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Benefits of Climate Action

Paris: Benefits of Implementing a Fossil-Free Zone

A report prepared by BuroHappold for C40 Cities Climate Leadership Group

CONTENTS

ACRONYMS AND TERMINOLOGY

AQ	Air Quality
COMEAP	UK Government Committee on the Medical Effects of Air Pollution
CRF	Concentration Response Function
CVD	Cardiovascular Disease
DEFRA	UK Government Department for Environment, Food & Rural Affairs
FFFS	Fossil-Fuel Free Streets
HRAPIE	WHO project on the Health Risks of Air Pollution in Europe
LYL	Life Years Lost
VHA	Value of Statistical Hospital Admissions
VOLY	Value of Life Years
FFZ	Fossil Free Zone
ZCR	Zone à Circulation Restreinte

Term	Definition	Source
μg/m³	A measure of concentration in terms of mass per unit volume. A concentration of 1 μg/m³ means that one cubic metre of air contains one microgram of pollutant.	DEFRA
Background concentration	Concentration of pollutants not explicitly emitted by local sources, but transported into the considered area.	BuroHappold | C40
Cardiovascular Disease	Disease related to the heart and circulation. Includes stroke and problems with arteries or veins in other parts of the body not just the heart.	King's College London
Concentration	The amount of a pollutant in a given volume of air. Generally expressed in microgram per cubic metre (μg/m³).	BuroHappold | C40
Concentration Response Function	A quantitative relationship between the concentration of a pollutant and an increased risk of an effect on health (in this case, mortality & morbidity)	BuroHappold | C40

Emission	Direct release of a pollutant into the atmosphere from a specific source in a specific time interval. Generally expressed in tons per year (tn /y).	BuroHappold | C40
Intervention Area	The area within the respective city that is being directly affected by the implementation of a city-action.	BuroHappold | C40
Life Expectancy at Birth	A valid and meaningful expression of mortality effects for both the impact of reduced pollution and the burden of current pollution.	BuroHappold | C40
Life Years Lost	Life Year represents one year lived for one person. Usually added up over the population and a specific duration, allows quantification of changes in timing of deaths. Life Years Lost is a result of deaths and represents the population mortality burden.	BuroHappold | C40
Life-Tables	Tables which show, for each age, the probability that a person will die before their next birthday (is given by 1 year age groups).	COMEAP
Morbidity	Rate of disease in the population	BuroHappold | C40
Mortality	Number of deaths in the population	BuroHappold | C40
NO_2	Nitric oxide (NO) is mainly derived from road transport emissions and other combustion processes such as the electricity supply industry. NO is not considered to be harmful to health. However, once released to the atmosphere, NO can rapidly oxidize to nitrogen dioxide (NO_2), which can be harmful to health	DEFRA
NO_X	NO_2 and NO are both oxides of nitrogen and together are referred to as nitrogen oxides (NOx)	DEFRA
Number of Attributable Deaths	A valid and meaningful way of capturing some important aspects of the mortality burden, across the whole population in any one particular year, of current levels of pollution.	COMEAP
PM	Particulate Matter - Collection of solid and liquid particles found in the air.	BuroHappold | C40

PM_{10}	PM10 is defined as the mass concentration of particles of generally less than 10 µg aerodynamic diameter. This fraction can enter the lungs. PM10 includes $PM_{2.5}$.	COMEAP
$PM_{2.5}$	$PM_{2.5}$ is defined as the mass per cubic metre of airborne particles passing through the inlet of a size selective sampler with a transmission efficiency of 50% at an aerodynamic diameter of 2.5 µg. In practice, $PM_{2.5}$ represents the mass concentration of all particles of generally less than 2.5 µg aerodynamic diameter. Often referred to as fine particles. This fraction can penetrate deep into the lungs.	COMEAP
Respiratory Disease	Diseases related to the lungs.	King's College London
Total Population Survival Time (life-years gained or lost)	A valid and meaningful way of expressing mortality effects of both the impact and burden questions, and is the most comprehensive way of capturing the full effects. There are difficulties in communication. The concept of a 'life-year' is not a difficult one to grasp, but it is difficult to interpret the very large numbers of life-years involved in total population survival. However, it is the most relevant index for policy analysis.	COMEAP
Value of Life Years	The monetary value of a year of life lost. It is based on studies that assess the willingness to pay for reducing mortality risks associated with air pollution	King's College London
Value of Statistical Hospital Admissions	The monetary value of a hospital admission	BuroHappold | C40
Whole City Area	The area of the entire urban scale within which the specific action is taking place. Usually determined by urban municipal boundaries.	BuroHappold | C40

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IMPORTANT NOTE

All information provided in this study is to illustrate the process and methodology used for the analysis discussed in the document.

BuroHappold is not making a recommendation, as to whether to proceed with a specific course of action within this study and accepts no responsibility for the realisation of prospective social, environmental, economic or financial outcomes. Actual results are likely to be different from those shown in the analysis because of inaccuracies in the input data, uncertainties relating to the underlying evidence and the fact that events and circumstances frequently do not occur as expected, and the differences may be material.

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EXECUTIVE SUMMARY

C40's enabling research programme on the benefits of inclusive climate action aims to support cities to not only tackle the challenge of climate change but more importantly realise the benefits of doing so.

The time for urgent climate action - C40 Cities must deliver 14,000 actions by 2020 in order to reach net zero emissions by 2050 to achieve the Paris Agreement's aspiration for a 1.5 degree world

The benefits of climate action - from green jobs and growth, to active, happier lives and cleaner air and water, have an immediate, tangible impact on people's lives.

Inclusive climate action provides opportunities – to tackle multiple mayoral priorities simultaneously and deliver multiple benefits to all segments of the population, and ultimately result in more transformational climate solutions.

This report summarises the benefits for the city of Paris from implementing a **Zero-Emission Zone** across the entirety of Paris' central district.

HEADLINE BENEFITS

The headline benefits below are summarised according to the key environmental, social, and economic outcomes that have arisen from the analysis. The figures displayed represent the eventual total impact of implementing central Paris' Fossil Free Zone (FFZ) by 2030. In reality, these impacts will be felt incrementally, as the effects of the initiative is in-line with the zone's phasing.

ENVIRONMENTAL IMPACT

Approximately **18% reduction in** overall non-background $PM_{2.5}$

SOCIAL IMPACT

Over 380 Deaths averted annually across the city population

Life expectancy increased by an average **18 days per person** across the city population

ECONOMIC IMPACT

Over € 215 Million of value through life years gained

Approximate costs avoided due to reduced premature mortality from **change in $PM_{2.5}$ levels.**

Over € 215 Thousand in healthcare costs avoided due to the reduction in $PM_{2.5}$.

1 INTRODUCTION

The C40 Cities Climate Leadership Group (C40) has a mission to enable cities to develop and implement policies and programmes that generate measurable reductions in greenhouse gas emissions and climate risks. In particular, following the ratification of the Paris Agreement, C40 is committed to ensuring that cities play their part in keeping the world within 1.5ºC of warming compared with pre-industrial temperatures, through direct action within the city limits. In support of this mission, C40 has launched a three-year research programme focused on articulating the Benefits of Climate Action and enabling cities to quantify and communicate those benefits in a compelling way that will drive the acceleration and expansion of climate action.

C40 and Johnson & Johnson have formed a partnership under a common goal of addressing issues surrounding urban air quality and its relationship to health. This partnership is designed to 'connect the dots' between improved air quality within cities, and measurably improved health amongst citizens. The alliance intends to initiate, consolidate or enhance implementable climate actions that align low-carbon and sustainable development with improved health outcomes. C40 seeks to support aligned climate and health actions, speeding up and scaling up positive impacts. The city-scale provides an evidence-base broad enough to remain significant, but focused enough to make a difference on the ground. This helps actors within city government make the case for action at both a political and financial level.

We have collected and analysed raw data from each city and combined it with evidence from existing literature and tools to identify replicable methods for measuring benefits. The findings will be shared with a wider group of cities through C40's network programmes, enabling enhanced testing of the approach. The aim is to enable C40 cities to effectively and efficiently measure the wider benefits of climate action, here specifically air quality, unlocking a greater speed and scale of action required to achieve climate safe, liveable cities.

1.1 THIS REPORT

This report outlines the initial findings from the benefits analysis prepared for the city of Paris, drawing on data and information provided by the city with regard to the implementation of a fossil-free zone, planned for full delivery in the city in 2030.

Section 2 describes the context of the intervention. Section 3 describes the key findings of this short study, including an overview of the input data used together with a record of the assumptions that have been made. Section 4 offers potential policy insights and opportunities for scaling up the selected action. Section 5 describes the methodology used to develop the analysis, including any notable limitations.

The work described in this report is focussed exclusively on the air-quality related health benefits associated with a single, specific, climate action in Paris. The monetised gains that are then accrued from these improvements in public health are then estimated.

2 PARIS' ACTION AGENDA

The city of Paris has proposed the implementation of a 'fossil-free zone' (FFZ) as the city's climate action for this project. This fossil-free zone will cover the entirety of the city's central district (Which falls organisationally within the jurisdiction of the Mayor of Paris, and falls geographically within the Boulevard Peripherique – 'Paris intra-muros'). The city has committed to fully implement the FFZ by 2030. This action falls under the city's broader pledge under the C40-led Fossil-Fuel-Free-Streets (FFFS) declaration. Other actions committed to under this declaration include the delivery of an entirely emissions-free public transport fleet by 2025 (eliminating all diesel in the fleet by 2020) and significant boosts to infrastructure intended to enable and encourage active travel (non-motorised transit / walking and cycling). Central Paris and the neighbouring territories are, by most standards, high-density urban environments (reaching levels of up to 20,000 inhabitants per square kilometre). Whilst this presents some challenges with respect to delivering universal access to green and open spaces, it offers a strong opportunity to decarbonise and de-toxify the core transport and logistics systems.

Signing onto the 'fossil-free streets declaration' is entirely consistent with the passing of the 2016 Paris Climate Accord, as the nation's capital continues to play a leadership role in the global fight against climate change.

As indicated, Paris's ambitious action falls within the city's growing agenda around building a healthier, cleaner, and more walkable city. Planning the FFZ is not only centred around removing fossil-fuel emitting vehicles from the streets of Paris, but this changed public realm is devised to further encourage a culture of walking, cycling, and public transport modes. To that end, the city has already implemented carbon-cutting measures within inner Paris with objectives of reducing transport-related emissions by 60% from 2009-2020[1].

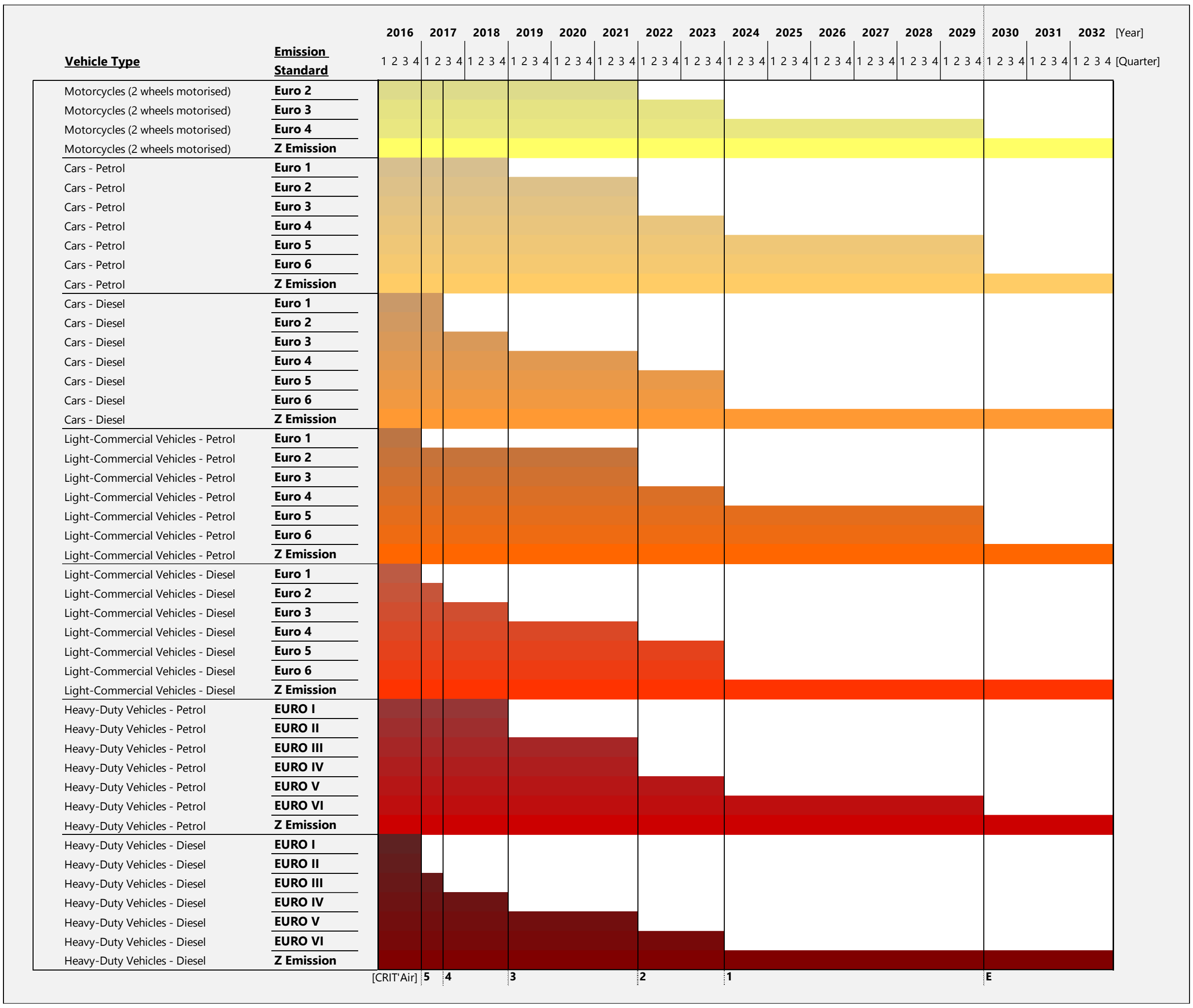
The regional plans – led by 'Ile-de-France Mobilité'[2] – to remove all fossil-fuel buses from the centre of the city and invest only in electric buses, marks a milestone in the city's shift towards an urban mobility revolution. By abandoning diesel- and gasoline-powered vehicles, the city administration is pioneering the transition towards electric mobility, and in doing so is investing heavily in innovation and experimentation in clean-mobility solutions. The city has accordingly committed to only procuring electric municipal vehicles from 2025 and to have a zero diesel fleet by 2020.

In 2017 the city government released an initial timetable, outlining a five-stage series of emissions-classification-tightening from present to 2030 that will culminate in the achievement of a fossil-free zone (FFZ) by 2030. Paris is also working with the Greater Metropolis over the feasibility of an extension of the current 'Zone à Circulation Restreinte' (ZCR) within the second motorway that circumnavigates central Paris – the autoroute A86[3].

The diagram on the following page shows how the different classifications of vehicles will be phased-out over the period 2016 to 2030. Each core colour (from yellow to red) represents one of the seven vehicle types. The saturation of the colour (from dark to bright) reflects the

[1] PARIS CLIMATE AND ENERGY ACTION PLAN (2012) - https://api-site-cdn.paris.fr/images/70923
[2] The regional authority for transport, and an important financial contributor.
[3] Confirmed by the City Participants (page 5)

regulatory standard for emissions, from the most polluting (Euro 1) to the least polluting (Zero emissions / electric).

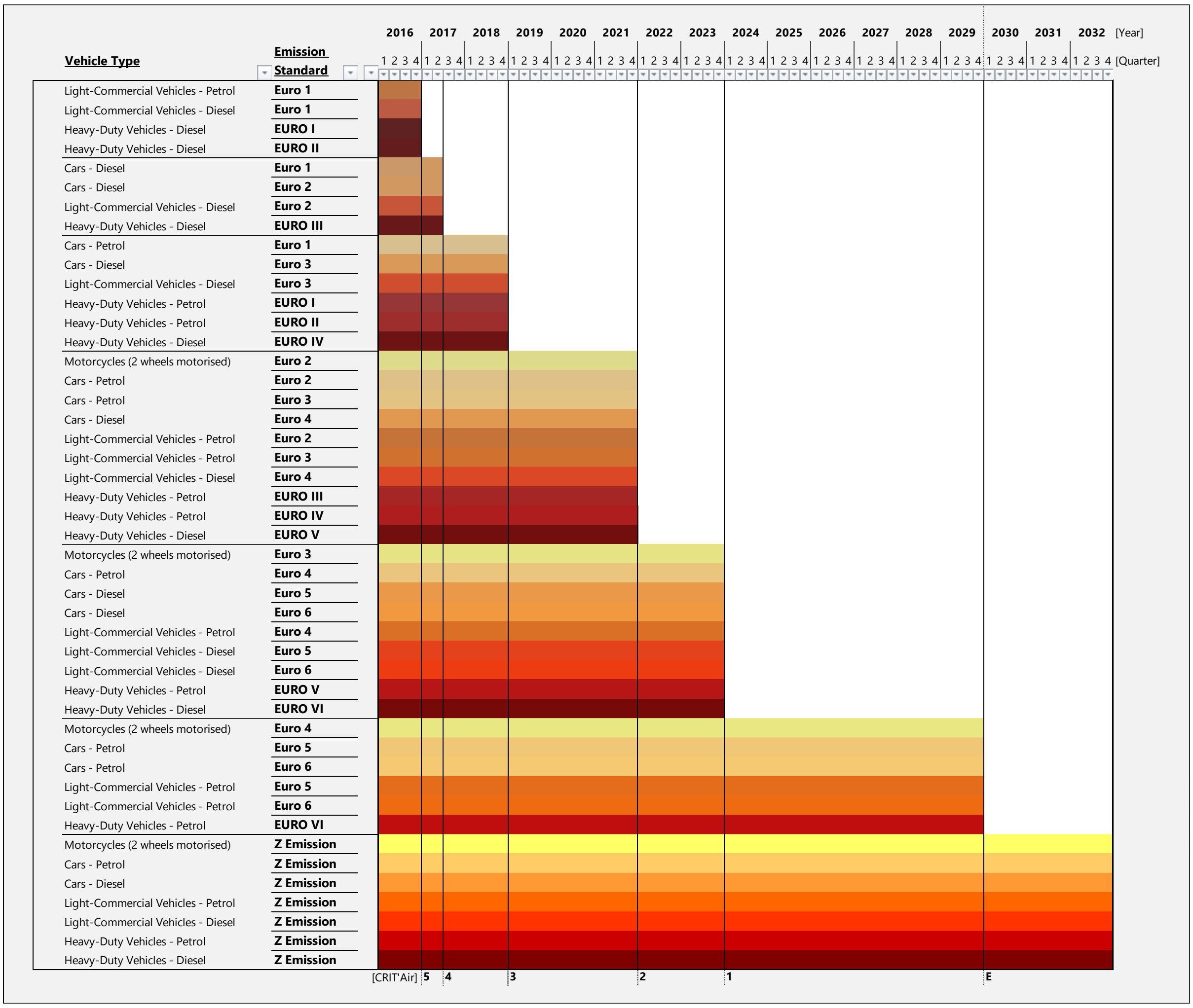


The above chart was interpreted from the information displayed within Annex 1 of 'the classification of vehicles pursuant to Articles L.318-2 and R.318-2 of the Highway Code'[4].

On the following page, the vehicles are re-ordered to show all vehicles that are phased out for a given classification-tightening step together. Thus, the longest bars represent the vehicle classifications that will be permitted to circulate in the city for longer.

By inspection, it may be observed that, under the current schedule, the greatest numbers of vehicle classifications will be prohibited in 2030 although, of course, this does not necessarily represent the greatest number of vehicles (or kilometres driven). All diesel-powered vehicles – i.e. the most polluting vehicle types – are set to be prohibited in the zone from 2024, whilst the remaining EURO 5/6 petrol vehicles will be permitted up until the full enforcement of the FFZ in 2030.

[4] Arrêté du 21 juin 2016 établissant la nomenclature des véhicules classés en fonction de leur niveau d'émission de polluants atmosphériques en application de l'article R. 318-2 du code de la route: https://www.legifrance.gouv.fr/affichTexteArticle.do;jsessionid=481BC5E2DCB350CCE1AF48F71C34F8FA.tplgfr40s_3?idArticle=LEGIARTI000032750255&cidTexte=LEGITEXT000032750239&dateTexte=20180222



The above chart was interpreted from the information displayed within Annex 1 of' the classification of vehicles pursuant to Articles L.318-2 and R.318-2 of the Highway Code'[5].

Beyond 2030, the focus of the city administration is likely to be on the continued de-carbonisation of the urban economy including the practice of off-setting emissions, where necessary, to get to the stated target of a zero-emissions city by 2050. These strategies are likely to fall-in line with Paris plan for 40% reduction in its global footprint of carbon-emissions by 2030 (80% by 2050), a plan positioned within the 'New Climate Air Energy Plan for Paris'[6].

Aim of measuring the benefits of this action

Through consultation with the city, it is understood that whilst there is general support for the implementation of a low emissions zone, there remain stakeholders who harbour concerns about the potential impacts of implementing such a zone. It is envisaged that the provision of global figures for health outcomes associated with the zone could yield

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[5] Arrêté du 21 juin 2016 établissant la nomenclature des véhicules classés en fonction de leur niveau d'émission de polluants atmosphériques en application de l'article R. 318-2 du code de la route: https://www.legifrance.gouv.fr/affichTexteArticle.do;jsessionid=481BC5E2DCB350CCE1AF48F71C34F8FA.tplgfr40s_3?idArticle=LEGIARTI000032750255&cidTexte=LEGITEXT000032750239&dateTexte=20180222

[6] Nouveau Plan Climat Air Énergie de Paris Projet adopté par le Conseil de Paris du 20-22 novembre 2017 Délibération 2017DEVE170

increased support for its implementation, and possibly for the acceleration of its delivery or the expansion of its coverage.

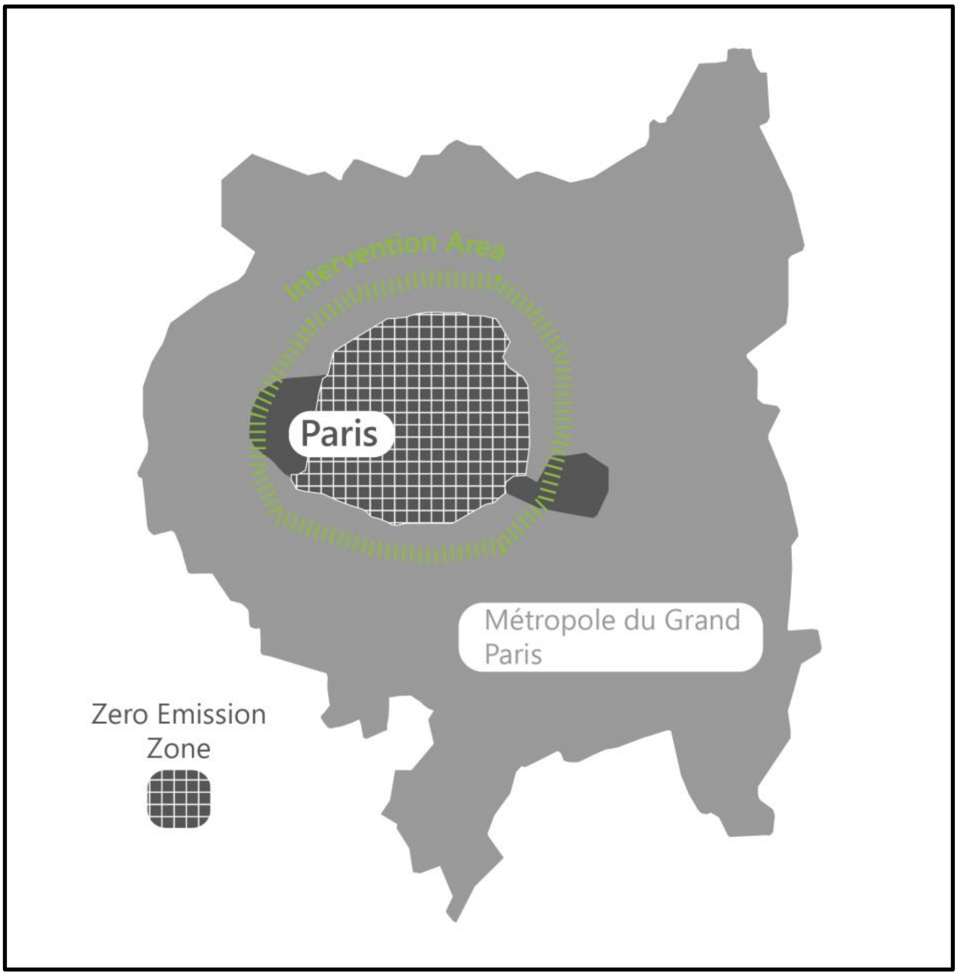
We understand that a report into some of the health outcomes associated with the implantation of the ZCR is forthcoming although the timing for this is uncertain. The purpose of this report, therefore, is to provide an early sense of what the potential impacts could be and how the implementation of the zone could be enhanced to increase its projected health outcomes.

Location and scale

The map on the following page illustrates the extent of the proposed FFZ relative to Paris' wider metropolitan area. The hatched area represents the extent of the current ZCR and the grey area represents the extent of the Metropole de Grand Paris (MGP). The area of central Paris is just over 100 square kilometres, whilst the area of the MGP region (without Paris) is approximately 720 square kilometres. Thus, together the total area of the MGP region is approximately 825 square kilometres. For reference, the population of central Paris is 2.2m and the rest of the MGP region is 4.8m, making a total of 7m over all. The total Paris Agglomeration counts a population of approximately 11.3m so there are a further 4.3 m urban dwellers living beyond the MGP region.

So far, progress has been made between Paris and the Greater Paris Metropolis in addressing the feasibility of extending the ZCR to the secondary ring-round that circumnavigates the city (the Autoroute A86). Studies have been conducted on the social and environmental ramifications of such an expansion, with the idea behind it being to extend the next-steps of the ZCR's transition towards a FFZ in 2030. Multiple issues still need to be navigated, primarily:

- Mediating 60 city mayors and their respective traffic authorities – many of which remain unconvinced by the current forecasts
- Managing the maintenance concerns of such a venture, especially given that automatic controls are not currently available, and would be essential to operating a zone expansion to motorways.



Time scales

Paris has pledged to cease procuring new diesel buses **immediately**, to only purchase zero-emission buses from **2025**, to ban all diesel vehicles by **2024** and, finally, to ban all combustion engine vehicles by **2030**. As this illustrates, there are multiple steps to be taken in order to achieve fulfilment of the fossil-fuel free streets pledge in its totality over the next 12 years.

Given the length of time involved it is clear that technological change and political circumstances are difficult to predict over the full period. Thus, an important aspect of the project is the creation of a flexible system and framework (namely the ZCR), which can be augmented and adjusted over time, to respond to any opportunities arising to speed up implementation.

3 BENEFITS OF PARIS' FOSSIL FREE ZONE

3.1 ENVIRONMENTAL BENEFITS

By implementing the FFZ in central Paris, the city will experience significant environmental gains, as road emissions account for a substantial portion of pollutants in the city.

These environmental benefits will vary across pollutants. This also depends on further action in ensuring the loss of fossil-fuel activity in the FFZ is not just displaced elsewhere. The city will see drastic reductions in the NO_2 – particularly within the intervention area – as transport is often a major source of this pollutant. Furthermore, $PM_{2.5}$ will also be significantly reduced, yet particulates produced from break- and tyre-wear will remain as these values do not currently change drastically between electric and fossil-fuel vehicles (approximately 35% of total vehicle emissions are estimated to come from brake- and tyre-wear[7]).

In terms of air quality improvements Paris's action will result in:

- **18%** reduction in $PM_{2.5}$; and
- **73%** reduction in NO_2

3.1.1 OVERVIEW OF DATA AND ASSUMPTIONS

The analysis undertaken was guided by Paris' comprehensive pollution monitoring data. Importantly, not all stations measure all the relevant pollutants – NO_2, NOx, and $PM_{2.5}$ – however the networks were comprehensive enough that accurate annual averages were able to be extracted for the desired pollutants – indicating crucial differentiations between inner Paris (the FFZ intervention area) and the city-region as a whole. All values captured within the analysis spreadsheet are annual background-agglomerated averages extracted from the most recent Airparif 2016 Paris Air Quality Summary[8]. This then meant that the analysis was able to draw upon accurate levels for NO_2, NO_X, and $PM_{2.5}$.

No major manipulation of the data was required for carrying out the pollution calculations as all inputs towards the final values were captured in the desired format – i.e. $\mu g/m^3$.

It is important to note the impact of the now well-known discrepancy between the real-world performance and the claimed performance of vehicles previously understood to have met European Union standards for vehicle emissions (Euro Codes)[9]. For this study, the team have modelled the removal of all tail-pipe emission from vehicular transport. This means that the above discrepancy has no impact on the health outcomes modelled for the 2030 zero emissions scenario. However, any modelling that seeks to consider the incremental impacts of the different implementation phases of the policy (as Euro 4, 5 and 6 vehicles are

[7] Source: https://www.airparif.asso.fr/_pdf/publications/rapport-zcr-161220.pdf
[8] Air Quality in Paris Region (2017): https://www.airparif.asso.fr/_pdf/publications/bilan-2016-anglais170830.pdf
[9] "NOx and PM emissions of a Mercedes Citaro Euro VI bus in urban operation" https://www.tno.nl/media/3442/nox_pm_emissions_mercedes_citaro_euro_vi_bus_tno_2014_r11307.pdf
IVL - Remote sensing testing: "Measurement of bus emissions 2010-2015" http://www.ivl.se/download/18.29aef808155c0d7f0504cb/1472802397237/B2254.pdf

gradually forbidden) would need to take into account this discrepancy, noting that there are wide variations between vehicle types and even manufacturers.

3.1.2 KEY FINDINGS

Due to Paris' action, there is an 18% reduction of the non-background $PM_{2.5}$ concentration[10], leading to the city's average being reduced by approximately 1 μg/m³ to 15 μg/m³. This reduction means that Paris' action diminishes the gap between the city's average concentration levels (16μg/m³), and the WHO air-quality guideline recommended $PM_{2.5}$ maximum of 10μg/m³. This significant gain in air-quality accounts for 15% of the difference between the initial and WHO recommended level, illustrating extremely encouraging progress for further enhancement.

Global example:

Studies conducted in Germany[11] concluded that there is a positive relation between the implementation of LEZs and a fall in urban PM levels. When comparing different cities, it has been found that the cities implementing other air quality policies without LEZs, did not experience a significant decrease in atmospheric pollution. In addition, there is a direct and positive relationship between the area affected by the policy and the outcome. The larger the area, the higher the impact. With this in mind, it can be argued that Paris' bold intention for an expansive FFZ indicates the positive feedbacks from parallel AQ-policies (mentioned within the above study) is likely to be magnified in comparison in the case of Paris.

3.2 SOCIAL BENEFITS

The social benefits associated with Paris implementing the central FFZ are deeply significant, in that the annual aversion of over **380 deaths** and over **90 hospital admissions**, as well as over **1,700 life years gained**, all relate to the city's decrease in $PM_{2.5}$ concentration. Life expectancy is also boosted by **18 days** per individual across the entire population, as an alternative measure of improved general health. In terms of the NO_2 concentration reduction, **6,160 deaths** and over **910hospital admissions** are

[10] Please note that this study recognises the 'non-background concentration' as the difference between rural/ambient concentration (away from the city/intervention area) and the value taken as the average concentration for Central Paris (this average excludes roadside and rural monitoring stations). The limitations of this method are: 1) the negative AQ-impact of surrounding traffic emissions on Central Paris and 2) the positive AQ-impact of the FFZ on the surrounding region. It is beyond the scope of this study to expand on this method further and conduct appropriate modelling mechanism to increase its precision.

[11] Wolff, H (2013) Keep your clunker in the suburb: low-emission zones and adoption of green vehicles. The Economic Journal, 124, 578

averted, as well as over **29,500 life years are gained**. Moreover, life expectancy is also expected to be improved by up to **300 days** per individual due to the drastic reductions in NO_2.

Additional social gains are expected, for example increased safety within the public domain – as a likely decrease in the quantity of vehicles on the roads within the FFZ will reduce the frequency of traffic, accidents, and congestion.

3.2.1 OVERVIEW OF INPUT DATA AND ASSUMPTIONS

The main assumptions concerning the population data, concerns the lack of availability of appropriate city-level data – in terms of and hospital admissions (per age/gender) – thus National population data was deployed, and the results scaled-down to the appropriate 'intervention-level'.

The city did however have access to city population data, including the contribution of Paris daily workforce that commute into the central FFZ zone. So in order to capture these populations within the analysis, a method of proportional down- or up-weighting was applied to the scaled national figures, according to the city-level demographics provided. In other words, the proportion of the population at each age for both city and national data was calculated, and the ratios of both were then taken into consideration. This then provided an 'age-specific weighting' that would act in addition to the overall city-to-national population size multiplier. These new ratios have then been applied to the health calculation for both $PM_{2.5}$ and NO_2.

3.2.2 KEY FINDINGS

Every year 48,000 deaths in France are attributed to poor outdoor air-quality[12], largely driven by pollution in the nation's main cities. Therefore in terms of $PM_{2.5}$, the implementation of the Paris' action will individually negate approximately 1% of France's total air-quality related deaths. When translating the reduction in terms of NO_2 concentration, the deaths averted account for approximately 13% air-quality attributable deaths for France as a whole[13].

[12] According to France's health agency 'Santé Publique France' – summarised within http://en.rfi.fr/environment/20160621-air-pollution-kills-48000-year-france

[13] The precise figure for Paris' annual AQ-related deaths is unknown, however scaling the national figures proportionally the population of Paris, the FFZ action is likely to contribute to up to 20-25% of AQ-related death aversions.

Global example:

A wider social benefit associated with the action may be considered to be the general improvement of citizen's wellbeing. Studies conducted in London[14] show that for patients most exposed to the LEZ area, the medical consultation for respiratory illnesses reduced by a value of 5% to 10%, and drug prescription for asthma decreased significantly. Again, as these studies have been conducted on LEZ's, Paris' FFZ will only further augment the positive social ramifications, as by definition the air-quality improvements will be even greater.

3.3 ECONOMIC BENEFITS

The measured benefits from implementing Paris' FFZ also include major costs avoided in terms of life years gained, and healthcare cost savings. In that sense, the main benefit to Paris' economy is accrued from the sheer number of deaths and hospital admissions averted. In relation to $PM_{2.5}$, over **€215 milion** avoided costs due to the reduction in deaths, and over **€215,000** for the healthcare cost savings from the aversion of respiratory- and cardiovascular-related hospital admissions.

3.3.1 OVERVIEW OF DATA AND ASSUMPTION

The monetised mortality values have been derived through adhering to national guidance from the French Government (€115,000 per Life Year at 2010 values[15], inflated according to GDP per capita growth since 2010). It should be noted that these values are significantly higher than EU-wide values, which are of the order of €40,000 per Life Year.

The monetised morbidity values have been derived using data provided for hospital admissions. In contrast to the mortality monetisation values, these values are materially lower than comparable values from Spain or the United Kingdom.

3.3.2 KEY FINDINGS

A core gain from implementing the FFZ, is the economic gain the city will derive from the sheer number of life years gained, and deaths averted. Whilst the action may only account for approximately 1% of France's 48,000 air-pollution related deaths (in terms of $PM_{2.5}$–related reductions), when scaling the figure down to the population of the MGP, or even central Paris alone, a significant number of air-pollution related deaths are being averted.

[14] The London Low Emission Zone Baseline Study, 2011. https://www.healtheffects.org/publication/london-low-emission-zone-baseline-study
[15] http://arirabl.org/publications/desaigues11-voly.pdf

4 COMMENTARY AND POTENTIAL POLICY INSIGHTS

This section of the report provides some general commentary on the above findings as they relate to the wider context of changes to the urban systems in Paris.

4.1 MAIN OBSERVATIONS

The introduction of the FFZ is likely to have significant positive health impacts through promotion of fossil-free transportation. These benefits can be further accentuated if a culture around walking and biking can be unlocked, building on the strong coverage of the Metro and RER train systems available in the city. The climate stewardship that Paris is committing to with the FFZ action should not be understated, particularly when placing the city's action on the global stage. By obliging to tackle all petroleum-based transport – leap-frogging the environmental dangers of reverting to petrol – Paris is pursuing a leading role in dovetailing environmental sustainability and urban public health .

4.2 OPPORTUNITIES FOR SCALING UP OR SPEEDING UP

An expectation of the C40 Benefits programme is to help cities consider ways in which they could scale up or speed up the action or actions being implemented. In the context of air quality, scaled up action implies either delivering improvements in health outcomes to a larger population or delivering more significant improvements in health outcomes to the existing population. Speeding up action offers material benefits because it will deliver improved health outcomes to a given population earlier than the original action would have done. This section summarises findings from two additional analysis undertaken to assess possibilities for scaling up and speeding up the ZCR action in Paris.

4.3 SCALING UP THE SPATIAL COVERAGE OF THE FOSSIL-FREE ZONE

As noted in Section 2 (p10-14) the city of Paris represents a relatively small portion of the urban area known as the Paris Agglomeration (or Unité Urbaine). Paris represents 3.7% and 20.8% of the Paris Agglomeration by surface area and population, respectively (INSEE 2014 Census). Considered another way, there is a population of up to 8.4m people who inhabit urban areas lying outside the ZCR. When the enforcement of the fossil-free zone commences within what is now the ZCR, the same population (or perhaps an even greater one) will inhabit these uncovered areas.

Notwithstanding that there is a clear rationale for applying emissions limits to the most intensively occupied part of the agglomeration (Paris), and that the single jurisdiction of the City of Paris administration is hugely advantageous for implementation, it is worthwhile considering in what ways citizens inhabiting the wider parts of the Paris Agglomeration could derive health benefits from implementation of the fossil-free zone. The team has thus considered some simple additional scenarios that may provide further insight into the potential for expanding the fossil-free zone in the future. These additional scenarios are described below.

4.3.1 CONSIDERING THE IMPACT UPON COMMUTERS WHO LIVE OUTSIDE THE ZCR BUT WORK INSIDE IT

The underlying research that supports analysis of the impacts of atmospheric pollution on health outcomes is based on whole-population studies for large numbers of people base on resident populations. Any attempt to calculate the health impacts of an intervention on non-resident populations therefore involves high-level approximation.

For the purposes of this study, the team prepared a simple calculation of additional health impacts on a commuting population using a time-weighted average exposure method. To take a simple example, if a commuter population spends an assumed 40% of their time in an affected area (as distinct from an assumed 100% for the ordinarily resident population), we down-weight the reduction in their exposure to the relevant pollutants to 40% of the reduction experienced by the ordinarily resident populations.

To assess the potential impact of implementing the fossil-free zone in the current ZCR upon the commuter population (resident outside the ZCR) we applied the time-weighted exposure of 13μg/m^3 to the known commuter population of 1.04m people. We assumed that the demographic profile of commuters was equal to that of the national demographic profile (in contrast to our treatment of the Paris population, whom we know to be younger than the national average).

Our high-level findings indicate that the potential health benefits accrued by the commuter population could increase the total benefit by approximately 21-26% in terms of mortality changes (80 deaths averted in addition to the 387 deaths averted amongst the ordinarily resident population, 1,740 life years gained in addition to the 2,194 life years gained amongst the resident population – all values for $PM_{2.5}$ pollution). The total economic value attached to these additional gains can be estimated at EUR56m – a significant sum.

It is understood that an in-depth study is being undertaken by the regional air quality monitoring body, AIRPARIF, to calculate the potential improvements to the health outcomes associated with the implementation of the fossil-free zone in the ZCR upon populations ordinarily resident in the adjacent urban areas within the Paris Agglomeration. It is expected that such a study would consider the effects of the fossil-free zone in the ZCR upon the air quality in the neighbouring areas, rather than the effects upon those who are commuting into the ZCR itself.

4.3.2 CONSIDERING AN EXPANSION OF THE FOSSIL-FREE ZONE TO COVER A MUCH LARGER POPULATION

Perhaps the most significant augmentation that could be made to the fossil-free zone would be to grow its spatial coverage to benefit a larger population. In an effort to address some of the long-term governance challenges in the Paris Agglomeration, a new administrative body has been set up to manage aspects of the urban and environmental systems in a much larger geographic area than the City of Paris. The Metropole de Grand Paris (MGP), launched in January 2016, holds limited jurisdiction over an area comprising the four central administrative Departments (Paris (75), les Hauts-de-Seine (92), la Seine-Saint-Denis (93) et le Val-de-Marne (94)) and a further 7 neighbouring communes. The population of the MGP region is estimated at approximately 7m people, representing 62% of the population, but distributed over just over 28.6% of the land area, of the Paris Agglomeration. The MGP region is notable for its relatively high density of urban development. With an average inhabitation density of over 8,500 people per sq km, the MGP region can be characterised as solidly urban – even if this level is less than half the density in central parts of the City of Paris.

Applying a fossil-free zone to such a large area would be a highly ambitious initiative covering an area of some 800 square kilometres. However, the urban quality of the area under consideration is in favour because high density urban development can more easily make the case for strong investment in public transport infrastructure. Research into implementing such a zone have alluded towards the need to define the boundaries according to physical transit boundaries, as opposed to administrative discontinuities. Therefore, the AutoRoute 86 – that circumnavigates central Paris – constitutes an apt and concrete boundary within which the ZCR could potentially be expanded to.

To assess the impact of such an initiative the team developed calculations that applied a total elimination in tail-pipe emissions to the non-background pollution across the MGP region. In order to account for the different demographic profiles of the urban core (central Paris) and the outer core (the MGP) the estimate was prepared by calculating health outcomes for the population of the MGP without central Paris and adding it to the values calculated already for central Paris.

Our high-level findings indicate that the potential health benefits accrued by the population of the MGP resident outside of the City of Paris could represent a value equal to the benefits accrued inside the existing ZCR. Based on these high-level calculations the economic valuation of these improved mortality outcomes exceeds EUR 200 million, taking the total for the MGP region to over EUR 400million. It should be noted that these values are much higher than they would be in another European country on account of the relatively high valuation of a Life Year in France (EUR 124,000 per year against an average for the EU countries of approximately EUR 40,000).

4.4 SPEEDING UP IMPLEMENTATION OF THE FOSSIL-FREE ZONE

As described in Section 2 (p10-12) of this report, the implementation of the fossil-free zone in Paris represents the culmination of a series of an incremental tightening of emissions standards for vehicles permitted to circulate in the city. This study has sought to calculate the health outcomes associated with the final step in the process, namely the removal of all combustion engines from the city in 2030. However, it is worth considering the pace of change reflected in the schedule of restrictions.

By inspection it may be seen that, under the current schedule, what many would consider highly polluting vehicles will remain circulating in the city until 2024, and what many would consider moderately polluting vehicles will remain circulating until 2030. It may also be observed that the rate of change is greater in the early phases of the policy implementation period than during the later phases. This may reflect to a certain degree the fact that a change from Euro 6 combustion engine to Zero emissions vehicle represents the most radical step in the process. It may also mask the possibilities of future Euro Codes (perhaps 7 and 8) emerging in the future. More stringent standards on combustion engine vehicles are under consideration at the present time and there is likely to be a continued focus on pollution reduction in addition to CO_2 emissions reductions.

Taking all of the above into account, and observing that vehicle manufacturers are progressing electric vehicle technologies rapidly, it would appear that there is significant scope to speed up the implementation of the FFZ in ways that address both human health and climate change needs. These can be listed as follows:

4.4.1 BRING FORWARD IMPLEMENTATION OF THE FOSSIL-FUEL-FREE PHASE FROM 2030

Maintaining the current pace of phasing out older vehicles would see phasing out of Euro 6 vehicles in between 2026 and 2028. The main barriers to moving to a full zero emissions scenario relate to the provision of adequate charging infrastructures and the wider economic challenges relating to business owners and individuals being required to replace vehicles faster than they might otherwise have done. With regard to both issues, close cooperation with the national government on infrastructure investment and 'scrappage' or incentive schemes will be critical. Public support for such changes will also depend on the clear presentation of health and other outcomes related to them.

4.4.2 DE-COUPLE EURO 5 AND EURO 6 VEHICLES IN THE PHASING-OUT SCHEDULE.

This is particularly important because, although several of the key emissions limits are the same for both Euro 5 and Euro 6 standards (PM for Diesel and Gasoline, NOx for Gasoline) recent research has shown wide discrepancies between real world performance of vehicles adhering to the two standards under test conditions. Thus, prohibiting Euro 5 vehicles sooner than currently scheduled would deliver significant reductions in real world outcomes in spite of the apparent equivalence in emissions under test conditions. Moreover, the FFZ will have to attend further differences between petrol- and diesel-powered Euro/EURO 6 vehicles. Under the current phasing strategy, there will be differing levels of control in 2018, and then again in 2020.

4.5 POSSIBLE FUTURE ANALYTICAL ACTIVITIES

The two main suggestions for further data collection are as follows:

1. The indirect impact of central Paris' action on the population of the peripheral metropolitan area.
2. Analysing phase-weighted health impact of the city's action, addressing the environmental, social, and economic gains expected to be accrued at each stage of the process up to and including 2030.

5 APPROACH

5.1 METHODOLOGY

For each climate action there are a number of steps that have been taken to assess the air quality related health impacts. These are described briefly below and will be elaborated for the specific context of the Paris' action in following sections. The steps below represent the core actions to be taken for a full analysis but these steps should be preceded by some preparatory steps.

The methodology will be covered in two key parts:

Section 5.2 will focus on planning the analysis process based on the overall C40 benefits analysis process, identifying actions and benefits that are appropriate to Paris' policy aims. The process describes the interrelations between the various components of the 'casual chain' – inputs, outputs, benefits.

Section 5.3 will cover the concepts specific to the analysis of air quality and its related health impacts. The analysis follows five consecutive stages:

1. Defining an action in terms of its key parameters
2. Determining what the air quality change will be
3. Linking the air quality change to health changes
4. Determining what the health changes will be
5. Considering ways to monetise health outcomes

5.2 PLANNING THE OVERALL BENEFITS ANALYSIS PROCESS

Reconciling scientific complexity and the necessity of facilitating rapid action in cities: Please note the technical team recognise the complexity of air quality and health science and have sought to undertake top-level analysis in a manner that can be relatively easily reproduced by participating cities without arriving at indefensible figures. This reflects C40's desire to support swift, evidence-based, climate action in cities. Acting on this principle means finding ways to take scientifically sound measures based on available knowledge and with suitable sensitivity checks to account for potential further developments of the field.

5.2.1 BENEFITS PATHWAY

Benefits pathways are a useful way to map out the benefits emerging from air quality actions. An action is any intervention on the ground that leads to a change in social, economic and/or environmental conditions, e.g. a Low Emission Zone, a BRT system, cleaner municipal bus replacement, etc. The output of this intervention is the physical or observable change that it brings about, e.g. an increase in number of people using public transportation, or decrease in number of vehicles within a given area.

Finally, the outcome is the benefit of this change to the city or population, e.g. a reduction in level of pollutants in the city, an increase in life expectancy. An output can also be a benefit in itself. The diagram below illustrates the possible outputs and outcomes/benefits associated with the FFZ in Paris.

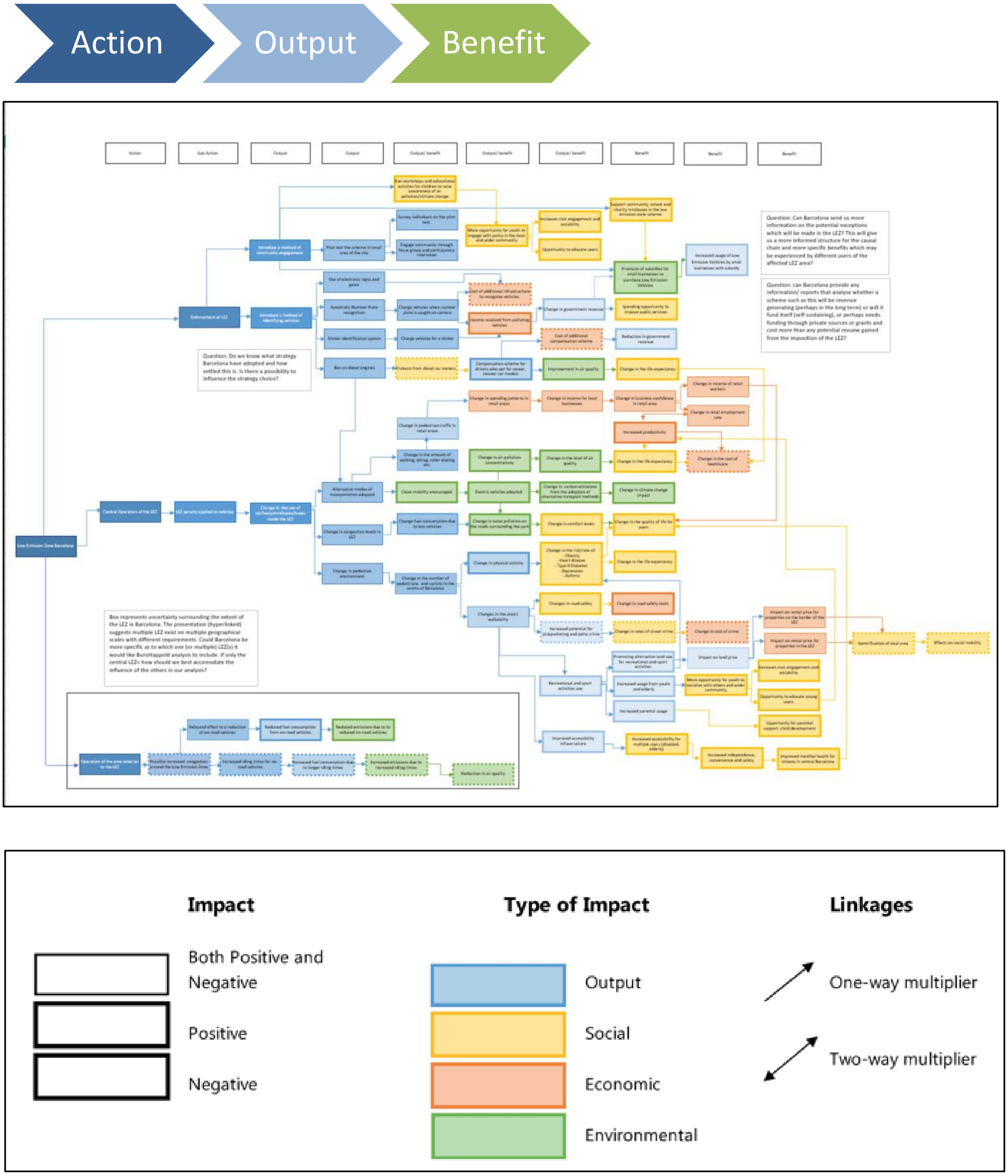


Figure 1 Benefits Pathways for Paris' FFZ. For high resolution version of the image please see supporting links in Appendix A

5.2.2 LITERATURE REVIEW

To support the benefits pathway the C40 and BuroHappold project team conducted an extensive literature review to identify list of available literature from other cities and similar research that could be used to support the causal links between the action and the anticipated outputs and benefits. This helped build a more complete picture of potential benefits. See Appendix A for a full list of literature.

Please note it is important to understand which benefits are the priority for the city, before commencing data collection. This keeps data collection and analysis targeted on the benefits that are likely to be most valuable or persuasive for city stakeholders.

5.2.3 DATA COLLECTION

Based on the prioritised benefits, the city team completed a data collection template to provide data from before and after the intervention. The data collected covered all elements of the benefits pathway: action, output and outcome. Collecting pre- and post-intervention data is essential for understanding the change over time, and any available time-series data can be particularly useful.

The key data requested from Paris included:

ACTION DATA

- Number of vehicles circulating in Paris classified by label type
- Emission factors by traffic type
- Proportion of vehicles upgrading to label C
- Change in the distance travelled by each vehicle after the action

POLLUTANT DATA

- NO_2 (g/µm^3): background concentration and annual average
- NO_X (g/µm^3): background concentration and annual average
- CO_2 (tonnes/year)
- $PM_{2.5}$ (g/µm^3): background concentration and annual average
- Contribution from roads to the non-background concentrations ($PM_{2.5}$ and NO_2)

HEALTH DATA

- Annual deaths per age and gender
- Annual population per age and gender
- Respiratory-related hospital admissions per age and gender
- Cardiovascular Disease-related hospital admissions per age and gender
- Annual average Value of a respiratory-related hospital admission
- Annual average Value of a cardiovascular disease-related hospital admission

5.2.4 DATA GAP ANALYSIS

The data provided by the city team was reviewed and gaps in the data were identified against the essential data required to measure the benefits for this study. Gaps were discussed with the city to understand what further local information might be available to fill any of these gaps, and which gaps should be addressed through a literature review (e.g. using proxy data and benchmarks). See section 3.1.1, 3.2.1, and 3.3.1 for further elaboration on the specific data gaps and assumptions made in response.

5.2.5 DATA ANALYSIS

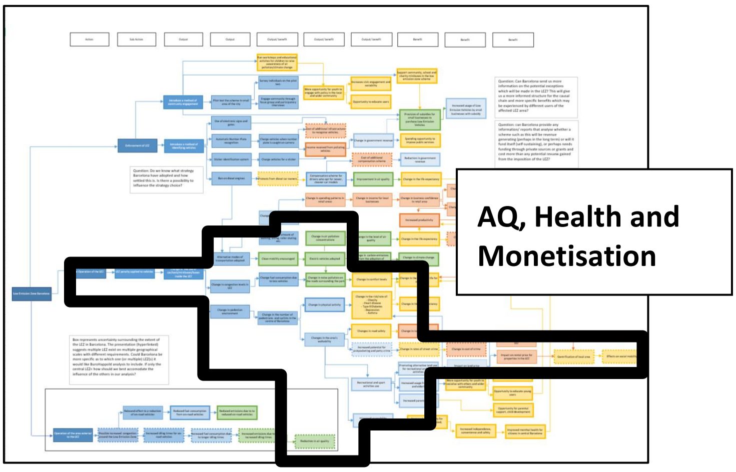
City data was combined with multipliers and proxy data from wider research to estimate the benefits of upgrading a proportion of the bus fleet to a EURO VI emission standard. Three types of measurement were used to estimate the benefits:

- **Monetisation** – economic multipliers were used to convert health benefits, into a monetary value.
- **Quantification** – utilising data from Paris, the change in air pollution as a result of the action - for a number of pollutants was calculated; and Life tables, were used to estimate the associated health benefits of the action from reduced air pollution.
- **Illustration** – based on research about other cities, examples of interventions in other cities were used to provide an indication of what the benefits in Paris might be. Illustration is particularly useful in cases where local city data is not available, but an indication of potential benefits is still needed.

5.3 THE ANALYTICAL BENEFITS PROCESS FOR AQ AND HEALTH

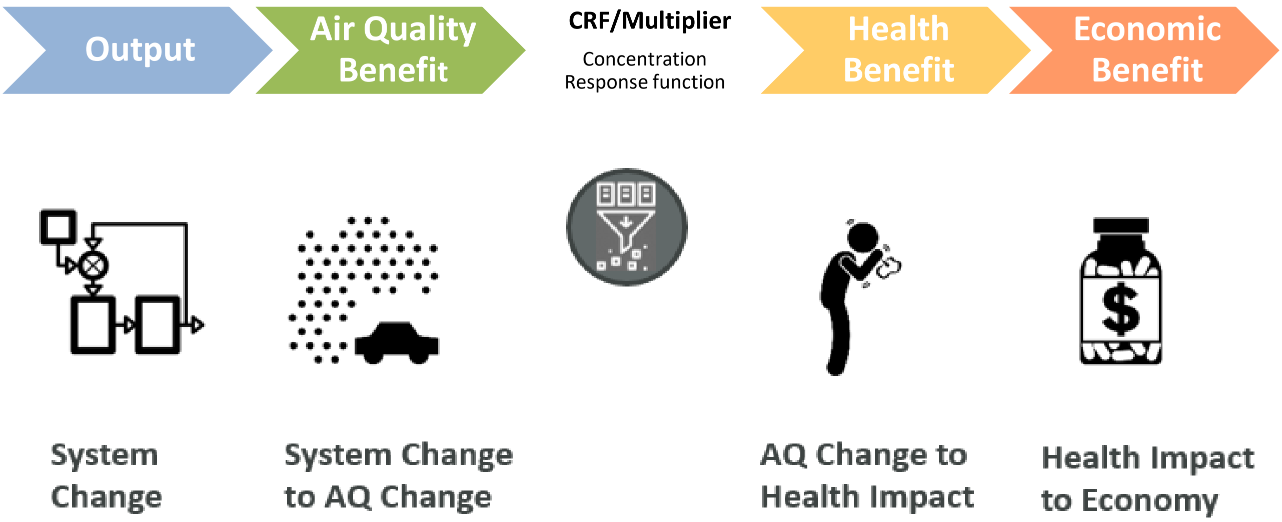
This section provides an overview of the specific analytical process to evaluate the air-quality related health impacts from urban climate actions.

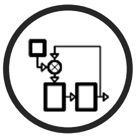
In order to measure impacts of a given action, it is important to understand the links between action, outputs, and benefits. This section will summarise the interrelations between the different elements of the calculation process –system change (action), air quality change (output/benefit), health outcomes (benefits), health impact to economy (benefits)



5.3.1 OVERVIEW OF PROCESS

This diagram summarises the analytical process:





5.3.2 DEFINING THE SYSTEM CHANGE

System change refers to a change in the main elements of the system or systems related to the action being measured. For example, introducing a ‘low emission zone’ may trigger changes in the city’s travel system including: reductions of the number of cars on the road, changes to citizens’ travel behaviour, initiatives to encourage alternative (public) transport modes, etc.

Understanding system change requires careful consideration of how the action will impact on other elements of the system or other related systems.

An important step is to determine how three different action-related scenarios might be defined. For this project we are using the following terms:

- No action scenario
- With action scenario
- Enhanced action scenario

It may seem obvious but it is important to state that the difference between the no-action scenario and the ‘with action’ scenario is the most effective way of determining the impact of implementing the action. We can use the enhanced action scenario to determine the potential value of scaling-up the action.

5.3.3 FROM SYSTEM CHANGE TO AIR QUALITY CHANGE

Once the system change is understood, the air quality impacts caused by these changes can be measured.

Changes in air quality can be quantified in both emissions and concentrations. The concentration of a given pollutant in the environment is a function of multiple factors including climatic conditions and all sources of emissions.

Within this study we are primarily concerned with $PM_{2.5}$, and NO_2. This is because changes in these pollutants carry the most significant impacts in terms of health outcomes. For each of these pollutants, there will be multiple sources located both in the city and in the surrounding region. Concentrations arising from sources outside the city can be significant and are termed background concentration.

A fall in emissions from an urban system will normally lead to a commensurate fall in concentration levels but only as far as the background levels. It is important to know the without action concentration levels for this analysis.

5.3.4 FROM AIR QUALITY CHANGE TO HEALTH IMPACT

Selecting a concentration response function (CRF)

The link between the change in air quality and the health impact is represented by what is termed a 'concentration response function' (CRF). CRFs are established through epidemiological studies and define a predicted change in a specific health risk in response to a change in the concentration of a specific pollutant. Thus, selecting the appropriate CRF will depend on the availability of:

- Concentrations data for specific pollutants
- Underlying population health-risk data

The CRFs used in this study link changes in concentrations of NO_2 and $PM_{2.5}$ with changes in risk of premature death/mortality mortality (from all causes) and cardiovascular and respiratory hospital admissions (as measures of risk of disease/morbidity).

Applying the selected CRF

Once the appropriate CRFs have been selected, they need to be applied to the baseline population health data in order to:

- Define a change in risk (due to the change in AQ)
- Estimate the change in death/mortality and disease/morbidity in the population.

Life-tables are used to calculate the changes in risk and the number of people suffering from a disease by gender and age group for a given population. Recognising these differences becomes crucial in order to fully realise the impacts of AQ changes across population demographics.

5.3.5 HEALTH BENEFIT MONETISATION

In the last step of the process, the city may wish to evaluate wider economic and financial benefits deriving from the identified health impacts. The impact from mortality can be monetised by multiplying the avoided Life Years Lost (LYL) by the Value of a Life Year (VOLY). The impact from morbidity can be monetised by multiplying the hospital admissions averted by the Value of a Hospital Admission.

5.4 LIMITATIONS

When looking at the case of Paris specifically, three main limitations has arisen out of the investigation:

1. The inclusion of OECD Purchasing Power Parity up-weighted values for VOLYs and VHAs. If a more recent VOLY or French-specific VHA were available, less manipulation would have been required.
2. The model within the spreadsheet does not account for phasing – assumes the FFZ is immediate and this the impacts will be felt in the short term. In reality, the action will be incrementally faced in and the benefits accrued will be incrementally felt accordingly.
3. Moreover, when addressing the additional ‘working population’ scenario, the model does not account for the significant number of Parisians that commute out of Paris on a daily basis, as well as not taking into account the impact of the FFZ on the populations of the Metropole du Grand Paris that will undoubtedly be indirectly affected.

6 BIBLIOGRAPHY

General Texts

Committee on the Medical Effects of Air Pollutants (UK Government): https://www.gov.uk/government/groups/committee-on-the-medical-effects-of-air-pollutants-comeap

Department for Environment Food & Rural Affairs [DEFRA], UK Government (2013). Impact Pathway Guidance for Valuing Changes in Air Quality: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/197900/pb13913-impact-pathway-guidance.pdf

Henschel, S., Chan, G., & World Health Organization. (2013). Health risks of air pollution in Europe-HRAPIE project: New emerging risks to health from air pollution-results from the survey of experts.

World Health Organization. (2013). Health risks of air pollution in Europe–HRAPIE project: Recommendations for concentration-response functions for cost-benefit analysis of particulate matter, ozone and nitrogen dioxide. UN City: Copenhagen, Denmark.

Action-Specific References

AirParif (2017) Air Quality in Paris Region – Summary Report 2016: https://www.airparif.asso.fr/_pdf/publications/bilan-2016-anglais170830.pdf

PARIS CLIMATE AND ENERGY ACTION PLAN (2012): Adopted by the council of Paris on 11 December 2012. Le Plan Climat Energie De Paris: https://api-site-cdn.paris.fr/images/70923

Wolff, H. (2014). Keep Your Clunker in the Suburb: Low‐emission Zones and Adoption of Green Vehicles. The Economic Journal, 124(578).

Health Effects Insititute (2011). The London Low Emission Zone Baseline Study. STATEMENT: Synopsis of Research Report - https://www.healtheffects.org/system/files/Kelly-LEZ-Statement.pdf

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