

# ARUP

## Lockdown has improved our air quality... how to avoid a surge in pollution afterwards?

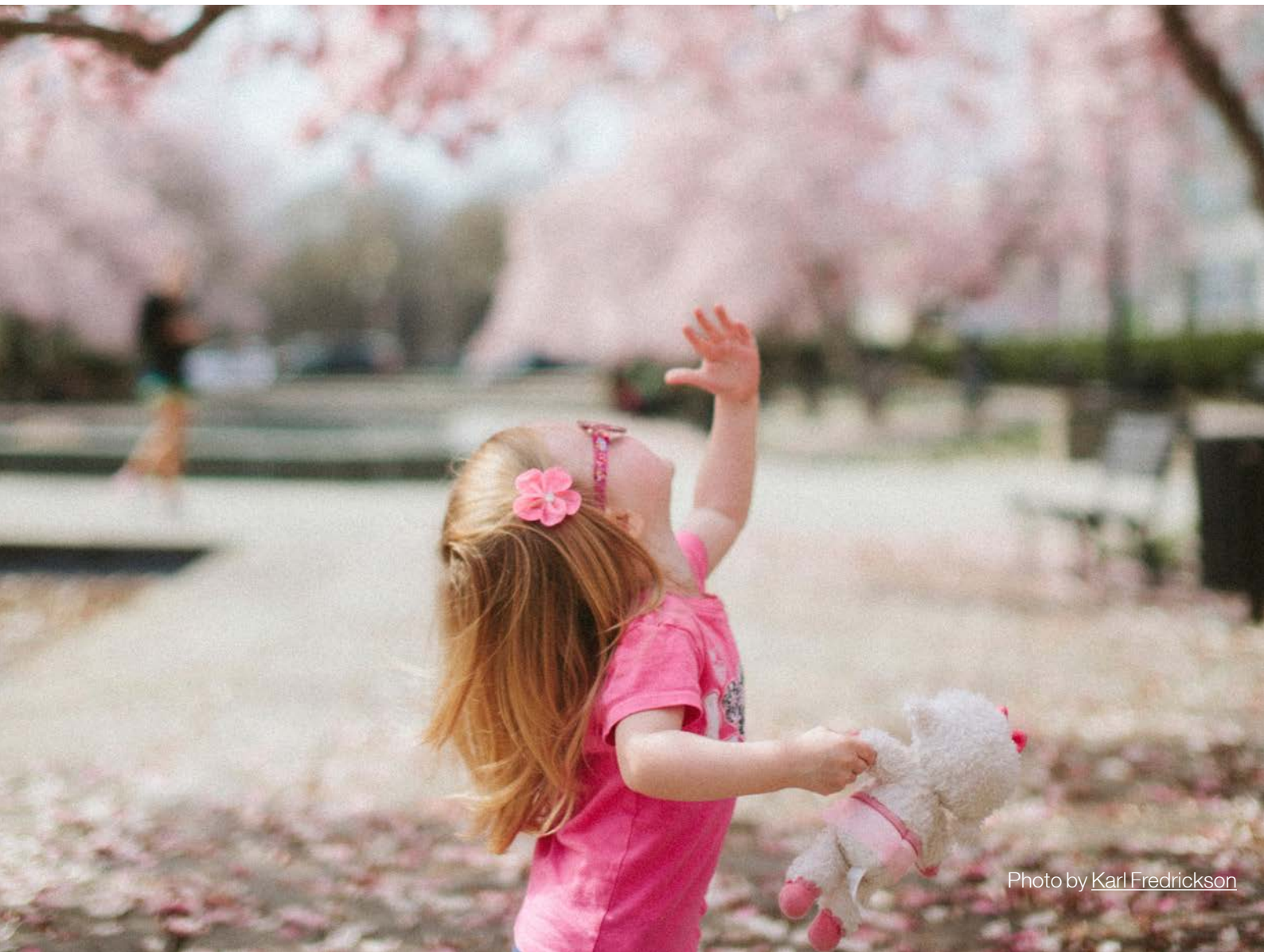
Ideas for Copenhagen, ranging from the practical to radical



**Copenhagen's air quality** has been improving year on year thanks to effective policies and expanding low-pollution public transport.

Air pollution has fallen dramatically as the country has locked down for COVID-19.

However as restrictions are eased, there is a risk of an increase in air pollution, if people avoid public transport for safety reasons.



# How could we maintain the clean air in Copenhagen?

The shutdown of Denmark and the rest of Europe has led to a drop of 35% in the nitrogen oxide air pollution in Denmark's cities<sup>1</sup>. However as the economy restarts, there is the danger of a rebound in pollution due to a return to private car use.

We have drawn on our expertise to present ideas that could help maintain these healthier levels when the lockdown is eased, as well as lead to many other co-benefits, such as reduced carbon emissions and improved safety.

# 35%

drop in nitrogen oxide pollution levels in cities as a result of Denmark's lockdown



## CONTINUE

### RECLAIM ROADS

for even more cycle paths

### EXTEND

the current Clean Air Zone to include vans and cars

### TIGHTEN

pollution limits on heavy goods vehicles

### ELECTRIFY

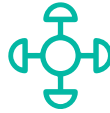
all public transport by aligning and bringing forward the current ambitions for electric buses.

### ON SHORE POWER

for cruise ships while in port

### DECREASE

construction related pollution through pre-fabrication, design for disassembly and all-electric construction vehicles



## ADAPT

### PLANNING

requirements to mitigate air pollution as part of all urban developments

### CITY OF NEIGHBOURHOODS

reduce the need for people to travel

### URBAN CANYONS

reduce the build up of street level pollutants when carefully designed

### REGENERATIVE

design that increases the city's biodiversity with more green spaces.

### PURIFICATION

of air by increasing green bio-diverse building envelopes, both facades and rooftops

### DELIVERY HUBS

to enable all-electric vehicles to complete the 'last-mile' of delivery



## INFLUENCE

### ENERGY PRODUCTION

in Denmark and Europe should switch to cleaner fuels to reduce background pollution

### INCENTIVISE

individuals and businesses to switch to low-emissions vehicles

### TRAVEL HABITS

to design out private vehicles from the city centre, by increasing transport hubs.

### CONSUMPTION

increases background pollution levels from international shipping

### MONITOR

in more locations in the city to raise awareness and help to quantify the impact of changes.

<sup>1</sup> Det Nationale Center for Miljø og Energi (2020) in a note to the Miljøstyrelsen (Danish Environmental Protection Agency) <https://dce.au.dk/aktuelt/nyheder/nyhed/artikel/reduceret-forurening-fra-vejtrafik-under-coronakrisen-giver-faerre-for-tidlige-doedsfald-og-sygedage-/>

# Introduction

Air pollution is the largest environmental health threat in Europe, with the average life expectancy in the European Union shortened by eight months due to pollution exposure<sup>1</sup>.

The COVID-19 crisis has led to untold human suffering, and its side-effects should not be celebrated.

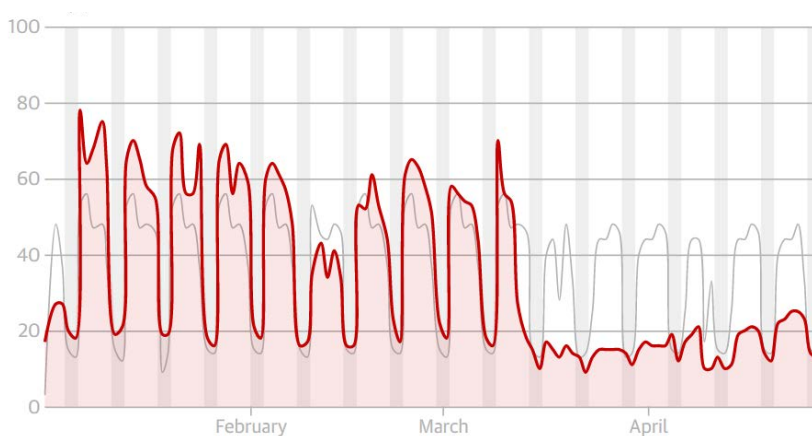
However the data from around the world has shown air pollution concentrations falling as cities go into lockdown in response to the virus. Our analysis suggests a decrease of up to 50% in nitrogen oxides levels in Copenhagen.

A recent poll found that 1/2 of public transport users in the UK would be less likely to use public transport after lockdown<sup>2</sup>.

With the virus set to cause long lasting consequences, a crucial question for city planners - how to avoid a rebound in private car use, eroding the hard fought recent improvements in air quality?

**“As cities move out of lockdown there is a risk of increased vehicle use as people choose personal car use over public transport”**

Michael Bull  
Environment Director, Arup



**WEEKDAY TRAFFIC PEAKS HAVE DECREASED 200% IN COPENHAGEN<sup>3</sup>**

TomTom - the location technology company - reports a traffic index for hundreds of cities based in part on data from satnav users. The index suggests how much longer a journey would take to complete than in ideal conditions.

For Copenhagen, the comparison between the 2020 and 2019 indexes for peak hours shows the impact of the lockdown on traffic, where weekday peaks have fallen from 60 to around 20.

<sup>1</sup> Centre for Research on Energy and Clean Air (2020) 11,000 air pollution-related deaths avoided in Europe as coal, oil consumption plummet [energyandcleanair.org/wp/wp-content/uploads/2020/04/CREA-Europe-COVID-impacts.pdf](https://energyandcleanair.org/wp/wp-content/uploads/2020/04/CREA-Europe-COVID-impacts.pdf)  
<sup>2</sup> Autotrader (2020) Consumers set to abandon public transport as a result of COVID-19 <https://plc.autotrader.co.uk/press-centre/news-hub/consumers-set-to-abandon-public-transport-as-a-result-of-covid-19/>  
<sup>3</sup> Seán Clarke (Guardian) The traffic data that shows the road into - and out of - Covid-19 lockdown, 27 Apr 2020 [www.theguardian.com/world/ng-interactive/2020/apr/27/the-traffic-data-that-shows-the-road-into-and-out-of-covid](https://www.theguardian.com/world/ng-interactive/2020/apr/27/the-traffic-data-that-shows-the-road-into-and-out-of-covid)



# What is Air Pollution?

Air pollution remains the single largest environmental health risk in Europe according to the World Health Organisation<sup>1</sup>, with many European cities suffering from poor air quality.

The most harmful pollution for citizens include nitrogen oxides, fine secondary particulate matter and ozone. These are all associated with negative health outcomes with both direct and indirect effects<sup>2</sup>.

- $\text{NO}_2$  is one of the highly reactive nitrogen oxides ( $\text{NO}_x$ ) gases. Its major source in cities is the combustion of fossil fuels. It is generally produced in larger quantities by older vehicles with diesel engines.  $\text{NO}_2$  is also a main contributor to the formation of nitrates in the atmosphere and, in the presence of ultraviolet light, to the formation of ozone.
- $\text{PM}_{2.5}$  (fine particulate matter with an aerodynamic diameter  $<2.5 \mu\text{m}$ ) can be of primary or secondary origin. The primary fraction is directly emitted from the source (e.g. from cars, or from boilers). The secondary fraction consists of sulphate, nitrate, ammonium and organic carbonaceous materials formed through chemical reactions of gaseous precursor such as  $\text{NO}_x$ ,  $\text{SO}_2$ ,  $\text{NH}_3$  and Volatile Organic Compounds (VOCs). For example, ammonium nitrates and sulphates are formed through the reaction of  $\text{NH}_3$ , originating mostly from agricultural activities, and of respectively  $\text{NO}_x$  and  $\text{SO}_2$  originating from the combustion of fuels.
- Ground-level ozone ( $\text{O}_3$ ) is formed from a chemical reaction between  $\text{NO}_x$  and VOCs. Sunlight breaks down  $\text{NO}_x$  and VOCs in a process called photolysis, after which oxygen atoms combine to form ozone. As a result, ozone concentrations tend to be highest in the summer when there are more sunny days.

## AIR POLLUTION MAY BE 'KEY CONTRIBUTOR' TO COVID-19 DEATHS

High levels of nitrogen dioxide, produced mostly by diesel vehicles, may be “one of the most important contributors” to deaths from Covid-19, according to research published in the journal *Science of the Total Environment*<sup>3</sup>.

Of the 66 administrative regions studied in Italy, Spain, France and Germany, 78% of coronavirus related deaths occurred in just five regions, and these were the most polluted, often with weather conditions that prevent dirty air from dispersing.

<sup>1</sup> WHO, 2018. Ambient (Outdoor) Air Quality and Health. [https://www.who.int/news-room/factsheets/detail/ambient-\(outdoor\)-air-quality-and-health](https://www.who.int/news-room/factsheets/detail/ambient-(outdoor)-air-quality-and-health).

<sup>2</sup> European Commission (2019) Urban NO<sub>2</sub> Atlas <https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/urban-no2-atlas>

<sup>3</sup> Yaron Ogen (2020) Assessing nitrogen dioxide (NO<sub>2</sub>) levels as a contributing factor to coronavirus (COVID-19) fatality, *Science of The Total Environment*, Volume 726. <https://doi.org/10.1016/j.scitotenv.2020.138605>

# Urban sources of pollution

According to the WHO, ambient air pollution contributed to 7% of all deaths worldwide. In particular, 16% of lung cancer deaths, 11% of chronic obstructive pulmonary disease deaths, and more than 20% of ischaemic heart disease and stroke are associated with ambient fine particulate matter<sup>1</sup>.

In Denmark, the Environmental Protection Agency monitors pollutants in the air in collaboration with the National Centre for Environment and Energy (NERI). Danish air pollution originates from transportation, energy production, agriculture, industry, waste treatment and construction<sup>2</sup>. This contributes to regional background levels of pollution which are a proportion of the air quality problem facing the population in cities.

However in step with – and partly because of – the reduction of the national and transboundary pollution, the air quality in cities has been improving recently, with Copenhagen no exception.

Today air pollution in many big cities is dominated by emissions from transport. And it is a complicated matter, because many different

compounds react mutually in the atmosphere, before they start to have impacts – either in the city or further afield<sup>3</sup>.

On average, traffic is the biggest source of air pollution, responsible for one quarter of particulate matter in the air<sup>4</sup>. The EU has introduced common limit values for exhaust emissions to limit pollution. The standards, known as Euro norms, define limits for car engine pollution and for the lead and sulphur content of fuels. Total emissions from traffic are more difficult to regulate. Local measures such as green zones, congestion charges and road pricing in European towns and cities are an attempt to limit general pollution.

Major Danish cities have established low emission zones in which heavy-duty vehicles are obliged to having filters that reduce the emission of particulate matter fitted. Driving without particle filters is not permitted in these zones.

Mayors have a wide array of tools at their disposal for improving air quality, including expanding low- or zero-carbon public transport; creating zero-emissions zones; requiring and promoting cleaner fuels for heating and cooking; enhancing incentives and infrastructure to support walking and cycling, and establishing city-wide air quality monitoring.

## AIR QUALITY MONITORING STATIONS IN COPENHAGEN



H.C. Ørsted Institutet



H.C. Andersen Boulevard

<sup>1</sup> EU Science Hub (2015) Urban air pollution – what are the main sources across the world? <https://ec.europa.eu/jrc/en/news/what-are-main-sources-urban-air-pollution>

<sup>2</sup> Danish Environmental Protection Agency <https://eng.mst.dk/air-noise-waste/air/>

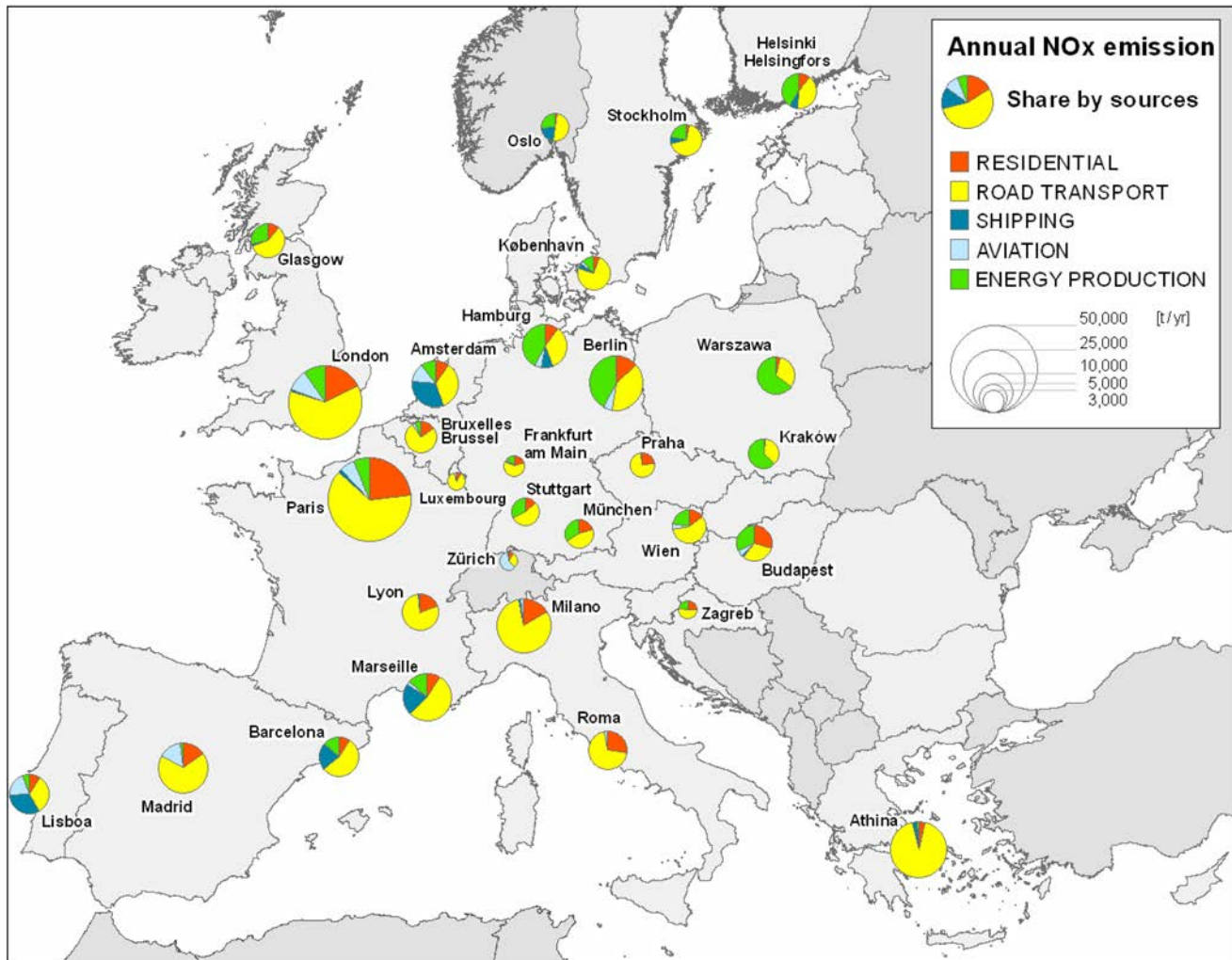
<sup>3</sup> McDonald K. (2012) Air pollution in the urban atmosphere: sources and consequences, Metropolitan Sustainability Pages 231-259 <https://doi.org/10.1533/9780857096463.3.231>

<sup>4</sup> European Commission (2019) Urban NO<sub>2</sub> Atlas <https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/urban-no2-atlas>

# NO<sub>2</sub> pollution sources

Data from 2016 shows road transport continues to be the largest source of NO<sub>x</sub> emissions (39% in the EU28), followed by the energy production and distribution sector, and the commercial, institutional and households sector<sup>1</sup>.

However, the contribution of the road transport sector to population exposure to ambient NO<sub>2</sub> concentrations, particularly in urban areas, is considerably higher, because its emissions are close to the ground and distributed across densely populated area.



<sup>1</sup> Sector share for NO<sub>x</sub> emissions, in 2015. Source: JRC, analysis based on EMEP gridded emissions

# Air pollution in Copenhagen

It is important to understand the role of each polluting source before making recommendations.

Air pollution in Copenhagen originates from both sources within the municipal boundary of Copenhagen (local), and regional sources originating in the rest of Denmark and Europe.

According to a 2013 study, NO<sub>x</sub> and NO<sub>2</sub> pollution was dominated by local sources, predominantly traffic<sup>1</sup>.

- Local road transport accounted for nearly 30% of measures NO<sub>2</sub>.
- The production of heat and power in district energy centres contributed approximately 10%.
- Neighbouring municipalities contributed about 25%, also dominated by road traffic.
- Ship traffic only contributed marginally, less than 5%.

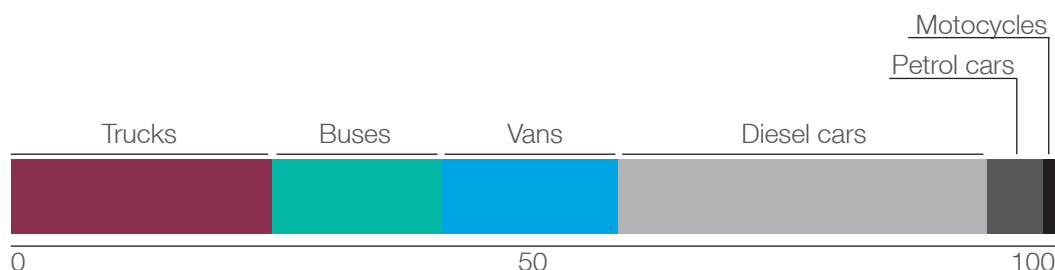
In contrast, PM<sub>10</sub> and PM<sub>2.5</sub> pollution was dominated by regional sources<sup>1</sup>.

- The regional contribution of PM<sub>10</sub> and PM<sub>2.5</sub> constitutes over 80% of measured pollution in Copenhagen.

It is clear the NO<sub>x</sub> pollution is dominated by emissions from road traffic. On streets, 80% of traffic is passenger cars, 16% vans and only 4% trucks and buses.

The 2019 Urban NO<sub>2</sub> Atlas<sup>2</sup> sheds light on the relative contributions to NO<sub>x</sub> pollution of inner city traffic, as shown in the graphic below.

- Because of their larger engines, the small number of trucks and buses contributed about 40% of NO<sub>x</sub> pollution, as much pollution as all the cars.
- Vans contributed about 15%, as much pollution as the buses.
- Of the passenger vehicles, diesel cars were by far the larger emitter of NO<sub>x</sub> pollution compared to petrol cars.
- Motorcycles' pollution contribution was relatively small.



Percentage of total NO<sub>x</sub> pollution from inner city traffic in Copenhagen<sup>2</sup>

<sup>1</sup> Jensen et al. (2013) Source Contribution to harmful air pollution in Copenhagen Videnskabelig rapport fra DCE - Nationalt Center for Miljø og Energi nr. 57. [www.dmu.dk/Pub/SR57.pdf](http://www.dmu.dk/Pub/SR57.pdf)  
<sup>2</sup> European Commission (2019) Urban NO<sub>2</sub> Atlas <https://ec.europa.eu/irc/en/publication/eur-scientific-and-technical-research-reports/urban-no2-atlas>

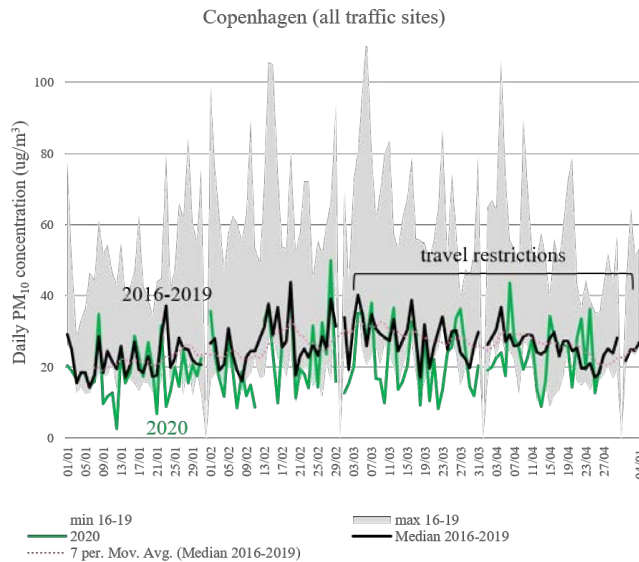
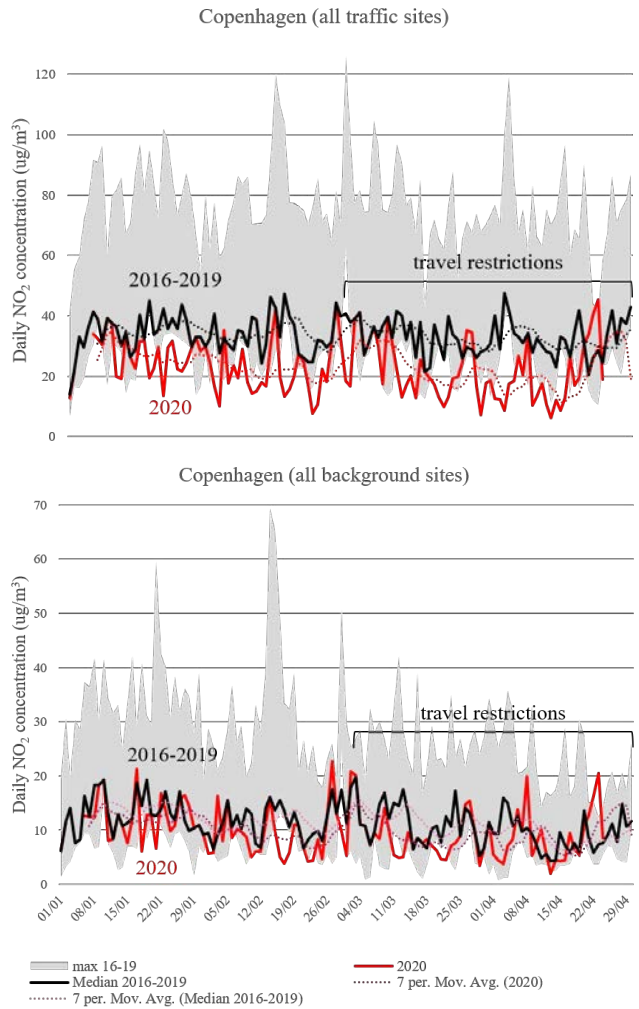


# Analysis: pollution during lockdown

As a result of the current lockdown, we can understand better the city's baseline pollution levels - reduced emissions at roadside locations but also background concentrations.

What does air pollution look like when cities are operating at a minimum? We have analysed the data for Copenhagen, to draw initial observations:

- Measurements at roadsides show NO<sub>2</sub> concentrations have reduced by up to 50% compared to the 2016-2019 average, but only marginally lower than in early 2020.
- Background NO<sub>2</sub> concentrations are broadly in line with 2016-2019 average. No meaningful change in background concentrations during the restrictions. The movement of people and goods to sustain essential services may be enough to sustain background concentrations at normal levels.
- Historically, there was a discrepancy of 20-25 ug/m<sup>3</sup> between background and traffic sites NO<sub>2</sub> levels. During the lockdown, the difference reduced to only 5-10 ug/m<sup>3</sup>, suggesting a significant change in concentrations at traffic sites.
- The current PM<sub>10</sub> concentrations are broadly in line with 2016-2019 average, suggesting very little change during the lockdown.





**49%**  
of trips to work or  
education by bike  
in 2018<sup>1</sup>

Photo by Sergio Souza



## RECLAIM ROADS

Copenhagen can easily claim to be the most bicycle friendly city in the world<sup>1</sup>, being consistently ranked as such. Now is a good time to reclaim the city's roads even further.

The share of trips by bike has been steadily increasing for nearly a decade. In 2018, 49% of trips to work or education were by bike, for all intents and purposes meeting the 50% 2025 target. The target could be increased now, and projects expanded to increase cycling infrastructure.

In order to help reduce background pollution levels in the city, Copenhagen should continue to work with the other municipalities on the cycle superhighways project, which spans across the Capital Region of Denmark.

- Municipalities have joined forces to build more than 750km of protected routes by 2045. Since 2009, eight highways have been built and are used by up to 29,000 cyclists per day<sup>2</sup>.

Cycling provides a highly-resilient transport network, both in times of pandemic to maintain social distancing. Many cities are rolling out “emergency” cycleways to boost bicycle use:

- Bogotá has turned 76km of vehicle lanes into emergency cycle routes, increasing capacity by 14%.
- New York has witnessed a surge in cycling as people avoid crowded trains, as temporary bike lanes offer a “hygienic alternative” to public transport.
- The UK government has temporarily made it easier for local councils to close roads to car traffic.
- Mexico City is considering a four-fold increase to its existing cycleways network.
- In Milan, traffic congestion has dropped by up to 75%, and the city plans to avoid a resurgence in cars by overhauling streets in favour of cycling.

<sup>1</sup> Copenhagen Kommune (2018) Bicycle Account: City of Cyclists [https://kk.sites.itera.dk/apps/kk\\_pub2/index.asp?mode=detalje&id=1962](https://kk.sites.itera.dk/apps/kk_pub2/index.asp?mode=detalje&id=1962)

<sup>2</sup> Super Cykelstier (2019) Cycle Superhighway Bicycle Account <https://supercykelstier.dk/wp-content/uploads/2019/11/Cycle-superhighway-bicycle-account-2019-UK-final-2.pdf>

# 20% : 60%

Freight accounts for 20% of urban traffic, but 60% of air pollution<sup>1</sup>



Photo by Mahkeo



## EXTEND CLEAN AIR ZONE

Currently there are clean air zones in Copenhagen, Aarhus, Aalborg, Odense and Frederiksberg<sup>1</sup>, but they only set pollution limits for trucks and buses (and vans from July 2020<sup>2</sup>).

The limits for heavy good vehicles (i.e. trucks) should be strengthened as they account for a comparatively large proportion of air pollution. The limits should also be extended to include private cars.

For Denmark, researchers have calculated there will be a 9% decrease in air pollution from road traffic for 2020. This will mean about 80 fewer premature deaths, 61,700 fewer sick days and 102 fewer hospitalisations for respiratory diseases<sup>3</sup>.

A report released in January revealed the price of air pollution for Denmark is 4,200 premature deaths, and around 79 billion kroner<sup>4</sup>.

Experience from around Europe:

- Stockholm, Gothenburg, Lund, Malmö, Helsingborg, Mölndal, Uppsala, and Umeå have low-emission zones. Heavy trucks and buses are excluded based on their age and emission class.
- In London, it costs over 100 kroner to drive in the low-emission zone with a diesel car from before 2015 or a petrol car from before 2006. Led to a 36% improvement<sup>5</sup>.

<sup>1</sup> P. Rode et al., Accessibility in cities: transport and urban form, LSECities (2014), p. 7; UN Habitat, Planning and design for sustainable urban mobility: global report on human settlements (2013), pp. 58, 68

<sup>2</sup> New requirements for low emission zones apply from 1 July 2020 <https://eng.mst.dk/air-noise-waste/air/reducing-traffic-emissions/danish-low-emission-zones/new-requirements-for-low-emission-zones-that-apply-from-1-july-2020/>

<sup>3</sup> According to the National Center for Environment and Energi (Det Nationale Center for Miljø og Energi) in a new note to the Danish Environmental Protection Agency (Miljøstyrelsen)

<https://dce.au.dk/aktuelt/nyheder/nyhed/artikel/reduceret-forurening-fra-vejtrafik-under-coronakrisen-giver-faerre-for-tidlige-doeedtsfald-og-sygedage-i/>

<sup>4</sup> According to the National Center for Environment and Energi (Det Nationale Center for Miljø og Energi) in the report 'The Danish Air Quality Monitoring Programme - Annual Summary for 2018'

<https://dce2.au.dk/pub/SR360.pdf>

<sup>5</sup> Central London ultra low emission zone - six month report, October 2019 [https://www.london.gov.uk/sites/default/files/ulez\\_six\\_month\\_evaluation\\_report\\_final\\_oct.pdf](https://www.london.gov.uk/sites/default/files/ulez_six_month_evaluation_report_final_oct.pdf)

“The measure of a country’s prosperity should not be how many poor people drive cars, but how many affluent people use public transportation.”

Michael Hogan



Photo by Krisztian Tabori



## ELECTRIFY ALL PUBLIC TRANSPORT

Electrifying public transport cuts local air pollution from the city centre.

Copenhagen’s public transport system is already on the way to becoming all-electric:

- [Electric S-trains and Metro](#)
- [A programme for replacing all diesel buses in Copenhagen by 2025. In late 2019, 48 electric buses replaced the 2A and 18 buses<sup>1</sup>.](#)
- [Four harbour ferries are set to be replaced by new all-electric versions in 2020<sup>2</sup>.](#)

In Frederiksberg, the goal is for all diesel buses to run on green fuels by 2030, however switching to bio-fuels still contributes to local air pollution. The ambitions of the two cities should be aligned towards electrification, and the targets brought forward if possible.

<sup>1</sup> State of Green (2019) New fleet of electric buses in Copenhagen <https://stateofgreen.com/en/partners/state-of-green/news/new-fleet-of-electric-buses-in-copenhagen-as-two-central-bus-routes-go-green/>  
<sup>2</sup> Alexandra Mollerup (Politiken) København får nye CO2-neutrale havnebusser, 28 Jun 2018 <https://politiken.dk/inland/kobenhavn/art6606236/K%C3%B8benhavn-f%C3%A5r-nye-CO2-neutrale-havnebusser>



Photo by Tobias Tullius



## ONSHORE POWER FOR CRUISE SHIPS

A mid-size cruise ship's diesel engine can use 150 tonnes of fuel each day, which would emit as much particulate as one million cars<sup>1</sup>. Standing on the deck of a cruise ship is similar to being in one of the world's most polluted cities, in terms of poor air quality<sup>2</sup>. It follows that docked cruise ships pose a health risk to those who live near them<sup>3</sup> if they continue to run their engines.

Therefore the Copenhagen has entered into a cooperation with Malmö and By & Havn to identify a solution. The first step is the design of an onshore power supply in Nordhavn<sup>4</sup>.

The project should be sped up to design of an onshore power supply for cruise ships at Ocean Quay in the North Harbour, which will be the first step towards ensuring that large cruise ships no longer have to burn off diesel when they are in port. The objective is to have the onshore power supply in

operation in 2021.

The issue of air pollution from cruise ships is not only found in the Port of Copenhagen, but also in most other ports in the Nordic region. Consequently, part of the funding from the City of Copenhagen is earmarked for cooperation with the other major port cities in the Nordic region.

The idea is to attract more ships that are able to use this type of power, by having more ports in the region that offer onshore power. Eventually making the Baltic Sea Region the most sustainable cruise destination in the world.

- The cruise industry transported over 26 million customers in 2018<sup>5</sup>
- In 2019, Copenhagen hosted 975,000 cruise passengers and 250,000 crew members.

<sup>1</sup> Transport & Environment (2017) Cruise ships <https://www.transportenvironment.org/what-we-do/shipping-and-environment/cruise-ships>

<sup>2</sup> Nabu (2019) Air is becoming slightly cleaner, while climate foot-print is worsening <https://en.nabu.de/news/2019/26855.html>

<sup>3</sup> New South Wales Environmental Protection Agency (2019) Cruise ship fuel compliance in Sydney Harbour <http://www.epa.nsw.gov.au/air/cruise-ship.htm>

<sup>4</sup> State of Green (2019) Reducing air pollution from cruise ships in the Port of Copenhagen <https://stateofgreen.com/en/partners/state-of-green/news/reducing-air-pollution-from-cruise-ships-in-the-port-of-copenhagen/>

<sup>5</sup> James Ellsmoor (2019) Cruise Ship Pollution Is Causing Serious Health And Environmental Problems <https://www.forbes.com/sites/jamesellsmoor/2019/04/26/cruise-ship-pollution-is-causing-serious-health>



Photo by Jacek Dylag



## CLEANER CONSTRUCTION SITES

Research estimated that construction is responsible for around 7% of  $\text{NO}_x$ , 14% of  $\text{PM}_{2.5}$ , and 8% of  $\text{PM}_{10}$  pollution in London<sup>1</sup>. Pollution near construction sites is a particular problem, and construction workers are exposed to dangerous levels of pollution<sup>2</sup>.

Three recommendations for future construction sites in Copenhagen:

### 1. Electric Non-Road Mobile Machinery

Diesel is the standard for construction equipment. However diesel engines release pollutants into the air which impact respiratory, cardiovascular, and neurological systems<sup>1</sup>.

- Electric powertrains eliminate not only local air pollution, but also reduce the heat, noise, and vibrations associated with diesel vehicles. Electric mobile machinery would make construction a more comfortable and safer environment.

### 2. Design for modular prefabrication

A design shift must be encouraged towards construction using elements and modules which are produced off-site in factory-like settings, transported to site and assembled.

- Air pollutants can be carefully managed in the factory, thereby reducing pollution at the construction site. Additional benefits include reduced on-site construction time, reduced waste, and a safer working environment.

### 3. Design for deconstruction

A detailed deconstruction plan should be required for all new construction projects to ensure in the future the demolition minimises demolition air pollution, maximises the potential for material re-use, and considers the safety of those doing the work.

- This will incentivise timber and hybrid construction materials, with associated benefits from reducing embodied carbon emissions in the construction sector.

<sup>1</sup> London Atmospheric Emissions (2016) <https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory--laei--2016>

<sup>2</sup> Centre for Low Emission Construction <http://www.clec.uk/>



Photo by Barthélemy de Mazenod



## AIR POLLUTION PLANNING REQUIREMENTS

A significant proportion of traffic in cities is generated by construction and civil engineering, including some of the most polluting diesel vehicles. Apart from the road traffic movements, there are also sources of air pollution that are attributed to the actual onsite construction; up to 15% of air pollutant emissions can be from construction and demolition activity and the machinery used in these processes<sup>1</sup>.

All new projects should be required to submit analysis demonstrating how the project will reduce (or not worsen) air pollution during both the construction and operation. In addition, deconstruction plans should account for how dust will be managed to minimise localised air pollution.

Putting ‘maintaining clean air’ at the heart of design helps to support other objectives, such as placemaking, more active and sustainable modes and reduced congestion.

Emissions from construction can be divided into three main categories:

- **Dust:** Particulate matter mechanically generated from construction activity contributing to PM<sub>10</sub> concentrations.
- **Construction Plant:** Exhaust emissions from diesel non-road mobile machinery contributing to elevated NO<sub>x</sub> and PM pollution.
- **Construction transport:** Road transport delivering and collecting construction materials and waste. Often these are heavy or light goods vehicles with diesel engines. Additionally, fine particles ‘tracked out’ onto the public highway on the wheels of these vehicles are also re-suspended and can remain in the air for many hours, day or even weeks.

<sup>1</sup> Considerate Contractors Scheme (2018) Construction dust and air quality [https://ccsbestpractice.org.uk/wp-content/uploads/2018/06/2018-6\\_BPH\\_AirPollutionGuide.pdf](https://ccsbestpractice.org.uk/wp-content/uploads/2018/06/2018-6_BPH_AirPollutionGuide.pdf)



Denmark's CO<sub>2</sub> emissions have reduced by 15%, mainly due to nearly all flights stopping, and a 25% drop in road transport <sup>1</sup>

Photo by Vestre



## CITY OF NEIGHBOURHOODS

Younger generations are demanding a new vision – one that regenerates our cities for people. New paradigms are emerging for successful design and there is a clear drive to change the standards of building, forsaking surface-level ‘greenwashing’ efforts for designs that facilitate sustainability and social integration, changing the cityscape holistically through the lenses of infrastructure, mobility and accessibility.

Could we envision a city of neighbourhoods instead of a city of cities? Chrono-urbanism is a vision put forward by the Mayor of Paris, imagining a built environment where all an inhabitant's needs can be met within a 15-minute radius of their dwelling. By treating the city as a smaller kit of parts, our efforts for change could be made more localised and achievable.

Could we envision regenerative infrastructure? Prioritising retrofitting over fresh construction can reduce waste, cost and carbon footprint.

- In Milan, seven derelict railway yards are being regenerated to create a green network across the city – a climate-based master plan.
- The New York High Line also demonstrates the wider social benefits of repurposed infrastructure, regenerating not only the surrounding environment and ecology, but also the locals, driving engagement with the development and highlighting regeneration as vital for reconceiving our cities and how we inhabit them.





Photo by [OMA Building Design](#)



## CAREFULLY DESIGN URBAN CANYONS

The micro-climate refers to a particular area's atmospheric conditions (temperature, humidity, wind, irradiance and pressure), and it plays a significant role in the concentration of air pollutants, and crucially their dispersion<sup>1</sup>.

It is crucial that urban design considers the need to create ventilated corridors, as areas sheltered from the wind often have elevated pollution levels, and they also create favourable conditions for the chemical reactions necessary to create ozone<sup>2</sup>.

Trees and green infrastructure can have an impact on helping with the dispersion of pollutants from local sources.

Local building heights also influence the mixing of pollutants with clean air. Studies addressing pollutant dispersion in relation to urban geometry show that urban ventilation is dependent on how the urban street grid is orientated to the prevailing wind directions<sup>3</sup>.

Computational Fluid Dynamics (CFD) simulations can be used to analyze how the geometry influence the wind flow around buildings, and should be an essential element of any urban design project.

<sup>1</sup> Henning Larsen (2018) How to Reduce Pollution with Urban Design <https://henninglarsen.com/en/news/archive/2018/08/10-how-to-reduce-pollution-with-urban-design/>

<sup>2</sup> EPA 2007

<sup>3</sup> Fu et al. (2017) Effects of canyon geometry on the distribution of traffic-related air pollution in a large urban area, Atmospheric Environment, pages 111-121 <https://doi.org/10.1016/j.atmosenv.2017.06.031>



Photo by [Gábor Molnár](#)



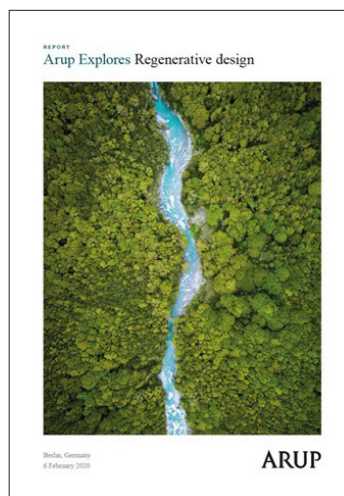
## REGENERATIVE DESIGN

Towards a net-positive future, 'regenerative design' calls for a rethink to the way we design and construct the built environment to improve societal resilience, restore planetary health and regenerate ecological systems.

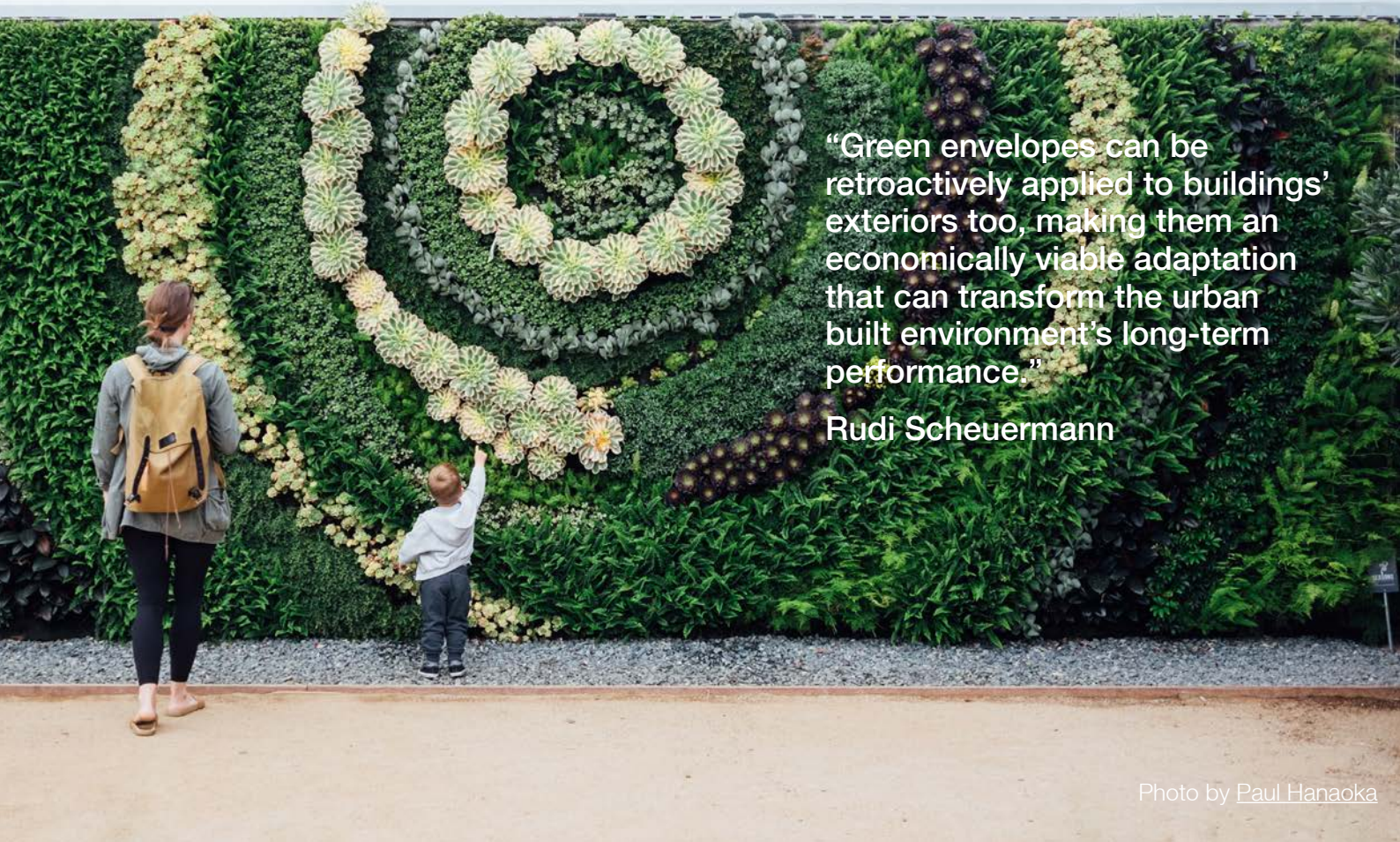
The lines that divide the built and natural environments, as well as those between humans and animals need to be re-considered and overcome. For years now, people have been creating 'human habitats' – a second and artificial nature – that we call the 'built environment.'

To progress towards regenerative design and systems for our planet, we will need to figure out how to design for all species; respecting planetary boundaries and utilising science-based targets as the common ground to help mother nature not only survive but thrive.

- Regenerative design gives us the opportunity to go beyond reducing harm to the planet, and use our skills to replenish resources, boost natural diversity and drive meaningful change for lifetimes beyond our own, all through changing the way we design.



In February 2020, Arup's Foresight team as part of their Arup Explores series brought together industry experts to explore the rationale for regenerative design across the built environment.



“Green envelopes can be retroactively applied to buildings’ exteriors too, making them an economically viable adaptation that can transform the urban built environment’s long-term performance.”

Rudi Scheuermann

Photo by [Paul Hanaoka](#)



## GREEN BUILDING ENVELOPES

The ongoing march to greater urbanisation challenges designers to create interventions that ensure cities remain liveable.

Good quality urban landscape and open space plays an essential role in improving public health – and evidence from recent global research is overwhelming – well planned, designed and managed landscape in cities can reduce the burden on the health service<sup>1</sup>.

The building envelope refers to its roof, façade and any other areas that connect the inside to the outside, usually representing 20-25% of a building’s total external area.

An additional benefit of green envelopes is to offset the Urban Heat Island (UHI) effect that drives up urban temperatures. Even in the height of summer, interventions like vegetated roofs can help bring down the temperature to ambient levels, whereas a conventional roof can be up to 50 degrees higher.

- Research<sup>3</sup> showed that if Greater Manchester increased its green infrastructure by 10% (in areas with limited or no green cover) the city would reduce its average temperature by up to 2.5°C, greatly offsetting the UHI effect.

1 Would You Be Happier Living in a Greener Urban Area? A Fixed-Effects Analysis of Panel Data, Mathew P. White, Ian Alcock, Benedict W. Wheeler and Michael H. Depledge, Psychological Science, published online 23 April 2013.  
2 Effectiveness of Green Infrastructure for Improvement of Air Quality in Urban Street Canyons, Environ. Sci. Technol. 2012, 46, 14, 7692-7699. <https://doi.org/10.1021/es300826w>  
3 Gill, Susannah & Handley, J.F. & Ennos, Roland & Pauleit, Stephan. (2007). Adapting Cities for Climate Change: The Role of the Green Infrastructure. Built Environment. 33. 115-133. <https://doi.org/10.2148/benv.33.1.115>



Photo by Shutterstock



## NO ROOFTOP UNUSED

Every roof in the city district of Utrecht is to be “greened” with plants and mosses or solar panels under plans driven by the success of a similar scheme for the municipality’s bus stops <sup>1</sup>.

Copenhagen could introduce an obligation to green the roofs of all the buildings in the city. A grant scheme could cover a proportion of the costs for homeowners and offices.

- The “no roofs unused” policy is part of an attempt to reinvigorate biodiversity in the city and create a less stressful and happier environment.
- In London, a green roof map<sup>2</sup> based on 2013 satellite data estimates there are around 700 green roofs in central London alone, covering an area of over 175,000m<sup>2</sup>.

<sup>1</sup> Daniel Boffey (2020) Utrecht rooftops to be ‘greened’ with plants and mosses in new plan <https://www.theguardian.com/world/2020/mar/27/utrecht-rooftops-greened-plants-mosses-vertical-forest>

<sup>2</sup> GLA Green Roof Map <https://www.london.gov.uk/what-we-do/environment/parks-green-spaces-and-biodiversity/green-roof-map>



Photo by Ivan Bandura



## ELECTRIC DELIVERY FROM FREIGHT HUBS

The transportation of goods (freight) is essential for the economy, however studies have shown it makes up a quarter of all NO<sub>x</sub> emissions<sup>1</sup>.

The last-mile of delivery is a problem in all cities, and many sustainable urban freight solutions have failed across Europe. However the issue must be addressed since heavy goods vehicle traffic in the city is major contributor to air pollution, and also poses a disproportionate danger to pedestrians and cyclists, and exacerbates traffic congestion when stopped for off-loading.

Freight hubs, also known as “urban consolidation centers”, could be explored to avoid large long-distance trucks making deliveries into the city. At the hubs, packages would be unloaded and redistributed into smaller all-electric vehicles.

The explosion of online and app-based delivery services during the lockdown has only made the challenges of last-mile delivery tougher.

Early attempts at freight hubs tended to fail as a result of financing, a lack of adequate facilities, and difficulty in recruiting freight companies willing to participate. However there have been some successes, notably in Nijmegen.

- Binnenstadservice Nederland has worked for over 10 years in 15 cities in the Netherlands<sup>2</sup>. The Urban Consolidation Centre (logistics depot and distribution service) handles good destined for multiple retailers and other organisations located in the city centre. The goods are bundled and delivered to shops in the city centre. Simultaneously packaging is returned to the consolidation centre.

<sup>1</sup> Eric Jaffe (Medium), 19 Nov 2019, The future of last-mile delivery has arrived ... in a small Dutch city <https://medium.com/sidewalk-talk/the-future-of-last-mile-delivery-has-arrived-in-a-small-dutch-city-f2fd8e2c0263>  
<sup>2</sup> Bestfact Case Study (2013) [http://www.bestfact.net/wp-content/uploads/2016/01/CL\\_1\\_074-QuickInfo\\_Binnenstadservice-16Dec2015.pdf](http://www.bestfact.net/wp-content/uploads/2016/01/CL_1_074-QuickInfo_Binnenstadservice-16Dec2015.pdf)

# 15%

international shipping  
accounts for 15% of  
background NO<sub>x</sub> pollution<sup>1</sup>

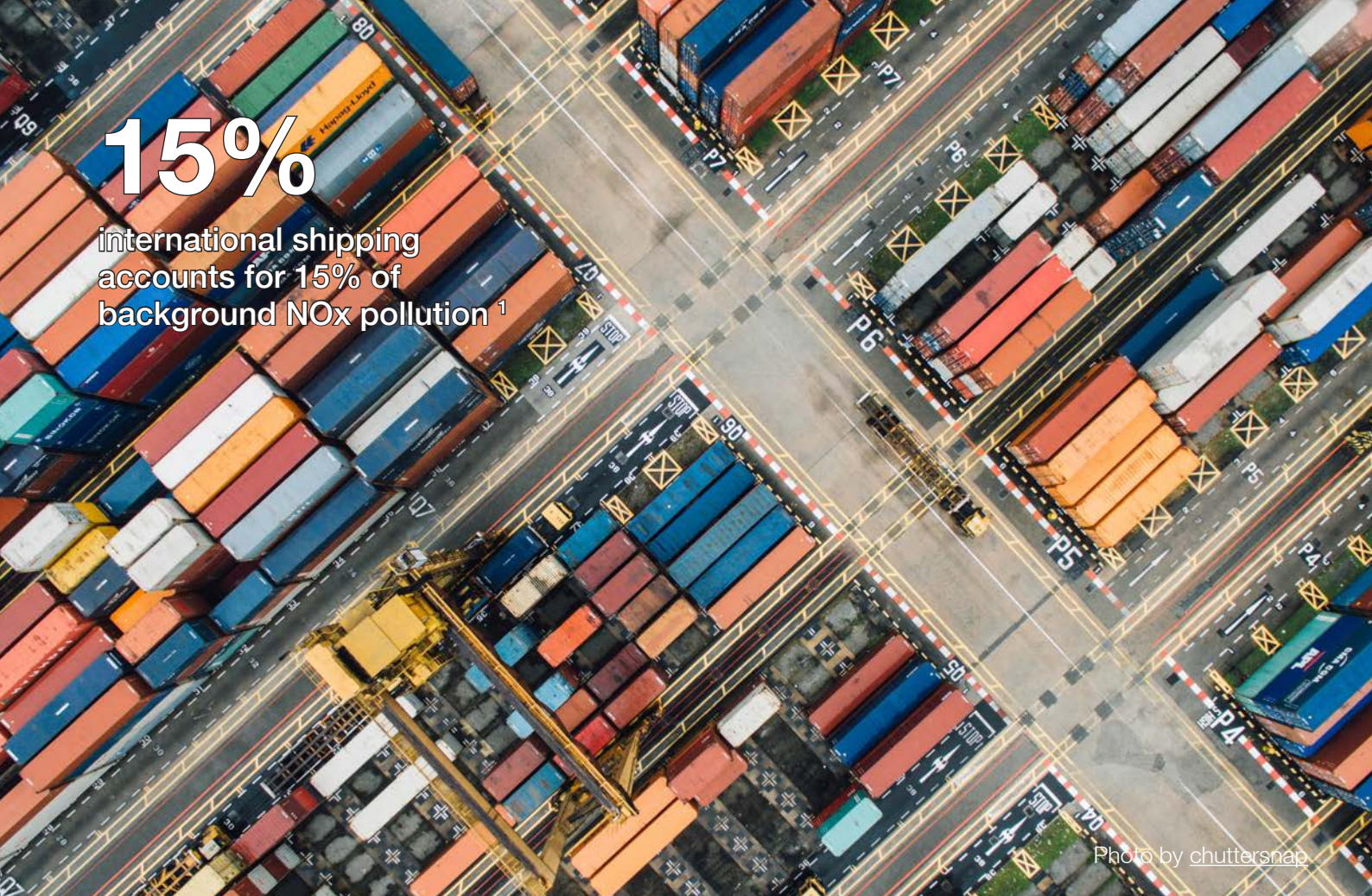


Photo by chuttersnap



## REDUCE CONSUMPTION

Across Europe, the whole transport sector reduced NO<sub>x</sub> pollution by 40% between 1990 and 2017, however over the same time pollution from international shipping actually increased by 26%. As a result, shipping now contributes to 15% of the background levels in Europe<sup>1</sup>.

The C40 report on urban consumption estimates that wealthy cities' consumption-based emissions contribute to 10% of global greenhouse gases<sup>2</sup>. As one such city, Copenhagen residents consume many goods that are transported around the world.

In order to reduce background levels of NO<sub>x</sub>, leaders, businesses and the public must adapt our consumption of shipped goods, which includes goods from sectors such as food, construction, clothing, vehicles and electronics.



<sup>1</sup> European Environment Agency (2019) Emissions of air pollutants from transport <https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-air-pollutants-8/transport-emissions-of-air-pollutants-8>  
<sup>2</sup> C40, Arup, and University of Leeds (2019) The Future of Urban Consumption in a 1.5°C World <https://www.arup.com/-/media/arup/files/publications/c/arup-c40-the-future-of-urban-consumption-in-a-1-5c-world.pdf>

# 28%

reduction in coal use for electricity  
in Denmark compared to April 2019<sup>1</sup>



Photo by [Gustavo Quepón](#)



## INFLUENCE ENERGY SECTOR

Measures introduced across Europe to combat COVID-19 have led to approximately a 40% reduction in average level of NO<sub>2</sub> pollution and 10% reduction in average level of particulate matter pollution over the past days<sup>1</sup>.

This effect comes as power generation in Europe from coal has fallen 37% and oil consumption by an estimated 1/3.

This is important as coal and oil burning are the main sources of background NO<sub>2</sub> pollution and particulate matter pollution across Europe.

- Coal power plants in the UK have been generating no power for more than two weeks, and Sweden recently closed its last coal power plant.

The major public health benefits of reduced coal and oil burning, over just one month, are a striking demonstration of the benefit to public health and quality of life if European decision-makers prioritise clean air, clean energy and clean transport in their plans to recover from the crisis, and reduce coal and oil consumption in a rapid and sustainable way.

<sup>1</sup> Centre for Research on Energy and Clean Air (2020) 11,000 air pollution-related deaths avoided in Europe as coal, oil consumption plummet <https://energyandcleanair.org/wp/wp-content/uploads/2020/04/CREA-Europe-COVID-impacts.pdf>



Photo by Andrew Roberts



## FURTHER INCENTIVISE ELECTRIC VEHICLES

With oil prices dipping into the negative on commodities markets, the price consumers pay for petrol and diesel will fall sharply.

Instead of letting this drive a resurgence in private car usage, the price differential should be used as an opportunity to raise funds to support the clean air transition.

The price of fuel could be maintained at current levels, with funds raised diverted to continue the current increase in electrical vehicle (EV) charging stations.

- Copenhagen Council has reserved hundreds of parking spaces for EV providers to set up and operate charging stations for a period of ten years.
- So far, over 100 charging points and over 200 parking spaces, one fast charging point and one hydrogen station have been established<sup>1</sup>.

There are approximately 2,500 taxis in Copenhagen<sup>2</sup>, and almost all the companies have already, or are exploring, electric vehicles. All new taxis purchased could be electric or hydrogen.

- Dantaxi has over 50 electric taxis and a hydrogen car. 4x35 is exploring solutions for future charging infrastructure and electric cars. 4x27 is similarly running trials. Two new providers, VIGGO and DRIVR have plans to run exclusively zero-emission vehicles<sup>2</sup>.

It should be noted that EVs address local NO<sub>2</sub> and combustion-related PM, however challenges remain with road, tyre and brake wear. These emitters of PMs may not be as toxic as combustion particles, but may still be an irritant in the same way as construction dust.

<sup>1</sup> State of Green (2019) More Electric Vehicles in Copenhagen <https://stateofgreen.com/en/partners/city-of-copenhagen/solutions/more-electric-vehicles-in-copenhagen/>

<sup>2</sup> Kathrine Fjendbo, Copenhagen Electric: Taxibranchen har nu for alvor sat strøm til den grønne omstilling, 13 Nov 2019 <https://pro.ing.dk/mobilitytech/artikel/copenhagen-electric-taxibranchen-har-nu-alvor-sat-strom-til-den-groenne>





Photo by [Lasse Møller](#)



## PUBLIC TRANSPORT HUBS

Enlarged parking facilities at Vanløse, Ørested, Ny Ellebjerg and other public transports hubs is likely to decrease private car use in the city centre.

The metro and S-train systems are key features of Copenhagen's well-developed public transport facilities.

Research confirms that closing streets to private traffic, renewal of the bus fleet and re-organisation of the public transportation significantly benefit air quality<sup>1</sup>.

- In Ljubljana, a 72% reduction of local black carbon (BC) was observed after restrictions on traffic were implemented.
- In Granada, reductions of 37% in BC and 33% in PM<sub>10</sub> concentrations were observed after a public transportation re-organisation.

<sup>1</sup> Titos et al. (2015) Evaluation of the impact of transportation changes on air quality, Atmospheric Environment, Volume 114, Pages 19-31. <https://doi.org/10.1016/j.atmosenv.2015.05.027>

## DESIGNING CLEAN AND GREEN CITIES

At the 2019 C40 World Mayors Summit, 35 mayors including Copenhagen pledged to deliver clean air for the more than 140 million people that live in their cities. By signing the Clean Air Cities Declaration, the mayors recognised that breathing clean air is a human right and committed to work together on an unparalleled global coalition for clean air.

*91% of people around the world breath air that exceeds agreed safe limits, leading to millions of premature deaths every year.*

But combating air pollution is a complex issue, with many interrelated causes. There are the obvious emitters from the transport and energy sector, but also contributions from buildings' own energy systems if they are not connected to a district energy system, and emissions from tourism, waste systems, as well as local industry.

Citizens look to their mayors for action, and mayors are responding with increasingly bold measures. In Shenzhen, all 16,000 buses are now electric, and the city is forcing out non-electric taxis. The Mayor of Rome made the shock pledge of a ban on diesel cars coming into force in 2020. In Copenhagen, there has been major investment in converting the existing district energy system to not only become zero-carbon, but also improve air quality compared to the existing power plants.

As engineers, designers and planners, the commitments made at the summit will impact our work as urbanisation and the need for new buildings and infrastructure in cities increases rapidly. With two thirds of the world's population living in cities by 2050, the infrastructure and buildings we design must help the cities accommodate growth while simultaneously reducing their environmental impact and, where possible, creating regenerative or restorative environments.

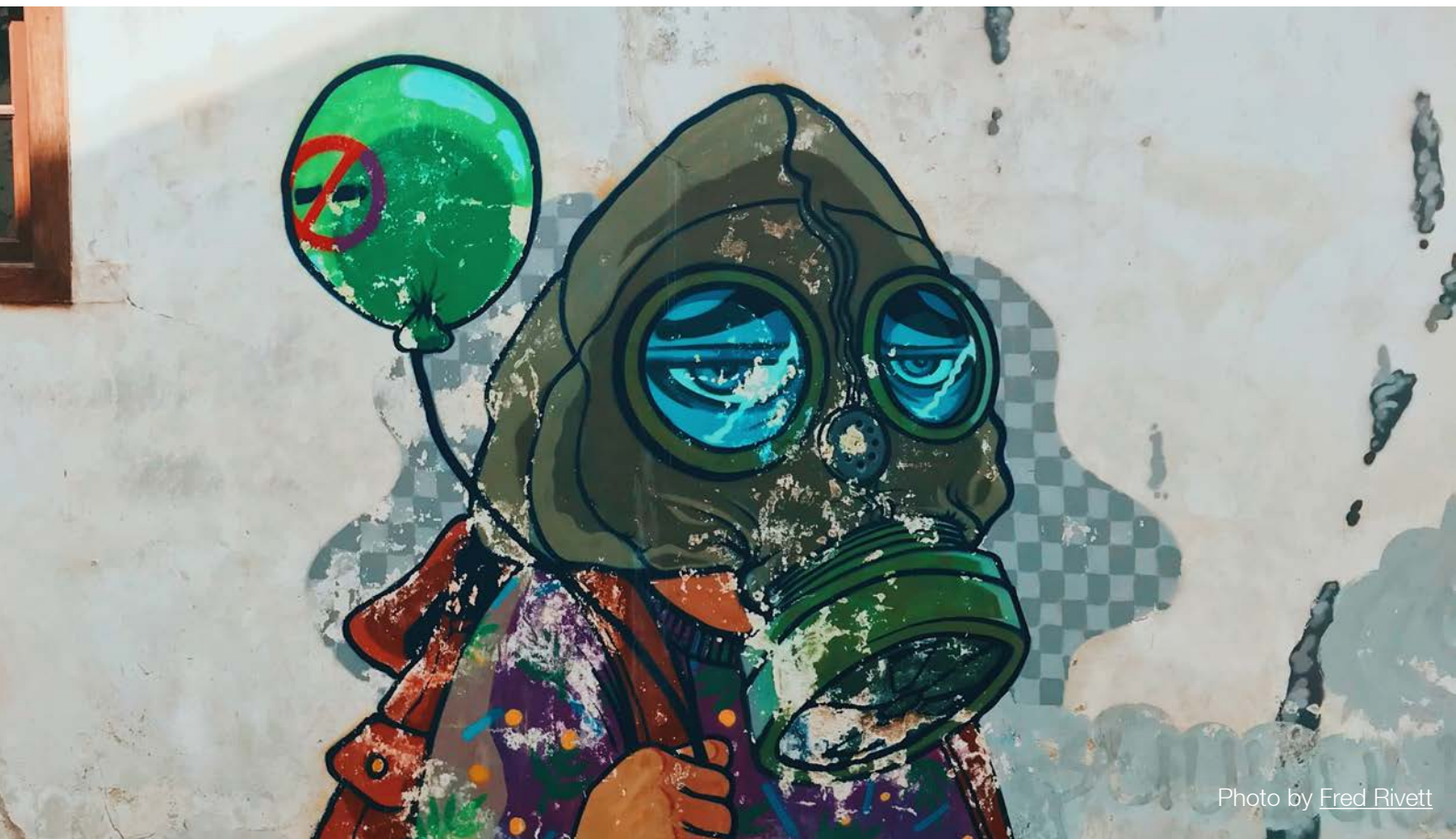
A fundamental element of the C40 network is that city officials around the world are now connected, enabling them to share challenges and lessons learnt with each other. Successes, whether that be a project or policy, are quickly disseminated around the network. A job well done in one city can generate similar work in many other cities.

It's important to remind ourselves that the work we do transcends far beyond the 'projects' we design. People remain at the core of why we do what we do. Our common goal is to shape a better world – for our friends and for our family – and our wider global community.

Together, we can make great impact. We can help ensure that our planet, our home, remains a liveable and resilient place where people from generations to come can enjoy a healthy life. If you ask me if this is the future I want, I would say this is the future we need.



Elliott More,  
Energy & Climate Engineer



## CLEAN AIR PROGRAMME

The widespread travel restrictions associated with the COVID-19 pandemic have demonstrated clean air is achievable in major global cities. However, we've always known what was necessary to deliver a clean and green city: reduce the need to travel through mixed use planning and place making; improve the accessibility of areas by active modes; and use electric public transport vehicles.

During the recent lockdown, NO<sub>2</sub> concentrations at traffic sites were lower by 12 ug/m<sup>3</sup> and 16 ug/m<sup>3</sup> in March and April, compared to the 2016-2019 average for those months. The change in background NO<sub>2</sub> concentrations in these months was negligible, at less than 1 ug/m<sup>3</sup>. PM<sub>10</sub> concentrations at traffic sites were lower by 7 ug/m<sup>3</sup> and 4 ug/m<sup>3</sup>, compared to the 2016-2019 average.



Our Clean Air Programme places air quality at the centre of all its projects to influence design and evaluation. We recognise a multi-disciplinary approach is needed to provide holistic solutions to the air quality challenges facing urban environments. Importantly, we draw on our global understanding of what works, what does not work and why.

Our recommendations are based on the evidence gathered from innovative data sources and analysis tools. In many cities, data is available for a range of activities, from traffic counts and public transport use to weather and air quality. However, while these sensors are present in the urban environment, their deployment and data collection have not necessarily been designed for city-scale analyses, resulting in gaps in our knowledge.

Such gaps have been highlighted when attempting to explain the impacts of the COVID-19 lockdown on air quality. Copenhagen has four real time sensors across its 88 km<sup>2</sup> area, so the observed concentrations represent only a small view of the local air quality across the city.

A comprehensive network of sensors to monitor activities within a city through time can provide useful evidence to support the design and evaluation of policies to deliver clean and green cities. Low cost units can complement the existing regulatory air quality stations due to the advances in sensor technology and packaging. For example, London<sup>1</sup> and Newcastle<sup>2</sup> have arrays of such sensors which publish concentrations automatically to the internet and are accessible by the public. These sensors can be used to establish baseline concentrations at sites before a development begins or a change in activity occurs. Equally, flexible sensor networks can be deployed where large numbers of people or vulnerable groups may be exposed to high pollution levels. Examples include transport hubs, hospitals and schools.



Justin Bishop,  
Senior Consultant, Arup



James Bellinger,  
Senior Consultant, Arup

<sup>1</sup> Breathe Map London, 8 Jun 2020 <https://www.breathelondon.org/>

<sup>2</sup> Urbanobservatory Sensor map, 8 Jun 2020 <https://www.urbanobservatory.ac.uk>



Photo by Neil Thomas

## RELEVANT COPENHAGEN INITIATIVES

Ren luft til københavnere 2013 (Clean Air for Copenhageners): <https://kk.sites.itera.dk/>

Clean Air - Danish efforts (Ministry of Environment): <https://eng.mst.dk/>

Copenhagen Solutions Lab for Air Quality: <https://cphsolutionslab.dk>

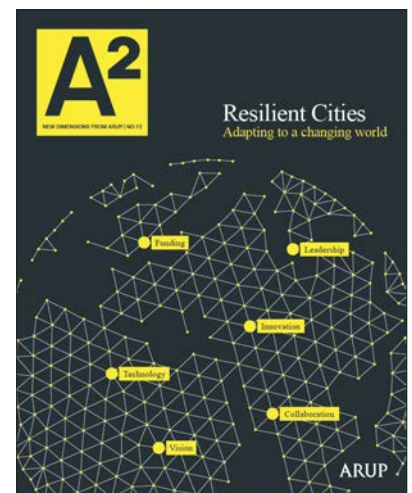
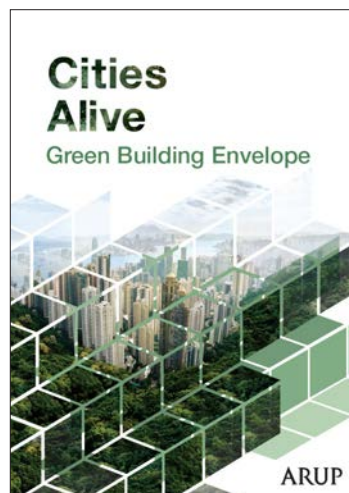
C40 Clean Air Cities Declaration: [www.c40.org/](http://www.c40.org/)

Cycle Superhighways: <https://supercykelstier.dk>

European Sustainable Cities Platform: [www.sustainablecities.eu](http://www.sustainablecities.eu)

100 Resilient Cities: [www.100resilientcities.org](http://www.100resilientcities.org)

## RELATED ARUP PUBLICATIONS:



## INTEGRATED CITY PLANNING

Holistic design in a sustainable manner

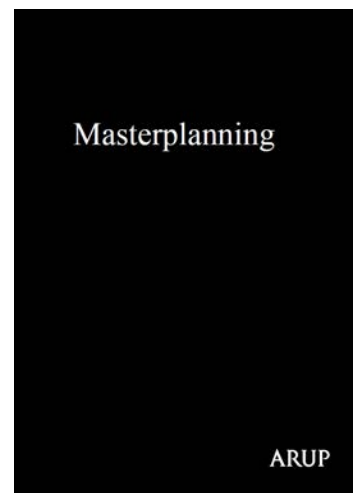
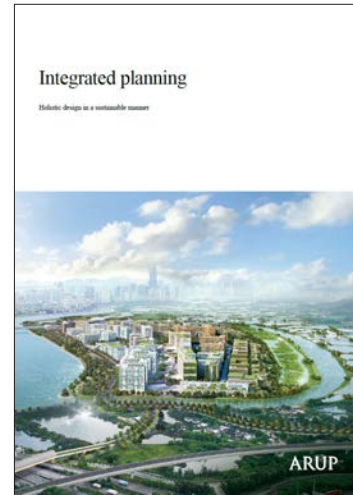
Arup approaches all projects in a holistic manner by applying an integrated planning approach. Bespoke teams of planners from across all the traditional planning disciplines – policy, town planning, masterplanning, environment and transport – work closely together.

Introduced by our founder, Sir Ove Arup, the integrated design concept requires the involvement of all professional design and engineering disciplines in the design process, in which all design aspects are considered thoroughly and integrated into a whole.

We are renowned for our multidisciplinary skills from planning and architecture to building design incorporating structural, civil, MEP engineering and other specialist skills. With this integrated design concept, Arup's planning team draws upon full resources and expertise from various disciplines to plan, develop and create many of the world's most sustainable projects and communities.

In everything we do, we take a holistic approach to balance the social, economic, environmental and cultural dimensions of human existence, delivering better places for people to work, stay and play.

We understand the planning challenges and issues faced by clients in both the private and public sectors. Respected worldwide for excellence in the built environment, we deliver innovative, futureproof, sustainable solutions. An integrated planning approach is applied to all projects, whether large or small. Bespoke teams of planners, from across to provide intelligent solutions to any challenges they face.



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Arup is an independent firm of designers, planners, engineers, consultants and technical specialists. Together we help our clients solve their most complex challenges. We strive to find a better way and shape a better world.

**We shape a better world**