BEST

Board on Environmental Studies and Toxicology

**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:**

- 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 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 |
| **Christopher Field** | Carnegie Institution of Washington |
| **Daniel Greenbaum** | Health Effects Institute |
| **James Hammitt** | Harvard University Center for Risk Analysis |
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| **Catherine Kling** | Iowa State University |
| **Alan Krupnick** | Resources for the Future |
| **Russell Lee** | Oak Ridge National Laboratory |
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| **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.

# Report Reviewers

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

| | |
|---|---|
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| **William Banholzer** | Dow Chemical Company |
| **Eric Barron** | National Center for Atmospheric Research |
| **Donald Boesch** | U. of Maryland, Cambridge |
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| **Kerry Smith** | Arizona State U. |
| **Kirk Smith** | U. of California, Berkeley |
| **Susan Tierney** | Analysis Group |
| **Michael Walsh** | Independent Consultant |

# 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 $SO_2$, $NO_x$, 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)**

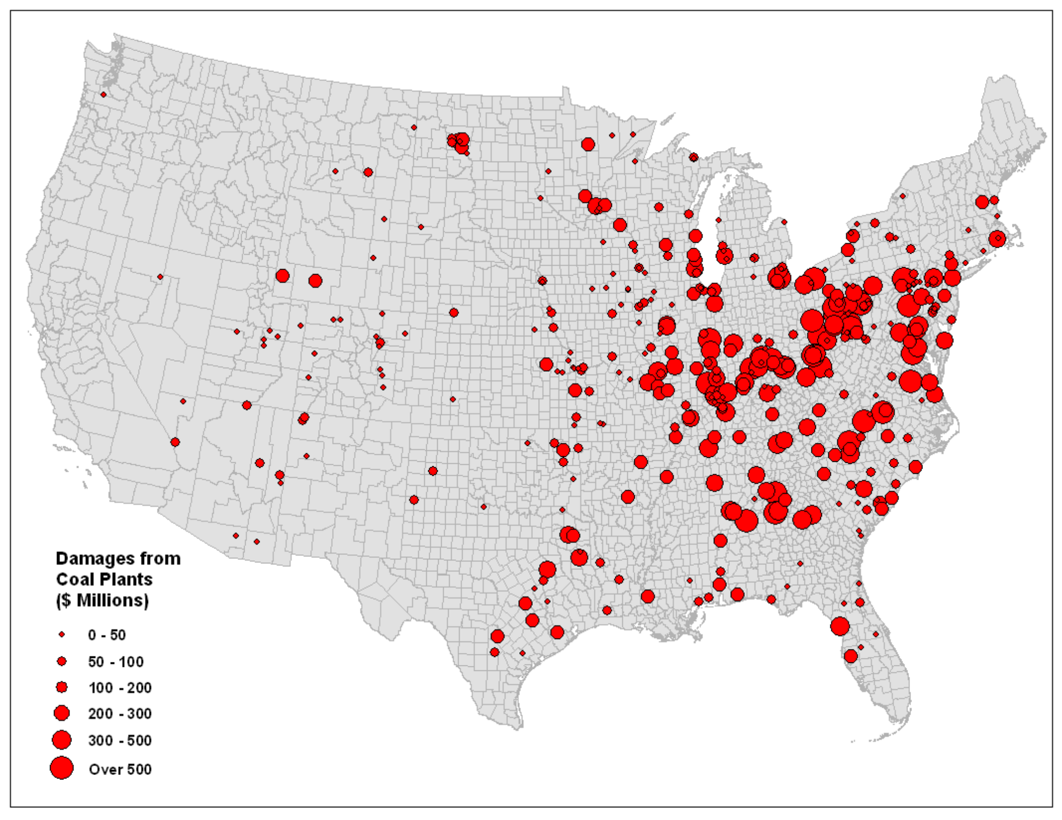
- Range of damages: 0.19 – 12.0 ($5^{th}$ – $95^{th}$ percentile) cents/kWh.
- Variation primarily due to variation in pollution intensity (emissions per kWh) across plants.

**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%.

# 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

**<u>Aggregate damages (2005):</u> ≈ $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.

**<u>Average damages per kilowatt hour:</u>**

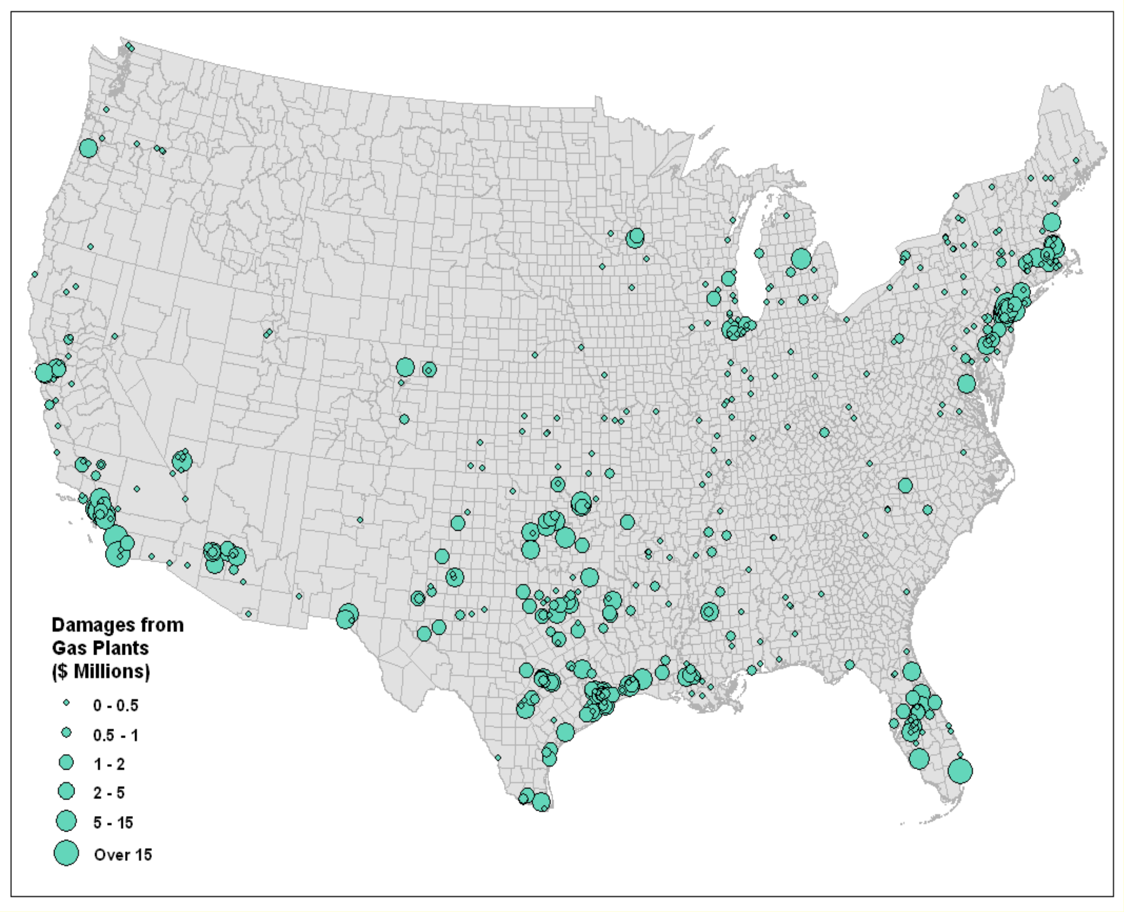
**0.16 cents/kWh (2005);** Range of damages: 0.001 – 0.55 ($5^{th}$ – $95^{th}$ percentile)

**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.

# 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

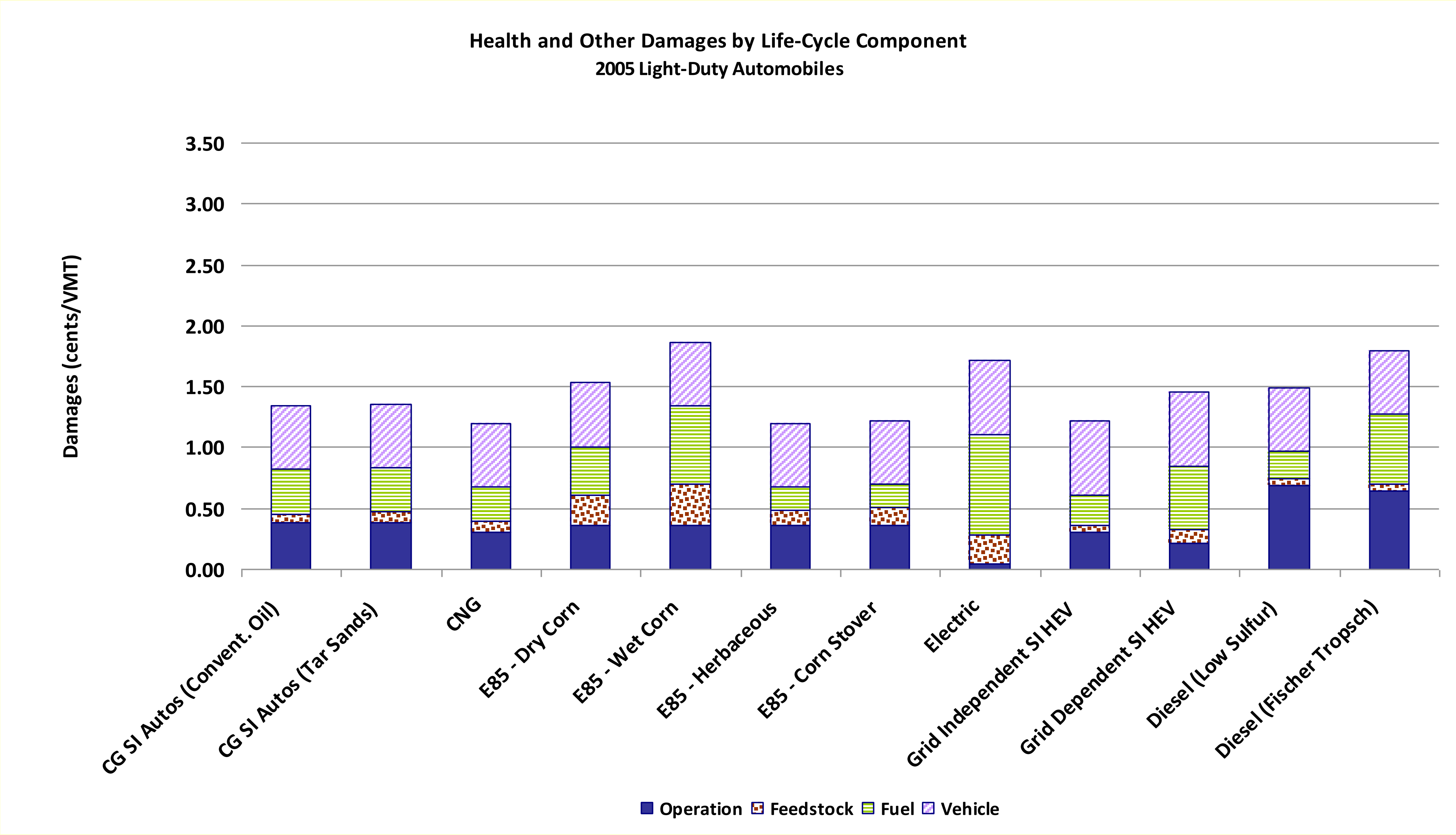
**Aggregate non-climate damages: ≈ $ 56 billion (2005)**

Light-duty vehicles: $36 billion

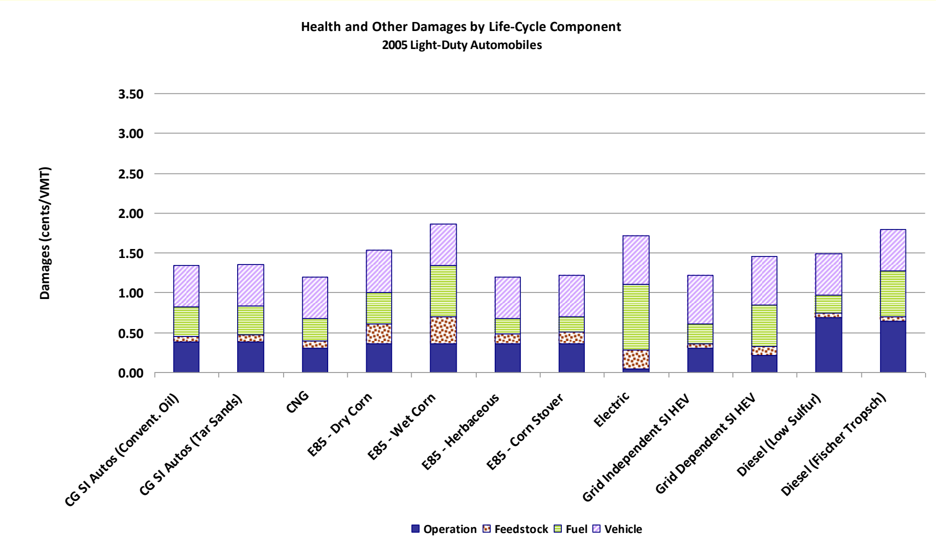
Heavy-duty vehicles: $20 billion

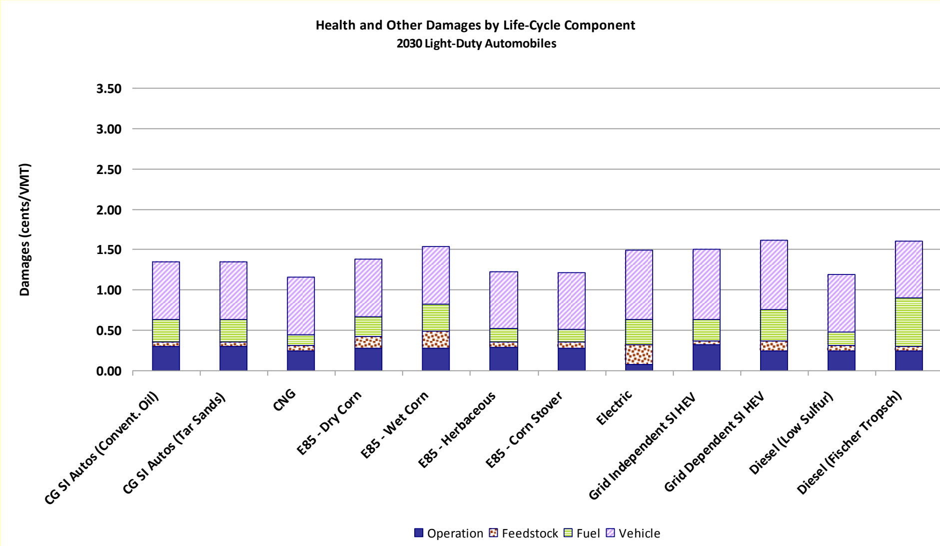
- Damages per vehicle-mile traveled (VMT) ranged from 1.2 cents to 1.7 cents.
  - 23-38 cents/ gasoline gallon equivalent
- Damage estimates did not vary significantly across fuels and technologies; caution is needed for interpreting small differences.
  - Some (electric, corn ethanol) had higher lifecycle damages
  - Others (cellulosic ethanol, CNG) had lower lifecycle damages

# Light-Duty Vehicles
# Non-Climate Damages in 2005



# Light-Duty Vehicles: Non-Climate Damages in 2005 and 2030

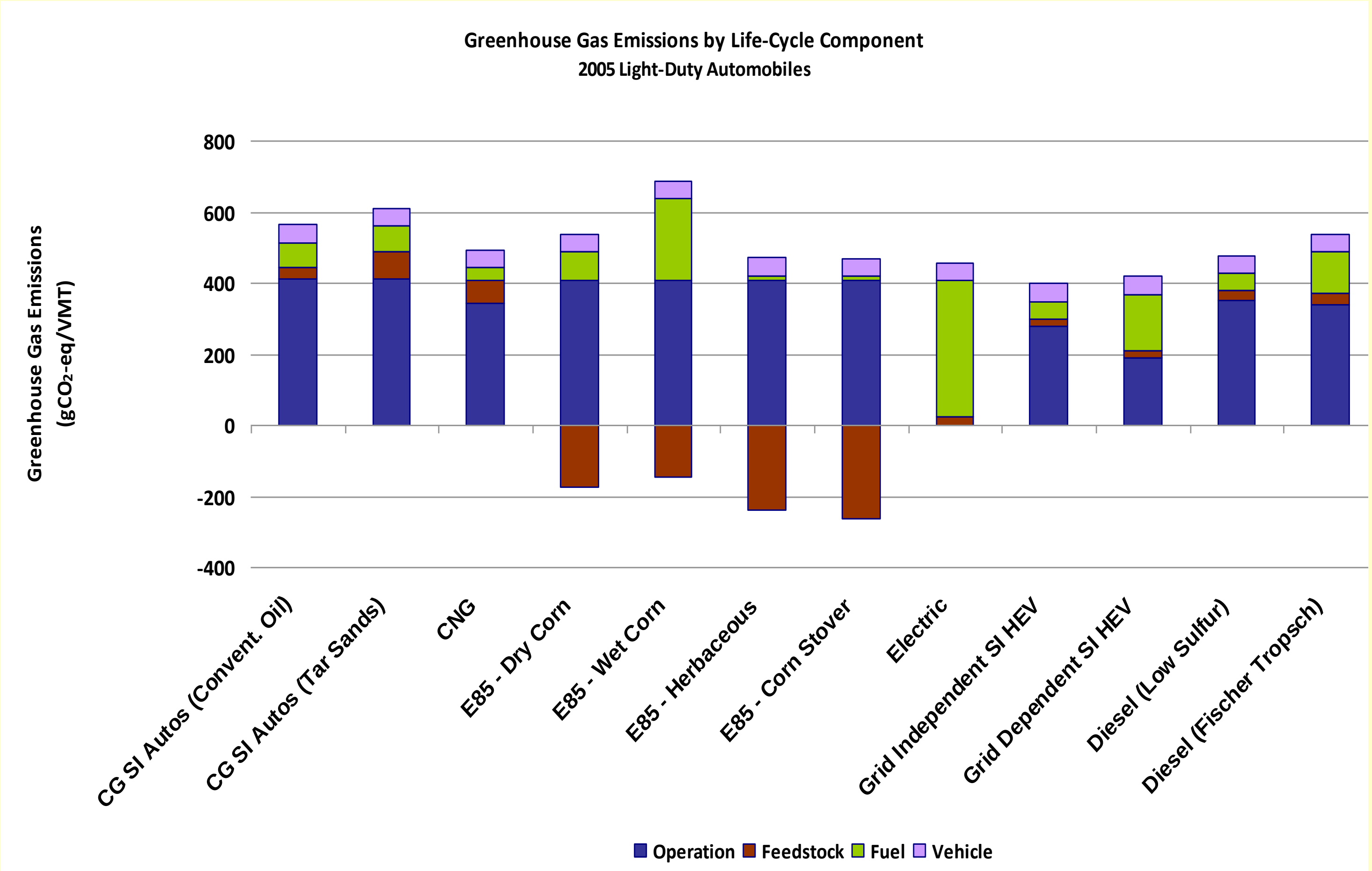



**CG SI = Conventional Gasoline Spark Ignition**

- 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

# Transportation
# GHG Emissions in 2005
# Light-Duty Vehicles

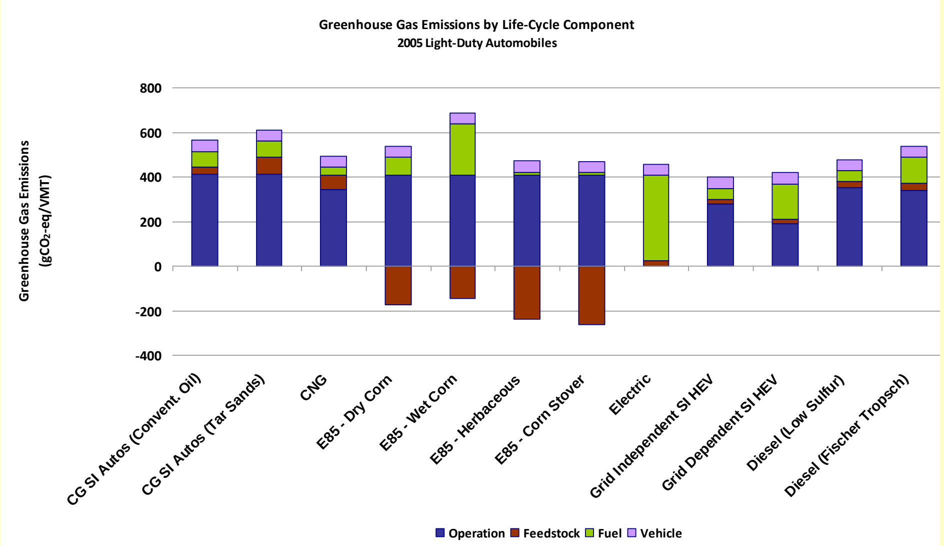


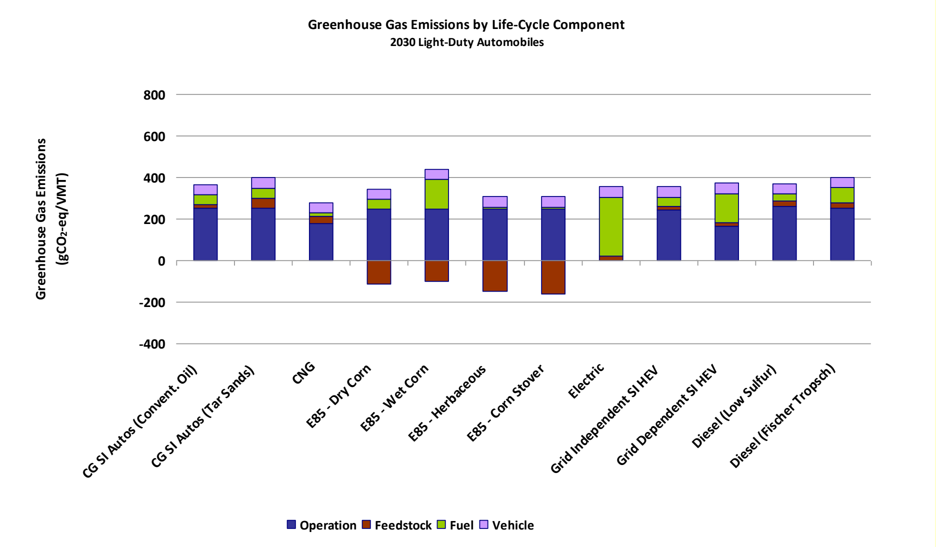

GHG lifecycle emissions did not vary significantly across fuels and technologies; caution is needed for interpreting small differences.

- 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.

# Light-Duty Vehicles: GHG Emissions
## 2005 and 2030




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

- 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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# 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)

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

# 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.