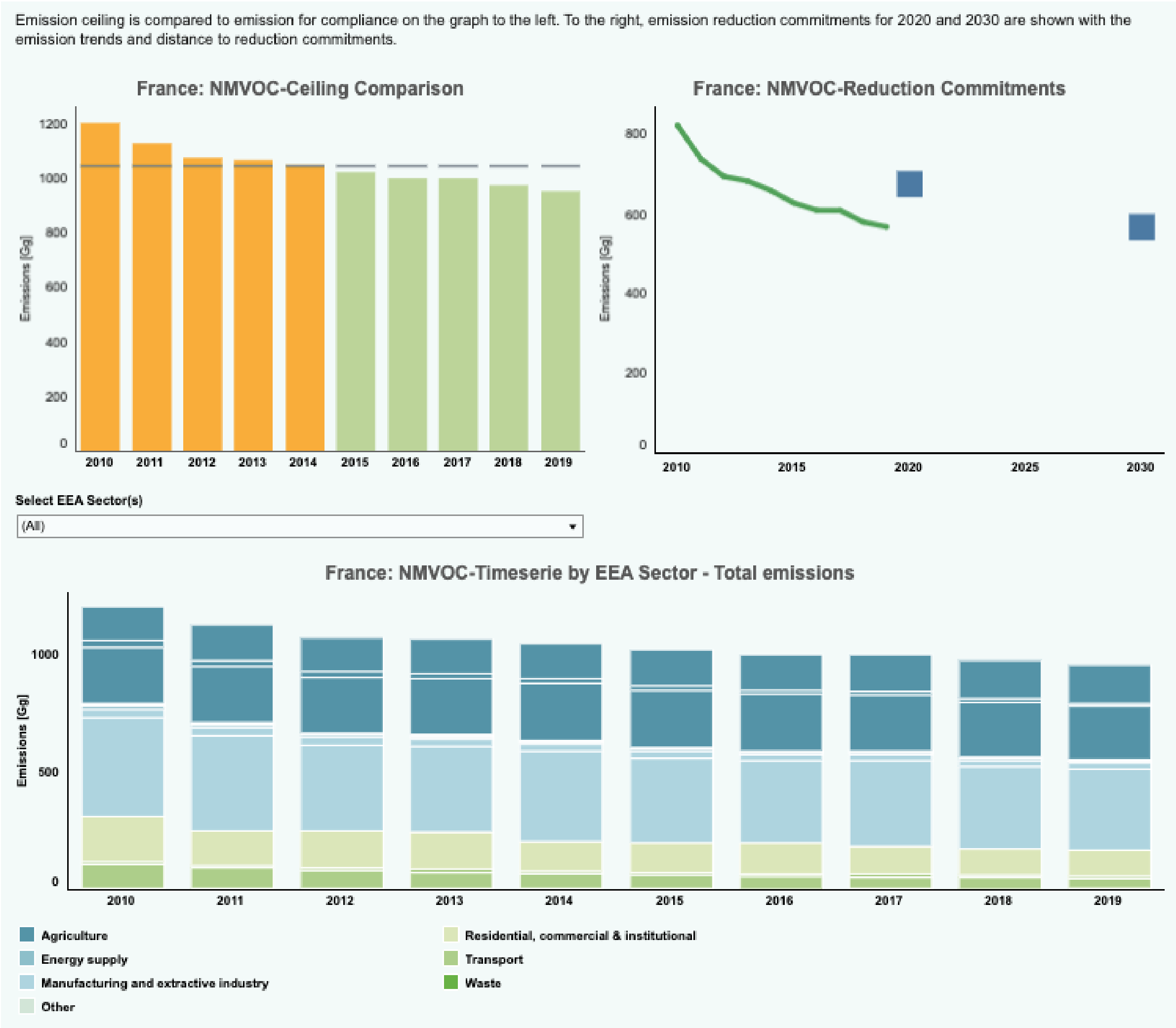


Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/france

Figure 13c: Nitrogen Oxide (NO_x)

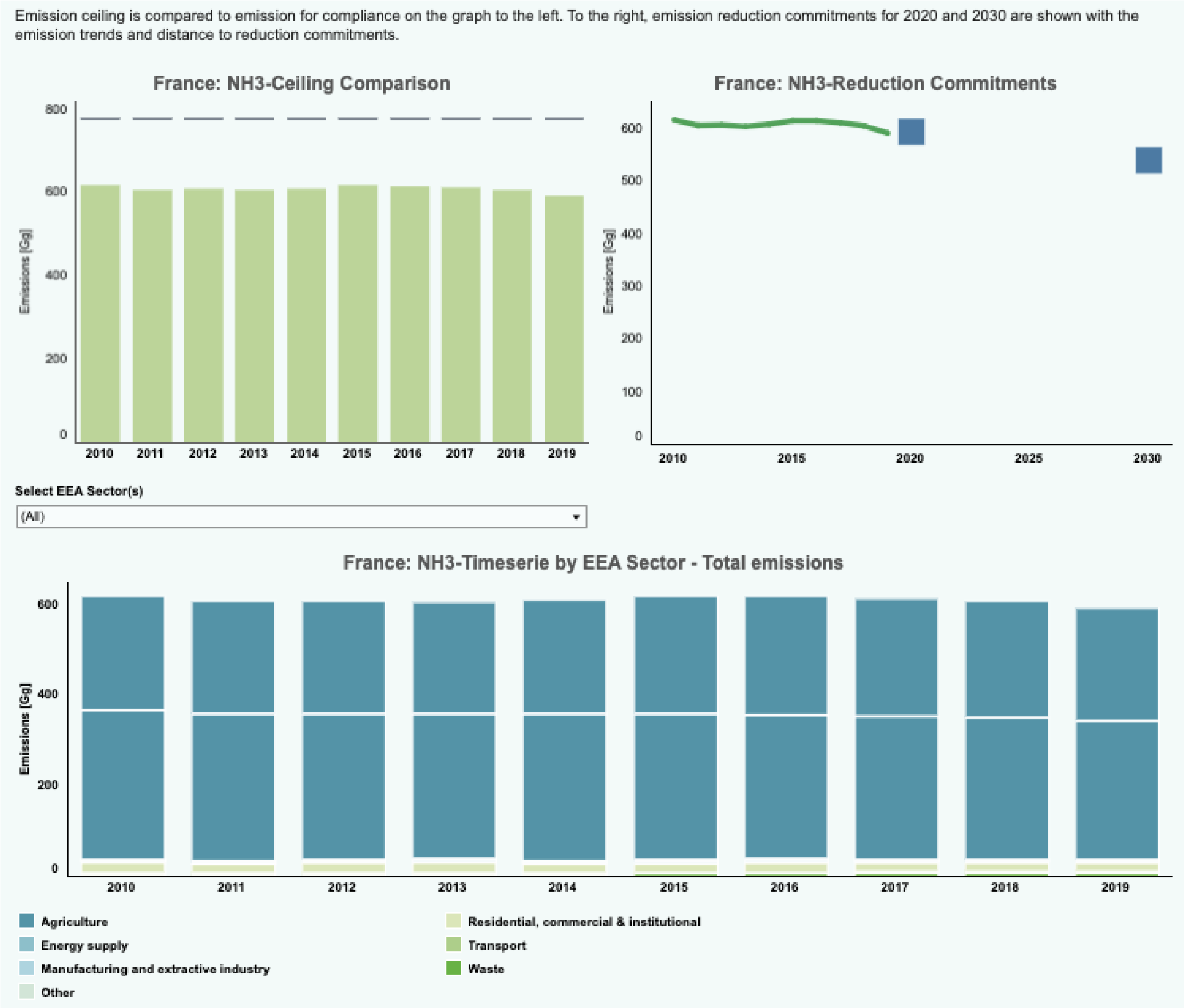
Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/france

Figure 13d: non-methane volatile organic compound (NMVOC)



Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/france

Figure 13e: Ammonia (NH3)



Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/france

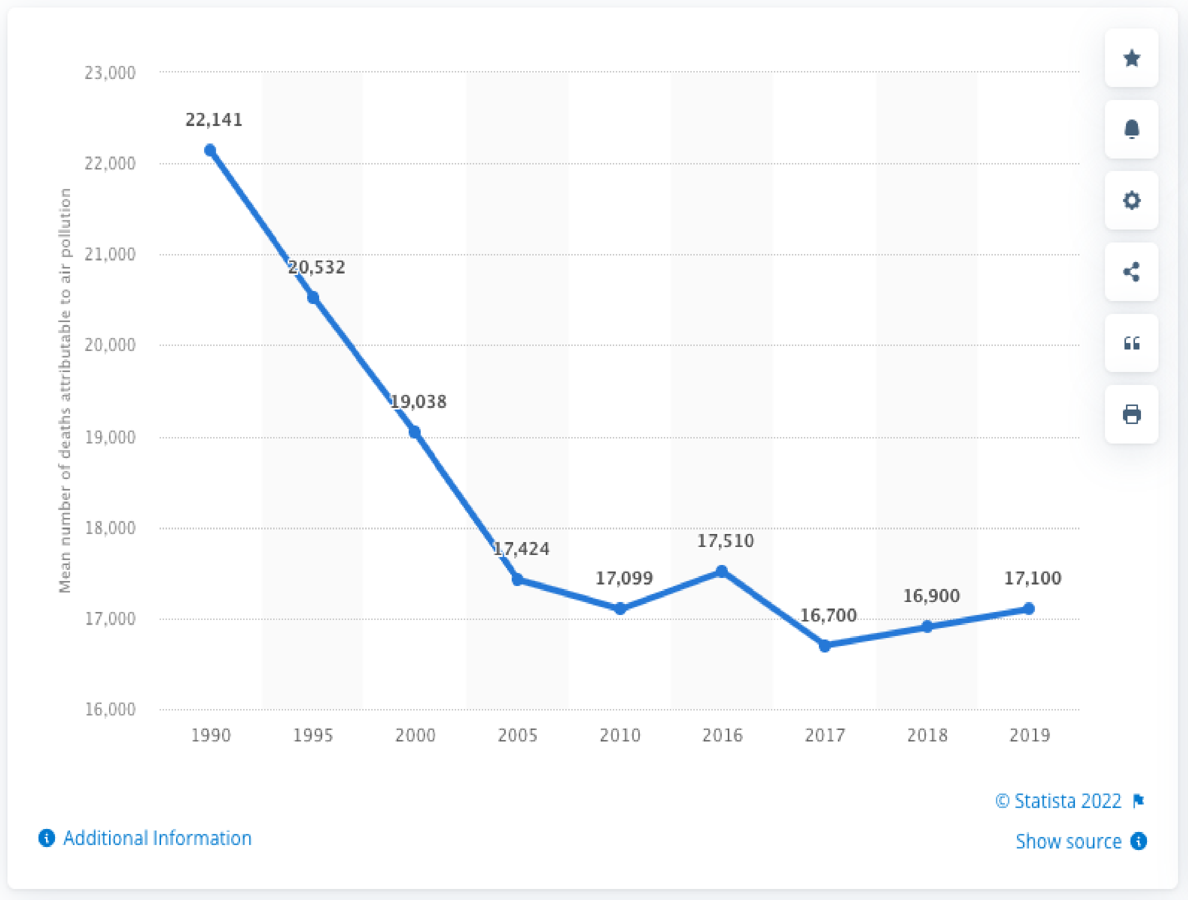
Table 6: France meeting the EU emission ceilings

Meeting emission ceilings										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NH3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
NMVOC	✗	✗	✗	✗	✗	✓	✓	✓	✓	✓
NOx	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓
SO2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/france

As discussed in the introduction, the overall air pollution in France appears to be at a good level except for some cities located in the northern France. The major pollutant characteristic of these cities is the high PM2.5 level. This claim is justified by the relatively declining trend of other pollutants as shown in Figure 13 and the early meeting of some of these pollutant emission ceilings (except PM2.5) as presented in Table 6. Furthermore, in the space of 29 years, Figure 14 presents how the death toll attributed to air pollution in France declined over time. Thus, it is important to consider the institutional framework for improving air quality in France. This is discussed in section 3.2.3

Figure 14: Number of Death attributed to Air Pollution in France



Source: https://www.statista.com/statistics/827689/air-pollution-deaths-france/

3.2.3 Review of Institutional Framework on Improving Air Quality in France

The framework with which the French government operate to improve air quality revolves around the following:

- Introducing more energy efficient systems into country-wide renovation of buildings and houses;
- Decarbonizing the fuel industry;
- Total removal of diesel-based fuels by 2024;
- Increase use of green technologies such as hydrogen and biofuels;
- Increase efforts in recycling;
- Creation of low emission zones, and;
- Combatting food wastage. (See **(**IQAir, 2022))

(Climate and Clean Air Coalition, 2021) discussed in detail the actions taken by the French government under the above-mentioned ways of improving air quality in France. These ways are discussed under the following headings:

1. Partner with Climate and Clean Air Coalition (CCAC) in 2012: by joining CCAC in 2012, France set on a joining of flattening the climate change curve and building a

healthier planet by reducing short-live climate pollutants and carbon emissions. This was done with the belief that solutions to address climate change also help to improve air quality. Bruce Poirson, the former Secretary of State to the Minister for an Ecological and Inclusive Transition said the following in 2019:

"Today, we know that by fighting climate change we also improve air quality, and the *benefit is twofold. That is why we want to mobilize all the tools, all the stakeholders,* to greatly reduce emissions of greenhouse gases and atmospheric pollutants together,"

Some of the prominent actions taken by France in partnership with CCAC include
(a) *Transitioning the cooling sector:* the transition involves the launch of the CCAC's Efficient Cooling Initiative in partnership with Japan, United Nations Environment Programme, Institute for Governance & Sustainable Development, and other countries and partners. France also launched an agreement called Biarritz Pledge with the aim of undertaking ambitious measures to improve energy efficiency in the cooling sector.
(b) *The first pillar of the France Relance:* The France Relance was released in 2020 by the French Government as a recovery plan to address the economic consequences of the COVID-19 pandemic. However, its first pillar which takes 30% of the total fund was solely dedicated to green transition – this includes investment for energy-efficient renovation programmes for private and social housing and public buildings, investment for sustainable mobility, investment for decarbonisation, and investment for green technologies which include hydrogen, biofuels, and recycling.
c) *CCAC-led BreatheLife Campaign:* Paris became a member of the CCAC-led BreatheLife Campaign which was set up as a global clean air initiative with the mission to combat climate and health effects of air pollution. Some notable measures that are planned to be taken by Paris include the reduction of the number of cars in the city by half, ban of diesel vehicles by 2024, and make Paris a more walkable city. In this campaign, Paris aims to set good examples for other cities in France. Other measures introduced by France include charging taxes for owning a vehicle, being among the few European countries that pay the highest bonuses for purchasing a new zero-emission vehicle and giving incentive for replacing polluting vehicles.

2. Low emission zones (LEZs): creating LEZs is one of the ways used by the French Government to improve air quality. Paris, Lyon and Grenoble are the major cities spearheading this method of controlling air pollutants. LEZs are planned to be extended to other cities that regularly exceed air pollution limits.

3. Prioritizing Climate Finance: in 2019, the French President announced the doubling of France contribution to Green Climate Fund. From 2018 to 2020, the French Government provided an annual sum of €5 billion to developing countries through the French Development Agency AFD to finance climate solutions.

4. Law on Energy and Climate: the 2050 carbon neutrality law of France was passed in 2019 (but updated in 2020) as part of its commitment to the 2015 Paris Agreement. The objective of the law is to reduce emissions to 1/6th of 1990 emission levels.

5. Counteracting food waste and loss: to achieve this, an Anti-Waste Law for a circular economy was passed in 2020 with the aim of halving food waste in the retail and catering sectors in 2025, and in other sectors in 2030.
6. Sector-by-Sector based solutions: the French government also considered some sector-specific solutions and the sectors considered include agriculture, waste, cooling, and transport sectors.
    a. Agriculture: improving air quality strategies, plans, and projects done in the agricultural sector include:
        i. Availability of feed-in-tariffs for electricity produced from biogas. This was available from 2011 to 2016 for power plants using vegetable and animal agricultural waste.
        ii. 2015 National Low-Carbon Strategy to reduce agricultural emissions to 12% by 2030.
        iii. Change of the feed-in-tariffs to feed-in-premiums in 2016 with the aim of granting a premium tariff to renewable electricity producers of larger biogas plants.
        iv. Setting up of tariff rebate of up to 40% on the cost of connecting biomethane facilities with distribution network in 2017.
        v. Setting up of the 2017 Plant Protein Plan by a French consortium of enterprises committed to lowering France's protein dependency. The aim of the plan is to accelerate the development of the alternative and plant-based protein sector while increasing the health and nutrition of livestock.
        vi. Offering further financial incentives such as grants and technical aid by the environmental and sustainable development agency (ADEME) for biogas development. The incentive also includes the exemption of biogas and biomethane mixed with natural gas from domestic consumption tax.
        vii. Project MONDFERENT (Methane emissions for cattle in France) at the National Agronomic Research Institution (INRA) was created to refine the emissions calculations for enteric fermentations and cattle manure management for national inventory.
        viii. 2018 Methane Energy and Nitrogen Autonomy Plan to cut emissions by reducing the overall use of inputs and increase the use of organic fertilizers.
    b. Waste: in the waste sector, the French government employed the following methods to improve air quality:

i. From 2012, the amount of private sector companies' organic waste allowed to be sent to landfills was reduced by the Waste Management Enforcement Law. In 2020, the scope of the law expanded to cover all companies that produce organic waste of over 10 tons annually. The companies are required to recycle their waste.
ii. Since 2016, it has been the responsibility of companies and administrative bodies to sort their waste. The French Government aims to also have a universal sorting of household organic waste in 2025.
iii. France topped the rank in the 2017 Food Sustainability Index as a result of the 2016 supermarket prohibition on throwing away unused foods. France was the first country in the world to do this.
iv. The 2018 Agriculture Bill required supermarkets to donate unused food to encompass institutional catering. In the same year, a waste reduction plan was also established for the catering sector and every restaurant was provided to-go boxes for uneaten foods.
v. The 2019 National Programme on Food and Nutrition was launched to fight against food waste and ensure sustainable and healthy diets. Investments to also improve environmental performance of agrifood industries were made. Lastly, energy efficiency certification was encouraged.
vi. The 2020 Multiyear Energy Programme that includes a 10-year energy plan mandating that biogas account for 7 – 10% of 2030 gas consumption was adopted. During this time, provision of subsidies to encourage renewable gas production was also made available by the French Government.
vii. Introduction of the 2020 Anti-waste law for a circular economy reinforced the penalties for intentional destruction of unsold but still edible food and set up mandatory procedures to monitor and control the quality of food donation. Also, a national "anti-food waste" label was made available to any legal entity contributing to the national objectives.

c. Efficient cooling: various approaches of improving air quality in the cooling sector include;
   i. The 2015 Act on Energy Transition for Green Growth provides measures to reduce the energy consumption of buildings and homes and put in place tax credits and interest-free loans for individuals and companies. It also requires energy efficient upgrades when renovating buildings and homes.
   ii. The 2019 Financial Bill which was adopted in 2018 provides tax credits and incentives for companies to install Hydrofluorocarbon-free (HFC-free) refrigeration and air conditioning equipment.

iii. In 2019, the Law on Energy and Climate included several measures against thermally inefficient homes. These include requiring homeowners to do an energy audit before renting or selling to let renters or buyers know the expected energy cost (this was adopted in 2022). Also, in 2021, homeowners were not allowed to raise rent until they have done energy efficient renovations. Lastly, the law plans to ban homes with extremely high energy costs from being rented starting from 2023.

iv. In 2020, the French Government included €6.7 billion in the recovery plan "France Relance" to provide adequate insulation for buildings to adapt to summer temperatures and heat waves. This provision is made to houses during renovation.

d. Transportation: the transport sector adopted the following;

i. The 2015 Law on Energy Transmission for Green Growth authorized the French local authorities to establish restricted traffic zones where vehicles must display their emission category according to the special emission stickers issued to each car.

ii. In 2017, among other commitments, France pledged to reduce black carbon emissions from ship's exhaust smoke after participating in the 74th meeting of the International marine Organizations' (IMO) Maritime Environment Protection Committee.

iii. In 2019, the French government allocated €264 million to the ecological bonus budget to purchase almost 42,800 electric passenger cars and almost 8,000 electric light commercial vehicles. The government also provided €395 million in 2020 to purchase about 100,000 electric vehicles.

iv. In the 2019 Orientation Law on Mobilities, 2040 was set as a target to end the sales of new passenger cars and light commercial vehicles using fossil fuels.

v. The Financial Bill 2020 that was adopted in 2019 sets an almost twofold increase of the maximum penalty for new high-emitting vehicles. In 2019, the amount was capped at €10,500 while in 2020, the penalty was €20,000.

vi. In 2020, the recovery plan "France Relance" added several provisions for green infrastructures and mobility. These provisions include cycling and public transit, railway infrastructure, greening of the state's fleet, and incentives for clean vehicles. (See (Climate and Clean Air Coalition, 2021))

3.3 HUNGARY

3.3.1 Introduction

The first contemporary legislation for the preservation of the environment and the natural world was passed in Hungary towards the end of the 19th century. Environmental social movements began to play a larger role in the late 1980s in the opposition to Hungary's state socialist system and the mainstreaming of ecological ideas, in addition to the expanding environmental and scientific concerns. There were certain regions where a comparable environmental dispute upset the populace more, while other places saw less animosity and media attention. The organizational, institutionalized, and civic framework conditions and environmental protection mechanisms all improved with the change in regime. Environmental contamination significantly decreased in the 1990s.

Shifts in money and existential position have shifted focus away from environmental concerns and toward society. Environmental policy gained prominence in politics with the post-1990 government shift. In the 2000s, there was a shift in the dynamics of Hungarian environmental policy, and activities related to spatial planning benefited greatly from the expansion of international organizations in Hungary and the institutionalization of social actors. The 2000s saw a rise in the importance of environmental policy in society. The 'fragmented' nature of environmental issues was the key factor. Widespread social collaboration is the only way to solve the issues given the growth of the Hungarian consumer society.

Although Hungary is well known for its strong economic activities that are centred on export and foreign trade, the large amount of exportation and industrial production taking place in Hungary elevates the level of pollution, thus, majority of the pollution are as a result of anthropogenic activities which result mostly into a rise in PM2.5 levels (IQAir, 2022). The National Public Health Centre also confirmed that the air quality has deteriorated in Hungary due to a high concentration of airborne particles (MTI-Hungary Today, 2021). According to the European standard, several cities in Hungary have been characterized with high PM2.5 level (where some these levels are termed moderate when compared at world level). Miskolc which is the city with the highest PM2.5 of 21.9 $\mu g/m^3$ level is ranked alongside with Várpalota as cities where air quality has deteriorated to unhealthy levels. Air quality in cities like are termed to be dangerous and concentrations of particles are also considered to be high in other twelve cities and towns, including Budapest. (See: (MTI-Hungary Today, 2021); (IQAir, 2022)).

Tables 7 and 8 shows the percentage of urban population in Hungary exposed to concentration of pollutants above EU standards and the health impacts of these pollutants on the population of Hungary, respectively.

Table 7:

Exposure - Hungary

The table below shows the percentage of urban population exposed to concentrations above EU standards for selected air pollutants such as PM10, PM2.5, O3, NO2 and BaP for the years 2015-2019.

		2015	2016	2017	2018	2019
BaP	annual mean	91.1	82.6	11.7	13.2	14.6
NO2	annual mean	1.9	1.9	1.9	1.9	2.1
O3	percentile 93.15	94.0	0.0	52.1	27.3	2.6
PM2.5	annual mean		0.0	0.0	0.0	0.0
PM10	annual mean	1.7	0.0	0.0	1.7	0.0
	percentile 90.41	26.0	2.3	57.4	51.0	2.2

Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/hungary

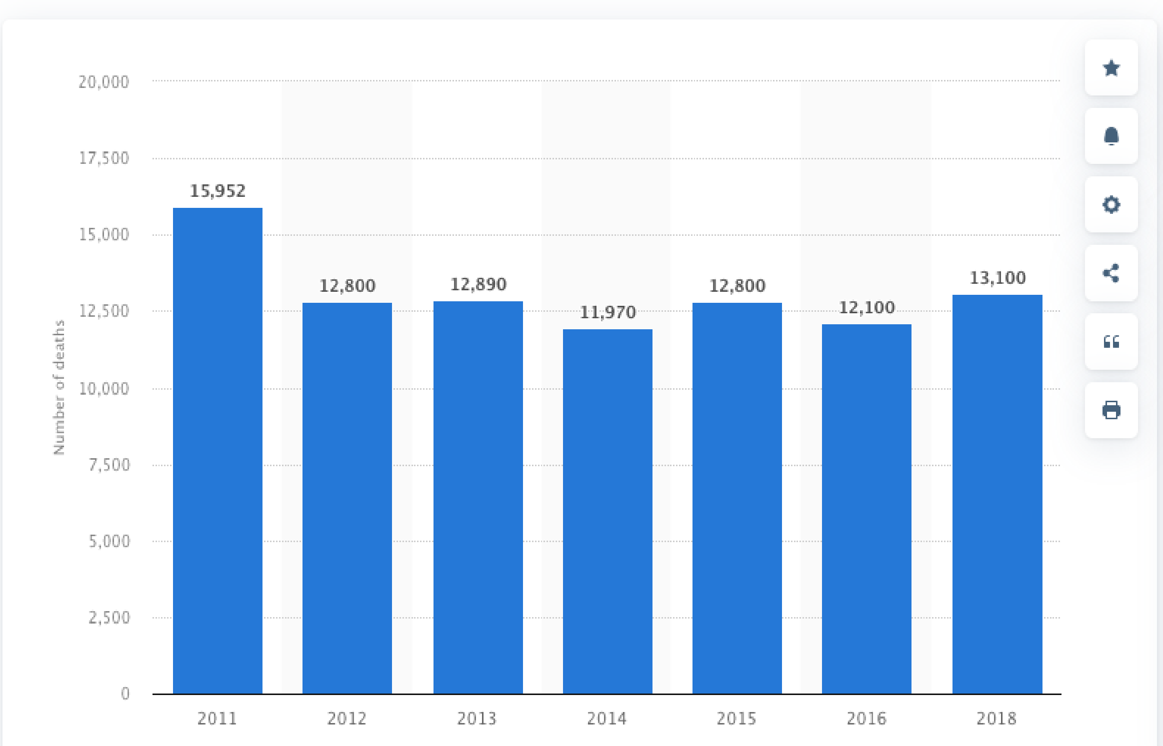
Table 8:

Health impacts

Country	Population (x1000)	Annual mean (PM2.5)	Premature Deaths (PM2.5)	Annual mean (NO2)	Premature Deaths (NO2)	Somo35 (O3)	Premature Deaths (O3)
Hungary	9,772	14.50	10,367	16.60	880	4,473	444
EU27	441,984	11.59	306,725	14.82	40,444	4,343	16,801
Total	622,882	12.48	414,949	15.62	66,412	4,578	20,852

Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/hungary

Figure 15: Number of Death to PM2.5 particle pollution in Hungary



Source: https://www.statista.com/statistics/790010/particle-pollution-deaths-hungary/

3.3.2 Main Causes of Air Pollution in Hungary

(IQAir, 2022) identified several causes of air pollution in Hungary to include the following;

1. Vehicular emissions: these are emissions from millions of cars populating the country. The effect is more pronounced in the rural areas where many vehicles of old engines are being used. The vehicles in these areas are not subject to the more stringent rules that apply to major cities.
2. Heavy-duty vehicles: the fact that Hungary is an exporting country makes the use of heavy-duty vehicles inevitable. These contributes massively to the level of pollutants in the country. Most of these vehicles use diesel fuels as their major source of power and as such contribute a great deal to the emitted pollutants.
3. Chimney Smoke: this is common in the rural areas of Hungary. Hundreds of thousands of the traditional houses of these rural areas use the heats from burning of woods and charcoal as their heating system during winter as well as for cooking and other domestic uses.
4. Power plants and factories: most of these plants make use of coal to supply energy to the numerous homes and businesses in all parts of the country. A common pollutant associated with the operations of these plants is sulphur oxides. In addition to the sulphur contents emitted, the operations of factories contribute greatly to the release of burnt plastic fumes into the atmosphere.
5. Other minor causes: these include pollution and fine particulate matter from construction sites and road repairs, emissions from the heavy machines used for construction and road repairs, and release of finely ground gravel and silica dust, as well as heavy metals and microplastic.

3.3.3 Improving Air Quality in Hungary

The United Nations Environment Programme (2015) documented some of the approaches employed by Hungary to improve air quality. These include;

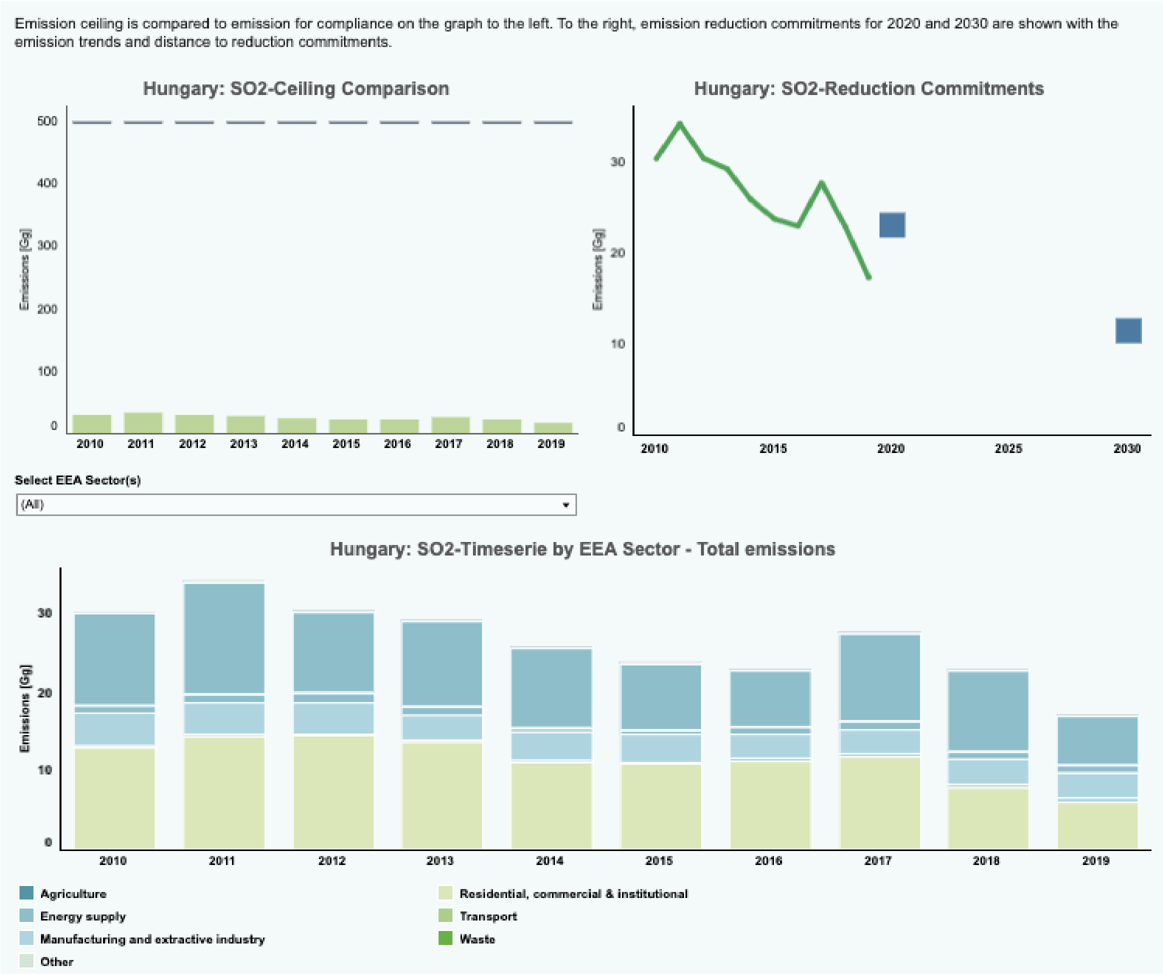
1) Policies and Programmes: the policies and programmes that were used to tackle air pollution by the Hungarian Government include the National Ambient Air Quality Standards, National Air Quality Policy, and the Air Quality Legislation/Programme. Important features of these policies and programmes (especially the Air Quality Legislation/Programme) are to ensure that the Hungarian legislation on air pollution is in full compliance with the EU standards and the control of air pollutants and the management of air quality is the most part as the same as the EU's practice. The three pillars on which the Hungary's national strategy on air quality on air pollution abatement was built include; (a) reduction of air pollution in regions where exceedances of emission limit values may occur e.g., cities with heavy traffic and the industralized areas; (b) maintaining the ambient air quality of the relatively clean regions; (c)fulfulling all obligations from international protocols e.g., The Convention of Long-Range Transboundary Air pollution and its protocols.
2) Industrial Emissions Regulations: approaches followed in this regard include following the industrial emission regulations of the December 2007 Industrial Emissions Directives (IED), promoting the investment of renewable energy, and incorporating

Energy Efficiency Incentives which include incentives for clean production and installation of pollution prevention technologies and incentives to move industries to less populated areas. Also, actions to ensure compliance with regulations were put in place such as monitoring, enforcement, etc.

3) Reduce emissions from Transport: this involves creating vehicle emission limits such as following the EU emission regulations for new light duty vehicles and introducing different emission limits for compression ignition (diesel) and positive ignition (gasoline, ethanol, etc.). Also, regulation on the fuel sulphur content was put in place (that is, the maximum allowable sulphur level in petrol and diesel fuels is 10ppm). Another important aspects of the regulation in the transport sector include the restriction on used cars importation, establishment of actions to promote non-motorized transport (e.g. sidewalks and bikes lanes and car-free areas etc.), and the introduction of an expanded and improved public transport. Lastly, inspections are carried out on cars based on the usage, that is, all cars older than four years are expected to be inspected every two years and public transport vehicles are inspected annually.
4) Reduce emissions from open burning. This solution is applicable to both outdoor and indoor burning. For outdoor burning, a legal framework to prevent open burning of municipal waste and/or agriculture waste was created while for indoor burning, solutions to reduce emissions such as indoor air pollution regulation, promotion of non-grid/grid electrification, promotion of cleaner cooking fuels and clean cooking stoves were adopted.

Without doubts, these approaches have helped to improve air quality in Hungary. The present and the expected level of Sulphur dioxide (SO_2) is presented in Figure 16 while the year at which Hungary met most of the emission ceilings is displayed in Table 9, as presented by

Figure 16: Hungary Sulphur dioxide (SO_2) trend and comparison with the EU Sulphur dioxide (SO_2) emission ceiling|| sector-by-sector emissions.



Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/hungary

Table 9: **Hungary meeting the EU emission ceilings**

Meeting emission ceilings										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NH3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
NMVOC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
NOx	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SO2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Source: https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets/hungary

3.4 Summary of the countries Institutional Framework

In general, it can be concluded that most of the institutional frameworks on improving quality took significant positive effects from the early 2000s. Without doubts, the approaches employed by these countries have contributed to the reduction of emissions, especially air pollutants and thus, improve the quality of air in these States. However, it is important to check the advantages and the disadvantages of the approaches employed in their bid to improve air quality. Therefore, this section gives a combined summary of the institutional frameworks of the selected countries under Advantages and Disadvantages headings.

Advantages:

1. most the plans of these selected countries are influenced by the EU plans, therefore, there is some degree of applicability to other EU States.
2. the plans and frameworks of these countries encourage social collaborations in solving environmental issues.
3. most importantly, the frameworks are human and environmental centered, therefore, they possess generational impacts, and they are futuristic.
4. with the main goal being the reduction of air pollutants, the solutions provided helps tackle climate change as well. (Campi, 2017)
5. enhanced cohesion between actions taken at local, national, European, and global levels (Campi, 2017).

Disadvantages:

1. non-uniformity in action plans within national levels e.g. in Germany, some States have more measures of improving air quality than others depending on the level of air pollutant. While this is good and reasonable on the one hand, on the other hand, air pollution cannot be bordered.
2. presence of influence from powerful individual in retarding the solution process of improving air quality - such as the case in Hungary
3. administrational lack of commitment, institutional fragmentation, and poor execution are part of the issues within institutional frameworks in some of the selected countries.

Table 10: Countries Air Pollution comparison table

	Germany	France	Hungary
Global rank in air pollution (of 118)	89	84	65
2021 Average US AQI	Good (44)	Good (47)	Moderate (57)
No. Of death from air pollution (2019)	29,300	17,100	13,100 (but 2018)
First year to completely meet emission ceilings	2018	2015	2010
Carbon neutrality current year target	2045	2050	2050

Source: figures were extracted from Statista IQAir, European Environment Agency as used in the discussion in this chapter

4. International Case Study Overview

BULGARIA - *"IMPACT OF AIR POLLUTION ON CAREER DECISIONS OF THE HIGHLY-SKILLED WORKFORCE IN SOFIA*"

According to the report, Sofia loses 13.4% of its GDP as a result of greater absenteeism and decreased productivity brought on by air pollution. A loss of this scale translates to EUR 15.838 billion over the course of five years, with no convincing signs that the city's air quality would improve noticeably. This modest estimate doesn't even consider other ways that too much air pollution might be expensive, such healthcare expenses, welfare expenditures, years of life wasted, or poorer educational attainment. A greater percentage of the talented workforce reports reducing their working hours or being less productive owing to air pollution, which is supported by the findings of the quantitative survey of the talented workforce. Additionally, the majority of those in the skilled workforce express readiness to pay for it, demonstrating not just the group's awareness of the problem but also their comprehension that It is a component that imposes a financial cost on itself.

The results of the analysis' several sections indicate that Sofia's air pollution is a serious problem. Additionally, most people are aware of the problem. The degree of air quality dissatisfaction in Sofia is among the highest in the European Union, and many residents view it as the single most significant problem in their city. Both the secondary and primary research used in this analysis confirm the extreme unhappiness with the current situation of Sofia's air quality. The data also shows that the problem of air pollution is noticeable enough that a sizeable portion of the skilled labor takes it into account when determining whether or not to go outside. The skilled employees in Sofia's labor market believe that poor air quality reduces their productivity, worsens their health, and ultimately increases the likelihood that they will leave the city.

Only a few Bulgarian cities are noted in the report as not experiencing an issue with high air pollution. They are unable to compete with Sofia's offer to skilled people working in these industries in terms of compensation, career possibilities, network, and city amenities because of their low capacity for high tech and business sector positions. Employers in these fields therefore need to think more carefully about how such non-financial factors as high air pollution levels can encourage top talent on the Sofia labor market to seek out international alternatives, which not only inhibits local growth but also has a broad negative effect on the Bulgarian economy.

Environmental advancements may occasionally be seen as luxury items that people with greater incomes are prepared to spend proportionately more on. According to other studies, people with lower incomes are more philanthropic and have less options for reducing their exposure to air pollution (e.g., they are less likely to spend the weekend in the country if air quality in the city is severely poor). People in Sofia were ready to spend up to 4.2 percent of their income, according to a World Bank study from 2000, to enhance the quality of the air. Due to the outdated nature of the study, this result should be viewed as a historical benchmark for what might determine willingness to pay trends for air pollution reduction in Sofia as opposed to an indication of what the current levels of willingness to pay for air quality improvements in the city might be. The results of the econometric models revealed that the respondents' willingness to pay was significantly positively influenced by household income and educational attainment. Older respondents and female respondents showed lower readiness to pay.

Deliotte, Commissioned by Clean Air Fund (2021, November) “*Impact of air pollution on career decisions ofthe highly-skilled workforce in Sofia”*

POLAND - "*Characteristics of selected elements of the air quality management system in urban areas in Poland***"**

In accordance with the Environmental Protection Act (PO), [7] agglomerations and major cities (with more than 100,000 inhabitants) establish zones in which the evaluation of the air quality in affecting the health of their inhabitants is conducted. The remaining areas are made up of voivodeships, apart from those with agglomerations and populations greater than 100,000, for which the air quality assessment is carried out to safeguard human health and plant life. Monitored pollutants of SO2, NO2, CO, C6H6, O3, PM10, and PM2,5 as well as the presence of heavy metals (As, Cd, Ni, and Pb) and benzo(a)pyrene in PM10 are all considered when determining the human health impact. In Poland, Voivodship Inspectorates for Environmental Protection (WIOS) carry out air quality monitoring in line with the voivodeship environmental monitoring programs. The Chief Inspectorate for Environmental Protection maintains oversight over the State Environmental Monitoring (PMS), a component of which measures referred to in the Voivodeship Programmes are carried out (GIOS). WIO measurements, together with mathematical modeling and estimating techniques, are used to determine the air quality in cities. On metropolitan lands, there are two different types of measurement stations: background stations and traffic stations, both of which are situated close to heavily used roadways. They want to research the effects of vehicle travel.

An important component of an urban air quality management system is information regarding the degree of air pollution. It has to do with upholding legal responsibilities to certain governmental entities. Both international treaties and domestic laws contain references to those commitments. Different degrees and amounts of detail are included when describing the air quality. On a nationwide scale, GIOS runs an information system based on data from PMS network monitoring stations and projections of future ozone concentration. WIOS provides information about their voivodeship region on their websites. In order to regulate urban air quality, several cities develop their own local information systems. One of these cities is Warsaw, which is developing the Warsaw Air Index (WIP), which is intended to include an algorithm for processing and displaying measurement data from PMS stations as well as a local network of other non-reference sensors independent from them. A prediction system that produces information for city citizens and aids in municipal administration decision-making is also expected to be part of the WIP.

Air pollution control strategies are based on three main areas of public intervention: activities aimed at limiting emissions from manufacturing facilities (point emission), eradicating pollution from residential areas (low-stack emission), and expanding public transportation while reducing the amount of vehicle traffic (linear emission). The magnitude of emissions produced in the residential sector is the greatest problem overall, according to the reports provided by WIOS. Legal requirements that apply to commercial organizations can eliminate point emissions, but based on Germany's experience, it should be anticipated that the magnitude of the problem with linear emissions in Poland would grow with time. Acts passed by regional parliaments are presently seen to be Poland's most effective methods for limiting surface pollution, according to statutory laws. Their objective is to impose restrictions and prohibitions on the use of certain fuels and combustion systems inside certain voivodeships.

The delegation of duties to self-governments without legal support at the national level, particularly in cases of emission requirements for combustion of fuels of power of up to 1 MW and admission of high emission fuels on the market, present the biggest challenges now for activities aimed at protecting ambient air. The voivodeship spatial development plan should relate to its development strategy, and the structure of coordination of the development policy should be made easier. Strategic objectives for air defense would thus be defined to include a territorial component.
The need to shift Poland's power generation paradigm away from fossil fuels and toward other energy sources, particularly renewable ones, as well as the need to reduce pollutant emissions from road transportation, are two crucial issues in the context of managing Poland's air quality.

Izabela Sówka, Dominik Kobus, Anna Chlebowska Styś, and Maciej Zathey, (2017), "**"***Characteristics of selected elements of the air quality management system in urban areas in Poland***"**

SWEDEN - "Influence of urban vegetation on air pollution and noise exposure – A case study in Gothenburg, Sweden"

Plants have been found to enhance microclimate, reduce air pollution, greenhouse gas emissions, mitigate storm-water runoff, and reduce noise. revealed that the development of children in elementary schools is improved by green urban areas surrounding schools and in schoolyards. These scientists ascribe a significant portion of the beneficial effects of urban greenery to reduced exposure to air pollution based on their epidemiological research. Therefore, there are compelling arguments for expanding our understanding of how vegetation affects urban air quality.

By affecting the physical transport and dilution of polluted air masses as well as by reducing the air circulation of open areas or boosting vertical mixing and ventilation in parks by increasing surface coarseness compared to lawns and other short vegetation, and thus turbulence, vegetation can change the levels of air pollution in the urban landscape. We came to the conclusion that, from a broad geographic viewpoint, there is a significant mass flow of air contaminants to urban vegetation. Even tiny decreases in concentration that affect large populations might result in major improvements in human health, yet these fluxes did not have a meaningful average impact on local air pollution concentrations.

However, there have been arguments made that the benefits of urban greenery in lowering local air pollution have been overstated. Even though several empirical studies of the direct impact of urban vegetation on local air pollution levels have been published, more empirical data is still required to quantify the impacts of greenery in cities on exposure to air pollution on a more granular level. While particle pollution levels were much lower in the tree-covered regions, there were no appreciable variations in the levels of gaseous pollutants between nearby open, treeless areas and those with trees. However, in Gothenburg, Sweden, Grundström and Pleijel were able to reduce the NO2 content by 7% by planting thick vegetation next to a busy road.

Peri-urban woods in Spain significantly impacted local air quality, according to Garca-Gómez et al. (2015). In addition, Al-Dabbous and Kumar demonstrated that the presence of roadside vegetation had a significant, wind-dependent impact on nanoparticle exposure in the vicinity of a busy road in Surrey, UK. Irga et al. discovered that areas in Sydney, Australia, with higher tree cover had lower atmospheric particle concentrations than other areas of the city.

In places with high traffic volumes where air quality rules are in place, nitrogen dioxide emissions are significantly higher. It has an impact on plants like epiphytic lichens and human health. Ozone is a secondary, locally prevalent contaminant that is known to have harmful effects on human health and plants. In highly polluted locations, O3 concentrations can be decreased by titrating with NO, although its regional nature implies that there is less fluctuation in O3 concentrations throughout the urban landscape than there is in locally generated pollutants, as discovered by e. Given that traffic noise is most around 1 kHz, vegetation's ability to absorb sound may have a considerable impact on sound levels.

Several roadways working together with numerous reflecting surfaces generate the sound field in an urban setting. To investigate the impact of a green leaf area on air pollution and noise, measurements at all locations were taken before and after leaf emergence. At a given distance from a transportation route, air pollution levels are lower at a vegetated site than at a non-vegetated site, and this impact is bigger ALE than BLE. Compared to nearby metropolitan contexts, park areas have significantly lower air pollution levels.

The study concluded that there is a significant variation in air pollution levels over the urban landscape of the City of Gothenburg, larger for PAH than for NO2, and the regional pollutant O3 had a significantly smaller variation over the urban landscape. However, sites and times with higher local pollutant levels (indicated by NO2) were associated with lower O3, as a result of O3 titration by NO. Furthermore, vegetation along a major traffic route helped to lower the levels of NO2 and particle PAHs, particularly benzo(a)pyrene. This impact was more pronounced for NO2 while leaves were on the trees.The concentrations of PAH and NO2 in the city were closely associated and the noise levels at critical frequencies for traffic noise are decreased by leaves.
However, the traffic noise levels and NO2 concentrations were associated. Lastly, due to the fact that parks have significantly lower air pollution (NO2 and PAH) levels than nearby areas near traffic (the "park effect"), separating people from traffic can significantly reduce people's exposure to pollutants. Promoting urban green spaces is also likely to have an even greater impact on this effect.

Jenny Klingberg a, ⁎, Malin Broberg b , Bo Strandberg c , Pontus Thorsson d , Håkan Pleijel, "*Influence of urban vegetation on air pollution and noise exposure – A case study in Gothenburg, Sweden*"

HUNGARY

With a population of 9.75 million, Hungary is located in Central Europe's Carpathian Basin. Debrecen, the second-largest city in Hungary, has around 200,000 residents, and it has two tram lines, sixty local bus routes, and three trolleybus routes. In this study, under typical operating conditions, they looked at the in-vehicle concentration and elemental makeup of PM coarse and PM fine in various public transportation vehicles. Both the trolleybuses and the local buses used in this study have been in operation since 2005 and 2009, respectively. The buses are powered by Euro 4 and Euro 5 diesel engines, and both are outfitted with preprogrammed heating and cooling systems [24]. The buses and trolleybus were not air-conditioned at the time of sampling; instead, they were driven with all windows open, as is customary in fine weather.
As a result, these buses (i.e., non-A/C local buses and non-A/C trolleybuses) were classified as non-air-conditioned vehicles in the sections that follow. The city's public transportation system uses two types of tramcars: the KCSV (old type) and the CAF (new type).

Budapest is Hungary's capital and has a population of 2 million. The transportation system includes a number of bus, trolleybus, tram, and metro lines; however, only the underground was used in this work. Currently, there are four metro lines in the capital city: Metro 1, Metro 2, Metro 3, and Metro 4. (M4). The metro carriages used in this study were in operation from 1976 to 2016 and were used on the Metro 3 (M3) line, which is the longest at 16.3 kilometres. The open windows in the metro cars allowed for cooling and air exchange because the carriages lacked an air conditioning system. The tunnels also featured a ventilation system of their own.

Significant PM levels were found, particularly on the older automobiles. The amounts observed within the various public transportation vehicles were 2–19 times greater than the values measured simultaneously outdoors at a traffic site or at urban backdrop locations. Therefore, even though passengers were only briefly exposed to this high amount of pollution, they nonetheless suffered considerable aerosol exposure. The origins of PM pollution might be determined with the use of elemental composition and enrichment factor analyses. The resuspension of the mineral and road dust, the engine's emissions, and many other interior sources were the causes of the high pollution levels. The detected interior sources, which included cleaning and disinfection products, seat fibers, abrasion from railroad tracks and wheels, and overhead wires, all had a substantial role in the PM pollution. High quantities of Fe, Cr, and Mn were discovered in cars working on trains; the cause was undoubtedly railway abrasion. Without adequate cleaning and maintenance, the air circulation systems may produce extremely high pollution levels, as we have demonstrated. The aerosol pollution was lower in electrical cars, and the exposure of the drivers and passengers could be further decreased by adopting cutting-edge air technology and adequate maintenance.

5. Background

In the following articles, an overview of the situation considering air pollution in the Czech Republic will be introduced. Firstly, we will explore the state of air quality in Czech Republic, relevant sources of air pollution and the history of air quality protection in Czechia. Secondly, administrative competencies of specific air protection authorities will be focused on.

Czech Republic: Air Pollution Background

The Czech Republic is a landlocked country in the Central Europe, sharing land borders with Germany, Slovakia, Poland, and Austria. The estimated population was 10,7 million people in 2022. The capital city of Prague is also the largest city, the city of Brno being the second largest.

According to the study from 2020 (AQLI, 2020), together with Poland, Slovakia, Slovenia, Hungary, Lithuania, Bulgaria, Romania, and other countries in Eastern and Central Europe, Czech Republic is one of the countries with highest level of air pollution in Europe. An essential indicator of the health effects of long-term exposure to air pollution is the *number estimate of premature deaths for the adult population over 30 years of age excluding external causes of death (accidents, suicides, etc.)*. National air quality statistics estimates of an annual loss of life (excluding death caused by external causes such as accidents and suicides) in 2020 was 121,532 people (SZÚ, 2021). Normally, the data could be used to estimate the number of deaths caused by exposure to particle PM however the SARS Cov-2 pandemic in 2020 significantly affected the overall mortality in the Czech Republic (an increase of about 10% is indicated). Therefore, the quantification of the share caused directly by the pandemic respectively PM is difficult to track. Furthermore, report from 2021 suggests that every adult person loses 2.9 days of their life due to breathing poor quality air accordingly to the estimates from 2020 (SZÚ, 2021).

A non-negligible amount of urban and country-side dwellers in the Czech Republic lives in areas where EU air quality standards for the protection of human health are regularly exceeded. Air pollution continues to have significant impacts on the health of Europeans, particularly in urban areas. These health impacts have economic costs, cutting short lives, increasing medical costs and reducing productivity through lost working days. The pollutants with the most serious impacts on human health are particulate matter, nitrogen dioxide and ground-level ozone. In the context of the Czech Republic, one of the biggest shortcomings of air pollution are the PM10 and PM2.5 particles. A case of the worst situation can be found in the city of Ostrava, where above-limit air pollution persisted even in 2020, when otherwise the air quality improved significantly generally, mainly due to temporary measures introduced against the COVID19 pandemic.

The following table compares the WHO recommendations regarding monitored pollutants (Global Air Quality Guidelines, ACQs) with the reality in the European Union:

Pollutant	Averaging time	ACQs according to WHO	EU Limit
PM 2.5 µg/m^3	A year	5	20
	A day	15	Not determined
PM 10 µg/m^3	A year	15	40
	A day	45	50
NO_2 µg/m^3	A year	10	40
	A day	25	Not determined
	An hour	200	200
$S0_2$ µg/m^3	A day	40	125
CO mg/m^3	8 hours	10	10

Table 8 Limits according to WHO and EU

The major source of dust particles and BaP come from households burning wood, coal or waste for heating (55 % of total PM10, 71 % PM 2,5, and 96% BaP) (ČHMÚ, 2021). A considerable share of the public energy and heat production sector prevailed in terms of emissions of SO_2 47%, NOx 21% and nickel 37%. Sectors of road freight transport, private car transport, non--road vehicles and other machines, e.g., in agriculture and forestry, contribute the most significantly to emissions NOx (40%). Other pollutants which give great cause for concern include ground-level ozone (O3) and polycyclic aromatic hydrocarbons (PAHs). Air pollution from PM and PAH is challenging, especially in areas affected by excessive industrial activity and transportation, or in rural households with low-quality heating who rely on wood and cheap coal as their main source of energy. Air pollution from industrial installations originates from the following: power generation, motor vehicles, metallurgy, machinery and equipment, glass, and armaments amongst others. These industries have the potential to have a bad impact on air quality. Private car ownership is relatively high with about 6,13 million (ČTK, 2021).

The map below (Figure 15) presents areas across the country where the limits of listed pollutants were exceeded in 2019.

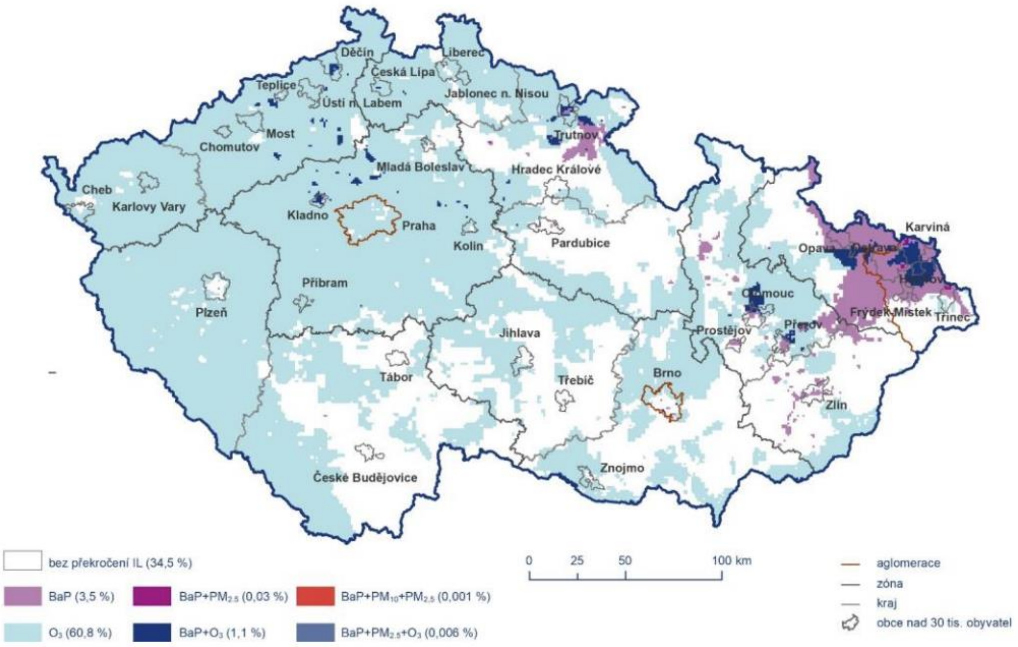


Figure 15 Areas with exceeded air pollution limits for the protection of health of selected groups of substances (ČHMÚ, 2020).

Czech Republic: Administrative competencies of various air protection authorities

Administrative activities in the field of air protection are performed by these air protection authorities in Czech Republic:

- Ministry of the Environment
- Ministry of Health
- Ministry of Agriculture
- Czech Environmental Inspection
- The Czech Trade inspection
- Customs offices
- Regional authorities
- Municipal authorities of municipalities with extended powers
- Municipalities

National level of air protection authorities

On a state level, there are several tools and potential solutions that are relevant considering improving air quality in Czech Republic. The tools applicable from state perspective can be divided into the following categories: Legal conditions of air protection measures, economic tools, conceptual tools, administrative tools, and sanctions.

The most important legally binding cornerstone of the Czech legislation on air protection is Act No. 201/2012 Coll., On air protection. The key concepts of this law are emissions and imissions. These need to be prevented and their current level reduced.

Unlike the previous amendment of the Act from 2002, the objective of the Air Protection Act is included directly in its text and says: “*Air protection means the prevention of air pollution and reducing the level of pollution to reduce the risks to human health caused by air pollution, reduction of the burden on the environment by substances introduced into the air and damaging ecosystems and creating the conditions for the regeneration of components of the environment affected by air pollution* (Act No. 201/2012 Coll., On air protection)." The Czech Republic, as a member state of the European Union, must at the same time comply with the Directive 2008/50/ EC of the European Parliament and of the Council on quality and cleaner air for Europe entered into force on 21 May 2008. The Air Protection Act aim is therefore also to elaborate and regulates the relevant regulations given by the Directive mentioned. This Directive is crucial for the development of pollutants in Europe while it regulates the levels of pollutants across borders.

Economic tools can be considered instruments of indirect action. This way, the state does not exercise its power on the behavior of regulated entities (municipalities, cities, citizens) directly, but gives the entity an opportunity the choice of behavior. In addition to the motivational function, the main functions of economic tools are also internalization and compensation. The economic instruments on individual subjects can be divided into two categories: positive and negative stimulation. The main two tools needed to be mentioned in this regard are thus air pollution charges and air protection subsidies. The law defines two fees that aim to contribute to air quality protection. These are a *fee for air pollution* (§19, Act No. 86/2002 On air protection) and a *fee for the production and import of regulated substances (which damage the ozone layer) and products containing them* (§29, Act No. 86/2002 On air protection).

The obligation to pay the *air pollution fee* is established only for stationary sources whose output exceeds 50 kW. The relevant municipal authority, municipal authority with extended powers or regional authority decides on the amount of the fee, depending on the size of the resource. The Air Protection Act distinguishes between extra-large, large, medium, and small sources. Extra-large sources consist of heat inputs greater than 50 MW regardless of thermal output, large sources reach a thermal output between 5 MW and 50 MW, medium sources reach 0.2 MW to 5 MW and small sources are those whose thermal output is lower than 0.2 MW. The table (Table 2) below shows which authority is competent to set a charge for air pollution for a specific source:

Type of a specific source of air pollution	Competency
Extra-large and large	Regional authority
Medium	Municipal authority with extended powers
Small	Municipal authority

Table 9 Competencies divided accordingly to the types of air pollution source
(Zpráva o životním prostředí České republiky v roce 2007. [online]. p. 214.)

For extra-large, large, and medium-sized sources, the fee is assessed based on the emission limits of discharged pollutants or certain technical conditions of operation. The final fee is rounded up to the whole 100 CZK and is collected by the customs authorities. The fee is ultimately the income of the State Environmental Fund of the Czech Republic. For small sources, the fee is determined based on the type of fuel for the heat source and its output as a flat-rate amount. The collection of the fee is made by the municipality itself, and the finance from the fee is income for the municipality's budget, but it must be used as an environmental protection tool.

The fee for the production and import of regulated substances (which damage the ozone layer) and products containing them is based on the regulations of the European Parliament and the Council: No. 2073/2000 on substances that damage the ozone layer and No. 842/2006 on certain fluorinated gases. While the Czech Republic is part of European Union these are also valid for the purposes of Czech legislation. The fee is set at a uniform amount of CZK 400 per kilogram of substance or product made from regulated substances. The producer himself is obliged to determine and calculate the amount of the fee and pay it to the State Environmental Fund of the Czech Republic. The Environmental Inspection contributes to enforcing this fee.

Furthermore, *tradeable emission permits* are also used in the Czech Republic for air quality protection, on the conditions for trading greenhouse gas emission permits.

Conceptual tools are concepts, plans and programs in various forms, which may be a mandatory instrument with binding indicators or contain binding parts, which are binding for the decision-making of the state administration bodies. If they do not have the character of a legally binding document, they play an important role in the application legislation. *National Emission Reduction Program* of the Czech Republic is the main and overarching conceptual tool that covers the entire territory of the Czech Republic. The program is developed by the Ministry of the Environment in cooperation with the relevant central administrative authorities and is approved by the government. The national program must be prepared at least once every four years and after the amendment to the Air Protection Act is effective, notify the European Commission. Another conceptual tool, in addition to the National Program, are the Programs improving air quality ("PZKO"). Unlike the National Program, which applies to the entire territory of the Czech Republic, PZKO is processed only for zones and agglomerations in which limits of pollution are exceeded. The Ministry of the Environment regularly carries out air pollution monitoring, during which it assesses compliance with air pollution limits. If it finds that these limits are exceeded in a certain area, it is obliged to draw up an air quality improvement program for these areas in cooperation with the regional or municipal authority and the relevant region or municipality in its independent competence. Air quality improvement programs are announced by the Ministry of the Environment in its journal. The programs aim to determine a specific procedure leading to the fastest and most efficient achievement of the required air quality.

South Moravian Region

Regional authority in South Moravian Region is competent by law to practice a spectrum of measures considering air protection. Below we list some of the main responsibilities of the regional authority (Regional office, Department of Environment) (§ 11, § 12 and § 13 of Act No. 201/2012 coll. On air protection):

- issues an opinion on the zoning plan and the regulatory plan of the municipality during its acquisition
- issues a binding opinion on the location and construction of the stationary sources
- issues permits and changes to permits for the operation of a stationary
- may set more stringent specific emission limits in the permit to operate stationary sources to reduce the level of pollution
- decides on the method of determining emissions by calculation in cases where the measurement cannot determine the actual level of pollution or for selected sources
- decides on the fee for air pollution at stationary sources of the establishment, for which the total amount of the fee exceeded the amount of CZK 50,000
- in case of doubt, issue a statement on the submission / non-submission of a dispersion study
- imposes the implementation of compensatory measures to reduce emissions from existing sources of air pollution or other measures to ensure the level of pollution
- sets emission ceilings for a stationary source or establishment in the operating permit
- sets special conditions for the operation of the source in case of exceeding the control threshold
- reviews decisions issued by municipal authorities in proceedings under special laws
- performs supervision in the field of air protection in its territorial competence
- cooperates with the ministry on the regional air quality improvement program
- prepares a time schedule for the implementation of measures stored in the PZKO program
- provides methodological assistance to municipal authorities
- makes information available based on the law, informs the public if the informative threshold, warning threshold or regulatory threshold is exceeded in the zone

As mentioned earlier, if the Ministry of the Environment finds that the limits for specific pollutants (see Table 2 above) are being exceeded in a certain area, it is obliged to draw up an air quality improvement program for these areas in cooperation with the regional or municipal authority and the relevant region or municipality in its independent competence. Within 12 months from the announcement of the program, the relevant municipality and region must, in connection with the announced program, draw up their timetable for the implementation of the measures imposed by the program. The municipality and the region must publish this plan on their websites. The program must be updated at least once every 4 years.

Transport in South Moravian region: Across the Republic there is growing trend of passenger transport which causes an increase of the level of air pollution. The increasing intensity of passenger transport can be illustrated by the number of cars registered in the region in 2015: more than 530 thousand and 75 thousand trucks, as stated by. Total length of 4.5 thousand km of highways and roads thus serve the dense road traffic. South Moravian region's location is a strategic middle point where many main routes connecting some of the major cities (Wien, Prague, Brno, Bratislava) meet. The levels of produced emissions were further highly affected by the global pandemic COVID-19. At the peak of the pandemic in 2020, emissions of all monitored pollutants and greenhouse gases, most notably CO emissions, fell by 15.8% year-on-year in the region. The drop in emissions was influenced by the effects of the covid-19 pandemic on the transport sector and the entire economy (CENIA, 2020).

Non-negligible part of enhancing the quality of air in South Moravian Region is the transition to cleaner energy while the local household heating is often obsolescent and causes significant ecological harm. South Moravian Region is considered to have good natural conditions and potential for the intensification of the use of renewable energy in the energy grid. The South Moravian region is one of the regions with the highest average annual length of sunshine, ranging around 1650 – 1800 hours (Isofen, 2021). below annually and thus its potential regarding solar energy is considerable (see **Chyba! Nenalezen zdroj odkazů.**; The World Bank, 2020). Due to the possible use of photovoltaics on many buildings (study by Jakubes & Járka (2015) showed a potential of installing a solar power plant on 55% of residential houses and 25% of other buildings) practically every municipality can prepare its own photovoltaic power plant project. The latest Territorial energy conception of the South Moravian Region 2018–2043 (SEVEn Energy, 2019) states that in 2014, there were approximately 3,330 photovoltaic power plant installed in the region, with a total capacity of approximately 445 MW.

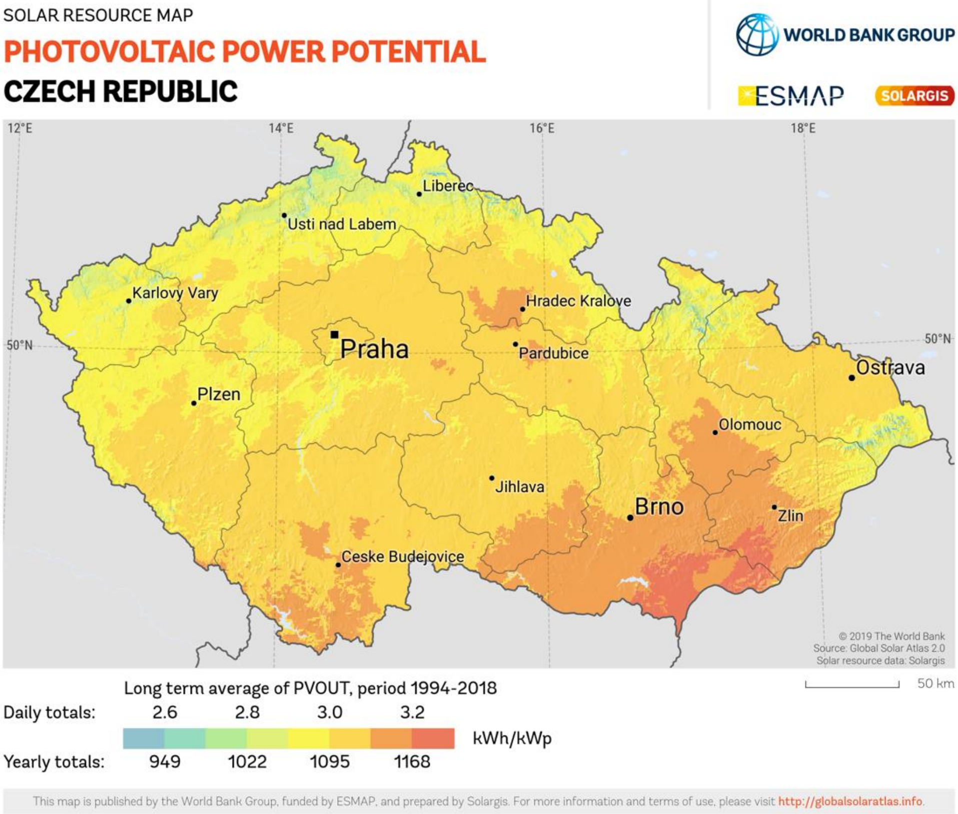


Figure 16 Photovoltaic power potential: Czech Republic (The World Bank, 2020)

Other sources of renewable energy shall also be considered in the following articles notwithstanding the fact their implementation comes with a different set of complications. Since suitable sites for development of hydropower plants are mostly occupied already, the possibilities of wind power plants, energy use of biomass will be examined in more detail.

The technological possibilities of current WTs (Wind Turbines) require that the potential site has annual average wind speeds in the axis of the turbine rotor of around 6 m/s and higher (the limit is set by the worldwide classification of sites suitable for the use of wind energy, the IEC 61400 Standard). There are very few locations in the territory of the South Moravian Region, where such wind speed would be present with the use of smaller turbines and therefore even the application of WT of this type is marginal in conditions of the region. However, as the height above the ground increases, the average speed of the air flow increases, the number of suitable locations expands significantly when evaluated at heights in which large WT rotors work (heights of 100 meters or more). The map by Institute of Atmospheric Physics of the Academy of Sciences of the Czech Republic (2009) below illustrates average windspeed in heights of 100 m above ground across the area of Czech Republic. As shown by the map, the sites with the highest potential regarding the wind energy are mainly to be found in the northern and southeastern part of the region. While the conditions are not the best throughout the state, there is still space for development (namely in the surroundings of Znojmo) in this regard, as both Territorial energy conception of the South Moravian Region 2018–2043 (TEC; SEVEn Energy, 2019) and the Update of wind energy potential in the Czech Republic from *the perspective of 2020* by Hanslian (2020) suggest. The latest TEC (SEVEn Energy, 2019) further states that in 2015, 13 wind turbines were registered in South Moravian Region.

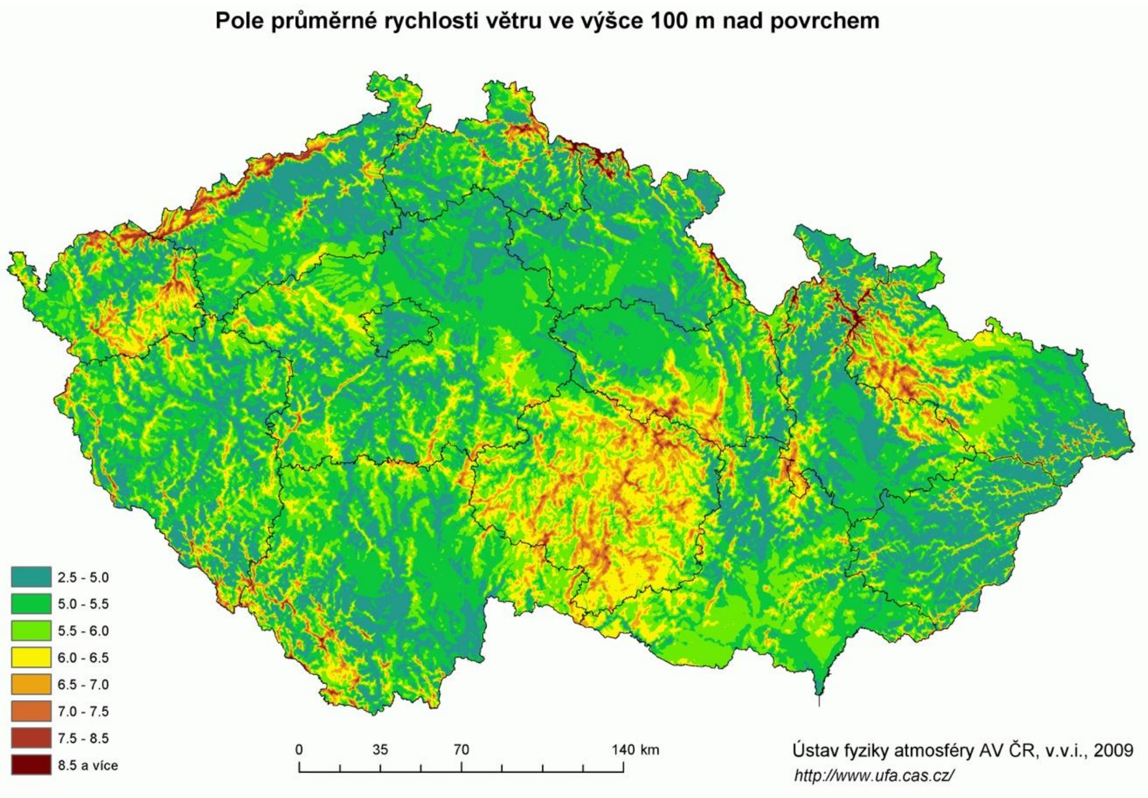


Figure 17 Map of average windspeed in 100 m above ground
(Institute of Atmospheric Physics of the Academy of Sciences of the Czech Republic, 2009)

Lastly, we will focus on the possibility of energy use of biomass in the region. A vital role in determining the potential of energy-usable biomass in the area is the structure of the soil, considering the method of management, state of local soils, and geographical fragmentation. According to the TEC from 2019 (SEVEn Energy, 2019) biomass is currently the most used renewable energy source in the region. In 2014, the consumption of biomass energy was 6 PJ, of which approx. 2/3 was in the form of firewood, used in households. The remaining 2 PJ are used in large energy sources, most significantly by Hodonín energy plant and the Congestion Charge Brno. Further development of the energy use of biomass and biogas is possible. However, development is dependent on the land use strategy and development plans of agricultural enterprises. There are several environmental consequences of an increased pressure on the use of biomass as an energy source. These include for example pressure on increased forestry and agriculture for the sake producing biomass. Furthermore, with challenges of climate crisis, loss of biodiversity, an increase in the extraction of wood from forests cannot be counted on in the future.

Currently, there are several activities by the Region authorities. The goal and a full list of activities for 2022-2023 described and explained in the strategic document Development strategy for South Moravian Region 2021+: Action Plan 2022-2023 (Jihomoravský kraj, 2021a)and SRJMK 2021+: Implementation and monitoring (Jihomoravský kraj, 2021b)
These activities consist of such as:

- Education for the prevention and reduction of dust during construction,
- Evaluation of air quality in South Moravian Region,

- Building solar energy capacities and increasing the energy efficiency at the municipalities' buildings,
- Support for energy efficiency measurements at schools,
- Support of cycling infrastructure development in South Moravian Region,
- Promotion and support sustainable forms of transport within South Moravian Region: Integrated transport system of South Moravian Region, cycling, intensified public transport possibilities to touristic destinations,
- Support of modernization of public transport vehicles,
- Subsidy programs aiming at the reduction of emissions from local heating of households in the South Moravian region.

To mention one of the current ongoing activities of the South Moravian Region of the Czech Republic, a massive program on modernization of household heating boilers is undergo. From 2016 to the present, approximately 3,800 non-compliant solid fuel boilers have been replaced in the South Moravian Region through boiler regional subsidies (Jihomoravský kraj, 2022a). Approximately 400 million crowns went to the applicants for this purpose (Jihomoravský kraj, 2022a). The subsidies programme is ongoing, and the current wave aims to support households with lower income. To do so, it is planned to use a total of 122 million crowns and in sum thus replacing around 920 non-ecological heating boilers (Jihomoravský kraj, 2022b). The subsidy programme is one of the many ways positive air protection behaviours can be endorsed on a regional level.

Municipal level

The main self-governmental subject in the Czech Republic is the municipality. A municipality can become a town if it fulfills several conditions such as having more than 3000 inhabitants, forming a coherent urbanized structure and containing certain public amenities. Additional rights are granted to municipalities with extended powers. Additionally larger cities can be divided into city districts. In many ways these districts are similar to municipalities and have their own administration and elected leadership but are in many ways dependent administratively on the larger city in which they are located which has a city-wide mayor and political representation. Most commonly the municipal department dealing with air pollution is the department of the environment, however the transportation department or the urban planning department ultimately play a role too.

Cities have the option to create programs with the goal of reducing air pollution (Vedral, n.d.). Other rights of cities regarding air pollution is creating a regulatory framework during special smog situations as defined by the law dealing with protection of the air with the goal of reducing that smog situation with extraordinary measures. Another right that cities have is regulating the burning of dry plant matter. For some stationary sources of air pollution, the city is part of the construction, zoning and approval procedures with specific levels of air pollution in the given area potentially playing a role in further decisions that are taken (Válek, 2015). Regarding air pollution from small local sources municipalities have the option to check people's boilers if there is suspicion of breaking the law, for example by using overly outdated models or for example using trash as a fuel.

When it comes to transportation policy the city has an increased amount of freedom. Fundamentally except for roads of State or Regional importance the city decides which projects to pursue, where to build roads, what their capacity will be etc. However, this once again is a more future oriented approach regarding new construction or the change of existing infrastructure. Cities can decide to create a car-free zone or to pedestrianize a given street, this is well within the options that the city has, and it is simply a matter of political will. A key right currently given to municipalities by the law is the concept of low emission zones which cities can establish, and which would regulate the entry of vehicles based on their emission category in essence limiting the entry of vehicles that do not meet certain standards, especially if there is a long-term problem of emission limits being overreached (Válek, 2015). The low emission zones are potentially the most powerful tool that cities currently have at their disposal; however, no Czech city has currently gone through with this policy. Another right that cities have is to determine the composition of their vehicle fleet, whether that is public transportation or the cars that the city or companies operated by the city use (Vaňhara, 2020). More generally the scope and quality of public transportation is also in the hands of the city which decides how the public transportation network will look like. Cities have to deal with the path dependencies set by previous infrastructure development and in its position as a metropolitan center for hundreds of thousands of people, many of whom commute by car into the city which the city currently cannot do that much about. Park and ride programs are often mentioned as a solution; however, they can ultimately increase car use (Jaffe, 2013) and to reach the necessary scale would require massive investments into expensive high rise parking garages or paving with asphalt large segments of the periphery of the town. In many aspects of infrastructure development, the city has the right to develop, however it is in many ways heavily financially dependent on the state or on EU subsidies, that are often distributed through the state institutions. Thus, the power of the city to act even in transportation policy is reduced, but in many ways, it is still one of the main areas where the city has some power to act if there is political will among the city leadership.

Overall, it can be said that while the city does have some degree of control over air pollution, the powers currently granted to it are not large and the state plays a much larger role legislatively while the power of the city is limited by wider societal trends such as suburbanization, increased car use and the development of industry. Finances are a key constraining factor and cities should band together as much as possible to lobby for an overhaul of the way in which resources gained from taxation are distributed throughout the state.

Metropolitan area of Brno - Core

Brno currently has an official population of around 380 000 however not all real inhabitants are registered in the city in terms of their permanent residence and the real number of inhabitants could be around 420 000 - 450 000 inhabitants (Benáčková, 2022). Brno is administratively further divided into 29 city districts. Brno has all of the rights that other cities have and thus the previous chapter is key to understanding the options of Brno.

In Brno one of the most important sources of air pollution comes from the transportation sector (OŽP MMB, 2020). The number of cars registered in Brno has been steadily growing at a pace of around 7 thousand per year with there being 206 481 personal vehicles registered in 2019 (Brno, 2019). However, this number does not include business related vehicles registered mostly in Prague but used in Brno or the number of cars coming from the quickly growing district of Brno-Venkov which forms the hinterland. In 2019 there was a total of 5 115 871 driven kilometers compared to 1 830 812 in the year 1992 (Brno, 2019). These growing numbers have severe consequences for air pollution.

Regarding other sources of pollution Brno has gone through quite a change. Brno has a rich industrial history which traditionally contributed much to both the economy of the city but also to air pollution, however Brno similar to many other European cities has transformed into a primarily service-based economy with that leading to lower air pollution levels. The remaining industry is more dependent on EU, state or regional policy and thus shouldn’t form the largest priority for the city of Brno when it comes to air pollution. Heating forms a sector that should be examined.

A key document regarding air pollution in Brno is the Action plan for improving air quality in Brno from the year 2020. Analysis has shown that the city of Brno has a problem with going over the legal immission limits with a particular focus on PM10, PM2,5 particles and nitrogen dioxide with the main problem being air pollution stemming from transportation (OŽP MMB, 2020). The action plan has 19 main measures (OŽP MMB, 2020).

- Residential parking
- Economic support of public transportation
- Realization of a backbone network of roads for cars
- Removal of air pollution stemming from a lack of smooth traffic flow
- Construction and repairs to the tram and trolleybus routes
- Park and ride systems
- Support for cycling
- Cleaning roads
- Planting new vegetation
- Ensuring space for tree roots
- Lowering emissions from the vehicle fleet falling under the city of Brno
- Reducing dust from construction
- Supporting the change of heating systems in households
- Further development of the system of energy management
- Reconstruction and modernization of the heating system
- Air protection during public procurement
- Updating the websites
- Regulating the burning of plant matter
- Enhancing monitoring of air pollution

Metropolitan area of Brno – Hinterland

To the population of Brno, we need to add a large number of people who commute to the city from the surrounding hinterland. The metropolitan area of Brno is comprised of 184 municipalities with over 696 000 inhabitants (Brněnská metrpopolitní oblast, 2020). These are the municipalities that are located in the vicinity of Brno and are connected to it by infrastructure such as railroads, regular roads, the highway D1. This vicinity and connections lead to a large degree of integration. Many inhabitants of these surrounding municipalities work in Brno or use it for cultural amenities. Many people commute by car instead of by buses or trains which exacerbates the problem of air pollution. The area south of Brno especially is more agricultural, leading to it being a source of air pollution too.

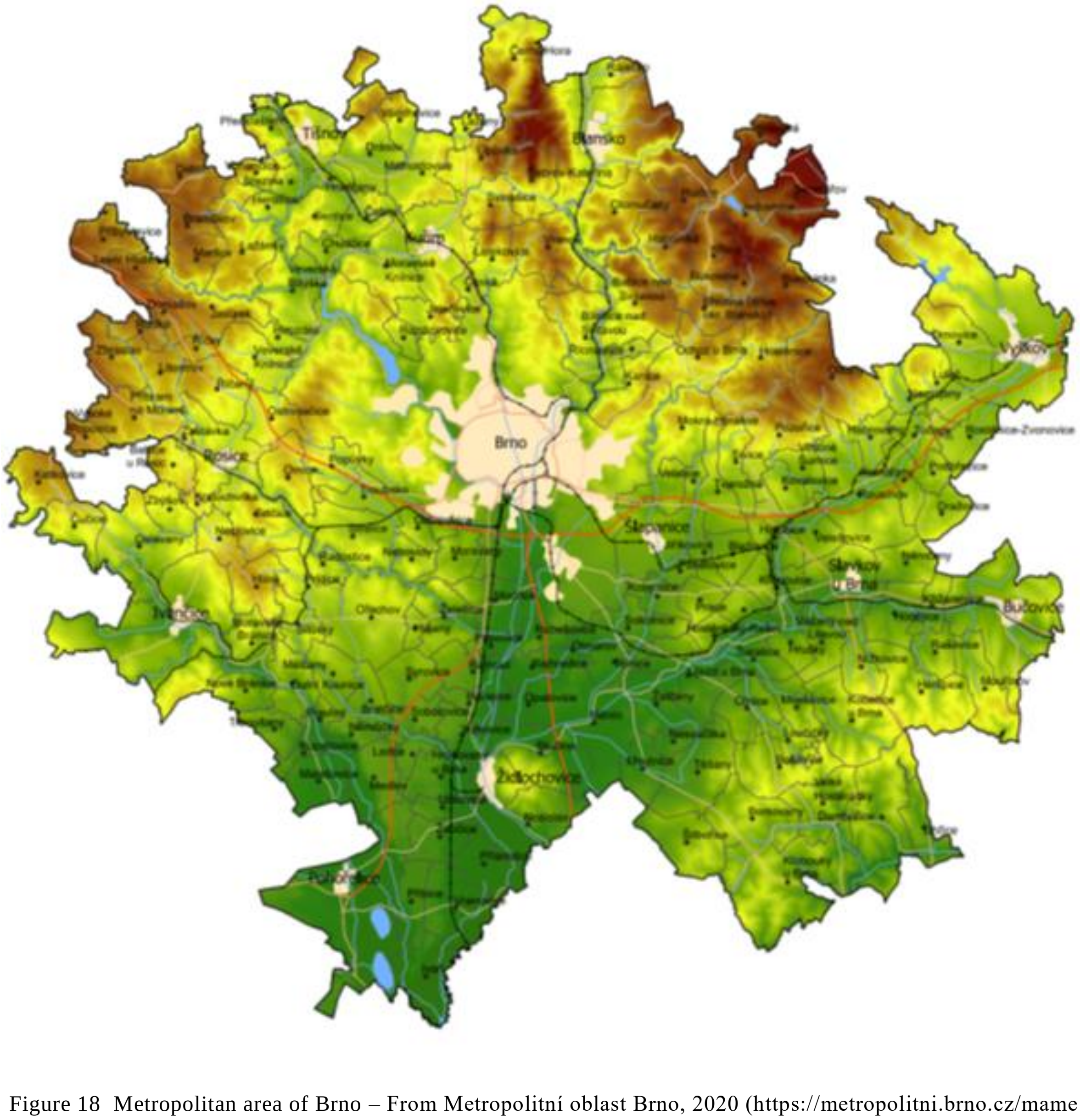


Figure 18 Metropolitan area of Brno – From Metropolitní oblast Brno, 2020 (https://metropolitni.brno.cz/mame-nove-vymezeni/)

In terms of the priorities set in the Brno Metropolitan Area plan, there is a focus on sustainable metropolitan transport, being reachable from abroad, water and land, waste management, modern and safe energy, education, meaningful construction, infrastructure and services for those who need them, strengthening cooperation and cultural heritage along with tourism (Metropolitní oblast Brno, 2020).

The towns and villages have many of the rights and options that the city of Brno has, but on a much smaller scale. One step that can be taken to limit further air pollution in Brno is to reduce new development in the hinterland that takes on the form of suburbanization and instead focus on creating a compact city in Brno. The reason why this policy should be pursued is to limit the number of cars that commute into Brno. This can be done through zoning plans; however, it is fundamentally up to the towns and villages involved and Brno has no legal recourse here as regional planning is not in an advanced state in the Czech Republic. Currently the city and its surrounding hinterland is part of the Brněnská metropolitní oblast association which seeks to coordinate and enhance cooperation; however, this association is primarily voluntary with limited rights which is why there are calls for the state to give legislative support to similar initiatives (Brněnská metropolitní oblast, 2022). In general, regional coordination is harder to achieve in the Czech Republic due to a very high level of municipal fragmentation where there is a large number of self-governing entities with smaller populations that still have rights. There is some upper-level support for these initiatives, however. The European Union supports the concept of Integrated Territorial Investments in situations where regional coordination makes sense. The goal should be among other things to support projects that can combat traffic problems stemming from suburbanization and air pollution which does not stop at the boundary of the given municipality.

6. Proposal

Vision of Brno

When it comes to long term planning and goals, one of the main documents is the Brno 2050 strategy. There are two main sections related to air pollution. The first is the section dealing with mobility and the second is the environmental section.

In the section titled A city with effective and sustainable mobility, the plan outlines goals such as enhancing the attractivity of sustainable forms of transportation such as walking, cycling and using public transportation with the goal of reducing negative effects of the current forms of transport within the city of Brno and its wider metropolitan area. Also mentioned is a focus on innovation, looking at mobility as a service, increasing the quality of the environment and creating a public transportation system that works for the people of Brno. These are the wider goals, which are supplemented through more specific targets. Worth mentioning is the goal of reducing individual automobile use from the current 39 percent of trips to 20 percent with an unspecified goal of reducing the number of cars per capita. A specific goal is increasing the percentage of ecological public transit vehicles to 100 percent from the current 30 percent, although this goal is undercut by the fact that natural gas is considered ecological, which is far from the truth. When it comes specifically to the topic of air pollution, the strategy sets an unspecified target of reducing concentrations of PM10 particles, PM2,5 particles, the concentration of Benzo(a)pyrene, the concentration of nitrogen dioxide - NO2. The goal of reducing concentrations of PM10 particles and nitrogen dioxide - NO2 is specified in the section dealing with a healthy environment, where for PM10 particles concentrations should drop from the current 28,4 µg/m3 to less than 10 with the same goal applying to nitrogen dioxide - NO2 where current concentrations are 30,8 µg/m3.

If we look at the priorities set in the Brno Metropolitan Area strategies, there are goals of creating a functional network and with a focus on public transportation and limiting individual car use, coordinating parking spaces with a focus on identifying locations for park and ride systems along with terminals, creating a unified network of cycle paths along with creating sustainable mobility plans for developing sites and there is also a vision of mobility as a service is also present in the Brno Metropolitan Area strategy (Brněnská metropolitní oblast, 2019).

Critical goals regarding the phenomenon

Our overarching goal is to improve the quality of the air that we breathe in Brno. Our plan presents multiple proposals that have the ultimate goal of reducing air pollution and thus improving the health of the citizens of Brno. Many of our proposals have additional benefits such as reducing noise pollution, improving the quality of public space, speeding up transit times and improving safety.

Application objectives

Our proposal seeks to be in line with the overall strategy of Brno as set forth in the Brno 2050 vision. Thus, we aim for a drop of PM10 particles from 28,4 µg/m3 to less than 10 and a drop of nitrogen dioxide - NO2 from 30,8 µg/m3 to less than 10. This amounts to approximately two thirds drop in concentrations and for the unspecified goals regarding PM2,5 particles and Benzo(a)pyrene we can set a similar goal to further specify the general goal of dropping concentrations.

Activities

A. Activities aimed at the pollution caused by mobile sources of air pollution

Since some of the main problems with overstepping the immission limits are related to transportation (OŽP MMB, 2020) policies aimed at reducing or changing the composition of vehicles in Brno form the most logical area to focus on. Unfortunately, some of this air pollution comes from outside the city or happens on transit routes such as the highway D1 (OŽP MMB, 2020) so in many ways the city has limited options. However, much can still be done by enacting large changes in the field of transportation policy in Brno with reducing the number of cars on the road forming the most impactful path to take. While some would argue that the air pollution problem can be solved by, it does need to be said that while electric vehicles do eliminate or rather outsource much of the air pollution, the tire pollution problem where the majority of particulate matter actually comes from tires (Carrington, 2022) is not fixed by them. Electric vehicles can thus be a positive change when it comes to nitrous oxide pollution, however not really when it comes to particulate matter. Focusing on air pollution stemming from transport is of utmost importance with a reduction of the overall number of cars being a path that Brno should embark upon. This is currently seen as a controversial statement and there must be a paradigm shift which makes it more palatable to pass. Fundamentally it also must be said that the goal of reducing car use is firmly stated in the Brno 2050 strategy and thus is in line with the long-term vision that the city adopted. The shift to electric vehicles should be supported in cases where vehicular use makes sense even in the future and obviously some degree of vehicular traffic is needed in a modern city. Taking this approach of reducing the number of cars has the added benefit of freeing up space and improving its quality (Szarata et al., 2017), reducing noise pollution which is also significantly harmful to human physical and psychological wellbeing (Bluhm et al., 2004 & Skånberg & Öhrström, 2002). Brno also currently has the sad distinction of having the most dangerous roads out of major Czech cities (Haluza, 2021). While our goal is primarily to solve air pollution problems, recognizing the other benefits of the approach to our task can help gain even more support. Transportation policy is unfortunately one of the most politicized and controversial areas that one can embark on, and many solutions can be costly, both in terms of finances and political capital. Our proposal seeks to pragmatically balance these factors and think big but also realistically. We recognize that some of these proposals, although leading to fulfilling an approved strategy of the city, are currently politically controversial, however they should at the minimum enter the debate and should be analyzed so that the city of Brno is ready for the day when significant change will be possible.

Figure 19 Transformation of Public space of Amsterdam (https://schlijper.nl/portfolio/)

Amsterdam in the 1970’s on the left, current day on the right - will Brno go through a similar change? From Schlijper, n.d, (www.schlijper.nl)

1. Focus on infill development with the aim of creating a compact city

The way that we live has profound consequences for our transportation needs and options. It is much more viable to walk, use public transportation or cycle when we live close to the places where we need to be. Many of the vehicles on the road of Brno are from suburban commuters, for whom it is much more comfortable to commute by car due to the larger distances and less viable public transportation connections. Thus, one of the main goals of Brno in coordination with its metropolitan hinterland is to reduce urban sprawl into far flung locations and instead focus on building new housing within the urban core of Brno where sustainable forms of transportation are much more viable due to the smaller distances.

2. Create a low emission zone

Municipalities have the option of creating low emission zones which would regulate which cars get to enter the zone based on the emission category that they fall into. This would limit the entry of the most polluting vehicles, many of which have outdated technologies leading to a much larger degree of air pollution when compared to newer more efficient cars. This step would lower air pollution and decrease the overall number of cars entering the low emission zone. Much inspiration can be found abroad as low emission zones have become a common fixture of western European cities. Brno already has already conducted a feasibility study which states that it would be an effective tool for reducing air pollution, especially when it comes to benzene and nitrogen dioxide (OŽP MMB, 2020); however currently it has delayed creating a low emission zone until the large city ring road is completed (Hloušková, 2019). However, since the ring road will be completed in 2035 at the earliest and most likely will take even longer, the city should not allow itself to be paralyzed when it comes to transportation policy simply because of missing infrastructure, that would most likely increase the overall number of cars anyway. Brno has the option of being a leader as currently no Czech city has used its right to create a low emission zone.

3. Reduce the growth of new parking spaces in Brno with the eventual goal of decreasing the amount of parking in the long term

While this recommendation goes firmly against current political goals and promises, research has shown that the availability of parking is a key factor affecting traffic levels (Shen at al., 2020). Simply put, more available parking spaces means more cars in Brno. Since the overall strategy of Brno is to reduce the number of cars, increasing parking spaces would go against this goal. Parking minimums for new construction should thus be reduced. Creative measures can be undertaken such as legalizing already existing parking spots and not constructing anymore such as happened in the case of the construction of the Community center Skála in Nový Lískovec. Because much new construction relies on constructing underground parking spots which are extremely costly, reducing parking minimums can also help alleviate the housing crisis by reducing the cost of new construction. Already existing parking spots should be converted into different uses. The freed-up space can be converted into greenery with the additional benefit of lowering air pollution. Due to the controversial nature of this recommendation this policy should not be formulated as an explicit goal of reducing parking spaces but as setting other priorities during the future reconstruction of streets such as more space for trees, outdoor seating for dining establishments or using experimental models such as parklet constructions.

4. Increase the cost of parking and continue expanding the residential parking system

While once again controversial, parking costs should rise as they can in some cases be effective in reducing traffic (Ostermeijer et al., 2022) and in general the parking costs should seek to internalize the externalities that vehicles cause such as air pollution or even the price that creating a parking space costs. The residential parking system should be further expanded with the overall goal of prioritizing residents continuing. The cost of obtaining a parking permit should be increased significantly for second and third cars both for residents and subscribers with first car permits seeing a smaller rise in price.

5. Building high quality separated cycling infrastructure

The current state of cycling infrastructure in Brno is not satisfactory. The amount of bike lanes is quite small, very often they do not form a coherent linear path, and many are simply paint on busy roads with insufficient activity from the police making sure that these lanes do not serve as secondary parking spaces such as can be seen on the new bike lane on Lidická. These form some of the main reasons why ridership of bikes hovers around 1% (Data Brno, 2022). Research has shown that among the main reasons why people don't use bicycles in cities is due to a fear for their safety (Pooley et al., 2013). Very often, the hilliness of cities and presence of inclines is used as an argument why cycling infrastructure does not make sense in certain cities, with this argument being heard in Brno too. It does need to be said that hilliness does reduce the tendency of people to cycle (Parkin et al., 2008) however this factor is often overstated with many hilly cities having a fairly large share of people who still choose to cycle (Manson, 2022), such as Oslo which placed in the 7th position of the Copenhagenize index of bicycle friendly cities (Copenhagenize Index, 2019). Electric bikes, which are fairly rapidly growing in popularity, are also a significant help in lowering the effect of hills along with tools such as applications showing the path with the least hills (Manson, 2022). Thus, while Brno will probably never reach Dutch levels of cycling, it is still a worthwhile effort to support cycling as there is still much growth potential. In general, protected bike lanes, separated from the road and parking should form the gold standard of future cycling infrastructure in Brno. Positive cases can be found locally such as the bike lane on Botanická street which has ample protection from the road and parking, although this protection ends when crossing an intersection.

Figure 20 Good example of safe cycling infrastructure. From Boston Magazine, 2016, (https://www.bostonmagazine.com/news/2016/01/07/cambridge-best-new-bike-lane/)

6. Explore options for supporting the transition to electric vehicles

While electric vehicles aren't an ideal environmentally friendly solution and overall, the number of vehicles in the city should decrease, the cars that remain should ideally be electric vehicles. Thus, temporary incentives such as electric vehicles having exclusive parking spaces or having to pay less for parking can be explored and tried. However, these solutions should be seen as temporary and should recognize that eventually most vehicles in the city will become electric, although this may take a while as the market share of electric vehicles is currently small and the overall age of the vehicle fleet in the Czech Republic is around 15 years.

7. Continue enhancing the public transportation infrastructure with more radial and tangential options

Brno has an excellent public transportation network and within the wider center of the city it is fast, comfortable, affordable and reliable. Very often even the outskirts of the city are well connected and getting to the historical center is relatively fast. However, when it comes to journeys that do not go through the city center but instead go from outskirts to outskirts, the journey suddenly becomes much faster by car. Thus, new infrastructure development should recognize that due to job opportunities increasingly being situated in less central locations, there needs to be more public transportation options that bypass the city center, which is in many ways overwhelmed by transit in hubs like Česká or Hlavní nádraží.

8. Stop public transportation wait times at intersections

One of the most important factors determining whether one uses a car or public transportation is the speed at which one arrives at their destination. Currently at many intersections public transportation waits in similar conditions such as cars for a green light. Many cities around the world have revamped this system and used real-time location tracking to make sure that public transportation vehicles generally have a green light most of the time. This would significantly speed up travel times with the added benefit of drivers stuck in traffic seeing that public transportation doesn't generally have to wait at red lights. This last effect is similar in many aspects to bus only lanes, which should be further expanded too. Brno currently has this system in place at certain cross-roads, however the system should be expanded further onto as many other crossroads as possible.

9. Support for cargo bikes and electric vans

In the historical city center much of the current traffic that we see is due to supplying of local businesses. Here a solution of reducing the overall traffic is unfeasible because it would harm local businesses, however changing the composition of that traffic is an option. A preference should be given to cargo bikes and the city should actively support them, for example by establishing cargo bike depots near busy areas. As electric vans further penetrate the market, support should be given to ensure that companies dealing with cargo make the switch.

10. Increase the number of car-free areas/streets

The number of zones where cars need special permission to enter such as in the historical city center currently should increase in the future. This can be done by expanding the same administrative system to different areas or it can be done through explicit closures of certain streets or areas for cars. In this sense it is important to realize that the decision not to pedestrianize the Veveří street was a missed opportunity to create a vibrant car-free shopping street similar to Mariahilferstrasse in Vienna. The fear that pedestrianizing will simply create more traffic problems elsewhere is in general unfounded and cities which went this path usually had less overall traffic that was smoother (Largey, 2013 & Flow, 2017). In this area the increased restrictions from the june of this year regarding entry of vehicles into the historical center are a good step forward.

11. Explore the options for a future congestion charge

While politically extremely controversial, a congestion charge can be considered the most effective policy to reduce the number of cars and thus air pollution (Nicholas & Tuss, 2022). When one has to pay to enter the city center by car, it certainly reduces the number of trips that people take as alternatives and suddenly becomes much more attractive financially. While a congestion charge is most likely not realistic in Brno in the short-term, the policy should be analyzed, and the city administration should look at successful cases such as London where air pollution levels decrease (Green et al., 2020). Research should be undertaken to determine at which price the potential congestion charge would be set and how it would work specifically in Brno.

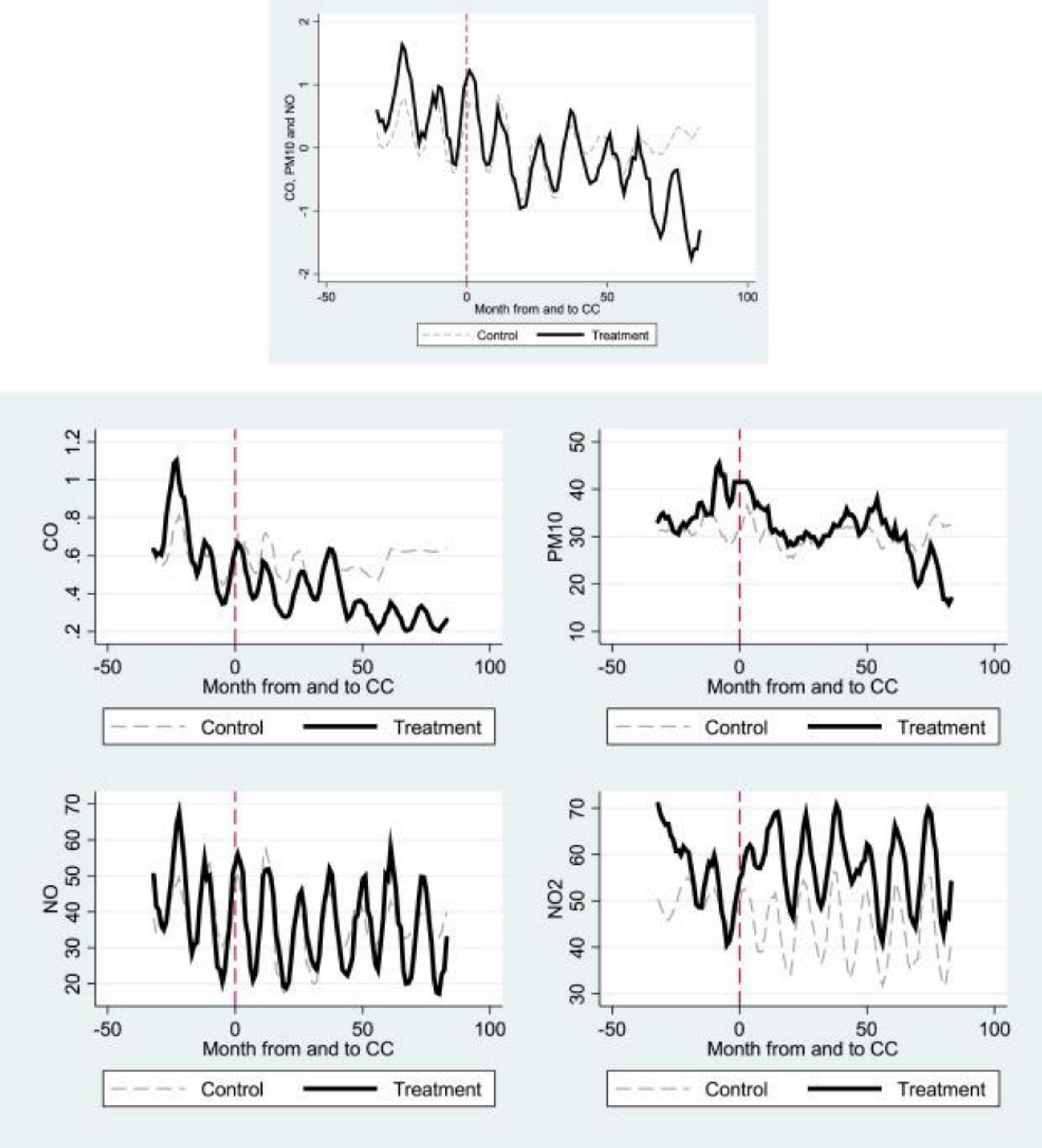


Figure 21 Effects of the London Congestion Charge on air pollution. From Science Direct, 2020, (https://www.sciencedirect.com/science/article/pii/S0166046220302581)

B. Green infrastructure related activities

1. New vegetation elements

Vegetation and green infrastructure have many positive impacts on the urban environment and its inhabitants. It increases air humidity, reduces, and dampens temperature fluctuations, reduces noise, slows water runoff during torrential rains, aesthetic function, improvement of mental health, and most importantly and relevantly for the cause of this paper: captures dust particles.

Phenomenon that is widely spread in the urban environment is the lack of space for sufficient and living greenery to develop. Many voices from across the scientific disciplines ranging from urbanism, dendrology and hydrology thus call for approaching the development of green spaces in the urban environment as whole new system of infrastructure that needs to be not neglected when planning a specific net of structures on a site.

2. Use of nature-based solutions (Green roofs, green walls, vertical gardens)

While space for the greenery may not be always present due to the complex system of already existing infrastructure (canalization, power, etc.) Rainwater management is a drainage concept that supports the preservation of natural drainage conditions in the form they were before urbanization (during new construction) or returning or approaching them in the case of application in existing buildings. The solutions we are suggesting thus aim to focus on the issue of increasing drought around Czechia, urban heat island effect and simultaneously they have a positive effect on enhancing air quality within urban environment. We suggest two nature-based solutions that may be viable taking in account the conditions of Brno's urban environment: Vertical gardens and green roofs.

The term "vertical garden" is used for any type of greenery installed on vertical surfaces, regardless of the location of the roots. The main types of vertical gardens are green walls (facades on buildings), free-standing green walls, green anti-noise walls.

Figure 21 Greenwall in Paris (http://www.parisdailyphoto.com/2013/08/green-wall.html)

Figure 22 Green anti-noise wall (https://soundproofcentral.com/block-freeway-noise/)

Figure 23 Green room, green free-standing wall (https://www.soll-galabau.de/aktuelle-news/ansicht-aktuelles/datum/2016/12/15/der-weite-weg-eines-mobilen-gruenen-zimmers.html)

Green roofs have a positive benefit both for the owner of the house and its surroundings. Thanks to thermal insulation properties, they save energy costs and cool buildings. In addition, they create a pleasant microclimate, especially in cities, where they replace the missing greenery. Lastly, most relevant aspect of their functioning is that they also have a positive impact on the quality of air in their surroundings. There are several types of green roofs, all of which have different benefits and functions.

Figure 24 Wetland Green Roof London
(https://greeninfrastructureconsultancy.com/wetland-green-roof-thriving/)

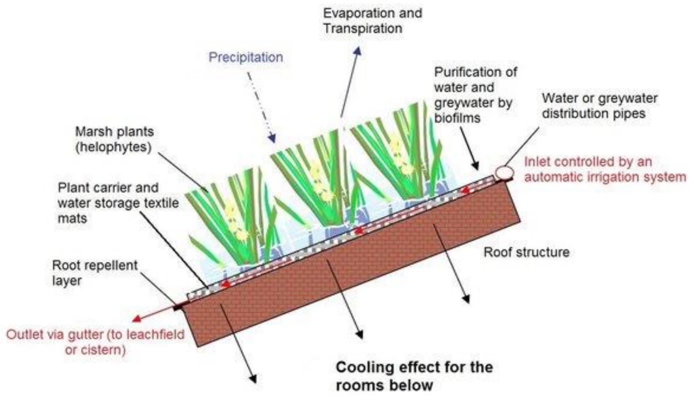


Figure 25 Structure of a wetland roof (M. Blumberg, 2020)

For example, the *wetland green roofs* mimic natural soil processes and us such acquire number of benefits. Their main contribution is wastewater treatment, namely domestic or industrial water. Water impurities are filtered as they pass through the vegetation layer and are further absorbed by plants as nutrients. To ensure proper drainage, the slope of the roof must be steep or moderately steep. The water treated in this way is further used for irrigation, for flushing toilets, or is discharged into the sewer. Furthermore, through the process of water evaporation the temperature of the surrounding air decreases (Blumberg, 2020; Zapater-Pereyra et al., 2016).

Figure 26 Intensive Green roof (Nelson, 2021, https://www.rooferscoffeeshop.com/post/the-living-roof-series-intensive-green-roofs)

Figure 27 Extensive green roof
(https://www.environdec.com/library/epd6070)

Like *wetland green roofs*, both *extensive and intensive green roofs* can also capture dust particles and greenhouse gasses, thus regulate the quality of air in its surroundings. While the extensive green roofs serve mostly as a tool for evaporation and capturing the dust particles, intensive green roofs may also function as place for the public use: many activities such as gardening, rest, community building and such (Snodgrass & McIntyre, 2010). *Intensive green roofs* are often being built on residential buildings, hotels, or underground parking lots while to support human activities on the roofs and to support the integration of larger plants, bushes, and trees, it is necessary for the roof to have a relatively flat surface. *The extensive green roofs* are much lighter systems with low demands and maintenance (fertilization and irrigation) which overall less expensive and are primarily associated with sites not accessible by the public or areas with steeper slopes. Through the adoption of extensive and intensive green roofs, a minimum performance of 25 l/m^2 water retention and 95% vegetation coverage is expected after 3 years from the implementation (Nelson, 2021; Snodgrass & McIntyre, 2010).

3. Ensuring adequate space for the roots of the greenery

For the healthy state of the urban greenery, it is important so that the city addresses not only the issue of new green elements in the public space but takes care of the already existing green infrastructure as well. Thus, critical aspect of green infrastructure management in to ensure that both trees and bushes have enough space for their rooting system. Root space is a fundamental factor for the preservation and quality growth of trees. A tree in natural conditions can have roots up to 3x wider than the crown (according to specific soil conditions). ČSN83 9061 – Protection of trees, vegetation and vegetation areas during construction work states the protection of roots during construction activities 2.5 m from the tree trunk. This can be done by land reparcelling, planning and so-called rootable cells. Rootable cells are a special underground plastic construction that prevent soil compaction and compression. They make it easier for trees to grow, get nutrients and the structure can also withstand the load of cars.

Figure 28 Root protection (https://greenblue.com/na/case-studies/)

4. Green Pass software

Variety of solutions can be adopted in an urban environment to ensure a positive development considering its air quality, climate, or noise levels standards. Therefore, to make an informed and knowledgeable decision, tools may help to identify the most suitable and efficient type of NBS for the specific site with its characteristic conditions. The Greenpass software evaluates different design solutions regarding thermal comfort and physiological equivalent temperature (PET), energy, water, and air fluxes. The Greenpass system consists of standardized tools, reports, and a unique set of Key Performance Scores (KPS) and Key Performance Indicators (KPI). Together, Greenpass tackles six urban challenges: climate, water, air, biodiversity, energy and costs. The basis of the software consists of 28 performance indicators (divided within the 6 challenges mentioned above) and 7 climate resilience key performance indicators. The result is measurable and cross-comparable data with a clear narrative value: it shows the impact green infrastructure and other measures will have on city life. Through this method, urban planners and decision makers can create various scenarios of implementing different combinations of solutions and later compare their efficiency, costs, and relevant parameters for the conditions of their city (GREENPASS, online).

Biotope City Wienerberg is the first GREENPASS Platinum certified Quarter. It is located on the site of former Coca Cola company in the South of Vienna and its size is approximately 7 ha. Besides being a climate adaptation champion, the project also reflects the issue of housing crisis and consists of approx. 950 apartments, of which 3/4 social housing. Thus, Biotope City Wienerberg practices sustainability in its complete sense, both environmental and social. Some of the impacts by optimized design compared to status quo consist of increase of green area by 2,5 ha, increase of leaf area by 11,1 ha, up to -2.2°C air temperature reduction, less reduction of rainwater run-off by 33 % or 40 % less of sealed area (IBA Wien, 2019; Kraus & Scharf, 2019). GREEENPASS has been used in the process of planning used NBS and thus has played a significant role in securing the final effects on increased biodiversity, reduction of runoff water, climate adaptation abilities and (most importantly) air quality of the area as well.

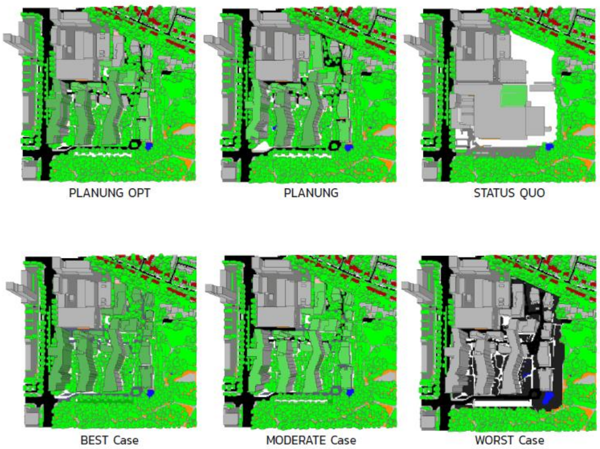


Figure 29 Biotope City Wienerberg Model (https://greenpass.io/2021/03/09/biotope-city/)

Figure 30 Biotope City Wienerberg realization (https://www.iba-wien.at/en/projekte/projekt-detail/project/biotope-city-wienerberg)

C. Heating sector development activities

1. Support the transformation of household heating systems

Local heating of households is currently the most problematic and overall most significant source of air pollution in the Czech Republic and Brno as well (Brzezina, 2021). Especially in rural areas with the absence of industrial activities, local heating stations are one of the main sources of emissions and the reason for poor air quality in winter. Specifically, heating powered by old boilers, low-quality fuel, or inappropriate heating methods (boiler maintenance, etc.) is a problem. The state contributes to the solutions for the issue of local heating by gradually introducing the obligation to replace outdated boilers with more modern and more effective machines control while simultaneously intensified monitoring illegal burning of waste. While heating in the core of the city is mainly powered by central grid, in the rural areas and hinterlands, heating systems are primarily run by boilers. Currently, the state has launched a program supporting the replacement of unsuitable boilers, officially called Boiler subsidies IV. The intent is to use a total of 122 million crown to help households with lower income to transform their obsolete boilers and support public education on the appropriate use of the boilers (ČTK, 2022). We suggest the city of Brno should support the communication of the ongoing campaign of the *local heating transformation* as well as *insulation of buildings*.

2. Development of energy management system

The introduction of energy management (EM) is a systemic and cost-friendly step that has multiple implications for the urban environment, ranging from climate mitigation to improving the quality of air or social challenges such as energy justice. The goal is to gradually achieve significant energy savings and improve the organization of work within the municipal or municipal authority while at the same time to address the issues mentioned earlier. Consistent EM has the following benefits:

stabilization of energy consumption and related expenses,

- cities only pay for the energy they use,
- early detection of accidents, black purchases,
- use of buildings in an energy-efficient manner
- by decreasing the energy consumption, production also decrease, having an impact on local quality of air

The basic tools of EM consist of:

- monitoring and targeting,
- incentive and subsidy programs,
- energy audits
- establishment of information system
- catalog of energy measures,
- public and private sector cooperation

The responsible person- energy manager- is a partner and consultant in the field of energy (energy supply and energy efficiency) for other departments of the city's authorities, subordinate organizations, real estate managers, resource managers and external experts and companies. For the sufficient adaptation of energy methods and know, there is a high need to create suitable conditions and define a sufficiently broad authority for the manager to be able to decide. We therefore suggest not to limit EM performance only per one person, but to assemble a *team of energy managers*, which would be composed of office staff and subordinate institutions so that their cooperation covers all agenda related to the use of energy. The city of Brno has already established the position of energy manager, it is therefore advisable to build on the great praxis and further develop the activities of energy management department.

D. Public Participation

Lastly, we highlight the need of including the public in decision-making in all the areas mentioned above. Studies from across fields (energy, green infrastructure, transport) have showed positive impacts of engaging public within the whole process of policy and decision making at a city authority level.

In the study by Willems et al. (2020) nine European green infrastructure projects have been presented, aiming to determine: (1) how participatory ambitions may differ across green infrastructure project phases; and (2) which tools are being practised to realise the participatory ambitions for each phase and whether these instruments differ across stages. The figure below (Figure 31) shows some of the tools used across the analysed projects.

	Design	Delivery	Maintenance
Legal		Statutory consultation (Aberdeen, Bergen, Bradford)	
Market-based	Joint grant application (Dordrecht); open call to develop prototypes (Gothenburg)		
Communicative		Community events (Aberdeen, Bergen, Bradford); newsletters (Aberdeen, Bergen); scale model (Bergen); visualisations (Bradford)	
Organisational	Urban living lab (Antwerp); new department (Dordrecht); dedicated project team (Gothenburg)		Establishment of partnerships (Enfield, Kent); appointment of community liaison (Kent)

Figure 31 The policy instruments used per phase and linked to the cases (Willems et al., 2020)

As Haf et al. (2020) state, up until recently, collaboration between citizen initiatives and local authorities in the energy sector has (if it was present at all) primarily had top-down participatory character, in the form consultations and surveys. Apart from the two mentioned, the three main, citizen-led types of participation within the energy sector are:

- Community and Cooperative Energy Projects,
- Public Activism and Campaigning
- Local Authority and Citizen Collaborations

Haf et al. (2020) further describe some of the good practices that aim to encourage and multiply such activities. These include e.g. Citizen Juries, Digital Participation, Citizen Assemblies, Joint-ventures, Cooperative energy groups or more creative methods such as living streets (Kovacs et al., 2018) or gamification.

Figure 32 Vilawatt project encouraged residents of Viladecans, Spain to switch to renewable energy sources (https://ec.europa.eu/regional_policy/en/projects/Spain/vilawatt-citizen-driven-initiative-in-viladecans-spain-saves-energy-and-boosts-local-economy)

An example from Spanish Viladecans, province of Barcelona may function as an interesting case study. The local government of Viladecans, set up an energy company based on citizen participation to promote the shift to environmentally friendly power sources and the renovation of homes to make them more energy efficient. Through peer-to-peer learning, competition and gamification public engagement in sustainable behaviour was promoted. Energy teams in each of the neighbourhood’s buildings converted project ideas (collected from a citizen forum) into concrete actions. Energy savings achieved by residents of buildings partaking in the project, were rewarded in virtual currency, called “Vilawatt”. Vilawatt was established as a way of converting energy savings into purchasing power (Cities of Tomorrow; European Commission, 2020; Haf et al., 2020).

The benefits stemming from public participation include (IPR Praha, 2016, pp. 20–21):

- Use of local knowledge
- Greater legitimacy and acceptance of the outputs of planning processes
- Early detection of potential conflicts
- Better dialogue between citizens, experts, and decision-makers

Despite the number of positive consequences of public participation in city planning, it is vital to acknowledge various limitations that may be caused through the process. Only with a sufficient understanding of these constraints are we able to design functioning participation processes and correctly define their purpose. Ignoring these limits to participation often leads to frustration and disappointment in the results of public engagement (IPR Praha, 2016). These limits include *Representativeness problem* (unevenly distributed accessibility or level of interest in participating with participatory activities among public societal groups) , *Efficiency*

Problem (risk of delaying planning processes due to administration), or *Abuse for particular interests.*

To minimise the chance of these risks to become a reality, (IPR Praha, 2016, p. 23) suggests to ask ourselves these 4 questions before starting participation process:

1. Can the results of public participation change the form of the plan/proposal?
2. Does the plan or proposal involve the public or other actors, or are they interested in it?
3. Do we have sufficient financial and human resources to ensure effective public participation?
4. Has public involvement in this proposal sufficient political interest?

If the answer to any of these questions is no, we may reconsider planning of the participation process. While mentioned limits may very easily become real, growing number of studies have supported the concept public participation and the number of benefits may not be neglected. Level of implementation of public participation is thus advisable.

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