National Research Council Report

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

Presentation by

Maureen Cropper
University of Maryland and Resources for the Future

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Study Origin and Task

Congress:

- Requested this study in the Energy Policy Act of 2005.
- 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 or energy or fully addressed by current government policy.

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
Christopher Field	Carnegie Institution of Washington
Daniel Greenbaum	Health Effects Institute
James Hammitt	Harvard University Center for Risk Analysis
Rogene Henderson	Lovelace Respiratory Research Institute
Catherine Kling	Iowa State University
Alan Krupnick	Resources for the Future
Russell Lee	Oak Ridge National Laboratory
H. Scott Matthews	Carnegie Mellon University
Thomas McKone	Lawrence Berkeley National Laboratory
Gilbert Metcalf	Tufts University
Richard Newell *	Duke University
Richard Revesz	New York University School of Law
Ian Sue Wing	Boston University
Terrance Surles	University of Hawaii at Manoa

* Resigned August 2, 2009 to accept appointment as Administrator of the U.S. Energy Information Administration.

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
- Did not present a point estimate of climate damages (per ton of CO2)
  - Identified how damages vary with key parameters of Integrated Assessment models

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 SO_2, NO_x, and PM emissions across the 48 contiguous states.

- 94% of the damages are associated with human mortality
  - Each statistical life lost valued at $6 million (2000 USD)

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 (5^{th} – 95^{th} 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 SO_2 per kWh hour will fall by 64% and that NO_x emissions per kWh will fall by 50%.

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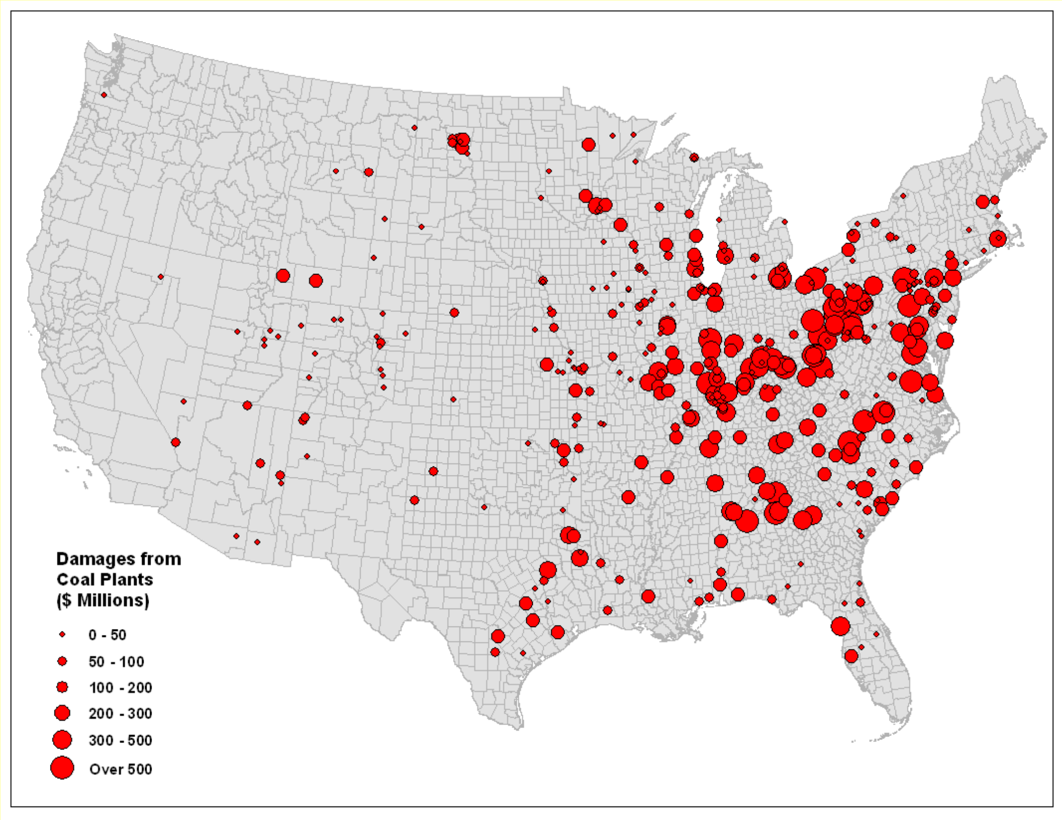
Electricity: Coal
Location of Sources of Damages

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

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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:

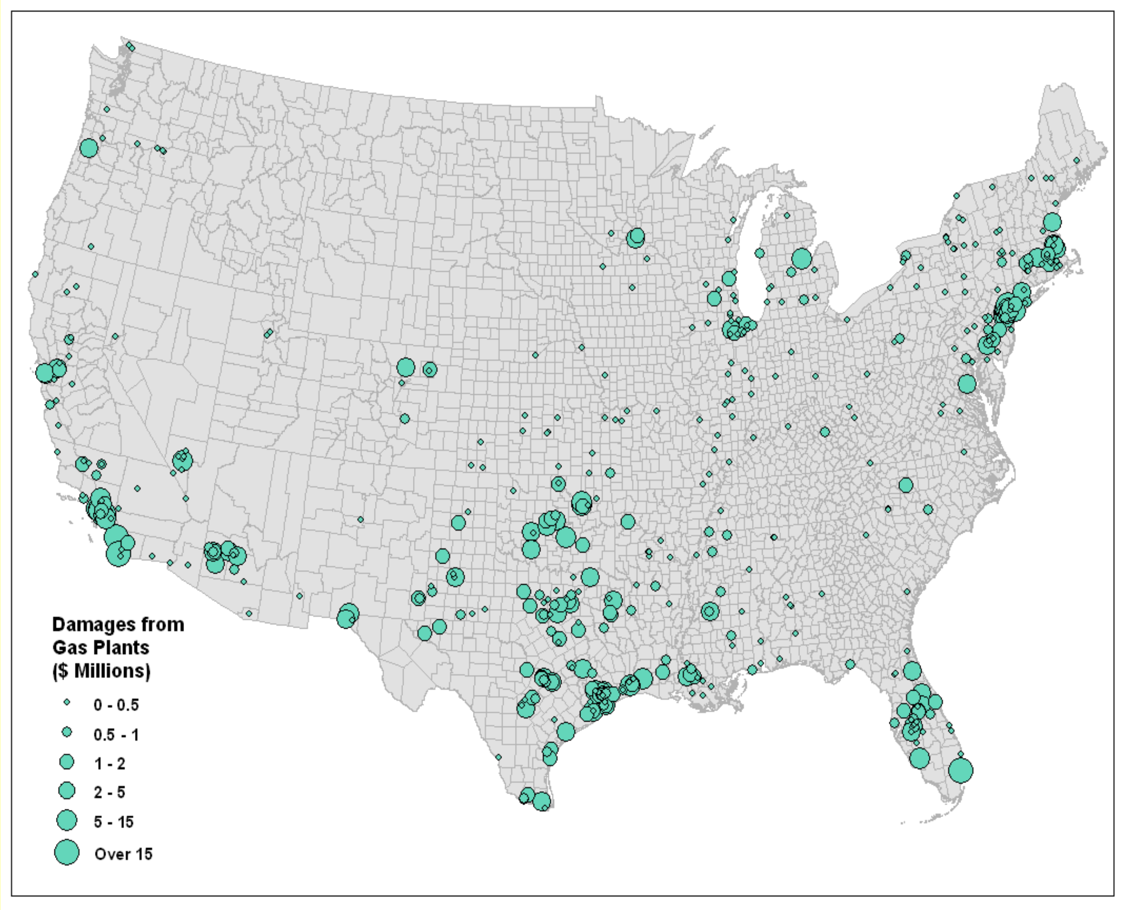
0.16 cents/kWh (2005); Range of damages: 0.001 – 0.55 (5^{th} – 95^{th} percentile)

0.11 cents/kWh (2030)

Fall in damages per kWh in 2030 explained by an expected19% fall in NO_x emissions per kWh hour and 32% fall in $PM_{2.5}$ emissions per kWh.

Electricity: Natural Gas
Location of Sources of Damages

Damage Estimates based on SO_2, 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.

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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.

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

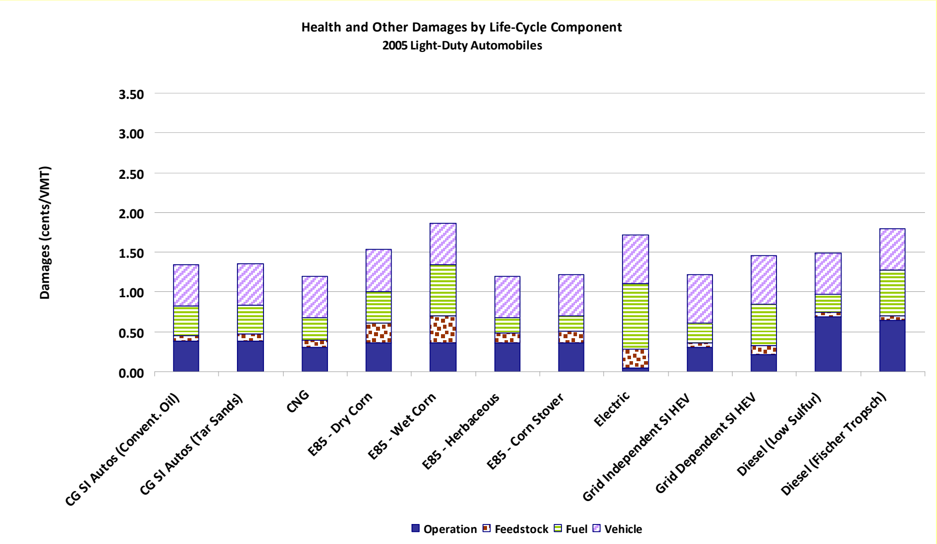
Aggregate non-climate damages: ≈ $ 56 billion (2005)

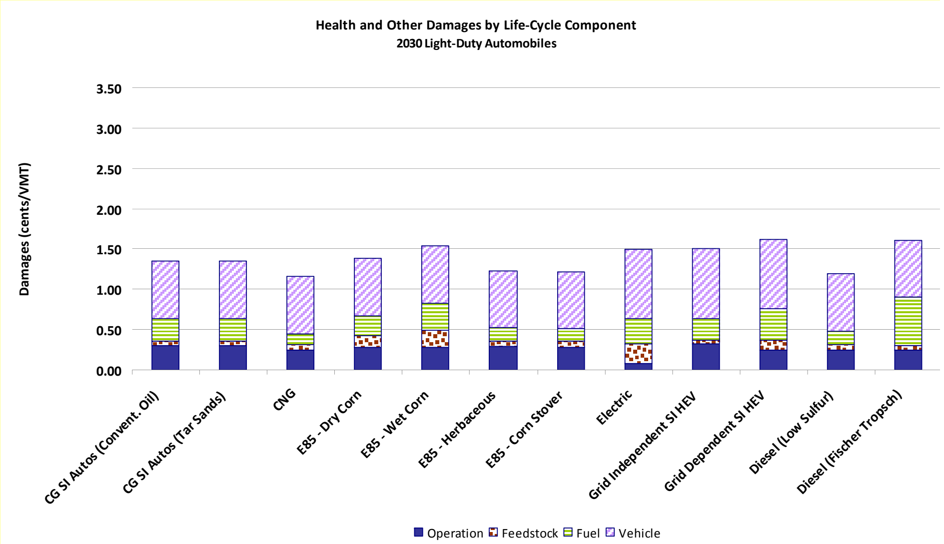
Light-duty vehicles: $36 billion

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: Health Damages in 2005 and 2030





CG SI = Conventional Gasoline Spark Ignition

- 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

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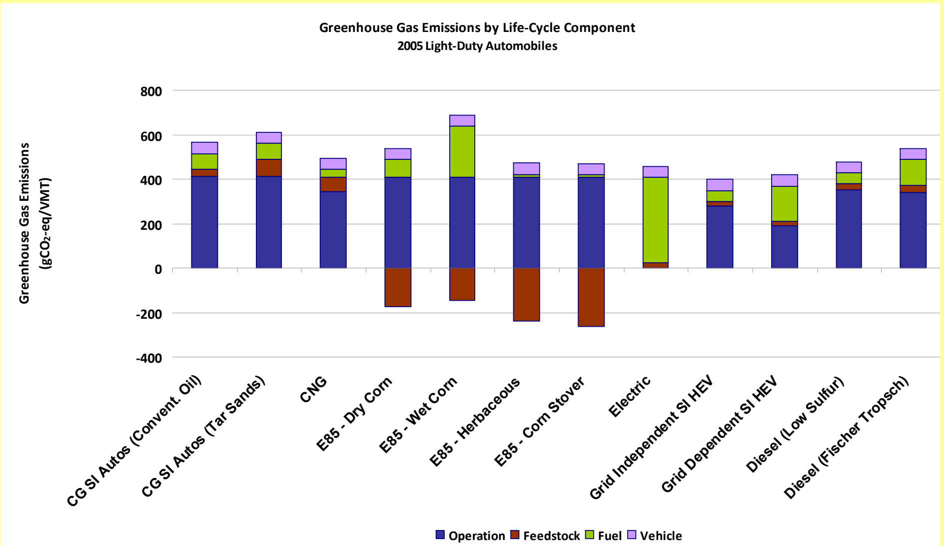
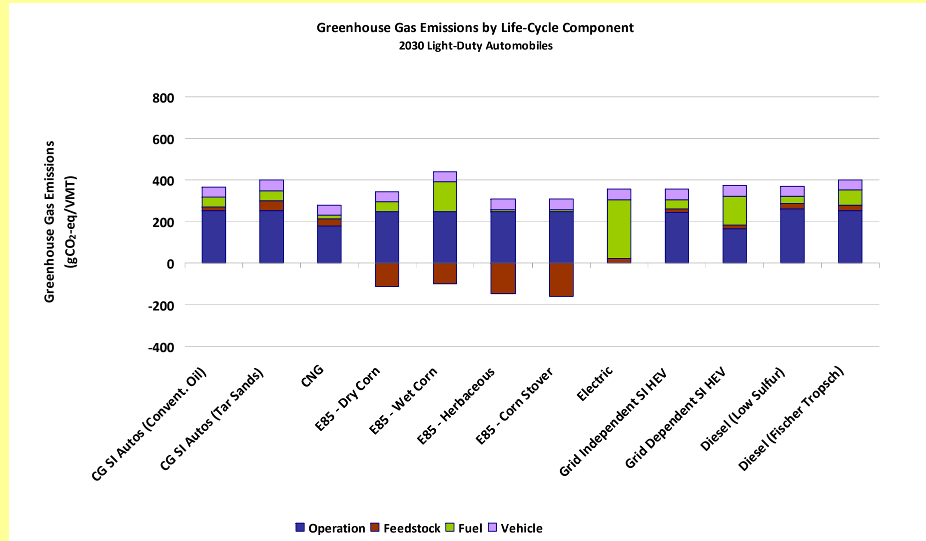
Light-Duty Vehicles: GHG Emissions
2005 and 2030





CG SI = Conventional Gasoline Spark Ignition; 1lb = 454 g

- 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.

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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
  - MSCC = $3/ton with gradual damage function

Combing Non-Climate and Climate Change Damage Estimates (2005)

Energy-Related Activity (fuel type)	Non-climate damage	Climate Damages (per ton CO_2-eq)		
		@$10	@ $30	@ $100
Electricity Generation (coal)	3.2 cents/kWh	1 cents/kWh	3 cents/kWh	10 cents/kWh
Electricity Generation (natural gas)	0.16 cents/kWh	0.5 cents/kWh	1.5 cents/kWh	5 cents/kWh
Transportation	1.1 to ~1.7 cents/VMT	0.15 to ~0.65 cents/VMT	0.45 to ~2 cents/VMT	1.5 to ~6 cents/VMT
Heat production (natural gas)	11 cents/MCF	70 cents/MCF	210 cents/MCF	700 cents/MCF

Infrastructure and Security

- **Grid Disruptions**
  - Failures in the electric grid due to transmission congestion and the lack of adequate reserve capacity are externalities.
  - Individual consumers of electricity do not take into account the impact of their consumption on aggregate load.
  - Further study needed to quantify costs and benefits of investing in a modernized grid—better able to handle intermittent renewable-power sources.

- **Accidents at Energy Facilities**
  - External costs are largely taken into account
  - In the case of our nation's oil and gas transmission networks, external effects are of negligible magnitude per barrel of oil or thousand cubic feet of gas shipped.

- **Nuclear waste**
  - Raises important security issues and poses tough policy challenges.
  - External effects are difficult to quantify.
  - Important to study these issues further.

Infrastructure and Security

- **Being a Large Buyer of Foreign Oil**
  - Reducing domestic demand can reduce the world oil price, and thereby benefit the U.S. through lower prices on the remaining oil it imports.
  - However, the committee does not consider this influence to be an externality.
- **Oil Price Shocks**
  - Sharp and unexpected increases in oil prices cause macroeconomic disruptions in the U.S. economy.
  - However, these disruptions and adjustments are not externalities.
- **Dependence on Imported Oil and Foreign Policy**.
  - Some effects can be viewed as externalities, but it is currently impossible to quantify them.

Conclusions

Quantified Damages are Damages from Ozone and PM

- Damages represent benefits of reducing pollution from 2005 levels
- Study did not calculate costs of pollution control, but supports reductions of SO2, NOx under CAIR
- Shows benefits of Tier II Emissions standards, HDD Rule

Not Quantified are Damages from:

- Climate change
- Hazardous air pollutants
- Water pollution
- Damages to ecosystems
- Infrastructure and security