Introduction

U.S. Greenhouse Gas Footprint

2005 United States Greenhouse Gas Emissions By Sector (MtA carbon equivalent)

- residential: 342 MtA (18%)
- commercial: 297 MtA (14%)
- transportation: 534 MtA (27%)
- other: 328 MtA (17%)

Carbon emissions from energy consumption in buildings:

- 56% of U.S. greenhouse gas emissions are from energy consumption in buildings.

Distributed Energy Resources For Improved Carbon Efficiency

Distributed Energy Resources (DER) are a range of energy conversion and storage technologies including small-scale power generation, thermal and electrical storage, and thermally activated cooling. These technologies can reduce the carbon-intensity of meeting end-use energy loads. Technologies include:

- Combined heat and power (CHP): on-site electricity generation (natural gas or fuel cells) with waste heat recovery for site heating needs. 60-85% of primary fuel energy can be utilized.
- Thermally activated cooling: Absorption and adsorption chillers use heat, rather than electricity, to provide cooling.
- Solar technologies: Photovoltaics provide renewable electricity. Solar thermal collectors can be used to provide heat for domestic hot water and/or thermally activated cooling. High temperature collectors can provide steam for industrial processes.

Storage: Storage devices such as batteries and thermal tanks can be used to improve reliability and to apply energy produced or purchased during a low value time to loads at a higher value time.

The Distributed Energy Resources Customer Adoption Model

The Distributed Energy Resources Customer Adoption Model (DER-CAM) is a site-specific, fully technology neutral DER investment and operation optimization tool developed by the DER team at the Berkeley Lab.

Inputs include:
- site hourly electricity and heating load profiles
- energy prices
- DER investment options
- operational constraints such as limits on carbon emissions

Outputs include:
- optimal DER investment
- optimal operating schedule
- performance measures such as annual energy cost, electricity and natural gas consumption, and carbon emissions attributed to energy consumption

Experiment: What are the economically optimal DER technologies for U.S. commercial buildings under a carbon tax?

DER-CAM was used to determine the economically optimal DER investment for prototypical commercial buildings in several U.S. cities under a range of carbon tax levels.

Building energy simulations were conducted to determine electricity, natural gas, space and water heating, and cooling loads for each building type in each location. City-specific weather, energy costs, and electric grid carbon-intensity values were used.

Building Types:
- health care (small and large)
- lodging (small and large)
- office (small and large)

Cities:
- Atlanta, Georgia
- Boston, Massachusetts
- San Francisco, California

Results: Technology Adoption, Costs, and Carbon Emissions

- Atlanta:
  - Electricity prices are too low to incent CHP.
  - Integrated solar thermal/absorption chiller systems are economic even without a carbon tax.
  - Solar collector/absorption chiller system size increases with carbon tax.
  - A realistic carbon tax of $100/tC incents less than one percent carbon reductions.

- Boston:
  - CHP is marginally economic without the carbon tax and is increasingly adopted with carbon tax.
  - Solar thermal/absorption chiller systems are economic.
  - A realistic carbon tax level ($100/tC) incents less than one percent carbon reduction.

- San Francisco:
  - All buildings considered would benefit financially from CHP, even without carbon taxes.
  - Carbon emissions reductions from DER investment are less than in Atlanta and Boston.
  - The relatively low electric grid marginal carbon emissions and high electricity prices in California induce some carbon-inefficient behavior, such as operating CHP when the heat is not needed.
  - Carbon taxes have little effect on investment behavior and almost none on carbon emissions.

Overall:
- A realistic carbon tax ($100/tC) is too small to incent significant carbon-reducing effects on economically optimal DER adoption.
- Cost reduction and carbon reduction objectives are roughly aligned, even in the absence of a carbon tax.
- A carbon tax greater than $500/tC would be required to incent significant adoption of carbon-free renewable energy.

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