The Breathe London Blueprint:

How cities can use hyperlocal air pollution monitoring to support their clean air goals

EDF ENVIRONMENTAL DEFENSE FUND™
Finding the ways that work

Contents

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BREATHE LONDON HELPED MAKE INVISIBLE POLLUTION VISIBLE.

The evidence is clear: Breathing dirty air is bad for our health and can be deadly. Around the world, nine out of ten people breathe unhealthy air, with the poorest people often hit the hardest.

Air pollution can be hard to see, so it's challenging for local officials to pinpoint sources and patterns to develop effective solutions.

New sensor technology is changing that dynamic, allowing us to map pollution street-by-street and identify patterns and hotspots like never before.

To meet this challenge, Environmental Defense Fund Europe (EDF Europe) - in partnership with the Mayor of London and leading science and technology experts – launched Breathe London, which mapped and measured pollution across the capital for two years.

With 100 lower-cost sensor 'pods' and two specially-equipped Google Street View cars, the Breathe London pilot project complemented and expanded upon London's existing regulatory monitoring network.

The main aims of the project were threefold:

- Advance the use and development of innovative, lower-cost monitoring techniques to support cities around the world;
- Enhance London's existing regulatory network to better understand pollution and assess targeted solutions for cleaner air, like the Ultra Low Emission Zone; and
- Make air pollution data publicly available and visualise it in new and innovative ways.

Many cities around the world have been watching Breathe London with interest in replicating our best practices.

We hope this guide illuminates how air pollution monitoring can play a critical role in informing clean air solutions and fostering healthier communities in your city.

What is London's Ultra Low Emission Zone?

In April 2019, London introduced the world's first Ultra Low Emission Zone (ULEZ). The ULEZ is an emissions-based charge that applies to all older, more polluting vehicles that enter the city centre. The ULEZ operates 24 hours a day, 7 days a week, every day of the year (except Christmas Day).

> "These findings, from our world-leading Breathe London sensor network, are a stark reminder that pollution hotspots exist across London and will refocus our efforts on improving air quality for all. As we face up to the current climate emergency, I hope the success of this scheme will act as a blueprint for cities around the world to battle their own toxic air emergencies."
>
> **THE MAYOR OF LONDON, SADIQ KHAN**

PART 1: REPLICATING BEST PRACTICES

What we learned

We designed this guide to provide you with the major lessons learned that can support your city's future monitoring initiatives. In this section you'll find best practices, including guidance to help you get started and answers to frequently asked questions.

A key question for any city considering the use of lower-cost sensors or mobile monitoring is, "Can they provide reliable data and insights?"

The short answer is yes, and more. Here's what we found.

YOU CAN USE EMERGING MONITORING TECHNOLOGIES AND TECHNIQUES TO IDENTIFY AND CHARACTERISE AIR POLLUTION.

Breathe London data produced insights that were broadly comparable to findings from London's extensive regulatory network, demonstrating that lower-cost sensor systems and mobile monitoring are valid options for generating useful data.

Supporting clean air goals

Even if you only have limited access to regulatory (or reference-grade) air quality monitors, you can assess a city's pollution levels and meet different goals, including:

FIND AIR POLLUTION HOTSPOTS

Lower-cost sensor systems and mobile monitoring can help you find air pollution 'hotspots,' or the places and times of day that need the most attention.

MEASURE HOW WELL AN INTERVENTION IS WORKING

A stationary sensor network can show trends and patterns continuously over long periods of time, while mobile monitoring can provide detailed pollution information on roadways.

RAISE PUBLIC AWARENESS

Information generated from lower-cost sensor systems and mobile monitoring can help you engage the public on air quality so they support action and understand the need for it.

THE SCIENTIFIC GAINS OF BREATHE LONDON

London's existing regulatory network provided an excellent opportunity to study the performance of lower-cost sensors and mobile monitoring to determine their reliability and accuracy.

Breathe London demonstrated that – with scientific expertise and robust quality assurance and quality control (QA/QC) procedures– lower-cost sensor systems and mobile monitoring can provide reliable data. Additional scientific advancements include:

Measuring CO_2 to better understand pollution sources.

If you want to gain insights into what is causing air pollution, measuring carbon dioxide (CO_2, a marker of burning fossil fuel) can help characterise emission sources and inform policy intervention decisions.

The amount of pollution observed relative to CO_2 – emission ratios – can help separate specific emissions (e.g., pollution per vehicle) from total emissions (e.g., traffic volume) as contributing factors. Changes in emission ratios over time can be a useful indicator of how well policies that address emissions standards are working.

Calibrating lower-cost sensor networks with a new, cost-effective method.

In order to ensure the accuracy of lower-cost monitors, they require appropriate calibration – a process that takes time and resources when relying on physical co-locations with reference-grade monitors. That's why the Breathe London team tested and validated an innovative, network-based method developed by project partner the University of Cambridge, that enabled simultaneous, remote calibration of the entire network.

Maximising insights with data limitations.

Breathe London developed criteria and strategies to maximise data insights even with the greater uncertainty of lower-cost sensors and low number of drive passes from mobile monitoring.

For the stationary network, lower-cost sensors have an increased level of uncertainty and bias compared to reference-grade technology. But if data is aggregated over multiple sites in a network, it's possible to estimate regional trends.

For the mobile monitoring, previous campaigns required a minimum of 15 repeat visits to assess average pollution on a road segment. With Breathe London, we developed a methodology that requires as few as five visits, which reduces both the time and resources needed.

Using hyperlocal measurements to improve air quality modelling.

Using the model developed by project partner Cambridge Environmental Research Consultants (CERC), Breathe London measurements were compared with modelled concentrations to identify pollution hotspots. These results were used to produce annual pollution maps and enhanced source apportionment at the city's schools, hospitals and care homes, as well as to calculate estimates of the pollution impacts of different policy scenarios.

Go deeper

For more detailed information on the scientific learnings from Breathe London, see the project consortium's technical report.

ASSESSING AIR POLLUTION DATA IN YOUR CITY

GETTING STARTED

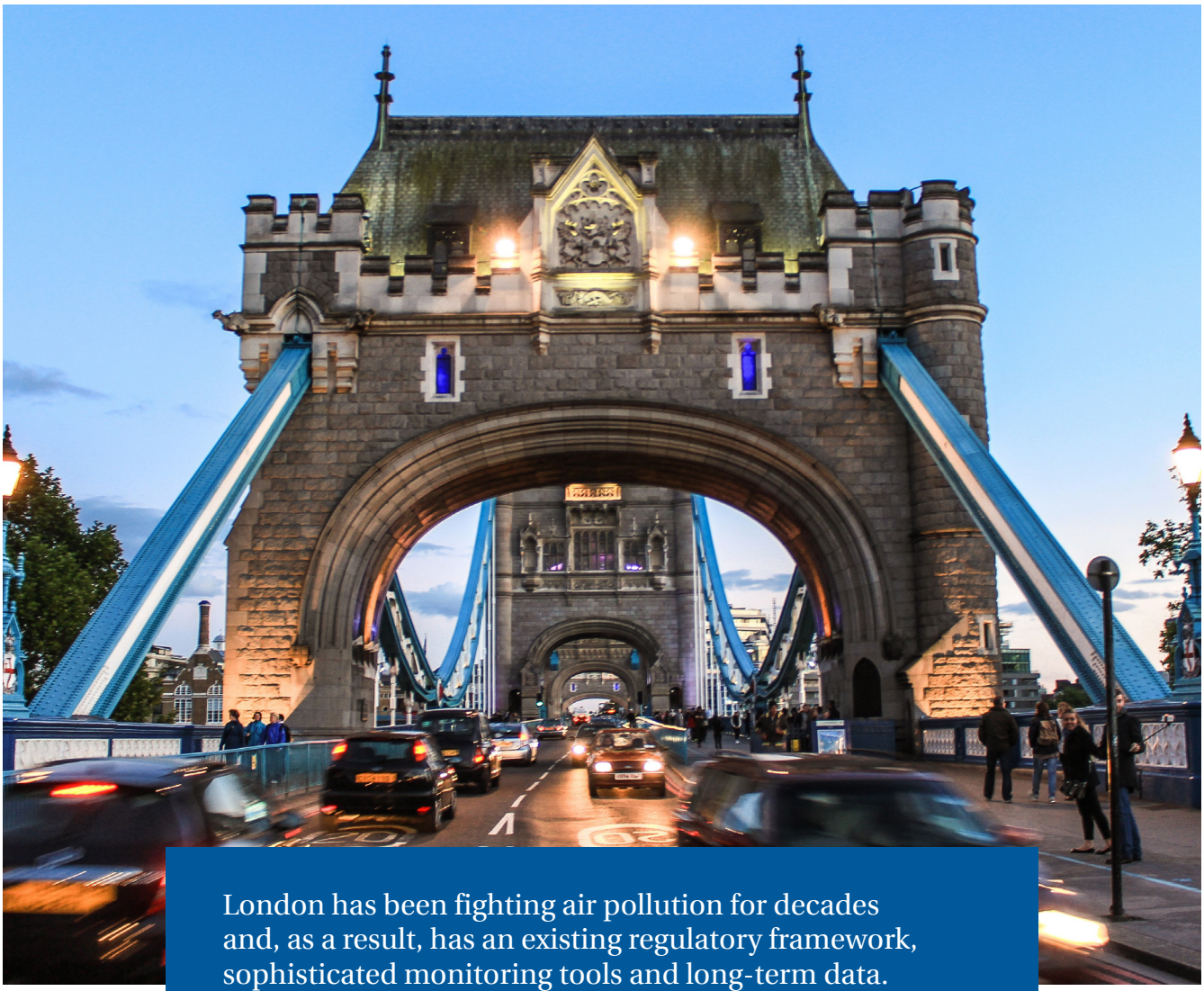
Understand your city

The first step in any pollution monitoring project is understanding your city's existing air quality landscape.

Key questions:

- **Action:** What is already being done to tackle air pollution? For example, existing clean air policies or legislation and pollution limits.
- **Data:** What data is available? For example, air pollution data from regulatory monitors or supporting data like emissions inventories, weather monitoring or modelled air pollution data.
- **Stakeholders:** Who is working on air quality issues and what is the collective state of knowledge? For example, local government, campaign groups or academia.

Every city will have a different starting place. Regardless of whether you have been monitoring air quality for years or tackling pollution is not a local priority, it's important to know the landscape where you live – and talk to those who have been working on the issue – to best determine where to start.



London has been fighting air pollution for decades and, as a result, has an existing regulatory framework, sophisticated monitoring tools and long-term data.

GETTING STARTED

Build your team

You need the right mix of specialists on your team to execute a hyperlocal monitoring project and turn the data into action. Experts will help you set goals, as well as design and implement monitoring systems and processes, make sense of the data and share findings to meet the goals.

You should begin to cultivate strong working relationships with local partners as early in the project as possible in order to leverage collective knowledge and align expectations and outcomes.

These experts can include:

Scientists and data experts

- Air pollution experts
- Emissions experts
- Dispersion modellers
- Health experts
- Environmental data analysts
- Data scientists
- Data management experts

Community members and local experts

- Local government, residents and businesses
- Community groups
- Schools, care homes, hospitals and doctor's offices
- Local NGOs or think tanks
- Landowners or site hosts

Monitoring and technical experts

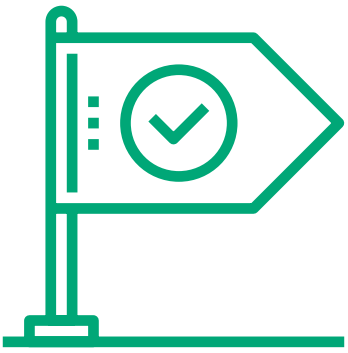
- Manufacturers
- Air monitoring systems providers
- Specialists in designing, testing and assessing systems
- Maintenance technicians
- Drivers for mobile monitoring

Other experts

- Project manager or coordinators
- Marketing and communications specialists
- Website and user experience designers

DESIGN

Set goals



Once you have a better understanding of your city's starting place, work with your team to identify challenges, opportunities and what you want to achieve.

Setting goals in consultation with air quality scientists and local communities can help determine whether your city could benefit from hyperlocal monitoring and, if so, create a monitoring plan to meet your goals.

Key questions:

- **Data gaps**: What air quality data is missing that you need in order to address air pollution?
- **People**: Are there certain communities or populations who are more vulnerable to the impacts of air pollution or might experience higher exposure due to where they live, work or play?
- **Obstacles**: What are the barriers to collecting data or inspiring the public to support action?

Goal setting examples

1. There is a gap in knowing…where and when air pollution and exposure is highest

GOAL: ***To find pollution hotspots and help target policies***

2. People who are more vulnerable are …children

GOAL: ***To measure the impact of a street closure in front of a school***

3. The biggest barrier is…people don't know if air pollution is a problem where they live

GOAL: ***To raise awareness of nearby pollution levels***

DESIGN

Create a plan

Once you have clearly defined goals and determined hyperlocal monitoring is the right approach, you will need to create a plan. Here are some of the most frequently asked questions to help you go about this process, including how Breathe London answered them and other tips.

Which pollutants should you measure and why?

The pollutants you measure should depend on the emission sources of concern in your city, including pollutants causing health impacts or those most relevant to your monitoring goal. If there are existing air quality limits in your city, monitoring the regulated pollutants is a good starting point.

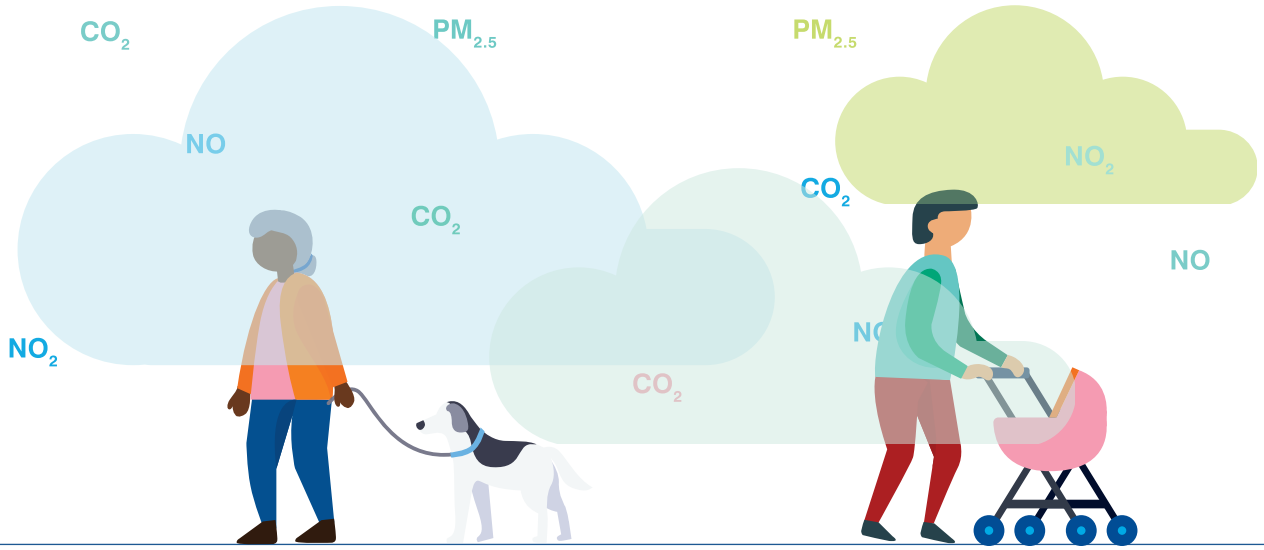
Through both the stationary and mobile monitoring, Breathe London focused on three key air pollutants that are prevalent in London and pose health risks:

- Nitrogen dioxide (NO_2)
- Fine particulate matter ($PM_{2.5}$)
- Nitric oxide (NO)

NO_2 is nationally regulated in the UK, and local government in London is expected to reduce $PM_{2.5}$. These pollutants come primarily from burning fossil fuels, like diesel and petrol vehicles or gas-powered heating for homes and businesses. NO and NO_2 pollutants, collectively known as nitrogen oxides (NO_X), interact in the presence of light and other pollutants which can lead to ground-level ozone, another pollutant harmful to people's health.

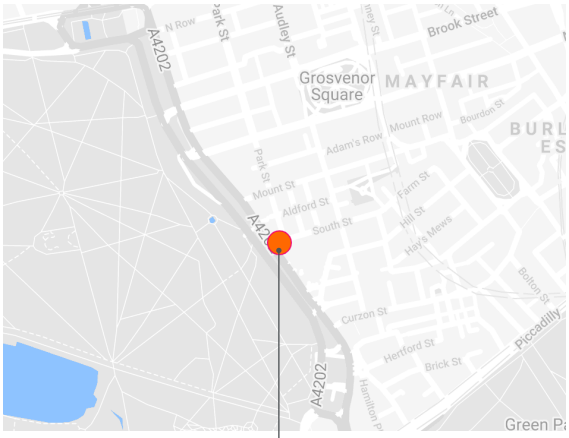
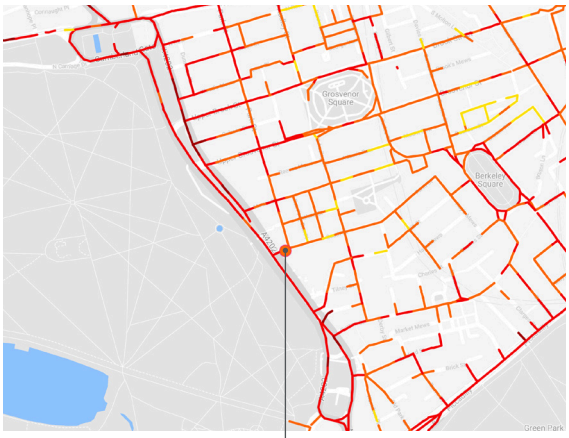
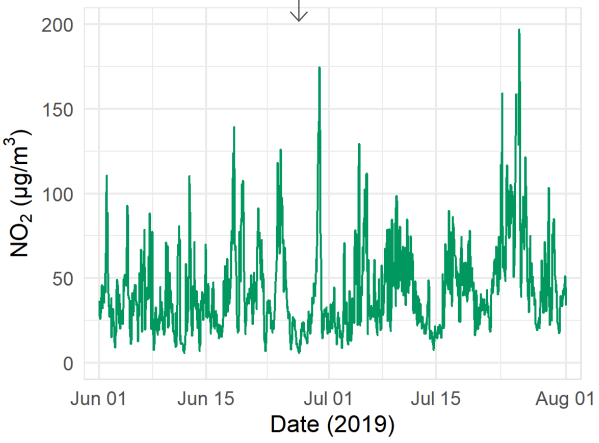
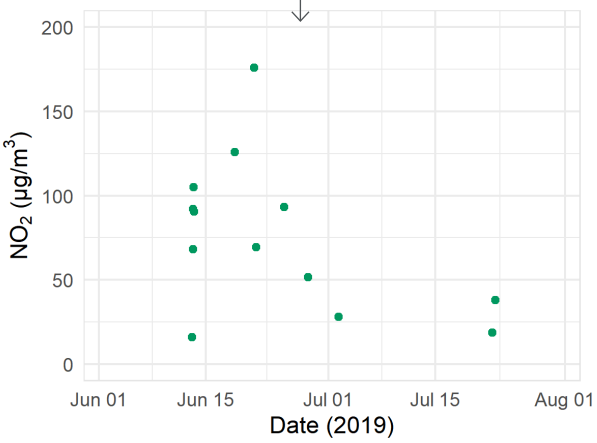
Breathe London also measured carbon dioxide (CO_2), a climate change gas that is also emitted from burning fossil fuels, to better understand local air pollution sources.

Keep in mind that air pollutants have different physical properties, as well as different health impacts, which have implications for how best to measure and map them.



Should you do stationary or mobile monitoring, or both?

There are trade-offs between stationary monitoring, for which monitors are mounted at a fixed location such a lamppost and measure pollution continuously, and mobile monitoring, for which monitors are specially-fitted to vehicles and measure pollution as they drive through the streets.

	STATIONARY MONITORING	MOBILE MONITORING
SPACE		
TIME		
	• Continuous at each location • At all hours of the day	• Not continuous at each location • During limited driving times

Images show 2019 annual mean concentration of NO_2 (µg/m^3) from the AQMesh pod at Park Lane and segment medians over the entire mobile campaign from Sep 2018 to Oct 2019. Bottom plots show a 2-month period between 1 June and 1 August 2019, comparing NO_2 concentrations (µg/m^3) from the AQMesh pod at Park Lane with median NO_2 concentrations from a mobile monitoring road segment located 35 metres away.

Mobile monitoring is useful for understanding *where* pollution is highest, but – because the measurements are not continuous – it can be difficult to know *when* pollution is highest or to distinguish real changes from weather-induced changes. With limited time in a large, congested city like London, it can also be challenging to cover enough ground with mobile monitoring to achieve the intended spatial coverage.

It's important to note that instrument set-up and data management for mobile monitoring can be more complicated and resource-intensive, which has additional cost implications.

If you have the resources, the two monitoring types can work together in stages – by using mobile monitoring for screening and identifying locations of concern, the results can inform where to place stationary monitors.

Breathe London wanted to advance the science of both lower-cost sensors and mobile monitoring, as well to as see how we could use both approaches to assess the impact of London's ULEZ. That's why our monitoring plan included both a stationary network and mobile monitoring.

Go deeper

For more guidance on deciding between mobile and stationary sensors, and how to combine them, watch this instructional video.

WEARABLES

In a Breathe London study by the Environmental Research Group at Imperial College London (formerly at King's College London), children from five London primary schools carried backpacks with 'wearable' air pollution monitors. The research aimed to understand how children are exposed to the risk of air pollution – and where and when the risks are highest.

The study found that children who walked to and from school through busy main roads were exposed to higher levels of air pollution than those that chose to travel through back streets. You can find more on the results of the wearables project here.

What do we mean by 'lower-cost?'

'Lower-cost' refers to air pollution monitors that are mid-range, both in terms of cost and accuracy. They are more expensive than very low cost indicative monitors but less expensive than reference-grade monitors. There is a wide range of lower-cost air quality sensors available, the market is evolving rapidly and the sensors can vary significantly in terms of reliability and number of pollutants measured.

It's important to keep in mind that usually the upfront purchase price of an air quality sensor does not reflect the overall cost of obtaining quality data.

When creating a budget, you will need to account for the entire 'sensor system,' which refers to other hardware and software components that have additional costs, such as power supply (e.g., solar panel). You will also need to factor in the cost of experts' time and maintenance, calibration and other data QA/QC activities, as well as obtaining the raw data.

ACCURACY

	LESS ACCURATE Very low cost £	±	MORE ACCURATE Lower-cost ££-£££	±	MOST ACCURATE Reference-grade £££-££££	±
Gaseous pollutant sensor	£ 10 - 100	30-50%	£ 100's - 1000's	10-30%	£ 4,000 - 15,000	5-15%
Particulate matter sensor	£ 20 - 200	50-100%	£ 100's - 1000's	25-50%	£ 10,000 - 25,000	5-25%
Sensor system	–		£ 1,000 - 8,000		£ 5,000 - 25,000*	
Processing and operation**	–		£ 200 - 500		£ 1,500 - 3,000	
Total***	£ 30 - 300		£ 1,500 - 15,000		£ 20,000 - 70,000	

The Breathe London stationary monitoring sensors fall in the lower-cost category and the mobile monitoring sensors fall in the reference-grade category.

**Includes cost of shelter and ancillaries.*
***Estimated cost (per annum) of data processing, calibration, QA/QC,* and analysis.
****Estimated cost of deploying and operating a sensor system comprised of one gaseous and one particulate matter sensor. More accurate sensors will incur additional costs with rigorous QA/QC to produce high quality data.*
***** Estimated uncertainty of measurement (±) for each sensor at the WHO limit values for gaseous pollutants and $PM_{2.5}$.*

LEASING OR OWNING?

You might lease monitors rather than purchase them if you're going to monitor for a shorter period (e.g., less than a year),) and a lease package could include upkeep, maintenance and sensor replacement. Leasing may end up being a more expensive option if you maintain your lower-cost sensor network over many years.

Which monitors should you use?

The monitors you choose will depend on several factors including:

- Monitoring goals and objectives
- Data quality you need
- Which pollutants you want to measure and the expected concentrations
- Budget and resources

Breathe London installed a network of 100 lower-cost AQMesh sensor 'pods,' with each pod containing several air quality sensors. For the mobile monitoring, two Google Street View cars were specially equipped with seven reference-grade air pollution monitors.

You should consider the sampling frequency of the monitors, or how often they take measurements, and align these capabilities with your monitoring goals. For example, if you want to use the network-based calibration method or better understand pollution sources by measuring CO_2, it is important to select monitors that can make rapid measurements.

You can find additional information on the types of monitors used by Breathe London and resources to evaluate the performance of lower-cost air pollution monitors.

PROS AND CONS OF LOWER-COST MONITORS

PROS

+ Price
The up-front cost can be significantly less than reference-grade monitors. For the same investment cost, you can place more lower-cost monitors to achieve greater coverage.

+ Size
Lower-cost monitors are not as bulky as reference-grade monitors, are easier to install and replace, and require less power to run.

+ Adaptability
You can easily relocate lower-cost monitors and put them in locations that are impossible for reference-grade monitors. Some can even be 'worn' via backpacks, like in the Breathe London wearables study.

CONS

- Longevity
Pollution sensors in lower-cost monitors can require more frequent maintenance, and some start declining in performance after a couple of years and need to be replaced.

- Certainty
Lower-cost sensor technology is usually less accurate and precise than reference-grade monitors. Lower-cost monitors are best for giving a relative indication of pollution levels and changes.

- Vulnerability
The smaller lower-cost monitors are more easily damaged, more susceptible to weather and environmental conditions, and can require extra protection or placement further away from the pollution source to prevent tampering.

Where should you place the monitors?

Once again, let your goals and available resources be your guide.

Breathe London aimed to provide an unprecedented level of detail about air quality across the city and to assess London policy to tackle air pollution. We put the pods on lampposts and buildings throughout the city. When deciding where specifically to place them, we used several guiding factors including:

- Filling geographic gaps in the existing regulatory network.
- Prioritising 'sensitive' locations, such as primary schools and hospitals.
- Assessing the impact of the ULEZ.
- Mixing traffic levels and site types (e.g., close to roads or away from major pollution sources).

It's important to place sensors where people are likely to be exposed to pollution. Data from the top of a tall building or in an obscured alcove at ground level, for example, will not tell you much about how people are experiencing air pollution.

Siting considerations can be a challenge when installing a large network of stationary monitors. See here for key logistical and siting considerations from our sensor network, like identifying power sources and factoring in pod weight and height.

What else should you consider?

The number of monitors and the amount of time needed will depend on what you are studying and your specific goals.

It is essential to let air pollution science guide you. Undertaking a monitoring campaign with too few monitors or within too short a timeframe could prevent you from drawing robust conclusions, and the effort and costs will have been wasted.

Where should you drive for mobile monitoring?

Your desired monitoring coverage should determine the drive plan, including starting with priority areas.

Our vehicles drove over 40,000 km on London roads and we used several guiding factors to decide where to drive, including:

- Full coverage inside the ULEZ boundary.
- Driving routes based on predicted pollution concentrations to target potential hotspots.
- Selecting areas of lower and higher deprivation, a UK measure that incorporates income, health inequalities and access to resources.

Mobile monitoring requires thinking through various pieces like parking, driver training and operating instruments in a moving vehicle. See here for key considerations from our mobile monitoring.

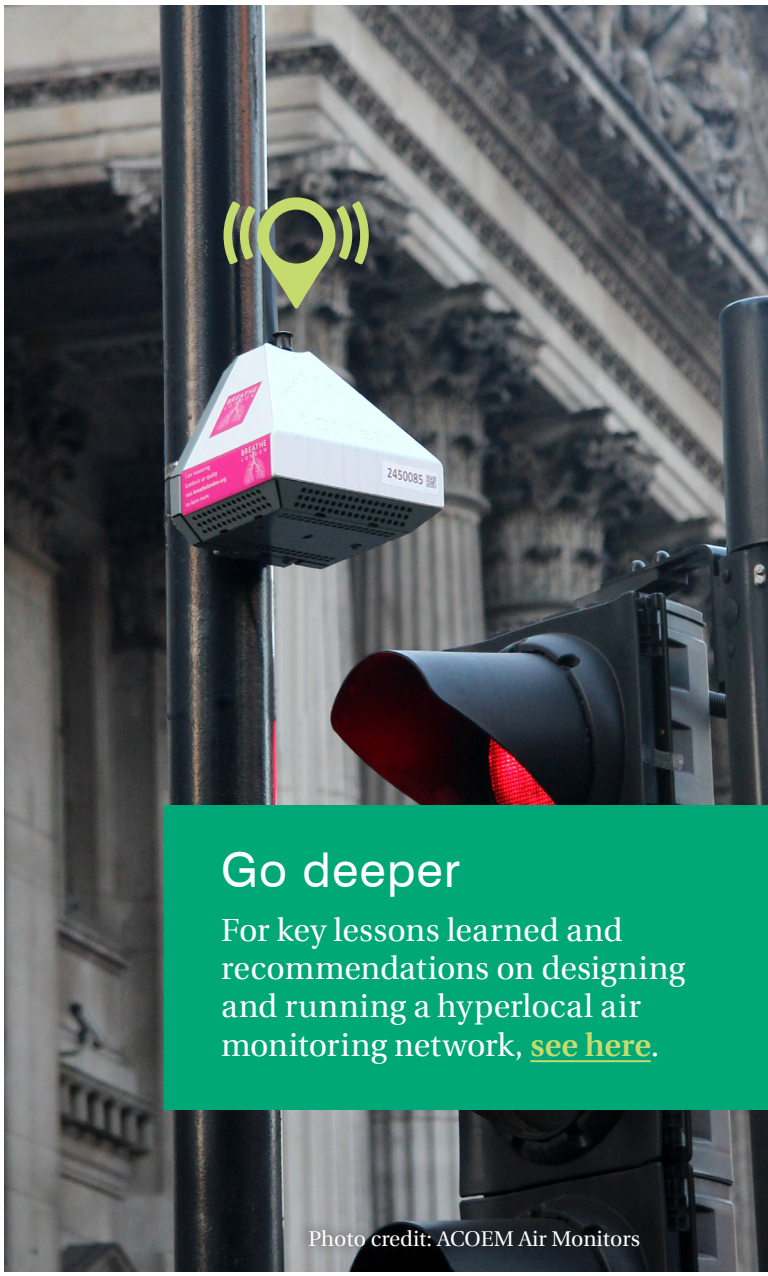
What if your city doesn't have a regulatory network?

You need at least one reference-grade monitor in your city to use lower-cost monitoring to assess policy. This could be an existing reference-grade monitor, e.g., at a university in your city, or you could purchase one as part of your monitoring project.

You can use the network-based calibration method and robust QA/QC procedures to improve the accuracy and comparability of lower-cost sensors relative to each other, based on a single reference-grade measurement site.

If you don't have access to any reference-grade monitors, there will be more uncertainty about the accuracy of absolute pollution levels. But you may still be able to characterise relative variations across the city and short-term variations in pollution (e.g., pollution by hour of day).

In Breathe London, nine AQMesh pods were co-located periodically with reference monitors to become qualified transfer standards, also known as the 'gold' pods. The team then co-located these gold pods with other pods across the network to calibrate them.



Go deeper

For key lessons learned and recommendations on designing and running a hyperlocal air monitoring network, see here.

Photo credit: ACOEM Air Monitors

PART 2: USING HYPERLOCAL MONITORING TO SUPPORT YOUR GOALS

Breathe London serves as a case study for how to design a monitoring project that addresses three goals:

1. Identifying pollution hotspots
2. Measuring how well an intervention is working
3. Raising public awareness

Below, we describe how Breathe London produced the data to achieve these goals in London, as well as suggestions for how to focus your resources and links to go deeper.

1. Identifying pollution hotspots

If you want to reduce air pollution but don't know the best location in the city to start, you can use lower-cost monitoring to identify pollution hotspots. These are locations where people are exposed to unusually elevated levels of pollution.

Breathe London's approach

We wanted to use measurements from our monitoring to find pollution hotspots at locations that weren't detected by the regulatory monitoring network or identified by the city's air quality model.

Several months into monitoring, we noticed one of the Breathe London pods was consistently measuring higher NO_2 pollution levels than the rest of the network. The pod was near the entrance of a bus garage, at the end of a residential street. Interestingly, the pod was often registering significantly higher NO_2 levels than the nearest regulatory monitor located on a busy, main road approximately 1.5 km away. This highlights the ability of hyperlocal data to identify previously undetected issues.

After we shared this data, the responsible government entity immediately began working with the bus operator to find ways to reduce pollution, including stopping buses idling outside the garage and upgrading some of the bus fleet to electric power. Continuous monitoring allowed us to see which times of the day the pollution levels were at their worst, so actions could be targeted accordingly.

Data shows the measures taken at the garage were effective and pollution went down since their introduction.

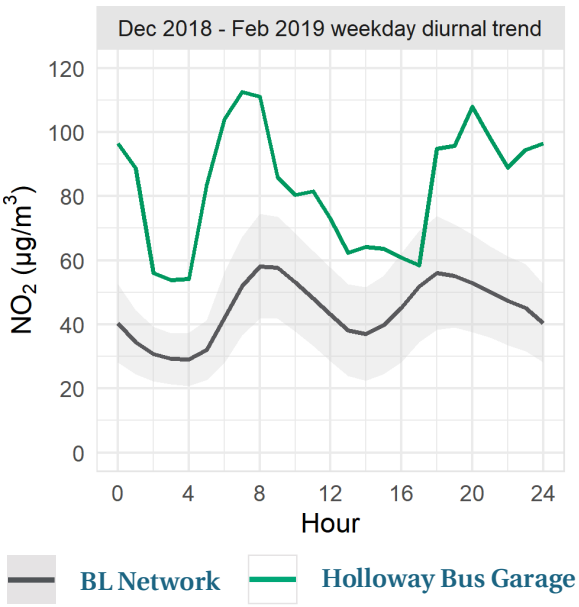
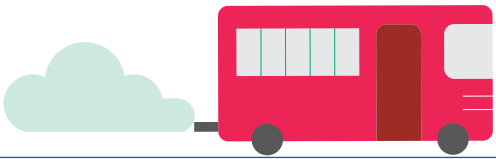
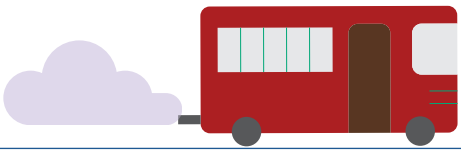


Figure 1 NO_2 levels at the Holloway Bus Garage pod were consistently higher than the Breathe London network average.





Hotspot identification is a great way to focus interventions and target resources where they will have the most benefit to your city's residents.

Focusing your resources

You don't need hundreds of monitors to get started on finding problem areas. Based on what we learned from Breathe London, here are a few suggestions for detecting hotspots with more limited resources:

- **Prioritise sensitive and suspect areas**: Are there particular areas where younger and older people live, work or play? Combine that knowledge with places where you suspect pollution might be a problem based on public complaints, poor compliance history or other local insights. You might start with monitoring these potential hotspots – like schools and hospitals near industrial facilities or busy roads – to better understand both where and when the pollution is highest.
- **Prioritise the times when people are likely exposed to pollution:** There are times when emissions are high and a large number of people could be exposed, like during a school drop-off, meal-times at restaurants, peak traffic commuting hours or nighttime industrial activities. The monitoring plan should prioritise these times so as not to miss opportunities for interventions that could most benefit people's health.
- **Go mobile**: Mobile monitoring is an effective screening tool because of the data's higher spatial coverage, so you might start by driving one monitor around to detect hotspots. Keep in mind that if mobile monitoring is limited to just a few vehicles, coverage in space comes at the expense of continuous monitoring in time.

What next?

Once you've detected a hotspot, you can work with your team to determine next steps and tackle the issue. Based on local knowledge and context of that area, you might deploy stationary monitors to measure long-term pollution levels and gather more data, or evaluate whether there are any immediate interventions you could try to lower pollution.

Using mobile monitoring to find pollution hotspots

Mobile monitoring data – like the information gathered by the reference-grade monitors in the Google Street View cars – can also provide key insights on areas where pollution levels are elevated. Analysis of the Breathe London mobile data showed areas not previously monitored, including major roads and quieter local roads, that are likely to exceed UK legal limits for NO_2 without further interventions.

Breathe London developed methods to find hotspots using mobile data and dispersion modelling. You can find more information here.

2. Measuring how well an intervention is working

Air quality monitoring can play a key role in determining or prioritising an action or 'intervention' to reduce pollution, and measuring the effectiveness of the given intervention. Maybe you've identified a hotspot on a busy road and decided to add cycle lanes or put in place a scheme to charge the most polluting vehicles in the city's busiest areas, like London's ULEZ.

How do you know if the intervention is making an impact on air quality?

Measuring whether an intervention is lowering air pollution is challenging. Weather and seasonal variations, as well as pollution travelling from outside city limits, can have a big impact on whether you are able to detect a reduction in pollution or not. For example, a windy day could improve air quality by dispersing pollutants that might have otherwise accumulated locally – making it difficult to attribute changes to a particular policy.

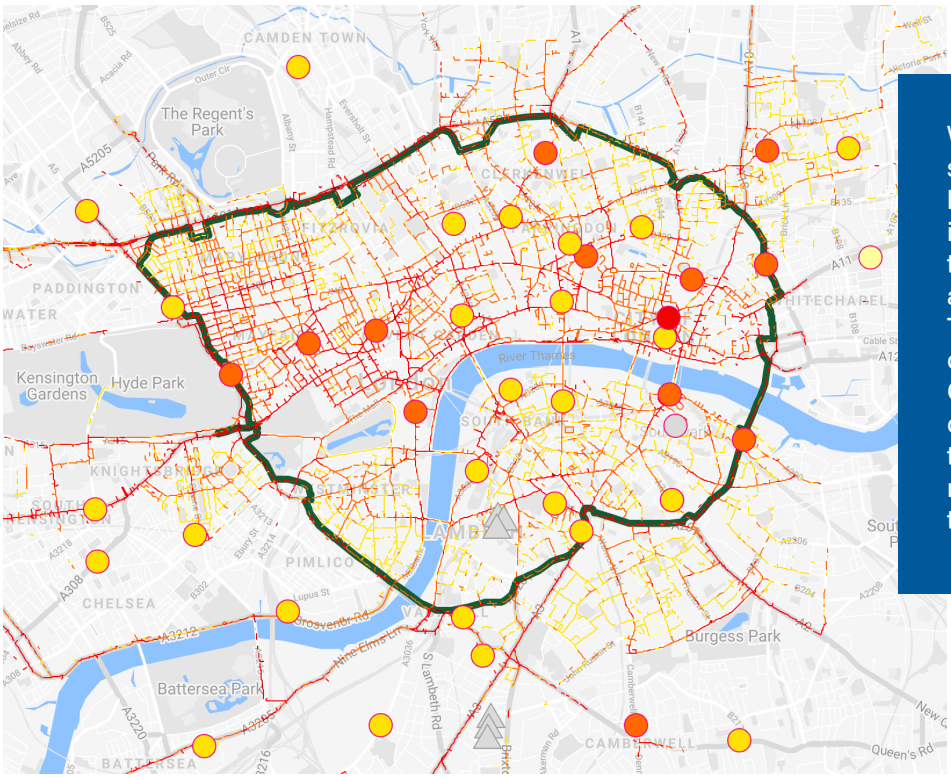
But with guidance from air quality scientists, lower-cost sensors and mobile monitoring can be used to estimate air quality improvements brought about by interventions.

The importance of baseline data

When air quality monitoring is new to a city, it can be useful to gather baseline data and establish a starting point against which you can measure future initiatives to lower pollution. You can use the technologies and techniques described here to measure and better understand pollution levels and trends across your city, regardless of whether there is an intervention to measure.

Breathe London's approach

In London, we assessed the impact of the ULEZ on NO_2 levels. Years of local baseline data was available from London's regulatory monitoring networks. Breathe London monitoring provided a more extensive baseline – with measurements beginning around seven months prior to the ULEZ launch date on 8th April 2019.



We designed the stationary network to have a mix of pods inside and outside the ULEZ, as well as along the boundary. To further ensure good coverage of the zone, the Google Street View cars drove primarily inside the ULEZ and within neighbourhoods along the boundary.

Figure 2 Breathe London pod locations, mobile monitoring measurement data and the boundary of the ULEZ.

What did we find?

Breathe London analysis found that air quality in Greater London had been improving for several years before the ULEZ was initiated. Multiple efforts that began prior to the start of the ULEZ, including the city updating to a cleaner bus fleet and many drivers choosing to replace non-compliant vehicles, had been driving the city's NO_2 levels down.

Although it's difficult to separate out the discrete impact of the ULEZ, it's clear the measure coincided with a significant drop in NO_2 pollution. We analysed Breathe London monitoring data and found, after the ULEZ start date, a 25% drop in NO_2 levels at monitoring sites inside the zone near roads and an average 8% drop for all Breathe London sites across Greater London.

Air pollution showed general improvement not only inside the ULEZ boundaries, but also throughout other parts of London where we measured. This finding suggests that the air quality benefits of the ULEZ could reach far beyond the zone itself.

COVID-19 LOCKDOWN ANALYSIS

When the UK Government first put in place restrictive measures to slow the spread of COVID-19 in March 2020, Breathe London data from the lower-cost sensor network helped us understand the changes in pollution levels. The greatest changes were between 6 am and 10 pm – average NO_2 reduced by 17-24% across the full network and 28-30% inside the ULEZ, compared to the average levels measured in the three months prior to lockdown.

These and other Breathe London insights were included as evidence in a **UK Government report** to support decisions on the air quality management measures needed in the wake of the virus.

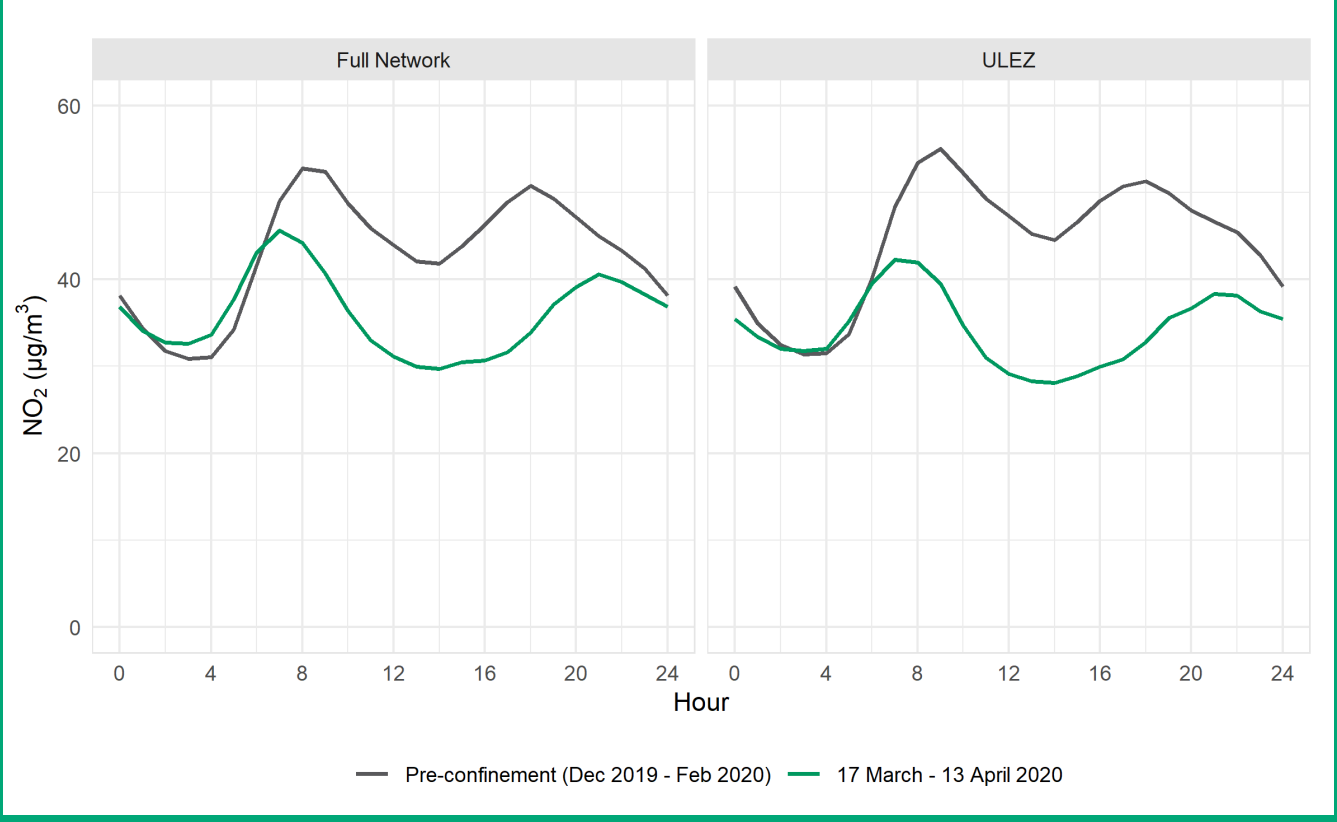


Figure 3 Observed changes in NO_2 pollution levels during the first four weeks of the UK's national lockdown in March-April 2020.

Focusing your resources

You don't need years of local baseline data to get an idea of whether an action is making a difference. Based on what we learned from Breathe London, here are a few suggestions for assessing discrete interventions with more limited resources:

- **Prioritise long-term measurement at a key location:** The longer you can measure before and after an intervention, the more likely you are to detect the effect if there is one. With limited resources, you could start by picking one key spot, and go for a longer measurement time-frame rather than having multiple locations.
- **Take advantage of existing opportunities:** Is there a city vehicle that is already regularly driving near the site of a traffic or road intervention? You might start by putting a reference-grade monitor in a car that drives a route near the intervention, and measure pollution before and after the intervention begins. If you pursue this option, it's worth considering that mobile monitoring is often more complicated for data collection and analysis.
- **Leverage other datasets:** Where air quality monitoring data is limited, other markers of success are also useful. Examining changes in other datasets in your city – like traffic counts, public transportation ridership and hospital admissions for asthma – can help fill out the picture of the intervention's impact.

Don't forget to factor in accuracy

In the list of lower-cost pros and cons, we noted that these monitors may not be as accurate as reference-grade monitors. Accuracy depends on the sensors used, weather, pollution levels and siting. Given the sensors' margin of error, interventions may have an impact that is too small to register.

For example, if a cycle lane reduces a pollutant by 5% but the margin of error on the sensor is +/- 20%, you probably won't be able to discern the impact of the cycle lane.

3. Raising public awareness

To sustain your city's commitment to reducing air pollution, it's important for people to understand how urgent the problem is and why they should support investment in new infrastructure, resources and projects.

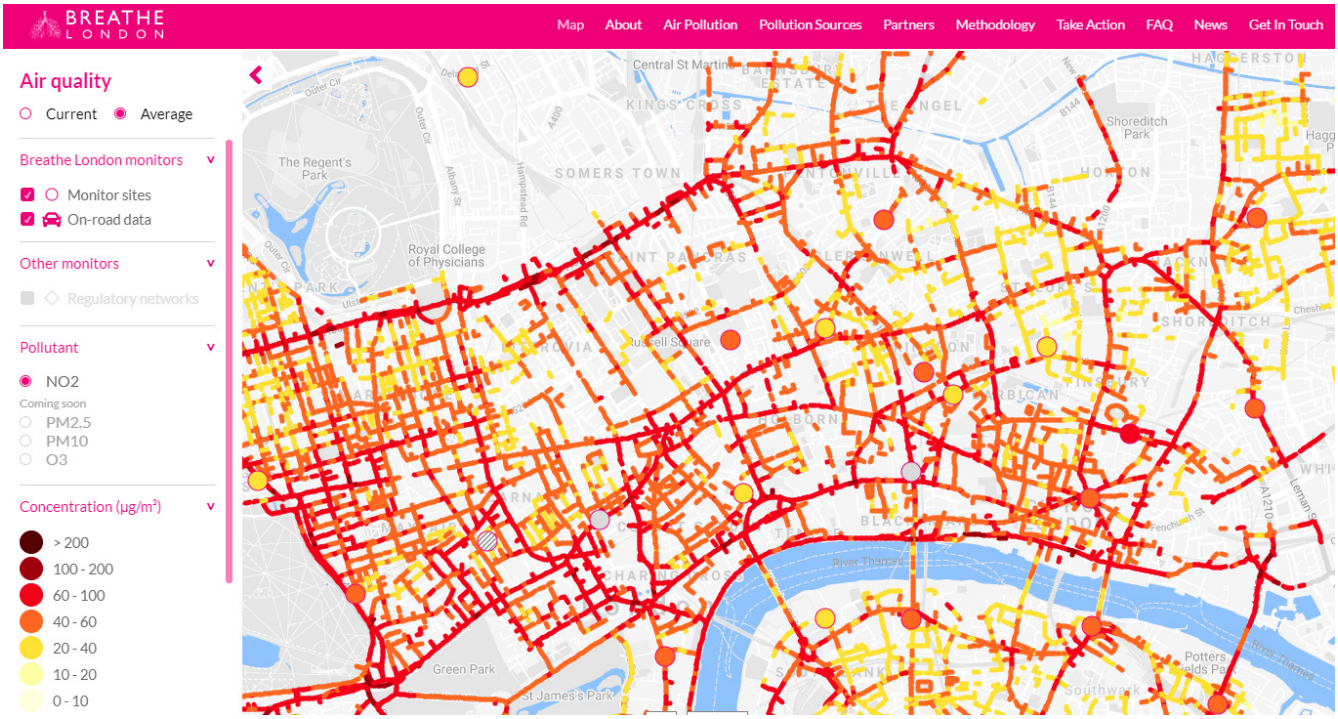
One way to inspire a sense of urgency is to raise public awareness using local data. The specific approach will depend on your city's starting place and goals.

Breathe London's approach

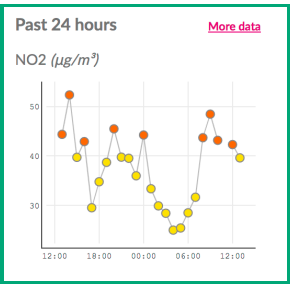
Transparency and open access to data were critical to the Breathe London pilot project, so the team created a dynamic, unique platform for sharing and visualising air pollution data with the public. The website contained specifics about the project itself, like how the data was collected and processed, and also displayed existing information about pollution's health impacts and ways citizens could take action.

The centerpiece of the site was an interactive map. Unlike any other website for the city, the map – allowed people to see current pollution levels from London's regulatory monitoring networks and the Breathe London network, as well as the on-road data from our mobile monitoring, together in one place. Over the course of the pilot project, thousands of visitors came to the site – mostly from the UK, but with interest from countries near and far as well, like France and India.

You can interact with the data from the Breathe London pilot project on a map on EDF's Global Clean Air site.



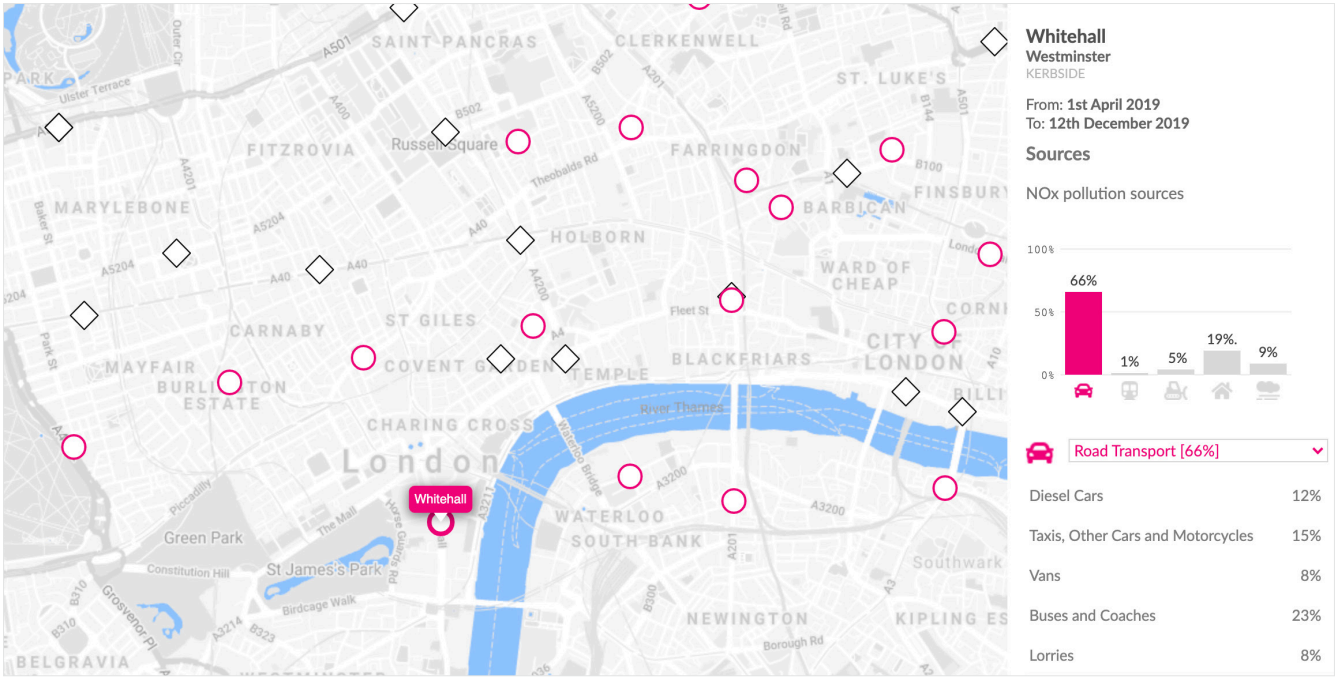
Users could also click on individual Breathe London pods to see a graph that showed how pollution changed over 24 hours, or dig deeper to see all of the recorded data over time at that location.



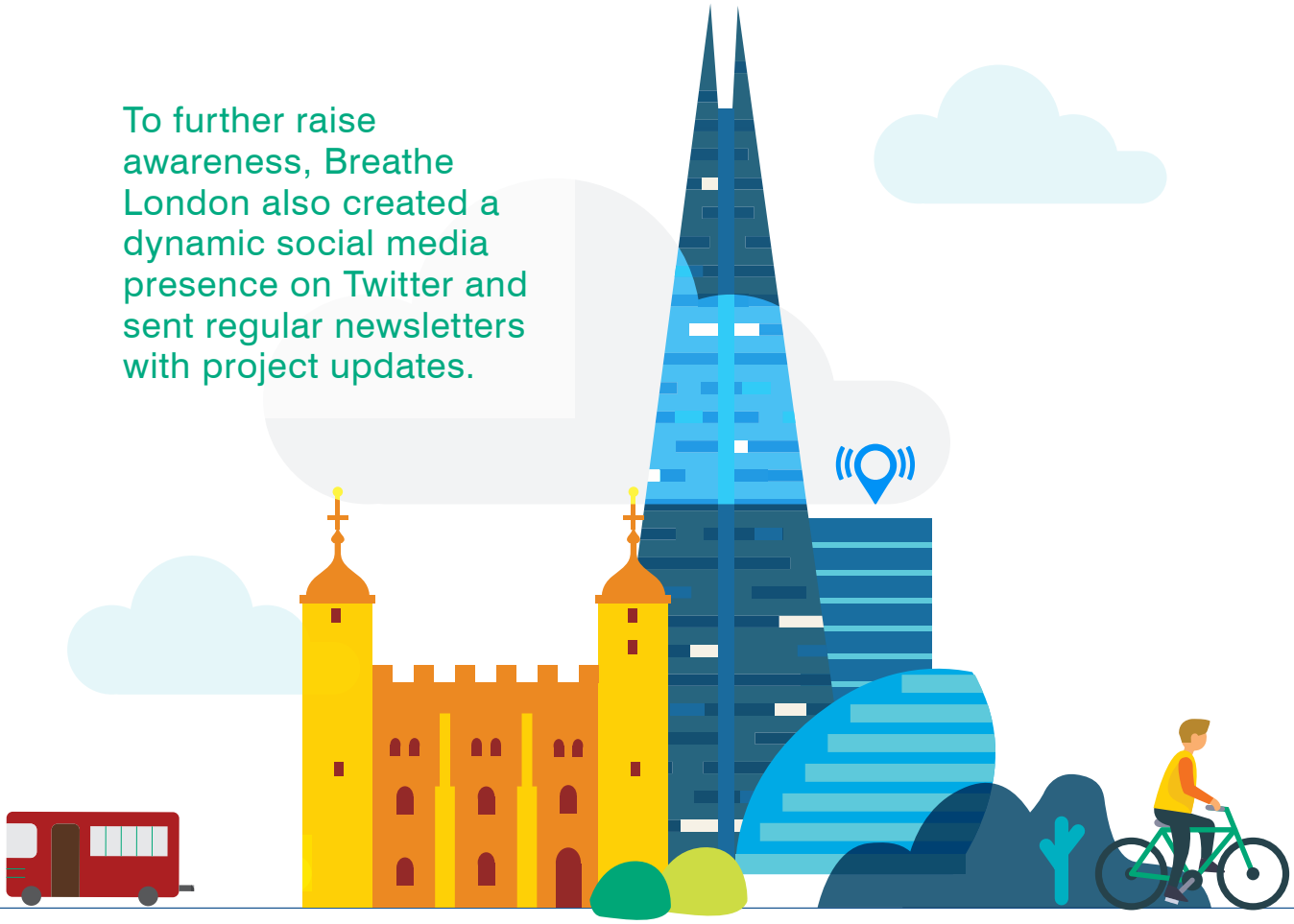
Understanding pollution sources

To help people understand the activities contributing to pollution, the map provided an interactive dataset on local sources of nitrogen oxides (NO_x) air pollution, using CERC's ADMS air quality model and London's existing emissions inventory.

People could select a monitoring location and view the breakdown of modelled pollution sources at that spot – showing how much of the pollution comes from sources like road transport or heating and powering buildings.



To further raise awareness, Breathe London also created a dynamic social media presence on Twitter and sent regular newsletters with project updates.



Voices from the community

It is really powerful that Breathe London shows how and especially why the air is so polluted. Change will only be demanded when policymakers and many of us understand the pollution sources that are making us sick.'

JEMIMA HARTSHORN, CO-FOUNDER OF MUMS FOR LUNGS

Our Lancell Street monitor has been very helpful over the months in knowing where we stand pollution wise in sending our children to school and in doing outside exercise. Evidence is central to increasing awareness and making positive change.'

SALLY NEWSOM, RESIDENT OF NORTH LONDON

The Breathe London data has given me a deeper understanding of the issues in my borough and I found it useful in discussions with fellow councillors, officers, developers, and residents. It has encouraged me to raise it as an issue when perhaps in the past I might have felt reticent about doing so.'

COUNCILLOR SUE ANDERSON, HARROW COUNCIL, LONDON

Tips for creating an air quality map

- Carefully consider your target audience and their needs. You should guide the user to the important information and avoid overwhelming them with data.
- Choose a colour scheme that will show variation among pollution levels. Monochrome maps tend to be less engaging and informative.
- User testing can tell you whether your audiences are taking away the intended information and better inform the design of the map or any visualisation of the data.
- Be realistic about uncertainty from lower-cost monitors. Don't try to show a high level of precision and accuracy if the data doesn't support it.
- Consider using existing resources – like a map application or an air quality index – rather than starting from scratch.

Focusing your resources

You don't need an interactive map featuring hundreds of monitors to raise public awareness. Based on what we learned from Breathe London, here are a few suggestions for raising public awareness with more limited resources:

- **Take advantage of existing data**: If any monitoring, modelling or emissions data already exists and is available to the public, you might start by consolidating, interpreting, visualising and promoting this air quality information.
- **Prioritise vulnerable communities:** Some people – like children and older people – are more vulnerable to pollution's health impacts. You might focus your communications and outreach to those who are concerned about or work to improve the health and wellbeing of vulnerable groups. You can monitor pollution at locations relevant to these groups and raise awareness among influential audiences, like school, hospital and care home decision-makers and community leaders.
- **Leverage a marketing budget and media outreach**: An extensive, expensive project may not generate awareness as much as a small project that everyone knows about. You might begin with short-term monitoring – like one month outside of a few schools at a time – and put funding behind promoting the project far and wide.

Marketing and communications

Regardless of your specific awareness aims, it's important to remember that air pollution data and monitoring alone will not change minds or inspire action. You need to carefully consider the target audiences you want to reach and determine which messages will speak to those audiences.

Marketing and communications experts can help you with that process, if you have the resources, as well as help you put together a comprehensive communications plan and share the data in a way that non-technical audiences can understand.

Whichever direction you choose, you need to engage local scientists or air pollution officials to analyse and interpret results. This will ensure that the information you're sharing is scientifically credible.

For more guidance on creating a communications plan for your monitoring project, see here.

CONCLUSION

An extensive network of expensive, reference-grade monitors isn't the only way cities can better understand hyperlocal air pollution and gain valuable insights. The Breathe London pilot project successfully demonstrated that lower-cost sensors and mobile monitoring can be a useful tool for your city to tackle local air pollution and protect people's health.

Breathe London's hyperlocal monitoring allowed city officials to identify hotspots, assess major interventions and better engage the public on London's air pollution crisis and the need for action. And importantly, the pilot project gained critical technical and scientific insights into deriving reliable data from hyperlocal monitoring techniques – lower-cost sensor networks and mobile monitoring – that can serve as a starting point for any city embarking on an air pollution monitoring effort.

We hope this guide has provided valuable lessons learned and insights from Breathe London and serves as a blueprint for how to do something similar in your city, regardless of your starting point. By keeping a spotlight on the threat of air pollution to our health and well-being, data from hyperlocal monitoring is increasingly becoming a viable option to inform better, higher-impact clean air solutions.

ACKNOWLEDGEMENTS

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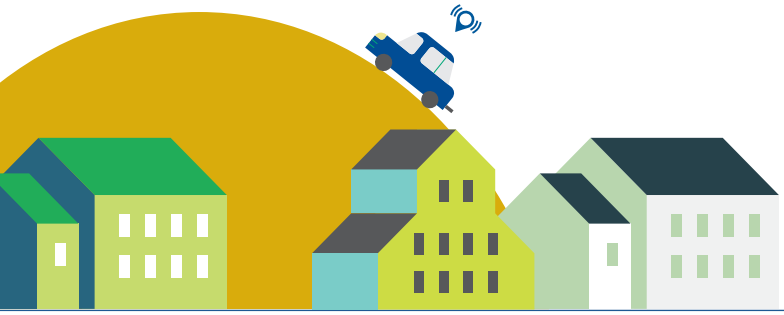
EDF Europe and the project consortium would like to thank the many hosts of Breathe London monitors including local councils, schools, and residents, as well as the scientific and project advisors, technology partners and other non-governmental organisation partners for their contributions. The lessons and insights gained from Breathe London draw from these collective efforts.

PROJECT CONSORTIUM

The Breathe London project consortium included ACOEM Air Monitors, Cambridge Environmental Research Consultants, Google Earth Outreach, the National Physical Laboratory and the University of Cambridge. The Environmental Research Group at Imperial College London (formerly at King's College London) ran the wearables study.

EDF ENVIRONMENTAL DEFENSE FUND Finding the ways that work | CERC | AirMonitors.co.uk Quality - Service - Innovation | Google Earth Outreach | KING'S College LONDON | UNIVERSITY OF CAMBRIDGE | NPL National Physical Laboratory



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