# Incorporating Air and Water Pollution into the National Income and Product Accounts


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# Overview

- Why air and water emissions accounts are important
- Accounts for Local Air Pollutants
  - Muller, Mendelsohn, and Nordhaus Approach
  - EPA's Estimates of Damage per Ton of Pollutant
- Accounts for Greenhouse Gases
- Accounts for Water Pollution Emissions
- Conclusion

# Why Are Pollution Satellite Accounts Important?

- Researchers have shown that the externalities associated with air and water pollution are significant—as are the expenditures undertaken to reduce pollution flows

- Examining trends in both emissions and expenditures to reduce emissions important for understanding how the nation is progressing
  - Trends in emissions will be more useful if the damages associated with emissions can be monetized

- I will focus on the damage associated with air and water pollution, with an emphasis on air pollution

# Measuring Emissions to Air by Emitting Sector

- The first step in measuring damages is measuring emissions to air by emitting sector.
- The next slide shows the format of the UN Core Air Emissions account, including both local and global pollutants
- Local air pollutants (e.g., CO, NOx, SO2, PM2.5) shown above the line, are provided by sector in EPA's National Emissions Inventory (NEI), every three years.
- Greenhouse gas emissions (e.g., CO2, methane), shown below the line, are provided by EPA annually, by sector.

# Core Air Emissions Account (tons)

| | Industries | | | | | Households | | |
|---|---|---|---|---|---|---|---|---|
| | Agriculture | Mining | Manufacturing | Transport | Other | Transport | Heating | Other |
| **Panel A: Local Pollution Pollutants** | | | | | | | | |
| NOx | 69.4 | 6.0 | 37.9 | 259.5 | 89.0 | 38.0 | 12.1 | 1.3 |
| CO | 41.0 | 2.5 | 123.8 | 46.2 | 66.2 | 329.1 | 51.2 | 5.7 |
| SO2 | 2.7 | 0.4 | 28.0 | 62.4 | 8.1 | 0.4 | 0.4 | 0.1 |
| PM2.5 | 7.0 | 0.1 | 8.5 | 9.3 | 4.4 | 6.0 | 2.8 | 0.5 |
| NH3 | 107.9 | | 1.7 | 0.2 | 0.9 | 2.3 | 11.4 | 1.2 |
| VOC | 5.2 | 6.5 | 40.0 | 16.4 | 27.2 | 34.5 | 29.4 | 3.2 |
| | | | | | | | | |
| **Panel B: Greenhouse Gases** | | | | | | | | |
| Carbon Dioxide | 10,610.3 | 2,602.2 | 41,434.4 | 27,957.0 | 82,402.4 | 18,920.5 | 17,542.2 | 1,949.1 |
| Methane | 492.0 | 34.1 | 15.8 | 0.8 | 21.9 | 2.4 | 15.5 | 1.7 |
| N2O | 23.7 | | 3.5 | 0.8 | 2.6 | 1.0 | 0.2 | 0.1 |
| F-GHGs | | | 0.3 | | 0.4 | | | |
| Sulphur Hexafluoride | | | | | | | | |
| Nitrogen Triflouride | | | | | | | | |

# Going from Emissions to Monetized Damages: Local Air Pollutants

- Use air quality modeling to translate emissions into ambient air quality.
  - Estimate change in ambient air quality due to current emissions
  - Will require emissions by detailed geographic location
- Estimate impacts of the spatially disaggregated changes in ambient air quality on health, agricultural output, other endpoints
- Monetize the changes in health outcomes and other endpoints
- Trace damages back to pollution emissions by sector and pollutant

# Muller, Mendelsohn, and Nordhaus Approach

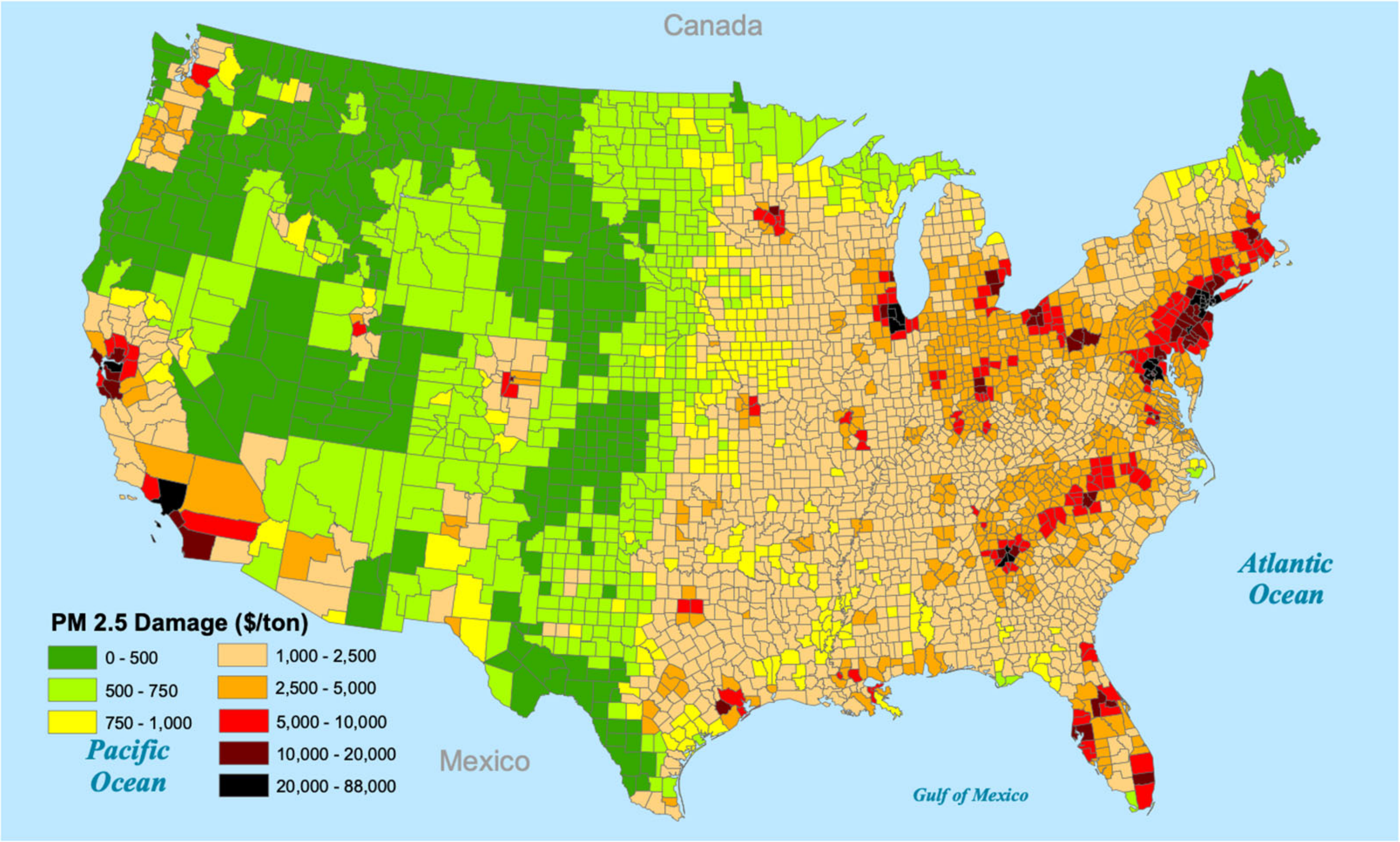
# Muller, Mendelsohn and Nordhaus (AER, 2011)

- Used the 2002 NEI and an integrated assessment model to estimate the Gross Economic Damages (GED) from air pollution, by sector
- Provided guidance for future efforts to determine the marginal value of damages by pollutant and sector
- Made clear the key pollution outcomes that drive estimates of air pollution damages, viz.
    - The impacts of PM2.5 and Ozone on adult mortality and how deaths are valued

# Muller, Mendelsohn and Nordhaus Approach

- Using the NEI, ran an air quality model to reproduce baseline concentrations of ambient PM2.5 and Ozone throughout the US
- Estimated a source-receptor matrix linking a marginal increase in emissions of each of 6 pollutants (PM2.5, PM10, SO2, NOx, NH3, VOCs) on ambient PM2.5, Ozone
  - Impact depends on the county and stack height at which the pollutant is emitted
  - Done for each of 6 pollutants x 3110 counties x 3 stack heights
- Evaluate increase in PM2.5, Ozone in each county on health and other endpoints using damage functions
- Value marginal damages

# Marginal Damages from Ground Level PM2.5



# Muller, Mendelsohn and Nordhaus Estimates of GED

TABLE 1—GROSS EXTERNAL DAMAGES AND GED/VA RATIO BY SECTOR

| Sector | GED | GED/VA |
|---|---|---|
| Agriculture and forestry | 32.0 | 0.38 |
| Utilities | 62.6 | 0.34 |
| Transportation | 23.2 | 0.10 |
| Administrative, waste management, and remediation services | 10.7 | 0.08 |
| Construction | 14.7 | 0.03 |
| Arts, entertainment, and recreation | 2.2 | 0.03 |
| Accommodation and food services | 4.2 | 0.02 |
| Mining | 3.3 | 0.02 |
| Manufacturing | 26.4 | 0.01 |
| Other services | 1.0 | 0.01 |
| Wholesale trade | 1.2 | 0.00 |
| Retail trade | 1.7 | 0.00 |
| Information | 0.0 | 0.00 |
| Finance and insurance | 0.0 | 0.00 |
| Real estate services | 0.0 | 0.00 |
| Professional, scientific, and technical services | 0.0 | 0.00 |
| Management | 0.0 | 0.00 |
| Educational services | 0.0 | 0.00 |
| Health care services | 0.7 | 0.00 |
| Total all sectors | 184.0 | |

*Note:* GED in $ billion per year, 2000 prices.

# MMN Damage Estimates by Pollutant for EGUs

TABLE 4—GED FOR COAL-FIRED POWER PLANTS BY POLLUTANT AND TYPE OF DAMAGE

| Pollutant/welfare endpoint | $SO_2$ | $PM_{2\cdot5}$ | $PM_{10}$ | $NO_x$ | VOC | $NH_3$ | Total |
|---|---|---|---|---|---|---|---|
| Mortality | 44.20 | 3.53 | 0.00 | 2.75 | 0.03 | 0.09 | 50.6 |
| Morbidity | 1.64 | 0.03 | 0.12 | 0.18 | 0.00 | 0.00 | 1.97 |
| Agriculture | 0.00 | 0.00 | 0.00 | 0.37 | 0.00 | 0.00 | 0.37 |
| Timber | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.02 |
| Materials | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 |
| Visibility | 0.22 | 0.01 | 0.02 | 0.02 | 0.00 | 0.00 | 0.26 |
| Recreation | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 46.12 | 3.57 | 0.14 | 3.34 | 0.03 | 0.09 | 53.4 |

*Note:* GED in $ billion per year, 2000 prices.

# How Is Premature Mortality Valued?

- MMN estimates of GED use EPA's Value per Statistical Life (VSL)

- VSL = amount that people would pay to reduce their risk of death by a small amount, aggregated over risks that sum to one statistical life
  - If each of 10,000 people would pay $200 to reduce their risk of death by .0001,

  The VSL = 10,000 x $200 = $2 million

- VSL estimated by compensation for risk of death on the job using hedonic labor market studies
  - VSL in 2000 dollars = $6.3 million

# Sensitivity of GED Results to Mortality Valuation

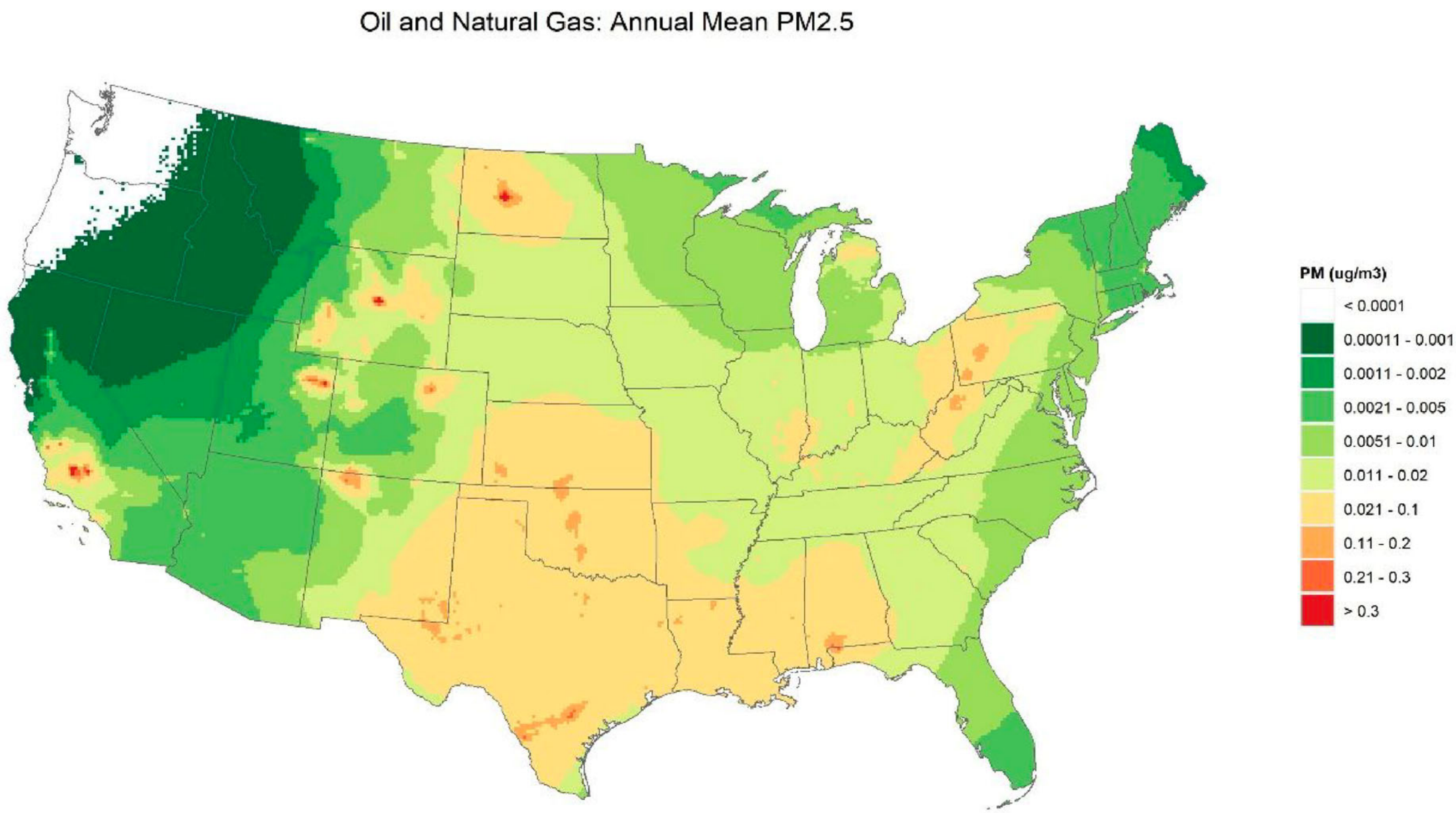
- MMN's base case takes EPA's VSL but uses the Value per Life Year Saved – the VSL is divided by discounted remaining life expectancy of a 40-year-old to generate the VSLY
    - Value of premature deaths = life years lost x VSLY
- Using VSLY: total GED = $184 billion (1.8% of 2002 GDP)
- Using VSL: total GED = $460 billion (4.4% of 2002 GDP)
- Results also sensitive to exposure response functions for PM2.5, O3

# EPA's Estimates of Damage per Ton of Pollutant

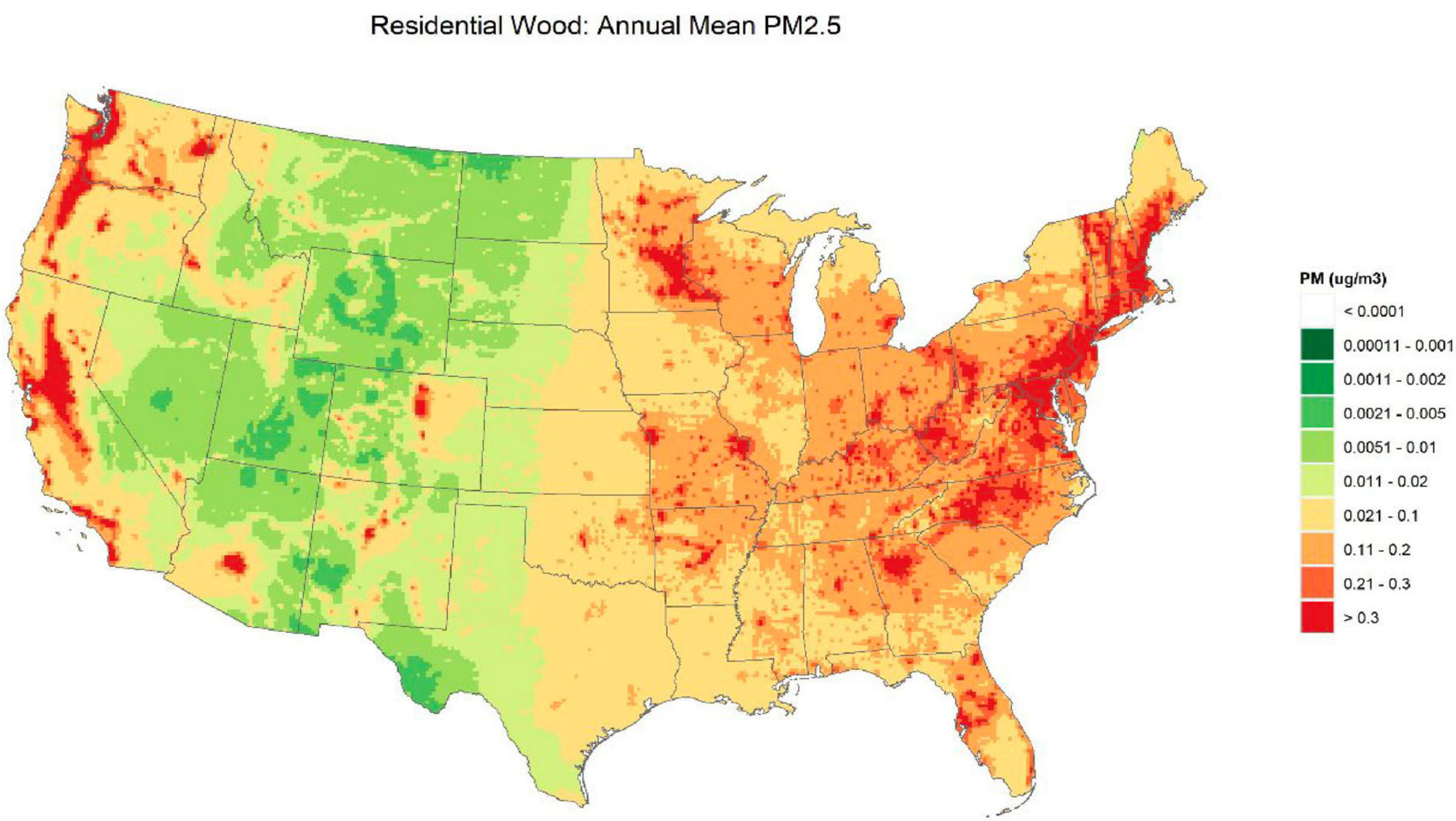
# EPA's Estimates of Damage per Ton of Emissions

- In 2022 EPA released estimates of cost per ton of pollutant for 21 sectors and 5 pollutants using the 2017 emissions inventory
- Sector-based PM2.5 Benefit Per Ton Estimates | US EPA
- Air quality modeling used to estimate source-receptor matrices for each sector-pollutant combination at a 12km x 12km resolution
- Impact of ambient PM2.5 and ozone on health estimated at a 12km x 12km resolution using BenMAP
- Mortality effects of PM2.5 and Ozone constitute 98% of monetized damages, using a 2016 VSL of $10.7 million

# Impact on Ambient PM2.5 of Oil and Gas Extraction



# Impact on Ambient PM2.5 from Woodburning Stoves



# Average Pollution Damage per Ton, By Sector

| | PM2.5-Related Damages | | | | Ozone-Related Damages | |
|---|---|---|---|---|---|---|
| Sector | Directly-emitted PM2.5 | SO2 | NOx | NH3 | NOx | VOC |
| Oil and Natural Gas | $97,900 | $19,400 | $8,080 | -- | $44,900 | $1,680 |
| Oil and Natural Gas Transmis | $138,000 | $29,800 | $13,700 | $73,400 | $61,200 | $7,490 |
| Pulp and Paper | $145,000 | $39,300 | $11,200 | $51,100 | $75,700 | $2,130 |
| Refineries | $368,000 | $50,900 | $23,100 | $112,200 | $57,500 | $11,500 |
| Residential Woodstoves | $473,000 | $34,600 | $33,100 | $200,000 | $39,000 | $12,300 |
| Synthetic Organic Chemical | $140,000 | $42,800 | $17,000 | $71,200 | $70,300 | $5,540 |
| Taconite Mining | $60,600 | $32,800 | $9,230 | -- | $45,800 | $29,600 |
| Electricity Generating Units | $137,000 | $73,000 | $6,400 | -- | $111,000 | |

# Average Pollution Damage per Ton, By Sector

| | PM2.5-Related Damages | | | | Ozone-Related Damages | |
|---|---|---|---|---|---|---|
| Sector | Directly-emitted PM2.5 | SO2 | NOx | NH3 | NOx | VOC |
| Brick Kilns | $227,000 | $44,000 | $26,900 | $130,000 | $78,800 | $10,700 |
| Cement Kilns | $157,000 | $42,300 | $14,600 | $63,900 | $68,900 | $16,900 |
| Coke Ovens | $281,000 | $53,500 | $25,600 | -- | $61,500 | $33,400 |
| Ferroalloy Facilities | $151,000 | $45,300 | $15,600 | -- | $95,900 | $7,230 |
| Industrial Boilers | $192,000 | $42,300 | $15,200 | $85,600 | $64,800 | $13,200 |
| Integrated Iron & Steel | $384,000 | $53,700 | $23,600 | $190,000 | $69,900 | $13,300 |
| Internal Combustion Engines | $166,000 | $38,700 | $10,700 | $75,300 | $54,800 | $8,510 |
| Iron and Steel Foundries | $261,000 | $54,300 | $24,000 | -- | $84,700 | $7,410 |

# Can EPA's Approach Be Used to Compute Satellite Accounts for Local Air Pollution?

- Issues with the National Emissions Inventory
  - Frequency
  - Residential v. territorial nature of emissions
  - EPA emissions will need to match NIPA sectoral descriptions
- Valuation Issues
  - Approaches described value marginal impacts of emissions
  - Would focus on mortality impacts of PM2.5 and Ozone
  - EPA's current VSL is based on hedonic labor market studies—so an acceptable market price—but details need to be worked out

# Accounts for Greenhouse Gases

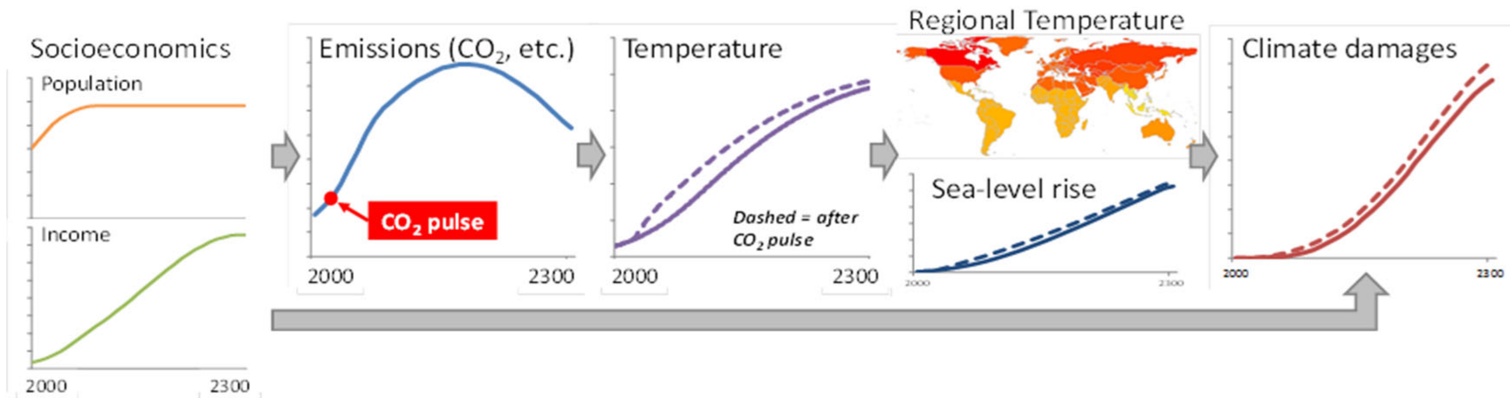
# Satellite Accounts for Greenhouse Gases (GHGs)

- EPA reports emissions of GHGs by sector, annually
  - BEA has constructed pilot supply and use tables for 2017
- Can these be valued using EPA's Social Cost of Carbon (SCC)?
  - The SCC measures the present value of net damages from emitting an addition ton of CO2 in a particular year, including the value of:
    - Changes in net agricultural productivity
    - Energy use
    - Human health
    - Property damage from increased flood risk

# 2017 Supply and Use Table for GHGs (Million Tons)

| Sector | Total GWP | Sector | Total GWP |
|---|---|---|---|
| Agriculture | 611.83 | Professional | 15.79 |
| Mining | 300.02 | Management | 9.79 |
| Utilities | 2152.34 | Administrative | 180.61 |
| Construction | 46.49 | Education | 7 |
| Manufacturing | 1028.84 | Health Care | 22.85 |
| Wholesale | 67.66 | Entertainment | 2.54 |
| Retail | 91.91 | Hospitality | 34.64 |
| Transportation | 657.49 | Other Services | 18.88 |
| Information | 8.1 | Government | 33.25 |
| Finance | 9.61 | Households | 1108.21 |
| Real Estate | 24.03 | Total Supply | 6431.87 |

# The 4 Steps of SCC Estimation




1. Projections of future population & GDP generate a $CO_2$ emissions path
2. $CO_2$ emissions path leads to predictions of mean global temperature change
3. Temperature change leads to damages, which are monetized and aggregated
4. Damages persist for many decades: discounting is used to sum them into a single present value

- This 4-step procedure is done with both baseline emissions and with a small additional amount (a pulse) of $CO_2$ emissions in a particular year.
- SCC is the per-ton difference in present value of damages due to the pulse.

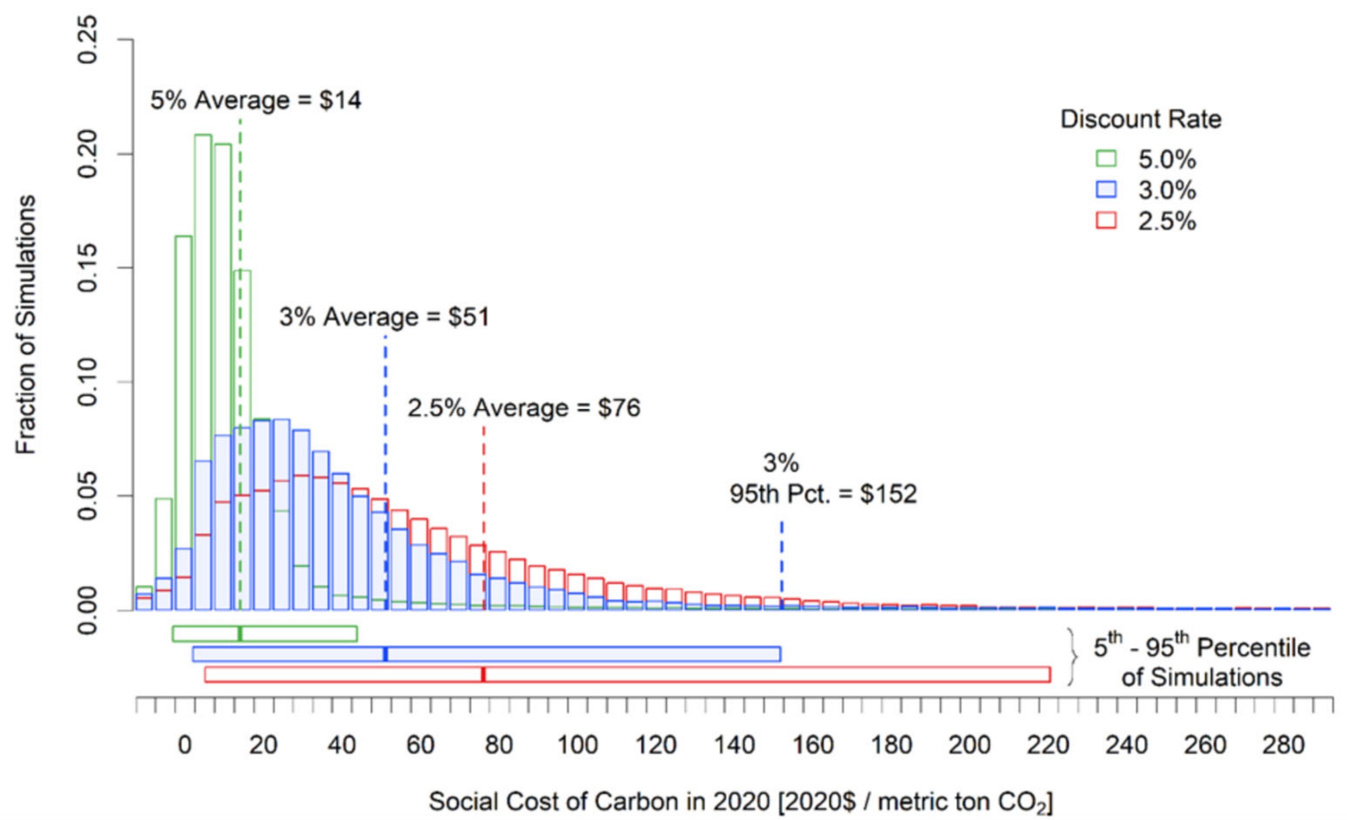
# US Government Calculation of the SCC

- Inter-agency Working Group began in 2009 and continued through 2016, until disbanded by Trump in 2017

- Combined results from 3 IAMs: DICE, FUND and PAGE
  - Using 5 equally weighted socio-economic scenarios
  - Using a common distribution over climate sensitivity
  - Preserving uncertainty in damage (and other) parameters in FUND and PAGE

- 150,000 Monte Carlo runs for each of 3 discount rates
  - 2.5%, 3.0%, 5.0%
  - Next slide shows distribution of results for all discount rates

# Frequency Distribution of Interim SCC Estimates in 2020$



# How to Improve Estimates of the SCC? (2017 NRC Report)

- "Unbundle" SCC estimation into 4 modules
  - Socioeconomic Module
  - Climate Module
  - Damages Module
  - Discounting Module
- Each module to be developed based on expertise within the relevant disciplines
- Uncertainty at each stage to be quantified and combined to generate a distribution of SCC values

# Recommendations of the NRC Report

- **Statistical methods and expert elicitation** should be used to project distributions of GDP, population growth and emissions into the future
- **Link between emissions and climate** should use a simple Earth system model that satisfies well-defined diagnostic tests
- **Damage calculations** should improve and update existing damage functions, drawing on recent scientific literature
- **Future damages should be discounted** at a rate reflecting rate of economic growth underlying damage projections
    - **Ramsey discounting will achieve this and allow correlation between climate damages and the discount rate**

# Improvements in Recent EPA SCC Estimates

EPA's November 2022 release of SCC estimates satisfies all NRC recommendations:

- Uses RFF's probability distributions over socio-economic pathways (Nature 2022) and the FAiR Earth Systems model

Incorporates 3 new sets of damages:

- RFF's GIVE model (Nature 2022)
  Captures Mortality, Agriculture, Energy, Coastal Damages
- The Climate Impact Lab's DSCIM model
  Captures Mortality, Agriculture, Energy, Coastal Damage, Labor supply
- Meta-analysis of damages by Howard and Sterner (2017)

# USEPA SCC Estimates, December 2023

**Social Cost of CO2, 2020 - 2050 (in 2020 dollars per metric tons of CO2)**
**Near-Term Ramsey Discount Rate = 2%**

| Emission Year | Damage Module | | |
|---|---|---|---|
| | DSCIM | GIVE | Meta-Analysis |
| 2020 | 190 | 190 | 200 |
| 2030 | 230 | 220 | 240 |
| 2040 | 280 | 250 | 270 |
| 2050 | 330 | 290 | 310 |

# SCC Issues from a National Accounting Perspective

- Can damages to other countries be included in the SCC?
  - Exports are included in the National Income and Product Accounts
  - The SCC measures damages from exports of pollution
- Valuation Approaches Used in EPA's SCC
  - Mortality is valued using EPA's VSL, based on hedonic wage studies. It is transferred to other countries using an income elasticity of 1.
  - Additional energy consumption, agricultural impacts and sea level rise valued using market prices

# Accounts for Water Pollution Emissions

# Physical supply table for gross releases of substances to water

| | Generation of gross releases to water | | | Accumulation | Flows with the rest of the world | Flows from the environment | Total supply |
|---|---|---|---|---|---|---|---|
| | Sewerage Industry | Other Industries | Households | Emissions from fixed assets | | | |
| **Emissions received by the environment** | | | | | | | |
| BOD/COD | 5,594 | 11,998 | 2,712 | | | | 20,304 |
| Suspended solids | | | | | | | |
| Heavy metals | | | | | | | |
| Phosphorus | 836 | 1,587 | 533 | | | | 2,956 |
| Nitrogen | 10,033 | 47,258 | 1,908 | | | | 59,199 |

# Availability of Water Pollution Emissions Data

- Point Source Emissions Data

  National Pollutant Discharge Elimination System (NPDES) covers emissions from point sources, including:

  - Animal feeding operations; Fish farms; Pesticide permitting
  - Industrial operations, including mining, oil and gas drilling
  - Municipal wastewater; Storm water Discharges

  - Data are reported in Discharge Monitoring Reports

- Non-Point Source Data
  - NPS data (e.g. agricultural runoff ) usually modeled using HAWQS

# EPA's Modeling of Ambient Water Pollution

- HAWQS Model
  - Models river, stream water quality at the watershed level
  - Simulates effects of crops, soils, and land uses on sediment, pathogens, nutrients, BOD, DO and pesticides
  - Possible for point source loads to be added by the user
  - Provides estimates of:
    - Dissolved oxygen
    - Total suspended solids
    - BOD
    - Nitrogen
    - Phosphorus
    - Fecal coliform

# EPA's Valuation of Water Pollution Damages

- Possible benefit categories to value:
  - Impacts on housing values
  - Recreation benefits
  - Non-use values
- BenSPLASH
  - Quantifies and monetizes water quality improvements
  - Six pollutants—DO, Fecal Coliform, N, P, BOD, TSS—combined into a water quality index (WQI)
  - Meta-regression of stated preference valuation studies are used to value the WQI

# Conclusions

- Sufficient data exist for Air Emissions Satellite Accounts
  - Definitely for GHGs
  - Also for local air pollutants, although frequency an issue
  - Both must be adjusted to meet sectors used by BEA
- Should be able to monetize air pollution damages
  - Using EPA's current approaches for damage per ton of local pollutants
  - Using the Social Cost of Carbon for CO2
- Accounts for water emissions possible but monetization of damages still in the future