Using green infrastructure to improve urban air quality

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Why urban air quality matters

- Air pollution is the biggest environmental risk to health
- 92% of global urban population live in cities that exceed WHO air quality guidelines
- Globally, outdoor air pollution kills ~3 million people/yr
- Air pollution causes ~50,000 premature deaths/yr in the UK
- Air pollution problem areas stubbornly refuse to go away!


Image: British Heart Foundation


Image: University of Manchester

World Health Organization, 2016; Landrigan, et al 2017 (The Lancet)

Health impacts of air pollution

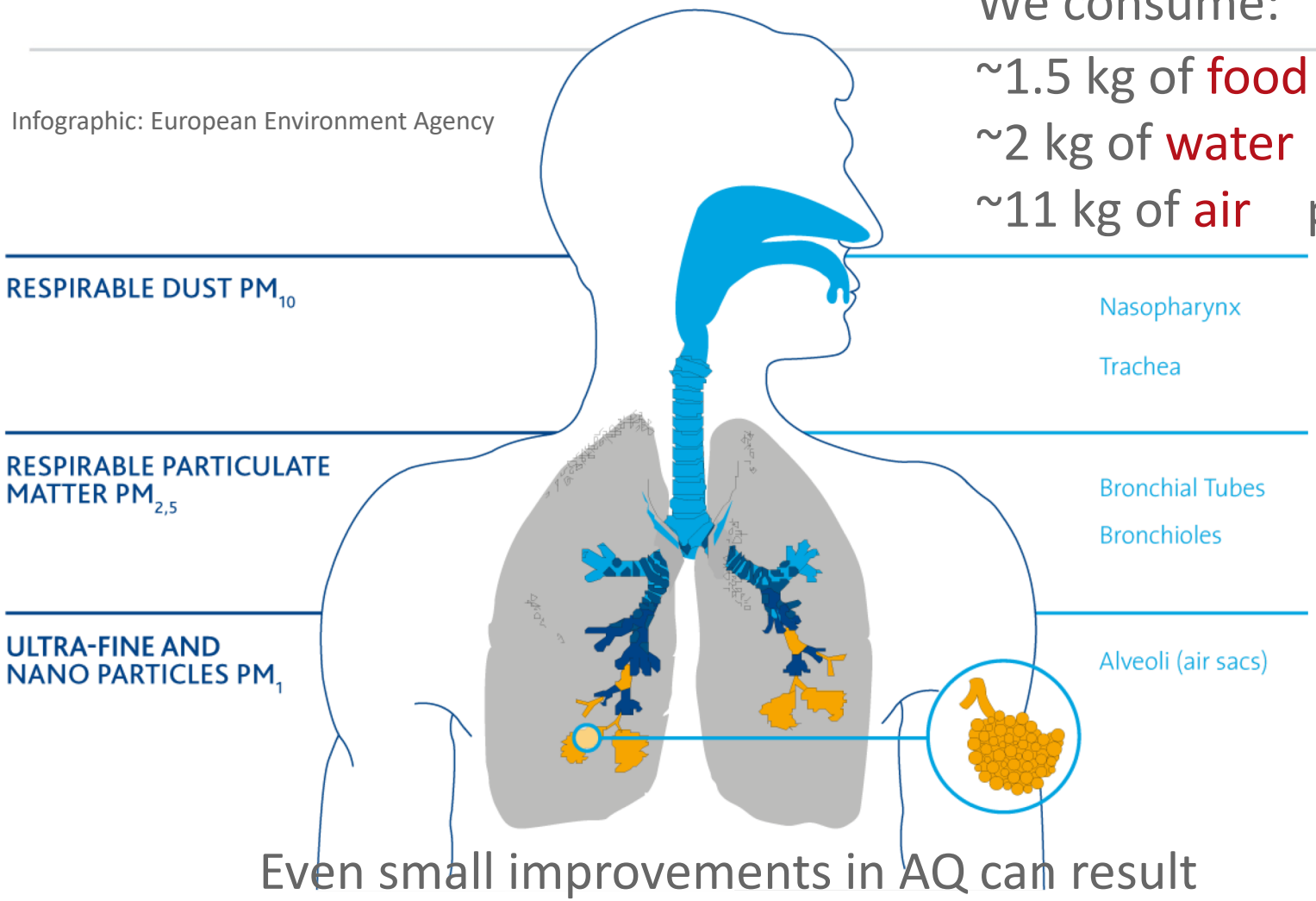
We consume:

~1.5 kg of food

~2 kg of water

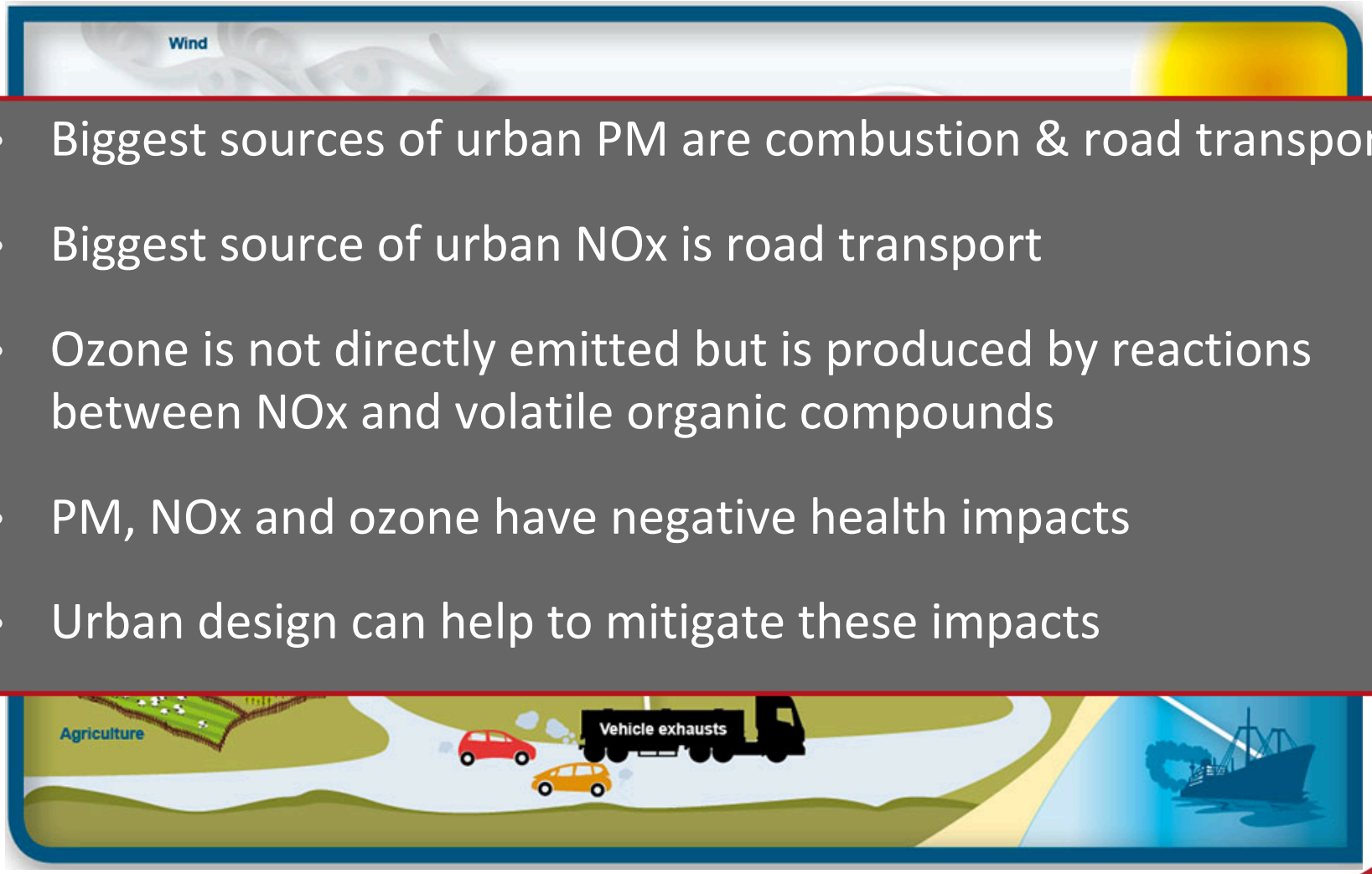
~11 kg of air per day

Infographic: European Environment Agency



Even small improvements in AQ can result in measurable improvements in health

Sources of air pollution



- Biggest sources of urban PM are combustion & road transport
- Biggest source of urban NOx is road transport
- Ozone is not directly emitted but is produced by reactions between NOx and volatile organic compounds
- PM, NOx and ozone have negative health impacts
- Urban design can help to mitigate these impacts

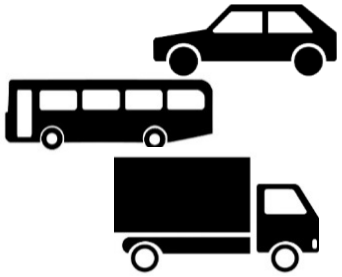
Reduce | Extend | Protect to mitigate air pollution impacts

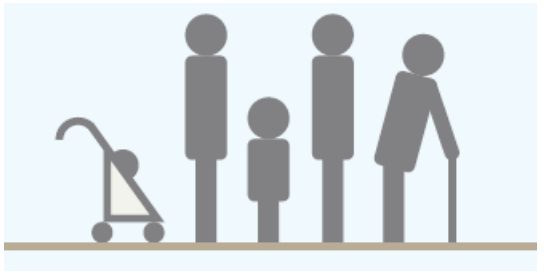
Lancaster University

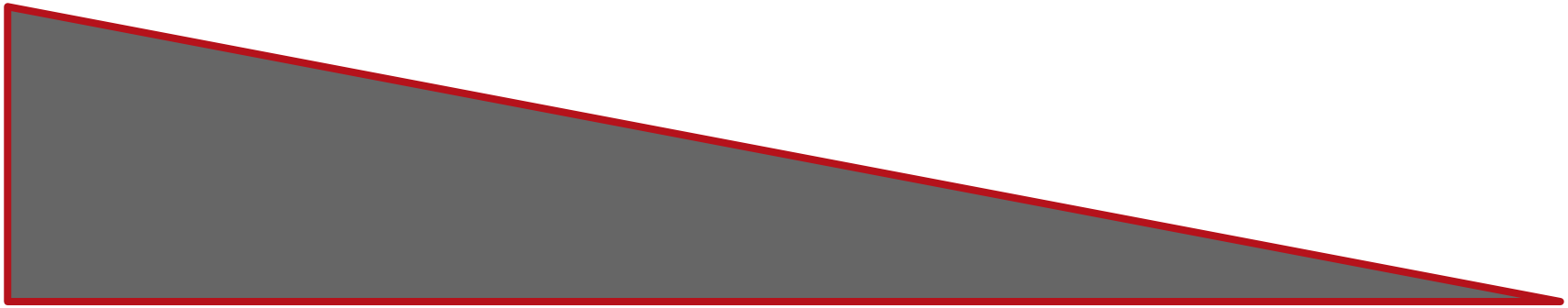
Reduce the SOURCE

Extend the PATHWAY

Protect the RECEPTOR





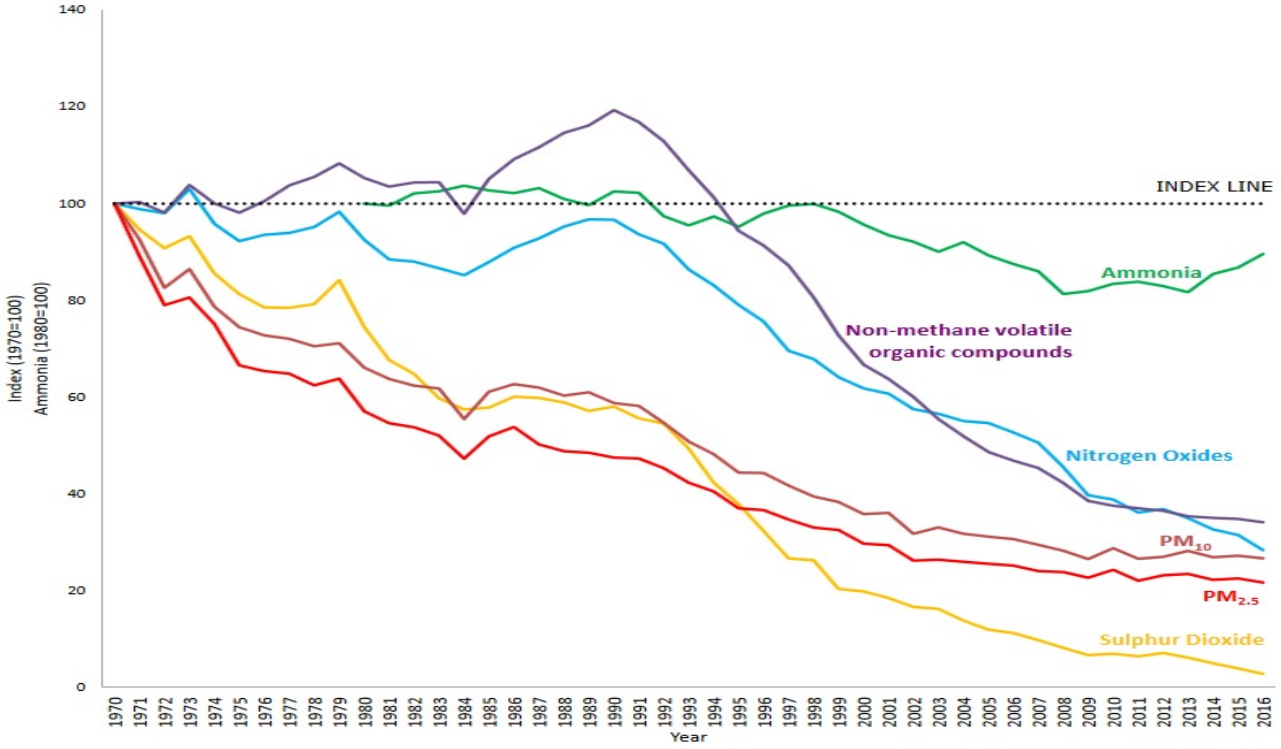


Reduce

The single most effective way to reduce urban air pollution is to reduce emissions

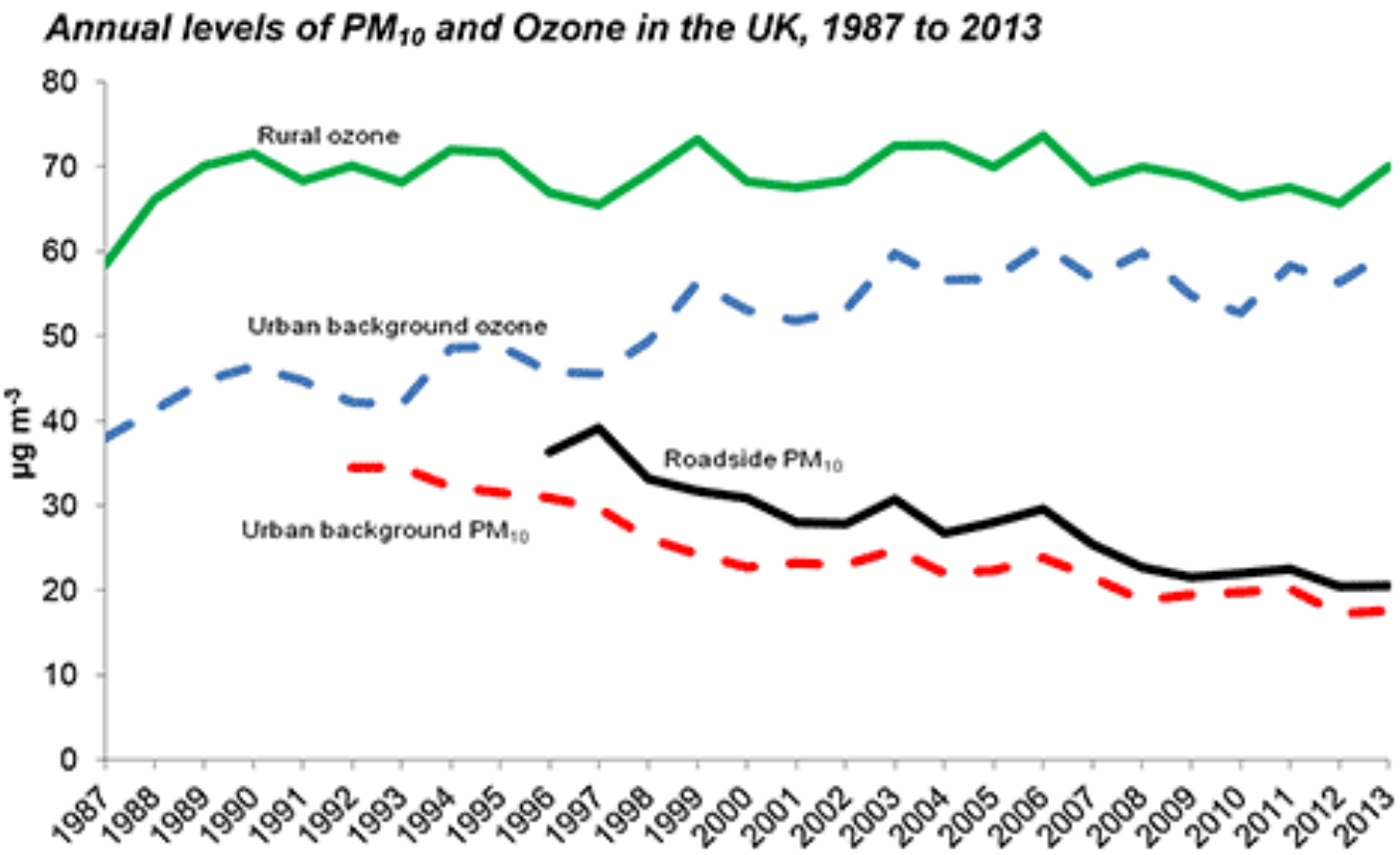
Defra National Statistics Release: Emissions of air pollutants in the UK, 1970 to 2016

Figure 1: Trends in UK sulphur dioxide, nitrogen oxides, non-methane volatile organic compounds, ammonia and particulate matter (PM_{10}, $PM_{2.5}$) emissions 1970 – 2016



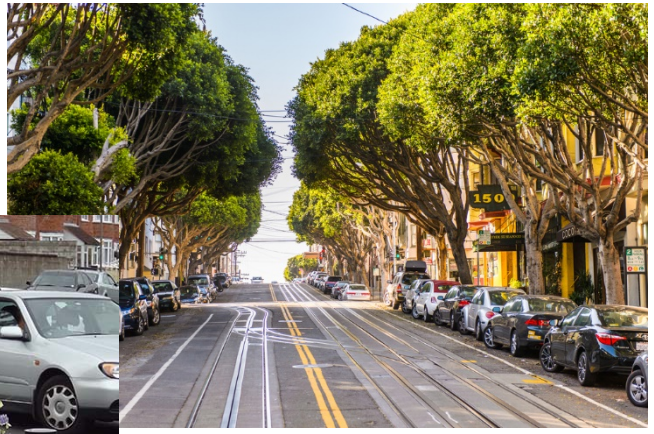
The index line is a comparator that shows the level of emissions if they had remained constant from the beginning of the time series.

Reduce



We have made progress, but not enough

Using green infrastructure (GI) to improve air quality (GI4AQ)



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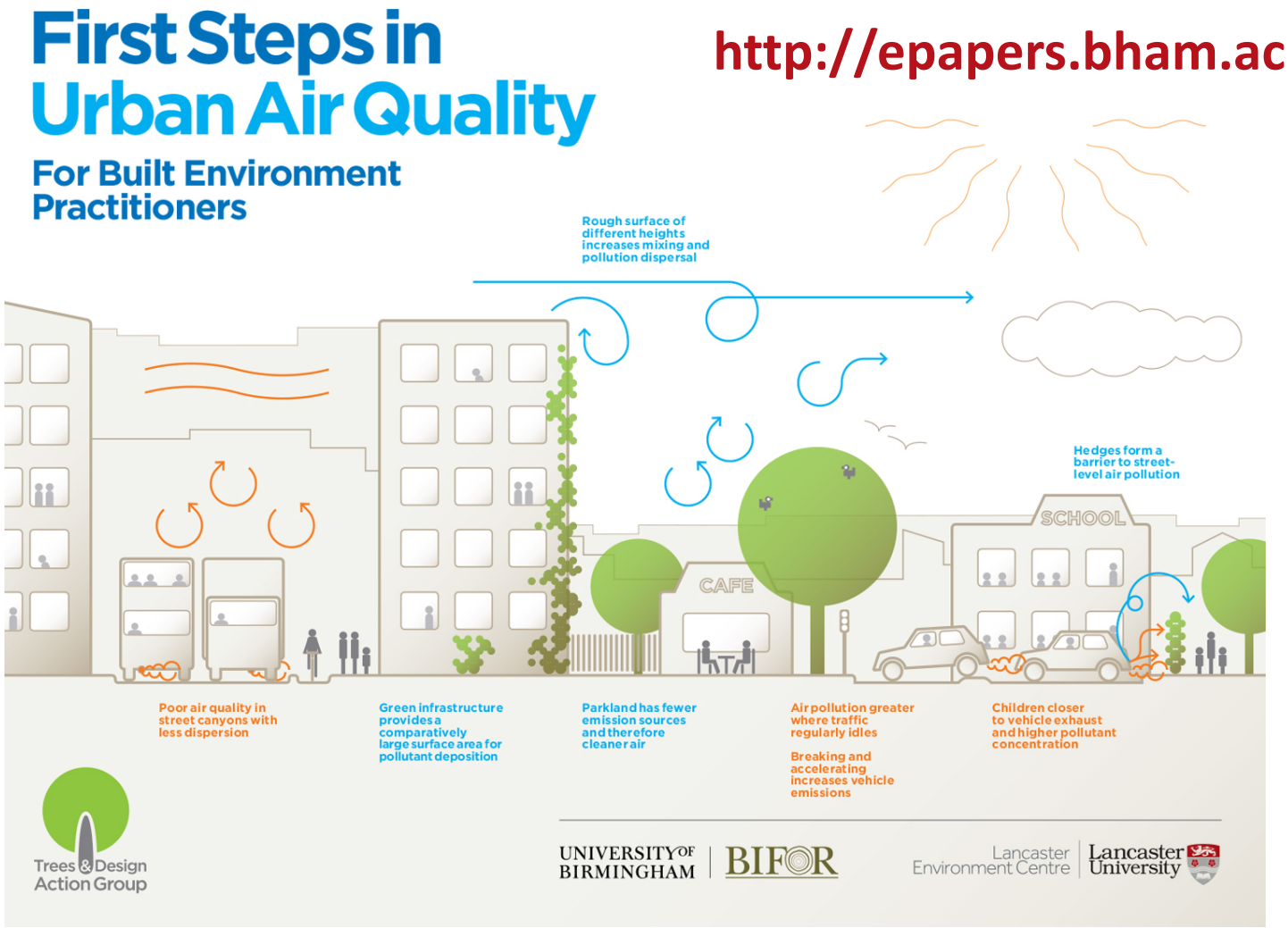
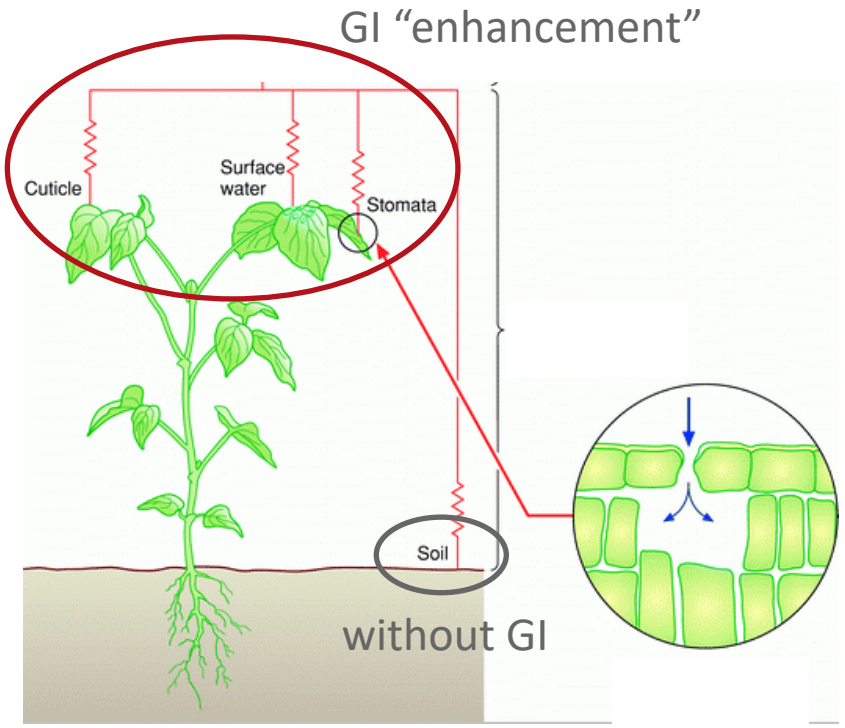


Protect | Deposition

Pollutant removal

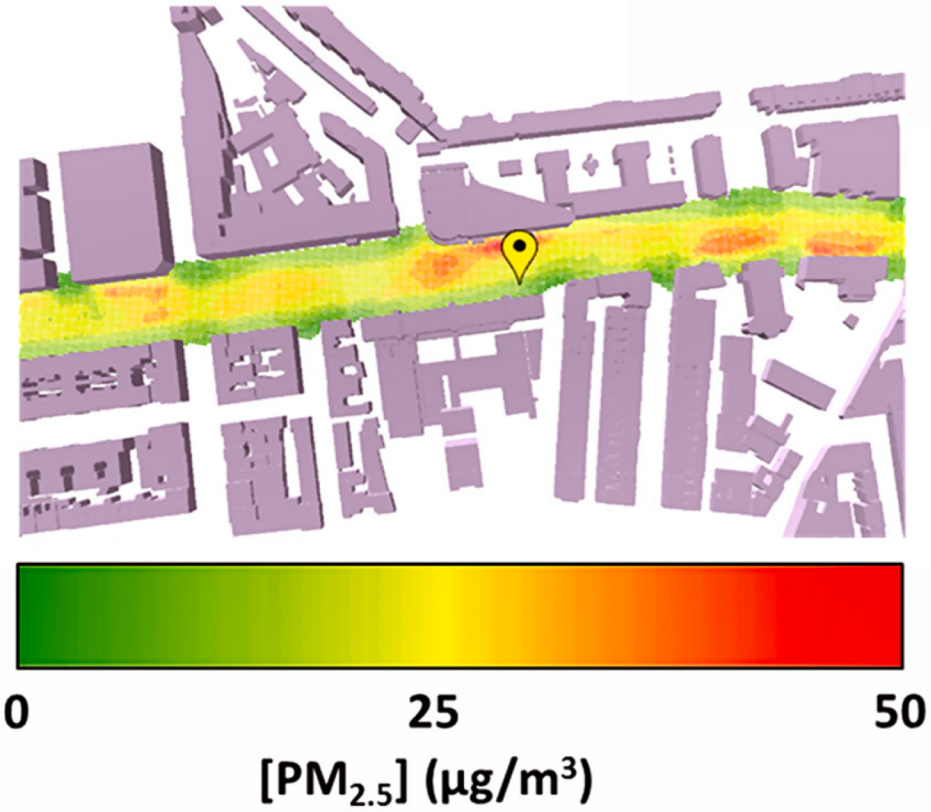
- Rate of dry deposition to a surface depends (in part) on:
  - Surface area
  - Surface morphology
- GI increases both relative to bare ground / buildings (e.g. area times ~4)



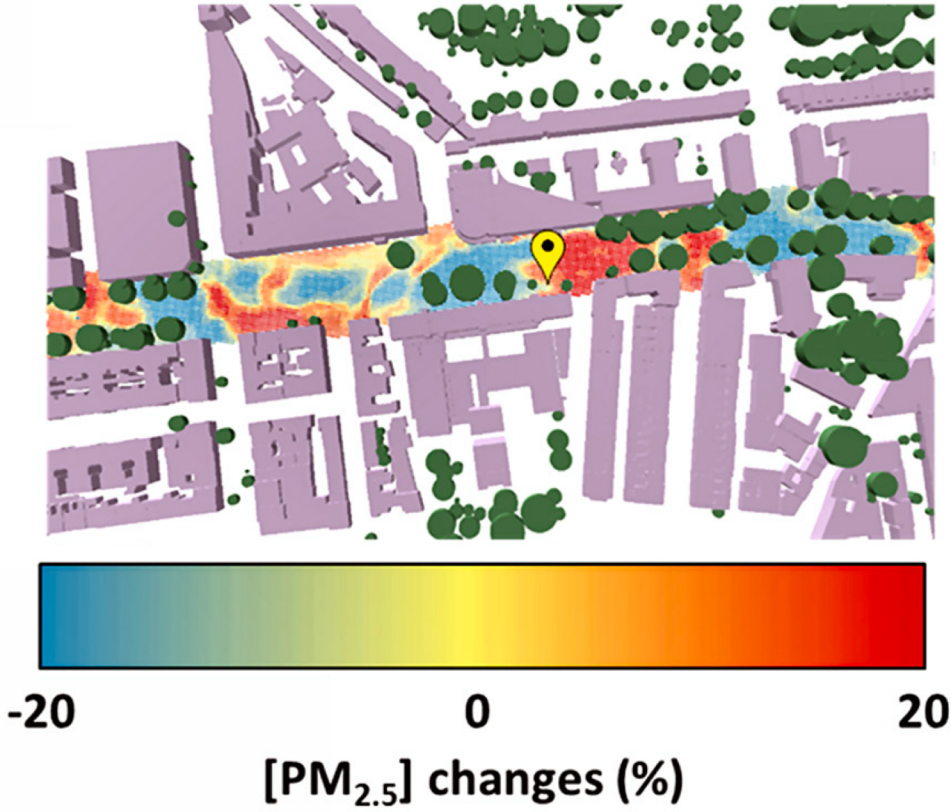
BUT to be effective in reducing concentrations

- you need a large quantity of GI
- acting on a small volume of air

Protect | Street Trees



PM2.5 concentrations
(without trees)

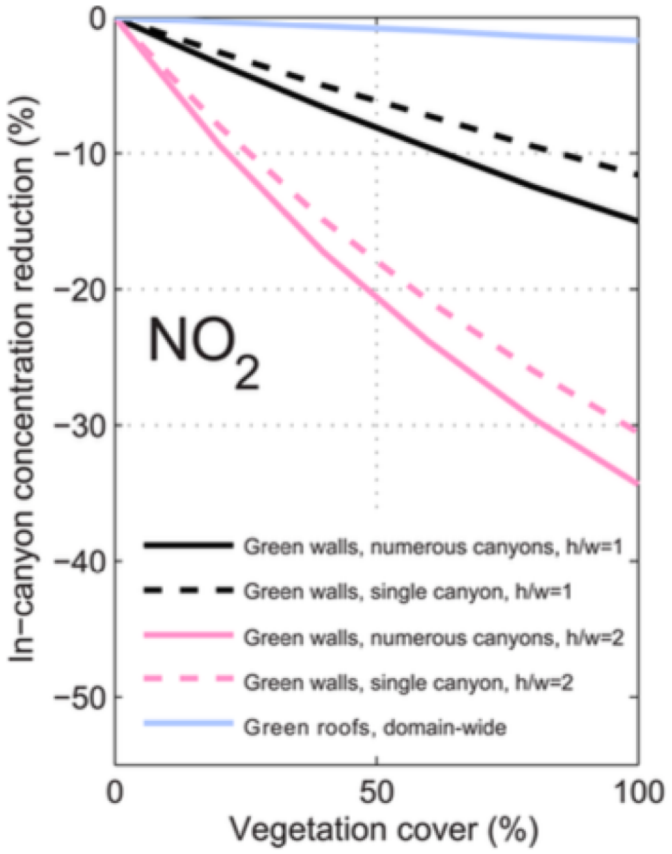


Changes in PM2.5 concentrations
(due to aerodynamic effect of trees)

Jeanjean et al., Urban Forestry & Urban Greening, 22, 41–53, 2017. doi: 10.1016/j.ufug.2017.01.009

Protect | Green Roofs & Walls

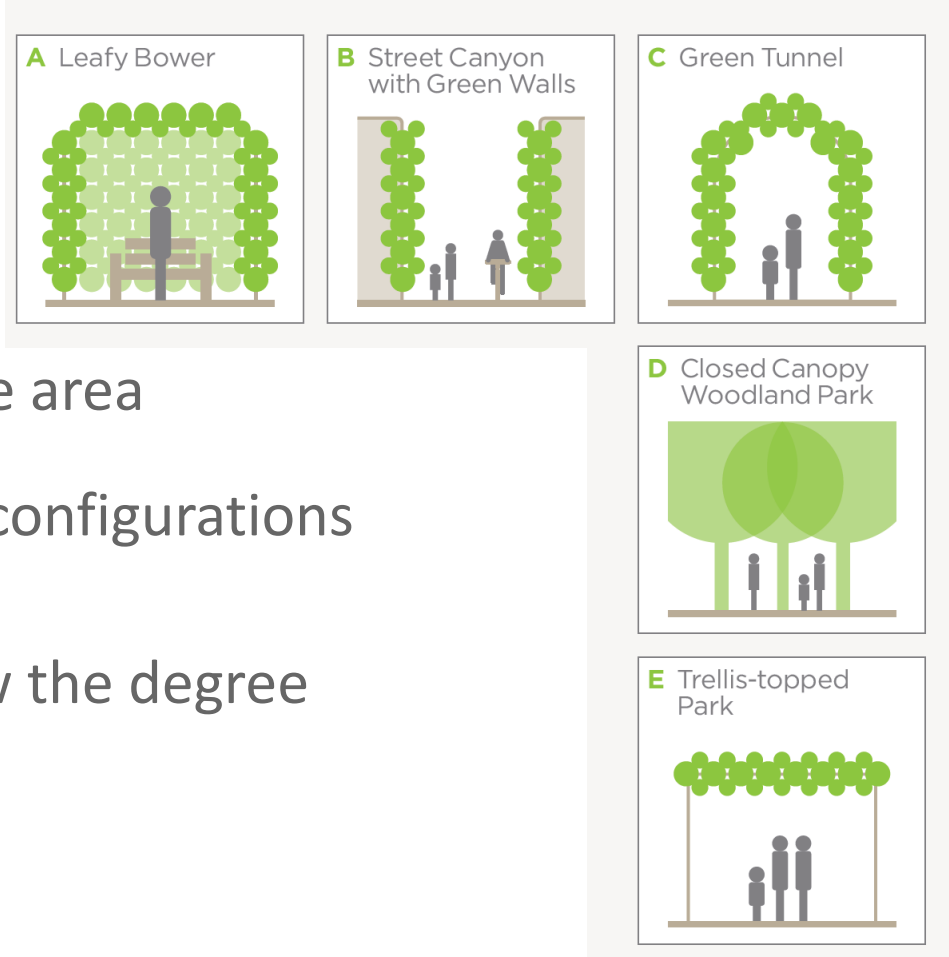
- Green roofs and green walls increase deposition rates
- But they are only **effective** in reducing concentration if acting on a **small volume** of air
- Green **roofs:**
  - open to a large column of air
  - negligible effect on pollutant **concentration**
- Green **walls** can be effective IF:
  - acting on **small volume** of air
  - relatively **large surface area**



Pugh, et al. Environ. Sci. Technol., 46 (14), 7692-7699, 2012. doi: 10.1021/es300826w

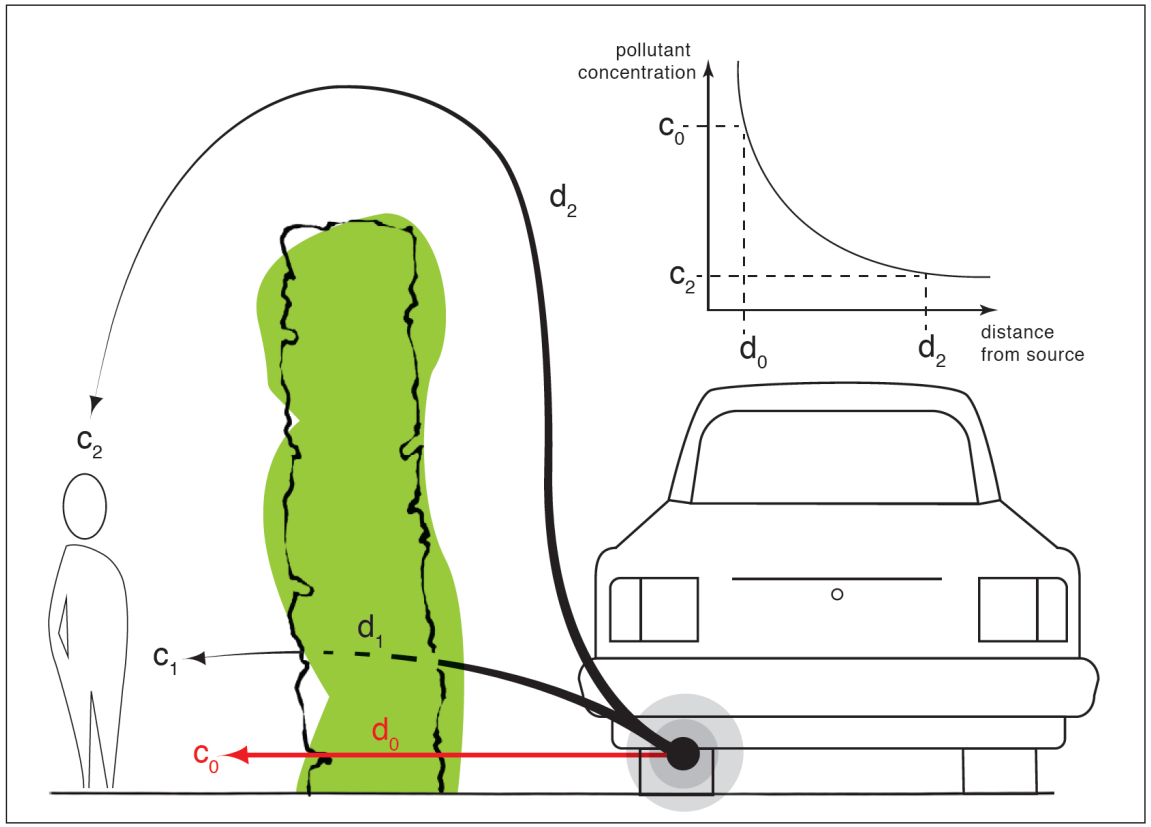
Protect | Green Oases

- Green oasis =
  - no emission sources
  - small volume of air
  - relatively large surface area



- GI can be used in many configurations to create green oases
- We don't currently know the degree of effectiveness of each

Extend & Protect | Green Barriers



- Impermeable barrier

-> extends path length

-> increasing dilution

- Green barrier

-> also enhances deposition

Extend & Protect | Green Barriers

Urban Form and AQ

But using GI4AQ is complicated because the morphology of the urban canopy is highly heterogeneous

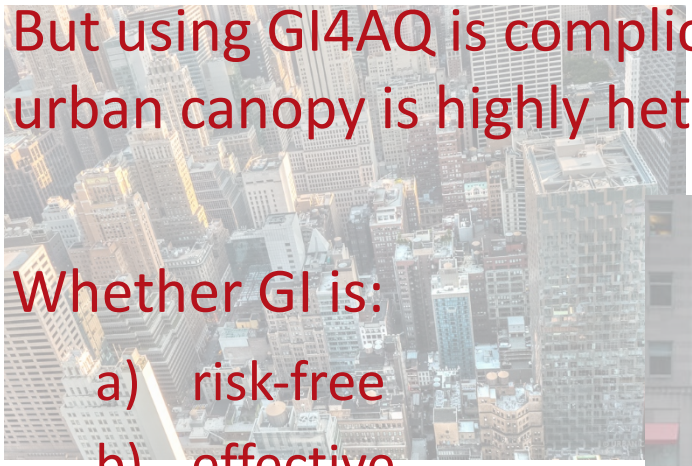
Whether GI is:

a) risk-free

b) effective

depends on:

- urban form
- location of pollution sources
- prevailing wind



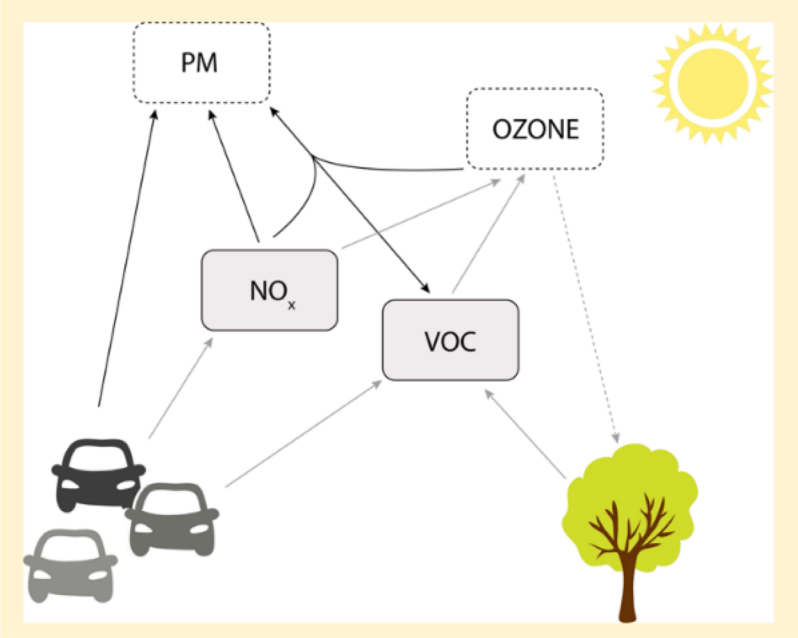




Biogenic VOCs

Vegetation emits biogenic VOCs

→ formation of secondary pollutants O_3 and aerosol (PM)



Churkina et al., Environ. Sci. Technol. 51, 6120-6130, 2017.
doi: 10.1021/acs.est.6b06514

The chemistry takes time →
impacts occur downwind of city

GI4AQ | Any Questions?

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