

Volume #4 - 2025

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FLUXES

The European Greenhouse Gas Bulletin by ICOS

Cities: from emission hotspots to climate action innovators

New greenhouse gas data guides cities towards net zero

The urban decarbonisation path – policy and payoffs

Tracking city climate action impact with digital tools

ICOS
Integrated Carbon Observation System

FLUXES by ICOS

FLUXES is a yearly publication by ICOS, the Integrated Carbon Observation System. The aim is to highlight climate issues to policymakers and journalists. The first volume was published in 2022.

ICOS is a Europe-wide greenhouse gas research infrastructure. It produces standardised data on greenhouse gas concentrations in the atmosphere as well as on carbon fluxes between the atmosphere, ecosystems, and oceans. This knowledge supports policymaking and decision-making to combat climate change and its impacts.

ICOS's high quality data is based on measurements from 180 observation stations – run by top universities and research institutions across 16 European countries, and is produced by nearly 800 scientists.

The ICOS Carbon Portal offers unlimited access to thousands of datasets and other advanced digital products as well as services. ICOS has European Research Infrastructure Consortium (ERIC) status with a legal capacity recognised in all countries within the European Union.

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Front cover: greenhouse gas monitoring equipment was installed across the city on Parisian rooftops to get real-time data on local emissions. Photo: Adobestock

FLUXES VOL. 4

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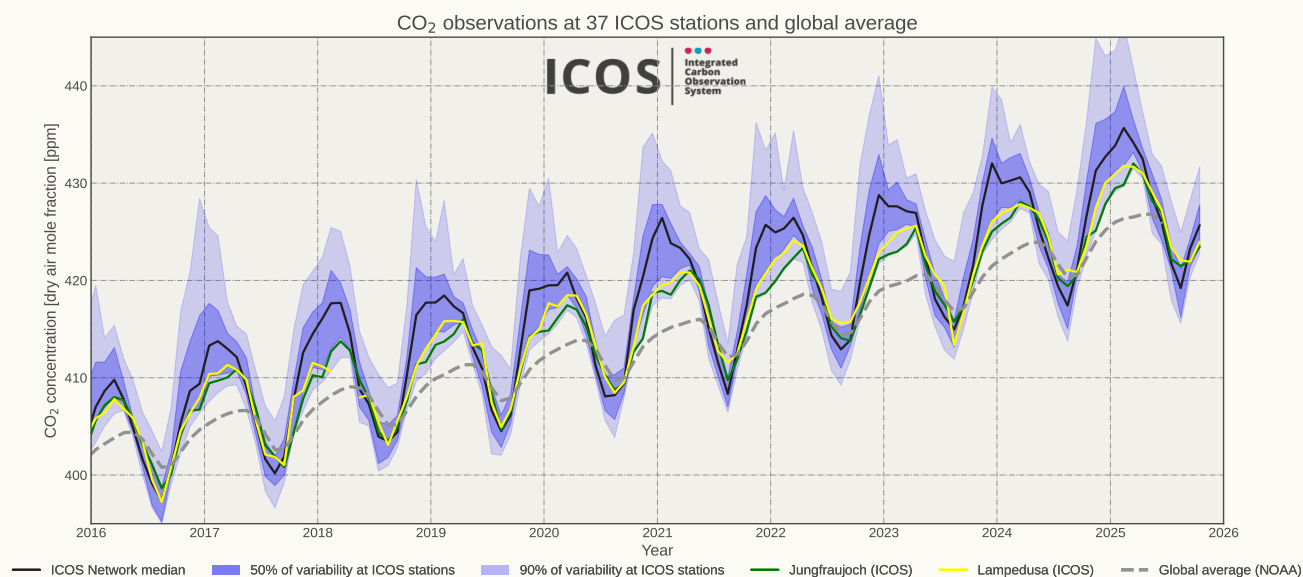
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Did you enjoy FLUXES? Does it help with your work? We want to know – give us feedback!



The ICOS Curve is the median of measurements from 37 stations in the ICOS atmosphere network. The dark blue area shows typical CO₂ concentrations for Europe, from half of the ICOS stations. The lighter blue area includes most of the ICOS observation stations. The curves show the seasonality of atmospheric CO₂ with more uptake during the spring and summer months, when plants grow.

Global atmospheric CO₂ concentrations continue to rise

The annual growth rate of carbon dioxide was 3.29 ppm/year in 2024, recent ICOS data show. This is an increase compared to previous years and yet another year off track from the goals of the Paris Agreement.

There are two main reasons behind the growing numbers:

- ▶ Continued fossil fuel use leading to record-high emissions of greenhouse gases
- ▶ A weakening of CO₂ sinks, like the terrestrial ecosystems

Terrestrial ecosystems are weakening in response to the rising global temperature. Extreme events like droughts and heatwaves disrupt plant growth and photosynthesis, which are processes that absorb atmospheric CO₂. Consequently, more of the CO₂ from fossil fuel emissions remains in the atmosphere and the atmospheric growth rate continues to increase.

The ICOS Curve data can be compared to other datasets, like the NOAA global average, that shows the background

The ICOS Curve

Near-Real-Time data is used to update the curve daily. The stations provide standardised, high-precision data.

The European CO₂ concentrations from ICOS atmosphere stations can be viewed via a graphical interface. The graph can be customised by selecting for example specific countries or regions, comparisons with the NOAA global average or Mauna Loa data.

The Curve tool is publicly accessible on the ICOS website: **icos-ri.eu** and **curve.icos-ri.eu**.

In the figure above, we highlight data from two monitoring stations that represent 'background conditions', which means that they are located far from human-induced emissions – the Jungfraujoch station at 3,500 m altitude in the Swiss Alps and the Lampedusa station in the Mediterranean Sea.

CO₂ levels from sites located farther away from emission sources. Because of closer proximity to emission sources like cities and industries, the ICOS Curve shows higher concentrations. ●

Science's role in decarbonising cities

Even if the political winds currently seem to be blowing in a different direction, decarbonisation is the order of the day. The rise in greenhouse gases continues, and we are on the way to rendering entire regions of this planet uninhabitable. It's pointless to deny this scientific finding. Cities are on the front lines of climate action, and they need scientific knowledge to support their ambitious decarbonisation plans. As a biologist and ecosystem scientist, I believe that the role of science has further developed from understanding our planet, towards using this knowledge to preserve it as a liveable habitat. Providing cities with the practical tools they need to achieve their climate goals is an important purpose of climate science.

For a city to truly tackle its greenhouse gas emissions, it must first know what it's up against. While many cities have emissions inventories, these are often based on broad estimates. To truly improve these, cities need a way to accurately identify the types of emissions and their exact sources. This is where science comes in. By using scientific analysis and real-time monitoring, we can validate a city's estimated carbon reductions and reveal what climate actions are working. This is crucial because a well-intentioned initiative might not yield the expected results. The more science a city integrates into its planning and monitoring, the better it can adapt and refine its strategies.

The ICOS Cities project was designed to push the boundaries of what is possible. In our three pilot cities, Paris, Zurich, and Munich, we intentionally 'over-instrumented' our sites to determine which emission observation methods are most effective. This innovative process helps us directly link our measurements to specific climate actions. For example, a distributed network of sensors can track changes in traffic or heating emissions, directly connecting them to a new policy or initiative.

This process is what I call 'inventory plus'. The main goal is to create a better, more accurate city emissions inventory by integrating real-world observations, scien-

DR WERNER KUTSCH

Director General of ICOS
and Coordinator of the
ICOS Cities project



tific analysis, and models to add crucial, actionable knowledge. Our work has already shown how direct measurements can either validate or challenge existing inventory assumptions, providing a significant boost to the effectiveness of climate action.

Cities are a major part of the EU's ambitious climate promises, and monitoring emissions is like a runner's watch when they're preparing for a marathon – it's essential for tracking progress. The EU can play a vital role by creating a legal framework for greenhouse gas observations and monitoring, similar to what already exists for air quality.

Science is not just an academic pursuit; it is a vital partner for cities in their race to decarbonise. By embracing advanced monitoring and measurement techniques, cities can transform their climate aspirations into measurable, lasting progress. ●

The ICOS Cities project brings together European citizens, policymakers, and top scientists in co-designing pioneering greenhouse gas measurement methodologies and services to support climate action in cities. The network consists of 15 cities in 13 countries.



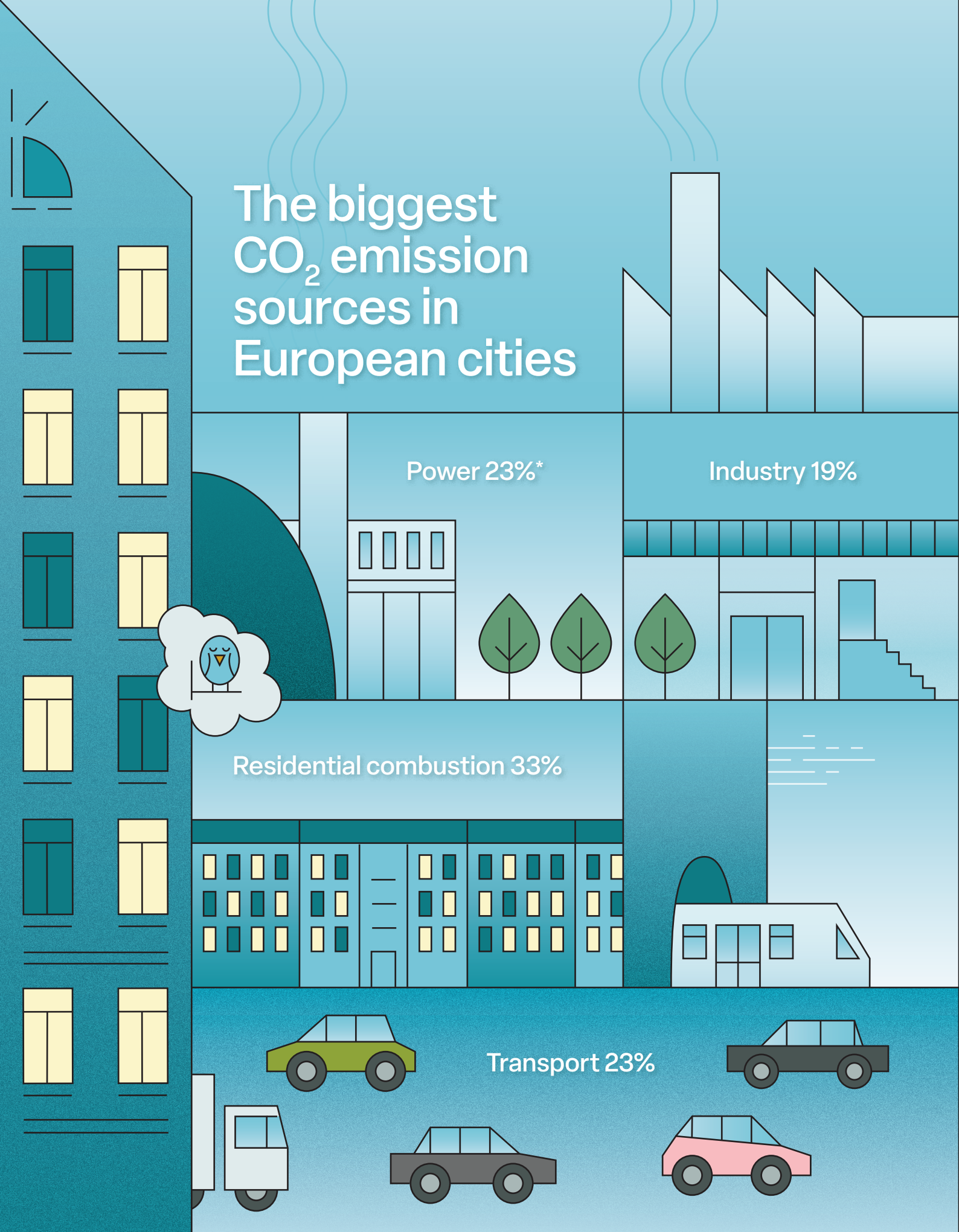
The biggest CO₂ emission sources in European cities

Power 23%*

Industry 19%

Residential combustion 33%

Transport 23%

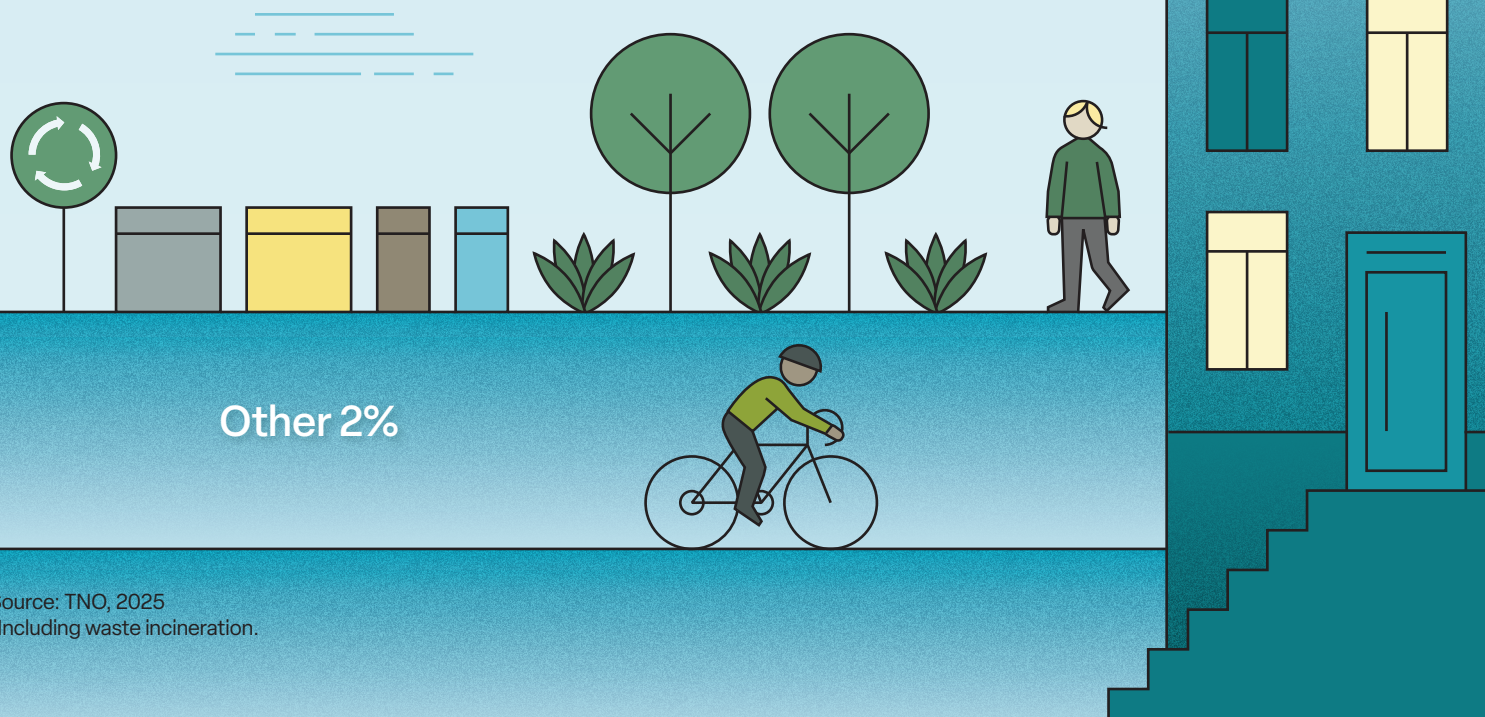


Power of cities

From hotspots to innovators

Cities emit a large amount of greenhouse gases, but they also hold significant potential to mitigate the climate crisis. While national governments set ambitious climate targets, cities are where policies turn into tangible action.

By Anna Gumbau and Charlotta Henry
Illustration Bassi Mattsson



Key takeaways

- **Cities turn policy into action.** While national governments set broad climate targets, cities are where policies become tangible solutions, influencing infrastructure and citizen behavior.
- **Cities are hubs for effective change.** Their concentration of people and resources allows for the efficient implementation of sustainable solutions, which can drastically reduce per capita emissions.
- **Data is crucial for success.** To ensure their investments are effective, cities must use accurate data to monitor emissions and track progress.

The world is rapidly urbanising, with nearly 70% of the global population expected to live in cities by 2050. Despite covering only 3% of Earth's land, urban areas are significant contributors to climate change, consuming over 75% of global resources and generating up to two-thirds of global carbon dioxide emissions, according to the UN's Intergovernmental Panel on Climate Change (IPCC).

"Accelerating decarbonisation in cities is crucial because they concentrate population, economic activities, and infrastructure that can either lock us into high-carbon pathways or lead the transition to sustainability," explains Professor **Bart van den Hurk**, Co-Chair of Working Group II on impacts, adaptation, and vulnerability at the IPCC.

Mitigation and adaptation, he notes, can and should go hand-in-hand, and cities can achieve this by changing their infrastructure and governance as well as supporting behavioural shifts.

Cities are also critical actors in sustainable transformation; while national governments establish broad climate targets and policy, the real impact often stems from implementation at the urban level.

"Cities can be powerful influencers – they have control over their own operations and infrastructure services," says Professor **Kevin Gurney**, an atmospheric scientist, ecologist, and policy expert at the Northern Arizona University.

He adds that, due to the concentration of people, cities are where "a lot of social norms can be developed – and behaviour and social norms are a big piece of the puzzle".

Emilio Servera, Project Officer at València Clima i Energia, Spain, agrees: "Local authorities engage directly with citizens. We are the first point of contact, we understand our citizens' needs better than other levels of government, and that makes it easier to implement climate projects."

In this way, cities can become innovation hubs with the potential to lead climate action. Many are already demonstrating this and making significant strides towards decarbonisation by investing in renewable energy, improving public transport, adopting green building standards, and working on green urban planning.

If scaled up, these efforts could play a pivotal role in decreasing emissions even as urban populations continue to grow.

Climate-smart growth and resource efficiency

With more than 2.5 billion people living in urban areas by 2050, a significant increase in greenhouse gas emissions is expected due to higher energy consumption, increased transportation, new building construction, greater waste generation, and expanded industrial activity.

One significant hurdle for megacities – those sprawling urban centres with populations exceeding 10 million – is the phenomenon of 'emissions lock-in'. Once infrastructure decisions are made, they become incredibly difficult and costly to reverse, effectively cementing a city's carbon footprint for decades.

“

Cities can be powerful influencers – they have control over their own operations and infrastructure services.

Professor Kevin Gurney

However, rapidly expanding urban areas stand at a unique crossroads, possessing the crucial opportunity to embrace sustainable practices and infrastructure.

On a global level, medium-sized cities are projected to see the most growth. This is where Professor Gurney sees the greatest potential for climate-smart solutions:

Influential city networks

Organisations like **ICLEI – Local Governments for Sustainability** and **Eurocities** facilitate crucial knowledge sharing and peer-learning between cities.

The following organisations also empower cities in the transition to a sustainable and climate-resilient future:

- ▶ **The EU Covenant of Mayors:** A large-scale initiative that brings together thousands of local and regional authorities across Europe to voluntarily commit to tackling climate change.
- ▶ **C40 cities:** A global network of mayors from cities around the world leading efforts to tackle the climate crisis.
- ▶ **EU Mission Climate-Neutral and Smart Cities:** Originally, 112 pioneering cities were selected to achieve climate neutrality by 2030, acting as innovation hubs for broader urban transformation. As of today, 377 cities from all 27 EU member states have submitted an expression of interest.
- ▶ **Green City Accord:** European mayors are actively participating in this EU initiative, committing to cleaner, healthier, and greener cities.
- ▶ **WWF One Planet City Challenge:** WWF engages with cities worldwide, guiding them to set and achieve ambitious climate targets, while promoting best practices and citizen engagement.

“Cities that are on the cusp of growing a lot have the opportunity to grow differently, unlike megacities that have really gotten to the point of emissions lock-in. That’s where the biggest opportunities are. The medium-sized cities can take a very different path.”

For instance, compact, walkable cities with good public transport systems have been shown to reduce per capita emissions compared to sprawling, car-dependent cities that lead to high-carbon lifestyles.

However, emissions can still be high in compact cities if the energy supply is fossil-based or if consumption patterns are resource-intensive, which shows the need for a holistic approach that addresses all sectors.

Biggest emission sources: transport and housing

The housing sector accounts for approximately 31% of global CO₂ emissions when considering direct emissions, according to the IPCC. Transport is another significant contributor, responsible for about 15% of human-induced global greenhouse gas emissions.

Emissions vary widely, depending on factors like wealth and citizens’ attitudes towards individual versus public transport.

“Many cities lack strong public transport networks, making residents dependent on cars,” says Dr **Felix Vogel**, Research Scientist at the Environment and Climate Change Canada and a member of the ICOS Cities Scientific Advisory Board.

Meanwhile, cities like Paris, London and New York developed subway systems early on, allowing mobility without cars. Cities are also investing in low-emission zones that restrict access for high-emission vehicles, alongside measures to expand cycling and pedestrian networks to cut transport emissions and improve urban resilience.

The concentration of people, money, and infrastructure makes cities the best place to implement resource-efficient systems, including to address sectors with larger emissions, such as buildings.

“Cities are usually more energy-efficient per capita than rural areas. For example, high-rise buildings with centralised heating and cooling systems are much more energy-efficient than single-family homes in the countryside,” Dr Vogel explains.

Indeed, compact, well-planned cities can drastically reduce per capita emissions, according to the IPCC. Public transport investments, for instance, can cut per capita transport emissions by more than half

We need daring cities with daring leaders

While national policies remain critical, local governments are stepping up with ambitious climate targets and innovative solutions. To reverse the trend of rising emissions, daring city leadership is needed.

“We now need daring cities with daring leaders, brave leaders. Our local governments have been setting targets on climate way before the national governments have done so,” says **Maryke van Staden**, Director at the Carbons Climate Center, ICLEI.

“We see the sub-national governments as leaders in this space. They have helped push to improve national policies that enable action at the local level,” she adds.

This proactive stance is backed by **Miranda Schreurs**, Professor, Environment and Climate Policy, at the Technical University of Munich and the leader of the ICOS Cities project’s climate policy team.

“A large number of cities have established climate neutrality plans that are well ahead of national targets. These were often adopted after local governments were pressured by their citizens to do more,” she says.

However, while cities are critical for implementation, national policies play a crucial role in enabling or

compared to car-dependent cities, reports the Institute for Transportation and Development Policy.

In addition to climate benefits, reducing urban emissions can also improve residents' well-being. One notable co-benefit is the reduction of air pollution, which is a major health concern in many cities.

By transitioning to cleaner energy sources and improving urban mobility, cities can significantly cut emissions of pollutants, directly improving air quality and benefiting citizens' health.

Why monitoring urban emissions is critical

As cities strive to reach their climate targets and reduce their impact on the planet, accurate monitoring of emissions is crucial.

"We need to know what's working and what isn't. Cities need solid information, with granular and sectoral details to help them prioritise," says Professor Gurney.

He adds that, while the general steps to lower emissions are known, efficiency is crucial. Cities need to know where, when, and how emissions are occurring to decide the best opportunities for mitigation.

hindering this as local governments do not have jurisdictional competence in all areas, Professor Schreurs explains. This makes national policy frameworks vital.

"National governments can shape policy expectations, mandate policy action, affect energy prices, and influence investment decisions. National governments also need to provide the financial and technical support that cities need for project implementation," she adds.

Van Staden also highlights the importance of enshrining strategic public sustainable procurement in national policy to drive local action.

"This is an enabling factor that can allow the local government in its whole operations to choose services and goods that are the cleanest, greenest, and with the least impact in terms of emissions." ●

“

Many cities lack strong public transport networks, making residents dependent on cars.

"The point is that, when a city decides to spend money on mitigation, it's not a question of what the big categories are – it's more that the actions have to be efficient," he explains.

Alongside helping with the initial prioritisation of mitigation actions, monitoring provides invaluable feedback and helps cities plan for future low-carbon development.

"Once we have enacted a policy, the second phase is tracking it over time. The sooner I know that it's not working, or it is working, the better off I am, I can change course. If it's working just as I thought, I can then reproduce that elsewhere. That feedback loop is crucial," Professor Gurney concludes. ●

“

A large number of cities have established climate-neutrality plans that are well ahead of national targets.

Professor Miranda Schreurs

Global trends in urban emissions reduction

Urban emission trends vary dramatically across the globe and are influenced by three important factors:

1. Policy & migration

“Globally, city emissions are still going up,” notes Professor **Kevin Gurney**. “But what is really happening is that the US emission curve is functionally flat, not rising or falling, and Europe has been going down in urban emissions.”

He largely attributes Europe’s downward emission trend to its proactive and forward-looking policy framework, saying that he thinks cities have followed decarbonisation policies very eagerly.

In contrast, Professor Gurney highlights a different trajectory in rapidly developing regions: “In India, China, South Asia, a lot of the emerging economies, urban emissions are still growing.”

The primary cause is not a lack of decarbonisation policies but a steady migration flow to cities. Even with stable or even slightly decreasing per capita emissions the urban emissions would still rise in these regions.

2. Trade

Cities typically ‘outsource’ significant amounts of greenhouse gas emissions to the regions that manufacture their building materials, vehicles, food, and consumer products.

“There’s a lot of carbon leakage where many European and US cities are becoming fundamentally consumerist cities, and they’re consuming from Asia. These regions now have become the sort of ‘production cities’ where emissions go up quicker,” Professor Gurney explains.

Consequently, most European and US cities have a larger carbon footprint than their local, territorial emissions would suggest.

“Even though much of the energy is consumed in cities, not all emissions occur within city boundaries.

Also, a lot of energy production happens outside urban centres, in power plants,” says Professor **Dominik Brunner** at Empa, Swiss Federal Laboratories for Materials Science and Technology.

If cities don’t consider emissions from the goods they consume or from activities outside their borders, they will significantly underestimate their climate impact, disregarding up to 41% of their emissions.¹ By taking into account both direct and indirect emissions, cities can tailor their mitigation strategies to be most effective for their particular city and emissions profile.

3. Population growth

Another critical challenge lies in the demography of developing economies, especially in Africa, where emissions are increasing faster than population growth. While rising emissions are partly driven by Africa’s rapidly growing population, they also stems from escalating energy demand, a continued reliance on fossil fuels, and an increase in private vehicle usage due to poor-quality or lacking public transport.

However, it is also an opportunity for global cooperation. As Professor Brunner argues: “we should do everything possible to help developing regions implement low-emission technologies now before their urban expansion locks them into high-carbon systems”. ●

1 IPCC Sixth Assessment Report

“

Even though much of the energy is consumed in cities, not all emissions occur within city boundaries.

Professor Dominik Brunner

City-to-city insights

Cities have unique strengths and resources for climate action.

By Charlotta Henry

1 What unique strengths or resources do cities have for climate action compared to national governments?

2 What kind of external support would help your city improve climate action planning?



Alejandro Gómez

Coordinator of European Projects and Urban Strategies
Valencia Clima i Energia, Spain

1 Local authorities have more direct contact with citizens and small businesses than other levels of government. Being in close proximity to the daily lives of people allows cities to address climate challenges, while ensuring a positive impact for all, including vulnerable groups.

2 The municipality needs human resources and capacity building. There is also a need for support to develop schemes that mobilise and align the funding, commitments, and decarbonisation projects of the private sector, academia, and civil society.



Dieter Müller

Head of Climate and Environmental Strategy
City of Zurich, Switzerland

1 Within their limited authority, cities can set and achieve more ambitious targets and invest in pilot actions, from which other cities can profit.

2 For action plans, it is always advantageous if the city, canton, and state are on a similar path. City-wide, Switzerland-wide, Europe-wide, or global networking can help to further consolidate our climate action planning.



Hanna Wesslin

Climate Director
City of Helsinki, Finland

1 Cities can act more quickly and flexibly than national governments, adapting policies to local needs. Many cities also own their own energy companies, giving them direct leverage over decarbonisation and renewable energy choices. When it comes to climate adaptation, challenges such as heatwaves, flooding, and urban planning are inherently local, making cities the most effective actors.

2 We need technical expertise and modelling tools to better forecast the impacts of different mitigation and adaptation policy scenarios, tailored to Helsinki's topography, building stock, transport systems, and climate risks (flooding, heat, sea-level rise).

Citizens count on local action

Inhabitants of Paris and Munich have more faith in local authorities than in national governments when it comes to climate action.

By Charlotta Henry



Key takeaways

- **Analysis of people's views on climate change.** A recent study by the European Social Survey investigated residents' views on climate change and their opinions on city policies.
- **Residents trust local authorities to implement climate action.** There is a bigger trust in municipalities than national governments.
- **Public support is strong.** A majority of city residents believe climate change is human-caused and support climate policies.

Cities are important players in mitigating climate change, so understanding the public's perception and support for climate action is paramount for policymakers. A survey,

conducted between 2023 and 2024 as part of the ICOS Cities project, shows that Paris and Munich residents put much more hope in their local authorities to mitigate climate change than they do in companies or their national government.

"The respondents seem to believe that local governments are the most likely to take action on climate change since many environmental public policies are implemented at the city or municipal level. The residents are also aware of how these policies affect their day-to-day lives and, therefore, hold more confidence in their municipalities when it comes to environmental action," explains Dr **Diana Zavala-Rojas**, Deputy Director (External relations) at the European Social Survey European Research Infrastructure Consortium (ESS ERIC).

This should "encourage local policymakers to continue taking action against climate change and putting more ambitious policies in place," she adds.

“

The survey shows that most residents are ready to make efforts to minimise their environmental footprint.

Dr Diana Zavala-Rojas

Read more about the survey on pages 16–17

tures soar above 40°C in many European cities. An overwhelming majority of respondents – 83% in Paris and 75% in Munich – reported experiencing higher summer temperatures, which underscores climate change’s direct and tangible impact on urban populations.

This public understanding and support provides fertile ground for ambitious climate action. Dr Zavala-Rojas believes the survey results can empower local climate actors to “show that most residents are ready to make efforts to minimise their environmental footprint”.

In fact, this is already taking place: In Munich, respondents indicated that they walk (46%) or cycle (37%) more for short journeys than they used to. Meanwhile, 40% say that they have reduced their household energy consumption.

Higher temperatures bring climate change close to home

The survey shows that a striking 76% of Paris and Munich respondents believe climate change is caused by humans, a significantly higher number than the 49% national average for Germany and 56% for France.

Agustin Blanco, Researcher at ESS ERIC, attributes this difference to an urban/rural divide in public opinion where city respondents tend to hold different values in comparison to rural residents.

The survey also shows an appetite for action from policymakers, says Dr Zavala-Rojas:

“Not only do a majority of respondents believe that climate change is caused by humans, but broad support also exists for environmental public policies aimed at limiting its impacts.”

This widespread consensus likely stems from increasingly palpable experiences, such as the intense heatwaves in 2019, 2022, and 2025, which saw tempera-

Raising taxes reduces green policy support

Another takeaway from the research is that public support fades when green policy starts hitting people’s wallets.

This was seen in responses to questions regarding subsidies for renewable energy and electric car purchases, underscoring the sensitivity of public opinion to the economic costs of climate policies.

Public support for certain policies also varied between the two cities. More respondents in Munich use cars compared to those in Paris, which translated to slightly less support in the German city for policies like banning fossil fuel cars by 2030 and low emission zones.

“A majority of residents in both cities support increasing taxes on fossil fuels,” says Dr Zavala-Roja. This is more pronounced in Paris, especially in policies that could affect private cars, she adds. ●

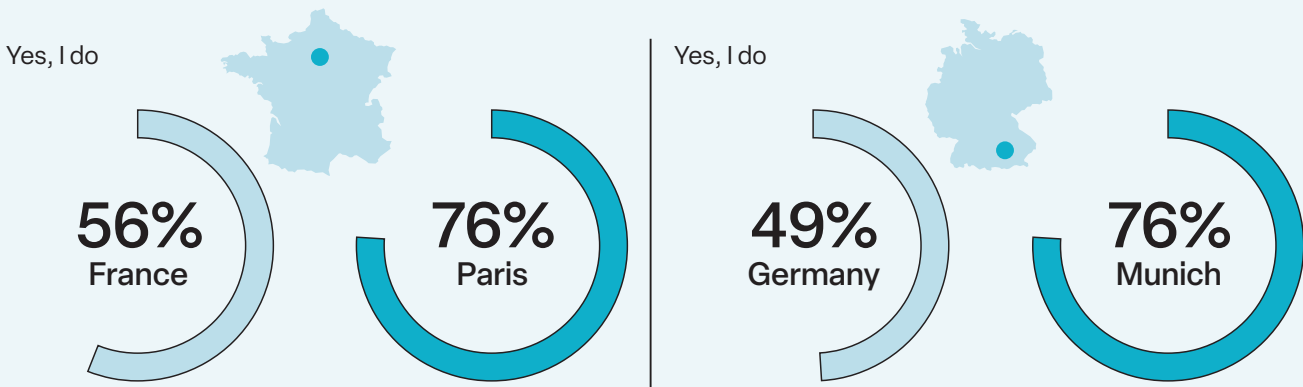
Paris and Munich

Residents’ views on
climate change and city
climate policies

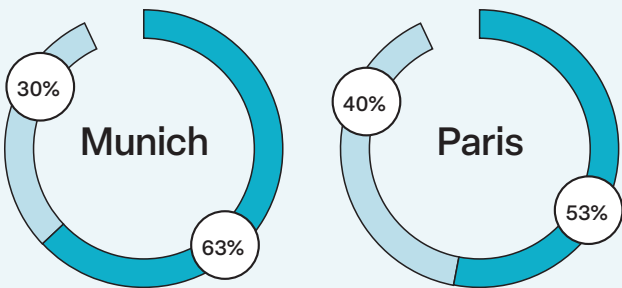
Read more
about the
survey on
page 14–15

The ICOS Cities panel survey was conducted in Munich and Paris in 2023 and 2024 by the European Social Survey, to explore residents’ views on climate change and their opinions on city policies. The survey had more than 1,000 respondents in Munich and more than 700 in Paris.

Do you think that climate change is caused entirely or mainly by human activity?

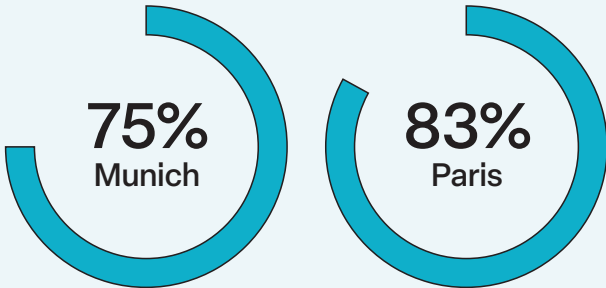


How worried are you about
climate change?



somewhat worried extremely or very worried

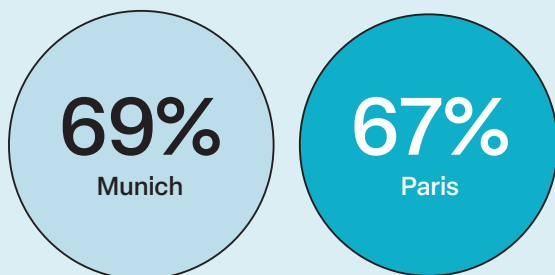
Have you experienced hotter
summers than before?



Yes, I have

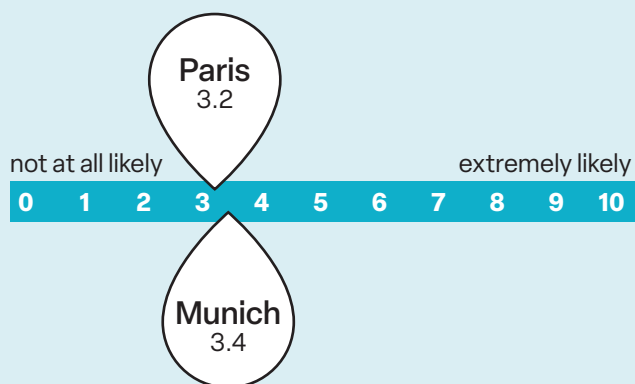
Are you for or against a low emission zone in your city?

strongly or somewhat for

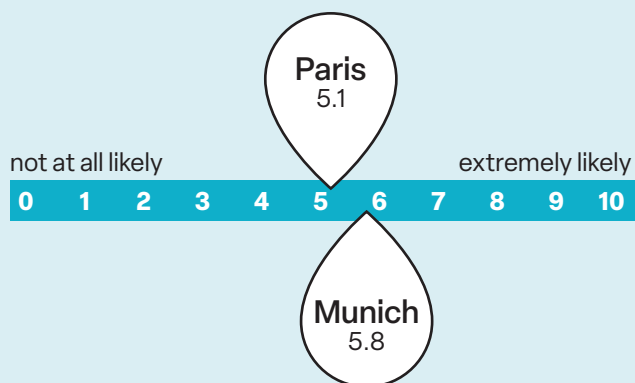


Who is more likely to take action to reduce climate change?

National governments

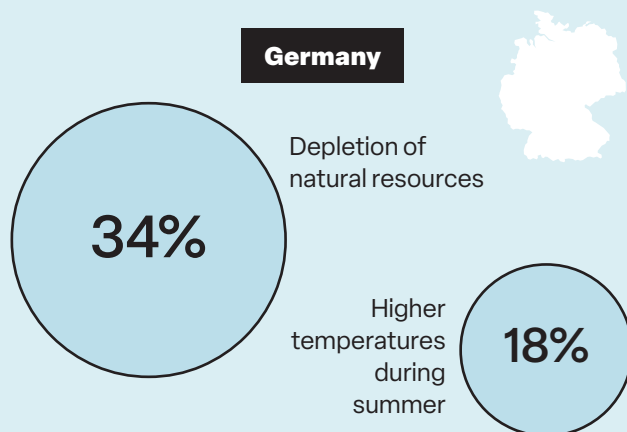


Municipalities

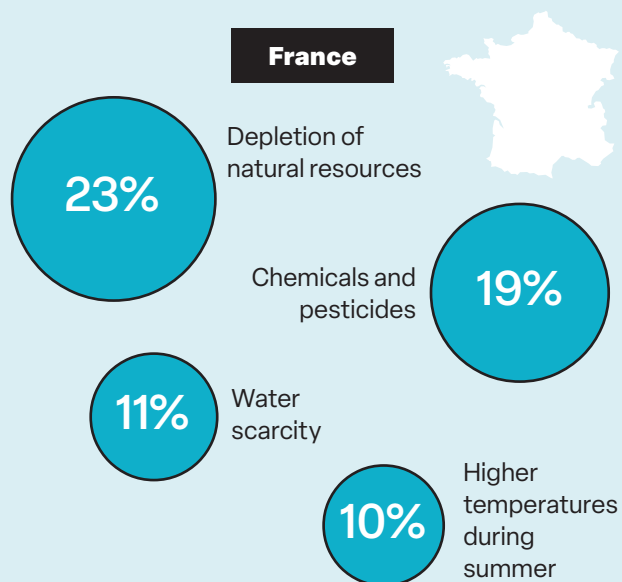


Which environmental problem do you consider to be the worst?

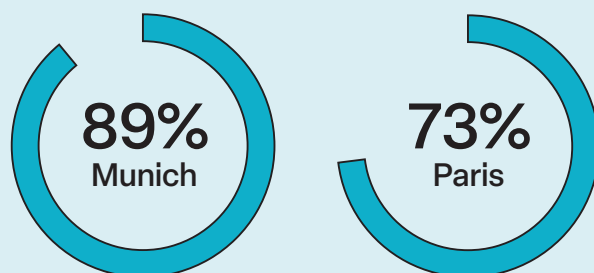
Germany



France



Are you strongly or somewhat in favour of using public money to subsidise renewable energy?





Climate risks in cities

Valencia under threat

Cities worldwide are increasingly vulnerable to a range of climate hazards. Many already face severe impacts, with threats such as flooding, extreme heat, drought, and wildfires becoming more frequent.

By Anna Gumbau and Charlotta Henry

Key takeaways

- ▶ **Immediate climate threats are a reality.** Many cities worldwide are already experiencing severe climate impacts.
- ▶ **Valencia is taking action.** The city is actively working on both mitigation and adaptation, with ongoing projects to reduce emissions and prepare for future climate challenges.
- ▶ **Long-term challenges remain.** Coastal cities like Valencia face significant, complex, long-term risks, particularly from sea level rise.

Extrême weather events, including storms, heatwaves, and flooding have caused up to 145,000 deaths in Europe over the past 40 years, with extreme heat accounting for over 85% of fatalities, according to the European Environment Agency. In the same period, economic losses from climate disasters have reached nearly 500 billion euros.

Valencia, a coastal city in Spain, is one of the cities facing rising sea levels, extreme heat, and intensifying storms. In 2024, a prolonged drought strained water supplies and increased wildfire risks. Later that same year, severe floods devastated parts of the province.

“This is not about projections anymore, but a matter of actually observing the impacts,” says **Emilio Servera**, European Projects Officer at València Clima i Energia, a public foundation implementing climate mitigation and adaptation projects.

“

This is not about projections anymore, but a matter of actually observing the impacts.

Emilio Servera, Valencia

Photo: Associated press

In the past few years, Valencia has seen more and more heatwaves, ‘tropical nights’, and droughts. In 2023, temperatures hit a record high of 44.5°C.

Active mitigation and adaptation work

Valencia has been actively working on climate change mitigation for decades. Its yearly emissions inventories show that approximately 35–45% of its greenhouse gas emissions come from the mobility sector, followed by electricity consumption, and natural gas in residential and tertiary buildings.

“Based on that diagnosis, Valencia has committed to advance towards climate-neutrality within its Climate Mission Valencia 2030. A series of ambitious projects are being implemented in domains such as mobility, energy, urban planning, housing, sustainable tourism, and re-naturalisation,” says **Alejandro Gómez**, Coordi-

In 2024, the province of Valencia in eastern Spain experienced catastrophic flash floods. The storm delivered over a year’s worth of rain in just a few hours, leading to widespread flooding across the region.

nator of European Projects and Urban Strategies, at Valencia Clima i Energia.

In recent years, the city has also doubled down on its adaptation efforts, including expanding green areas, creating urban green spaces to combat heat island effects, and increasing urban tree canopy to provide shade and improve air quality.

Alongside this, the city has implemented water conservation measures and invested in infrastructure to manage stormwater and prevent flooding. This infrastructure helps to mitigate the immediate consequences of climate change while also providing long-term benefits for both residents and the environment.

Future risks

Coastal cities like Valencia face looming long-term challenges, such as sea level rise. This increases the risk of coastal erosion, flooding, and saltwater intrusion, threatening infrastructure, freshwater supplies, and biodiversity.

In turn, these could lead to significant economic costs, the displacement of populations, and disruptions to tourism. This highlights the urgent need for adaptive measures in vulnerable coastal cities.

“Adaptation to sea level rise is a huge challenge which we are currently putting aside as we are not clear on what exactly needs to be done. This is clearly a long-term challenge that cities like ours will need to tackle by setting up robust adaptation measures,” says Servera.

Without adaptation, the vast majority of low-lying islands, coasts, and communities face substantial risk from these hazards. To mitigate these challenges, cities are implementing various adaptation strategies, such as building coastal defences, restoring natural barriers, improving drainage systems, and implementing spatial land use strategies, according to the IPCC. ●

Decarbonising cities

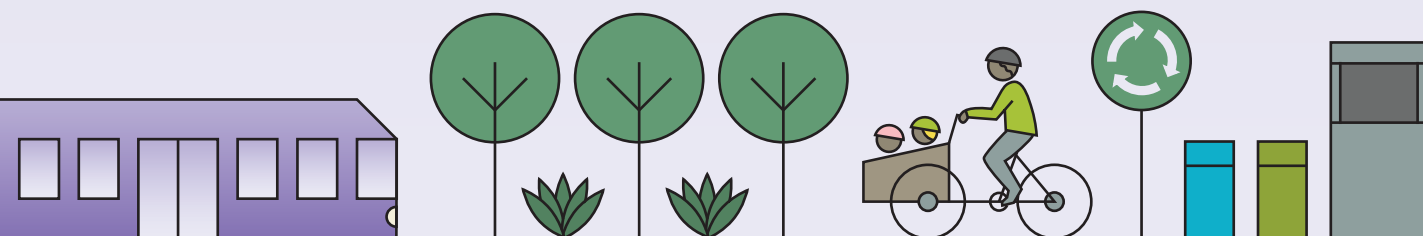
On the path to urban decarbonisation

Decarbonising cities is not just about reducing emissions: it is about building healthier communities, robust economies, and increasing climate resilience. This requires a fundamental reimagining of urban planning, transport, energy systems, and green spaces.

By Kira Taylor
Illustrations Bassi Mattsson

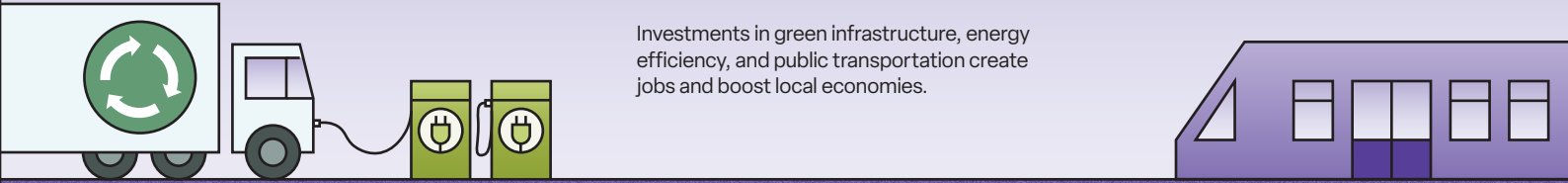
Why decarbonise cities?

Urban areas are major sources of greenhouse gas emissions. Reducing their reliance on fossil fuels and choosing sustainable solutions not only addresses this but also brings many other benefits for cities.



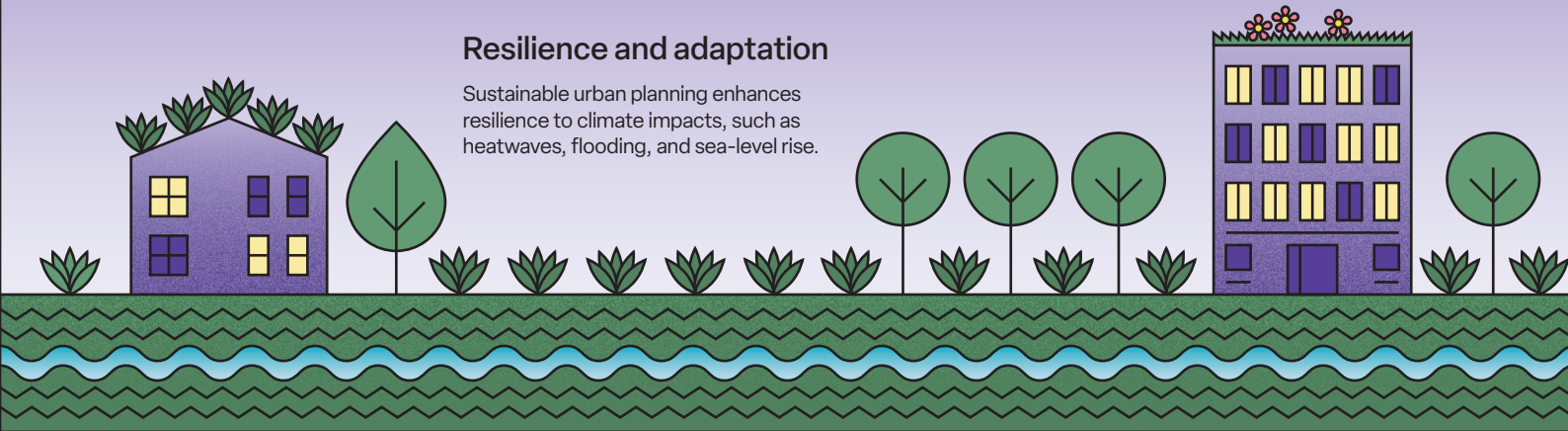
Economic benefits

Investments in green infrastructure, energy efficiency, and public transportation create jobs and boost local economies.



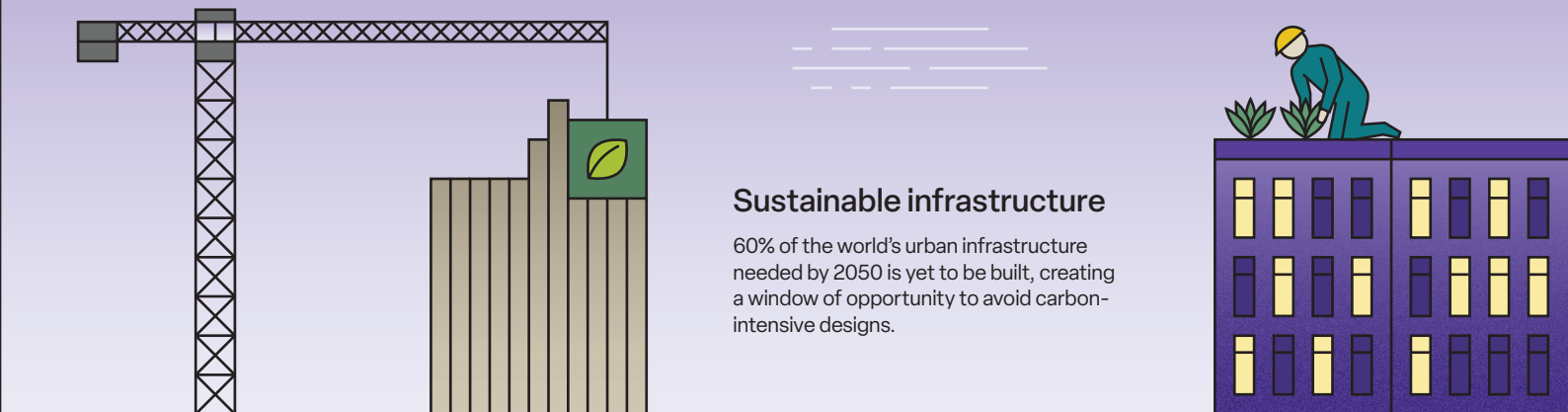
Resilience and adaptation

Sustainable urban planning enhances resilience to climate impacts, such as heatwaves, flooding, and sea-level rise.



Sustainable infrastructure

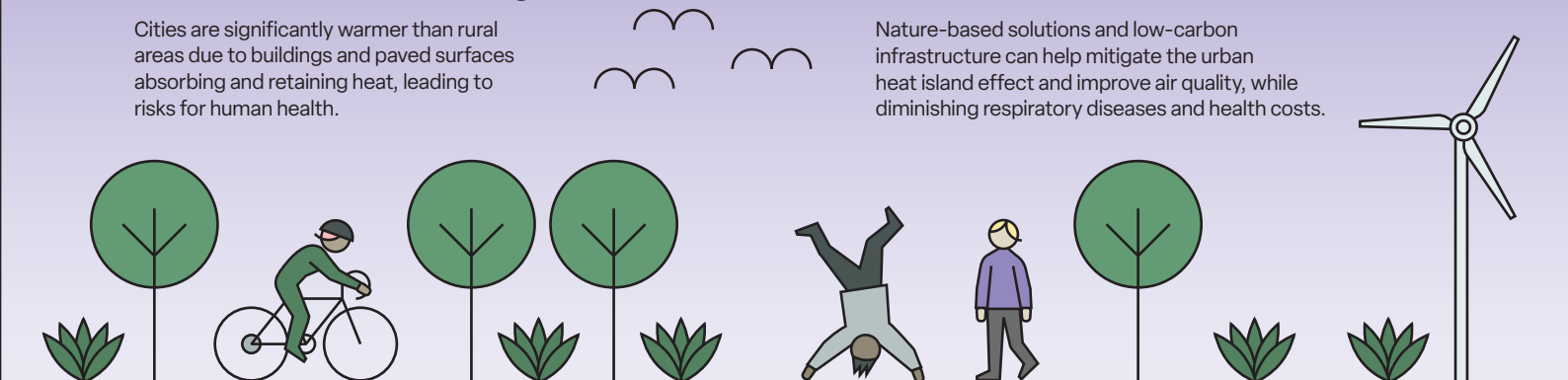
60% of the world's urban infrastructure needed by 2050 is yet to be built, creating a window of opportunity to avoid carbon-intensive designs.



Public health and well-being

Cities are significantly warmer than rural areas due to buildings and paved surfaces absorbing and retaining heat, leading to risks for human health.

Nature-based solutions and low-carbon infrastructure can help mitigate the urban heat island effect and improve air quality, while diminishing respiratory diseases and health costs.



Key takeaways

- **Urban decarbonisation brings many benefits.** Decarbonising cities is not only about cutting emissions, but also improving public health, strengthening economies, and building climate resilience.
- **Effective decarbonisation requires a holistic approach.** Cities must integrate solutions across key sectors, including transport, buildings, and green spaces, to achieve their climate goals.
- **Policy, finance, and public engagement are crucial for success.** While many solutions are available, implementing them requires strong political will, smart funding, and citizen buy-in.

Cities are hotspots for emissions, making urban climate action critical to meet the European Union’s goal of cutting net emissions by 55% by 2030 and reaching climate neutrality by 2050.

Many EU cities are taking steps to become more sustainable places to live and work, with city authorities producing climate action plans to chart a path to climate neutrality and build their resilience to global warming.

These plans aim to keep cities on track with the global goal to limit warming to 1.5°C above pre-industrial levels. They underscore the need for rapid change, particularly in wealthy cities.

“Achieving climate goals requires integrated urban planning, sustainable transport, energy efficiency, and nature-based solutions, all supported by strong governance and finance mechanisms,” says Professor **Bart van den Hurk**, Co-Chair at the IPCC Working Group II on impacts, adaptation, and vulnerability.

Decarbonising transport

Beyond simply getting people from A to B, efficient and accessible transport systems are fundamental enablers of freedom, opportunity, and connection. Improving access to sustainable mobility not only reduces the carbon emissions of a city but also improves public health and wellbeing by decreasing air pollution.

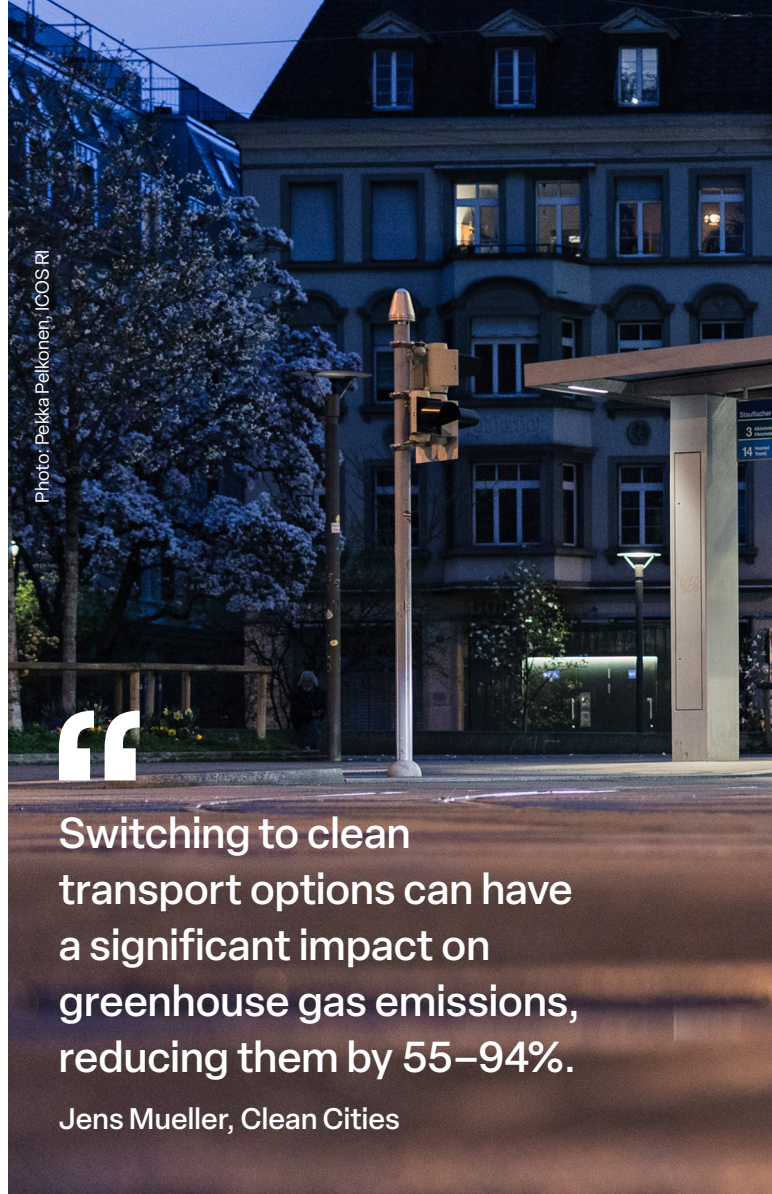


Photo: Pekka Pellkonen, iCOS RI

“Switching to clean transport options can have a significant impact on greenhouse gas emissions, reducing them by 55–94%.

Jens Mueller, Clean Cities

“Switching to clean transport options can have a significant impact on greenhouse gas emissions, reducing them by 55% to 94% with policies and technologies that are already available,” says **Jens Mueller**, Deputy Director at Clean Cities, who worked on a study¹ that modelled policy scenarios in Brussels, Madrid, Greater Manchester, Milan, and Warsaw.

Measures include improving public transport, switching to low-carbon fuels, increasing cycle lanes and pedestrian zones, and discouraging people from using private cars, particularly those running on fossil fuels.

To ensure its transport sector is zero-emission by 2030, Amsterdam is combining vehicle electrification with cycling, public transport, low-emission zones for diesel vehicles, and zero-emission zones for vans, lorries, mopeds, and scooters.

¹ Clean Cities: (E)Mission Zero: Towards zero-emission mobility in European cities, 2024



Meanwhile, Oslo aims to have a zero-emission public transport system by 2028 and has redesigned its city centre for walking and cycling. London has expanded its ultra-low emission zones, which discourages the most polluting vehicles from entering the city, and Paris has introduced low-emission zones, pedestrianised major roads along the Seine, and expanded cycling infrastructure.

“These measures are replicable with the right political will, investment, and public engagement. Success very much depends on tailoring policies to local conditions and ensuring public transport and active travel alternatives are accessible,” says Mueller.

The effectiveness of different policies varies between cities. Northern European cities have made rapid progress by prioritising a shift to cycling and public transport, while Southern and Eastern European cities often have higher car dependency, making measures like public transport electrification, bus lanes, and

low-emission zones more important, Mueller adds.

“Investments in walking and cycling infrastructure can deliver rapid change at limited costs in almost any city, as demonstrated by cities like Barcelona, Ljubljana, or Wrocław,” he says.

Decarbonising transport is not just key to reducing urban emissions and improving health, but also for ensuring compliance with progressively tightening EU regulations in this sector. For example, the EU plans to phase out sales of new combustion engine cars by 2035 and will introduce a carbon price on road transport fuel in 2027, which is likely to increase the cost of petrol and diesel for consumers.

Reducing emissions from buildings

Another significant source of urban emissions is the construction and energy consumption of buildings.

More than 85%² of Europe's existing building stock is likely to still be in use in 2050, the deadline for the EU to achieve climate neutrality. However, almost 75% of Europe's buildings are energy inefficient and the share of renewables in heating and cooling was only 26% in 2023.³ Fossil fuels still dominate household heating and are expected to remain a large part of it up to 2030 and potentially beyond.⁴

A major renovation drive is required to improve energy efficiency, decarbonise heating and cooling systems, and prepare buildings for future heat stress or flooding.

The type of work required depends on the city's climate and building stock. For example, to address its ageing, inefficient building stock, the Estonian capital of Tallinn has started a renovation project to revamp apartment buildings and create inclusive, sustainable spaces, like courtyards. Its city-owned buildings are also transitioning to local, clean, and efficient district heating, which will be expanded to include apartment buildings.

In Italy, Milan is developing a social housing project that aims to be zero-carbon by 2050. It will include buildings that use energy, heating, and cooling from renewable sources. The project also aims to have 60% of the surrounding area designated as green space and an emphasis on green mobility, including a 1,200 m² bike garage, 10 electric car charging terminals, and a shared neighbourhood car fleet.

Meanwhile, the Hungarian city of Szeged is taking advantage of the country's abundant geothermal resources by switching its gas-fuelled district heating system to this renewable energy source. Szetav, the city's district heating provider, and currently the largest local CO₂ emitter, estimates the switch could reduce its emissions by 60%.

EU legislation is being implemented to support building decarbonisation. For example, under the EU's energy efficiency law, public buildings are required to undergo renovation at a rate of 3% per year. Municipalities with over 45,000 inhabitants must also prepare local heating and cooling plans. Meanwhile, a new EU law on buildings requires countries to renovate the 16% worst-performing buildings by 2030.

The EU additionally plans to introduce carbon pricing for building heating in 2027 and to phase out

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Almost 75% of Europe's buildings are energy inefficient and the share of renewables in heating and cooling was only 26% in 2023.

Eurostat 2025

fossil fuel boilers by 2040, which makes cities's decarbonisation efforts essential.

Nature as part of the solution

Green urban areas, including parks, forests, and gardens, have wide-ranging benefits for cities, including carbon sequestration, temperature regulation, improved well-being, and habitats for biodiversity. Less research has been conducted on the impact of blue urban areas, such as rivers and lakes, but these can also help capture carbon,⁵ improve flood resilience, and regulate temperatures.⁶

“On a city level, green areas take up 4-10% of urban emissions and this is likely to increase as human-caused emissions reduce,” says Professor **Leena Järvi** at the University of Helsinki.

Professor Järvi's research shows that all green areas matter. For example, in Nordic cities, urban lawns are likely to absorb between 30-50% of what a boreal forest would.

“Traditionally, people think that urban forests are those places where carbon sequestration takes place. However, our research shows that actually the built vegetation, so street trees, lawns, or any kind of green area, is also important in absorbing CO₂,” says Professor Järvi.

Preserving existing green spaces should also be a core focus as it can take time for new ones to reach a point where they act as a carbon sink, she says.

5 Nordic Council of Ministers: Enhancing Carbon Storage through Green and Blue Infrastructure, 2024

6 L. Fricke, R. Legg, N. Kabisch: Impact of blue spaces on the urban microclimate in different climate zones, daytimes and seasons – A systematic review, Urban Forestry & Urban Greening, Vol 101, 2024.

2 European Environment Agency, 2024

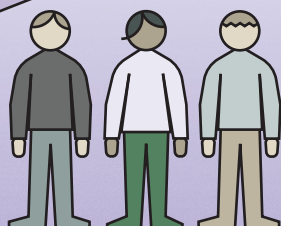
3 Eurostat, 2025

4 Statista, 2025

Effective policy frameworks for decarbonising cities

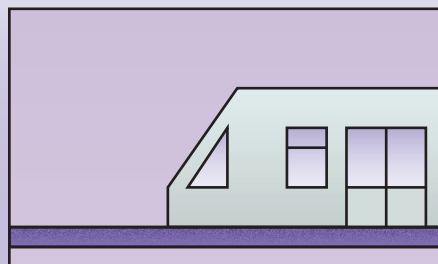


Financial instruments, such as green bonds and climate funds, to drive sustainable urban investments.

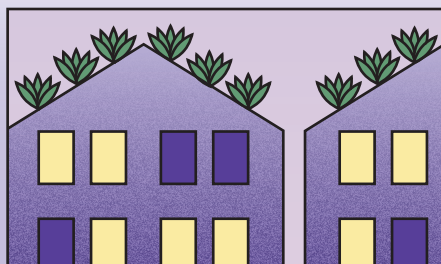


Participatory governance models that involve communities in policy design and implementation.

Public transport investment to reduce dependency on private vehicles.

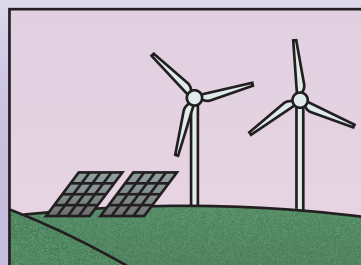
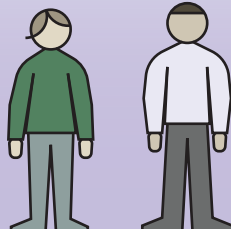


Support for private homeowners to increase efficiency and decarbonisation during renovations.



Sustainable urban planning to design cities with economic growth, social well-being, and a minimal environmental impact. Adopting green standards to improve energy efficiency in buildings.

Carbon pricing mechanisms to incentivise low-carbon solutions.



City Climate Action Plan

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Street trees, lawns, or any kind of green area, are also important in absorbing CO₂.

Professor Leena Järvi

Challenges also exist when it comes to fitting green areas into cities where space is already restricted.

“Limitations include space constraints in dense urban areas, high initial costs, and the need for long-term maintenance and governance frameworks to ensure effectiveness,” says Professor van den Hurk.

Another challenge is that green areas like gardens tend to be privately owned, limiting what local authorities can do. On top of this, what is considered an ‘ideal garden’ is not always the most beneficial for carbon sequestration and biodiversity.

“The current trend is that you have a beautiful, wide lawn and maybe a few trees. Messy looking green areas, which are probably best for taking up carbon dioxide, for biodiversity, and any of the co-benefits, are not seen as appealing,” says Professor Järvi, adding that this requires a mindset change and campaigns to promote the benefits of this style of garden.

Good planning is also needed, including considering what trees best suit a city and allowing sufficient space for roots and branches to avoid damaging infrastructure, like buildings and tram lines.

Cities will also need to work on this to comply with new EU laws. Under the Nature Restoration Law, EU countries must maintain or increase urban green space and canopy cover by 2030 unless existing coverage is already substantial. By 2031, they should

increase total national urban green space, including integrating this into buildings and infrastructure.

Challenges and opportunities ahead

Although climate action is urgently needed and has the potential to improve cities, implementing it is a challenging task. The European Commission’s Joint Research Centre warns of insufficient community engagement and low public awareness, alongside inconsistencies between local policies and national and EU strategies. There are also challenges around upscaling cleaner technologies and bridging regional disparities.

Professor Van den Hurk emphasises the importance of inclusiveness in the decarbonisation process:

“Equitable access requires policies that promote affordability, subsidies for low-income communities, open-access data platforms, and capacity-building programmes to enhance technology adoption in developing regions.”

Money is available for this, including direct funding through the EU’s Mission for Climate-Neutral and Smart Cities, the European Urban Initiative, and the EU’s LIFE programme. The European Investment Bank’s framework loans also help cities to boost clean energy and adapt to climate change. Alongside this, the bank runs an advisory platform to help adaptation in urban areas. ●

City-to-city insights

Many cities have innovative climate programmes to encourage behavioural changes.

By Charlotta Henry

1 Can you share one innovative policy or programme your city is using to cut emissions?

2 How is your city encouraging behavioural changes and what has been most effective?



Hanna Wesslin

Climate Director
City of Helsinki, Finland

1 Helsinki has introduced a binding whole-life carbon limit value for new residential apartment buildings. This ensures that at the planning stage, both the operational emissions and also the construction-related emissions are constrained.

2 One initiative is the 'Think Sustainably' service, which ranks local businesses like cafés, restaurants and shops by sustainability criteria, enabling customers to choose greener options. This both increases awareness and gives businesses incentives to improve.

Another effective tool has been the 'transport climate panel', where a randomly selected group of citizens weigh in on how to transition to zero-emission transport in a way that's fair and practical. This helps align policy with what people are actually willing and able to do.



Dieter Müller

Head of Climate and
Environmental Strategy
City of Zurich, Switzerland

1 The City of Zurich supports startups and non-profit organisations in implementing innovative approaches to climate protection with a programme called KlimUp. We also bring stakeholders together in the Klimaforum, a dialogue platform for businesses, experts, and city representatives to develop solutions for climate protection.

The City of Zurich is investing around 2.3 billion Swiss francs in the expansion of the renewable district heating supply to replace gas and oil heating systems.

2 Zurich offers citizens funding programmes for heating replacement, operational optimisation, and energy-efficient building renovations. For companies and institutions, we have a toolbox for reducing emissions, such as those from flights.



Barbora Volánková

Project Manager
Environmental Department of
Brno city, Czech Republic

1 We have subsidy programmes for residents or companies to support green measures. We give support for building green roofs, greening courtyards, using public transport, and so on. We also offer environmental education and awareness for schools.

2 We organise local energy and climate days, such as the 'Earth Day' and 'Let the climate in Brno be great'. We cooperate with local companies and organise events to support sustainable measures, e.g., events dedicated to energy saving, Environmental, Social, and Governance issues, or carbon storage in wooden buildings.

The benefits of natural infrastructure

Nature-based solutions are crucial for cities to achieve their carbon neutrality targets, but the effectiveness depends on careful integration into city planning.

By Kira Taylor • Illustration Bassi Mattsson

City planning is an immensely complex task, and in every city, there are different economic, geographic, cultural, and political challenges to be considered.

Nature-based solutions are often considered ‘a nice-to-have’ and used as an add-on to other climate action strategies.

However, nature-based solutions can actually be very effective in reducing net emissions when implemented correctly, according to a recent, award-winning scientific study.¹

“Cities can quantify the impact of nature-based solutions on reducing greenhouse gas emissions and identify the locations where different types of nature-based solutions would be most effective,” says the scientific team lead, Professor **Zahra Kalantari** at KTH, the Swedish Royal Institute of Technology.

Quantifying benefits in this way is an important step in integrating nature-based solutions into climate plans, particularly as

it can help secure policy backing and economic support.

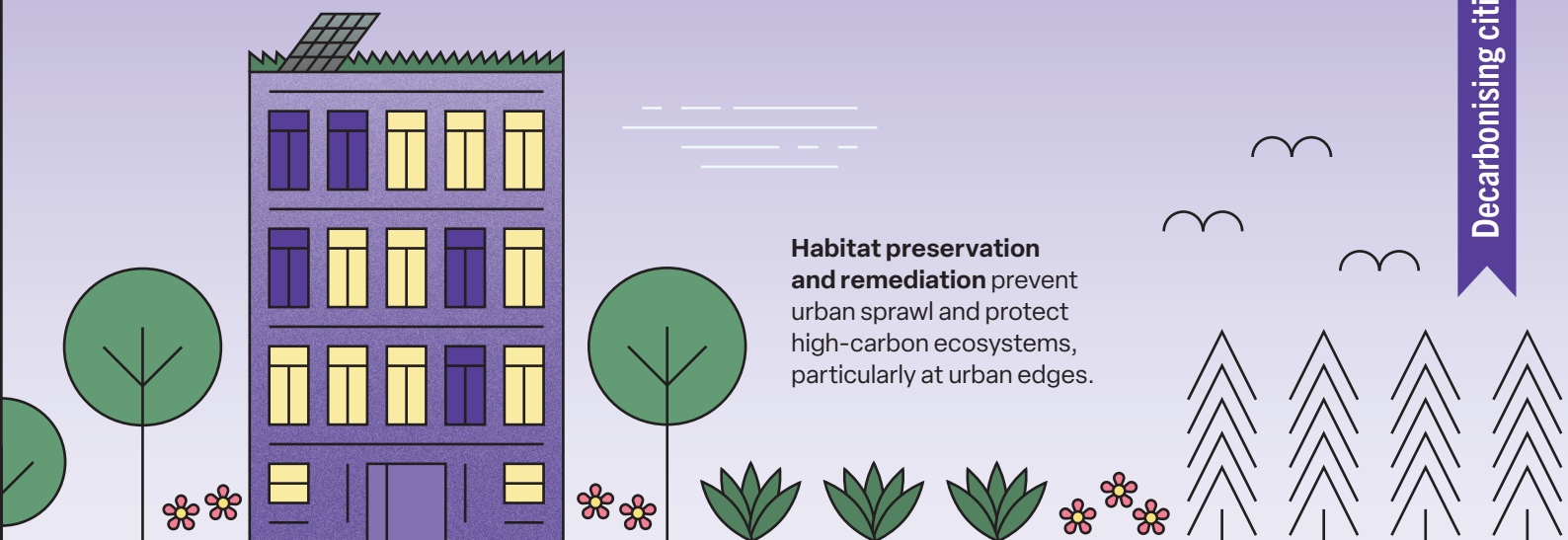
It is very important to involve a multi-disciplinary team of experts when designing nature-based solutions to maximise their effectiveness.

“In particular, it is often beneficial to engage local stakeholders and be guided by their knowledge so that the solutions achieve the desired benefits and avoid unexpected downsides,” says Professor Kalantari.

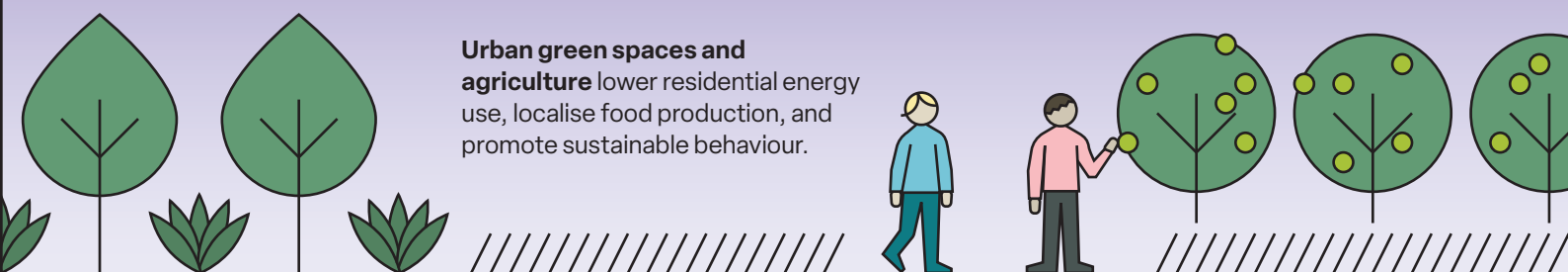
Technical aspects can be designed by experts or engineers, similar to traditional ‘grey’ infrastructure. However, they will need support from specialists in local botany or ecology to select the right plants.

“When designing solutions, cities must consider the entire socio-ecological system and how it will function and be maintained,” Professor Kalantari concludes. ●

¹ Pan, H., Page, J., Shi, R. et al. Contribution of prioritized urban nature-based solutions allocation to carbon neutrality. *Nat. Clim. Chang.* 13, 862–870 (2023)



Habitat preservation and remediation prevent urban sprawl and protect high-carbon ecosystems, particularly at urban edges.

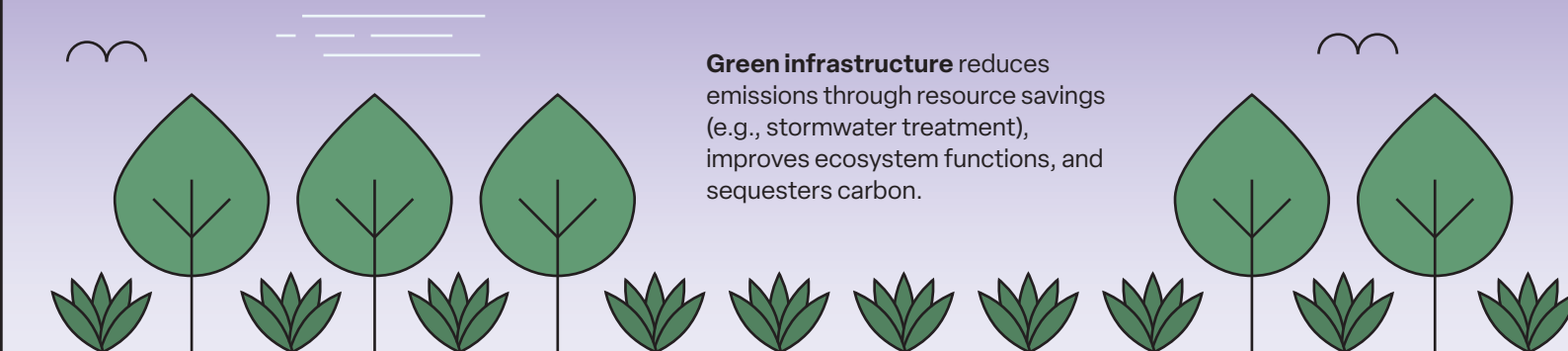


Urban green spaces and agriculture lower residential energy use, localise food production, and promote sustainable behaviour.



Green buildings, such as green roofs and facades, improve insulation, reduce energy demand, and regulate indoor temperatures.

Street trees and green pavements* reduce the urban heat island effect and sequester carbon.



Green infrastructure reduces emissions through resource savings (e.g., stormwater treatment), improves ecosystem functions, and sequesters carbon.

*permeable surfaces that allow water to drain through

Emissions monitoring

Cities exploring new technology for emissions monitoring

Knowing whether climate actions are effective is crucial for cities, but gathering precise, up-to-date emissions data is a challenge. Advanced sensor technology can help, providing frequent, accurate updates and empowering urban centres striving towards a low-emission future.

By Sean Goulding Carroll

Key takeaways

- **New technology provides accurate greenhouse gas data.** Advanced sensor networks are a game-changer, offering a powerful and precise way to monitor emissions in real-time.
- **Hybrid approaches are the future.** The most effective strategy for cities is to combine traditional emissions inventories with new sensor technology for more accurate and useful data.
- **Data empowers policymakers.** Taking a hybrid approach helps cities verify emission totals and gives policymakers the specific, detailed information they need to design, evaluate, and improve climate policies.

The first step for local governments looking to understand their carbon footprint is to compile the emission-producing activities in the city into an emissions inventory.

Inventories have become the global standard for reporting emissions thanks to their inclusion in the Paris Climate Agreement¹. Signatory countries are obliged to report their national greenhouse gas emissions annually. Ambitious local governments can

¹ Also part of the Kyoto Protocol in 1996 and the UNFCCC National Inventory Documents.

Small, low-cost sensors for measuring CO₂ concentrations have been installed on lampposts in Zurich to support climate action with data.



also choose to track their emissions, although they have no mandated timeframe in which to do this.

These inventories use information from the public and private sectors to quantify emissions-producing activities, such as electricity production, traffic, heating and cooling in buildings, industry, and waste management.

“Emissions inventories are fundamental to setting climate goals,” says Dr **Hugo Denier van der Gon**, Principal Scientist on Air Quality and Climate at the Dutch Organisation for Applied Scientific Research (TNO).

“You cannot create meaningful climate actions without an inventory. If you don’t know what your emission source sectors are and how big they are, you are working in the dark,” he explains.

However, while inventories provide valuable data and are useful for identifying emissions sources, they usually do not offer the level of detail needed to take action and mitigate emissions.

Limitations of traditional inventories

Policymaker’s detailed questions, such as which buildings are producing the most emissions or the benefits of planting trees along a particular road, are generally too specific for emissions inventories to answer.

“Many cities lack access to timely, local, and precise data with high spatial resolution,” says Dr **Ivonne Albarus**, Senior Science Officer, Working Group I, Technical Support Unit at the IPCC.

“The accuracy of emissions inventories depends on the availability of local data, such as the number of cars, the fuel type they use, the amount and origin of the energy consumed in the city, and so on,” she explains.

Inventories fail to capture when and where emissions are most intensive as they are updated annually at most and take a broad view of the entire city, says Dr **Jocelyn Turnbull**, Principal Scientist, Carbon Cycle at the New Zealand Institute for Earth Science.

“Emissions inventories are great for tracking how whole-city emissions are evolving over time, but we need more detailed, granular information if we want to be able to see where the opportunities for mitigation are and track how well specific mitigation actions are working,” she explains.

Photo: Pekka Pelkonen, ICOS RI

“

We need more detailed, granular information if we want to be able to see where the opportunities for mitigation are and track how well specific mitigation actions are working.

Dr Jocelyn Turnbull

Mapping emissions in real-time

In contrast to emissions inventories, atmospheric greenhouse gas observations are based on readings from sensors in strategic locations around cities. This technology allows cities to map greenhouse gas emissions in real-time time. As part of the ICOS Cities project, Paris, Zurich, and Munich, complemented their statistical emissions inventories with direct greenhouse gas observations.

“Our measurements provide an independent, faster method of observing emissions,” says Dr **Lukas**



IPCC Special Report on Climate Change and Cities

In March 2027, the Intergovernmental Panel on Climate Change (IPCC) will publish a key report about the critical role of urban areas.

- **Focus:** The latest science on climate impacts and risks, adaptation and mitigation solutions related to cities.
- **Purpose:** Provide policy-relevant information to help urban leaders make informed decisions and leverage the full potential of cities in tackling climate change.

Klaus Kürzinger and Christian Becker in the Munich team are using a flask sampler to compare and validate greenhouse gas monitoring data, ensuring that the measurements meet ICOS's high accuracy standards.

Emmenegger, Head of Laboratory at Empa, Swiss Federal Laboratories for Materials Science and Technology, and scientific team lead for Zurich in the ICOS Cities project.

“It’s instrumental to have an independent method that shows whether what you aimed for is actually being observed in the atmosphere.”

In the ICOS Cities project, sensors were positioned across the three pilot cities in a variety of ways: strapped to tree trunks and lampposts, installed on rooftops, and even attached to mobile phone network base stations.

The project started gathering data in 2022 and is set to conclude at the end of 2025, with selected networks expected to become permanent fixtures.

The sensors ranged in price and accuracy, from a hundred euros to hundreds of thousands of euros for the high-end equipment. Using the cheaper sensors allowed for a greater quantity to be installed and more readings to be collected. Meanwhile, the more sophisticated, expensive instruments on rooftops or towers allowed scientists to obtain precise measurements and see more subtle changes in greenhouse gas concentrations.



“We like to say that the atmosphere can’t lie – it sees the sum of all the emissions, mixed together,” says Dr Jocelyn Turnbull (on the right), pictured with Professor Andreas Christen.

The sensor networks unveiled fascinating insights into the fluctuating emission patterns across each city. (See pages 38–47)

Inventories and observations working hand-in-hand

The ICOS Cities project’s findings show that combining emissions inventories with atmospheric observations provides the most accurate and useful information for local governments.

“The atmospheric observation will tell you your total emissions have decreased by 10% – OK, great, but why? You still need to understand the emission sources, which will allow you to pinpoint in which sectors reductions were achieved. That’s where the inventory side comes in,” says Professor **Thomas Lauvaux** at the University of Reims.

For Professor Lauvaux, atmospheric observation is a verification step that allows cities to check the accuracy of their inventories:

“

The atmospheric observation will tell you your total emissions have decreased by 10% – OK, great, but why? You still need to understand the emission sources, which will allow you to pinpoint in which sectors reductions were achieved.

Professor Thomas Lauvaux

“The atmospheric monitoring system is almost like having an accountant that goes line by line to verify the totals.”

This argument is echoed by Dr Turnbull: “We like to say that the atmosphere can’t lie – it sees the sum of all the emissions, mixed together. So, by combining the atmospheric observations with enhanced inventory-methods, we can find out where our inventories are working well, and where they are getting things wrong.”

Combining emissions inventories with atmospheric observations can also help citizens follow their city’s climate action, says Dr Denier van der Gon.

“Policymakers and citizens don’t generally have an idea of what changes in greenhouse gas concentrations mean, but if you translate it to data that are available in emissions inventories, such as saying that saving so many kilotons of CO₂ is equivalent to having 5,000 fewer cars driving in the city centre – people will understand that,” he explains.

Looking to the future

Making use of the captured data is one of the most important factors when setting up a greenhouse gas monitoring network.

“There is a wealth of data becoming available, much more so than was available 10 or 20 years ago. We are still exploring how to work with that wealth of information,” explains Dr Denier van der Gon. “Even very smart individuals cannot do this alone, so artificial intelligence or machine learning techniques will really help us to deal with these huge quantities of information.”

“Artificial intelligence can be used to scale the knowledge gained from larger cities to smaller cities. Rather than saying that, if a city with a population of 500,000 people has a certain number of cars, then a city with 250,000 people will have half that amount, AI can help to extrapolate in a much more sophisticated manner,” he says.

“With artificial intelligence and machine learning, the transfer of knowledge from one city to another will be much more accurate and detailed,” he adds.

The project will also produce guidelines outlining how cities can make the connection between atmospheric observations of greenhouse gases and their emissions inventories.

In the future, there may also be emissions measurements taken from above the atmosphere as satellites

can now observe ‘urban plumes’ – rising columns of warm air and greenhouse gases generated by cities, explains Dr **Andreas Christen**, Professor of Environmental Meteorology at the University of Freiburg.

“They’re not yet at the resolution that they can provide emission estimates for smaller cities – they can mostly track large megacities and power plant plumes. But that’s a technology that will improve,” he says.

“This would allow us to calculate emissions not only from a single city or from the cities of a particular region, but worldwide for every city.” ●

IG³IS Guidelines: A new standard for urban emissions

The recently published 'Urban emission observation and monitoring good research practice guidelines' provide a new framework for cities to accurately monitor and manage their greenhouse gas emissions.

- **Purpose:** Help cities move beyond basic, city-wide totals and acquire the detailed, reliable and robust emissions data needed to take specific, targeted action. This framework uses atmospheric information to supplement traditional activity-based data.
- **Tailored approach:** Recognising that every city is unique, the guidelines highlight the pros and cons of all available greenhouse gas observational measurement methods. This allows cities to choose the most suitable approach based on their specific needs, geography, climate, and available resources.

The guidelines have been produced by the Integrated Global Greenhouse Gas Information System (IG³IS) and the World Meteorological Organization (WMO), with the input from ICOS Cities scientists.



Access the guidelines here:
<https://doi.org/10.59327WMO/GAW/314>



Roof and street-level sensor networks

Small sensors on roofs and street-lights measure greenhouse gases closer to their source, enabling individual sources to be pinpointed and emission hotspots to be identified.



Total column measurements

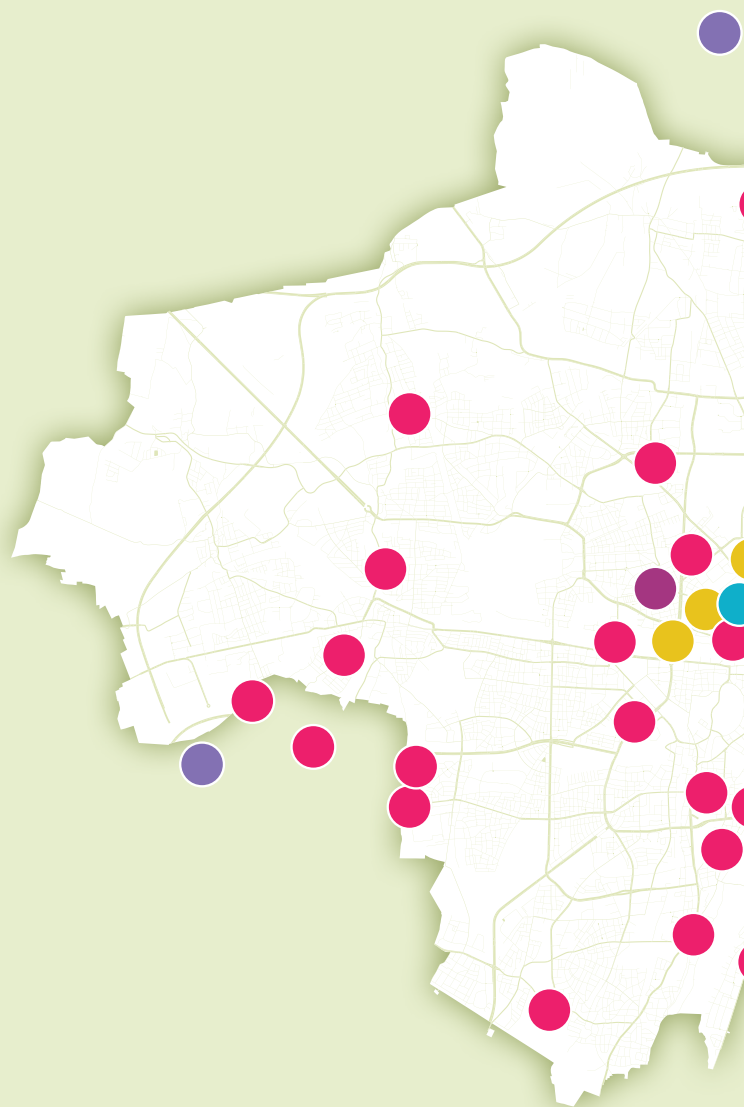
Sun-tracking instruments installed upwind and downwind of a city measure greenhouse gases in the entire atmosphere by tracking very small changes in sunlight due to the greenhouse gas enrichment over the city.



Turbulent flux measurements

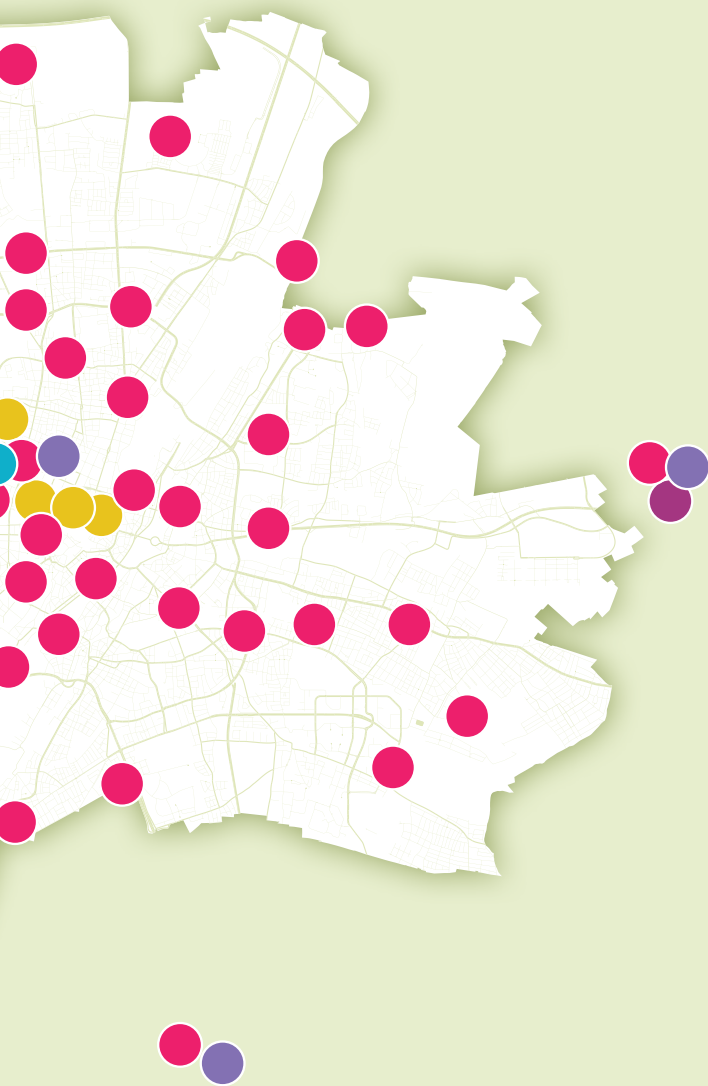
By simultaneously measuring the strength of wind and greenhouse gas concentrations with specialised equipment on towers over the city, the emissions can be inferred from the underlying urban surface.

Options for monitoring greenhouse gases in cities



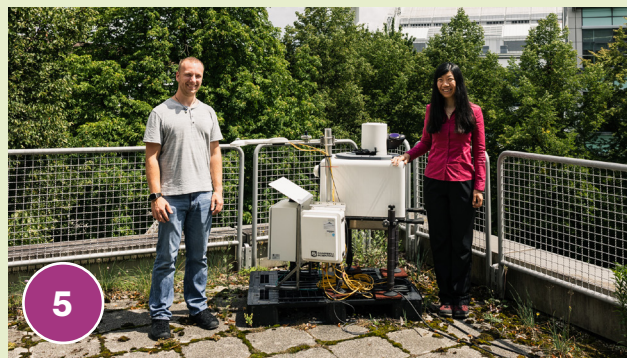
No two cities are alike – therefore, each city requires a tailored set of sensors to accurately monitor greenhouse gas emissions.

Greenhouse gas monitoring network in Munich. To test various types of emission monitoring equipment, the three pilot cities, Munich, Zurich and Paris, were equipped with different greenhouse gas sensors all across the cities. This map shows the equipment used in the city of Munich. Total column measurements (2) were used in Munich as an alternative to high-precision sensors on towers (6).



Urban biospheric monitoring

Tracking the vitality of vegetation and soil conditions allows the quantity of greenhouse gases released and absorbed by urban nature to be estimated.



Atmospheric wind profile observations

Laser beams are used to study the movement of air in the atmosphere up to around 3,000 meters. This is important for understanding how the emitted greenhouse gases spread to different parts of the city.



High-precision up- and downwind towers

High-precision sensors on tall towers continuously measure the concentration of greenhouse gases and detect small changes in greenhouse gases upwind and downwind of cities. This tall tower is located in Romainville, Paris.



Tracking Zurich's path to carbon neutrality

Walking through the streets of Zurich, you may not notice the small, grey devices working quietly across the city. Yet these boxes are providing a wealth of information on the Swiss city's progress in reducing its greenhouse gas emissions.

By Sean Goulding Carroll

Photo: Pekka Peikonen, ICOS RI

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While emissions inventories are based on data gathered by governments or disclosed by businesses, atmospheric observations make it possible to independently check carbon levels.

Dr Lukas Emmenegger

Key takeaways

- **Verifying climate progress.** Zurich is using atmospheric sensors to independently track its progress towards carbon neutrality. These have revealed that its fossil carbon emissions are lower than previously estimated.
- **A permanent system.** The city plans to integrate a permanent, budget-friendly sensor network to continue monitoring greenhouse gas emissions and boost transparency.

Thanks to atmospheric observation sensors, local authorities in Zurich are now able to track their progress towards the city's goal of achieving carbon neutrality by 2040.

Positioned by the ICOS Cities project in 2022, the 60 sensors are gauging the evolution of greenhouse gas emission levels over time. Preliminary results reveal positive news as they suggest that the city has significantly lower fossil carbon emissions than previously thought.

Before the ICOS Cities project, Zurich was fully reliant on its emissions inventory for an overview of its carbon emission levels. This inventory uses public and private data to compile sources of carbon emissions and the quantities released, tracking sectors such as heating, energy production, industrial processes, road traffic, land use change, and waste management.

However, it lacks real-time data, something that can be provided by sensors.

“While emissions inventories are based on data gathered by governments or disclosed by businesses, atmospheric observations make it possible to independently check carbon levels,” explains Dr **Lukas Emmenegger**, Head of Laboratory at Empa, and scientific team lead for Zurich in the ICOS Cities project.

By comparing data obtained from the sensor network with the city's emissions inventory, local authorities can pinpoint key emission sources, enabling targeted, data-driven climate action.

From rooftops to trees

Small sensors were installed on public signs and trees around the city, with larger greenhouse gas monitoring equipment mounted on rooftops. Through a partnership with Swisscom, the ICOS Cities team installed instruments, sampling lines, and wind sensors on the company's buildings and rooftop antennas.

“We had the luxury of being able to choose between the hundreds of base stations that the telecom provider has in the city and to model which of those locations would work best for atmospheric recordings,” says Dr Emmenegger.

In addition, the city police provided access to their telecommunication antenna on the Hardau tower complex in the heart of the city, which stands 114 metres above street level.

Once the instruments were installed, models simulating the movement of greenhouse gases within the city were used to calculate emissions based on observational data. The measured CO₂ concentrations were then attributed to specific fossil fuel and natural sources.

However, the nearby forests complicated things as the natural flow of carbon produced and absorbed by nature, known as biogenic flux, made determining human-induced emissions more difficult.

“It’s very important that we are able to determine the biogenic flux from nature accurately, otherwise we may draw the wrong conclusions about the CO₂ flux from human activities,” says Dr Emmenegger.

In light of this, the project team improved their models to account for a wide range of factors, such as the number of trees, prevailing wind patterns in the city, and human respiration.

Tracking climate action transparently

After three years of observations, the project team was able to develop three largely independent approaches to quantify Zurich’s greenhouse gas emissions. This laid the groundwork for a permanent emissions monitoring system in the city, with the local government choosing to continue the mid-cost sensor network combined with high-resolution atmospheric modelling.

“At the end of the project, we would like to have created an observation network and model system which is as precise and as budget friendly as possible. That’s what the ICOS Cities project is all about,” says Dr Emmenegger.

The data generated by the atmospheric observation sensors will also help boost transparency around mitigating emissions, providing citizens and the media with information on the city’s progress towards its climate goals.

“If Zurich’s CO₂ emissions drop to nearly zero by 2040 in line with the city’s climate mitigation goal, we should be able to observe that through observations in the atmosphere,” says Dr Emmenegger.

“The local politicians are very interested in having that capability for many reasons, but an obvious one is that it creates trust between residents and the municipality,” he adds.

Collaboration is also key to the project’s success, he says.

“One of my major messages is really you cannot do this by yourself. You need collaboration both with the city and with private partners. You need to trust each other and find a willingness to contribute to a common goal.” ●



How do cities assess their emissions?

Understanding a city's environmental impact begins with a comprehensive greenhouse gas emissions inventory, quantifying the emissions produced across various sectors.

By Nidhi Misra

A greenhouse gas emissions inventory is a systematic assessment of all greenhouse gases produced within a city's geographical boundaries. It includes emissions from:

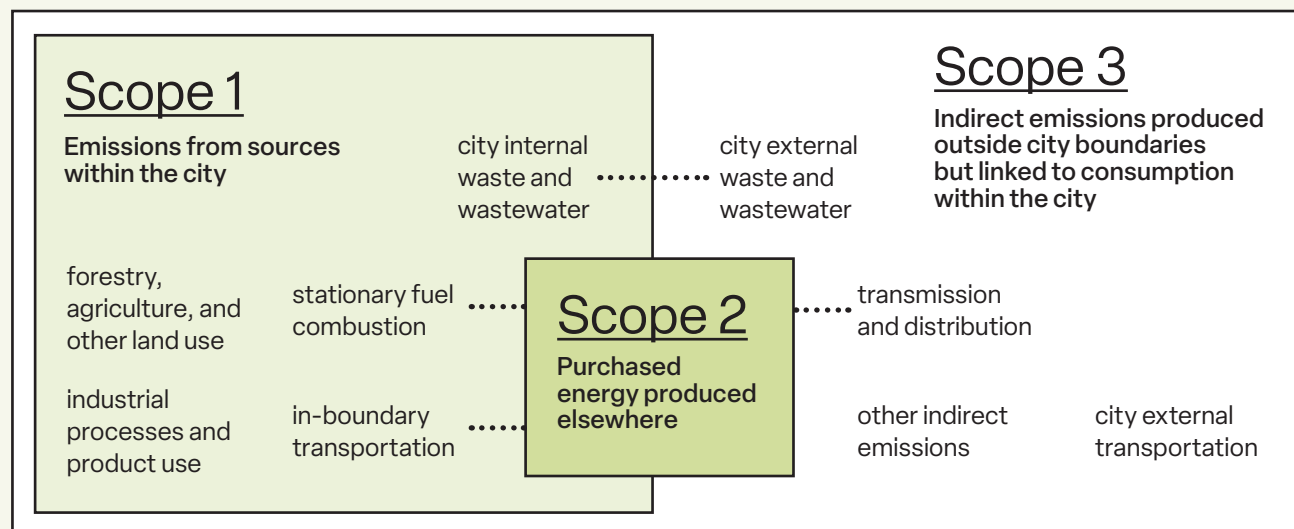
- ▶ Transportation
- ▶ Combustion for residential heating
- ▶ Industry
- ▶ Waste management
- ▶ Other sources, like agriculture and leaks from gas distribution networks

When compiling an inventory, the city starts by gathering activity data, such as fossil fuel consumption within specific sectors, and then multiplies this by an emission factor, such as how much CO₂ is released per amount of diesel used.

There are several different guidelines which can help cities to set up their inventories. The most common are:

- ▶ **Global Protocol for Community-Scale GHG Inventories** (GPC), which organises emissions into three scopes (see infographic)
- ▶ **Baseline Emissions and Monitoring Inventory** BEI/MEI, which tracks energy consumption to guide local sustainable energy and climate action plans
- ▶ **Hybrid or national methods** like France's Bilan Carbone Methodology or Germany's BSKO Standard that combine local data collection practices with national data sources and international standards
- ▶ **Official reporting platforms**, like the CDP ICLEI Track and My Covenant tools that cities can use to log their emissions ●

Cities use the emission scope framework to measure and manage greenhouse gas emissions. This allows them to set realistic baselines and targets, identify high-impact areas, and track progress towards climate goals.



Source: ICLEI



New, real-time emissions data upgrades Munich's climate action

In a bid to better understand the impact of its climate mitigation measures, the German metropolis of Munich is updating the way it tracks greenhouse gas emissions. Over 100 atmospheric sensors were installed across the city, providing policymakers with a more nuanced picture of the city's emissions.

By Sean Goulding Carroll

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Thanks to the broad coverage, the team can detect local emission hotspots and emission sources previously unaccounted for.

Professor Jia Chen

Key takeaways

- **Real-time, detailed data.** Munich's extensive sensor network provides an unprecedented, real-time understanding of urban emissions, helping to identify local 'hotspots' and previously unaccounted sources.
- **Improving inventories.** The new data is used to upgrade the city's traditional emissions inventories, providing more accurate and timely information for policymakers.

The new monitoring network, with its comprehensive geographic coverage, provides city authorities with an unprecedentedly detailed understanding of Munich's emissions in real-time.

The team installed some 100 CO₂ sensors and 30 air quality sensors across the city at a cost of around 300 to 1,000 euros per sensor. Another set of 20 higher-end sensors, costing around 10,000 euros each, were also deployed to provide more detailed monitoring.

“With this new approach we can understand greenhouse gas emissions at a completely new scale, spanning from the city-level to local sources, such as traffic and power plant emissions. Thanks to the broad coverage, the team can detect local emission hotspots and emission sources previously unaccounted for,” says **Jia Chen**, Professor of Environmental Sensing and Modelling at the Technical University of Munich (TUM) and leader of the ICOS Cities team in Munich.

These include emissions from Oktoberfest, a local gas network leak, a sewage treatment plant, and an abandoned landfill.

Another set of sensors measuring atmospheric CO₂, CH₄, and CO concentrations – one at each compass point surrounding the city and one in the city centre – were also installed to provide readings upwind and downwind of Munich.

These column sensors, each costing around 100,000 euros, made it possible to distinguish emissions generated within the city from those originating elsewhere.

“With this equipment, we can measure the greenhouse gas concentrations in the air before entering the city and after passing through the city,” says Professor Chen.

Boosting inventory accuracy with observational data

The city had previously relied solely on emissions inventories, which compiled greenhouse gas data from a variety of sources, such as energy use statistics, traffic activity data, and national emission factors.

However, some of these figures were estimates. For example, traffic emissions are estimated based on average weekday traffic volumes.

As part of the project, the team revamped the city's emissions inventories, both temporally to show the trend of emissions over the year, and spatially to show where these come from.

Although inventories offer a reliable, big-picture view, they lack the precision of direct measurements. Compiling a city inventory is also a time-consuming process because of the limited data availability – often delayed even up to two to three years, says Professor Chen.

“For Munich policymakers, this lag has meant that the efficacy of climate measures cannot be determined quickly,” she adds.

Atmospheric sensors have sped up this process significantly – for example, city emissions can be determined with a lag of only a week.

Revealing Munich’s real-time emissions

The introduction of atmospheric sensors, coupled with the data from the improved emissions inventory, provides Munich’s policymakers with a more accurate overview of emissions, allowing them to refine urban climate action plans.

“By combining both, we can monitor and evaluate the emissions of a certain city area over the years and see whether the mitigation policies in that area generated tangible effects,” says Professor Chen.

“The benefit is that the city can confirm via actual measurements if the mitigation policy is working and where more actions are potentially needed. This also helps improve the quality of future emissions inventories,” she adds.

“Our study has so far revealed, for example, that traffic-related carbon emissions in Munich dropped by 15.9% in 2020 due to COVID-19 and have not returned to pre-pandemic levels as of 2024,” she explains. It was also determined that human respiration accounts for about 8% of the direct human-caused carbon released in Munich.

Alongside this, the team created a detailed model of urban nature capable of tracking activities such as photosynthesis and respiration much more accurately than before. The model showed that nature can significantly help offset human-caused carbon emissions, particularly during high-growth seasons in the summer.

“This means that the city could extend green infrastructure to reach their climate goals,” Professor Chen points out.

The knowledge gained in Munich will not only help the Bavarian capital, but also support atmospheric observation networks due to be rolled out in cities across the continent, she adds.

“The idea is that, at the end of the project, we can develop a sensor network catalogue, and each city can decide – depending on their financial situation and the level of accuracy they require – how many sensors are necessary to cover their needs,” she explains. ●

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The benefit is that the city can confirm via actual measurements if the mitigation policy is working and where more actions are potentially needed.

Professor Jia Chen

Photo: Pekka Pelkonen, ICOS RI



Detecting emissions from Parisian rooftops

The installation of atmospheric observation sensors has allowed Paris to more accurately assess the amount of carbon it emits. New data confirms that the French capital's greenhouse gas emissions have decreased by 25% in the last decade.

By Sean Goulding Carroll



Dr Benjamin Loubet and Dr Laura Bignotti monitoring emissions on the roof of the Sorbonne University in central Paris. Here, the team has installed eddy covariance emission monitoring equipment to measure the net exchange of gases, such as carbon dioxide and methane, between the ecosystem and atmosphere.

Key takeaways

- **Verifying climate progress.** Paris's new sensor network confirms that its greenhouse gas emissions have decreased over the past decade.
- **A diversified approach provides detailed insights.** By using a variety of sophisticated sensors, the city is gaining new insights into seasonal emission patterns and the positive impact of urban forests.
- **Real-time data empowers policy.** The real-time emissions data is a game-changer for policymakers, allowing them to verify results and design more targeted and effective climate actions.

While emissions inventories offer valuable estimates of emissions-producing activities, their compilation is complex and infrequent – Paris's city inventory, for example, was last updated in 2022.

“This means that policymakers must base their decisions on outdated data,” says Dr **Ke Che**, Postdoctoral Researcher at the Laboratory for Climate and Environmental Sciences (LSCE) and part of the ICOS Cities team. “Additionally, these inventories may lack comprehensive information – for instance, some emissions sources may be missing.”

To address this, the team installed a network of greenhouse gas concentration and flux sensors across central Paris, setting up the longest and largest deployment of CO₂ sensors over any city.

When combining the new real-time observational data with the emissions inventories, the city authorities get a complete and accurate picture of urban emissions and a reliable foundation for designing targeted mitigation measures.

“This will give us a more accurate estimate of the total emissions in Paris,” Dr Ke says.

“The direct observations also provide a standardised and up-to-date approach that helps improve and validate CO₂ emission estimates.”

Mapping CO₂ from ground to sky

Starting in 2022, the Paris team deployed the largest number of field measurement techniques out of all the



cities in the ICOS project, foregoing low-cost sensors in favour of more sophisticated observation equipment.

To achieve accurate readings, sensors were installed at varying heights across the city, from the semi-forested area of Vincennes to the urban centre of Jussieu. Monitoring equipment was also attached to a tethered balloon in downtown Paris that was capable of ascending up to 300 metres to measure the vertical distribution of atmospheric CO₂ concentration. Readings from the urban sites were complemented with measurements from the more rural areas of Saclay, Grignon, and Fontainebleau.

Initially, the team looked at attaching sensors to the city's churches to take advantage of their height compared to other Parisian buildings, but their historical importance was ultimately a barrier.

“Gaining access to rooftops in strategic locations to install sensors proved to be difficult, as building

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While Paris serves as a case study, our approach is designed to be applicable to other cities as well.

Dr Ke Che



Monitoring equipment installed on the 128 metre Romainville tower in Paris.

owners were sometimes sceptical, and it required a lot of negotiation and paperwork to authorise it,” says **Olivier Laurent**, ICOS Cities researcher at the LSCE.

Despite the challenges, the project team successfully rolled out a comprehensive network of around 50 sensors of different types across the metropolitan region.

Paris' emissions dropped by 25%

Preliminary project findings confirm that the French capital's greenhouse gas emissions have decreased in the last decade by 25%.

The new data provides further insight into seasonal dynamics, showing that, in the centre of Paris, the winter months tend to see a rise in carbon emissions, with a clear decrease in summer as people leave for the coast or the countryside.

“Urban forests, such as in Vincennes, were also found to be important CO₂ sinks, suggesting that the

expansion of urban greenery could mitigate urban emissions,” says Dr **Laura Bignotti**, Postdoctoral Researcher at the French National Research Institute for Agriculture, Food and Environment (INRAE) and part of the ICOS Cities team.

State-of-the-art radiocarbon measurements (14CO₂) upwind and downwind of the city further enabled the team to directly estimate the fraction of fossil fuels in Parisian emissions, providing robust data for policy-makers to build their emission reduction plans on.

Based on this vast and unprecedented deployment of observing systems, the Parisian scientific team is seeking to develop more general criteria for installing tailored urban sensor networks worldwide, each customised to a city's unique emission profile, budgetary limits, size, and density.

“While Paris serves as a case study, our approach is designed to be applicable to other cities as well,” Dr Che concludes. ●

Tracking climate actions

Tools for monitoring and guiding urban climate action

How do cities know if their climate actions are working? Innovative tools and data services are emerging to answer this critical question. These solutions, from open data initiatives to online platforms, are providing cities with the information required to measure progress, optimise strategies, and achieve their environmental goals.

By Kira Taylor



ICOS Cities
open source
data portal
[citydata.icos-
cp.eu](http://citydata.icos-cp.eu)

Key takeaways

- **Data is key for effective policy.** Cities need reliable, granular data to identify where emissions are coming from, enabling them to prioritise actions that will have the greatest impact.
- **A new generation of tools is emerging.** Innovative platforms and services are helping cities measure, visualise, and even predict emissions in real-time.
- **Understanding and using data is a challenge.** While many tools are available, cities – especially smaller ones – often lack the expertise and resources to effectively use the data.

Open-access data platforms like ICOS Cities, combined with analytical services and tools, can help policymakers see where emissions are being reduced and which policies could deliver the greatest climate benefits.

“Data is important to assess the magnitude of different emission sectors – and then to identify where emissions reductions will be most effective,” says Dr **Andreas Christen**, Professor of Environmental Meteorology at the University of Freiburg.

Cities want to know exactly where their emissions come from in order to understand which sectors to address, explains Dr Christen, who works on the ICOS Cities project, exploring which methodologies can be used to quantify city emissions on different scales and ensuring data is useful.

“Let’s say your city does a large-scale tree planting initiative – is that actually helping to absorb some of the emissions or is that not relevant? If the city implements traffic changes, will that actually have effects?” says Professor Christen.

Contextualising data for cities

ICOS Cities is also working on prototypes to help contextualise this data for cities on different scales and across various sectors, as well as developing ways of bringing cities together to discuss this. (See page 54)

Private services are also exploring this. For instance, Origins.earth, a consortium partner in ICOS Cities, is

converting open-source emissions data into a tool that cities can use to track their real-time emissions, divided by sector.

“The tool we have developed aims to address three needs of communities: visualise, evaluate, and predict,” explains **David Duccini**, Chief Executive Officer at Origins.earth. “Automatically, every day, we compute the inventory of the region. Automatically, we run the atmospheric model. Automatically, we integrate data from high-precision stations into the model and ensure that the input data are consistent with the physical observations,” he adds.

For the past six years, the company has measured the daily human-induced emissions of the greater Paris area and its 11.9 million inhabitants in real-time.

Alongside providing this data, Origins.earth’s tool provides scenarios to evaluate the effectiveness of green policies, which can help define targets for climate action plans. This tool is useful for two reasons: to help communicate with citizens about the measures creating changes in their cities and to evaluate public policy, says Duccini.

“Actions to reduce emissions often require citizens to make major changes in their lifestyle and habits. Think, for example, of changes in public mobility or low-emission zones. Graphically visualising the impact of their efforts and making the results tangible, even to non-climate specialists, strongly contributes to citizen engagement,” he explains.

Administrations must also integrate metric indicators into their decarbonisation plans to assess the impact of policies and determine what is required in the future to reach the city’s goals, says Duccini. This is something Origins.earth aims to show with its forecast function.

A range of tools available

Other tools are also available to help cities. This includes Kausal, which provides monitoring and collaboration services as well as scenario-building tools, and ClimateView, which helps with monitoring and developing action plans.

Meanwhile, the Net Zero Planner tool, designed as part of the Climate-Neutral and Smart Cities mission, is freely available to all cities and helps assess the cost of policies versus the benefits. Google’s Environmental Insights Explorer (EIE) can also provide insights into

transport and building emissions, rooftop solar potential, and tree canopy cover.

“While data quality varies by region, Google’s EIE and Climate TRACE¹ serve as a useful starting point for cities developing their emissions inventory data collection methods. The tools are free, easy to use, and provide data cities may not currently have,” says **Yasmina Grieco**, Expert in Green and Digital Transform-

1 Climate TRACE tracks emissions using satellites, other remote sensing techniques, and artificial intelligence to deliver a detailed look at global emissions.

What if observational data were freely available?

One outcome of the ICOS Cities project is the vision of a European network of greenhouse gas observations in cities. This network would continue integrated observations not only in Paris, Munich, and Zurich, but a number of additional cities.

“If we can continuously produce standardised and reliable data in – let’s say – 10 to 15 representative cities, companies like Origins.earth could use that data to calibrate their services and apply them in dozens of other cities,” says Dr **Werner Kutsch**, Director General of ICOS and Coordinator of the ICOS Cities project.

This ‘ICOS Cities Network’ would ideally provide the observational data and tools (mainly in the form of models) to improve the climate action services outlined above.

“We might call these cities calibration cities,” adds Kutsch.

These cities would boost scientific knowledge to improve inventories, better plan city’s action, and to verify their impact. If ICOS ran these observational network and scientific services, it would free cities from paying high costs for observations.

“The challenge is to convince the ICOS member countries to invest public money into the necessary infrastructure and its maintenance,” Kutsch says.

mation at ICLEI Europe – Local Governments for Sustainability. She recently co-authored a study² using Google’s dataset to analyse how urban transport infrastructure affects walking and cycling rates in over 11,000 cities.

“What’s particularly valuable is seeing the huge variety in solutions – some are expensive, some are cheap, some require major urban redesign, others work with existing infrastructure. This kind of comparative analysis is exactly what we need in climate policy because it shows us context specific solutions,” Grieco explains.

Challenges in collecting data

Distinguishing where carbon emissions come from is complex but essential to show cities where reductions are needed. CO₂ is emitted from many different sources in urban areas, including transport, industry, and buildings.

The ICOS Cities project team is exploring how to disentangle these emissions, including differentiating between naturally occurring carbon emissions and those from burning fossil fuels. The team is also looking at ways to identify carbon dioxide emissions from particular sectors by tracking other pollutants, like carbon monoxide or nitrous oxides.

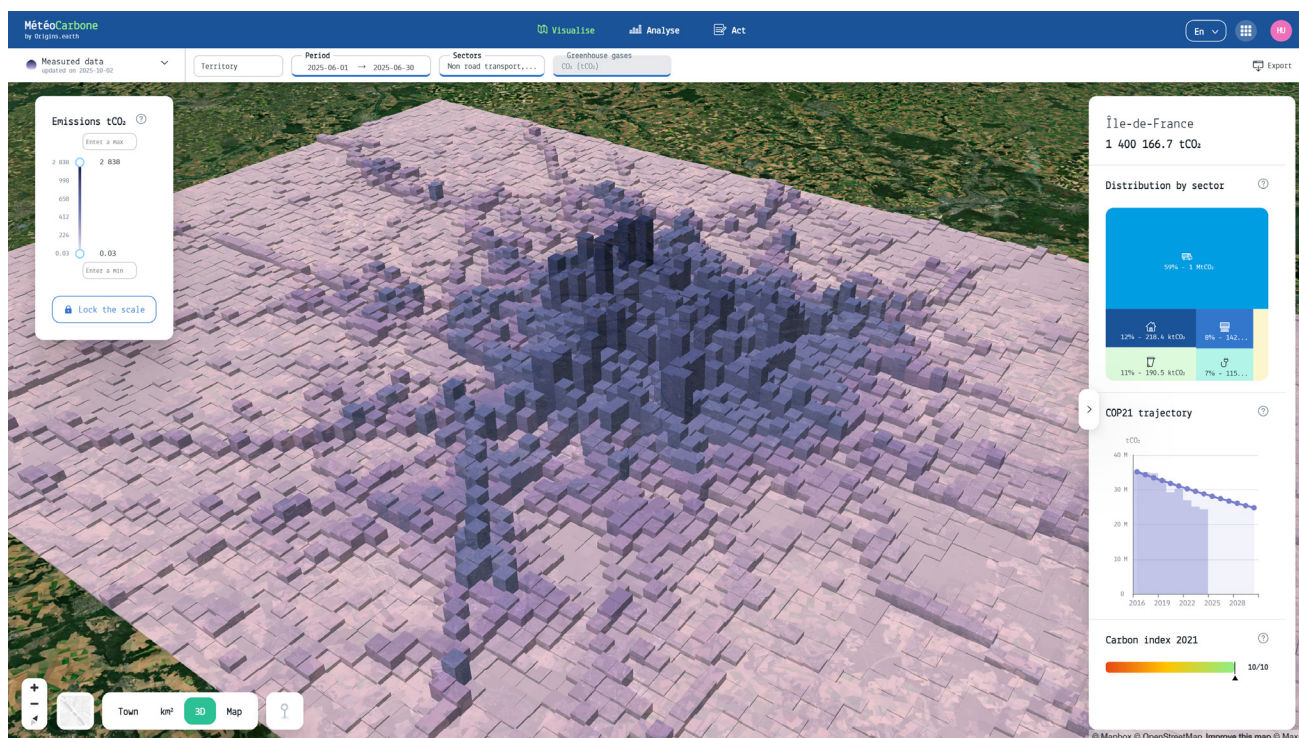
“For example, in addition to the emission of carbon dioxide during combustion, there is also an emission of the pollutant carbon monoxide. This is not found in CO₂ emissions from breathing or when microbes decompose soils, so we can use this to help attribute CO₂ to sources,” says Professor Christen.

Time and geographical indicators can also help build a picture of emissions from different sectors. For instance, the change in emission levels during rush hours and no-car days can reveal the scale of emissions from road transport.

Understanding data is crucial

Collaboration between different stakeholders and departments is key, particularly when setting targets, says Grieco. For example, the boundary of a city may be defined differently in different data sources, risking inconsistent reporting.

2 A. Millard-Ball, M. Reginald, Y. Yusuf, & C. Bian, Global health and climate benefits from walking and cycling infrastructure, Proc. Natl. Acad. Sci. U.S.A. 122 (24) e2422334122, 2025



Among other features, the Météocarbone tool from Origins.earth visualises the total emissions over the city of Paris in 3D.

“The real challenge isn’t just getting the data – it’s making sure people understand and can act on it. For example, the transport department might share data, but if the sustainability team can’t interpret what they mean, you’re stuck,” she explains.

“You need sectoral departments to sign off on carbon reduction targets and show how they’ll actually hit the numbers. Most climate plans fail here – there’s a disconnect between who analyses the data and who has to deliver results. The most successful cities get all relevant departments collaborating from the start, not just sharing data after decisions are made,” Grieco adds.

However, the sort of insights that companies like Origins.earth offer are not yet widely accessible for cities, partly due to the sheer cost of monitoring stations, says Duccini. These services also require political backing, all the relevant actors to work together, and financial and human resources.

Professor Christen also highlights the capacity challenges faced by cities, particularly smaller ones.

“It is clear that medium and small cities do not have the resources to monitor emissions on their own or even to use the data. There’s a shortage of staff and expertise in many cases,” he explains.

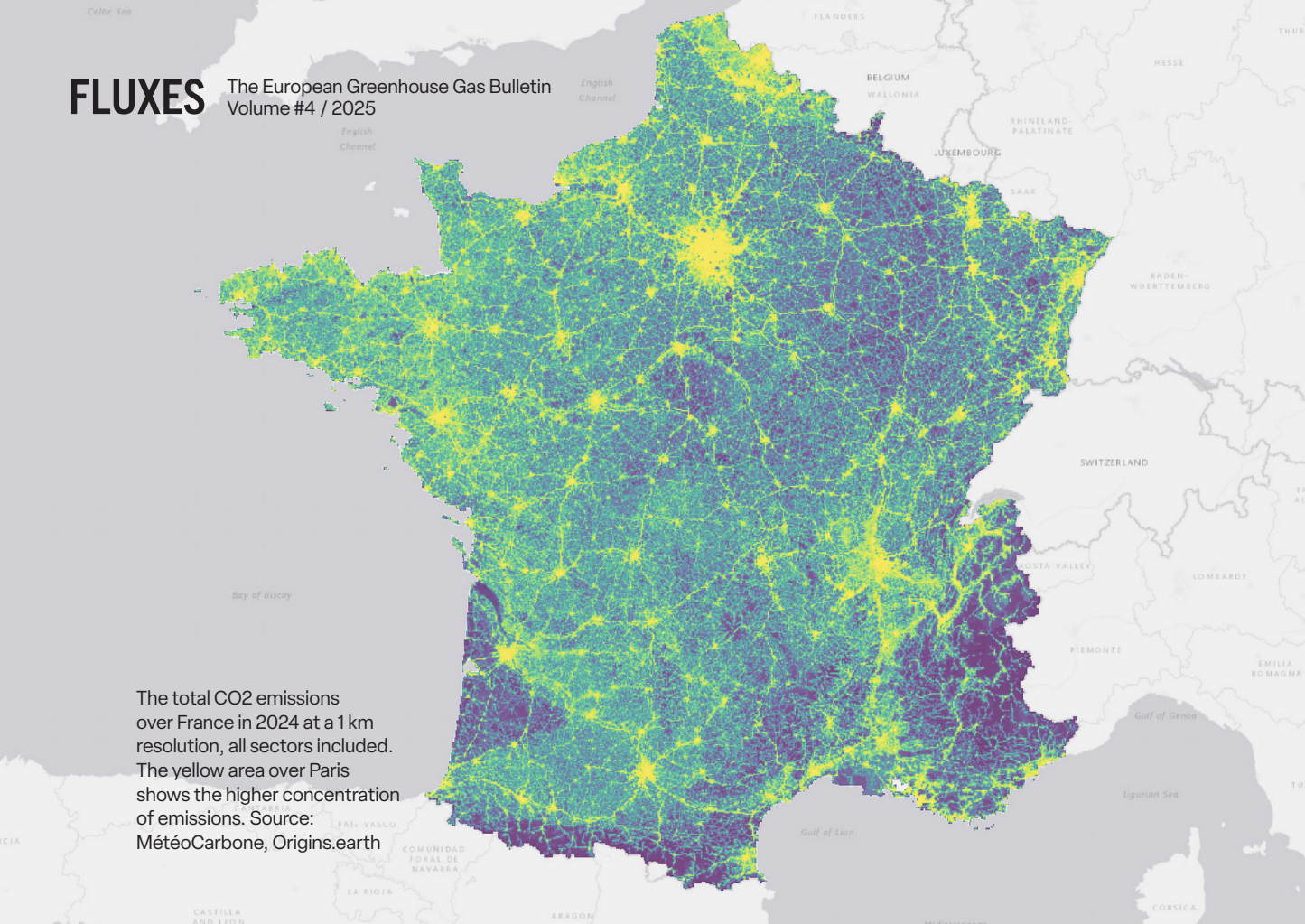
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The real challenge isn’t just getting the data – it’s making sure people understand and can act on it.

Yasmina Grieco, ICLEI Europe

Despite these challenges, there is a clear benefit for cities to not only understand their emissions but also to see how these could be affected by future policy. According to Duccini, the recent Olympic Games hosted in Paris are a concrete case study of the benefits of Origins.earth’s tool.

“By studying the detailed impact in the individual geographical areas of the city, we were able to learn a lot about how to optimise the regulation of city traffic, for example,” he says. ●



Paris climate scenarios: evaluating the region's race to decarbonise

Paris is on a promising track to meet its 2030 climate targets – but the city's ambitious goal of becoming carbon-neutral by 2050 will require a far more significant set of actions. This is the central finding of a recent ICOS Cities study using a new climate scenario tool.

By Charlotta Henry

If Paris's climate action plan is fully implemented, the city should be on track to meet its 2030 climate target.

"However, the current policy package falls short of the city's 2050 net-zero goal," says Dr **Ivonne Albarus**, who is part of the team behind the ICOS Cities study.

The findings also reveal a critical socio-economic dimension of climate action, with significant differences in how emissions are being reduced across the Paris metropolitan area, between the urban core and the suburbs.

"For example, the wealthiest central districts are seeing substantial reductions, especially in the traffic sector, thanks to strategies like the city's Low Emission Zone (LEZ). However, in the less affluent suburbs, resi-

dents still rely heavily on personal vehicles, limiting the impact of these urban policies,” Dr Albarus explains.

In Paris’s less prosperous eastern suburbs, the residential sector also holds a significant potential for emissions reductions, as many of these neighbourhoods have older, less energy-efficient buildings.

“Low-income neighbourhoods, particularly in the eastern parts of the city, offer the greatest reduction potential but are also the most vulnerable to the costs and constraints of climate policies, such as mandatory renovations and traffic restrictions,” says Dr Albarus. “This is why social inequalities must be considered in policy design.”

While the study concludes that Paris is well-positioned for its 2030 targets, a full transition by 2050 is not yet guaranteed. It will require a comprehensive push to expand policies across the entire metropolitan area, invest in public transport, and accelerate the adoption of new technologies.

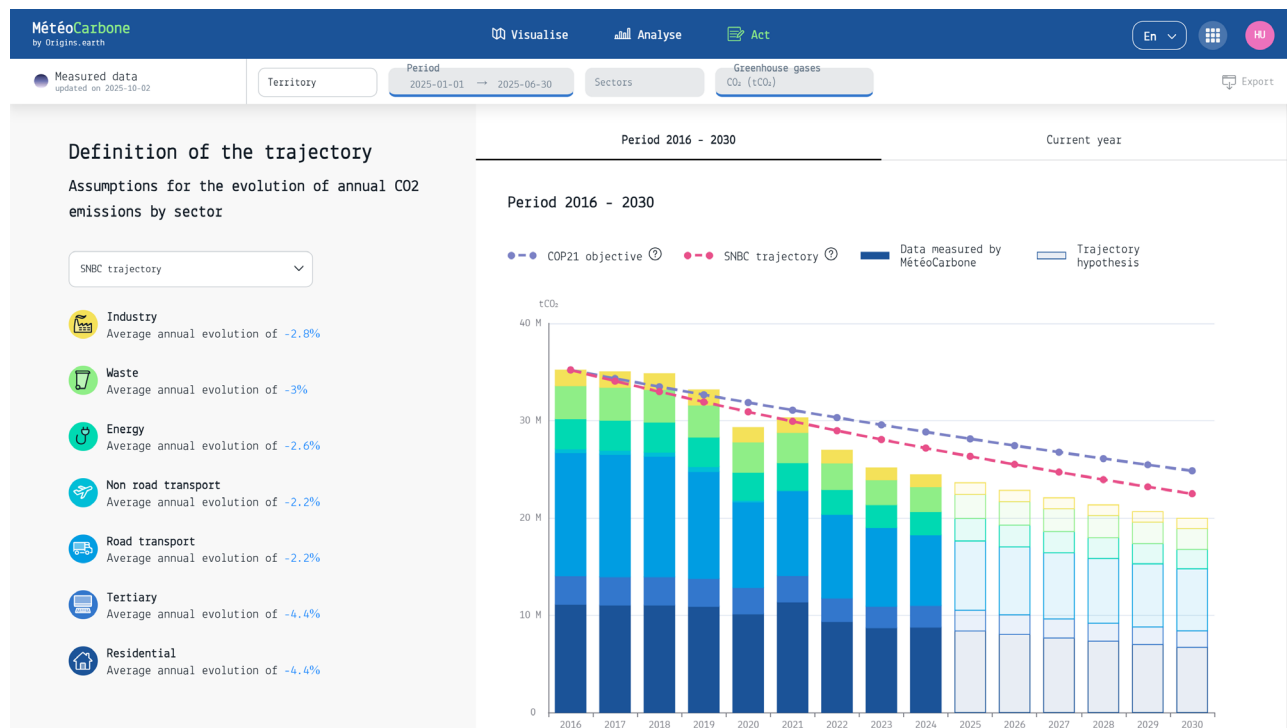
“In short, Paris must act quickly, design its policies in a socially just way, and scale up its ambitions beyond the current trajectory to ensure both 2030 and 2050 goals will be achieved,” says Dr Albarus. “Using

New tool combining emissions with climate action policies

The ICOS Cities’ study used the Origins.earth Dynamic Inventory, a powerful new tool which provides a detailed look at urban CO₂ emissions:

- It enables cities to evaluate whether their climate actions are yielding the expected results and to see where adjustments are needed.
- It processes information from over 80 databases to create a detailed emissions map.
- It enables the quantification of the impact of key mitigation measures in building and transportation sectors.
- It maps how different climate action scenarios would affect future CO₂ emission reductions.

science to navigate this complex urban landscape is the key to turning ambitious climate goals into measurable, equitable progress.” ●



This MétéoCarbone panel view shows the impact of local emission reduction policies and helps to verify whether the actual trend in emission reductions is in line with the commitments made by the city. The blue dash line shows the reduction trajectory to be followed to achieve the COP21 targets, while the red dash line shows the reduction trajectory decided by the country or local authority. The histograms show the actual emissions measured by the network.

Turning raw data into climate solutions

Monitoring greenhouse gas emissions can help cities understand hotspots and the effectiveness of their policies, but this requires navigating vast, complex datasets. The ICOS Cities project is developing tools to make emissions data more understandable and useable.

By Kira Taylor

“Part of the ICOS Cities project has been to make data more useful to cities. ICOS Cities data is open access, so it’s available to everyone, but it’s quite abstract. It provides in-depth knowledge from a physics and atmospheric science point of view, but remains relatively detached from the on-the-ground challenges of city actors,” explains Dr **Katie Berns**, a researcher at Aalto University, working on the project.

Based on feedback from city authorities and policy-makers, the team has designed three prototypes:

1. Policy dashboard for emissions data

The policy dashboard is designed to contextualise ICOS data in relation to other datasets already collected by cities, bringing together sector-based insights with geographic and demographic data, and enabling cities to look at emission hotspots, track emissions data over time, and explore future projections.

Because similar dashboards tend to be quite expensive, the idea is to have an open-source tool that allows smaller cities to only use the features they require, making it cheaper.

2. City-to-city collaboration

The team is also exploring matching cities of similar sizes and with similar challenges to enable them to learn from each other.

“We’d really like to create a space where cities can share ideas and initiatives that they’ve been working on: what works, what doesn’t work. I think a lot of cities are quite open to sharing their successes, but not necessarily their failures,” says Dr Berns, adding that it is important for cities to incorporate existing knowledge and learn from one another.

Cities in Europe are already collaborating through many initiatives, but the project team is hoping to add another dimension to this.

3. Citizen engagement infrastructure

This infrastructure aims to enable policymakers, city officials, and residents to work together to define climate challenges, refine project options, and explore impacts using ICOS and city data. It also enables them to review, implement, and share results.

A central element of this service is the ‘scenario selector’ tool that uses ICOS emissions projections to predict the impacts of potential projects and help cities weigh up the costs and benefits of different climate measures.

Dr Berns hopes that, in addition to being developed into services, these prototypes will also inform existing ones and show how data sets can be integrated.

“Cities are already using a lot of dashboards and tools. So it is important to consider how new services might fit into pre-existing digital ecosystems,” she explains. ●

City-to-city insights

Cities are keen on using data for improving climate action.

By Charlotta Henry

1 Is your city using data analytics or specific software tools to identify where climate action efforts would be most effective?

2 What kind of data analytics or software tool, if it existed, would be a 'game-changer' for your city's climate planning?



Alejandro Gómez

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Valencia Clima i Energia, Spain

1 We do not really have a specific tool but we mostly use greenhouse gas inventories and the Net Zero Planner, provided in the Cities Mission, in order to estimate 2030 decarbonisation pathways.

2 A game changing tool would be one that estimated the real impact of specific greenhouse gas reduction actions, with temporal and spatial accuracy. The link between projects and greenhouse gas reduction is often complex and uncertain. This is particularly true for projects that depend on shifting citizen habits or that rely on indirect impacts.



Dieter Müller

Head of Climate and Environmental Strategy
City of Zurich, Switzerland

1 The City of Zurich monitors the effectiveness of its climate protection measures based on the development of target indicators published online in the Net Zero Cockpit. Users can also interactively visualise scenarios that demonstrate the impact of measures on target achievement. This is a version of Causal Path adapted to the needs of the City of Zurich.

2 Near-real-time values and visualisations would help provide a timely overview of concentration trends (e.g., for continuous air pollutants) and potentially reveal the impact of measures. Additionally, AI-based analyses would help identify 'patterns' of potential measures. Future measures could also be anticipated based on concentration trends.



Hanna Wesslin

Climate Director
City of Helsinki, Finland

1 For the moment, we don't have analytics or software tools in use for this purpose.

2 A real game-changer would be a tool that could provide a far more precise and transparent picture of both direct and indirect emissions. Current methods like traffic emission calculations still rely heavily on assumptions.

For example, a comprehensive construction project database that highlights main emission sources would greatly improve the evidence base for decision-making.

The most transformative, however, would be an integrated platform that combines a holistic view of the city's emissions and adaptation needs with the costs of climate actions, allowing measures to be prioritised by cost-effectiveness.



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