

Toxic Air Pollution as a Sustainability Challenge

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India air pollution at 'unbearable levels', Delhi minister says

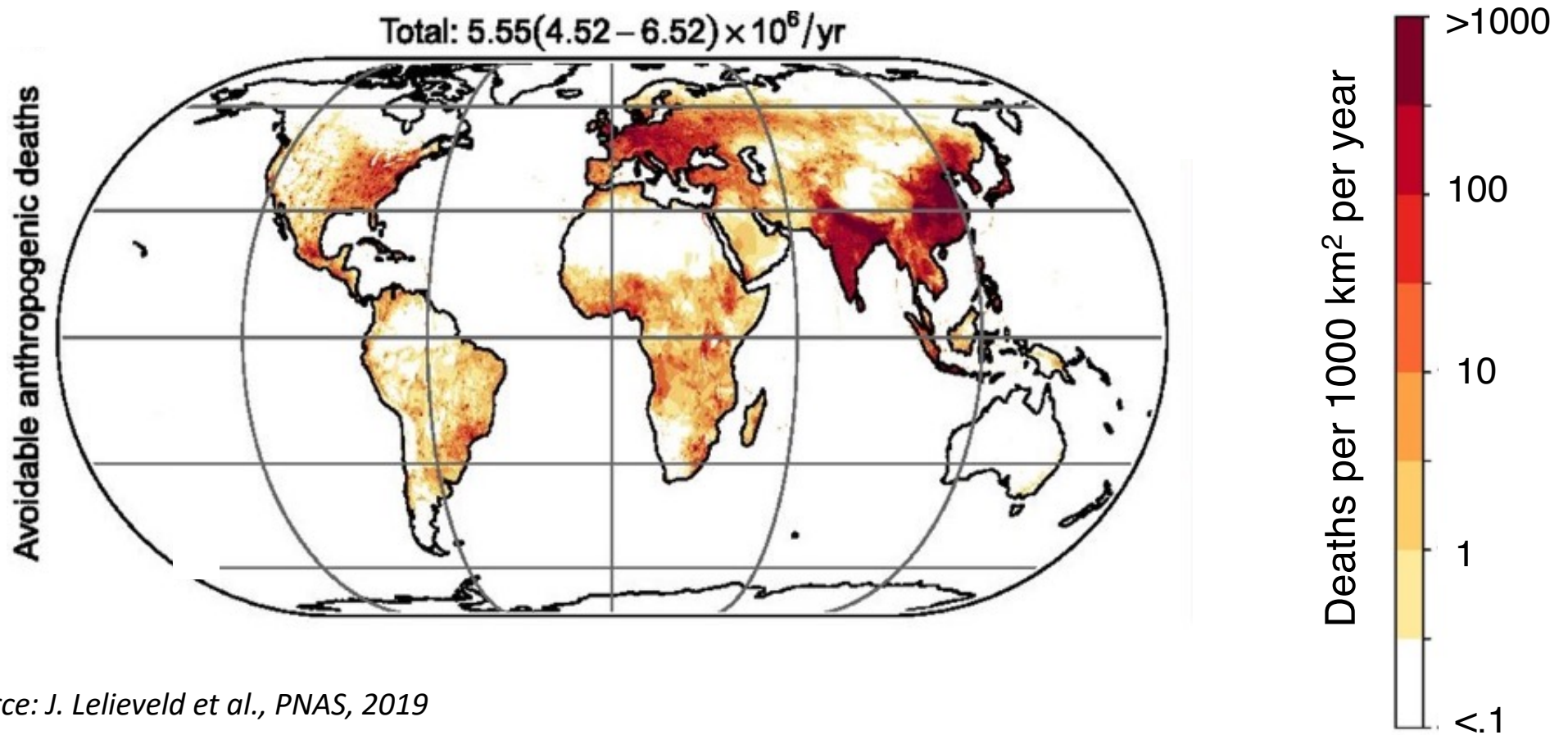
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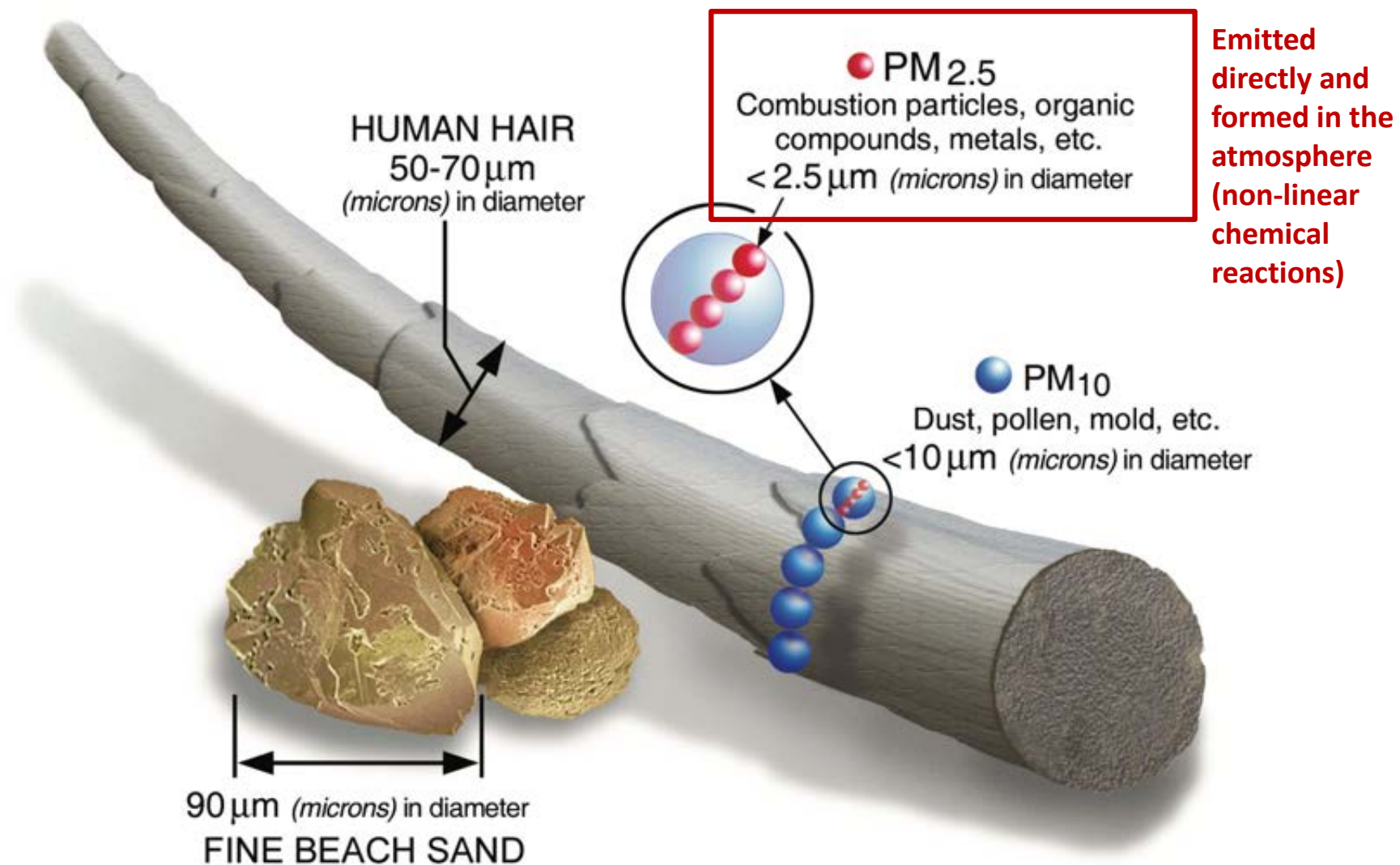
Air quality in Delhi has deteriorated into the "hazardous" category

Air pollution in the north of India has "reached unbearable levels," the capital Delhi's Chief Minister Arvind Kejriwal says.

Avoidable deaths from human emissions



Source: J. Lelieveld et al., PNAS, 2019



Source: US EPA

Mercury: A long-lived toxic air pollutant



Flickr/JonPinder cc

Photo: W. Eugene Smith

LEAST MERCURY		
Anchovies	Herring	Sardine
Butterfish	Mackerel (N)	Scallop*
Carfish	Atlantic Chub	Shad (American)
Clam	Mullet	Shrimp*
Crab (Domestic)	Oyster	Sole (Pacific)
Crawfish/Crayfish	Perch (Ocean)	Squid (Calamari)
Croaker (Atlantic)	Plaice	Tilapia
Flounder*	Pollock	Trout (Freshwater)
Haddock (Atlantic)*	Salmon (Canned)**	Whitefish
Hake	Salmon (Fresh)**	Whiting

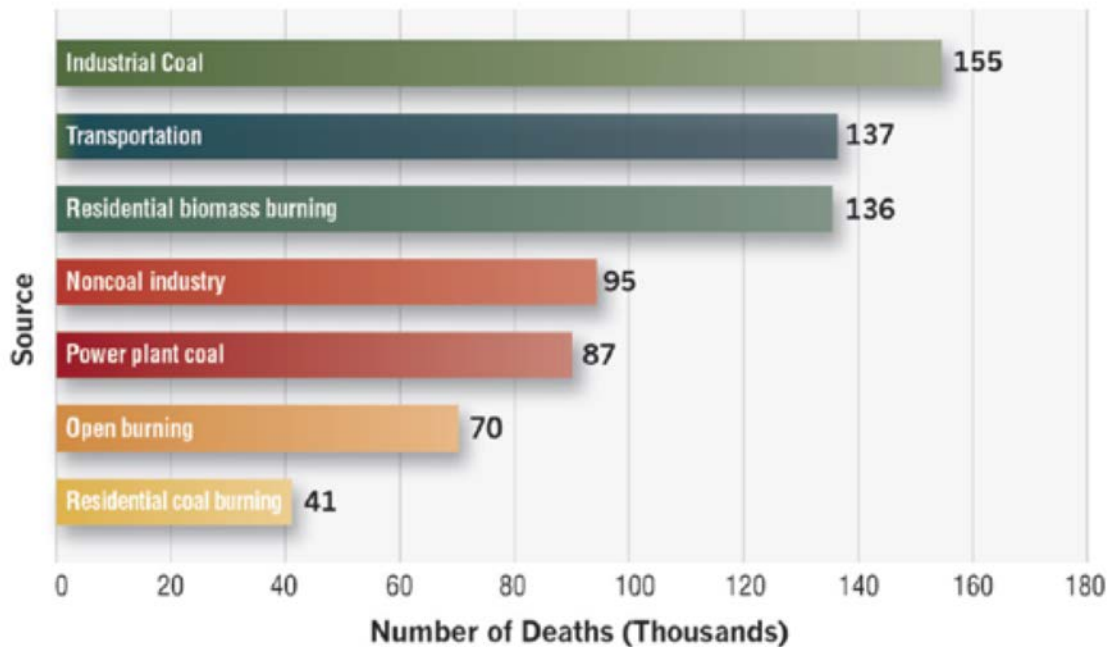
MODERATE MERCURY		
EAT SIX SERVINGS OR LESS PER MONTH:		
Bass (Striped, Black)	Jacksmelt	Skate*
Carp	(Silverside)	Snapper*
Cod (Alaskan)	Lobster	Tuna (Canned)
Croaker	Mahi Mahi	chunk (light)
(White Pacific)	Monkfish*	Tuna (Skipjack)*
Halibut (Atlantic)*	Perch (Freshwater)	Weakfish (Sea Trout)
Halibut (Pacific)	Sablefish	

HIGH MERCURY		
EAT THREE SERVINGS OR LESS PER MONTH:		
Bluefish	Mackerel	Tuna
Grouper*	(Spanish, Gulf)	(Canned Albacore)
	Sea Bass (Chilean)*	Tuna (Yellowfin)*

HIGHEST MERCURY		
AVOID EATING:		
Mackerel (King)	Shark*	Tuna
Marlin*	Swordfish*	(Bigeye, Ahi)*
Orange Roughy*	Tilefish*	

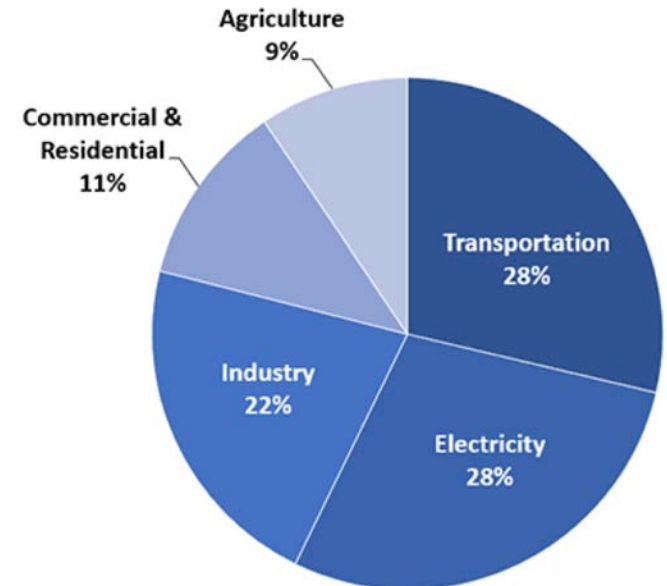
Air pollution and greenhouse gases come from common sources

Source contributions to air pollution mortality in China



Source: HEI, 2018

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2016



Source: US EPA

Prevent health
damages from
PM_{2.5} and
mercury



Ensure access to
energy

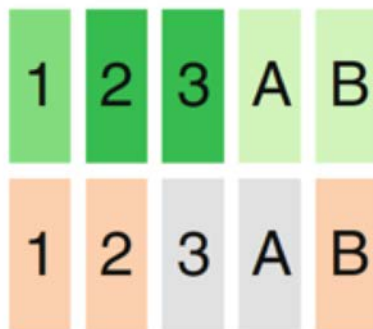
Mitigate climate
change



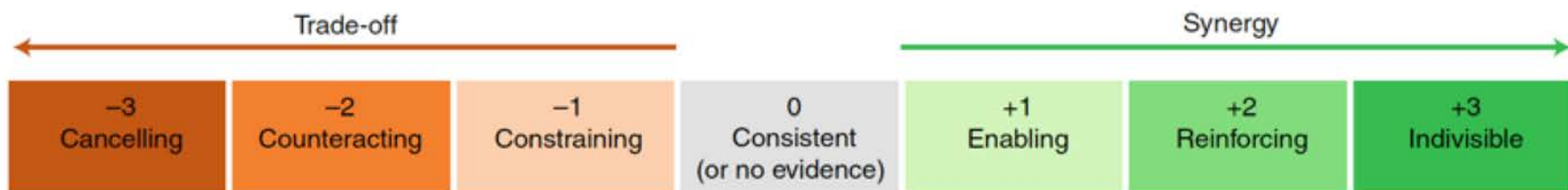


SUSTAINABLE DEVELOPMENT GOALS





Synergies and trade-offs between climate action and Sustainable Development Goals



Nerini et al., *Nature Sustainability*, 2019



Worse

Air Pollution

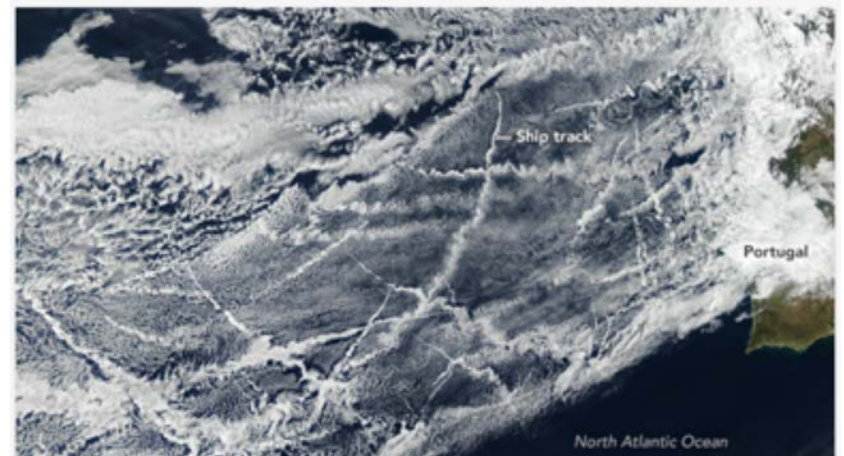
Better



Better

Climate change

Worse



Questions

1. How do policies and strategies interact, and can they achieve multiple sustainability goals simultaneously?
2. How can engineering research inform practical actions towards sustainability?

A Systems Approach to Informing Sustainability Challenges



Technologies



Environment



People

**Institutions &
Policies**

A Systems Approach to Informing Sustainability Challenges

Regional and global-scale climate and atmospheric chemistry models



Figure: <http://bit.ly/2K7gvlt>

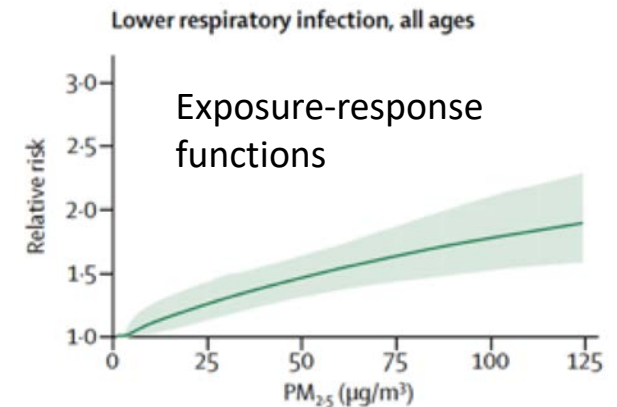


Figure: Cohen et al., 2017

Emissions inventories and technology options

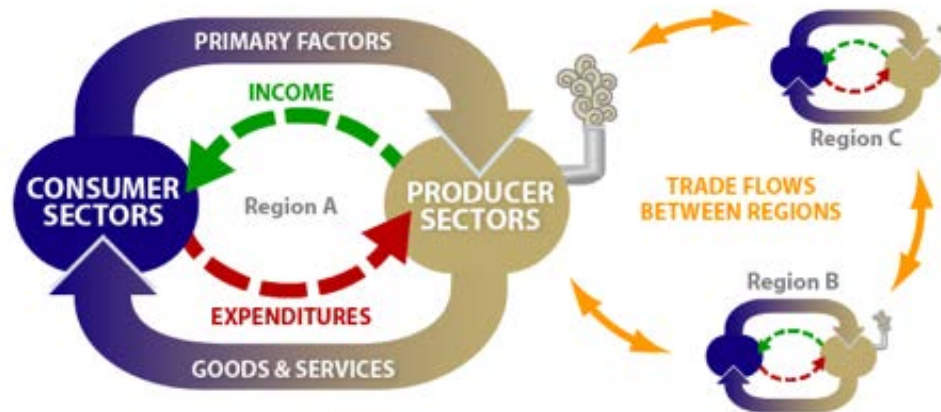


Figure: MIT EPPA Model

Policy context, production-consumption, and monetary flows



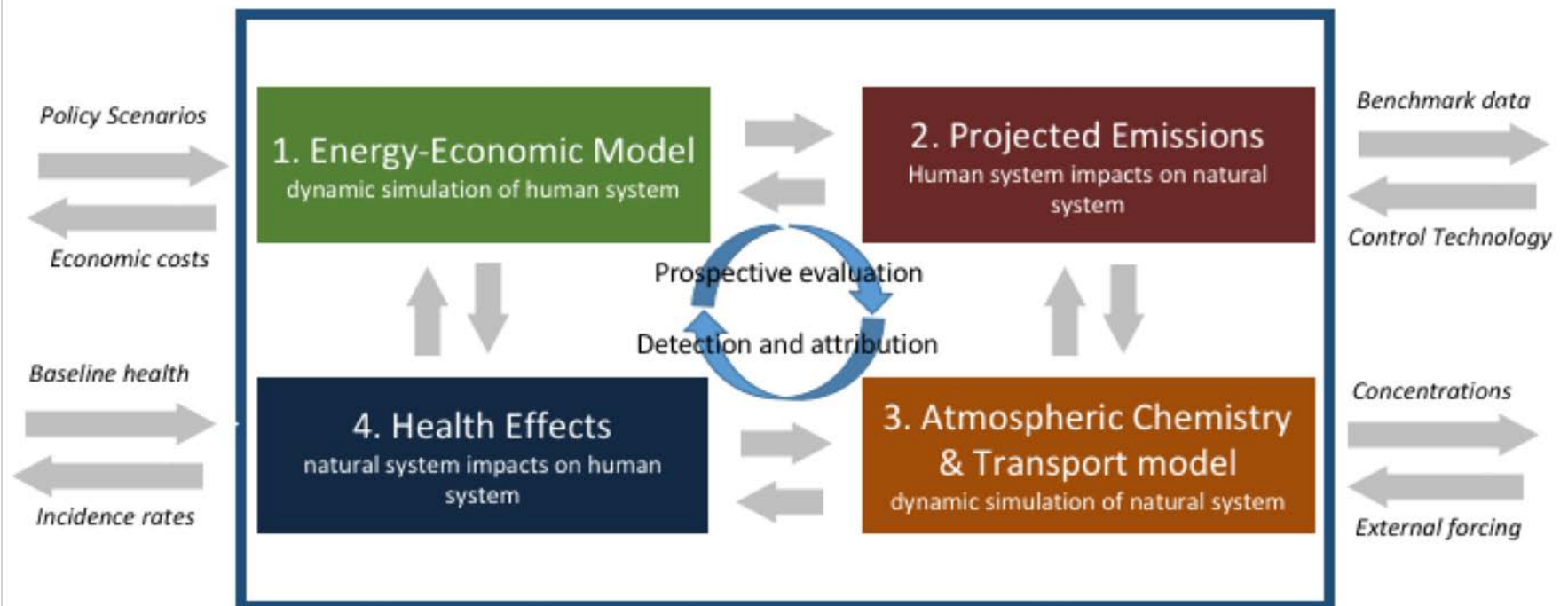
Mingwei Li, PhD 2019,
MIT Department of
Earth, Atmospheric, and
Planetary Sciences
(now postdoc, Princeton)

M. Li, D Zhang, C. T. Li, K. M. Mulvaney, N. E. Selin, and V. J. Karplus. 2018. "Air Quality Co-Benefits of Carbon Pricing in China." Nature Climate Change, 8:398-403.

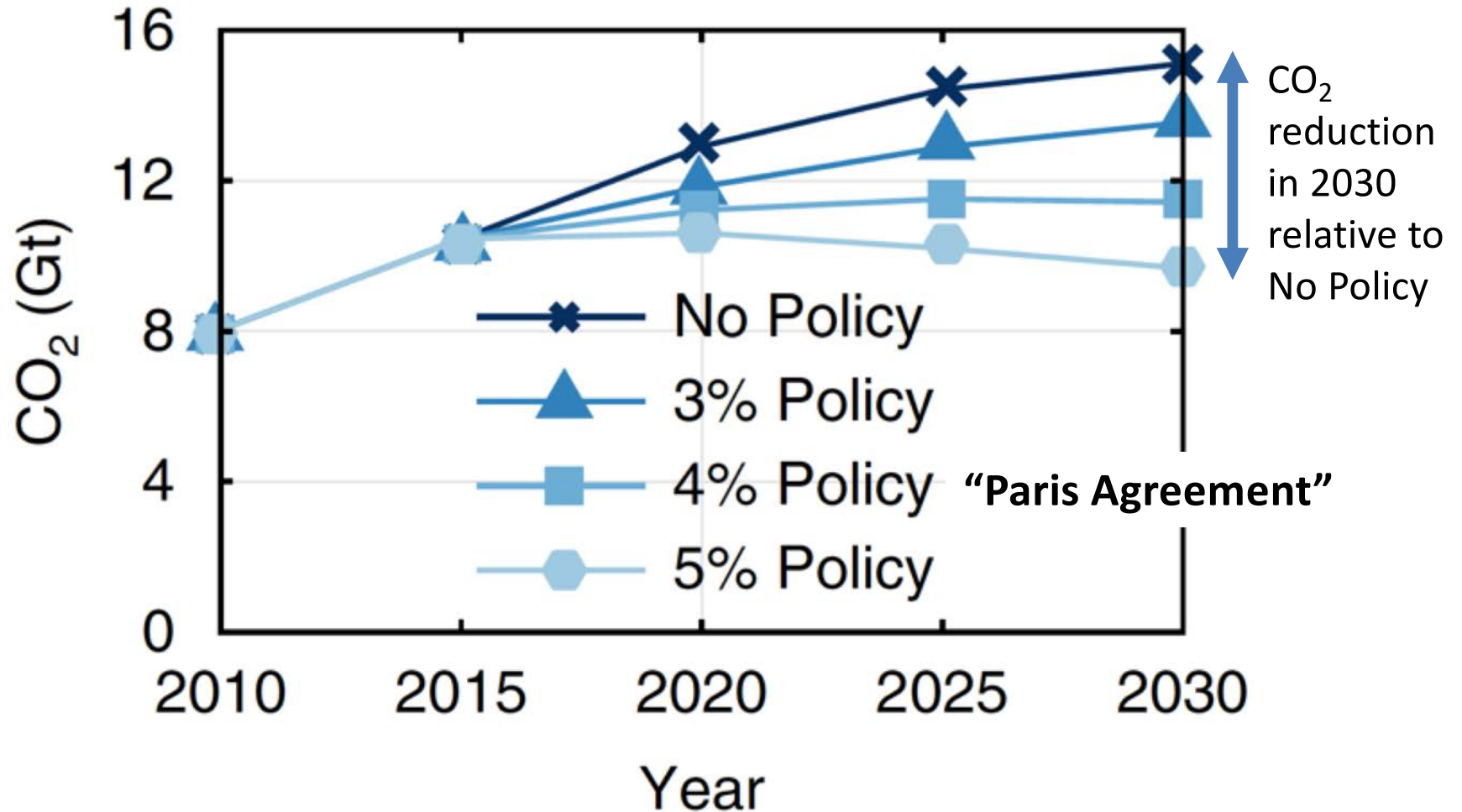
How will China's Paris Agreement commitments affect air pollution?

A Systems Approach to Informing Sustainability Challenges

REACH (Regional Emissions, Air Quality, Climate and Health) framework



CO₂ emissions from China: scenarios



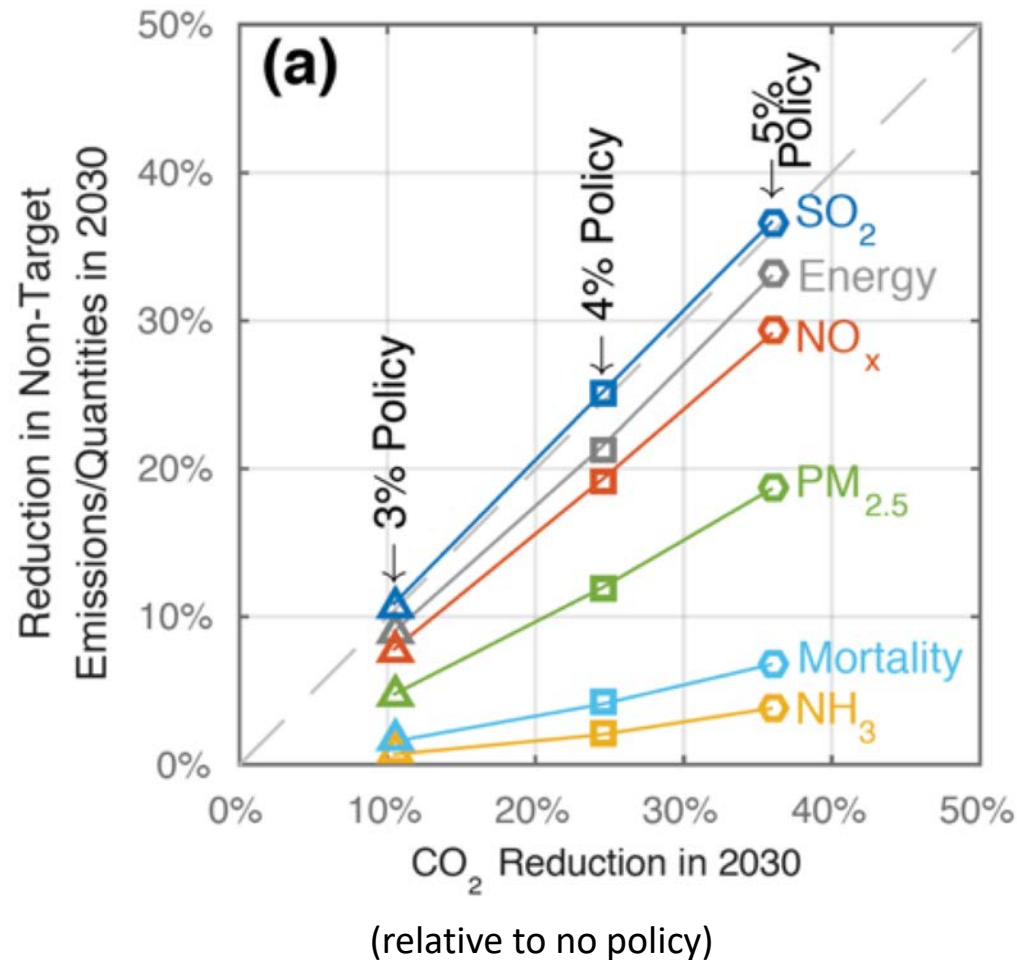
Paris Agreement has air pollution benefits



-11.9% population-weighted concentration of PM_{2.5}

95,000 premature deaths avoided

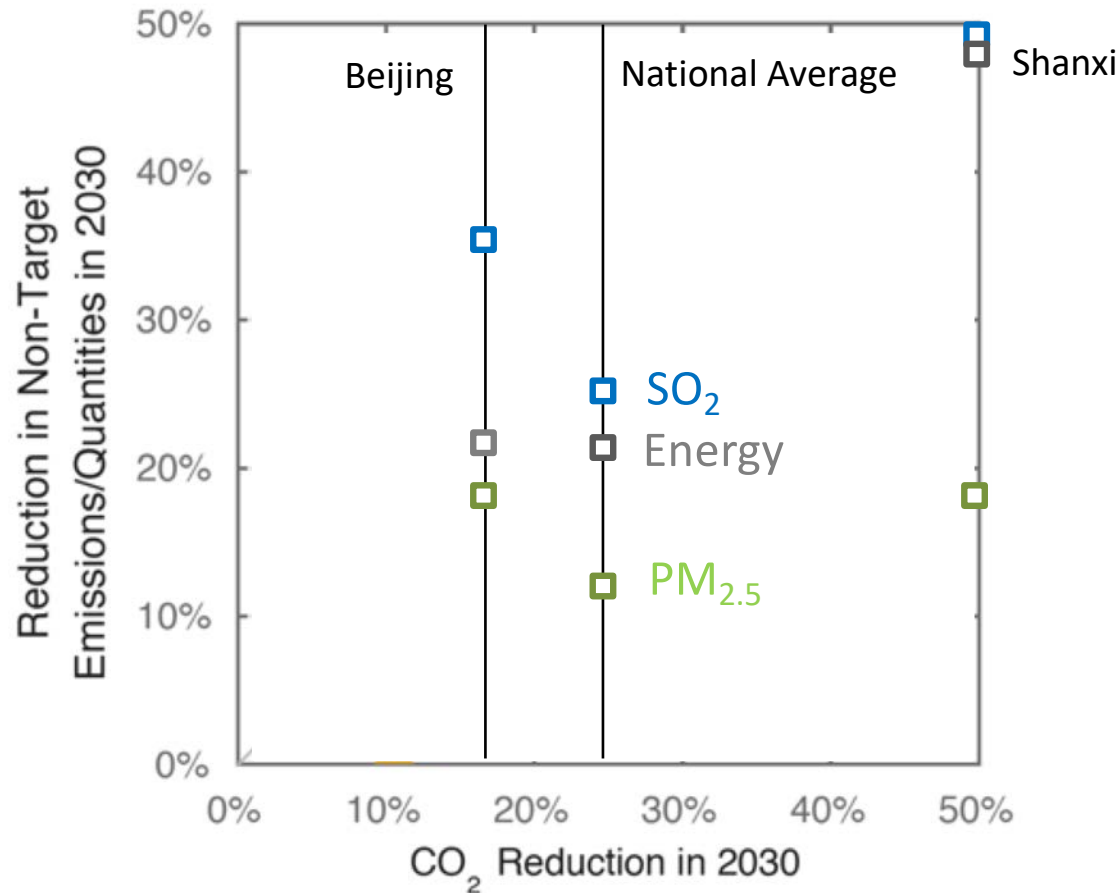
PM_{2.5} impacts as a function of CO₂ intensity reductions in China



SO₂, NO_x, NH₃ combine in the atmosphere to form PM_{2.5}. The chemical process can be non-linear.

PM_{2.5} also has non-anthropogenic sources that contribute to mortality.

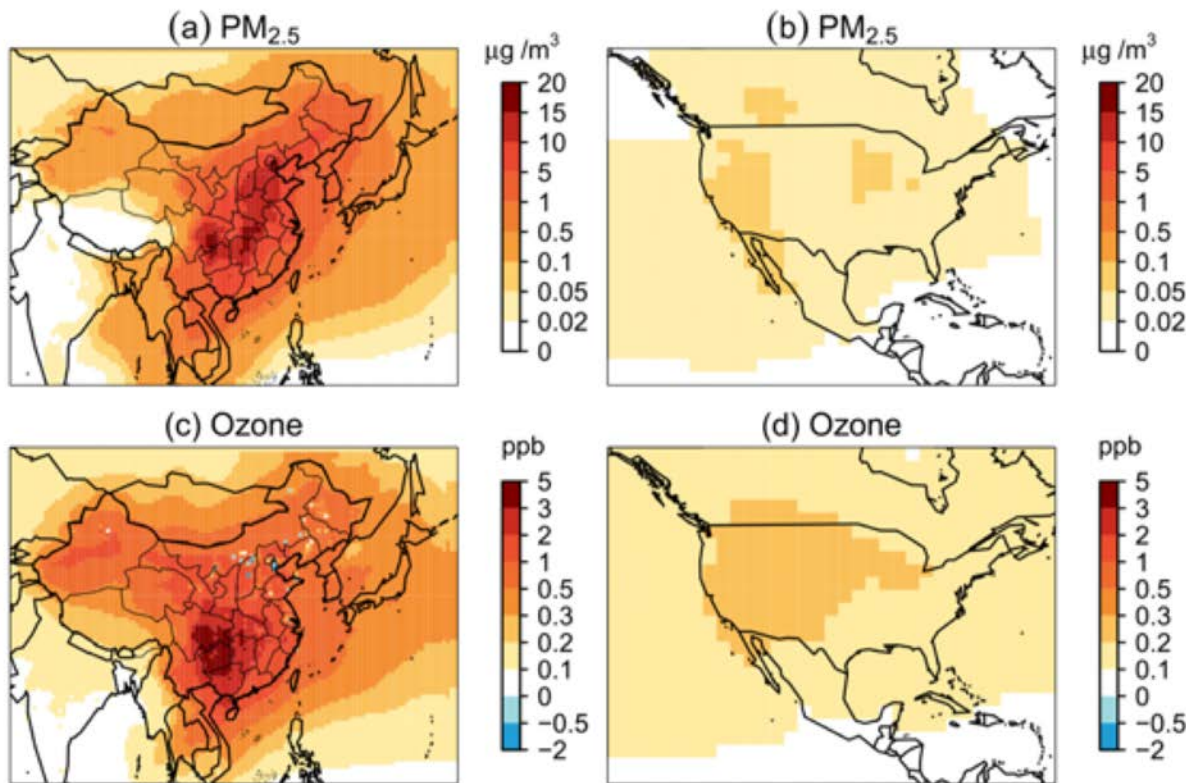
Provincial impacts differ from the national average (4% policy)



Beijing: low-cost CO₂ abatement opportunities also reduce SO₂ emissions via **economics**

Shanxi: coal producer
Reductions in SO₂ do not translate into PM_{2.5} due to **non-linear chemistry**

Reduced pollution and mortalities from Chinese climate policy



Mortalities avoided:

China: 95,200

Korea: 1,000

Japan: 2,000

US: 600

China: 54,300

Korea: 300

Japan: 1,500

US: 1,300

*For comparison: U.S.
Cross-state Air Pollution
Rule (2016) avoids
roughly 20 mortalities
from ozone.*

M. Li, D. Zhang, C.-T. Li, N. E. Selin, and V. J. Karplus. 2019. "Co-benefits of China's climate policy for air quality and human health in China and transboundary regions in 2030." *Environmental Research Letters*, 14, 084006.



Emil Dimanchev,
M.S. In Technology
and Policy, MIT, 2018

*E. Dimanchev, S. Paltsev, M. Yuan,
D. Rothenberg, C. Tessum, J.
Marshall, and N. E. Selin. 2019.
"Health co-benefits of sub-national
renewable energy policy in the U.S."
Environmental Research Letters, 14,
085012.*

What about in the US? Will renewable energy policies benefit air pollution?

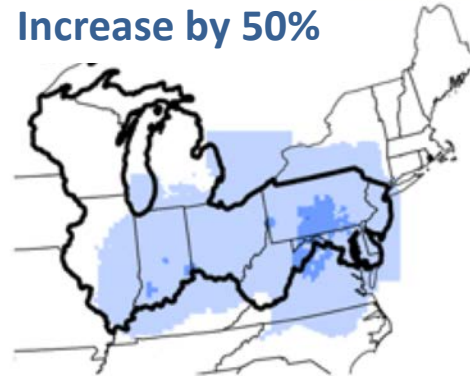
PM_{2.5} impacts of renewable energy policies in Midwest U.S.

13% renewables

Existing mandates

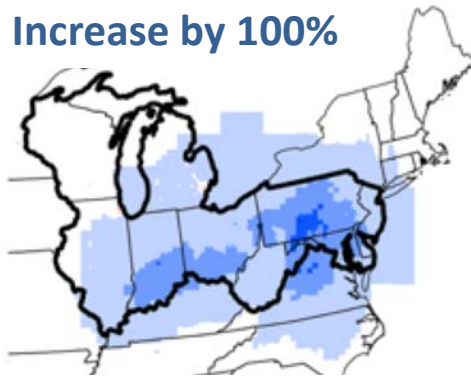


Increase by 50%



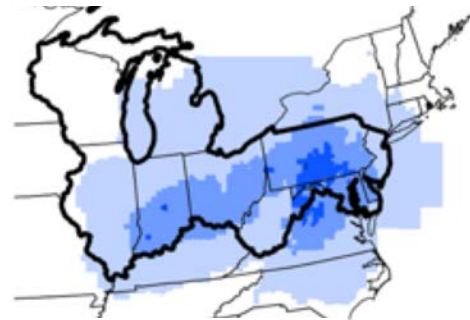
20% renewables

Increase by 100%



26% renewables

Set a CO₂ price instead

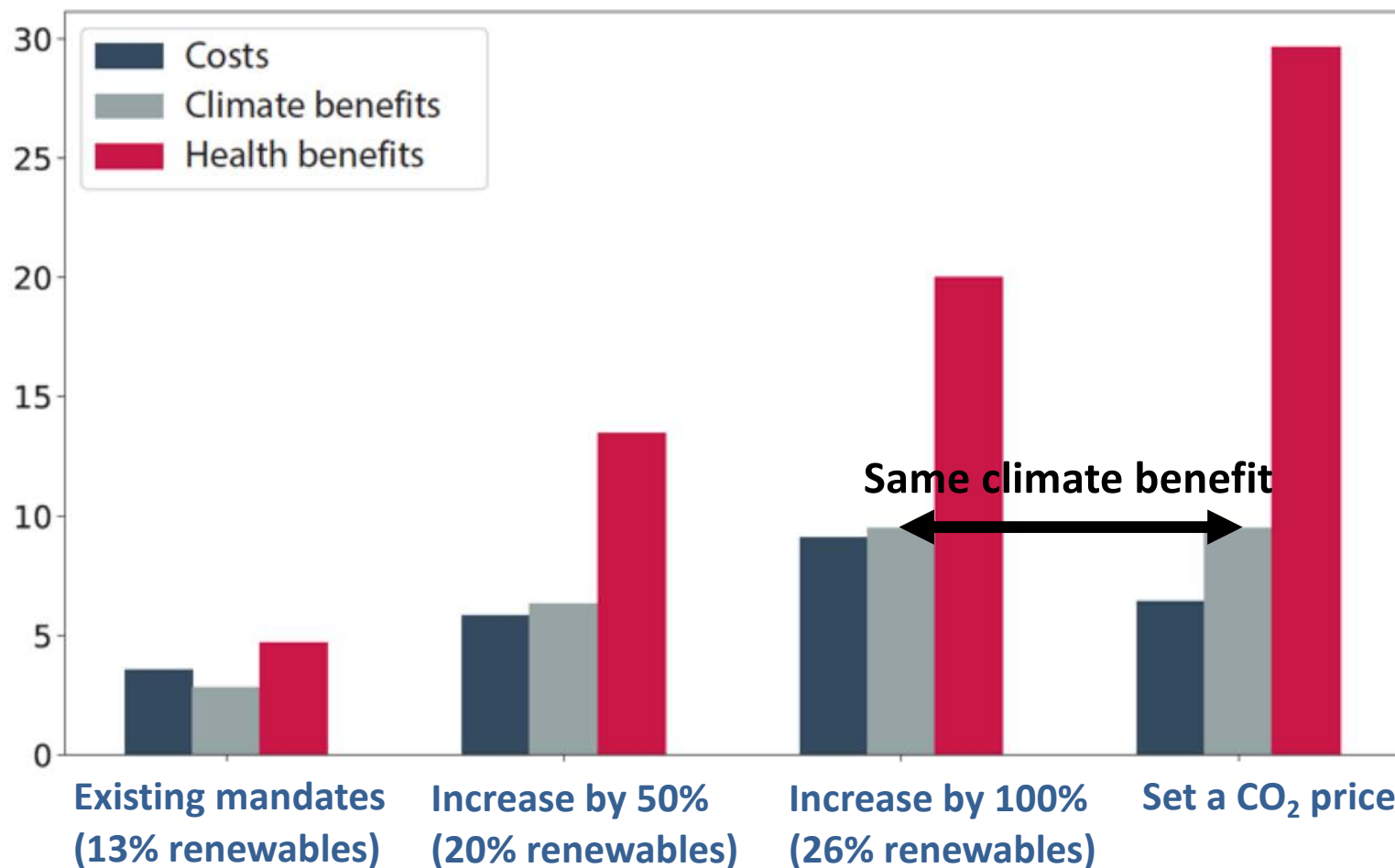


Policy region

-1.5 -- -2.0 -1.0 -- -1.5 -0.5 -- -1.0 -0.1 -- -0.5 0.1 -- 0.1

Change in PM_{2.5}, micrograms per cubic meter, relative to no policy case

Costs and benefits (\$US billions, relative to no policy)



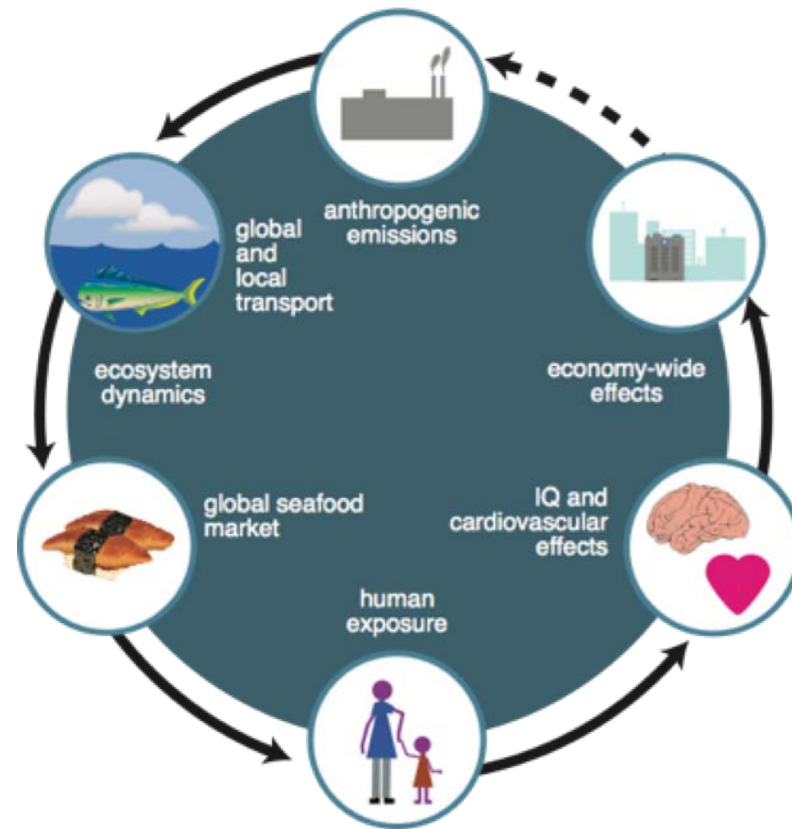


Amanda Giang, PhD '17
Engineering Systems, MIT, now
Assistant Professor, University
of British Columbia

A. Giang and N.E. Selin, 2016. "Benefits of Mercury Controls for the United States," Proceedings of the National Academy of Sciences, 113(2), 286-291.

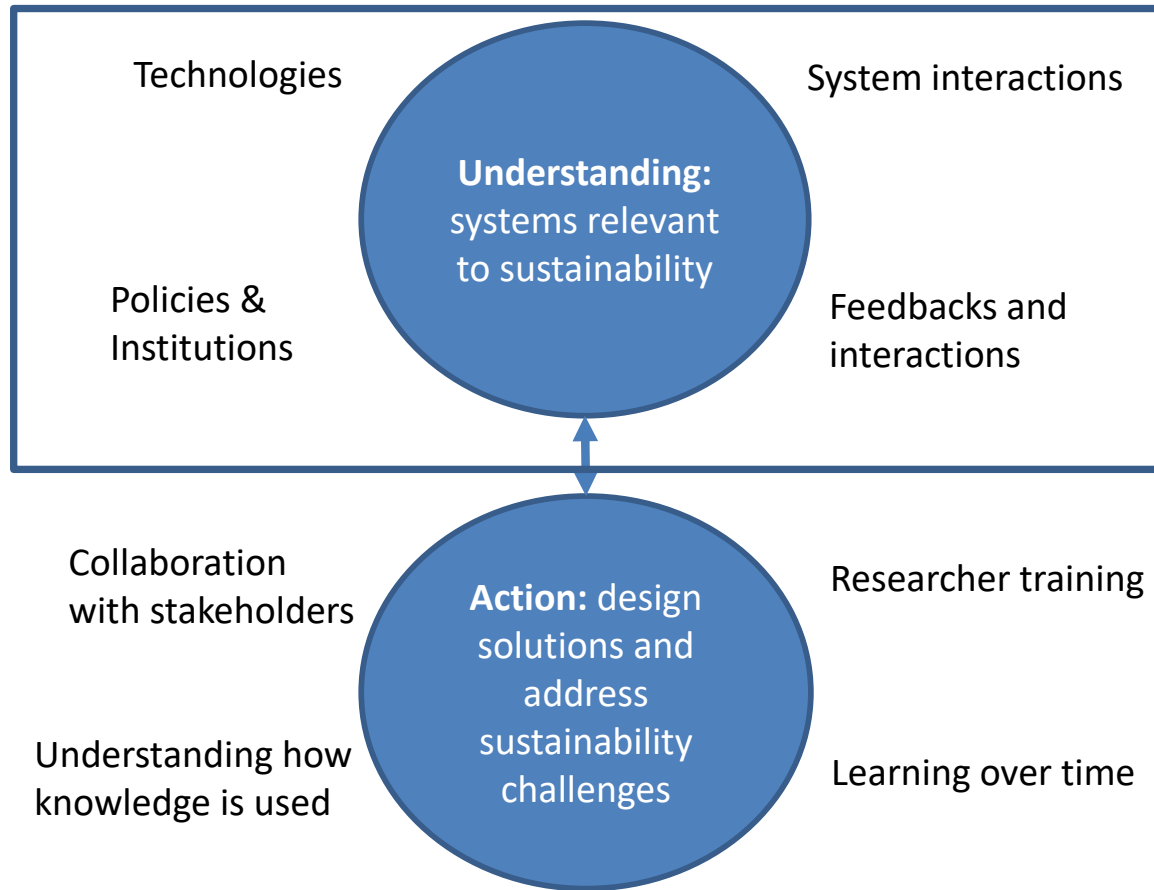
What are the benefits of reducing longer-lived air pollutants like mercury?

U.S. Supreme Court on the Mercury and Air Toxics Standards: “the quantifiable benefits from the resulting reduction in hazardous-air-pollutant emissions would be **\$4 to \$6 million** a year” (Michigan v. EPA, 2015)



Our work: benefits to 2050 estimated at **\$3.7 billion/year**

Bridging understanding and action for sustainability: an engineering perspective



1. How do policies and strategies interact, and can they achieve multiple sustainability goals simultaneously?

2. How can engineering research inform practical actions towards sustainability?

Adapted from Clark et al., PNAS, 2016

Understanding how knowledge is used



May 21, 2019, U.S. House of Representatives

U.S. efforts to roll back Mercury and Air Toxics Standards

Information about the benefits of policies – and cost of rolling them back – important to account for in legal and regulatory procedure.

<https://energycommerce.house.gov/committee-activity/hearings/hearing-on-undermining-mercury-protections-epa-endangers-human-health>

Understanding how knowledge is used

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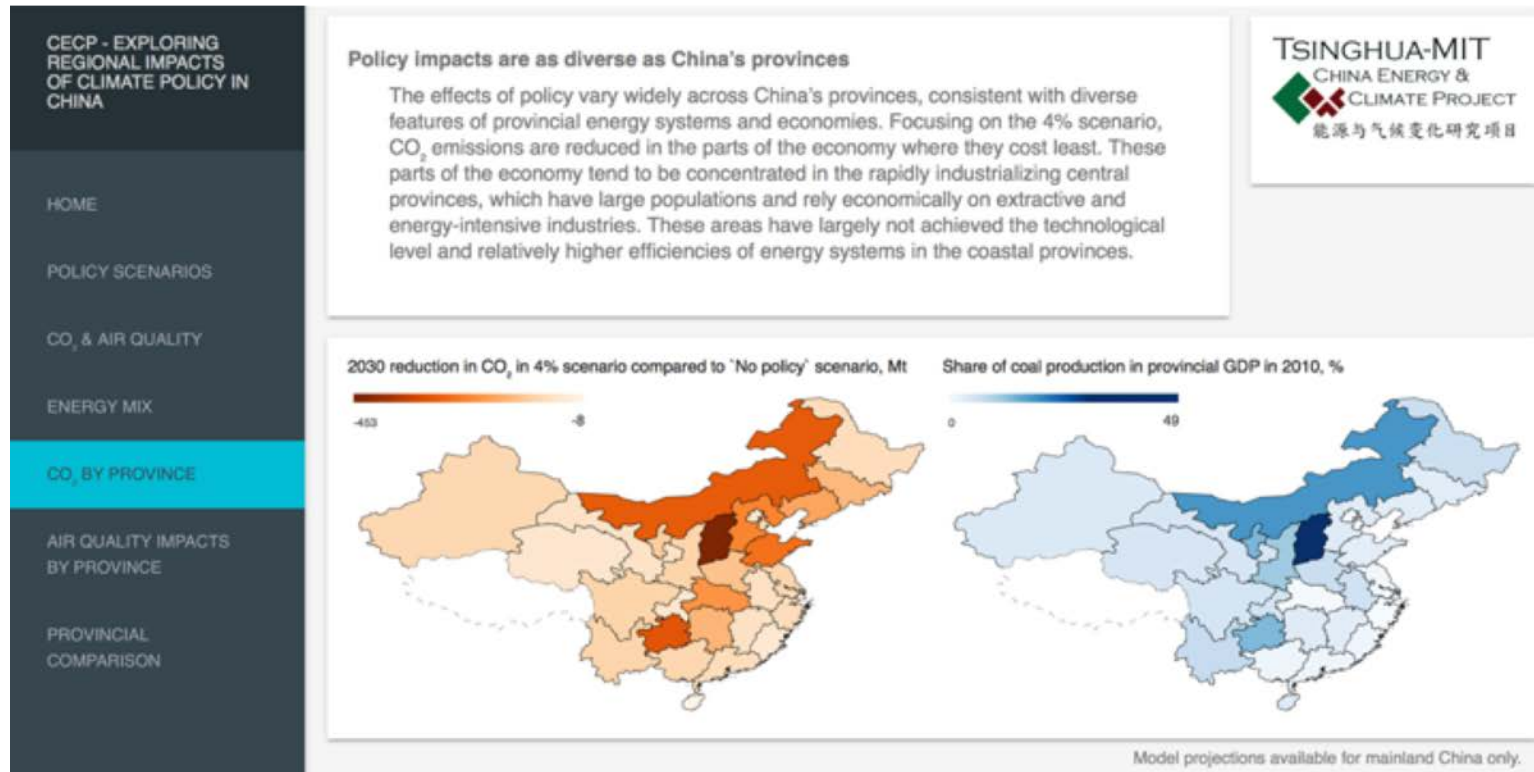
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3. Creating and implementing outreach strategies to engage relevant policymakers and other stakeholders in dialogue.
4. Providing coaching and communication training to make engagement effective.

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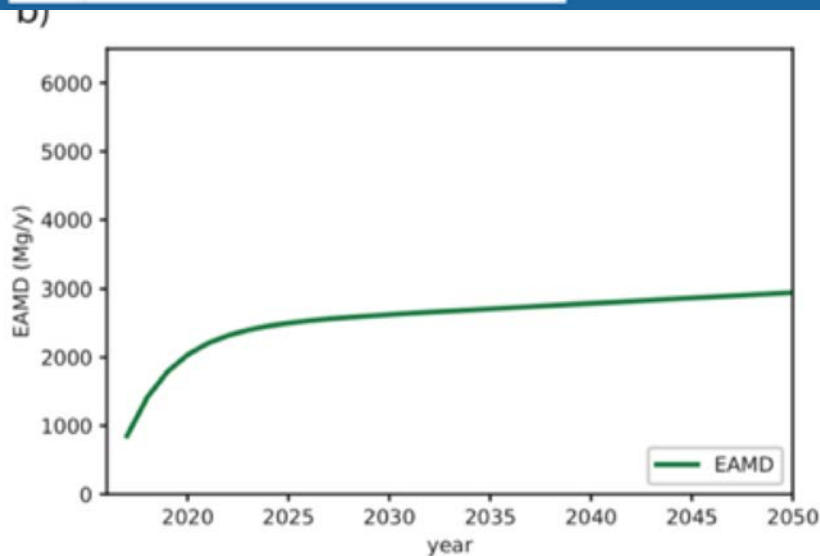
<http://policylab.mit.edu>

Collaboration with stakeholders



See: <http://cecp.mit.edu>

Learning over time



"Effective Anthropogenic Mercury Deposition," a new metric that accounts for long-term impact of present-day emissions

N. E. Selin. 2018. "A proposed global metric to aid mercury pollution policy." *Science* 360(6389):607-609.



SUSTAINABLE DEVELOPMENT GOALS



Acknowledgments



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Publication links and more info at: <http://mit.edu/selingroup>

