EcoCAR EV Challenge

- UC Davis was recently selected to participate on the EcoCAR EV Challenge in collaboration with GM, US DOE, MathWorks, and Argonne National Laboratory
- Designing and building an autonomous all-wheel drive electric vehicle
- Students at any level and major are eligible and encouraged to participate
- 4-year project
- Info session: Tuesday May 24, 5-6pm Kemper 1003
- https://forms.gle/RSHeFdNXjeV7biGz9

EVs and local air pollution

ECI 189G: Lecture 13

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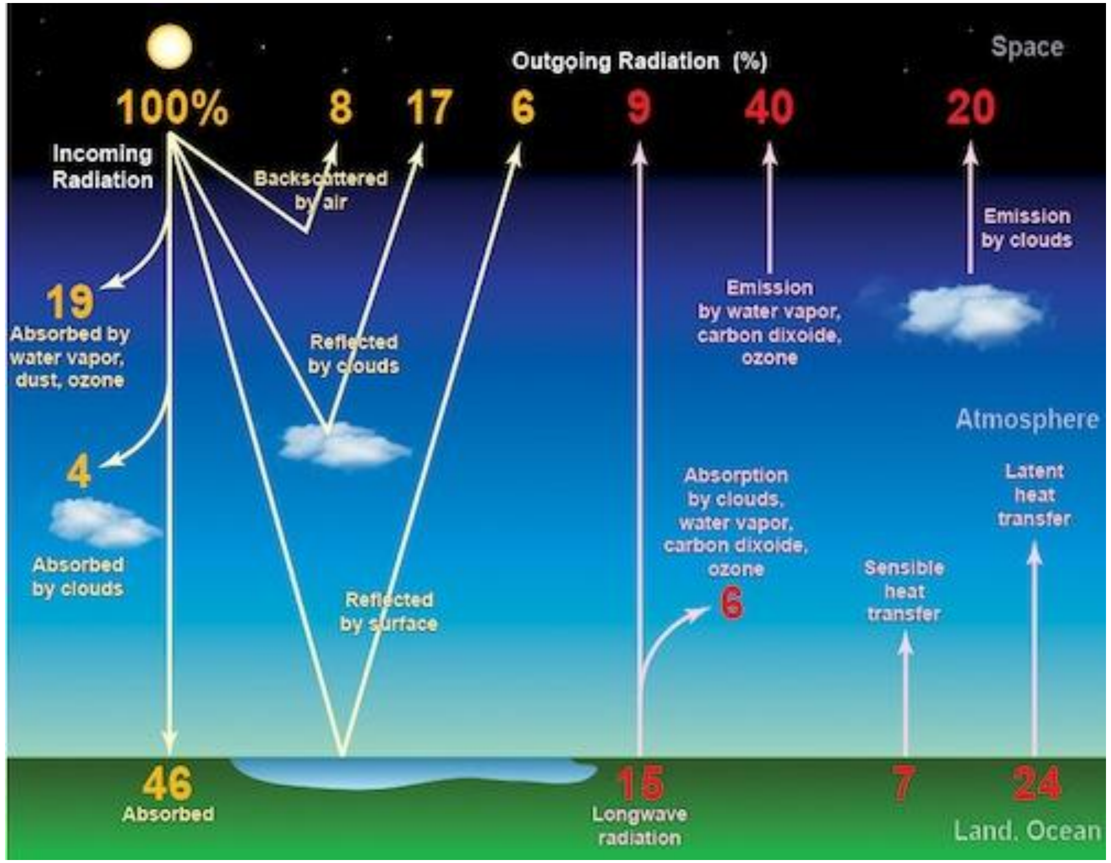
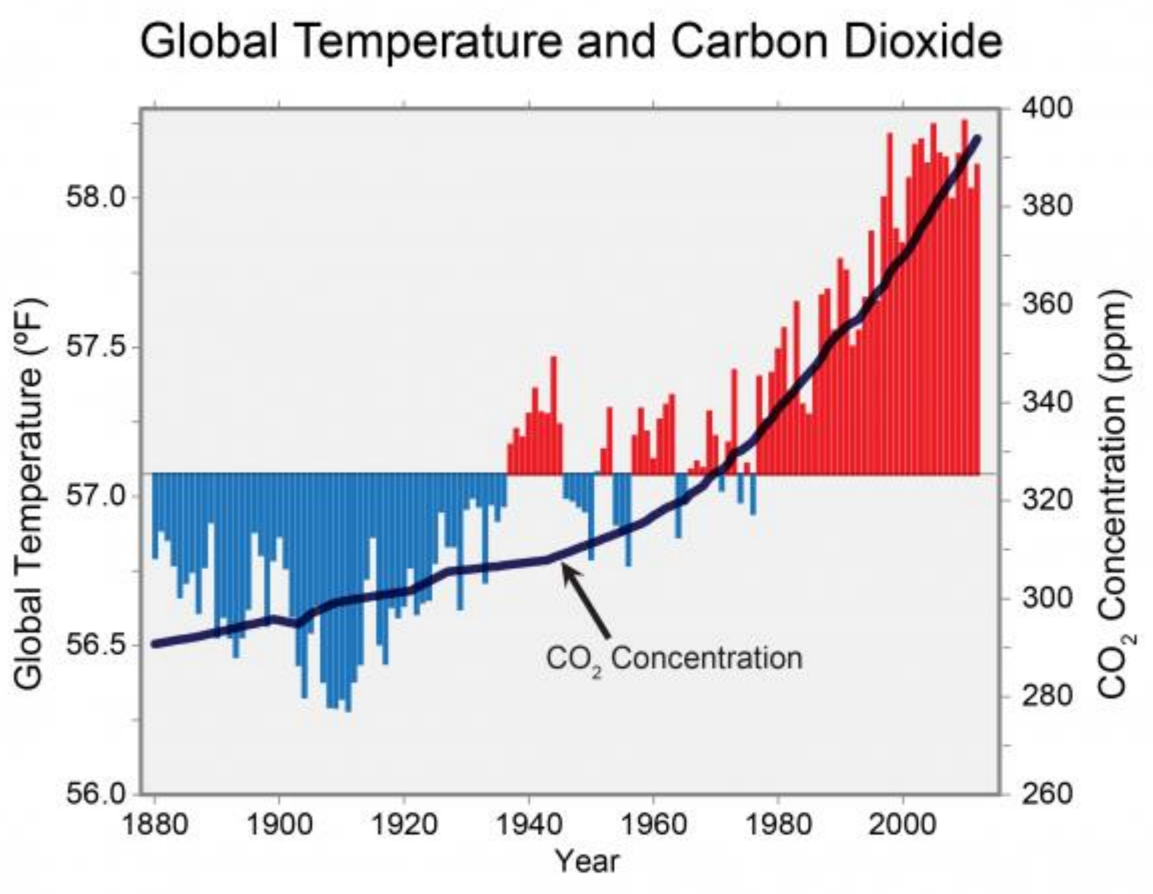
Spring 2022

Combustion emissions: local pollutants vs GHG emissions

- When fossil fuels are combusted, the emissions associated with combustion are categorized in two different ways:
  - **Greenhouse Gas Emissions (GHGs)**: chemicals from human activity that strengthen the greenhouse effect and ultimately lead to climate change.
  - **Local Air Pollutants**: emissions that lead to lower air quality that is associated with negative health outcomes or increased toxicity for the local environment.

Carbon dioxide – greenhouse gas





- CO_2 prevents outgoing radiation energy, trapping heat in Earth’s atmosphere (hence greenhouse gas [GHG])

Other GHGs and CO_2e

- While CO_2 is the most prevalent GHG, there are other pollutants that have a larger effect on global warming
- Note that the difference between 20 and 100 year time periods due to how long the compounds exist in the atmosphere

IPCC Sixth Assessment Report Global Warming Potentials

Greenhouse Gas	100 Year Time Period			20 Year Time Period		
	AR4 2007	AR5 2014	AR6 2021	AR4 2007	AR5 2014	AR6 2021
CO_2	1	1	1	1	1	1
CH_4 fossil origin	25	28	29.8	72	84	82.5
CH_4 non fossil origin			27.2			80.8
N_2O	298	265	273	289	264	273

Types of air pollution

- The major air pollutants:
  - Carbon Monoxide (CO)
  - Lead
  - Nitrogen Oxides (NO_x)
  - Ozone (O_3)
  - Particulate Matter (PM)
  - Sulfur Dioxide (SO_2)

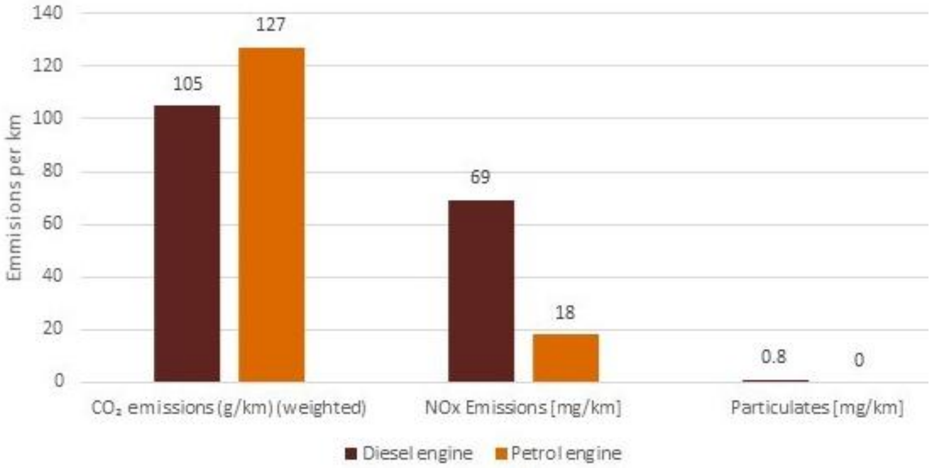
Carbon Monoxide (CO)

- CO is a colorless, odorless gas resulting from incomplete combustion of fossil fuels
- Carbon monoxide binds with hemoglobin competitively with oxygen—low levels can lead to cardiovascular effects and high levels can be poisonous and lead to death
- Primarily from fossil fuel engines (motor vehicles, construction equipment, boats). Also arises form industrial processes and wood burning

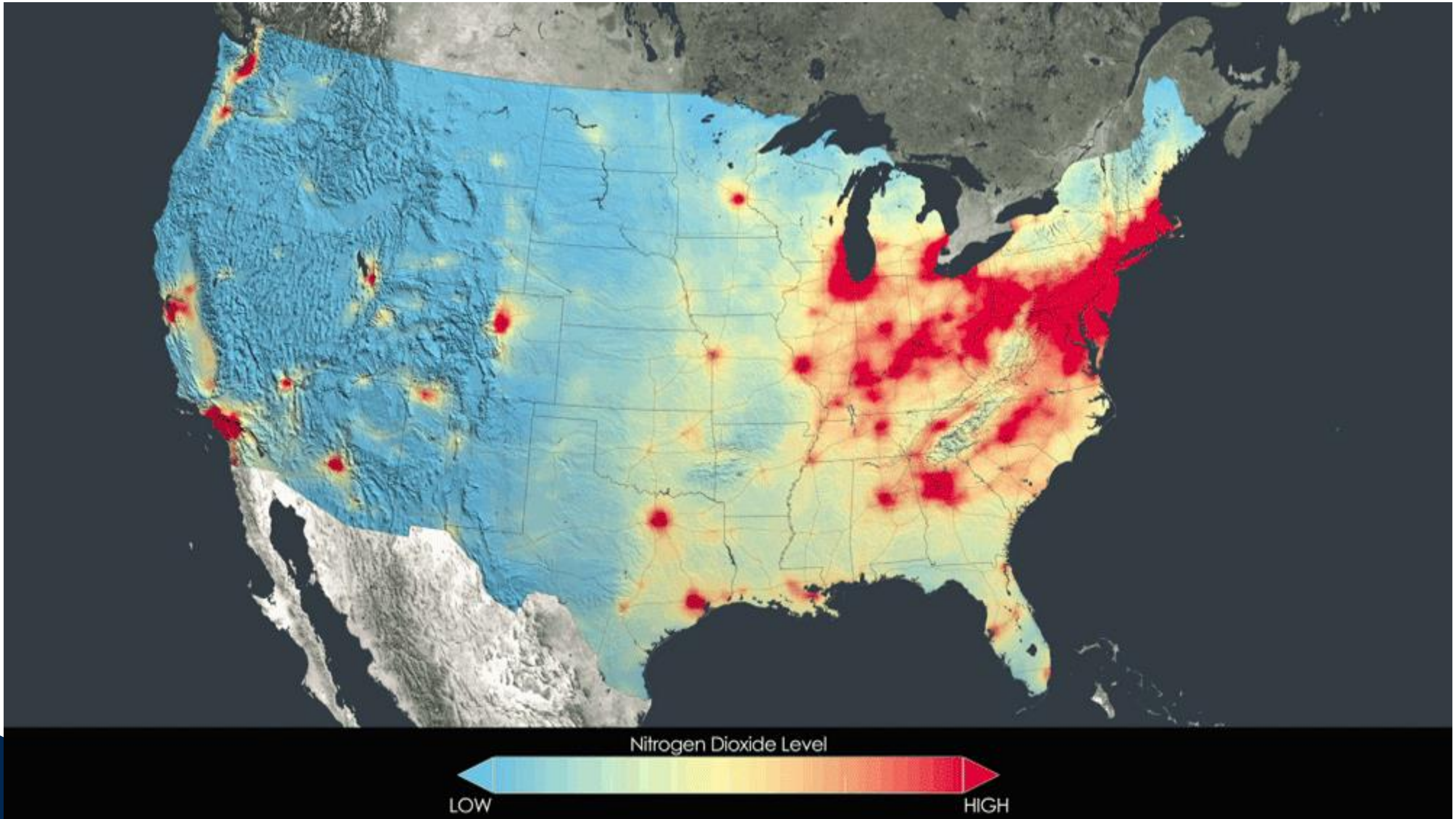
Nitrogen Oxides (NO_x)

- NO_x are a family of poisonous, reactive gases formed by combustion at high temperatures
- Often appears as a brownish gas, it can interact with volatile organic compounds to produce smog and acid rain
- Known to exacerbate asthma and has been associated with heart disease, diabetes, birth outcomes, and even increased mortality rates
- Comes from both mobile sources (particularly from diesel) and industrial sources such as power plant boilers and turbines

Figure 1: Diesel and petrol emissions test performance for a UK top selling mid size car (with the same engine power output)



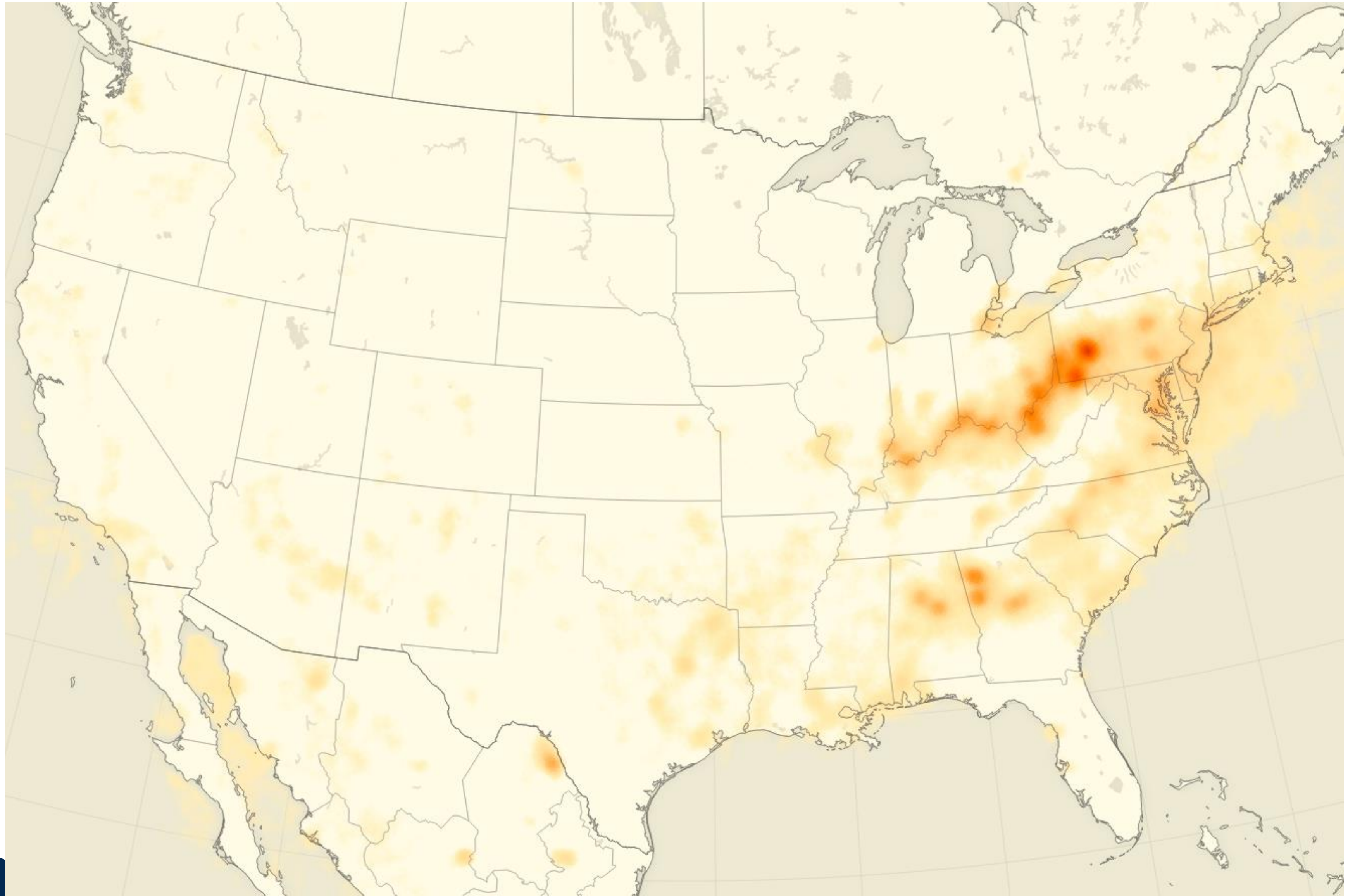
NO_x in the US, change over time



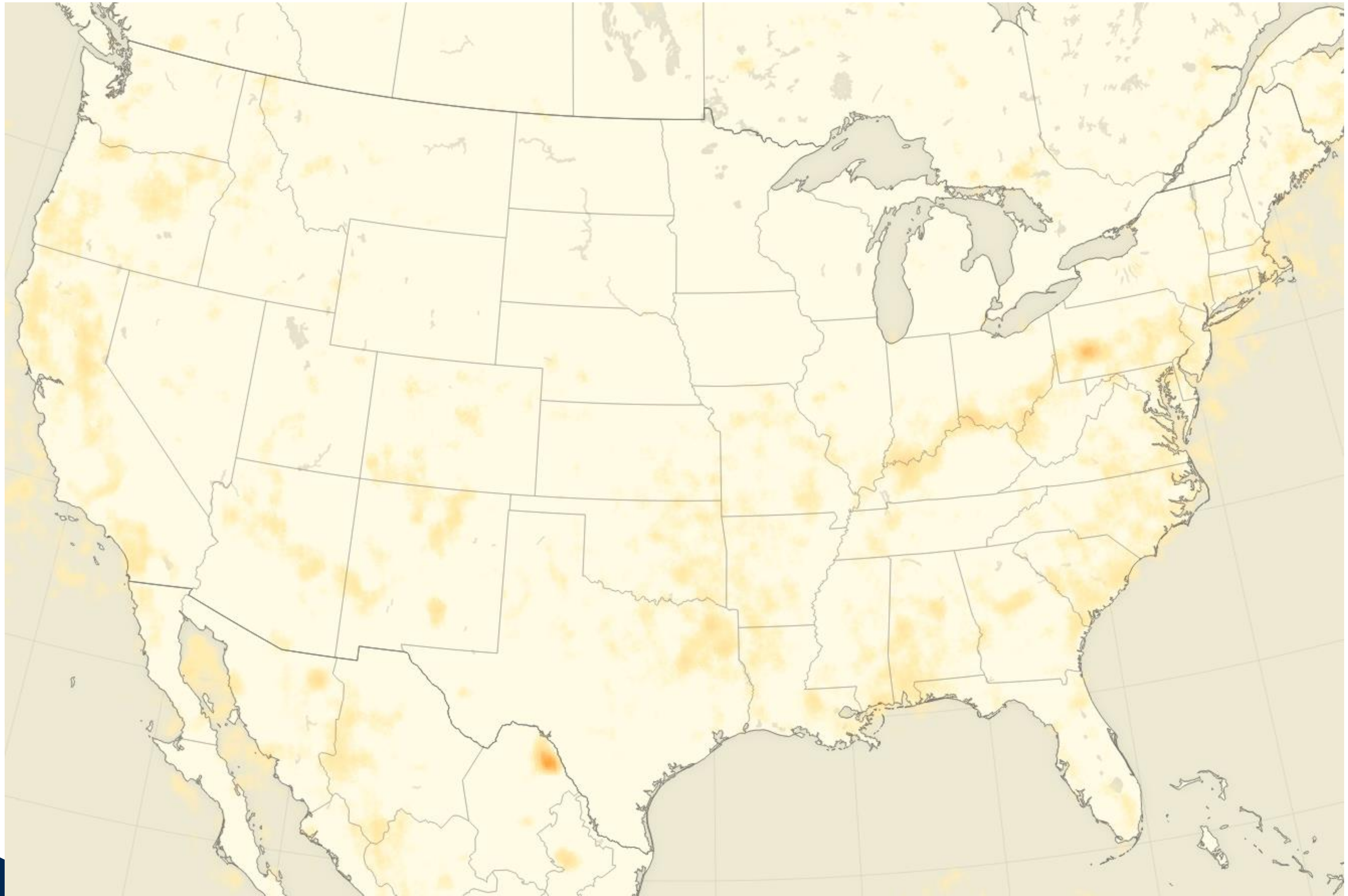
Sulfur Oxides (SO_x)

- Most often in the form SO_2, a common precursor to acid rain
- Largest source of SO_2 is from fossil fuel combustion at power plants (especially coal plants)
- Harmful to respiratory system and causes difficulty breathing, can react with other compounds to form PM
- At high concentrations, acidity of SO_x can even damage plants

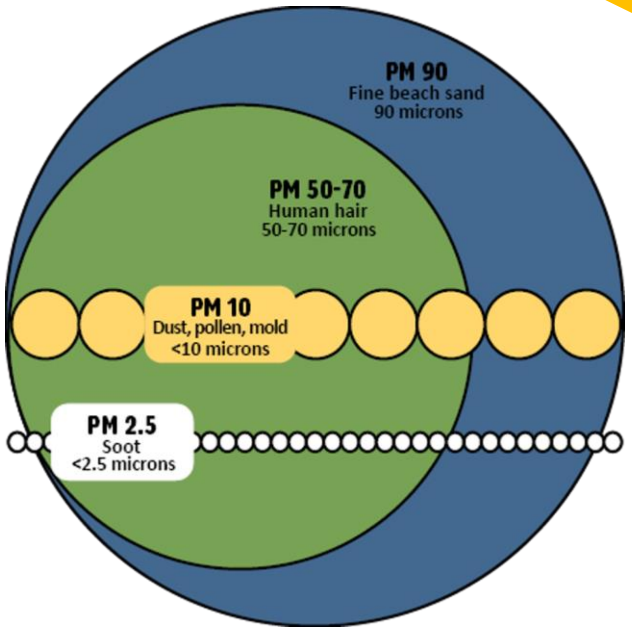
SO_x 2005-2007



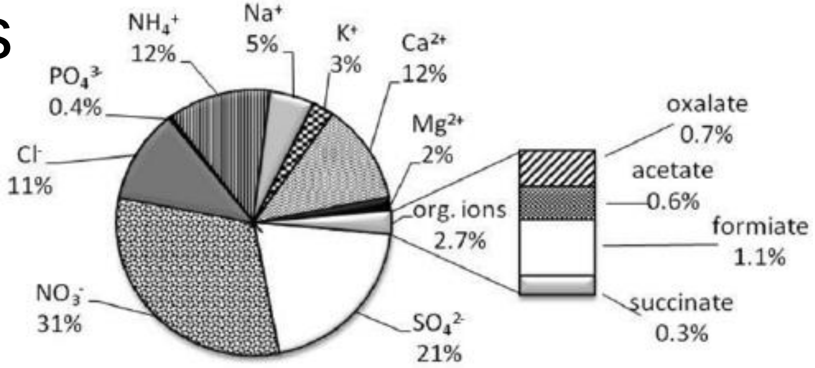
SO_x 2011-2014



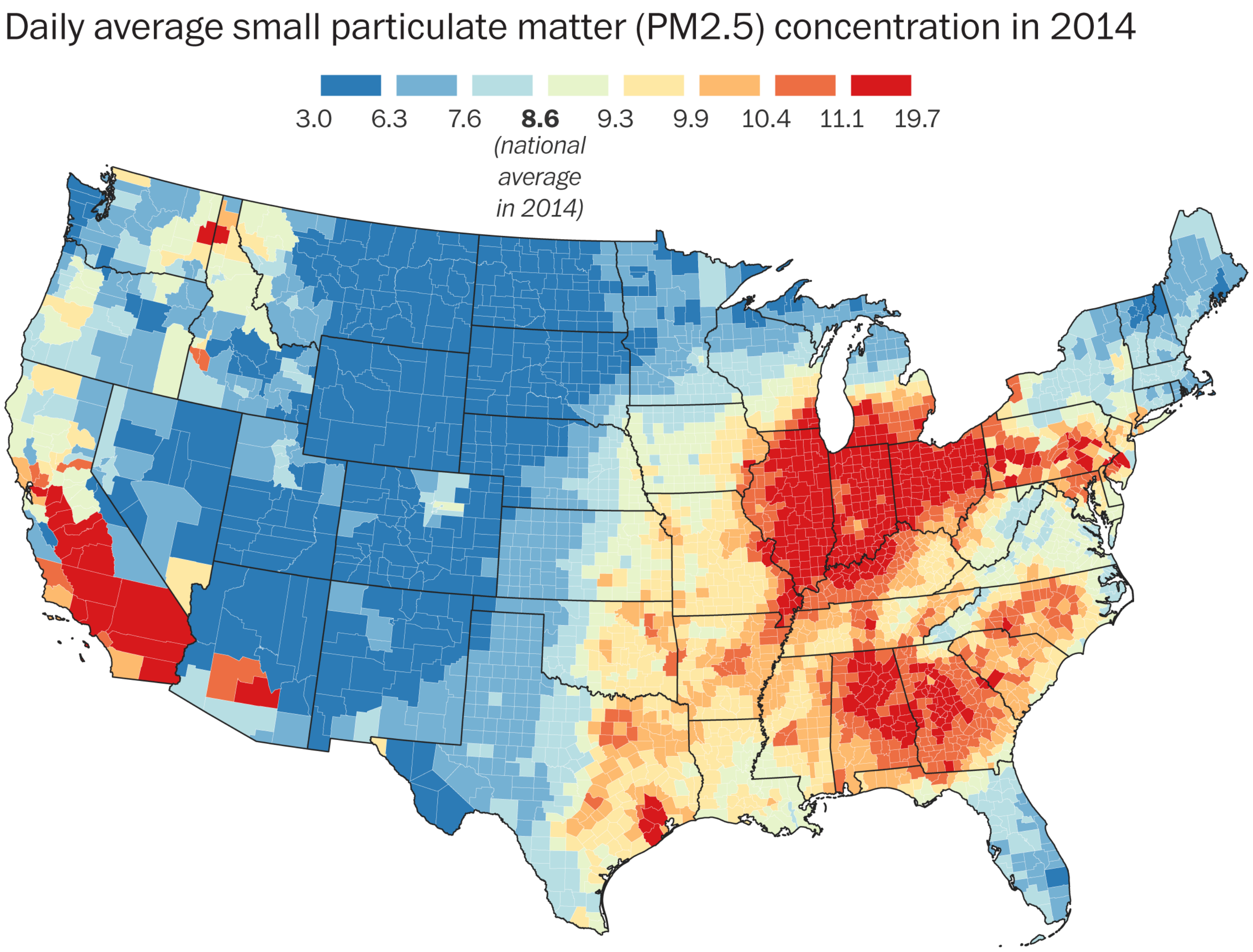
Particulate Matter (PM)



- Particulate matter are a mixture of solid particles and liquid droplets in the air
  - PM10, coarse particulate matter: particles of 10 micrometers or less
  - PM2.5, fine particulate matter: particles of 2.5 micrometers or less
- Cause health problems when PM10 and PM2.5 settle into the bronchi and lungs
- PM2.5 accounts for 4.2 million annual deaths worldwide—the fifth leading risk factor for death
- The dirtier the combustion, the more PM is emitted



Distribution of PM2.5 in the US



Source: Robert Wood Johnson Foundation County Health Rankings THE WASHINGTON POST

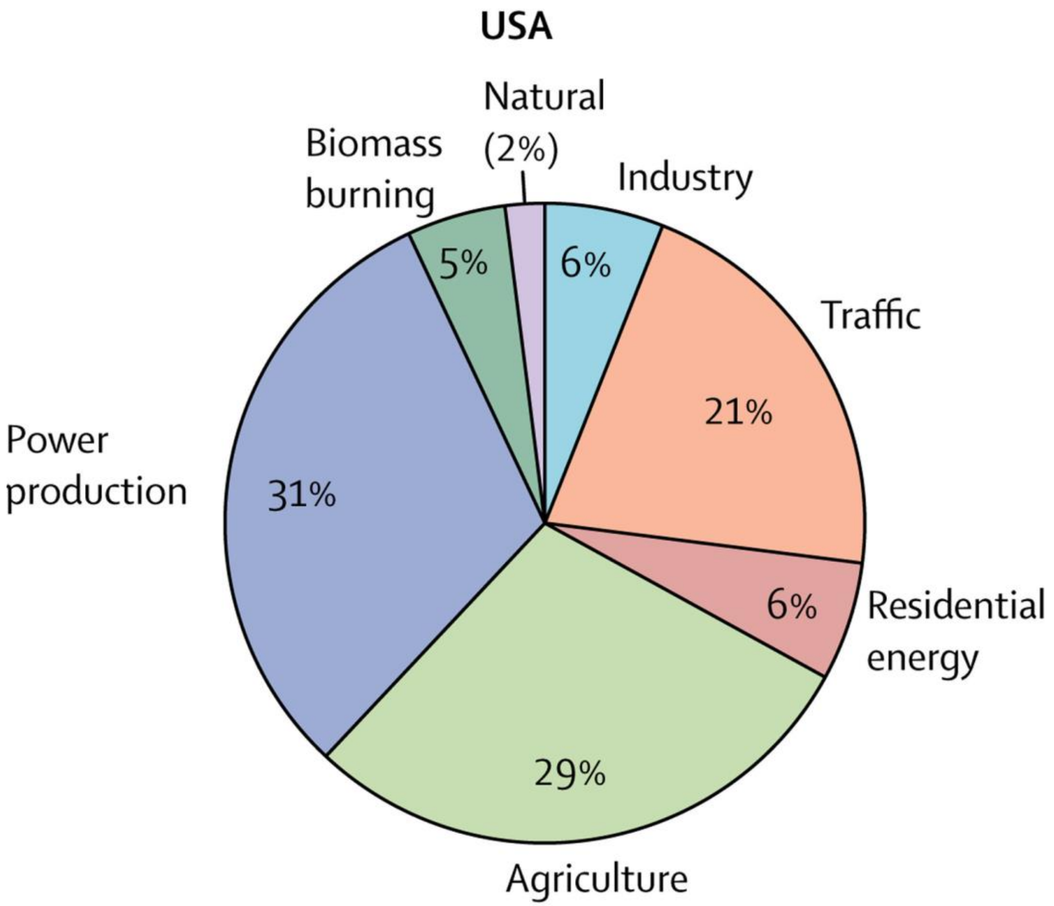
What is AQI?

- The EPA establishes a generalized “Air Quality Index” (AQI) that represents a “yardstick” for air pollution from 0-500.
- Pollutants included in the index are: ground-level ozone, PM, carbon monoxide, sulfur dioxide, and nitrogen dioxide

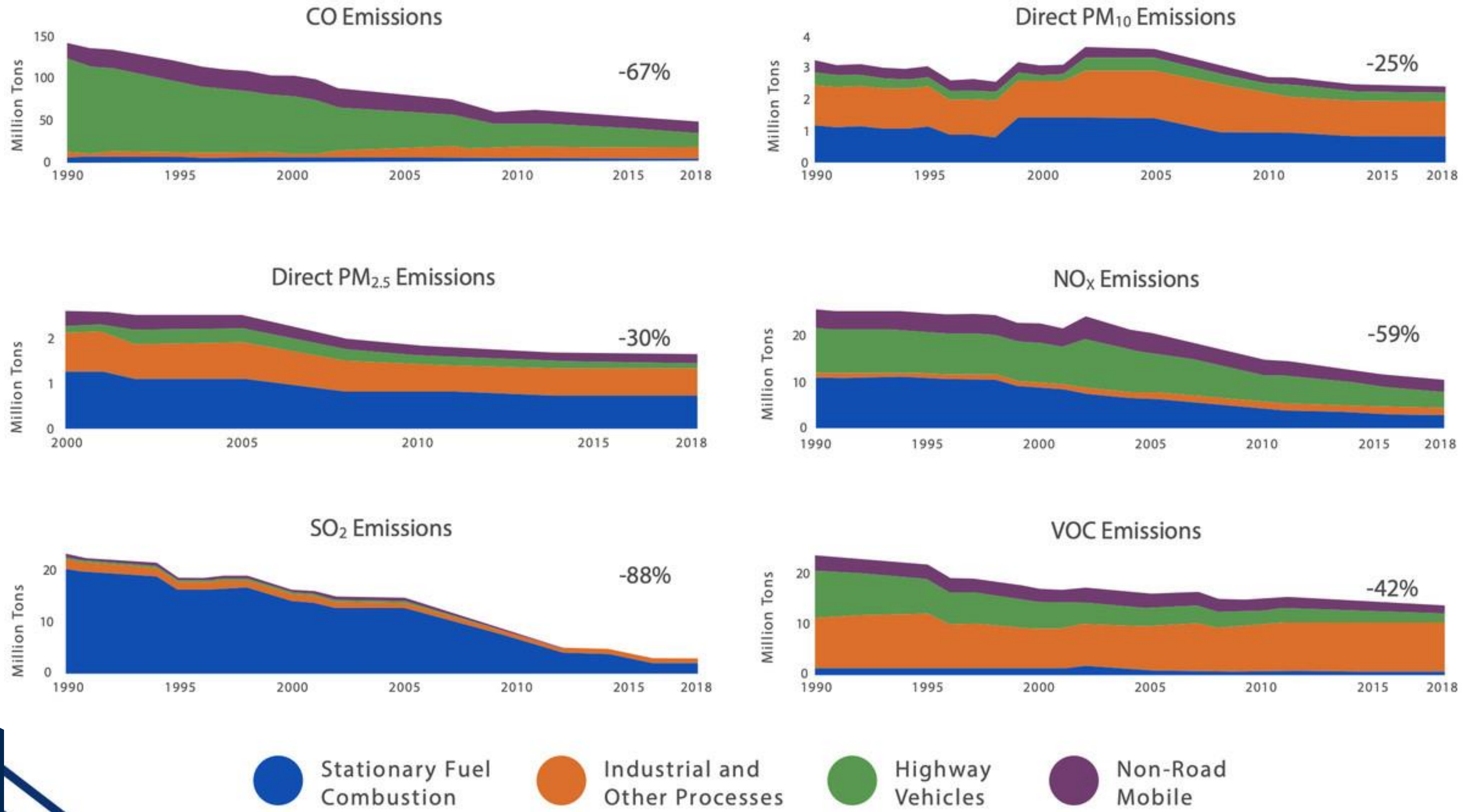
Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Major sources of pollution emissions

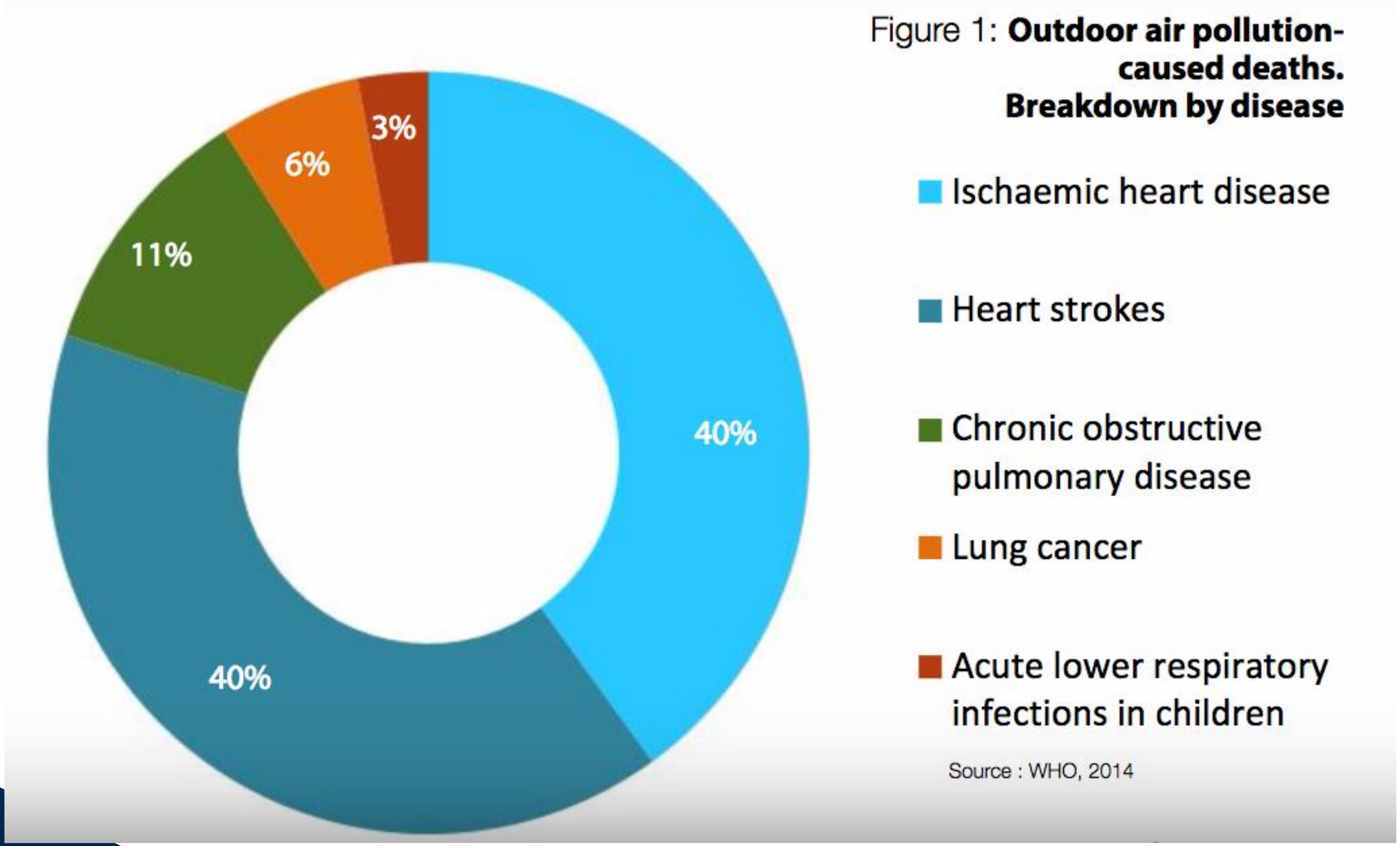
Emissions (10^6 tonnes / year)							
Source	CO	Particles	H/C's	NO_x	SO_x	Total	%
Transport	40.7	1.4	6.0	8.4	0.9	57.4	44.9
Stationary fuel combustion	7.2	1.8	2.3	10.3	16.4	38.0	29.7
Industrial Processes	4.7	2.5	8.3	0.6	3.1	19.2	15.0
Solid waste disposal	1.7	0.3	0.6	0.1	0	2.6	2.0
Miscellaneous	7.1	1.0	2.4	0.1	0	10.6	8.3
Total	61.4	7.0	19.6	19.5	20.4	127.8	
%	48.0	5.5	15.3	15.3	15.9		100



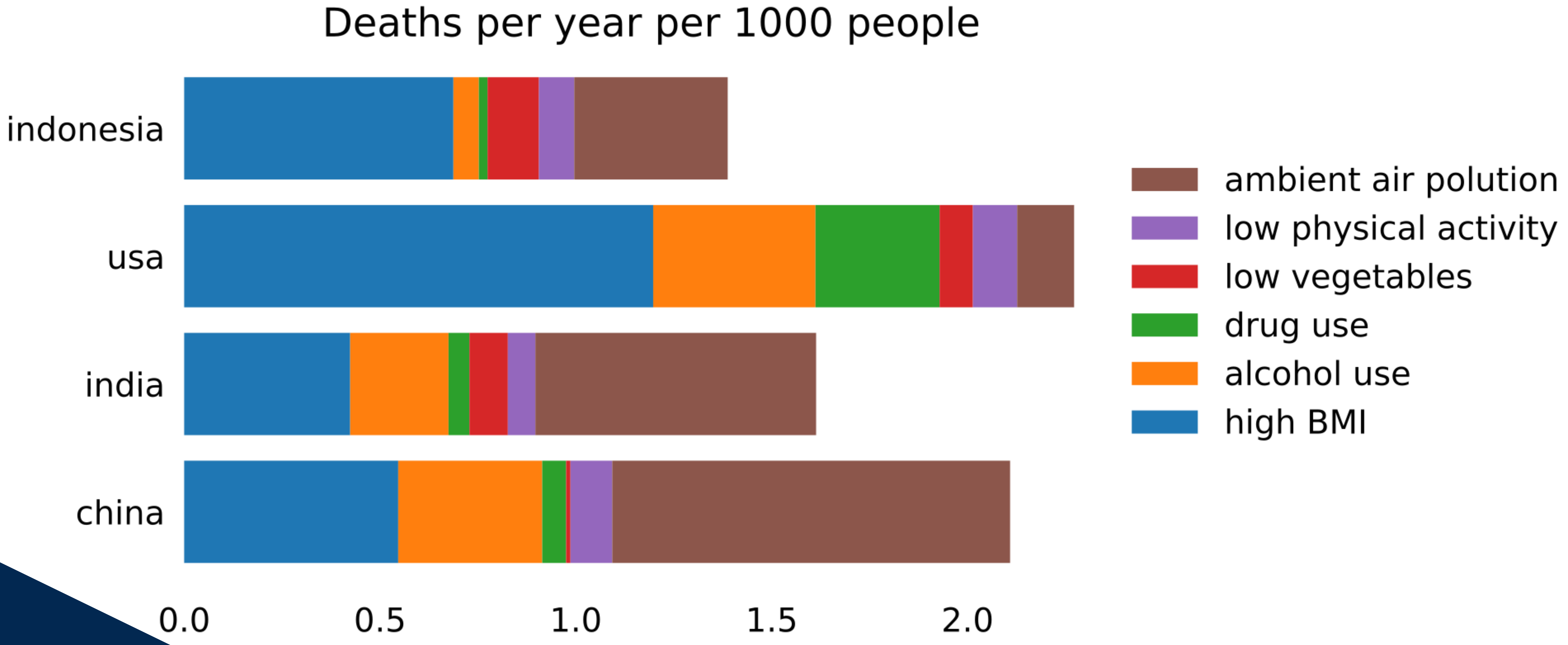
Changes in pollution over time



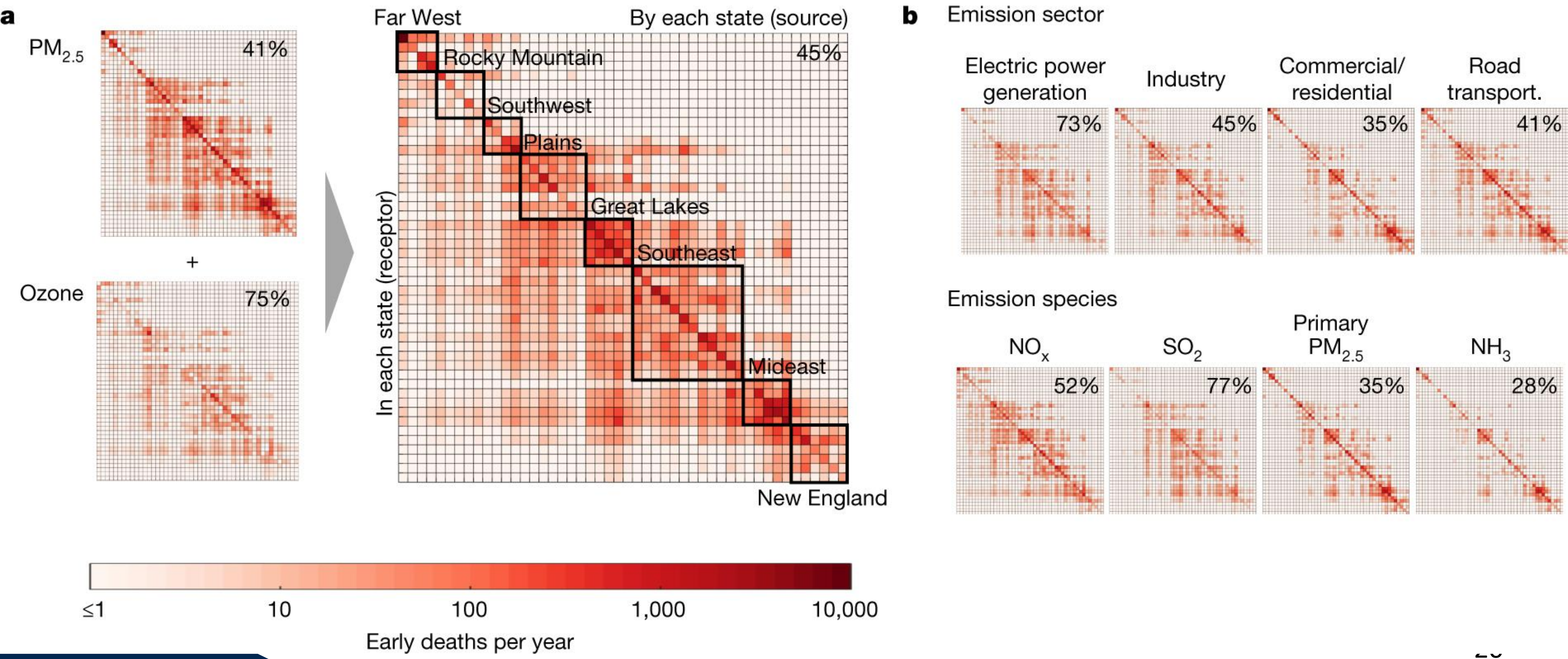
From air quality to health damages



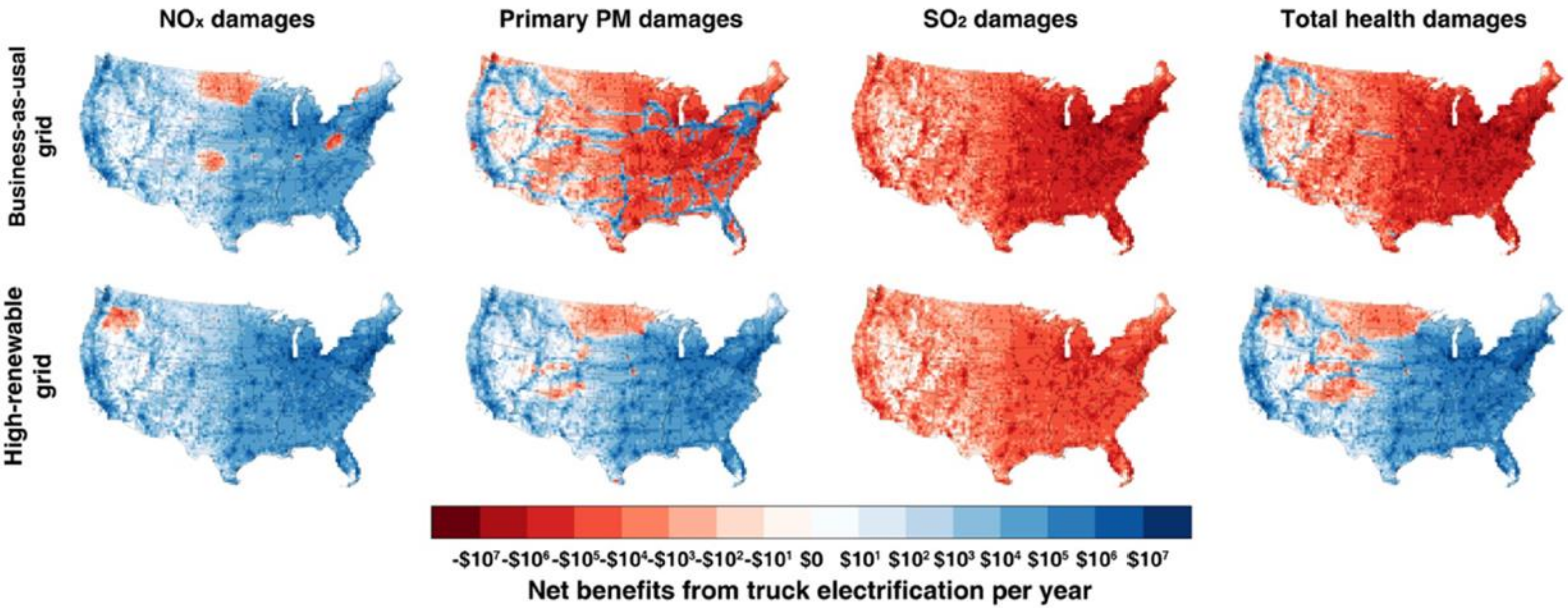
Air pollution is deadly!



Mortality from air pollution



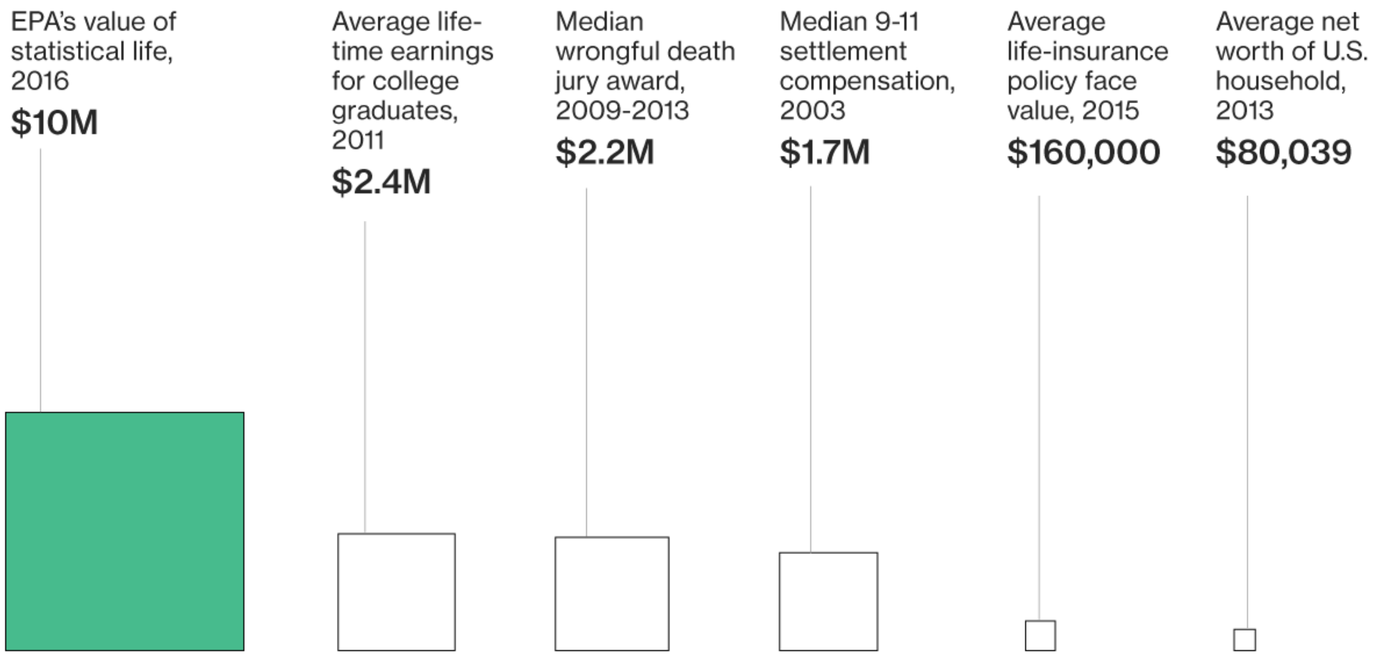
Translating from health impacts to economic damages



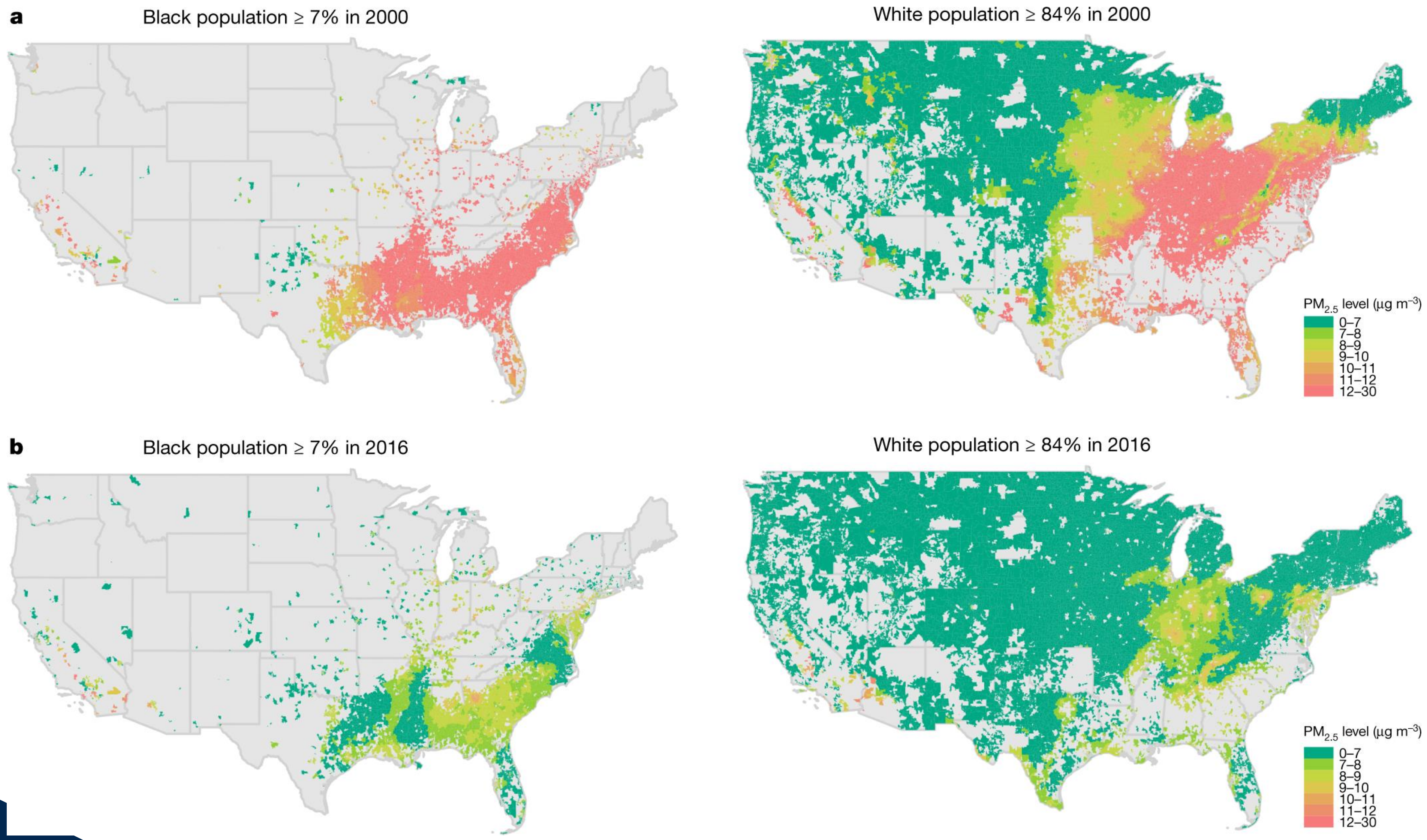
- Why would we do this calculation?
- How would you value health/mortality in dollars?

Value of statistical life (VSOL)

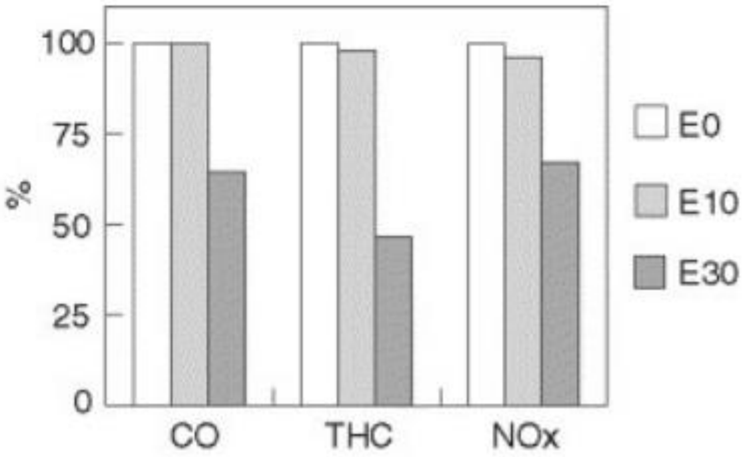
- This is not a dollar value on individual lives, it is helpful for conducting cost-benefit analysis
- How much should the government spend to reduce risks associated with public health?



Pollution and equity issues

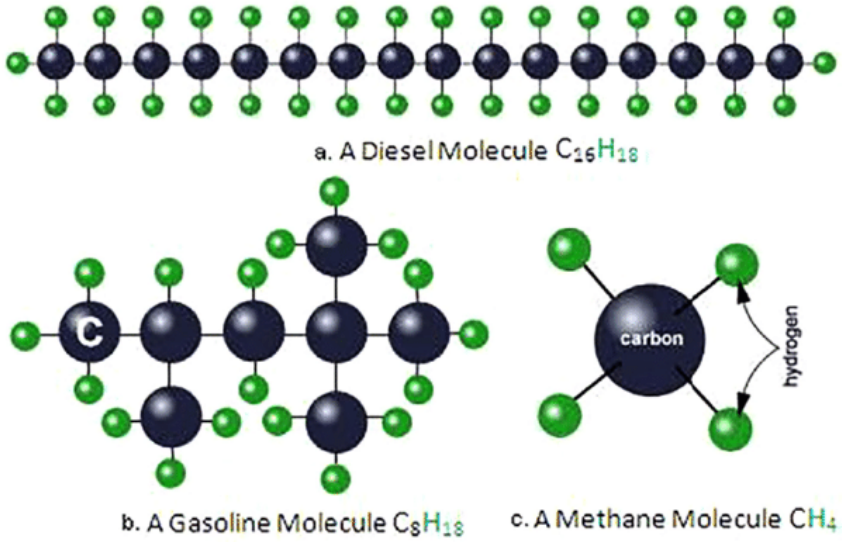


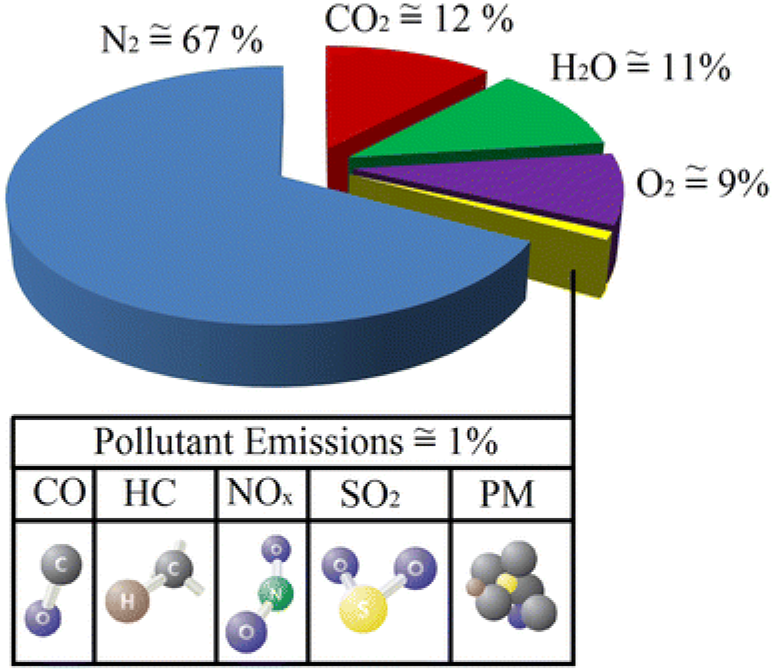
Pollution from gasoline cars



- Gasoline combustion leads to emits:
  - GHGs: CO_2, CH_4, N_2O
  - Local air pollutants: CO, NO_x, PM, and unburned hydrocarbons
- CO_2 is emitted at a rate of 8,887 grams per gallon of gasoline
- Other combustion by-products can vary depending on many conditions

Pollution from diesel vehicles



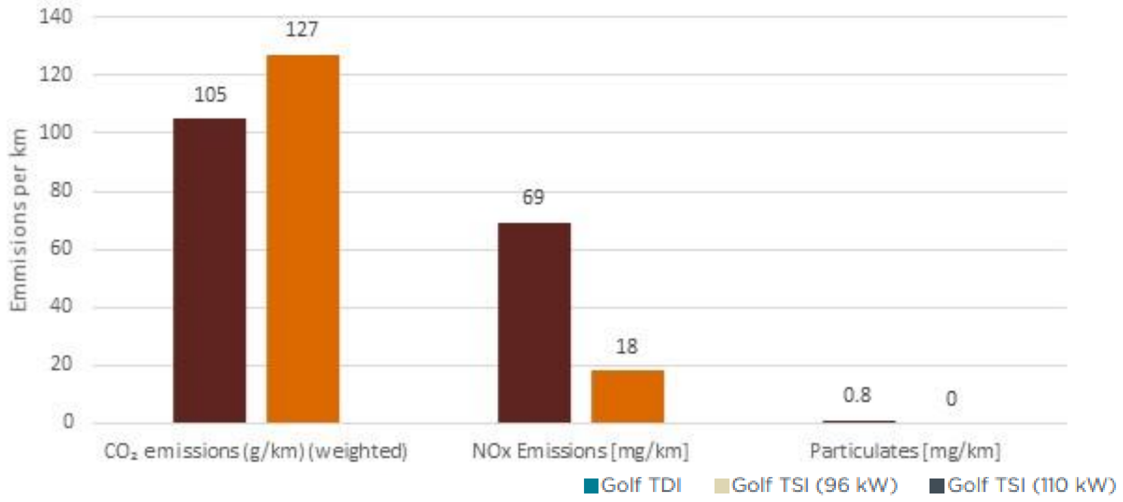


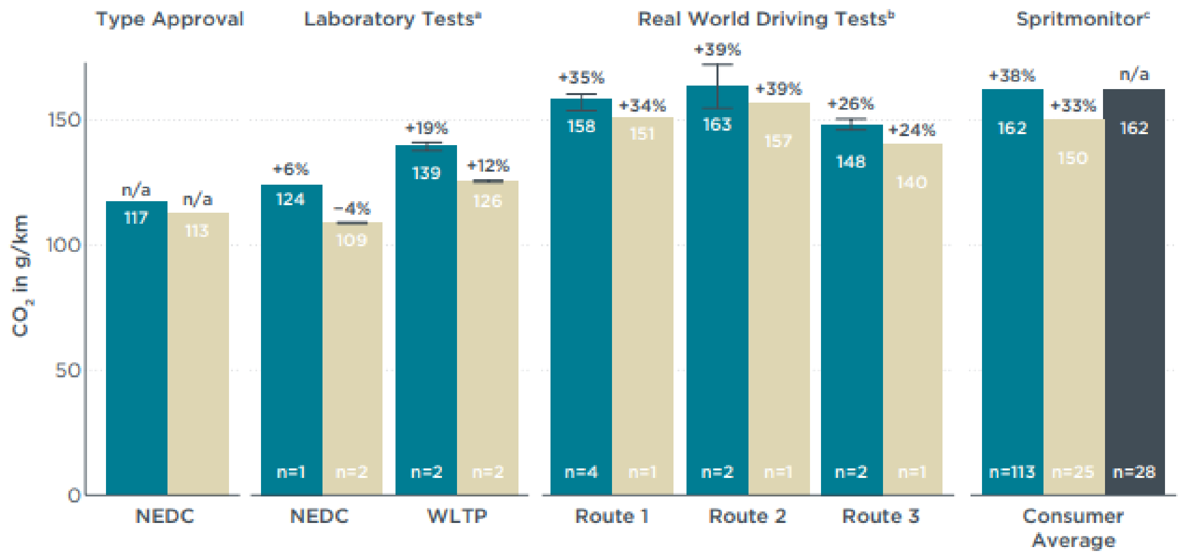
- Diesel also emits:
  - GHGs: CO_2, CH_4, N_2O
  - Local pollutants: CO, hydrocarbons, PM, and NO_x
- These are the same pollutants as gasoline—but in very different quantities

Diesel vs gasoline emissions

- Diesel vehicles tend* to be more efficient than gasoline vehicles, especially at highway speeds – hence they emit slightly less CO_2
- However, pollutants from diesel are *substantially* worse than gasoline vehicles

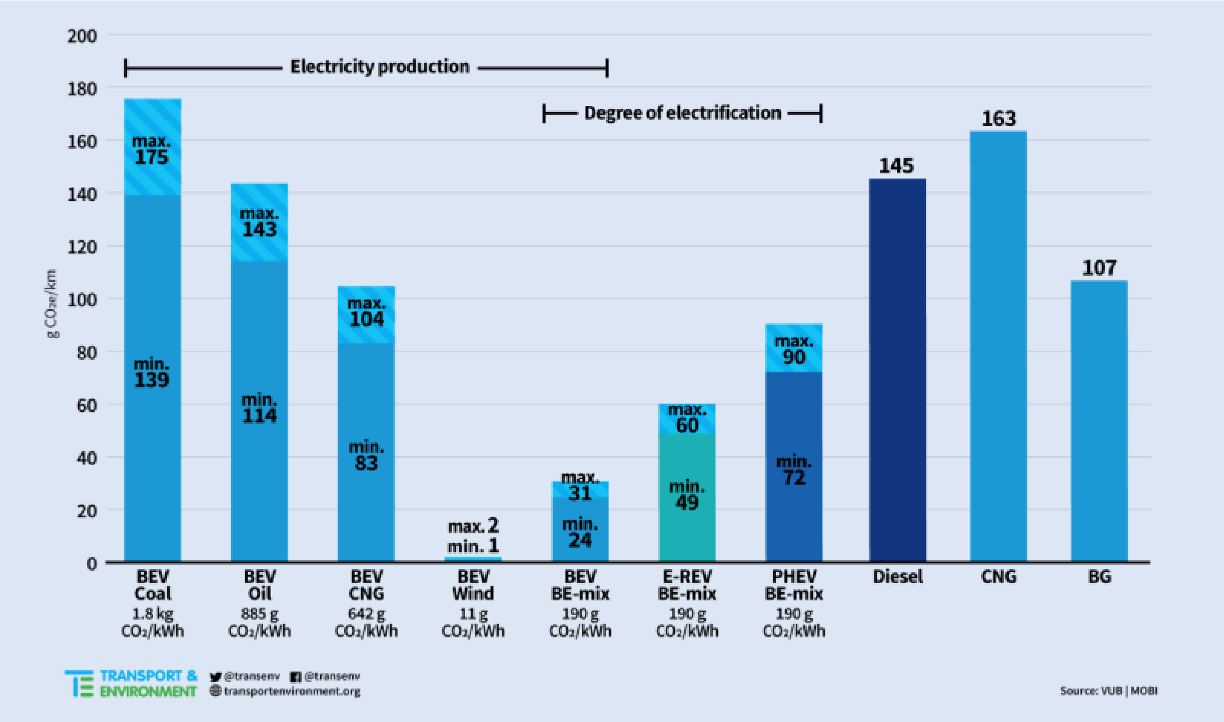
Figure 1: Diesel and petrol emissions test performance for a UK top selling mid size car (with the same engine power output)

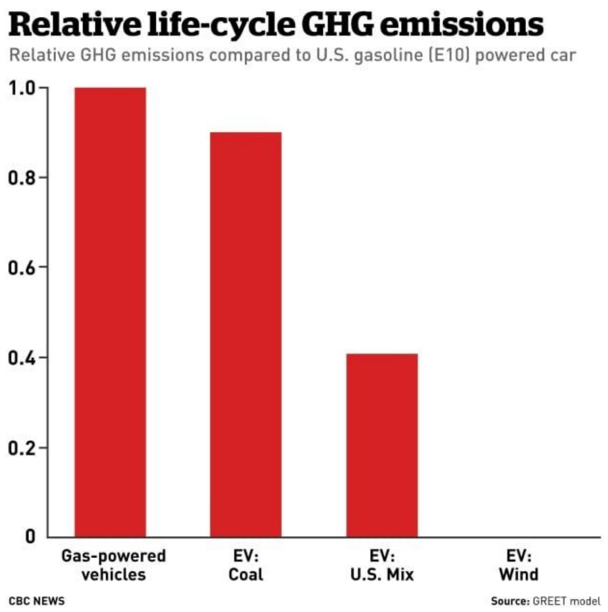


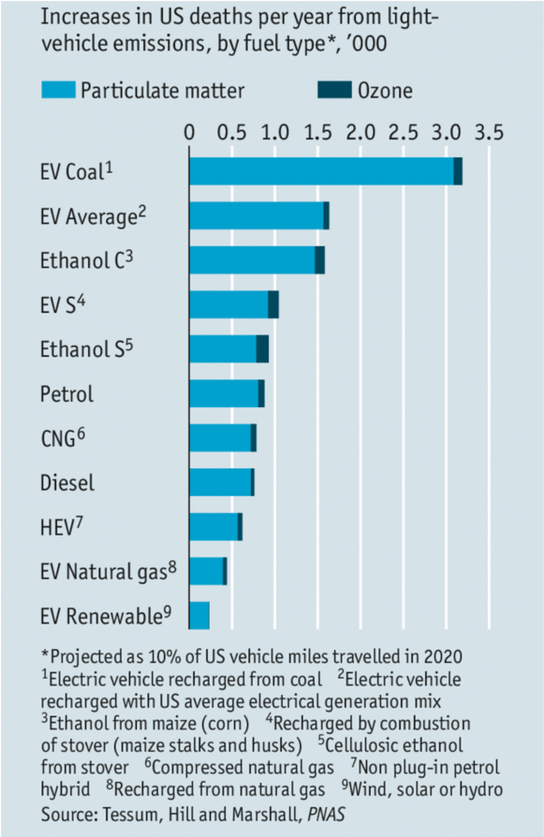


Local pollution from EVs?

How does an EV compare by fuel source to gasoline cars?







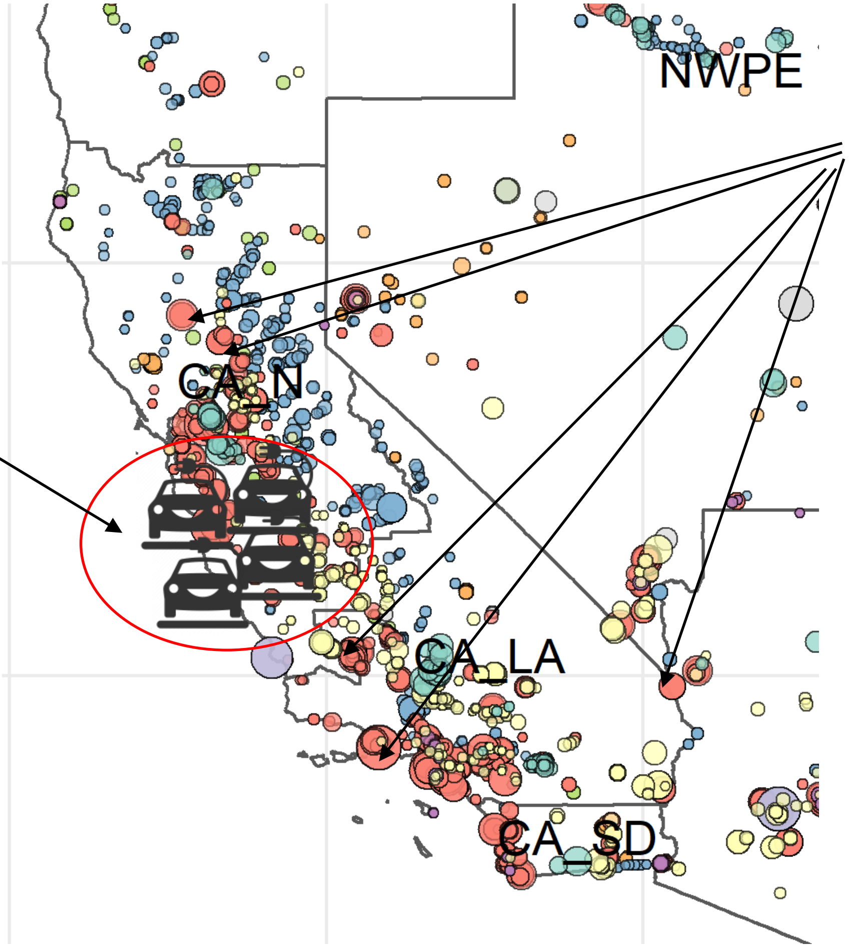
Pollution benefits from switching to an electric vehicle

Scenario 1: Gas cars

Local air pollution in the south bay from cars

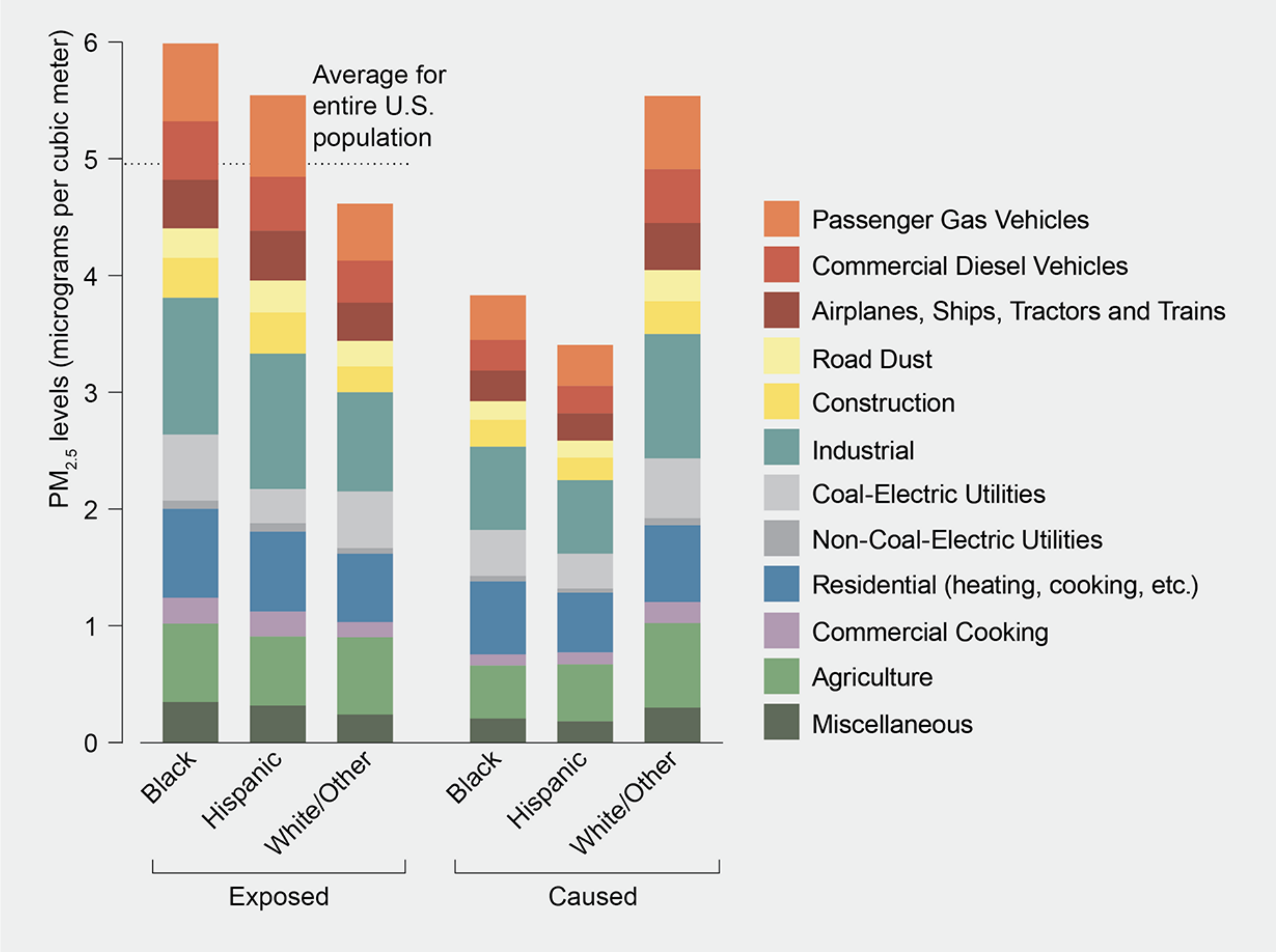
Scenario 2: Gas cars replaced with EVs

No more local pollution from cars



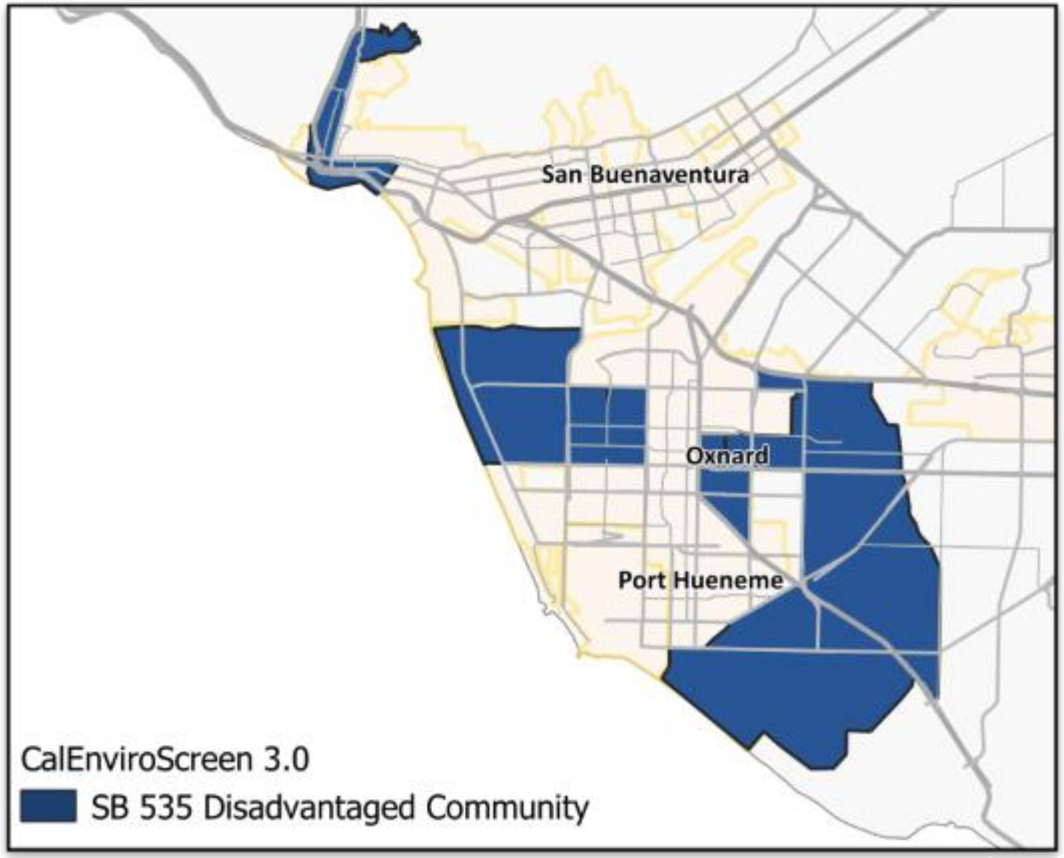
…but now pollution could be coming from power plants. What communities are these affecting?

Equity issues of transition



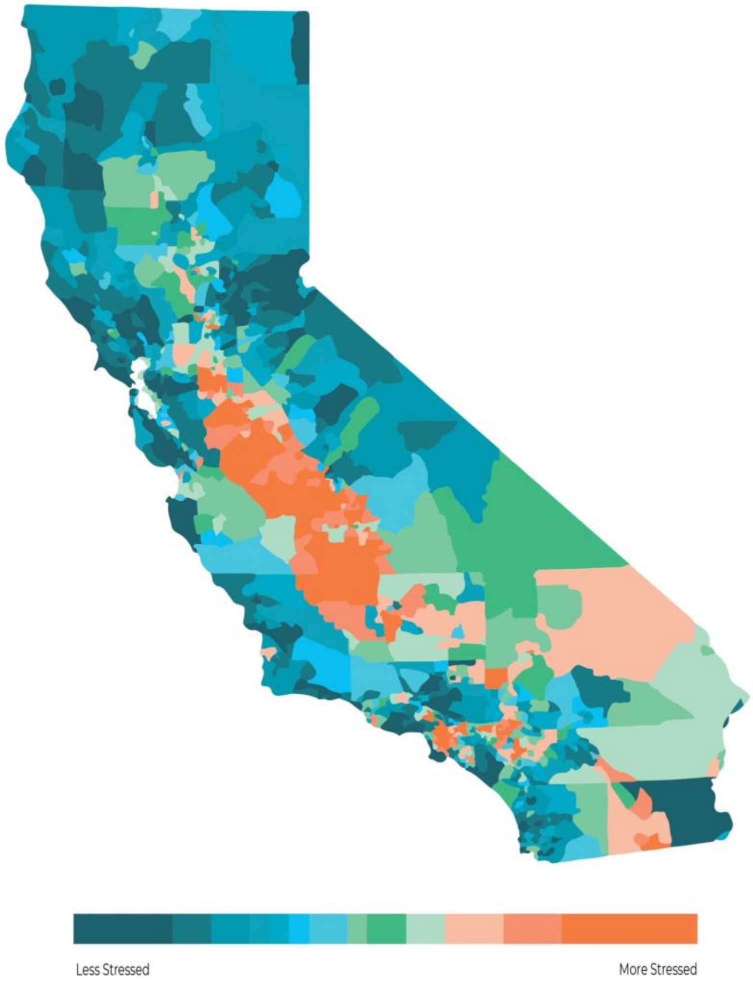
Electrifying heavy-duty could provide disproportionate *benefits*

- Many freight corridors pass through disadvantaged communities
- Electrifying these corridors could reduce a large amount of local air pollution in these areas
- Many regulatory policies are currently keeping these benefits in mind as they make decisions to support electrification

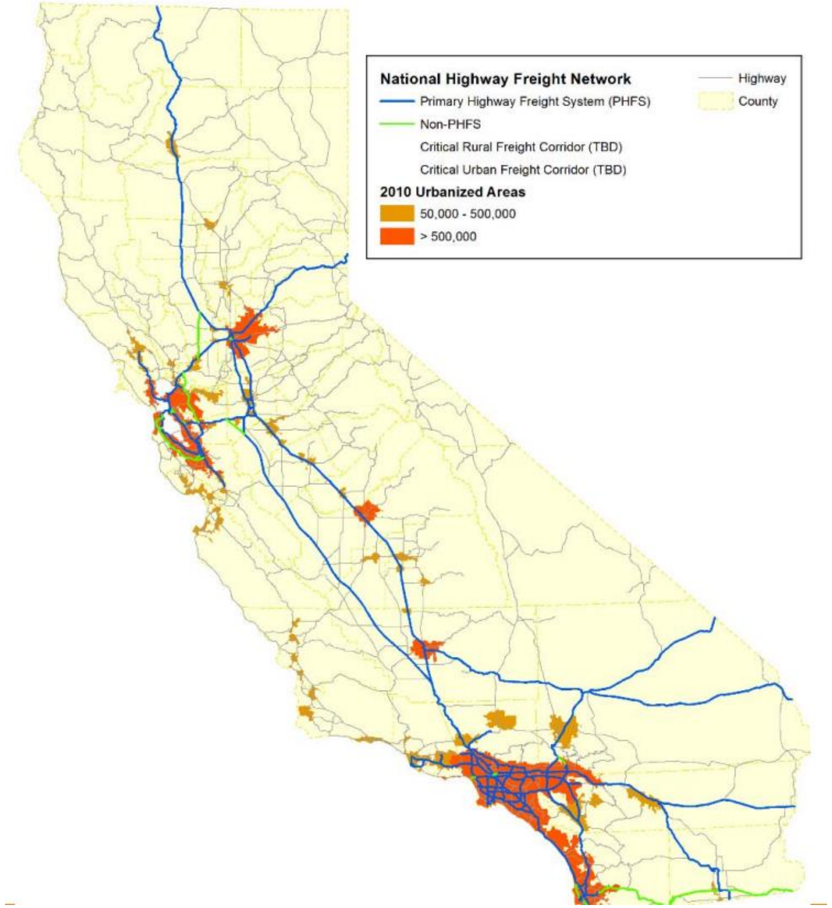


Pollution benefits from electrifying freight

California's disadvantaged communities



California's freight corridors



EVs and air pollution

- Generally, we know that electric vehicles will reduce air pollution compared to gas cars
- However, impacts may be distributed heterogeneously: some populations may benefit more than others—it's even possible that some populations could be harmed
- Modeling and understanding these impacts is important for policymakers and regulators to understand the effects of their actions