Health Burdens and Racial-Ethnic Disparities of Air Pollution from US Oil and Gas Lifecycle Stages

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Sierra Club

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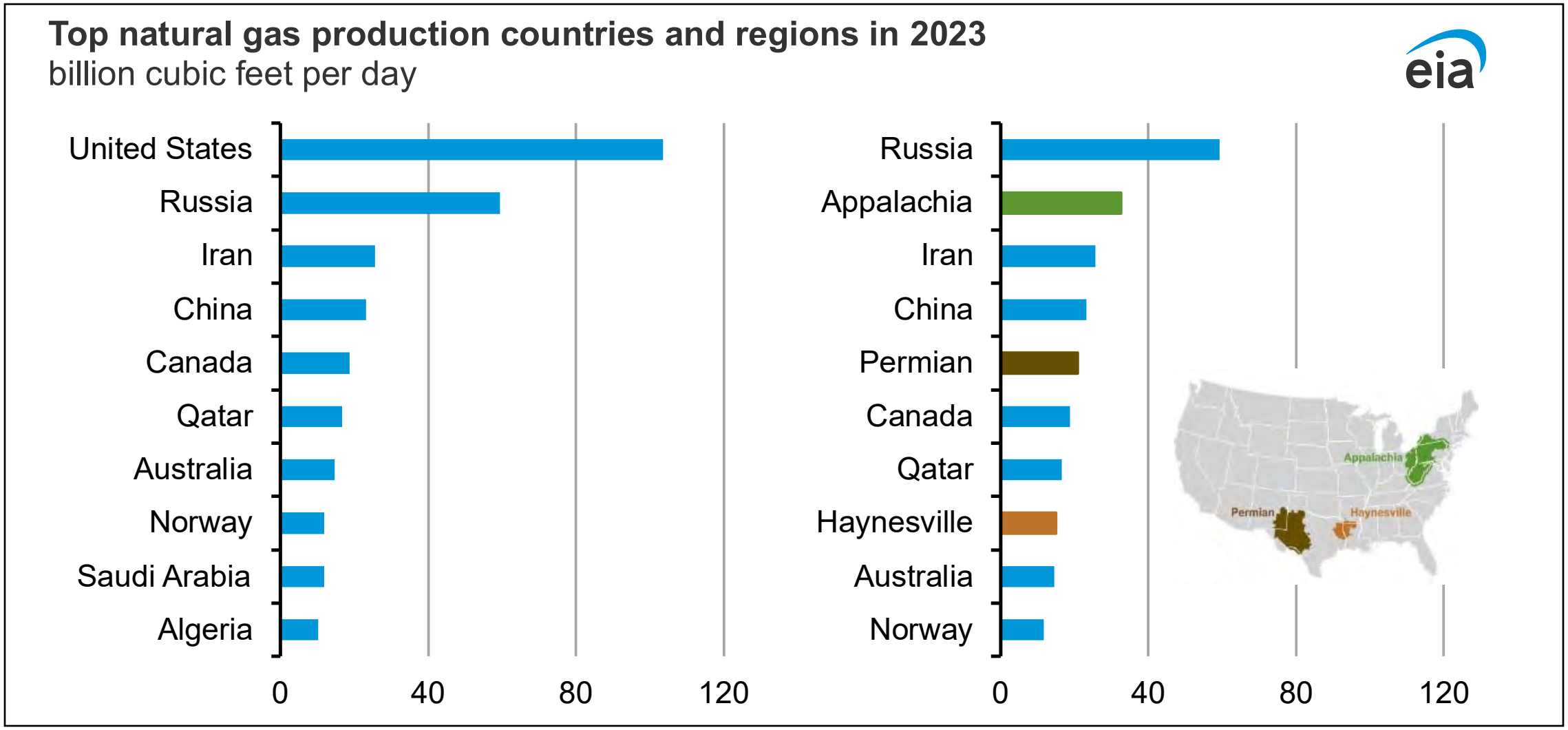
- Stockholm Environment Institute (Seattle)
- George Washington University (DC)
- University of Colorado, Boulder
- US National Oceanographic and Atmospheric Administration (NOAA)

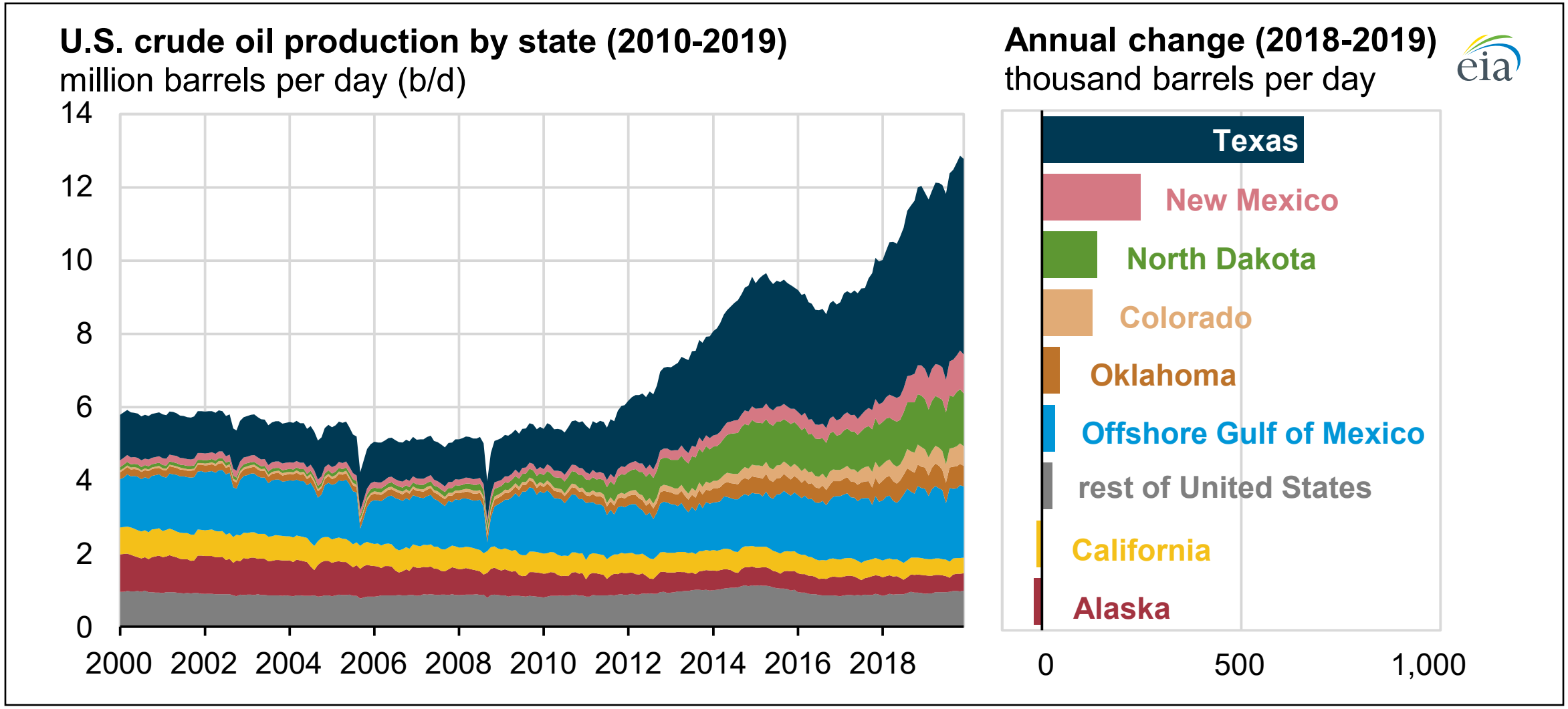
National Contributions to Global Natural Gas Production



[Energy Information Administration (EIA), https://www.eia.gov/todayinenergy/index.php]

US largest global producer of natural gas (and oil)

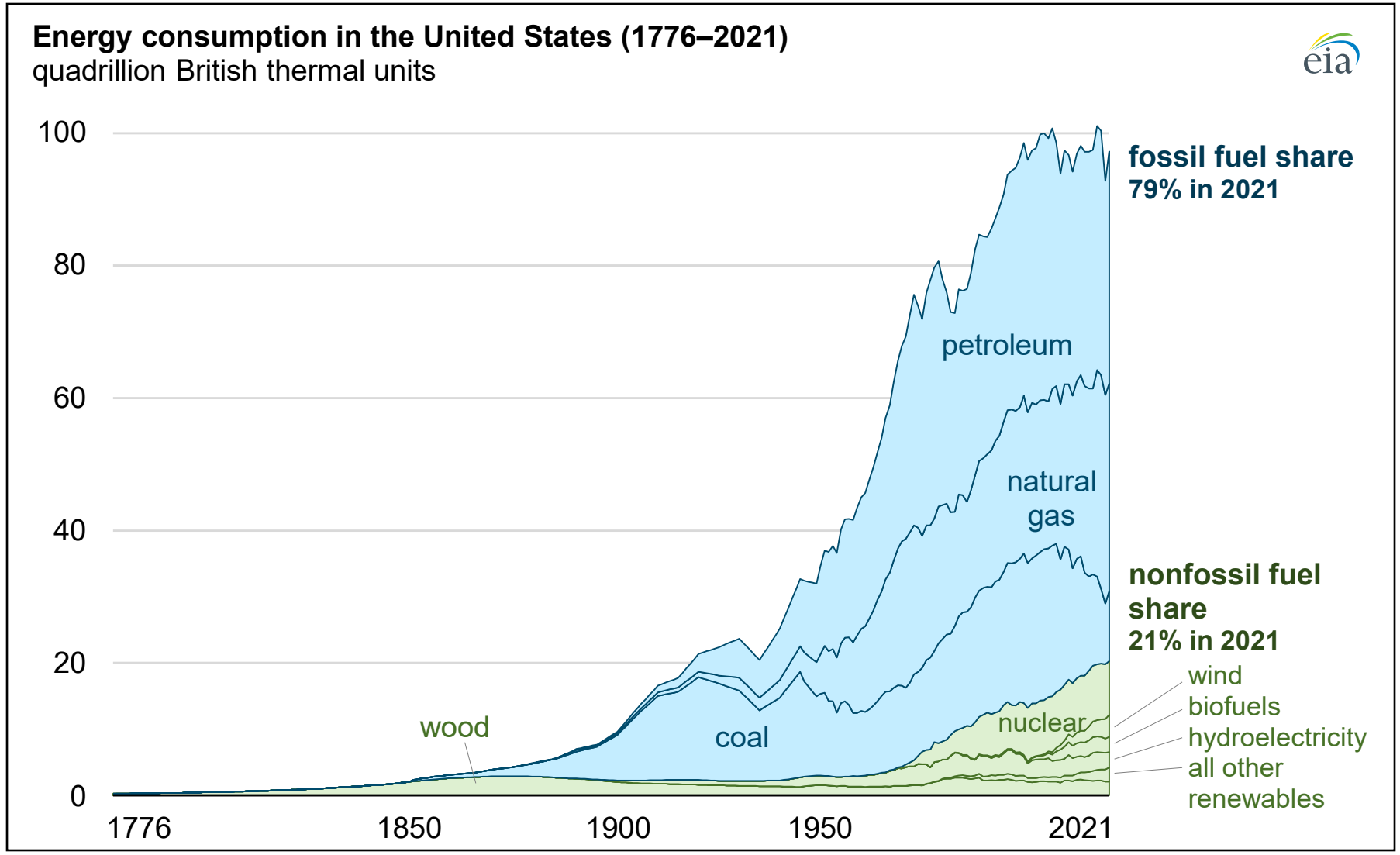
Trends in US Crude Oil Production



[EIA, https://www.eia.gov/todayinenergy/detail.php?id=43015]

Steep growth since 2011 in oil (and natural gas) production spurred by unconventional oil and gas (O&G) and phase-out of coal

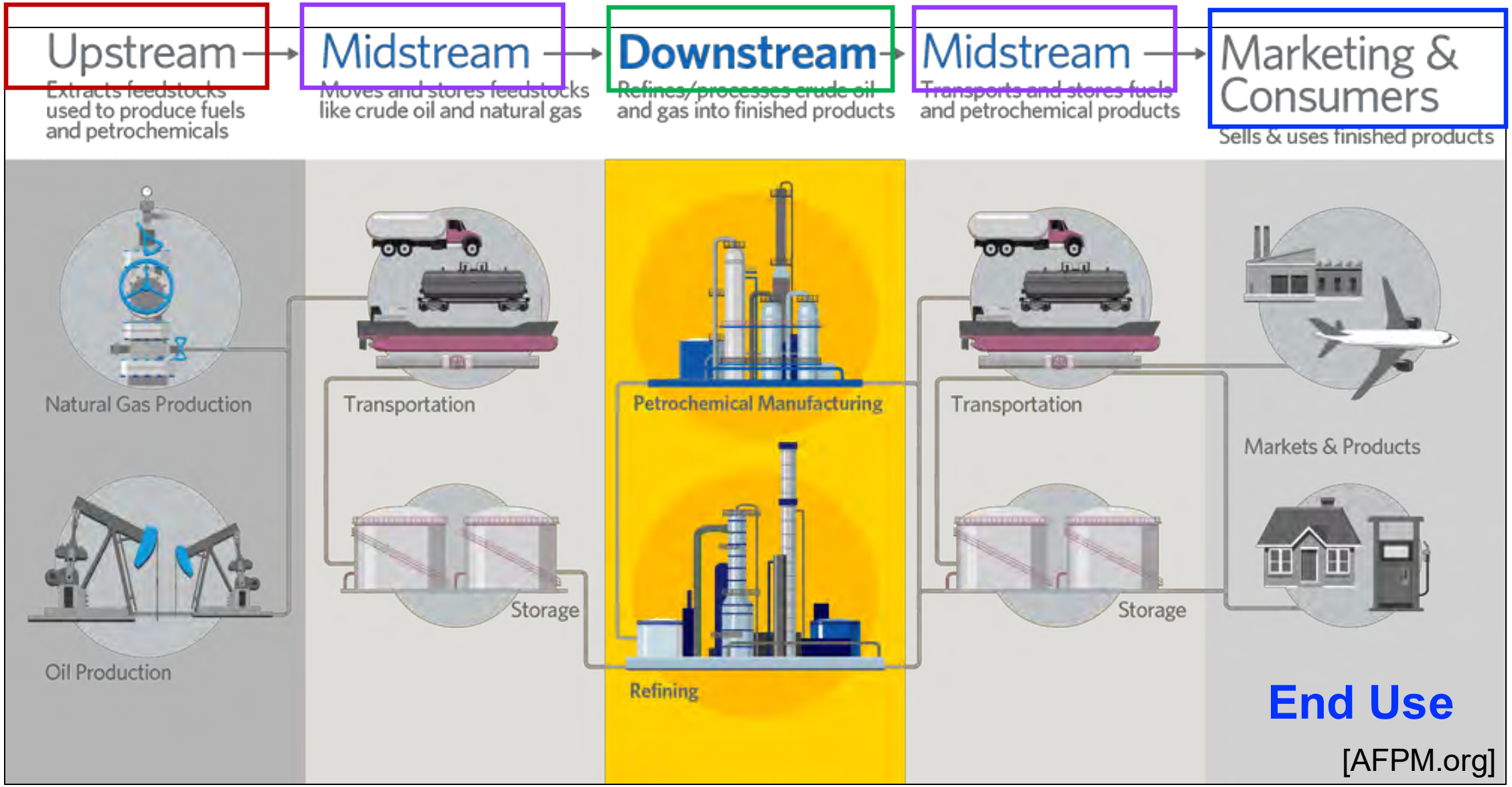
Trends in US Energy Consumption



[EIA, https://www.eia.gov/todayinenergy/detail.php?id=52959]

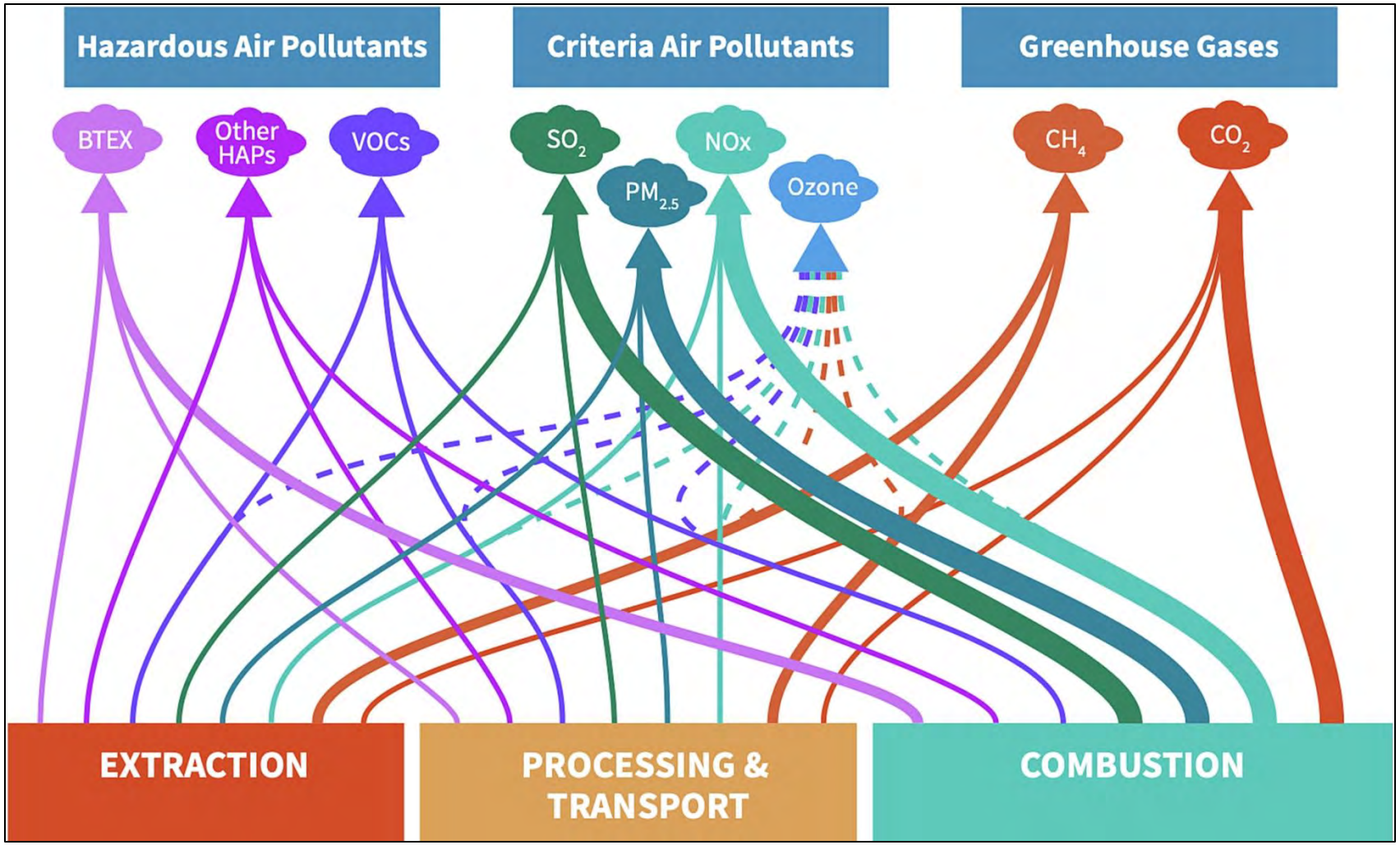
Growth in demand for O&G continues to grow, despite pledges to Paris Climate Accord

Major Stages of the Oil and Gas Lifecycle



End use includes combusted crude and refined fuels and non-energy products (waxes, plastics)

Activities in All Stages Produce Pollutants



BTEX: benzene, toluene, ethylbenzene, xylene

HAPs: Hazardous air pollutants

VOCs: volatile organic compounds

NO_x: nitrogen oxides (NO + NO_2)

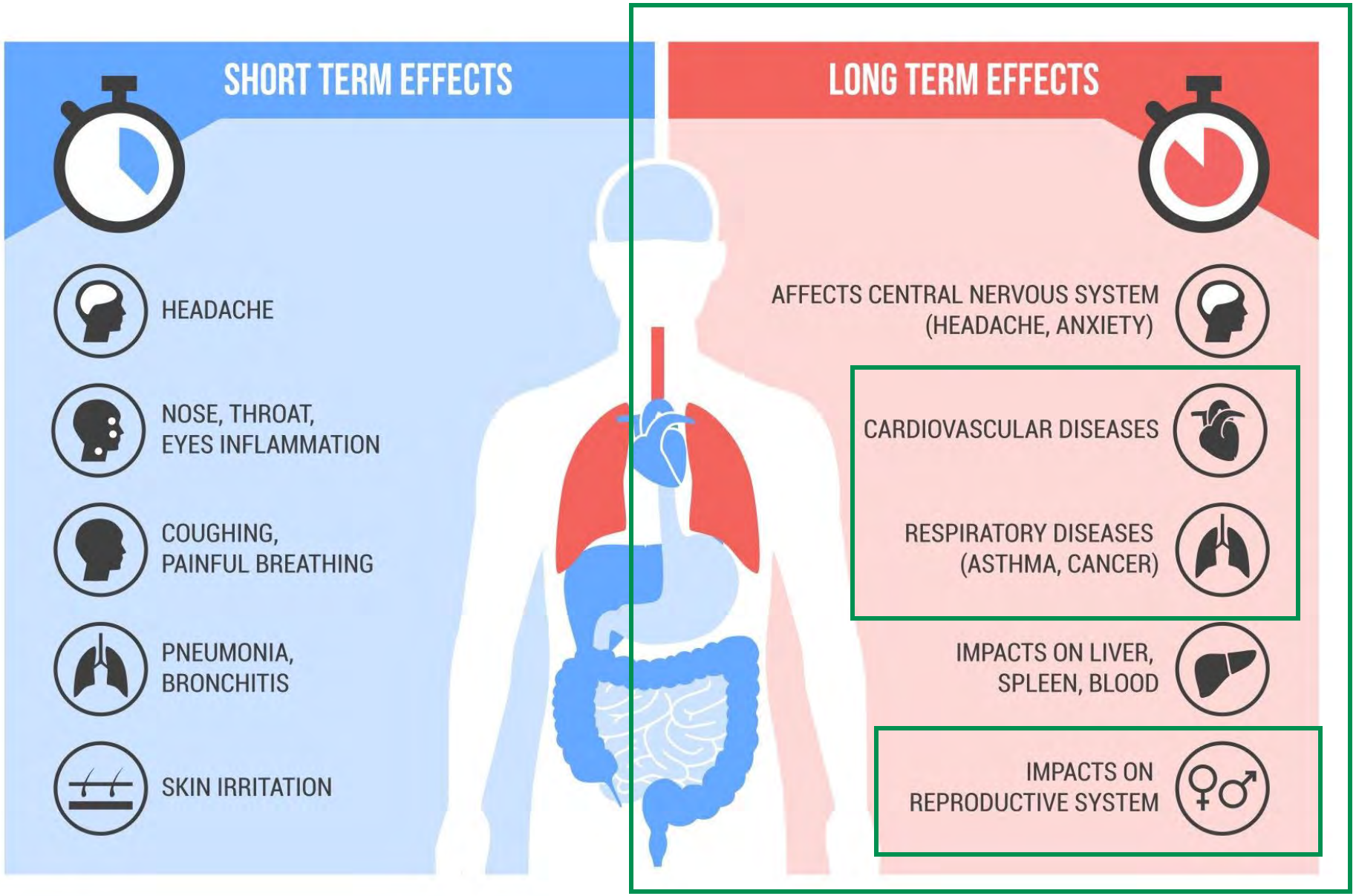
$PM_{2.5}$: Small particles

[Adapted from Donaghy et al. 2023]

Directly emitted: NO_x, primary $PM_{2.5}$, most VOCs/HAPs

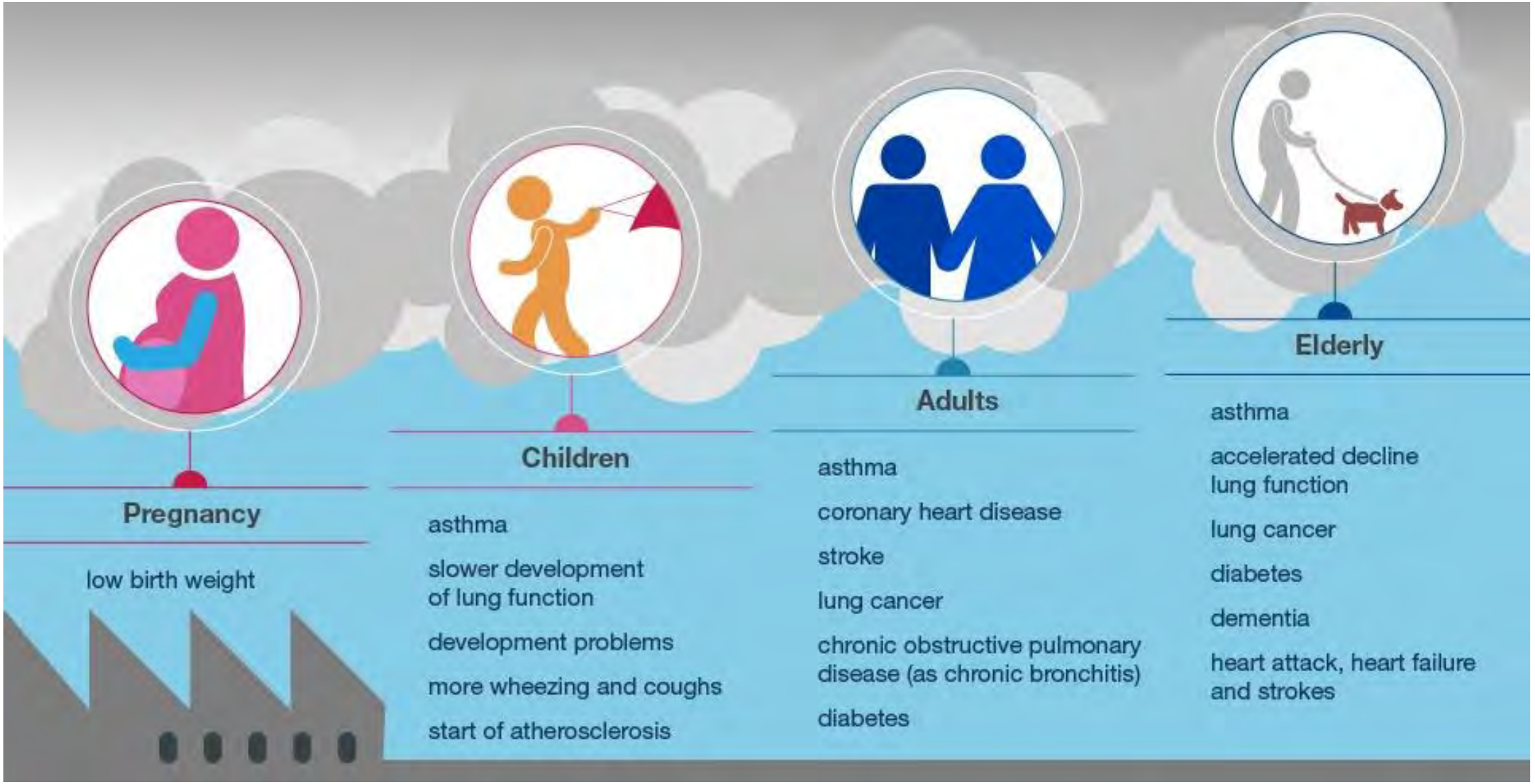
Formed via chemical reactions: secondary $PM_{2.5}$, VOCs/HAPs such as formaldehyde, ozone

Air pollution impacts every organ of the human body



Source: https://airqoon.com/

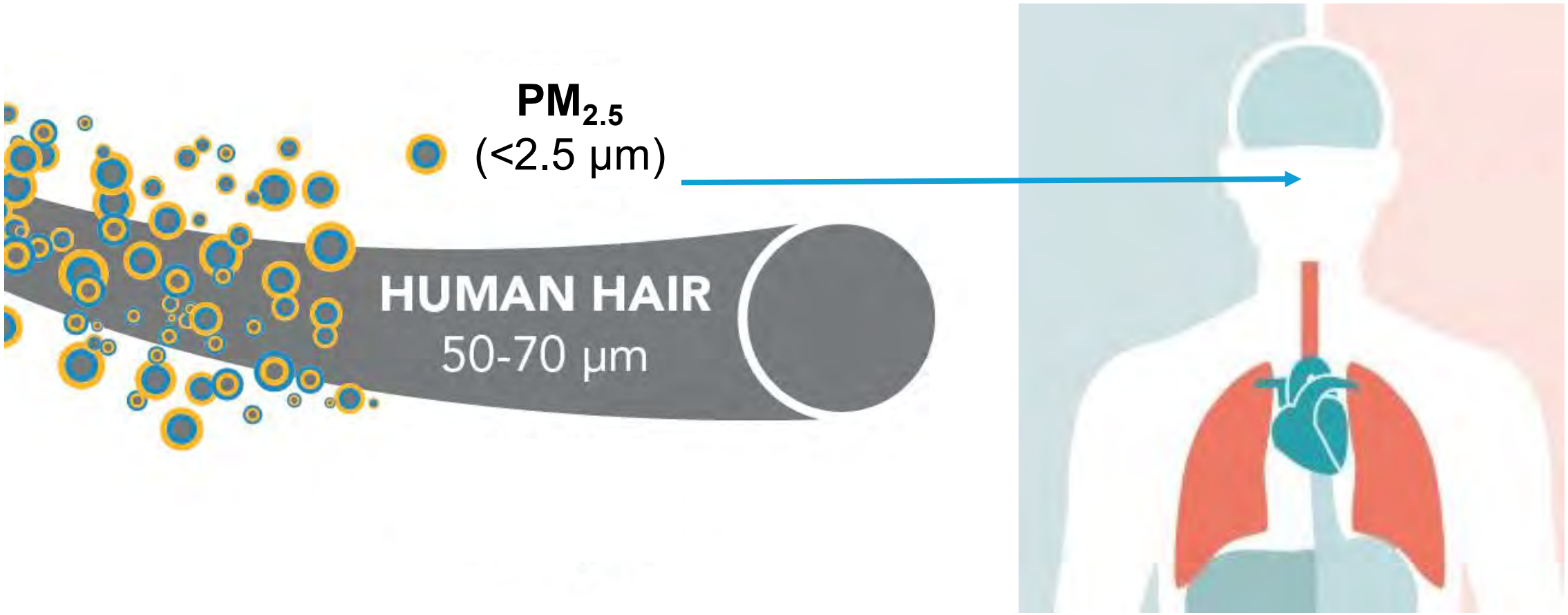
Air pollution affects people throughout their lifetime



Source: https://www.gov.uk/government/publications/health-matters-air-pollution/health-matters-air-pollution

Fine Particles ($PM_{2.5}$)

Particles that are mixtures of multiple chemicals that are air small enough to penetrate deep into the lungs



Exposure to $PM_{2.5}$ causes **respiratory** and **cardiovascular** diseases that may lead to early death

Exposure to $PM_{2.5}$ also associated with preterm birth

Ground-level ozone (O_3)

- Secondary pollutant (not emitted)
- Ingredients for its formation include sunlight, VOCs (or CO) and NO_x
- Long-term exposure associated with chronic obstructive pulmonary disease (COPD) leading to premature death across all population age groups

Source: https://www.ourair.org/gooduphigh-badnearby-ozone-infographic/

Nitrogen dioxide (NO_2)

- NO_2 is one of the two NO_x compounds
- Well established that long-term NO_2 exposure linked to onset of asthma amongst children
- Increasingly accepted that long-term NO_2 exposure also linked to premature mortality amongst elderly

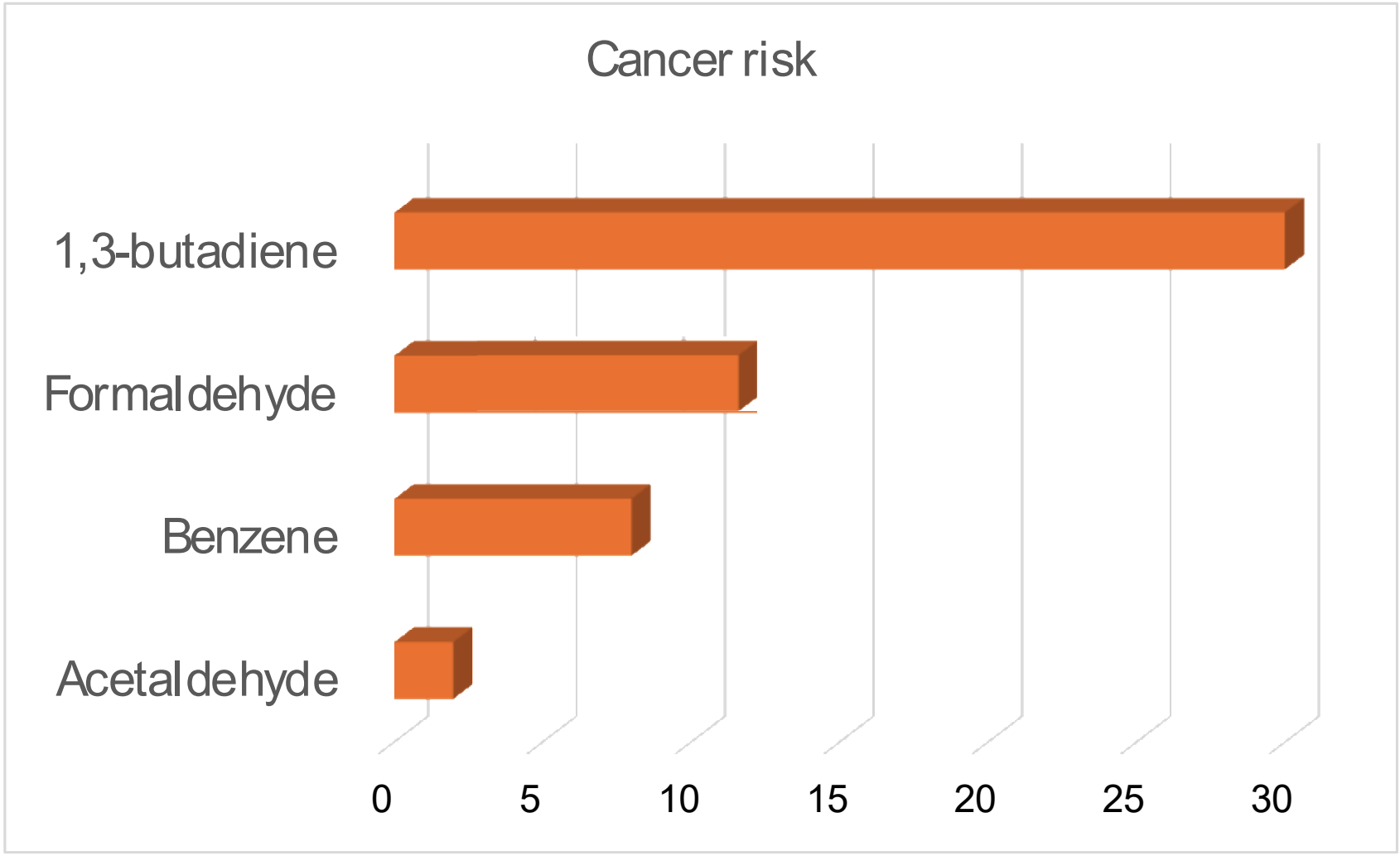
Source: https://www.london.gov.uk/sites/default/files/hia_asthma_air_pollution_in_london.pdf

First UK case with air pollution on death certificate

Foundation created in her name campaigning for clean air for all: https://www.ellaroberta.org/

Volatile Organic Compounds (VOCs)

VOCs that are known carcinogens



X-axis:
Unit Risk Estimate or one in a million risk of developing cancer

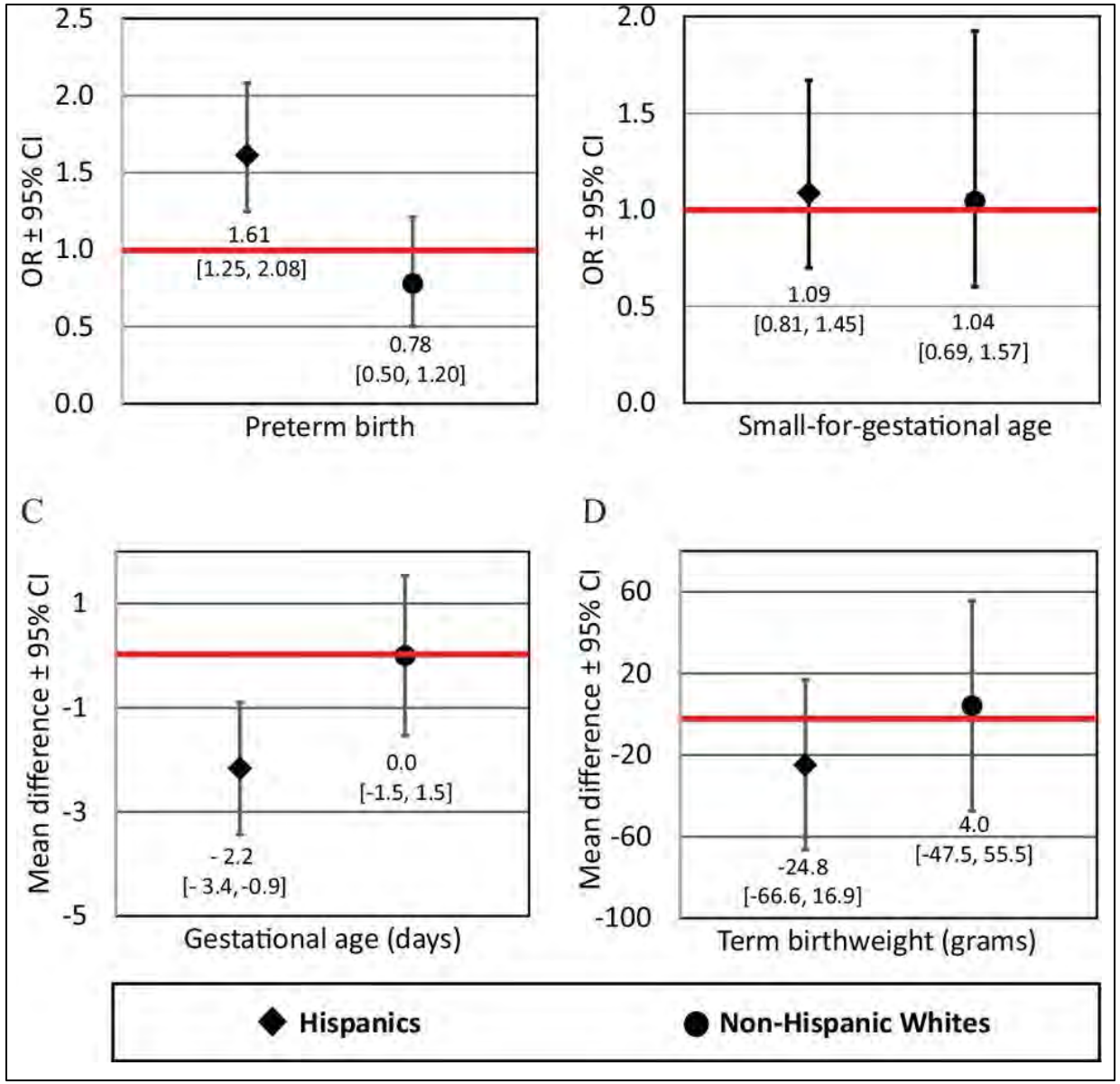
For example,
There is a 2 in a million chance to develop cancer from sustained lifetime exposure to 1 μg m^{-3} acetaldehyde

Benzene is emitted, others are emitted and produced from chemical reactions

[Loh et al., 2007]

Unjust Exposure to O&G Air Pollution

Example past study assessing unjust health burden from natural gas flaring



OR: odds ratio

Hispanic population closer to flaring wells, so greater likelihood than non-Hispanic white population of preterm birth (by 0.9-3.4 days)

Unjust exposure from:

- placement of infrastructure (extraction wells, pipelines, compressor stations, downstream chemical manufacturing plants)
- proximity to more intense flaring
- proximity to busy roadways

[Cushing et al., 2020]

Motivation for Our Study

So much already known about O&G harm to health, so why another study on this topic?

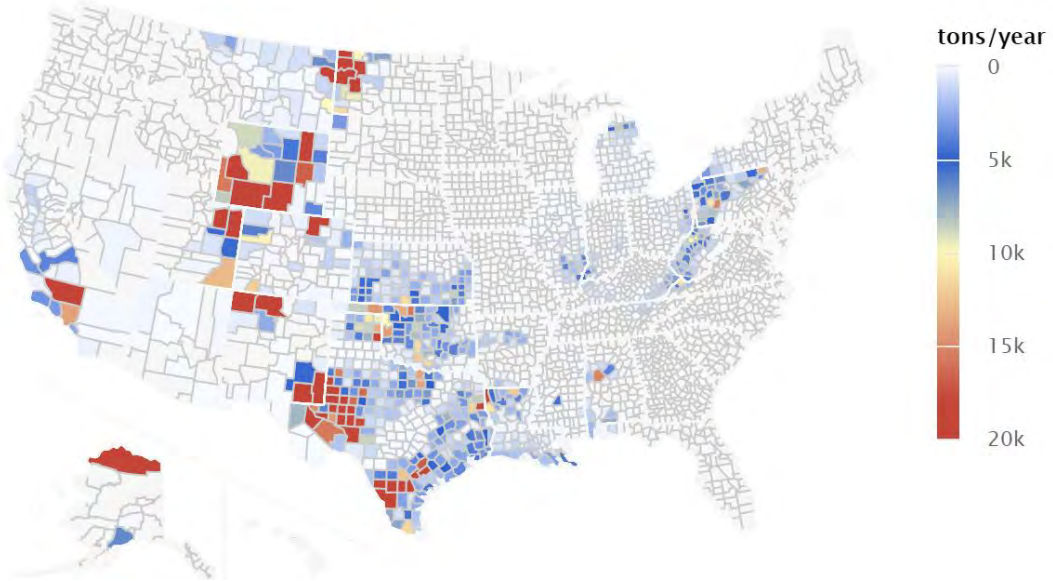
Past studies not sufficiently holistic:

- Focused on a single O&G lifecycle stage (mostly production)
- Focused on a single pollutant (typically $PM_{2.5}$)
- Focused on a specific state or natural gas basin
- Combined O&G with coal for fossil fuel focused analysis
- Used reduced complexity chemistry transport models that may not be suitably representing harmful secondary pollutants
- Environmental injustice typically focus on inequitable exposure, quantification of inequitable health outcomes is rare

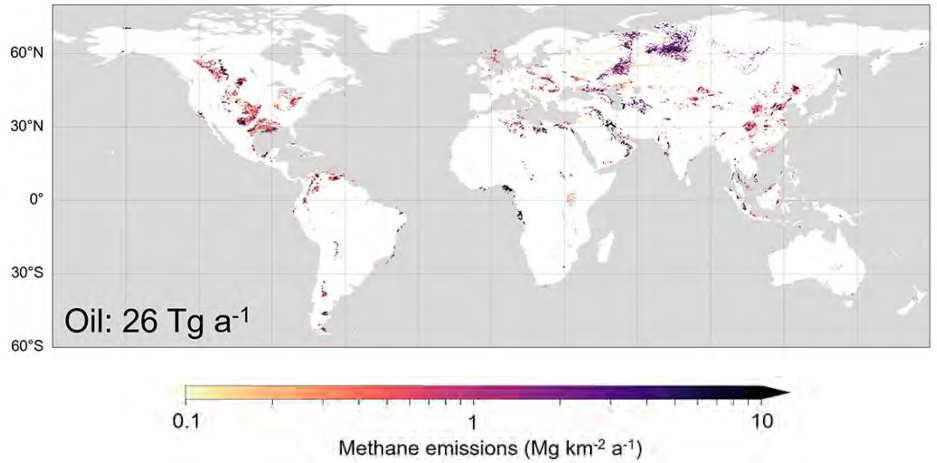
Vital for directing policies that prioritize the most adversely affected communities

We construct a unified inventory of air pollutant emissions for 2017

US EPA National Emission Inventory (NEI) 2017



Global Fuel Exploitation Inventory (GFEI) for methane



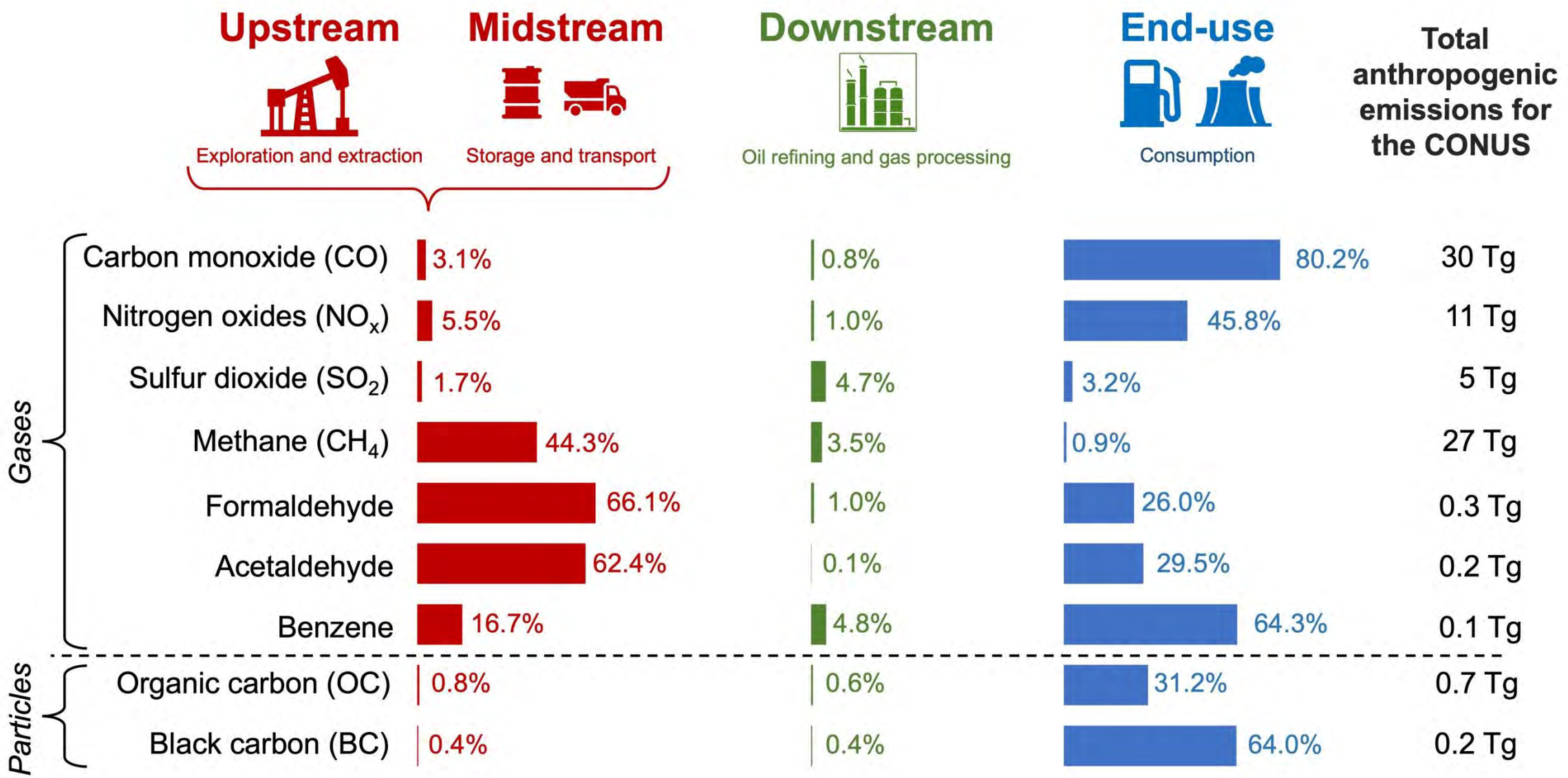
Fuel-based Inventory for Vehicular Emissions (FIVE)

Aviation Emissions Inventory Code (AEIC)

Community Emissions Data System (CEDS) for shipping and outside US

Our inventory is for 2017 as most contemporary datasets were available for 2017

Air pollutant emissions from the US oil and gas lifecycle



Oil and gas activities in the US accounts for more than half of CO, NO_x, formaldehyde, acetaldehyde, benzene, and BC anthropogenic emissions

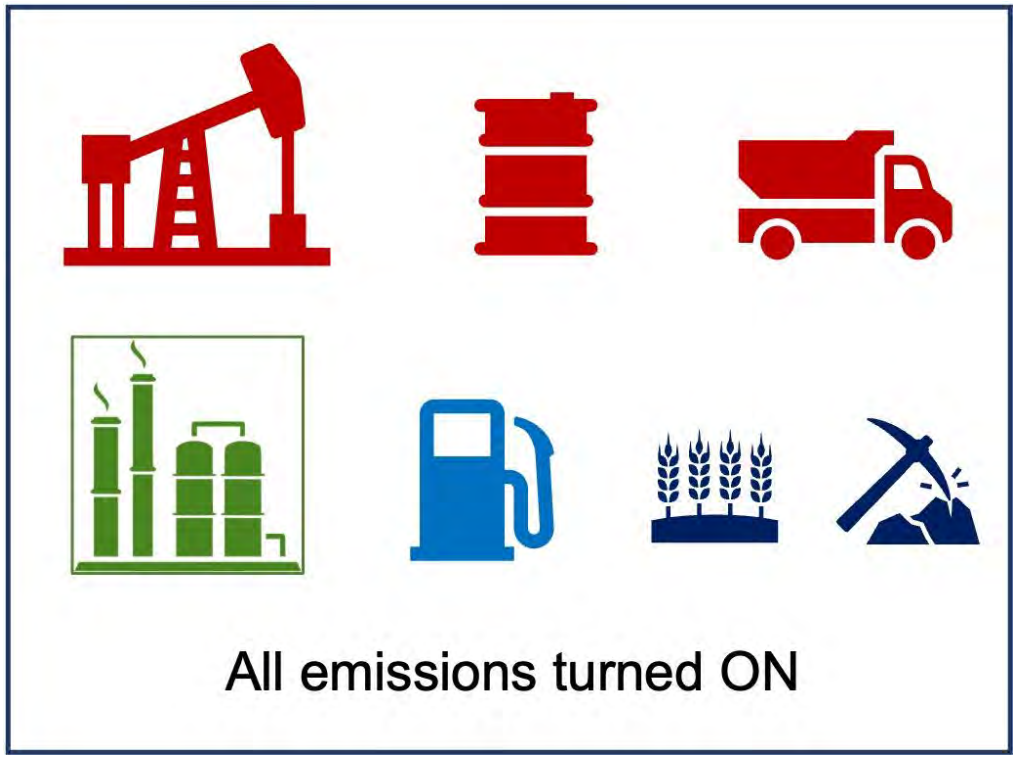
Computer models are used to determine impact of individual sources on air quality and health

Emissions

GEOS Chem

Meteorology

Model runs



→ Estimate baseline of air pollution

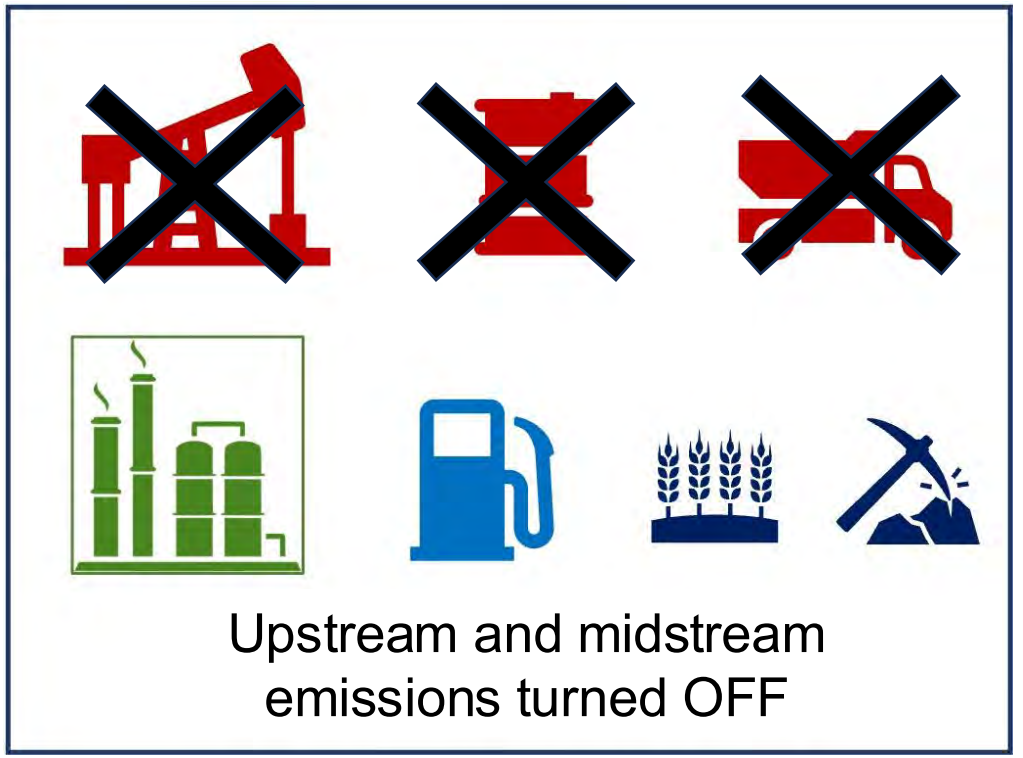
Computer models are used to determine impact of individual sources on air quality and health

Emissions

GEOS Chem

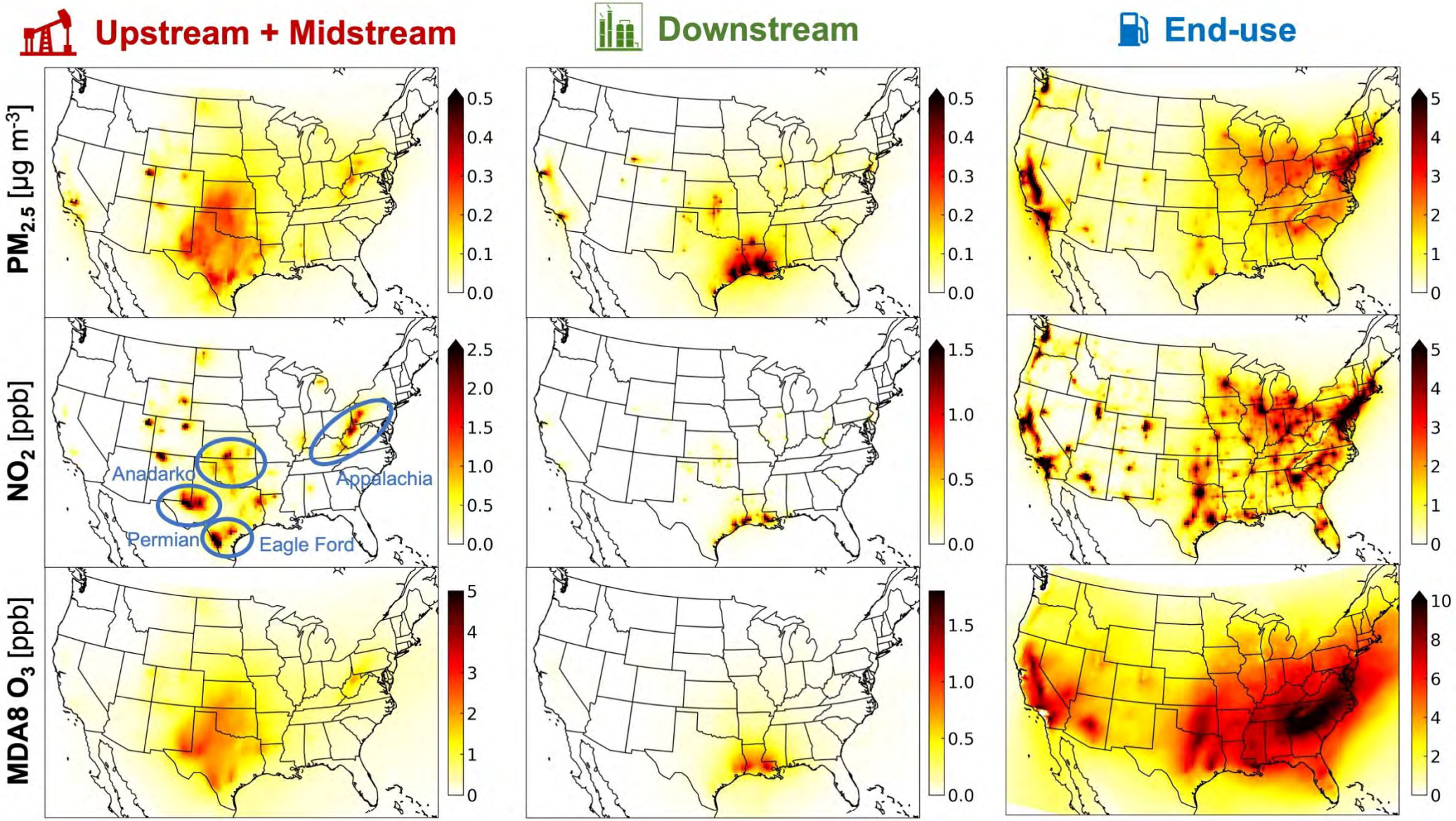
Meteorology

Model runs



→ Estimate contribution of upstream and midstream activities

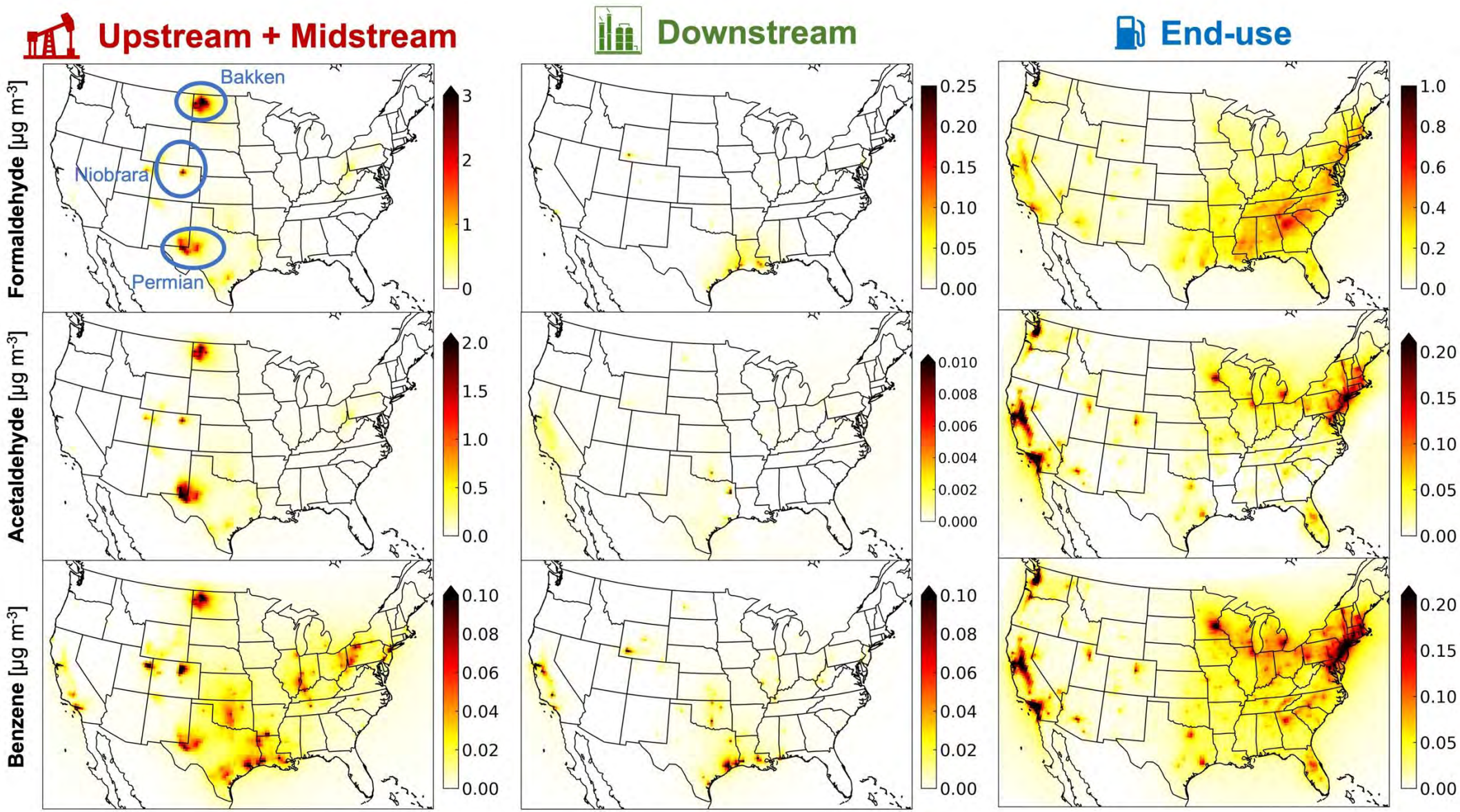
Health-harming pollutant concentrations from oil and gas activities in 2017



Largest enhancements from end-use activities, mainly in California and eastern US

Combined upstream/midstream in Texas and neighboring states, downstream in Texas and Louisiana

Annual mean HAPs concentrations linked to oil and gas activities

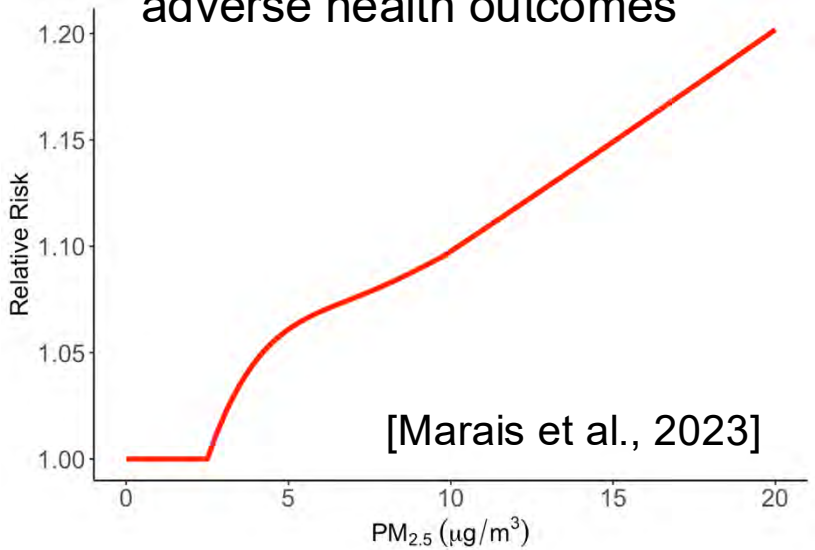


Contribution of oil and gas activities to benzene is less than formaldehyde and acetaldehyde.

Lower benzene emissions and formaldehyde/acetaldehyde also formed from other VOCs

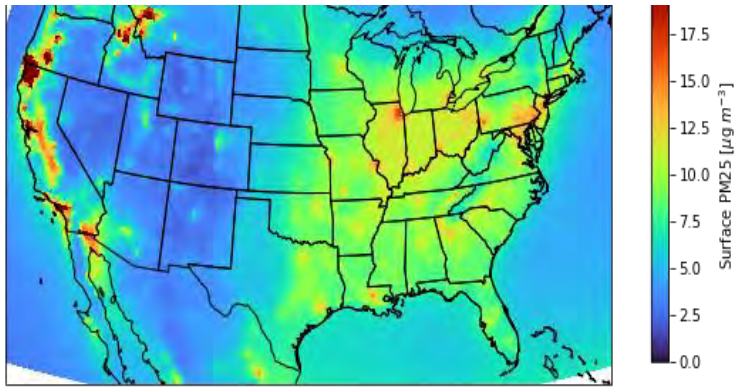
Estimating health burden of O&G air pollution exposure

Health-risk assessment models relate long-term air pollution exposure to adverse health outcomes

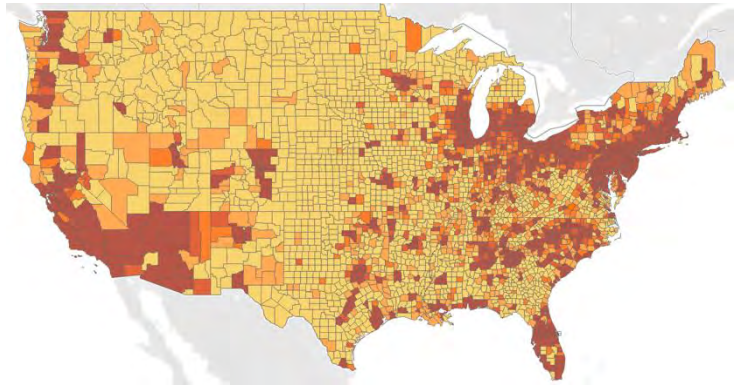


[Marais et al., 2023]

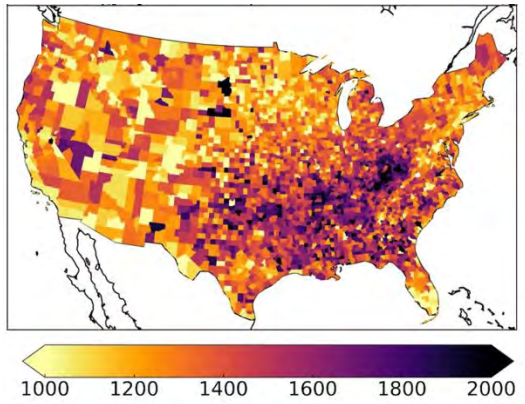
Air pollutant concentrations with and without the O&G lifecycle stage



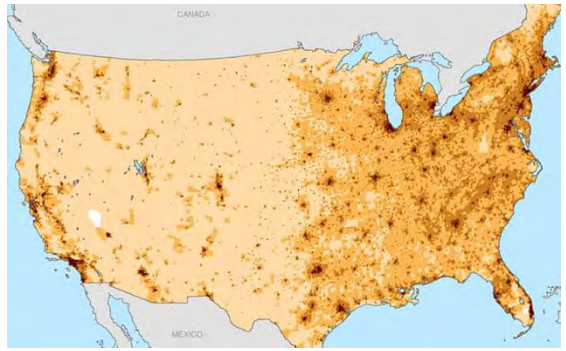
Proportion of health outcome linked to the O&G lifecycle stage



Health burden estimates



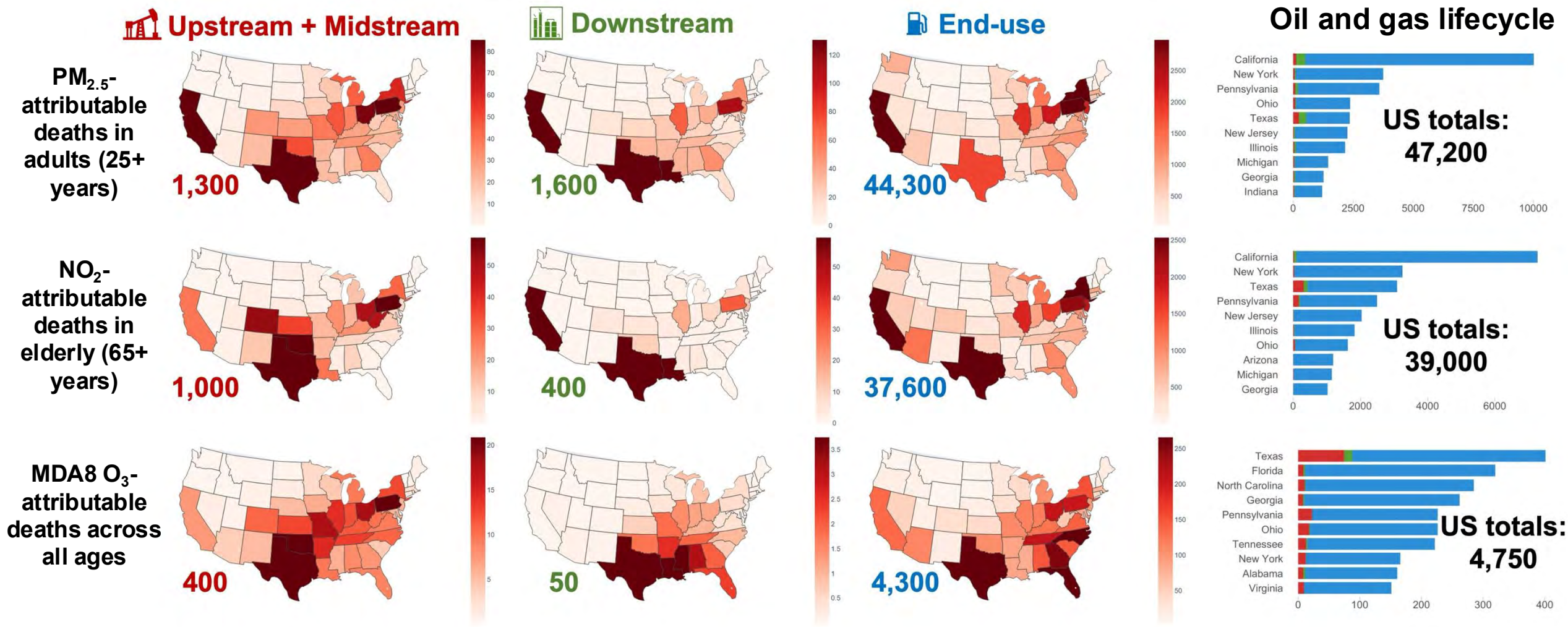
Baseline health data from US CDC



Population data from WorldPop

Annual premature mortality linked to oil and gas air pollution

Non-accidental mortality in adults from $PM_{2.5}$ and elderly from NO_2, COPD mortality from MDA8 O_3

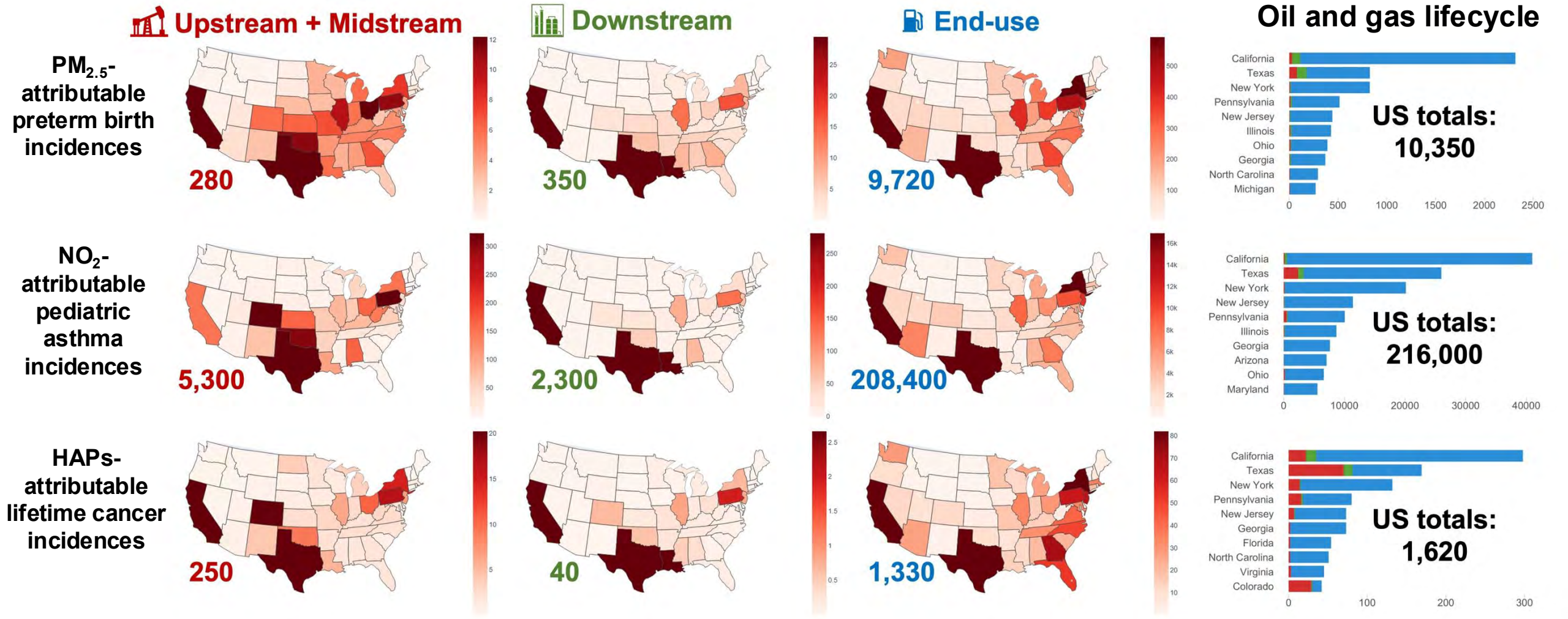


91,000 premature deaths in CONUS linked to oil and gas activities in the US.
1,170 premature deaths in southern Canada and 440 in northern Mexico

2-3% of all early deaths in the US

Preterm births, asthma and cancer incidences from oil and gas air pollution

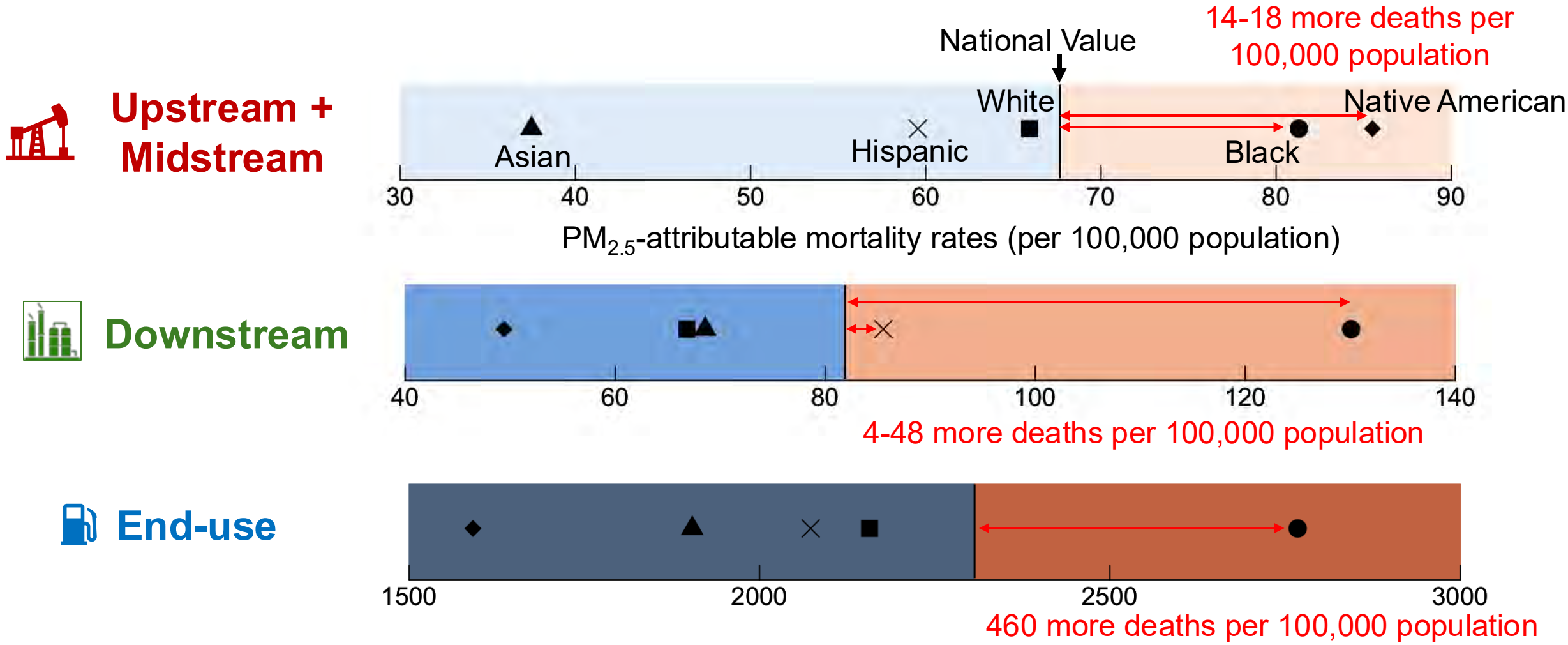
Preterm births from $PM_{2.5}$, childhood-onset asthma from NO_2, lifetime cancers from HAPs



US oil and gas air pollution is linked to 3% of preterm births, 10% of pediatric asthma incidences, and 4% of all respiratory and hematologic cancers in the US

Absolute disparities in oil and gas air pollution health burden

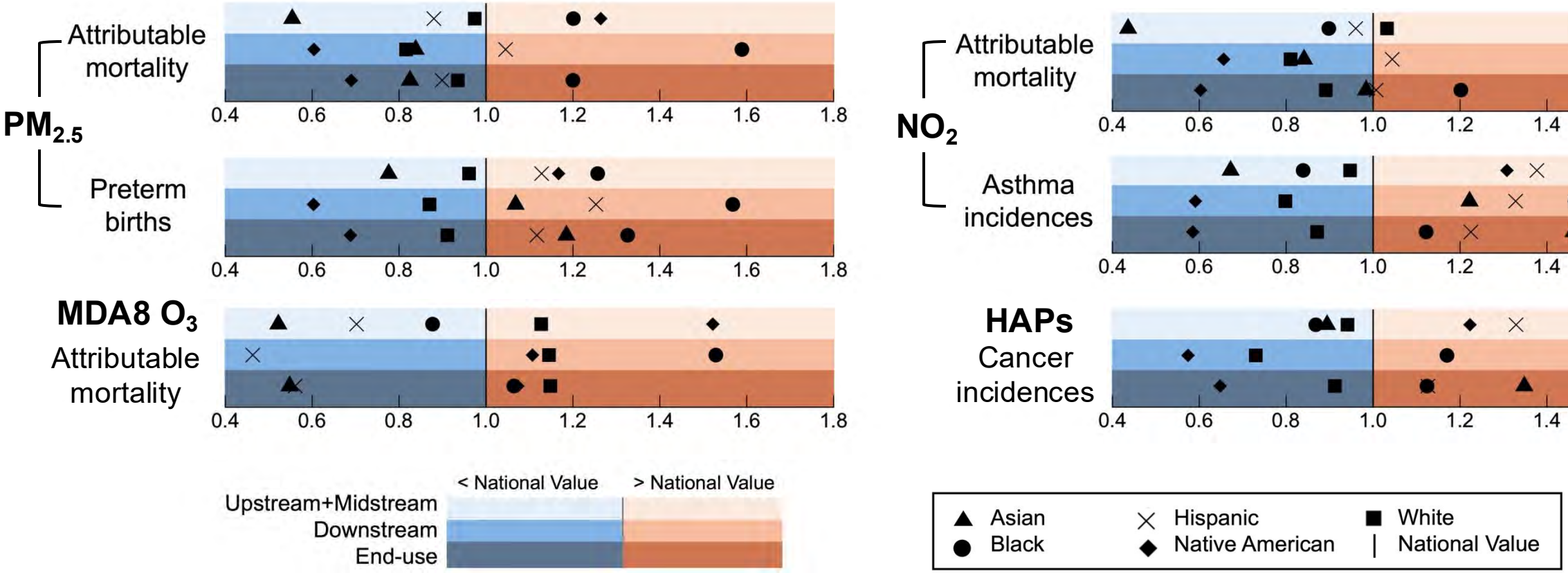
We estimate population-standardized health burdens for each racial and ethnic group as well as the national average for the total population. Subgroup population demographic data from ACS estimates.



Absolute racial and ethnic disparities for the end-use stage are much higher than the other stages

The inequitable health burden of oil and gas air pollution

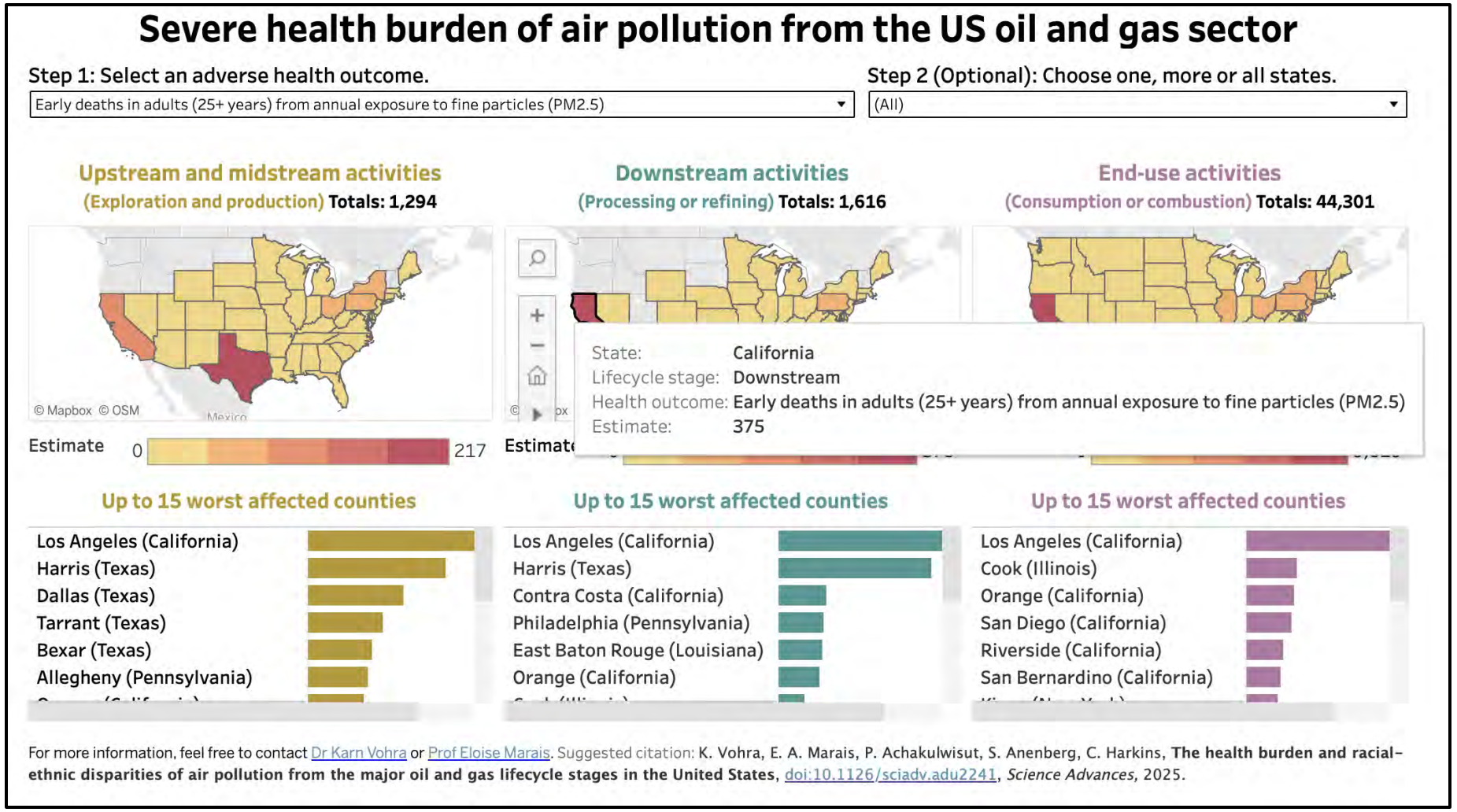
Population-standardized health burdens for each racial and ethnic group normalized to the national value



Air pollution health burden in Native Americans is 20-50% greater than the national average mortality rates. Burden in the Black population is 20-70% higher than the national estimates. Air pollution asthma and cancer incidence rates in Asian population are 35-50% higher than the national value. Greatest relative disparities almost all occur in the downstream stage

Explore the health burden results in our interactive dashboard

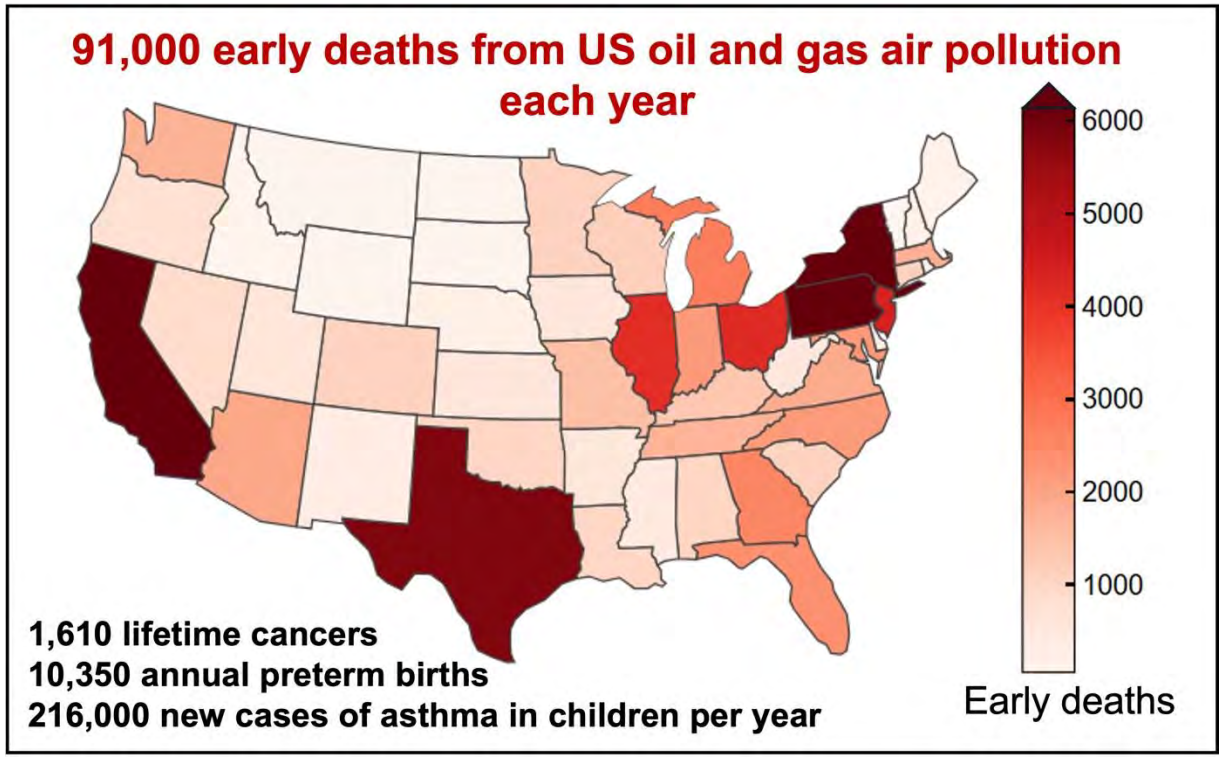
https://bit.ly/US_oilgas_healthburden_dashboard



OR

SCAN ME

The severe and unjust health burden of oil and gas air pollution!



https://www.theguardian.com/us-news/2025/aug/22/air-pollution-oil-gas-health-study

https://richardconniff.substack.com/p/oil-and-gas-air-pollution-is-a-killer

https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(25)00264-5/fulltext

Glass half full, our health burden estimates support substantial health benefits and reductions in unjust exposure that can be achieved with a transition away from oil and gas to cleaner alternatives.