National Research Council Report

Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use

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Presentation by

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Study Origin and Task

Congress:

- Directed the Department of the Treasury to fund the study under the Consolidated Appropriations Act of 2008.

Study Task:

- Define and evaluate key external costs and benefits – related to health, environment, security, and infrastructure – that are associated with the production, distribution, and use of energy but not reflected in the market price of energy or fully addressed by current government policy.
What the Study Committee Found

- There are many external effects related to energy production and use in the U.S.

- We were able to monetize a wide range of damages, although many other external effects were not monetized because of insufficient data or other reasons.

- Monetized damages from energy production and use in the U. S. added up to more than $120 Billion in 2005, not including climate change damages.
Committee Roster

Jared Cohon (Chair) Carnegie Mellon University
Maureen Cropper (Vice Chair) University of Maryland, College Park
Mark Cullen Stanford University School of Medicine
Elisabeth Drake Massachusetts Institute of Technology (retired)
Mary English University of Tennessee, Knoxville
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Richard Newell * Duke University
Richard Revesz New York University School of Law
Ian Sue Wing Boston University
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* Resigned August 2, 2009 to accept appointment as Administrator of the U.S. Energy Information Administration.
## Report Reviewers

Review was overseen by: **Lawrence Papay**, SAIC (retired) and **Charles Phelps**, U. of Rochester

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What is an Externality?

An activity of an individual or an organization that affects the well being of another agent and occurs outside the market mechanism.

• Externalities can be positive or negative.
• Most positive effects of energy production and use are reflected in the market prices of energy and are therefore not externalities.
• Failure to account for externalities can lead to distortions in making decisions and to reductions in the welfare of some of society’s members.
• Government intervention in the form of taxes, regulations or other instruments, can correct these distortions.
Study Approach

- Selected Areas
  - Electricity Generation
  - Transportation
  - Heat for Buildings and Industrial Processes
  - Climate Change
  - Infrastructure and National Security

- Considered full life-cycle

- Focused on air pollution effects for non-climate damages

- 2005 and 2030 reference years

- Different approaches for Climate and Non Climate Damages
Non-Climate Damage Approach

• Damage Function Approach:
  Emissions >> Ambient Concentration >> Exposure >> Effect >> Monetized Damages

• Effects of air pollution on human health, grain crop and timber yields, building materials, recreation, and visibility of outdoor vistas.

• Modeling used to estimate damages-- based primarily on SO₂, NOₓ, and PM emissions across the 48 contiguous states.

• Most of the damages are associated with human mortality.
Electricity: Coal
406 coal-fired power-plants

Aggregate damages (2005): $62 billion (non-climate damages)

- 50% of plants with the lowest damages—which produced 25% of net generation of electricity—accounted for only 12% of the damages.
- 10% of plants with the highest damages—which produced 25% of net generation—accounted for 43% of the damages.
- Variation in damages primarily due to variation in tons of pollutants emitted.

Average damages per kilowatt hour (kWh):
3.2 cents/kWh (2005)
- Range of damages: 0.19 – 12.0 (5th – 95th percentile) cents/kWh.
- Variation primarily due to variation in pollution intensity (emissions per kWh) across plants.

1.7 cents/kWh (2030)
- Fall in damages per kWh in 2030 due to assumption that pounds of SO₂ per kWh hour will fall by 64% and that NOₓ emissions per kWh will fall by 50%.
Electricity: Coal
Location of Sources of Damages

Damage Estimates based on $SO_2$, $NO_x$, and PM emissions

- Air Pollution Damages from Coal Generation for 406 plants, 2005
- Damages related to climate-change effects are not included
Electricity: Natural Gas
498 Natural Gas-Fired Plants

**Aggregate damages (2005):** ≈ $740 million (non-climate damages)
- From plants that account for 71% of net generation from gas is lower than those for coal-fired power plants.
- 50% of plants with the lowest damages accounted for only 4% of aggregate damages.
- 10% of plants with largest damages accounted for 65% of damages.
- Each group generated 25% of electricity from gas.

**Average damages per kilowatt hour:**
- 0.16 cents/kWh (2005); Range of damages: 0.001 – 0.55 (5th – 95th percentile)
- 0.11 cents/kWh (2030)
  - Fall in damages per kWh in 2030 explained by an expected 19% fall in NO\textsubscript{x} emissions per kWh hour and 32% fall in PM\textsubscript{2.5} emissions per kWh.
Electricity: Natural Gas
Location of Sources of Damages

Damage Estimates based on $\text{SO}_2$, $\text{NO}_x$, and PM emissions

- Air Pollution Damages from Natural Gas Generation for 498 plants, 2005.
- Damages related to climate-change effects are not included.
Electricity: Other Sources

Nuclear Power:

- Other studies found that damages associated with normal operation of plants are low compared with those of fossil-fuel-based power plants.
- External costs of a permanent repository for spent fuel should be studied.

Wind and Solar Power:

- Electricity generation from wind and solar is a small fraction of the total U.S. electricity production. External effects, which are largely local (e.g. land use), are much smaller than those for fossil-fuel plants.
- As the use of renewable sources grows, their external effects should be reevaluated.
Electricity: GHG Emission Estimates

Coal-fired plants:
• 2005 Average Emissions: 1 ton of CO$_2$/MWh of power generated

Natural gas fired plants:
• 2005 Average Emissions: 0.5 ton of CO$_2$/MWh of power generated

Other energy sources:
• Life-cycle emissions of GHGs from nuclear, wind, solar, and biomass appear so small as to be negligible compared to those from fossil fuel generated electricity
Transportation

• Committee focused on highway vehicles, as they account for more than 75% of transportation-energy consumption in the U.S.

• Energy Sources: oil (petroleum/diesel), natural gas, biomass, electricity, and others

• Four life-cycle stages (well-to-wheel) were considered:
  (1) Feedstock: fuel extraction and transport to refinery
  (2) Fuel: fuel refining/conversion and transport to the pump
  (3) Vehicle: emissions from production/manufacturing of the vehicle
  (4) Operation: tailpipe and evaporative emissions
Transportation

Aggregate non-climate damages: ≈ $ 56 billion (2005)

- Light-duty vehicles: $36 billion
- Heavy-duty vehicles: $20 billion

• Damages per vehicle-mile traveled (VMT) ranged from 1.2 cents to 1.7 cents.
  – 23-38 cents/ gasoline gallon equivalent

• Damage estimates did not vary significantly across fuels and technologies; caution is needed for interpreting small differences.
  – Some (electric, corn ethanol) had higher lifecycle damages
  – Others (cellulosic ethanol, CNG) had lower lifecycle damages
Light-Duty Vehicles
Non-Climate Damages in 2005

Health and Other Damages by Life-Cycle Component
2005 Light-Duty Automobiles

- CG SI Autos (Convent. Oil)
- CG SI Autos (Tar Sands)
- CNG
- E85 - Dry Corn
- E85 - Wet Corn
- E85 - Herbaceous
- E85 - Corn Stover
- Electric
- Grid Independent SI HEV
- Grid Dependent SI HEV
- Diesel (Low Sulfur)
- Diesel (Fischer-Tropsch)

Damages (cents/VMT)

- Operation
- Feedstock
- Fuel
- Vehicle
Light-Duty Vehicles: Non-Climate Damages in 2005 and 2030

- Damages in 2030 are similar to 2005, despite population and income growth
  - Fuel economy (CAFE) and diesel emission rules reduce 2030 damages

- Damages are not spread equally among the different lifecycle components.
  - Vehicle operation accounted in most cases for less than one-third of the total damage
  - Other components of the life cycle contributed the rest
  - Vehicle manufacturing is a significant contributor to damages
GHG lifecycle emissions did not vary significantly across fuels and technologies; caution is needed for interpreting small differences.

- Some – cellulosic ethanol – were lower
- Others – tars sands petroleum and Fischer Tropsch diesel – were higher

Vehicle operation is in most cases a substantial relative contributor to total lifecycle GHG emissions.
Substantial improvements in fuel efficiency in 2030 result in most technologies becoming much closer to each other in per VMT lifecycle greenhouse gas emissions.
Transportation: Future Reductions in Non-Climate & Climate Damages

- Substantially reducing non-climate and climate damages would require major technical breakthroughs, such as
  - Cost-effective conversion of cellulosic biofuels.
  - Cost-effect carbon capture and storage for coal-fired power plants and substantial further reductions in traditional emissions.
  - Increase in renewable energy capacity or other forms of electricity generation with lower emissions

- Further enhancements in fuel economy will help reduce emissions, especially from vehicle operations
Energy for Heat

- Production of heat as an end-use accounts for about 30% of U.S. primary energy demand, mostly natural gas.

- Aggregate damages from heating by gas in 2005: $1.4 billion (non-climate damages).

- Heating for Residential and Commercial Buildings and Industrial Sector: 11 cents/MCF

- Damages in 2030 may increase if new domestic energy development results in higher emissions or if more liquefied natural gas is imported.

- The greatest potential for reducing damages lies in improving energy efficiency.
  - Energy efficiency in the buildings and industrial sectors may increase by 25% or more by 2030.
Estimating Climate Change Damages

• Energy production and use is a major source of GHG emissions, principally CO$_2$ and methane.

• The committee reviewed existing Integrated Assessment Models (IAMs) and the associated climate-change literature.

• Sought to explain why estimates of damage per ton of CO$_2$-eq vary across IAMs
  – Did not endorse a single point estimate
  – Range of estimates: $1 - $100/ton CO$_2$-eq
Climate Change
Key Factors

- Key factors in IAMs that drive damage from a ton of CO$_2$-eq are:
  - Rate at which future damages are discounted
  - How fast damages (as a % of GDP) increase with temperature (gradual or steep)

- With steep damage function
  - Damage = $30/ton with a 3% discount rate
  - Damage = $10/ton with a 4.5 % discount rate

- Holding discount rate at 3%
  - Damage = $30/ton with steep damage function
  - Damage = $3/ton with gradual damage function
## Combining Non-Climate and Climate Change Damage Estimates (2005)

<table>
<thead>
<tr>
<th>Energy-Related Activity (fuel type)</th>
<th>Non-climate damage</th>
<th>Climate Damages (per ton CO₂-eq) @ $10</th>
<th>@ $30</th>
<th>@ $100</th>
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<tbody>
<tr>
<td><strong>Electricity Generation (coal)</strong></td>
<td>3.2 cts/kWh</td>
<td>1 cts/kWh</td>
<td>3 cts/kWh</td>
<td>10 cts/kWh</td>
</tr>
<tr>
<td><strong>Electricity Generation (natural gas)</strong></td>
<td>0.16 cts/kWh</td>
<td>0.5 cts/kWh</td>
<td>1.5 cts/kWh</td>
<td>5 cts/kWh</td>
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<td><strong>Transportation</strong></td>
<td>1.1 to ~1.7 cts/VMT</td>
<td>0.15 to ~0.65 cts/VMT</td>
<td>0.45 to ~2 cts/VMT</td>
<td>1.5 to ~6 cts/VMT</td>
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<td><strong>Heat production (natural gas)</strong></td>
<td>11 cts/MCF</td>
<td>70 cts/MCF</td>
<td>210 cts/MCF</td>
<td>700 cts/MCF</td>
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Infrastructure and Security

Activities that pose externalities but need further study:

• **Grid Disruptions**
  – Failures in the electric grid due to transmission congestion and the lack of adequate reserve capacity are externalities.

• **Nuclear waste**
  – Raises important security issues and poses tough policy challenges.
  – External effects are difficult to quantify but important to study

• **Dependence on Imported Oil and Foreign Policy.**
  – Some effects can be viewed as externalities, but it is currently impossible to quantify them.

Activities for which externalities are largely now taken into account:

• **Accidents at Energy Facilities**
  – External costs are largely taken into account (insurance, tanker design)

Activities that are likely not externalities:

• **Being a Large Buyer of Foreign Oil**
  – Reducing domestic demand can reduce the world oil price;, however, the committee does not consider this influence to be an externality.

• **Oil Price Shocks**
  – Sharp and unexpected increases in oil prices disrupt the U.S. economy, but these disruptions and adjustments are not externalities.
Conclusions

- Non-climate damages from electricity generation and transportation exceed $120 billion for the year 2005. These damages are principally related to emissions of NO$_x$, SO$_2$, and PM.

- The above total is a substantial underestimate because it does not include damages related to climate change, health effects of hazardous pollutants, ecosystem effects, or infrastructure and security.

- How much a burden should be reduced depends on its magnitude and the cost of reducing it.

- Reducing emissions, improving energy efficiency, or shifting to cleaner methods of generating electricity could substantially reduce damages.