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I will be brief. There are two dimensions to the air pollution and climate change scenario. The first is the impact of air pollution on climate change, and the second is the impact of climate change on air pollution itself, the two faces of the same issue. I will first provide a little background and perspective on air pollution. Air pollutants comes in two forms, particles and gases, and you can divide each of those into pollutants that are either primary or secondary. Primary pollutants are those emitted from a source, and secondary pollutants are not, but are chemically formed in the atmosphere after primary precursors are emitted. Both particles and gases can be either primary or secondary, which is kind of interesting in the case of some particles.

Regarding the particle perspective, emitted particles are primarily either organic carbon or black carbon, otherwise known as elemental carbon, which is basically soot. Particles can also be formed secondarily in the atmosphere, which is an interesting notion, with particles being formed in the atmosphere from precursors, largely gases. Organic carbon is also a secondary pollutant - these are secondary organic aerosols formed through chemical reactions in the atmosphere. Very importantly, there are other secondary particles, sulphate particles and nitrate particles, that are formed entirely through chemical reactions from sulphur dioxide and nitrogen dioxide precursors through oxidation, and when coupled with an ammonium ion, will form a small particle.

Regarding some of the very familiar gases that are emitted, we have carbon monoxide, sulphur dioxide, nitrogen dioxide, methane, volatile organic compounds, and then, very importantly, we have the secondarily formed compound ozone, which is formed through precursors, nitrogen oxides and volatile organic compounds, in the presence of ultraviolet radiation or higher temperatures. Whereas most pollutants are warming, the important cooling pollutants, sulphate and nitrate, are often not appreciated.

Viewing air pollution on one axis and climate warming or cooling on the other axis, we can split into four quadrants. The two quadrants where there is little controversy are the lose-lose and the win-win ones. In the lose-lose quadrant, uncontrolled fossil fuel use as one example will increase air pollution and lead to increase in warming. In the win-win quadrant, we have reduced fossil fuel use, reduced methane, which does not really have a downside to it, and use of wind, solar and hydropower.

The more problematic and challenging quadrants are those where you have trade-offs, where you either win with air pollution or lose with climate, or win with climate and lose with air pollution. A great example of that of light-duty diesel in the lose-win category. There is an older seminal paper (Mazzi and Dowlatabadi, 2007) that looked at the UK policy of encouraging reduction in CO2 emissions resulting in increased light-duty diesel vehicle use, with in turn projected decreases in CO2 emissions and substantial benefits to climate. The downside was the increase in black carbon as a result of increased diesel use, which is not just a warming pollutant but also has substantial health implications due to increased particulate concentrations. It was estimated that this would result in approximately 100 excess deaths per year, and all the morbidities that underlie the fact that there is increased mortality. Therefore, there was a trade-off between improving climate and degrading air pollution and harming health.

The win-lose category is also interesting where one improves air pollution while creating disbenefits to climate. One example is sulphur control, which was a major victory in the US in the context of controlling acid rain. Controlling sulphur content in coal and in power plants had a major impact on air pollution, with large reductions in sulphate concentrations, which is a cooling pollutant. So, in this case reducing air pollution produced a disbenefit with respect to climate. A second good example is catalytic converters in automobiles. We have three-way catalytic converters in automobiles, one of which oxidizes carbon monoxide because we want to reduce carbon monoxide concentrations.

The result of oxidising carbon monoxide is to produce CO2, and clearly then you have a disbenefit in terms of the climate change scenario but a benefit in terms of the air pollution scenario.

The last thing I will touch on is the interaction of climate change and air pollution, and the two most highly profiled scenarios are those with respect to ozone and with respect to particular matter. Ozone is projected to increase with increasing temperatures and increasing UV radiation, just because there is more secondary formation of ozone due to atmospheric chemical reactions, in addition to the increase in precursors to ozone. Regarding particulate matter, it is also projected to increase with increasing temperatures, both the secondary variety from increased reactions, as well as the primary particles from increased wildfires and dust.

I will leave you with these four points. While most air pollutants are climate warming, some important ones are climate cooling, and that complicates mitigation strategies. Air pollution climate change trade-offs are important to consider in mitigation, and I highlighted instances of win-lose and lose-win scenarios. Something I did not touch on was a focus on sources in mitigation rather than individual pollutants, and finally there was the topic I touched on very briefly, which was that climate change is expected to increase concentrations of some pollutants, with implications for health as a result of the increase in pollutants.