Increasing the Positive Impacts of Renewable Energy Deployment in the United States: *A Journal Presentation to KCI2*

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Presentation Context

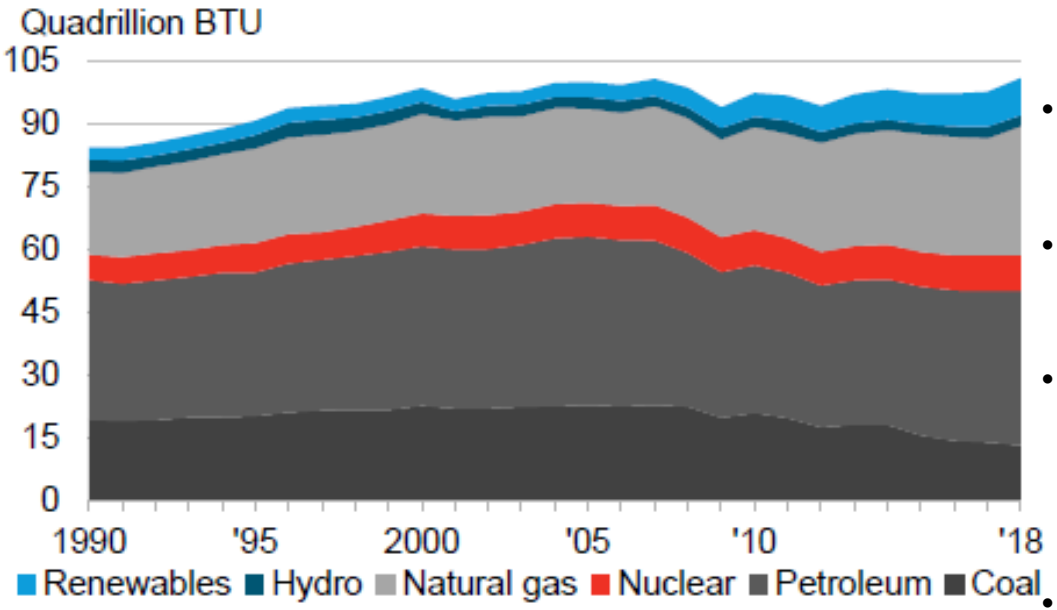
- This presentation responds to paragraph 6 of SBI Agenda item 14 and SBSTA Agenda item 7 Conclusions:
    - "The SBSTA and the SBI agreed that the KCI, at its 2nd meeting, will exchange lessons learned and best practices on analysis and assessment of positive and negative impacts of the implementation of response measures by Parties"
- This presentation is based on the publicly available, peer reviewed article: Jonathan J Buonocore *et al.* 2019. "Climate and health benefits of increasing renewable energy deployment in the United States" *Environmental Research Letters* 14 114010. Available at: https://iopscience.iop.org/article/10.1088/1748-9326/ab49bc.
    - The United States does not endorse the findings of the article or the data on which they are based, though this among other sources of information, contributes to our government's and other governments' understanding of the impacts of renewable energy deployment. The content and specific findings of this article remain the responsibility of its authors.

Presentation Overview

1. Background and Motivation
2. Problem Statement and Study Question
3. Methods and Models
4. Data Analysis
5. Study Conclusions and Limitations
6. References
7. Question and Discussion

Background and Motivation

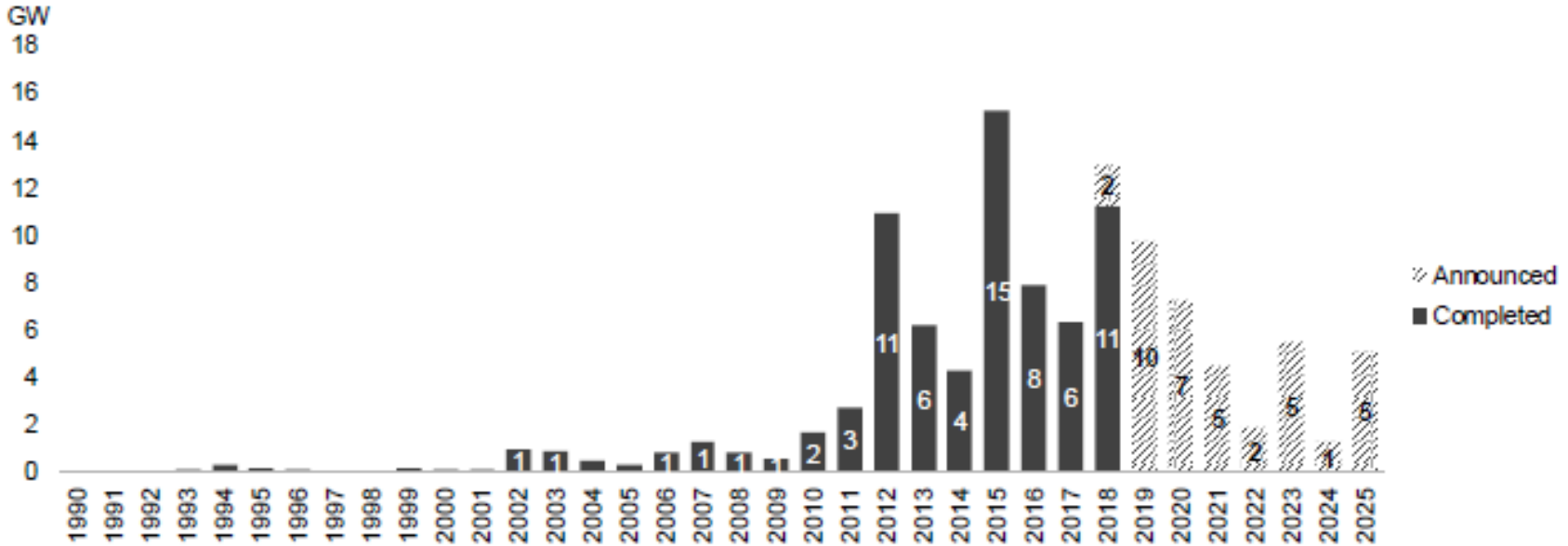
U.S. Primary Energy Consumption by Fuel Type



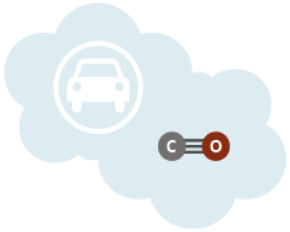
Source: EIA, BNEF "2019 Sustainable Energy in America Factbook. Available at: https://www.bcse.org/wp-content/uploads/2018-Sustainable-Energy-in-America-Factbook.pdf

- U.S. energy consumption has been slowly increasing over time.
- Nearly 80% of the U.S. energy demand is met by fossil fuels
- Coal consumption hit its lowest level since the mid-1970s in 2018, down 42% from its peak in 2005.
- In 2018, natural gas and non-hydro renewables saw the largest gains, increasing by 10.4% and 7.4%, respectively due to near-record levels of installations and increased demand for power.
- Hydro generation declined 3.3% after a drier year in the West.

Coal Fired Power Plant Retirement Accelerated in 2018

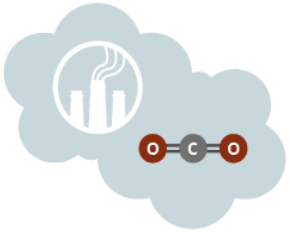


Source: EIA, company announcements, BloombergNEF Notes: "Retirements" does not include conversions from coal to natural gas or biomass; includes retirements or announced retirements reported to the EIA through October 2018. All capacity figures represent summer generating capacity.



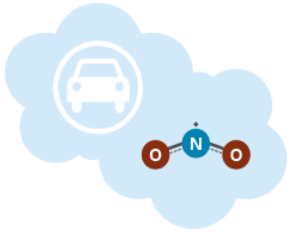
CARBON MONOXIDE

A gas generated by the incomplete combustion of fuels – primarily from road transport. Affects human health, as it reduces oxygen-carrying capacity of the blood. It also reacts with other atmospheric gases to produce ozone.



CARBON DIOXIDE

A gas generated by the burning of fossil fuels in the production of electricity. Also emitted by natural processes. Human emissions are linked with rising atmospheric CO_2 levels and anthropogenic global warming.

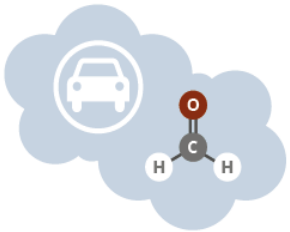


NITROGEN OXIDES

Primarily created by combustion in road transport. Nitrous oxide is an important global warming contributor, whilst nitrogen dioxide is involved in ground-level ozone forming reactions, and is also a component of smog.

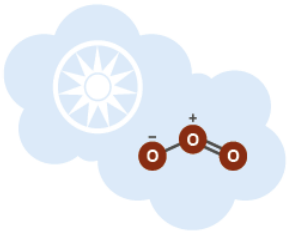
SULFUR DIOXIDE

The primary source of sulfur dioxide is the burning of fossil fuels to generate electricity. It can contribute to smog, reacts with water to produce acid rain, and can also cause wheezing and breathing problems for asthmatics.



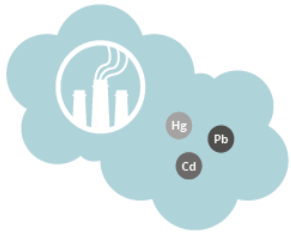
VOCs

VOCs (volatile organic compounds) are emitted naturally by vegetation. Amongst significant human sources is road transport, as well as solvents. They can contribute to formation of ground-level ozone and smog.



OZONE

The ozone layer shields us from UV radiation, but ground-level ozone is a major pollutant. It's formed from other pollutants in the presence of sunlight. Ozone is a major component of smog, and can also cause health effects.



HEAVY METALS

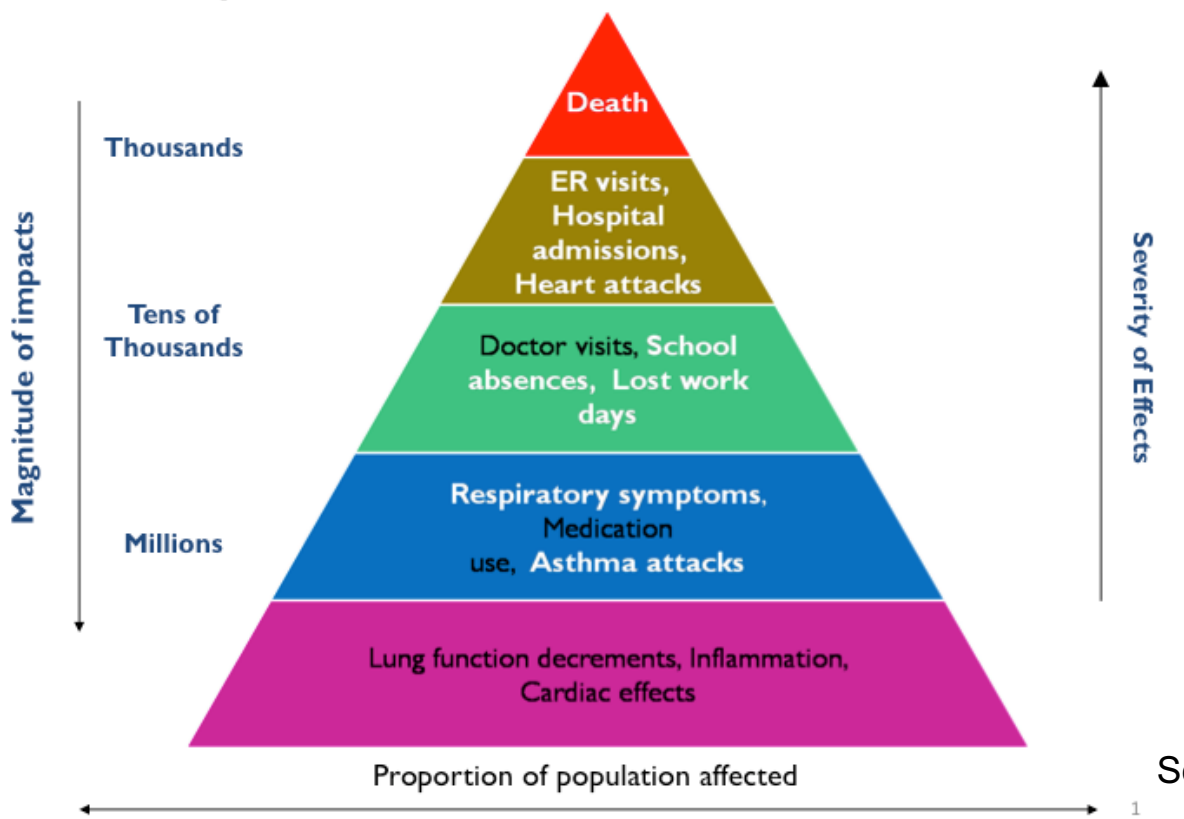
Heavy metals are released into the atmosphere from a range of sources, including burning of fossil fuels and road transport emissions. Some, such as mercury and lead, have toxic health effects in humans.

PARTICULATE MATTER

Particulate matter is composed of a huge number of different components. Some are directly emitted, while others are generated by reactions in the atmosphere. They cause haze and can also cause lung problems if inhaled.

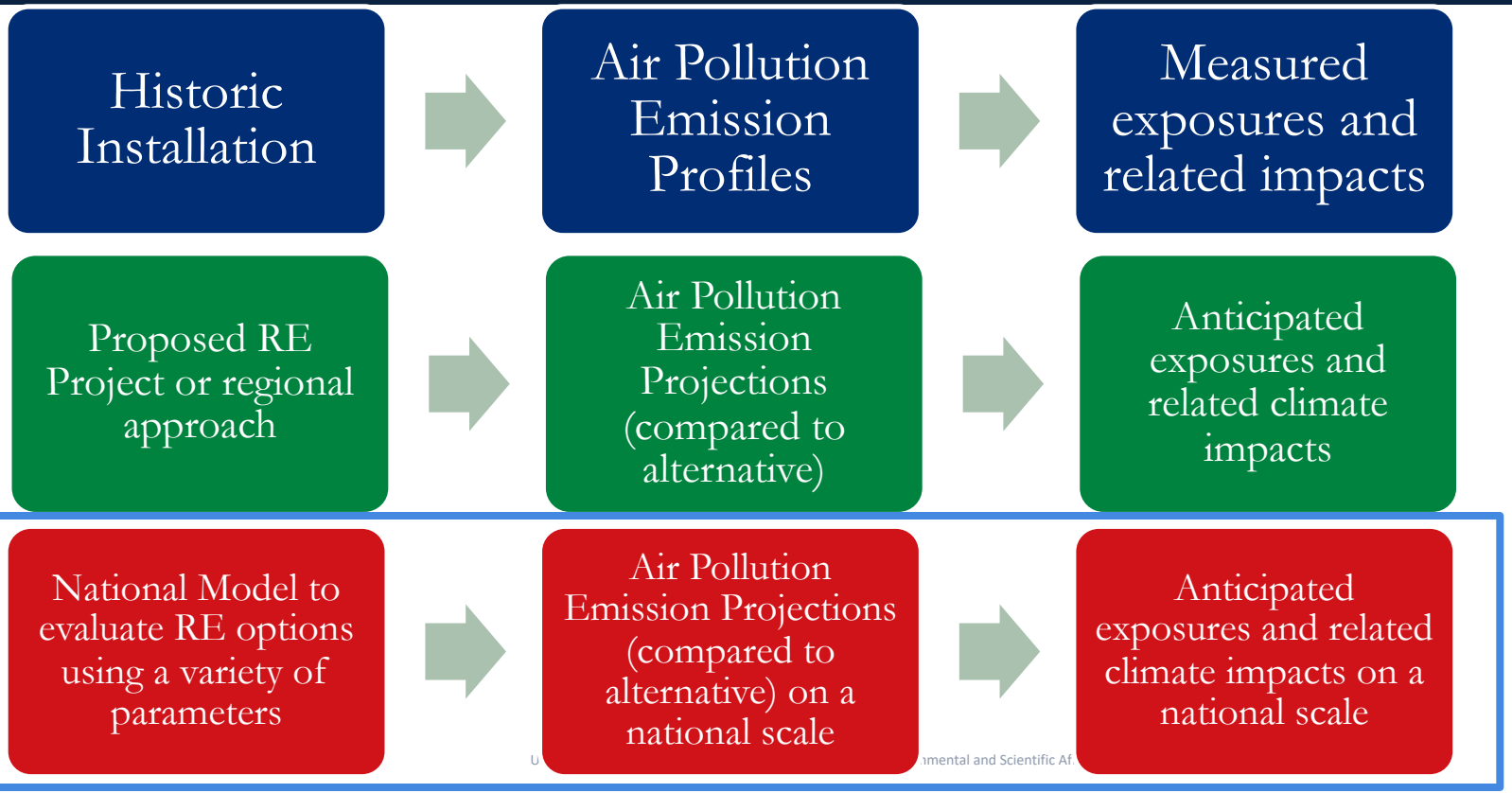
Electricity generation through fossil fuel combustion contributes to GHG emissions and atmospheric pollutants associated with increased morbidity and mortality.

Air Pollution-Related Health Impacts Vary



Source: US EPA

Research Landscape



Problem Statement and Study Question

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Jonathan J Buonocore *et al.* 2019. "Climate and health benefits of increasing renewable energy deployment in the United States" *Environmental Research Letters* 14 114010

- Problem Statement: The climate and health benefits of the growth of RE has been assessed historically and the benefits of specific projects or project types in specific regions have been projected, no one has built a model to evaluate the climate and health benefits of a series of RE projects at different sizes across the United States – taking into account seasonal variation in health impacts of emissions.

- Question - Where will renewable energy installations in the United States produce the greatest public health and climate benefits?

LETTER

OPEN ACCESS

Climate and health benefits of increasing renewable energy deployment in the United States*

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Keywords: renewable energy, air pollution, greenhouse gas mitigation, climate policy, health impact assessment

Abstract

The type, size, and location of renewable energy (RE) deployment dramatically affects benefits to climate and health. Here, we develop a ten-region model to assess the magnitude of health and climate benefits across the US. We then use this model to assess the benefits of deploying varying capacities of wind, utility-scale solar photovoltaics (PV), and rooftop solar PV in different regions in the US—a total of 284 different scenarios. Total benefits ranged from $2.2 trillion for 3000 MW of wind in the Upper Midwest to $4.2 million for 100 MW of wind in California. Total benefits and highest cost effectiveness for CO_2 reduction were generally highest for RE deployment in the Upper Midwest and Great Lakes and Mid-Atlantic US and lowest in California. Health was a substantial portion of total benefits in nearly all regions of the US. Benefits were sensitive to methane leakage throughout the gas supply chain.

Introduction

Use of fossil fuels contributes to climate change and health impacts of air pollution [1–5]. Electricity generation is a major source of CO_2, one of the main greenhouse gases (GHGs) driving climate change. Electricity is also a major source of air pollutants that harm health—sulfur dioxide (SO_2), nitrogen oxides (NO_x), and fine particulate matter ($PM_{2.5}$) [6]. In 2017, electricity generation was responsible for 1,941.4 million metric tons (MMT), or 29.5% of GHG emissions in the United States [7]. In 2014, US electrical generation was also responsible for 68% of SO_2 emissions, 12% of NO_x emissions, and 34% of primary $PM_{2.5}$ emissions [6]. Emissions from electricity generation were responsible for 31 000 excess deaths in the US in 2010 [5]. Deploying renewable energy (RE) generation is one of many strategies that can reduce reliance on fossil fuels, prevent emissions of GHGs, and reduce the health burden and other environmental impacts of electricity generation [8–11].

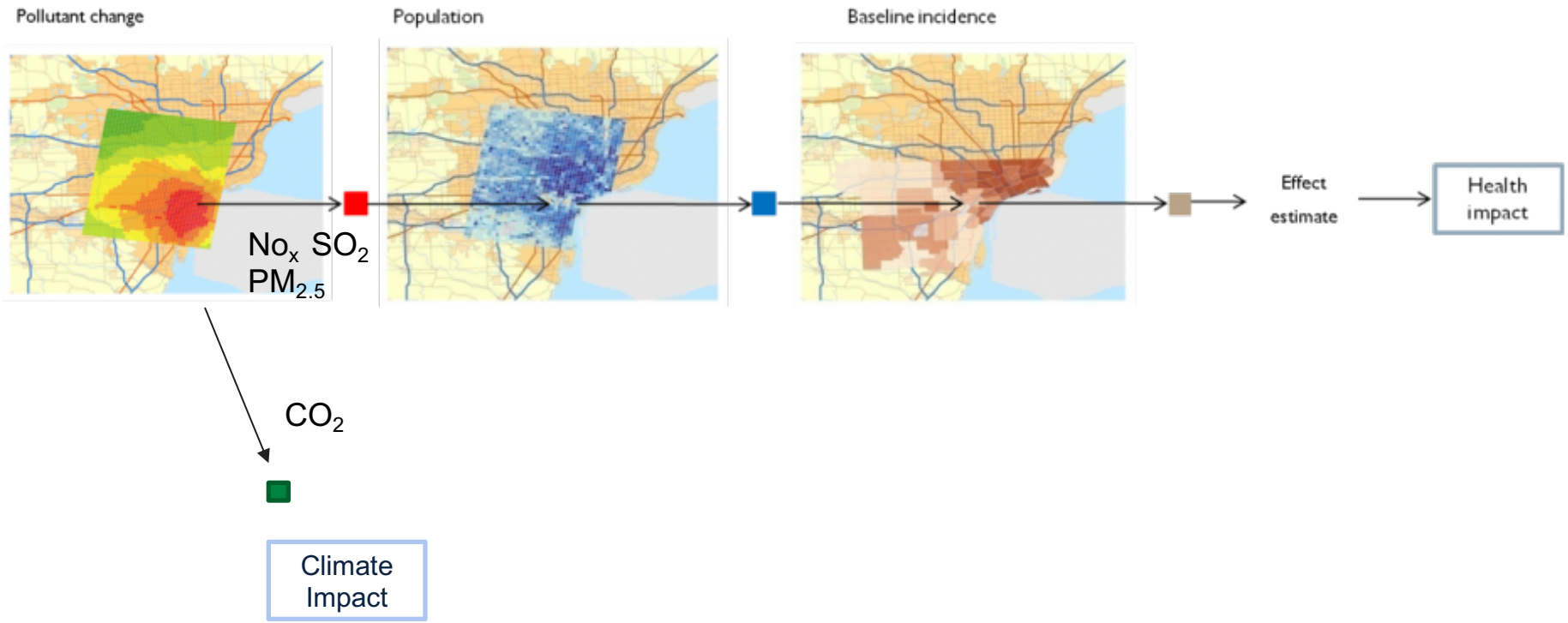
The climate and health benefits of the growth in RE has been assessed historically [12], marginal benefits of incremental increases have been assessed for past years [13], and the benefits of either specific project types or projects in specific regions has been assessed [9, 10, 12, 14, 15]. To build on this, we evaluate a series of RE projects at different sizes and across all regions of the US for the year 2017, using consistent methods to estimate benefits, and using health benefit modeling that incorporates seasonal differences in health impacts of emissions.

To do this, we developed the Environmental Policy Simulation Tool for Electrical Grid Interventions, v2.0., (EPSTEIN 2.0), a model to estimate health and climate benefits of RE projects, throughout the US. EPSTEIN 2.0 builds on EPSTEIN 1.0, which was geographically limited to the Mid-Atlantic US [9]. We use EPSTEIN 2.0 to simulate the benefits of wind, utility scale solar PV, and rooftop solar PV, deployed at a variety of sizes, in 10 different regions of the US (figure S1), and evaluate and rank different RE types and locations in terms of health benefits, CO_2 avoided, and

*Strategic deployment of wind and solar can maximize carbon reductions and health gains

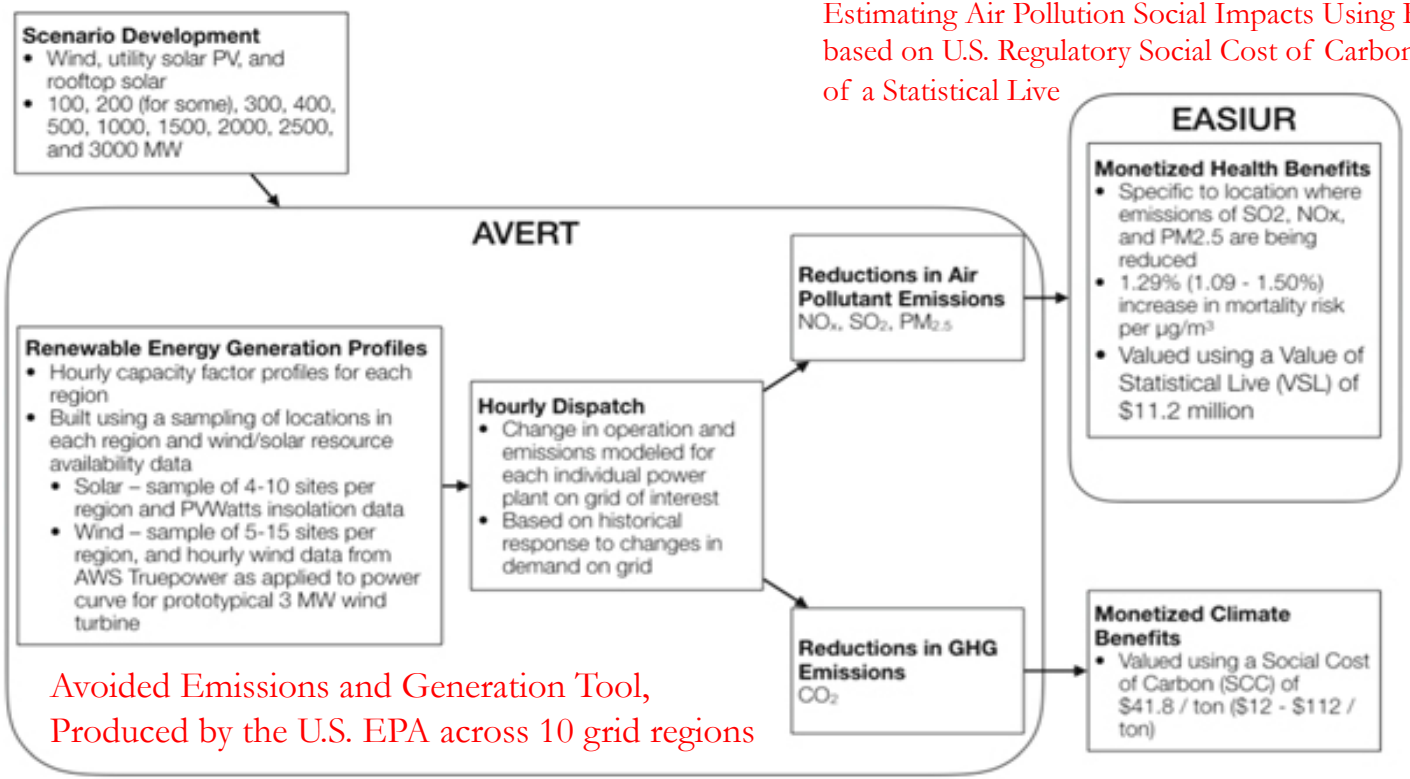
Methods and Models

Model Projects Impacts based on Projected Air Pollution Changes of RE vs. Alternative



The Authors Developed the Environmental Policy Simulation Tool for Electrical Grid Interventions, v2.0 (EPSTEIN 2.0)

Estimating Air Pollution Social Impacts Using Regression, based on U.S. Regulatory Social Cost of Carbon and Value of a Statistical Live



Avoided Emissions and Generation Tool, Produced by the U.S. EPA across 10 grid regions

Data Analysis

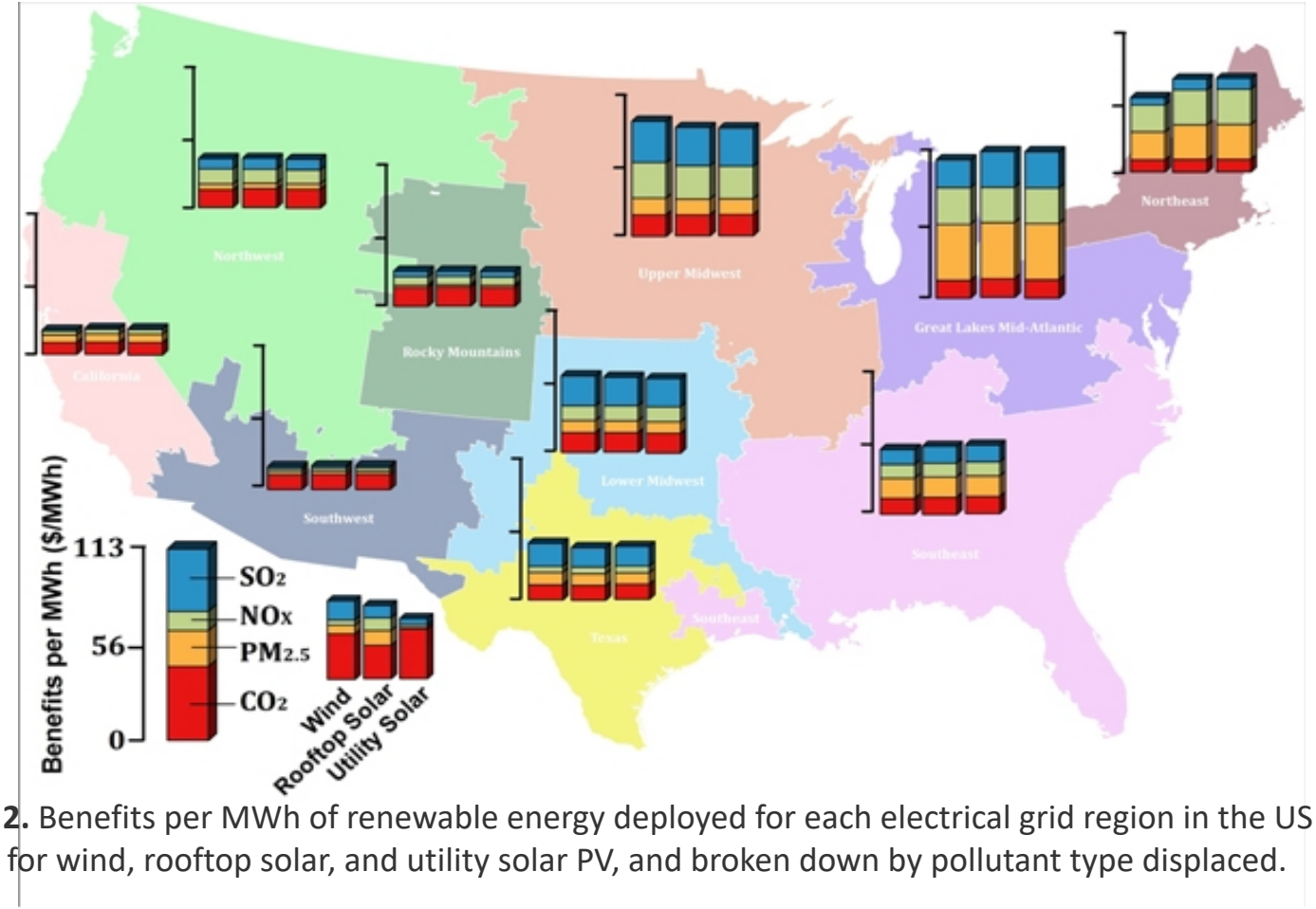


Figure 2. Benefits per MWh of renewable energy deployed for each electrical grid region in the US Benefits are shown for wind, rooftop solar, and utility solar PV, and broken down by pollutant type displaced.

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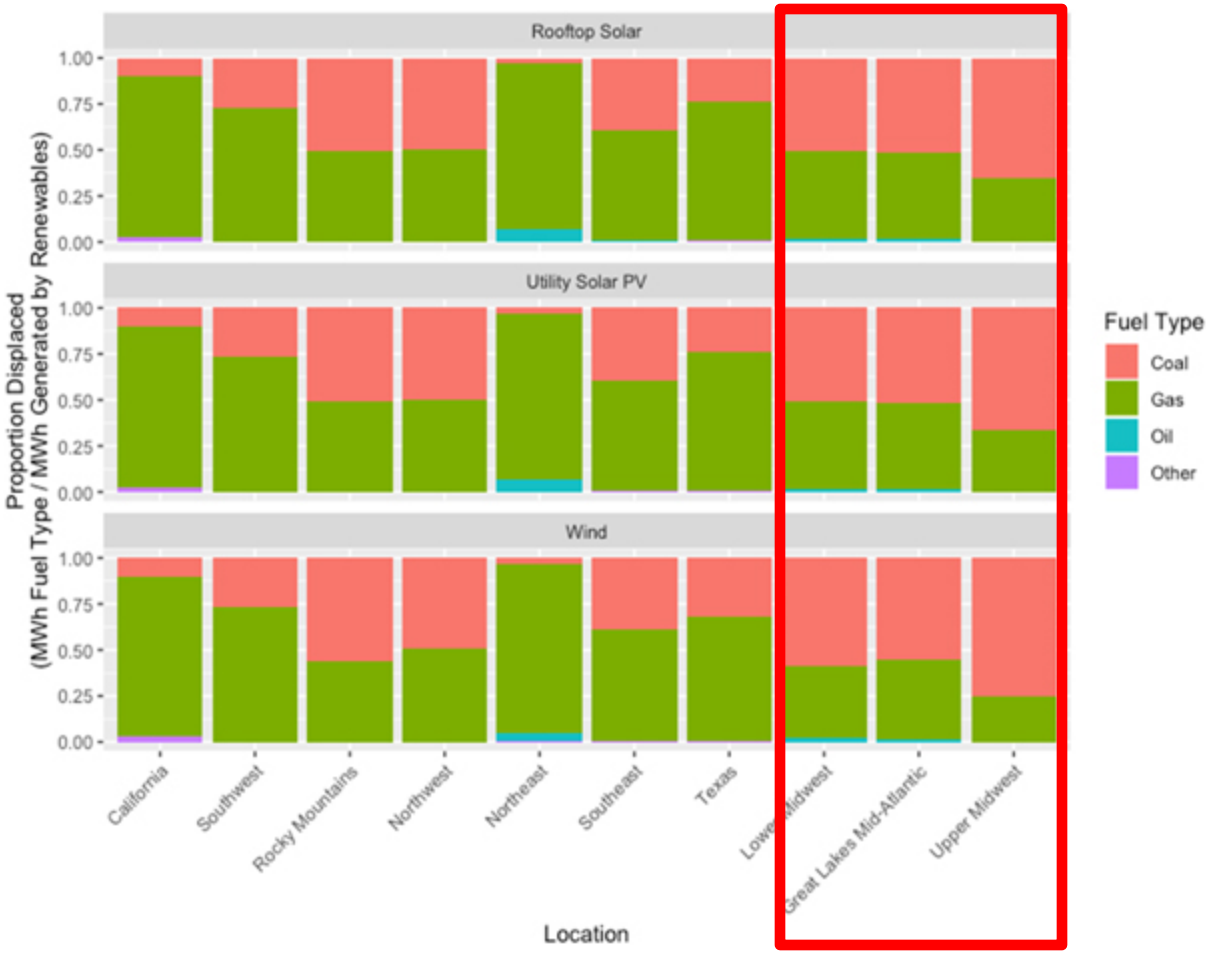
Proportions of plant primary fuel types displaced, by location and renewable energy type (MWh/MWh).



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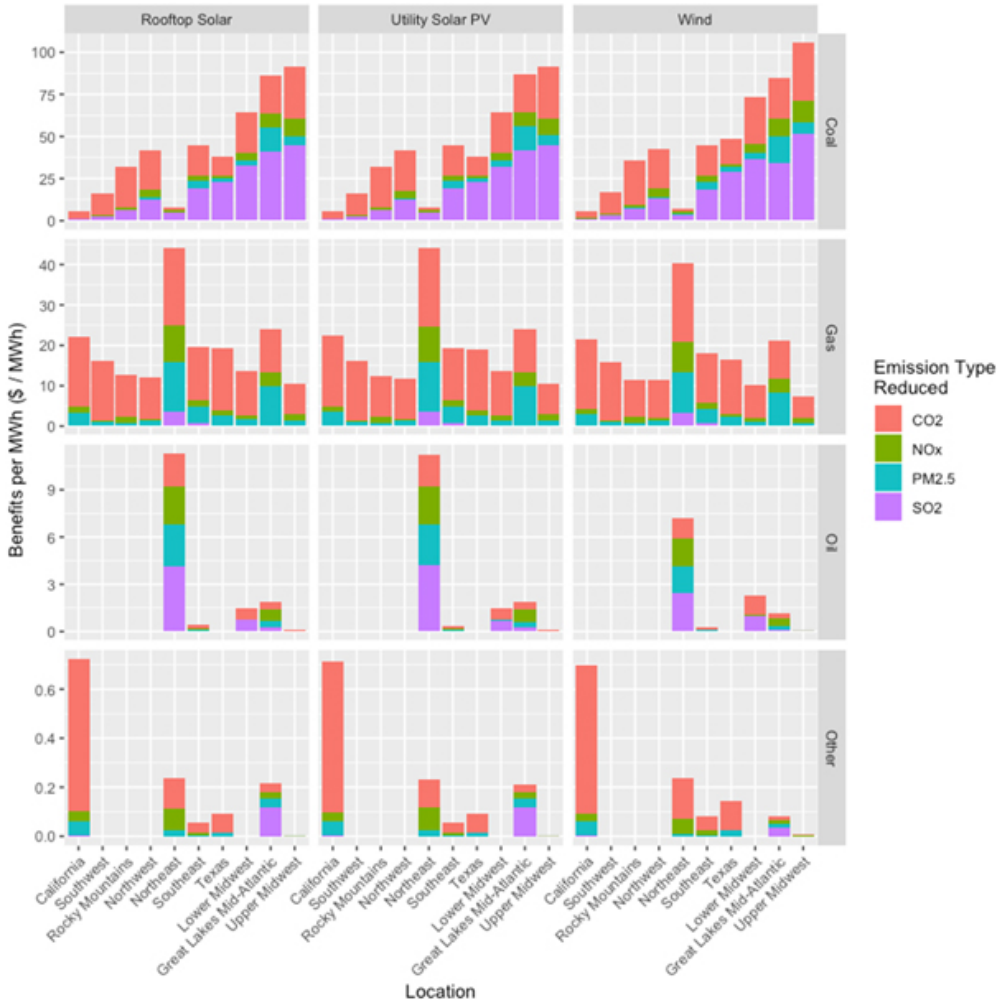
Benefits per MWh by primary fuel type displaced by location and renewable energy type.



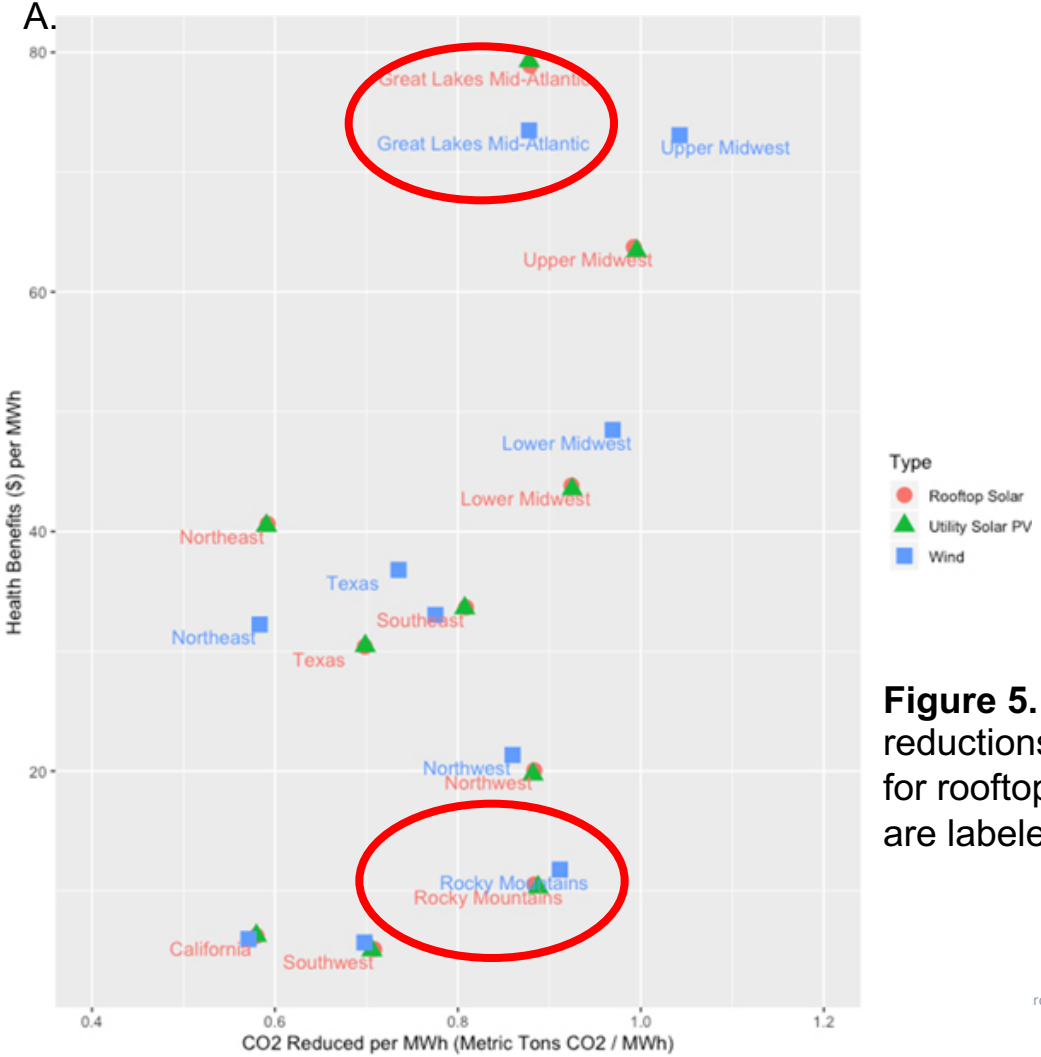
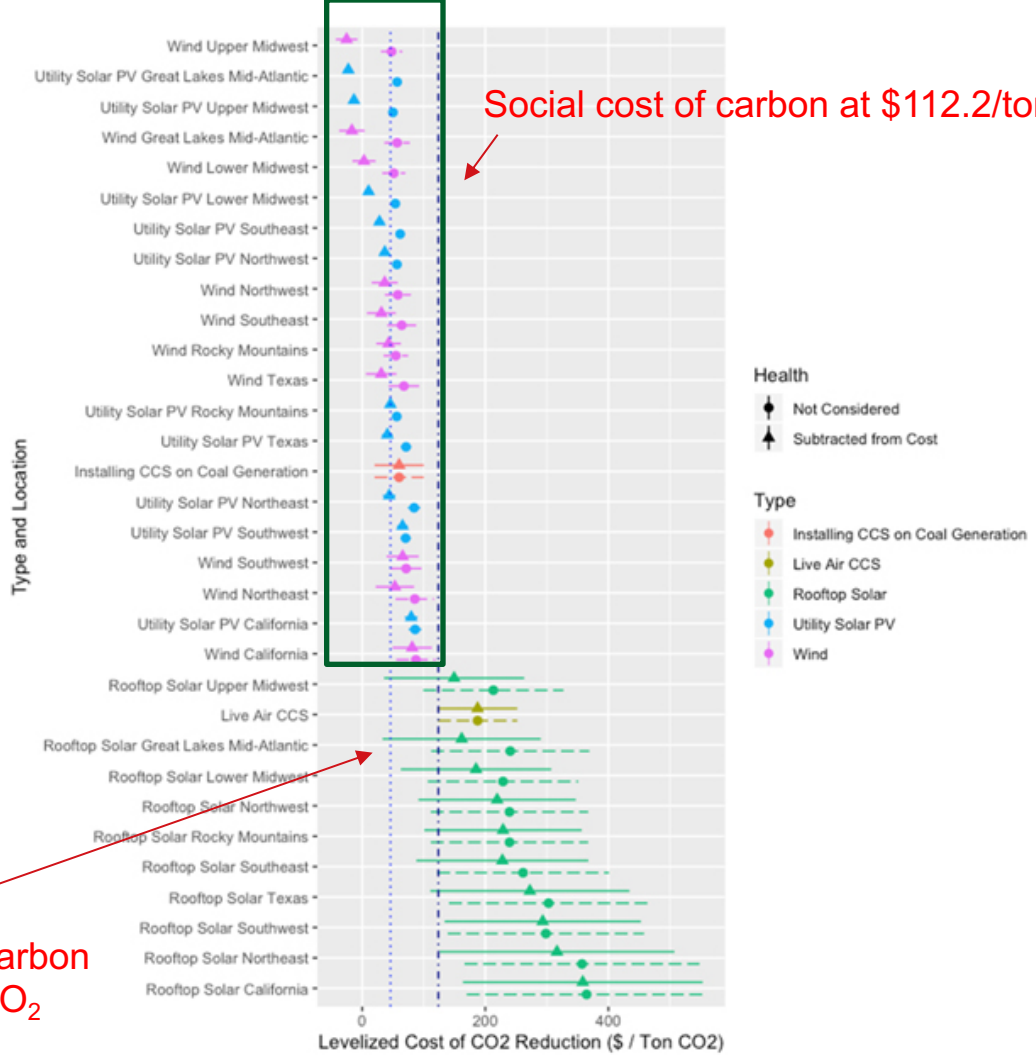


Figure 5. (a) Health benefits and CO_2 emissions reductions, by region and renewable energy type. Points for rooftop solar and utility solar PV overlap. Not all points are labeled to prevent over-plotting.


Social cost of carbon at $112.2/ton CO_2
Social cost of carbon at $41.80/ton CO_2
Type and Location
Wind Upper Midwest
Utility Solar PV Great Lakes Mid-Atlantic
Utility Solar PV Upper Midwest
Wind Great Lakes Mid-Atlantic
Wind Lower Midwest
Utility Solar PV Lower Midwest
Utility Solar PV Southeast
Utility Solar PV Northwest
Wind Northwest
Wind Southeast
Wind Rocky Mountains
Wind Texas
Utility Solar PV Rocky Mountains
Utility Solar PV Texas
Installing CCS on Coal Generation
Utility Solar PV Northeast
Utility Solar PV Southwest
Wind Southwest
Wind Northeast
Utility Solar PV California
Wind California
Rooftop Solar Upper Midwest
Live Air CCS
Rooftop Solar Great Lakes Mid-Atlantic
Rooftop Solar Lower Midwest
Rooftop Solar Northwest
Rooftop Solar Rocky Mountains
Rooftop Solar Southeast
Rooftop Solar Texas
Rooftop Solar Southwest
Rooftop Solar Northeast
Rooftop Solar California
0
200
400
Levelized Cost of CO2 Reduction ($ / Ton CO2)
Health
Not Considered
Subtracted from Cost
Type
Installing CCS on Coal Generation
Live Air CCS
Rooftop Solar
Utility Solar PV
Wind

Study Conclusion

Study Conclusions

- This model framework and information can be useful for governments, RE developers and investors for developing RE deployment strategies that maximize both CO_2 reductions and health benefits;
- Results show that RE deployment is a cost-effective method to reduce CO_2 emissions, and that health benefits can be an important component of the full benefits of RE projects;
- With the current electrical grid, RE deployment is more cost effective at reducing CO_2 emissions than live air CCS or coal with CCS. Cost effectiveness varies substantially by region where the RE type is delayed but varies less between type of RE;
- Health impacts and benefits of the different CO_2 reduction strategies can be a substantial part of the total impacts, cost and benefits of a given project;
- Information on health benefits can be useful to build political support for climate policies.

EPSTEIN 2.0 Limitations

- EPSTEIN 2.0 is limited by the two models feeding it.

- Avert does not capture the degree of detail that other electrical grid models can capture, including:
  - Plant upgrades and retirements, changes in response form changes in fuel price, transmission upgrades, policy changes, pollution control status, market changes, challenges due to fuel mixing and other factors.

- EUSIUR does not capture:

  - Ozone or morbidity endpoints due to PM2.5 or ozone (under-estimates health impacts.
  - Doesn't' disaggregate results for different fuel types, or take into account life cycle analysis to account for fuel production itself or fugitive emissions.

References

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Context - Revisited

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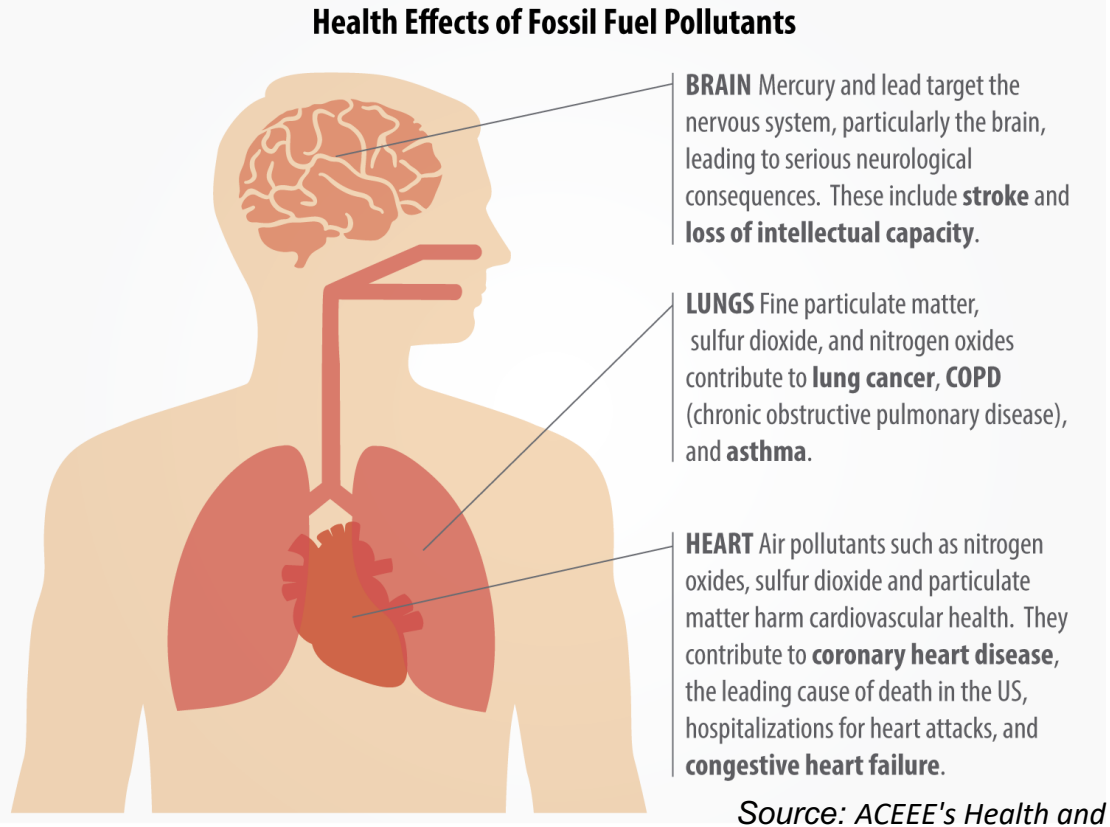
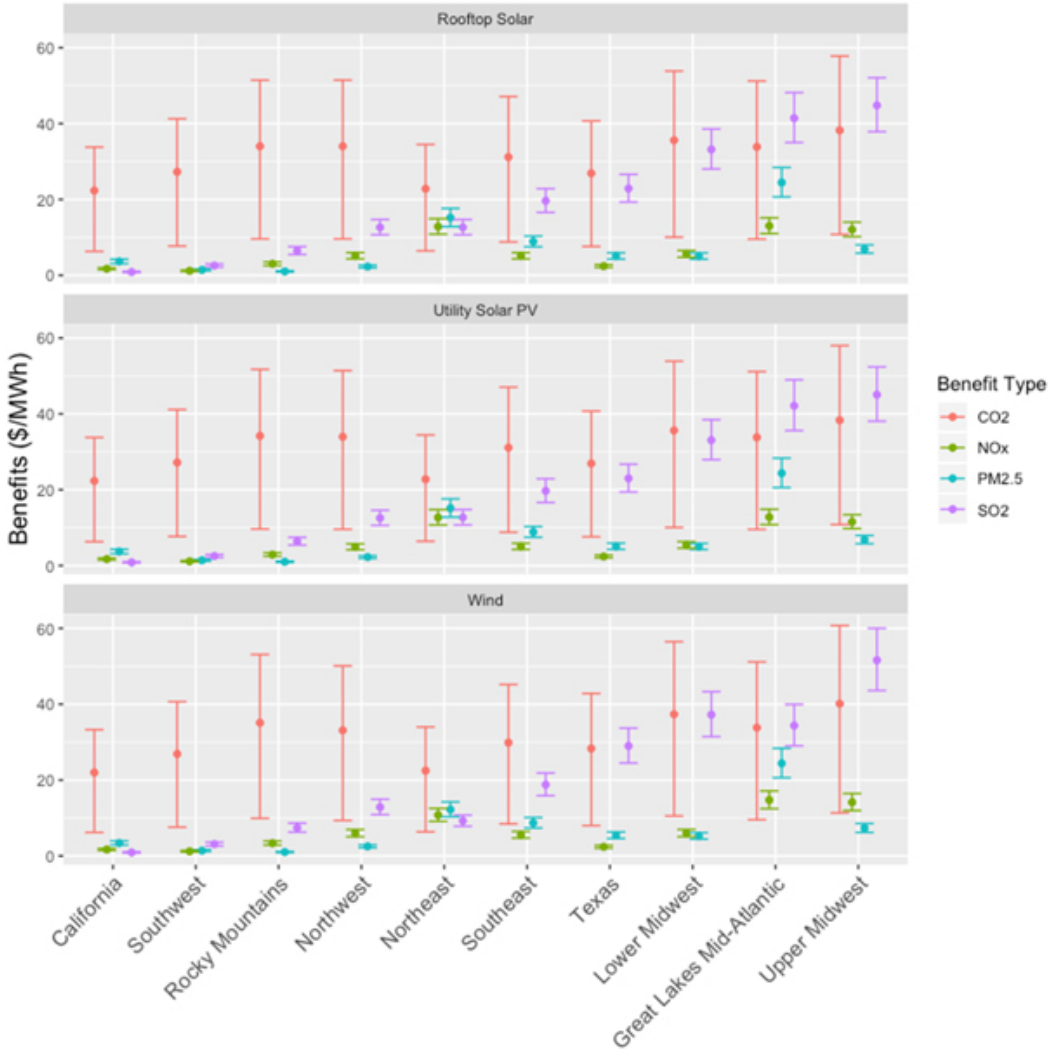
Discussion and Questions

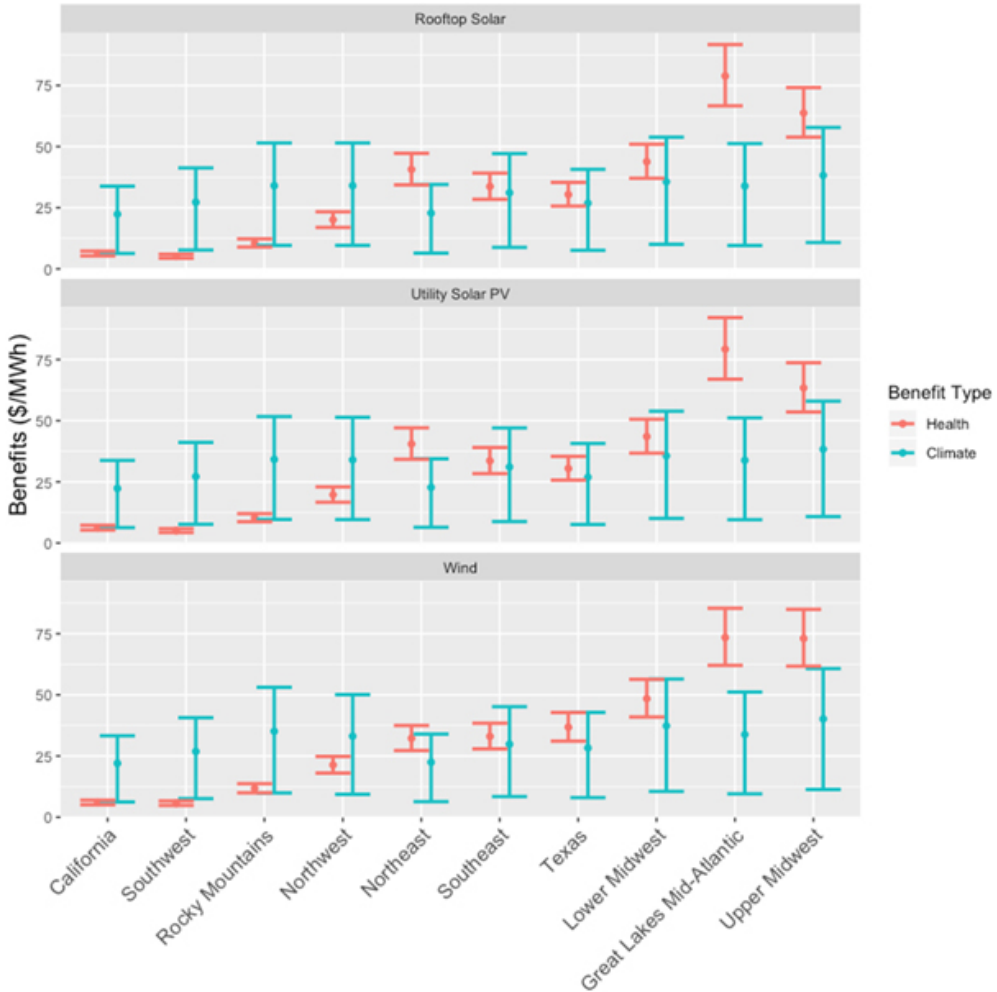
Extra Slides

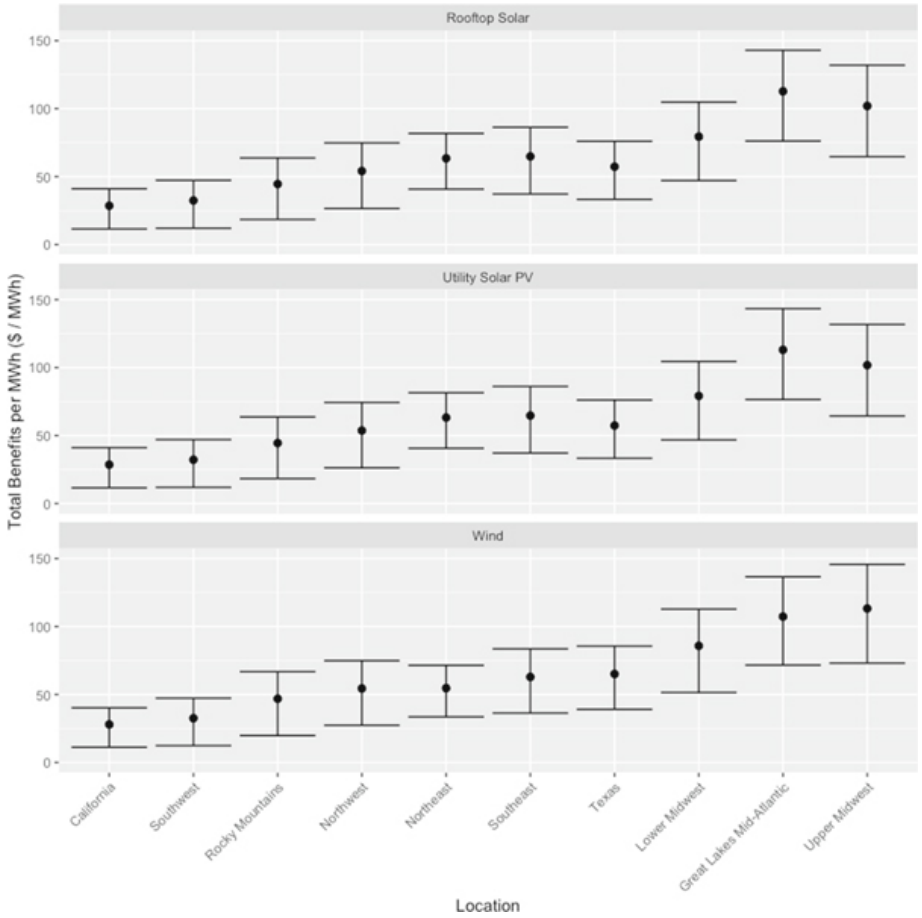
Fossil Fuel Combustion Products are Associated with Health Impacts



Source: *ACEEE's Health and Environment Program*


Rooftop Solar
Utility Solar PV
Wind
Benefits ($/MWh)
0
20
40
60
California
Southwest
Rocky Mountains
Northwest
Northeast
Southeast
Texas
Lower Midwest
Great Lakes Mid-Atlantic
Upper Midwest
Benefit Type
CO2
NOx
PM2.5
SO2


Rooftop Solar
Utility Solar PV
Wind
Benefits ($/MWh)
0
25
50
75
California
Southwest
Rocky Mountains
Northwest
Northeast
Southeast
Texas
Lower Midwest
Great Lakes
Mid-Atlantic
Upper Midwest
Benefit Type
Health
Climate


Rooftop Solar
Utility Solar PV
Wind
Total Benefits per MWh ($ / MWh)
150
100
50
0
California
Southwest
Rocky Mountains
Northwest
Northeast
Southeast
Texas
Lower Midwest
Great Lakes
Mid-Atlantic
Upper Midwest
Location