Toxic Air Pollution as a Sustainability Challenge

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

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

Total: $5.55 \times 10^6 \text{ per yr}$

Source: J. Lelieveld et al., PNAS, 2019
Emitted directly and formed in the atmosphere (non-linear chemical reactions)
Mercury: A long-lived toxic air pollutant
Air pollution and greenhouse gases come from common sources

Source contributions to air pollution mortality in China

Source: HEI, 2018

Source: US EPA
Prevent health damages from PM$_{2.5}$ and mercury

Ensure access to energy

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

Nerini et al., *Nature Sustainability*, 2019
Worse Air Pollution Better
Worse Climate change Better
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

Emissions inventories and technology options

Exposure-response functions

Policy context, production-consumption, and monetary flows

Figure: MIT EPPA Model

Figure: Cohen et al., 2017

Figure: http://bit.ly/2K7gvit
How will China’s Paris Agreement commitments affect air pollution?


Mingwei Li, PhD 2019, MIT Department of Earth, Atmospheric, and Planetary Sciences (now postdoc, Princeton)
A Systems Approach to Informing Sustainability Challenges

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

1. Energy-Economic Model
   - dynamic simulation of human system

2. Projected Emissions
   - Human system impacts on natural system

3. Atmospheric Chemistry & Transport model
   - dynamic simulation of natural system

4. Health Effects
   - natural system impacts on human system

Prospective evaluation
Detection and attribution

Policy Scenarios
- Economic costs
- Baseline health
- Incidence rates

Benchmark data
- Control Technology
- Concentrations
- External forcing
CO₂ emissions from China: scenarios

- **No Policy**
- **3% Policy**
- **4% Policy**
- **5% Policy**

"Paris Agreement" CO₂ reduction in 2030 relative to No Policy
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 CO$_2$ intensity reductions in China

SO$_2$, NO$_x$, NH$_3$ 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 PM₂.₅ 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

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

20% renewables

26% renewables

Change in PM$_{2.5}$, micrograms per cubic meter, relative to no policy case
Costs and benefits ($US billions, relative to no policy)

- Existing mandates (13% renewables)
- Increase by 50% (20% renewables)
- Increase by 100% (26% renewables)
- Set a CO₂ price

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

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

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

Giang and Selin, 2016
Bridging understanding and action for sustainability: an engineering perspective

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Adapted from Clark et al., PNAS, 2016
Understanding how knowledge is used

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.

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

Understanding how knowledge is used
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2. Working with faculty to identify the policy implications of their work.
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

Policy impacts are as diverse as China's provinces

The effects of policy vary widely across China's provinces, consistent with diverse features of provincial energy systems and economies. Focusing on the 4% scenario, CO₂ emissions are reduced in the parts of the economy where they cost least. These parts of the economy tend to be concentrated in the rapidly industrializing central provinces, which have large populations and rely economically on extractive and energy-intensive industries. These areas have largely not achieved the technological level and relatively higher efficiencies of energy systems in the coastal provinces.

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

Acknowledgments

Selin Group and collaborators participating in this work, especially:

Students: Mingwei Li (PhD ‘19, now Princeton), Amanda Giang (PhD ‘17, now UBC); Emil Dimantchev (MS ‘18)
Collaborators and coauthors, especially V. Karplus (Sloan) for economic modeling, C. Tessum and J. Marshall (UW) for InMAP model

Funding:
U.S. EPA Air, Climate, Energy (ACE) Center; MIT Joint Program on Science and Policy of Global Change (and its industrial and foundation sponsors); MIT Environmental Solutions Initiative, IDSS Seed Fund

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