An academic expert view: urban environments + air quality

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New Delhi India Gate War Memorial, 17 Oct 2017 and 8 April 2020 (Source: the Guardian)

Ana,

Thank you for making the time to discuss air quality in urban environments with me. The quality of air we breathe links into a great many aspects of how cities and towns function and how people enjoy them (or not) – including the transport we use, the green and blue space we have to use, and the industrial and land management activities that take place in and around us. I'm looking forward to hearing your views about actions that can be taken by those who run urban environments, and citizen action groups as well, to improve air quality for the benefit of people and nature.

To begin with, could you summarise your background and experience, and projects and research you working on that focus on air quality? I know your remit is broad.

Ana: Sure. I am a Senior Research Scientist at the University of Maryland Baltimore County, with 20 years' experience in research applications of satellite remote sensing, with a particular focus on air quality. For 12 years I led NASA's Applied Remote Sensing Training Program (ARSET), which empowers and supports various groups of people worldwide to integrate satellite data into environmental management. Currently I am the International Lead for NASA's Wildland Fire Management Program and a co-Investigator within NASA's Health and Air Quality Applied Sciences Team (HAQAST), where I work with countries in southern Europe and Latin America in particular on air quality applications and building capacity in satellite data use for wildfire management and monitoring. I have 15 years' experience working with local and state government to develop air quality and climate change policies and program evaluation.

Gareth: Thanks for this overview and context, Ana. I will link some of our discussion points about air quality to an urban system (which links to the UN Sustainable Development Goals, or SDGs) with ecological, physical and socio-economic parts to it, joined together by governance and knowledge sharing (per the diagram below). Air quality is a key focus in section 15 (good health), and it links into many other parts including governance, transport, the built environment, our use of greenery and natural habitat, and education. I'm sure these aspects will crop up in our discussion.
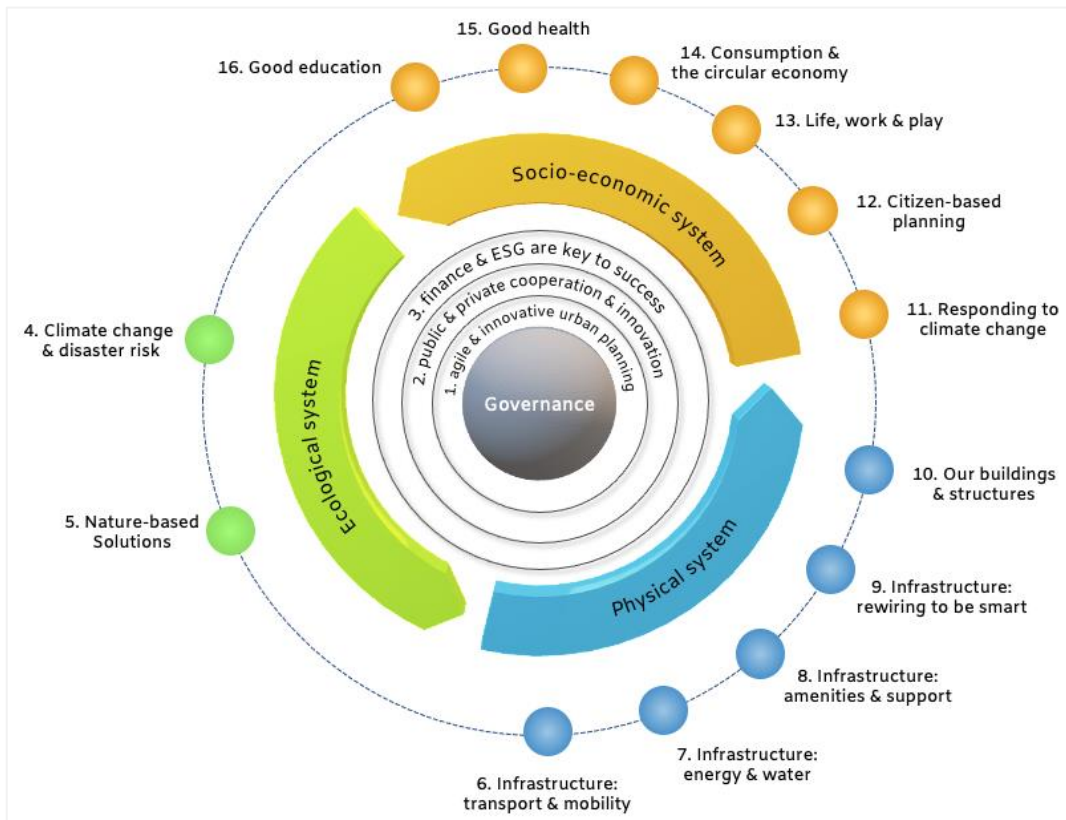
Urban system image by author

Gareth: Just to set the scene for people about the general context of air quality, is there a globally accepted definition that people use, or does it vary around the world? And what exactly are the pollutants of air quality – if I understand correctly, they are different to the pollutants we talk about for climate change?

Ana: You are right that different definitions of air quality exist. The definition of air pollution provided by the World Health Organization (WHO) is that it is "contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere."

It is definitely important to clarify which pollutants cause health-related issues to people versus those that contribute to climate change, also called greenhouse gases (I should also add that I'd like to see air quality and climate change linked together in a clearer and more coordinated way). We don't refer to greenhouse gases like CO2 or methane when we discuss air quality. CO2 and methane trap heat and are of course a major focus for combatting climate change. The air pollutants we focus on that are major public health concerns are pollutants that cause health problems such as respiratory diseases like asthma. These pollutants include particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulfur (sulphur) dioxide (these are the five main areas of focus identified by the WHO).

Gareth: Thanks for clarifying this important point about the area of focus for air pollutants and how it differs to the area of focus for climate change and greenhouse gases, Ana – whilst noting that there is an opportunity to align messaging about them perhaps. To your point about having greater societal awareness of the differences, I wonder if the media and politicians could help to ensure clarity about climate change pollutants and air pollutants, and how we need to focus on all of them.

From my understanding, which includes reading about the work of the Air Quality Life Index (AQLI) and their reports of air quality around the world, the situation with air quality varies greatly around the world depending on where we live, at a country level down to a specific local level.

I have also seen information published by the WHO that states air pollution is estimated to cause 7 million premature deaths and results in the loss of millions more healthy years of life. Ambient (outdoors) air pollution alone is estimated to be responsible for 4.2 million deaths a year, they say. [15-19] The WHO puts air pollution on an equal footing with smoking and unhealthy eating, and that it contributes to many illnesses and non-communicable diseases.

Is air pollution and poor air quality particularly acute in developing economies? For example, I have seen various reports about poor air quality in developing parts of the world, including statistics that show how parts of Africa and Asia are home to many (not all) of the world's most polluted countries, and cities. [15-20] I appreciate that cities in developed economies suffer from poor air quality too, so I'm not suggesting that it isn't an important matter or focus for developed economies.

Ana: Poor air quality is a global problem and a global challenge, but it is indeed worse, and worsening, in lower middle-income countries (LMICs) and low-income countries (LICs), especially in Africa and South Asia. I have direct experience with Africa: I am collaborating with a group that has received funding from the National Science Foundation in the US ([NSF](#)) to conduct pilot workshops to identify solution to air quality challenges in the African continent. including through scientific field campaigns, and I am seeing first-hand some of their challenges. The largest cities in Africa – such as Cairo, Kinshasa and Lagos – have major air quality problems to contend with (along with many other challenges). The continued population growth in large African cities, sources of pollution within these cities, other anthropogenic activities and seasonal burning of land that takes place has led to a decrease in air quality.

I am also working on a [NASA Earth Sciences Applied Sciences](#) sponsored project focusing air quality that is seeing me liaise with teams in Uganda, Bolivia and Ecuador. The goal of this work is to leverage Earth satellite monitoring to track urban air pollution in cities within these countries. One of the things I have come to appreciate through this project is that there is very little surface monitoring of air quality currently taking place in these places, which means that we do not have good data to work with. If we can capture more and better data, we can discuss specific ways to resolve it. Having more surface monitor air quality data makes satellite data more useful since these two data sources can be combined. For the first part – surface monitoring – we need to be realistic about how to make it happen. Traditional air monitoring equipment is expensive to purchase and operate, and most teams in Africa and other developing parts of the world do not have the resources to purchase and maintain expensive monitoring equipment. They need cheaper equipment, and good governance to use it properly and ensure data informs good policy.

Elsewhere in the world where living standards are higher, air quality isn't perfect by any means. In fact, air quality is considered as one of the leading environmental health issues globally. Perhaps not everywhere, but certainly in many parts of the world this is the case.

Meteorology is a key driver of air quality. Wind direction and wind speed makes a big difference, since a good wind ventilates an area and can clear away pollutants. Areas that are coastal, with their coastal breezes, clear out polluted air as opposed to places inland that typically cannot do this. Places at altitude do not tend to ventilate well, which is why many of them are more polluted than many of us realise. However, there is always local context to consider. Meteorological patterns like wind can move pollution from its source to other areas, like for example smoke moving into urban areas from elsewhere.

In Europe, the air quality in many cities isn't as good as it should be. You can see it through satellite imagery. When you look at NO2 (nitrous dioxide) levels in Europe for example, countries like the UK and Belgium light up compared to countries in southern Europe, which is a feature of the industrial activity they and other parts of northern Europe have.

In South America, seasonal burning is a problem in some countries. Again, the use of satellite imagery can raise people's awareness about specific local air quality problems, and it can help to tell a story about how it can be improved. For example, we produced analysis of Earth observations showing air quality trend in cities in central and eastern Bolivia over the past 15 years, which could be an effective communication tool (to in turn help to drive policy improvements).

Fires and land burning are big problems, as I mentioned earlier. It's a global challenge. Sometimes it's done because of agricultural clearance needs and therefore economic reasons, sometimes it's because of an agreement to use prescribed burning to reduce wildfire risk. Prescribed burning is used a lot in the US, for example. Some Californians are seeing their air quality getting worse in the short term as a result of prescribed burning, and there isn't universal agreement about its overall benefits in terms of the long-term exposure to air pollution. We are lacking in studies about the air quality and health impacts from prescribed burning in the parts of the world that face wildfire risks. Whilst noting these points about California, the air quality in many US cities is pretty good.

The developing world is where we need more science and data focus about air quality to drive improvements, I think. It would be good if the scientific community was able to focus more on combatting air pollution in developing countries, including funding for science-based research that directly contributes towards better policy and action to improve their air quality. Developed economies such as those in Europe and North America have challenges, for sure, and they are mostly heading in the right direction. They know what they need to do and they have a good density of air quality monitoring networks that deliver high quality continuous data, whereas much of the developing world such as Africa and India do not currently have this and their air quality levels are in reverse. Whilst some lower-income countries are getting more monitoring, the quality of the monitors in many cases still needs to be determined (e.g. low-cost sensors)

Gareth: I appreciate this context, Ana. Given the situation that exists around the world, perhaps we can talk a bit more about the causes of the problems we are seeing. You mention land burning being a problem (be it to prevent wildfire, or for land management). What about other factors? I presume that air pollution in urban environments is inextricably linked to our means of transport and how we move around, and that our use of road vehicles (cars including EVs, lorries/trucks, motorbikes and mopeds et al) is a key factor to the quality of air we breathe.

Are you aware of any studies conducted that analyse in detail different modes of transport and the impact they have on air quality? I am anticipating that air pollution varies with the pattern of fossil fuel vehicle use, such as whether vehicles keep their engines running at traffic lights and the effect of traffic jams on air pollutants. As well as fumes from exhausts, the fine dust released from car tyres and the use of brakes and the continuous disturbance of dust on roads are presumably also contributing factors (which applies to EVs as well as fossil fuel powered vehicles).

Rush hour traffic in Ho Chi Minh City, 2023 – what impact do all these mopeds and scooters have on air pollution? (photo by author)

Ana: I can't point to specific scientific studies about air quality and traffic volumes, but clearly there's a link. I have seen traffic looked at in terms of city climate plans, and there are some implicit links in this to air quality.

In the US, where I live, transport is a key issue to address. The car remains king: people prefer to drive rather than use public transport and I don't know if this situation can be changed. Take Washington DC for example. The subway is not a good option for many. Ridership is falling, so the city is raising prices to pay for it, which lessens the appeal to use it further. It is cheaper to drive than take the subway, and in many cases, it is far more efficient for people to drive to get to where they need to go.

EVs are being put forward as a key solution to the climate problem in the US, but they are not going to solve everything. If the electricity generation is not from sustainable sources, we are not making any difference. The US has shut down a lot of coal-fired power plants, it must be said, and I was personally involved for nearly 10 years in community and political action to get   one coal power station shut down in the Washington DC area. There are high hopes that the US Bipartisan Infrastructure Bill (2021), which has many energy components to it, will improve things and push us towards green electrification.

Recent climate plans by many cities and local areas have generally been well received. Indeed, Fairfax County where I live recently received an award for their Climate Adaptation and Resilience plan. It took some 18 months to put together, and an inclusive approach to it was taken for it. It included urban heat island issues and mitigating actions such as heat respite centres.

However, I have noticed that the plan does not specifically discuss air quality – I think these are missed opportunities for cities and states to consider air quality in climate change and adaptation plans, or at a minimum to link them to existing air quality plans if they exist.

Gareth: To continue your point about transport, I have spent time in Southeast Asia recently where the use of mopeds is still prevalent – they rule the roads more than cars in countries like Viet Nam and Laos. Public transit in these places is being built, which is good to see, but I wonder what will happen to the air quality of their cities if cars become more common as people in these countries advance in terms of their material wealth. Hopefully their investments in public transport will negate the risk of becoming clogged with cars, as Japan in East Asia has achieved, with its excellent public transport network (the best in the world, in my opinion).

Ana: Parts of Asia have certainly made great strides. What China has been able to achieve in the last decade with its public transport has been very impressive. The advancement in their high-speed rail, for example, surely helps towards the broad picture in which air quality across the country is improving. I appreciate that other parts of Asia, especially South Asia in countries such as India and Bangladesh have big air pollution problems. It will be interesting to see how Southeast Asia develops (which is something that the AQLI discuss in their 2022 global analysis).

Gareth: You mention also the opportunity to link air quality into / with city / town climate plans. I saw this link being made at a [Cities Climate Action Summit](#) event in London in April 2023 – air quality was being linked with climate change and adaptation work by several speakers at this event, which I thought was encouraging. Perhaps, as part of an update to city climate plans, those responsible for overseeing them can build air quality targets and key actions into them, and articulate how they will perform air quality monitoring, set targets and act to achieve them, with more community and business engagement also?

Ana: I think there is much to be gained by linking air quality with climate plans – and it is good to hear about the examples you gave in the UK about this happening. In the case of the US, there is pretty good community involvement in local climate plans so this could be leveraged to link into air quality matters.

Community involvement seems to be fairly good in other developed economies too, overall, but it is not as good in developing economies. A key focus needs to be on societal awareness so people can appreciate the difference between living in a polluted local area and living in a clean air area.

For example, there is a big difference between living 0.5km from a highway and 1km away from one (which is much better for our health). Perhaps low-cost air quality sensors operated by citizens in these areas could help people see with their own eyes the much higher exposure levels for those near highways. In terms of general awareness of the public, proximity to large highways is something that we should all know about.

Gareth: On your point about low-cost sensors, if I understand correctly, air quality equipment is getting cheaper all the time, and low-cost monitoring equipment can be quickly attached to street furniture such as lampposts.

It seems to me that this type of monitoring can make a positive overall difference, even accepting that the quality and accuracy of low-cost air monitoring is not as good as more refined but more expensive sensors and equipment.

Ana: Yes, I think so. Scientists like to conduct in-depth field campaigns and publish papers on our findings. This of course has value, but I think there also needs to be a focus as well on setting up low-cost sensors especially in developing economies and ensuring people locally can use them for the long-term to drive positive change.

Citizens in various parts of the world are taking action themselves by using low-cost sensors to bring problems to the attention of policy makers, which I think is a good thing. Whilst some scientists are not keen on the low-cost equipment approach, because the monitors are not highly accurate, good outcomes can result from their use. There have been instances in the US where citizens purchased their own low-cost sensors to draw attention to an air pollution problem, which then lead to a municipal or city authority to take action. In the US, the EPA now supports and even promotes their use. Whilst this type of citizen action may cause some extra work to local authorities, it should be welcomed. In parts of the world where low-cost sensors can't be afforded, research-funded initiatives could consider using them instead of high-quality equipment (ideally in conjunction with them).

Gareth: The linkage between air quality and the ecological environment is an area that I'd like to discuss. Most urban areas are lacking in greenery and water bodies. Do you know of any studies that look at the linkages of green and blue density in urban environments to air quality?

Ana: I have seen it related to some of the general measures. Trees are good, we just need to ensure we know all aspects to them. In certain parts of the US, certain trees can make ozone pollution worse due to a release of a particular hydrocarbon called isoprene. For sure, this isn't a reason to not plant trees, because they offer many benefits to us. Green spaces such as parks reduce the density of the urban population, and this contributes positively to reducing air pollution.

Air pollution is noticeable in compact, dense cities where green and blue infrastructure is in specified areas rather than incorporated into the overall urban design. Take, for example, cities like Athens, Madrid and Paris, which often suffer quite bad air pollution because they are dense (and in Athens' case, it sits in a "bowl" that traps pollution). However, the flip side is that cities that are less dense encourage more driving.

Gareth: Maybe we can achieve utopian urban environments that have an appropriate type of urban density combined with excellent public transport to avoid the use of cars, and good quality active mobility options (walking, bikes and others). That will take time to evolve, if it ever does.

Looking at mental health and air quality, is there enough societal awareness about air pollution and its impacts on people's mental health?

I read a study from April 2021 which describes an extensive and long-running review of [air pollution and its impact on mental health](#) from childhood through to adulthood. Findings indicated that the more air pollution people were exposed to as children, the more likely they were to experience mental illness when they turned 18 – which was found to be the age when initial symptoms of mental illness often appear. The findings also suggest that exposure to nitrogen oxides in early life may be a nonspecific risk factor as young people grow into adulthood.

This research indicates that exposure to air pollution may moderately increase the severity of mental illness and increase the social and financial burden of mental illness on communities. I read that scientists are still trying to figure out exactly what happens in brains exposed to air pollution that affects mental health and cognition. One theory I noted is that it is linked to inflammation in the brain, which can damage neurons that are involved in nervous system's regulatory responses, which in turn can impact mental health.

Noting your point about linking climate plans with air quality, is there an opportunity to engage citizens better about air quality and the mental health of kids, in both developed and developing quality? We talk a lot about climate change, but most people cannot see the impact of it.

Ana: The air quality story is a good one to tell with the public because it can resonate. We can see poor air quality right in front of us, so it feels that it is impacting us right here and now, which can make it a pressing matter for people. In our work to shut down a coal plant that I mentioned earlier, I found that focusing on air quality helped to show the impacts more than the climate argument.

To tell the story well, we need better monitoring to know what the root causes of the problem are. As I mentioned earlier, we need better monitoring especially in developing regions and countries like Africa and India. To conduct good planning in the cities that face big air quality problems, we need factual evidence to know what the problem is and then use it to drive better government policy. Monitoring gives us tools and ammunition to do something.

In Uganda for example, the wood burning that takes place, and the charcoal industry outside of its cities, significantly impact air quality. Yet these activities are currently an important part of the economy, so what should a solution be to change things, and how quickly can it be implemented? Also, I've noticed that a lot of people have left the country to pursue their goals elsewhere – while I sympathize with their desire to for example study abroad, it's important that local people lead the charge for change to take place.

Gareth: I wonder if the need for better air quality monitoring and action to cut pollution might be able to link, for developing economies, to accessing funds in the climate Loss & Damage fund that has been set up after COP27.

Ana: I come back to the monitoring need because it gives us the tools and means to act. It can tell you how often air quality levels are inadequate, in micro areas (not just generally in one city). Monitors can be set up to suit different areas in a city – some areas need more monitoring than others, which can change over time.

When people receive the right training, they can develop maps that show specific impacts of air pollution – and also the benefits of improving air quality. For example, in an area of Santa Cruz in Bolivia, the air quality is worse in specific parts of the city; and in the eastern part of the province there is more particulate and NO2 pollution because of land burning. There is a lack of ground-based monitoring to see how it is developing. Pilots of air monitoring help, but in order for them to be effective they need to support good policy development. Helping to inform policy in an appropriate way should be included in the scope of work for any air quality monitoring / assessment pilot or research activity.

Poor air quality in Santa Cruz, Bolivia, 2022 (Source: Bolivian government)

Gareth: So, the design of the scope of air quality projects should ensure that a range of stakeholders, including stakeholders who are involved in policy making, are part of the project set-up?

Ana: Yes. As I mentioned earlier, we must ask ourselves if we need a field campaign with high-quality instruments for every study. Scientists like field campaigns because of the quality of scientific outputs, but after we pack up our equipment and return home, what happens afterwards – are the results used locally for short and long-term benefit? Low-cost sensors are not as good as the costlier high-quality instruments,

but they can be good at supporting effective translation of results into policy and action.

This is part of the work I am doing in Portugal and Spain, in terms of where the barriers are that block things happening. It is not enough to publish papers; we need to see practical application.

Gareth: Are there common targets and goals that air quality initiatives should focus on, or does it always depend on local context?

Ana: Just having a target for certain particulate levels can be a good start, which can be used in a number of ways. It's possible to correlate hospital data to concentrations of known air pollutants, for example and it should be quite straightforward to do this. Then from here, we can set air quality improvement targets in percentage terms in each city, and over time, look for the corresponding decrease in hospital admissions

As we mentioned at the start of this discussion, the WHO currently tracks five different pollutants, which is a good start even though it is not a complete picture. In Europe there are more targets in place.

What we don't know enough about is the cumulative effect of various combinations of air pollutants on our health – there are a lot of pollutants to consider (a lot more than "the top five"). Particles include many different types of aerosols with different chemical compositions – for example, black carbon, sulphate aerosols, organic aerosols and others. We would benefit from more analysis on this – to assess the effect of reducing some pollutants but not others and study the impacts on people's health. Perhaps this is something that can be incorporated into the scope of air quality research projects (when feasible).

Gareth: I can see that there is much still to do overall to improve air quality, but if we look back over the past twenty years, it seems that there is a lot more appreciation of the situation and questioning of about it, and some good actions are being taken?

Ana: Yes, I would say so. Ultimately, the climate question may drive air quality improvements. Improving energy sources will drive better air quality, for example, as will tackling the transport challenge (including cars).

Air toxicity is the other side of air pollution that we need to consider. This needs more attention. The presence of mercury and lead are still factors to consider in various locations, for example.

Gareth: On this point about making improvements, I am a strong advocate of driving good governance and proper accountability to make positive change happen in urban places. Without good governance and accountability the best research, analysis and plans can only make a limited impact.

Guidelines released by the WHO in September 2021 aim to help national governments to combat the problem of air pollution (of those five major pollutants, particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2) sulphur dioxide (SO_2) and carbon monoxide (CO). Can city and town authorities use these to set practical targets for their local areas (appreciating that political systems differ in different countries)?

Ana: Just having the actual pollutant levels, and a percentage reduction target against them, is a start, especially with aerosols. We know there is a clear link between aerosol concentration and health. We have existing studies that correlate hospital data with reduction targets (in this case a decrease in for example hospital admissions). It should be straightforward.
If cities can track a handful of key metrics (e.g. the WHO 5), that's a start. Perhaps they can agree on more comprehensive plans \ [not sure what we meant by advances?] over time, maybe working with research establishments to consider other pollutants and look at the problem more holistically (per my point above, there's a lack of research on multi-pollutants).

Gareth: On a societal level, for individuals, are simple apps we can use on our smartphones that provide an air quality index worth using? I remember using one when I lived in Singapore during a bad haze period (caused by smog from burning in Indonesia) in 2015, and also in Sydney in December 2019 when we had bad air quality due to nearby bushfires (from the Black Summer bushfires of 2019-20).

Haze in Singapore due to agricultural burning in Indonesia, 2015 (Source: self)

Sydney smoke haze in December 2019 (Source: self)

Ana: Smartphone apps can be useful at a generic level for citizens. It helps to know how they work, to understand how accurate they are. Their accuracy depends on how close you are to the nearest monitor. If your app is interpolating between two sensors that are far away there could be some inconsistencies or loss of information, because a lot of assumptions go into interpolations, but they do give people a general idea, which is positive overall.

Gareth: I see examples of how national level action is too generic, and there are good examples of local action and local autonomy to get things done – which is achieving some results. I wonder if there are certain types of finance packages and solutions for urban improvement projects that can have air quality improvement requirements linked to their required goals and objectives to be achieved to secure the finance?

Ana: US local areas have a lot of autonomy. A lot of cities are doing some interesting work with their climate and resilience plans. I appreciate that in other parts of the world government is much more centralised. Perhaps we need a good balance of autonomy with central guidance to help steer things. A national or state government can help to set the tone for local areas, which can be combined with people who care about their own neighbourhoods where there is a passion to get things done.

Gareth: What would you say are some of our biggest areas of focus over the next ten years for the world's air quality?

Ana: Up to 2030, transport especially in developing countries such as Africa and SE Asia. That's my key point if I had to choose. Second would be a way to tackle the big agricultural burning that takes place in many parts of the developing world. How can the economic drivers to it be changed? It's a tough challenge because of the economic drivers of agricultural livelihoods in such places, but it's growing in size, and we need to work out how to tackle it.

Gareth: Thank you very much for your thoughts and perspectives on the challenges of ways to improve urban air quality, Ana. Some very interesting insights!