Health Co-Benefits of Carbon Standards
Part 2 of the Carbon Standards Co-Benefits Study

www.chgeharvard.org/health-co-benefits
The Co-Benefits of Carbon Standards Study

Part 1 – May 27, 2014

- Emissions Changes
- IPM Model

Part 2

- Air Quality Changes
- CMAQ Model
- Human Health Co-Benefits
- BenMAP Model

Part 3

- Ecosystem Benefits
  - Acid Rain
- Crop & timber production
- Visibility Improvements

Assumptions:
- Reference Case
- Scenario 1: Power Plant
- Scenario 2: Electricity Sector
- Scenario 3: Cost of Carbon
Three Questions

1. Are there health co-benefits from reducing carbon emissions from power plants?

2. If so, how much, when, and where?

3. How do different options for power plant carbon standards influence the magnitude of the co-benefits?
1. Are there health co-benefits from reducing carbon emissions from power plants?

Yes. Addressing carbon emissions can reduce other harmful emissions and provide added health benefits.

2. If so, how much, when, and where?

3,500 lives saved every year for the top scenario, soon after implementation, with benefits in all lower 48 states.

3. How do different options for power plant carbon standards influence the magnitude of the co-benefits?

Policy choices make a big difference. Can’t take health co-benefits for granted. The stronger the carbon standard, in terms of both stringency and flexibility & efficiency, the greater the health co-benefits.
Jonathan Buonocore, Sc.D., Program Leader; Climate, Energy, and Health; Center for Health and the Global Environment; Harvard School of Public Health
WHAT ARE CO-BENEFITS?

GLOBAL CLIMATE CHANGE

Carbon dioxide

Other pollutants:
- Nitrogen oxides
- Sulfur dioxide
- Particulate matter

EMISSIONS

AIR QUALITY:
ground-level ozone, fine particle pollution
(smog and soot)
Health Co-benefits in this Study

Lower Fine Particulate Matter ($\text{PM}_{2.5}$) Benefits
• Premature deaths avoided (i.e., lives saved)
• Heart attacks avoided
• Other cardiovascular hospital admissions avoided
• Respiratory hospital admissions avoided

Lower Ground-level Ozone Benefits
• Premature deaths avoided (i.e., lives saved)
• Respiratory hospital admissions avoided
Putting the Pieces Together

• Lower Power Plant Emissions of Co-pollutants = Cleaner Air

• Cleaner Air = Fewer Premature Deaths and Illnesses from Air Pollution
Reference Case

• Reflects conditions in 2020 under business as usual (no carbon standard)
• Energy demand based on EIA 2013 Annual Energy Outlook
• All current air quality policies fully implemented
• Decreases power plant CO$_2$ emissions by \(~15\%\) from 2005 by 2020
Scenario 1: Power Plant Improvements

- Low stringency, low flexibility, no end-user efficiency
- Most similar to option favored by some industry groups and states
- Limited to options “inside the fence line” for existing power plants such as heat rate upgrades
- Decreases power plant CO$_2$ emissions by $\sim2\%$ from 2020 reference case ($\sim17\%$ from 2005)
Scenario 2: Electricity Sector Improvements

- Moderate stringency, high flexibility, high end-user efficiency
- Most similar to proposed Clean Power Plan
- Establishes benchmark emissions rate for each state
- Allows states many compliance options
- Includes large investments in energy efficiency
- Decreases power plant CO$_2$ emissions by $\sim$24% from 2020 reference case ($\sim$35% from 2005)
- Clean Power Plan target: 30% from 2005 by 2030
Scenario 3: Cost of Carbon Improvements

- High stringency, moderate flexibility, no end-user efficiency
- Requires CO₂ pollution control measures up to a cost of $43 per metric ton of carbon in 2020
- Moderate flexibility, does not include demand-side energy efficiency
- Decreases CO₂ emissions by ~39% from 2020 reference case (~49% from 2005)
Question 1

Are there health co-benefits from reducing carbon emissions from power plants?
Question 2

How much, when and where do the health co-benefits occur?
How Much & When?

Health Co-benefits for Top-performing Scenario 2:

• 3,500 premature deaths avoided each year (9 per day)
• 1,000 hospital admissions avoided each year
• 220 heart attacks prevented each year

Health co-benefits occur soon after implementation
Where?

• Health co-benefits are widespread with all lower 48 states receiving some benefit.

• Top 12 for premature deaths avoided are: PA, OH, TX, IL, MI, NY, NC, GA, MO, VA, TN, and IN.

• Co-benefits are greatest where there are a large number of exposed people and air quality improves the most.
HEALTH CO-BENEFITS: LIVES SAVED IN THE YEAR 2020
SCENARIO 2: ELECTRICITY SECTOR IMPROVEMENTS

THIS MAP SHOWS:
THE CHANGE IN NUMBER OF PREMATURE DEATHS AVOIDED PER YEAR UNDER SCENARIO 2 FROM THE 2020 REFERENCE CASE BY STATE. SCENARIO 2 IS THE MODERATE STRINGENCY, HIGH FLEXIBILITY & ENERGY EFFICIENCY OPTION AND IT RESULTS IN THE LARGEST HEALTH CO-BENEFITS.

Positive values = increase in # of lives saved per year | Coal plant locations from U.S. Energy Information Administration 2012, 2013
HEALTH CO-BENEFITS: PRECIDENT CHANGE IN LIVES SAVED IN YEAR 2020
SCENARIO 2: ELECTRICITY SECTOR IMPROVEMENTS

THIS MAP SHOWS:
THE CHANGE IN RATE OF LIVES SAVED UNDER SCENARIO 2 FROM THE 2020 REFERENCE CASE BY COUNTY. SCENARIO 2 IS THE MODERATE STRINGENCY, HIGH FLEXIBILITY & ENERGY EFFICIENCY OPTION AND RESULTS IN THE LARGEST HEALTH CO-BENEFITS.

Positive values = increase in rate of premature deaths avoided | Coal plant locations from U.S. Energy Information Administration 2012, 2013
HEALTH CO-BENEFITS: HOSPITAL ADMISSIONS AVOIDED IN THE YEAR 2020
SCENARIO 2: ELECTRICITY SECTOR IMPROVEMENTS

THIS MAP SHOWS:
THE CHANGES IN NUMBER OF HOSPITALIZATIONS RELATED HEART AND LUNG DISEASE UNDER SCENARIO 2 FROM THE 2020 REFERENCE CASE. SCENARIO 2 IS THE MODERATE STRINGENCY, HIGH FLEXIBILITY & ENERGY EFFICIENCY OPTION AND IT RESULTS IN THE LARGEST HEALTH CO-BENEFITS.

Positive values = Increase in # of hospital admissions avoided per year | Coal plant locations from U.S. Energy Information Administration 2012, 2013

Units: hospitalizations avoided per year
- 64 to 79
- 33 to 64
- 17 to 32
- 9 to 16
- 5 to 8
- 3 to 4
- < 1 to 2

LEGEND
- Major Cities (>500,000)
- Operating Coal Plants
Question 3

How do different options for power plant carbon standard influence the magnitude of the co-benefits?
Policy Choices Make Big Difference

Scenario Comparison:

*lives saved per million tons of CO₂ reduced*

- Scenario 1 = -0.2
- Scenario 2 = 6.6
- Scenario 3 = 3.6
Scenario 1: Power Plant Improvements
(low stringency, low flexibility/efficiency)

• Lowest CO$_2$ reductions
• Little to no health co-benefit
  – slight increase in premature deaths and heart attacks due to emissions rebound in SO$_2$
• Patchwork pattern
Scenario 3: Cost of Carbon Improvements
(high stringency, moderate flexibility/no efficiency)

• Greatest CO$_2$ reductions
• High health co-benefits but not as large as Scenario 2
  – due to more fossil generation and no end-user efficiency
• Spatial pattern similar to Scenario 2
Charles Driscoll, Jr, PhD, NAE; Distinguished Professor and University Professor of Environmental Systems Engineering; Department of Civil and Environmental Engineering; Syracuse University
Bottom Line

Health Co-benefits are Directly Related to Air Quality Benefits
AIR QUALITY CO-BENEFITS: FINE PARTICULATE MATTER (PM$_{2.5}$) IN THE YEAR 2020

SCENARIO 2: ELECTRICITY SECTOR IMPROVEMENTS

Units: PM$_{2.5}$ concentration in micrograms per cubic meter ($\mu$g m$^{-3}$)

LEGEND
- Major Cities (>500,000)
- Operating Coal Plants

THIS MAP SHOWS:
CHANGES IN CONCENTRATIONS OF PM$_{2.5}$ IN SCENARIO 2 FROM THE 2020 REFERENCE CASE. SCENARIO 2 IS THE MODERATE STRINGENCY, HIGH FLEXIBILITY & ENERGY EFFICIENCY OPTION AND IT RESULTS IN WIDESPREAD CLEAN AIR CO-BENEFITS.

Positive values = Increase in PM$_{2.5}$ | Negative values = Decrease in PM$_{2.5}$ | Coal plants locations from U.S. Energy Information Administration 2012, 2013
AIR QUALITY CO-BENEFITS: FINE PARTICULATE MATTER (PM$_{2.5}$) IN THE YEAR 2020

SCENARIO 1: POWERPLANT IMPROVEMENTS

Units: PM$_{2.5}$ concentration in micrograms per cubic meter (ugm$^{-3}$)

LEGEND
- Major Cities (>500,000)
- Operating Coal Plants

THIS MAP SHOWS:
Changes in concentrations of PM$_{2.5}$ in Scenario 1 from the 2020 reference case. Scenario 1 is the low stringency, low flexibility option limited to power plant upgrades and it results in few clean air co-benefits.

Positive values = Increase in PM$_{2.5}$ | Negative values = Decrease in PM$_{2.5}$ | Coal plants locations from U.S. Energy Information Administration 2012, 2013
AIR QUALITY IMPROVEMENTS: PEAK SUMMER OZONE IN THE YEAR 2020
SCENARIO 2: ELECTRICITY SECTOR IMPROVEMENTS

Units: ozone concentration in parts per billion (ppb)

LEGEND
-3.6  0
Major Cities (>500,000)  Operating Coal Plants

THIS MAP SHOWS:
CHANGE IN CONCENTRATIONS OF PEAK SUMMER OZONE IN SCENARIO 2 FROM THE 2020 REFERENCE CASE. NEGATIVE VALUES REPRESENT SCENARIO 2 IS THE MODERATE STRINGENCY, HIGH FLEXIBILITY & ENERGY EFFICIENCY OPTION AND IT RESULTS IN THE LARGEST HEALTH CO-BENEFITS.

Positive values = Increase in summer ozone | Negative values = Decrease in summer ozone | Coal plant locations from U.S. Energy Information Administration 2012, 2013
Part 3: Ecosystem Benefits

![Leaf images]

![Bar chart showing mean number of fish species](chart.png)

![Diagram of acid deposition effects on trees](trees.png)

![Scenic landscape images](landscape.png)
In Summary

1. Are there health co-benefits from reducing carbon emissions from power plants?

Yes. Addressing carbon emissions can reduce other harmful emissions and provide added health benefits.

2. If so, how much, when, and where?

3,500 lives saved every year for the top scenario, soon after implementation, with benefits in all lower 48 states.

3. How do different options for power plant carbon standards influence the magnitude of the co-benefits?

Policy choices make a big difference. Can’t take health benefits for granted. The stronger the carbon standard, in terms of both stringency and flexibility & efficiency, the greater the health co-benefits.

Full report: www.chgeharvard.org/health-co-benefits
Back Pocket Slides
Fossil Fuel Generation in 2020

TWh

- Combined Cycle (Gas)
- Combustion Turbine (Gas)
- Coal (without CCS)
- Biomass co-firing
- Coal (with CCS)

Reference case
Scenario 1
Scenario 2
Scenario 3

CCS = carbon storage and sequestration
HEALTH CO-BENEFITS: LIVES SAVED IN THE YEAR 2020

SCENARIO 1: POWERPLANT IMPROVEMENTS

This map shows the change in number of premature deaths avoided per year under Scenario 1 from the 2020 reference case by state. Scenario 1 is the low stringency, low flexibility option limited to power plant upgrades and it results in the lowest health co-benefits.

Positive values = Increase in # of lives saved per year | Negative values = Decrease in # of lives saved per year | Coal plant locations from U.S. Energy Information Administration 2012, 2013

Units: premature deaths avoided per year

Legend:
- Major Cities (>500,000)
- Operating Coal Plants

21 to 40
11 to 20
1 to 10
0
-9 to -1
-19 to -10
-33 to -20
HEALTH CO-BENEFITS: PERCENT CHANGE IN LIVES SAVED IN YEAR 2020
SCENARIO 1: POWERPLANT IMPROVEMENTS

This map shows the change in rate of lives saved under Scenario 1 from the 2020 reference case by county. Scenario 1 is the low stringency, low flexibility option limited to power plant upgrades and it results in the lowest health co-benefits.

Positive values = increased rate of premature deaths avoided | Negative values = decreased rate of premature deaths avoided | Coal plant locations from U.S. Energy Information Administration 2012, 2013
HEALTH CO-BENEFITS: HOSPITAL ADMISSIONS AVOIDED IN THE YEAR 2020
SCENARIO 1: POWERPLANT IMPROVEMENTS

Units: hospitalizations avoided per year

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<thead>
<tr>
<th>Value Range</th>
<th>Color</th>
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<tbody>
<tr>
<td>5 to 8</td>
<td>Blue</td>
</tr>
<tr>
<td>3 to 4</td>
<td>Light Blue</td>
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<td>1 to 2</td>
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<tr>
<td>-4 to -1</td>
<td>Red</td>
</tr>
<tr>
<td>-10 to -5</td>
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</tbody>
</table>

LEGEND
- Major Cities (>500,000)
- Operating Coal Plants

THIS MAP SHOWS:
THE CHANGE IN NUMBER OF HOSPITALIZATIONS AVOIDED UNDER SCENARIO 1 FROM THE 2020 REFERENCE CASE BY STATE. SCENARIO 1 IS THE LOW STRINGENCY, LOW FLEXIBILITY OPTION LIMITED TO POWER PLANT UPGRADES AND IT RESULTS IN THE LOWEST HEALTH CO-BENEFITS.

Positive values = increase in # of hospital admissions avoided per year  |  Negative values = decrease in # of hospital admissions avoided per year  | Coal plant locations from U.S. Energy Information Administration 2012, 2013
AIR QUALITY IMPROVEMENTS: PEAK SUMMER OZONE IN THE YEAR 2020
SCENARIO 2: ELECTRICITY SECTOR IMPROVEMENTS

This map shows change in concentrations of peak summer ozone in Scenario 2 from the 2020 reference case. Negative values represent Scenario 2's moderate stringency, high flexibility & energy efficiency option and it results in the largest health co-benefits.

Units: ozone concentration in parts per billion (ppb)

Legends:
- Major Cities (>500,000)
- Operating Coal Plants

Positive values = increase in summer ozone | Negative values = decrease in summer ozone | Coal plant locations from U.S. Energy Information Administration 2012, 2013
Fine Particulate Matter (PM$_{2.5}$) Health Effects

• Restricted activity days, lost work days, respiratory symptoms
• Hospital admissions and emergency department visits (asthma, cardiovascular, respiratory)
• Heart attacks
• Premature death
Ozone \((O_3)\) Health Effects

- Respiratory symptoms, medication use, asthma attacks
- Doctor visits, school absences, restricted activity days
- Emergency department visits, hospital admissions (respiratory causes)
- Premature death