Energy Efficiency in Buildings and Industry: A Low Carbon Future

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OUTLINE

• Climate challenge can be solved
  — By changing technologies, policies, and behaviors

• Buildings are key

• Solutions are
  — Technologically feasible
  — Economically justified
Where are we headed? Climate change

• **Bad news: physical effects**
  — Emissions continue to increase
  — Observations of climate change show greater effects sooner than expected in 2004 IPCC Assessment

• **Hope for the future: mitigation and adaptation**
  — Local and state governments are taking action
  — U.S. House and Senate each developed draft legislation to address climate change
  — 193 national governments met in Copenhagen in December 2009 and agreed that further mitigation is needed, but failed to reach binding agreement
Global Carbon Market: $126B 2008 - doubling each of last 3 years
Volumes transacted in 2008 (total 4,811 MtCO$_2$e)

Innovation Funding in American Recovery and Reinvestment Act

- Renewable energy and energy efficiency
- Health IT
- Health research
- Innovative programs
- High speed rail
- Broadband
- Education and training
- Advanced vehicles and biofuels
- Smart grid, interconnection and transmission
- General research
- Fossil energy R&D
- General energy research

Billions

[Bar chart showing various categories of innovation funding]
U.S. Carbon Emissions & Recent Draft Legislation


2006 AEO

2 MMtCO2e Reduction in Projected Emissions in 2030

2009

APGR CO2e
+1.2% 2006
+0.3% 2009

TARGET
2010-2050
-4%

Growth in electricity use continues to slow

3-year rolling average percent growth

**History**

<table>
<thead>
<tr>
<th>Period</th>
<th>Annual Growth</th>
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<tbody>
<tr>
<td>1950s</td>
<td>9.8</td>
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<tr>
<td>1960s</td>
<td>7.3</td>
</tr>
<tr>
<td>1970s</td>
<td>4.7</td>
</tr>
<tr>
<td>1980s</td>
<td>2.9</td>
</tr>
<tr>
<td>1990s</td>
<td>2.4</td>
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<tr>
<td>2000-2008</td>
<td>0.9</td>
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<tr>
<td>2008-2035</td>
<td>1.0</td>
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</tbody>
</table>

**Projections**

- Structural Change in Economy - Higher prices - Standards - Improved efficiency

Source: *Annual Energy Outlook 2010*
“Solutions” to reducing energy/carbon use rely heavily on Energy Efficiency and Renewable Energy.

Full implementation of the IEA 25 energy efficiency recommendations is essential to achieve the 450 scenario.
REALITY CHECK: Back to the Future?
Efficiency contributed to large decrease in energy intensity (E/GDP) from 1973 to 2005 in U.S.

Avoided 74% of supply growth

- Efficiency & conservation in buildings, cars, & industry
- Shift away from heavy industry to services
Energy Consumption by U.S. Buildings

• 71% of U.S. electricity consumption

• 54% of U.S. natural gas consumption

• 39% of U.S. carbon dioxide emissions

U.S. buildings are responsible for more CO$_2$ emissions than any country in the world except China & US.
Buildings’ Energy Consumption by End Use Services

Space conditioning, lighting, water heating, refrigeration and electronics account for 87% of primary energy used by buildings.
U.S. Average Energy Use per New Appliance

Index relative to 1972 = 100

- Gas Furnace -25%
- Central air conditioner – 50%
- Refrigerator(2016) -78%
Average Energy Use Per Cycle of New Clothes Washers

Energy Factor

MEF

Source: AHAM Factbooks
Efficiency and carbon-neutral supply are complements

Target date: 2020 for new residential buildings
2030 for new commercial buildings
Natural gas and renewables account for the majority of capacity additions from 2008 to 2035

2008 capacity
- Natural gas: 338 (33%)
- Nuclear: 101 (10%)
- Other renewables: 40 (4%)
- Other: 119 (12%)
- Hydropower*: 99 (10%)

Total capacity: 1,008 gigawatts

Capacity additions 2008 to 2035
- Natural gas: 116 (46%)
- Nuclear: 8 (3%)
- Other renewables: 92 (37%)
- Other: 2 (1%)
- Hydropower*: 1 (0.4%)

Total capacity additions: 250 gigawatts

* Includes pumped storage

Source: Annual Energy Outlook 2010
Nonhydropower renewable sources meet 41% of total electricity generation growth from 2008 to 2035

Source: Annual Energy Outlook 2010
Energy efficiency is carbon mitigation


**Figure 25**
Residential electric savings potential for year 2030

Conservation supply curve for electric energy-efficiency improvements in the residential sector. For each measure considered (the energy savings is achieved at a cost per kWh less than the average residential retail price of 9.4 cents/kWh, shown as the horizontal red dashed line.)

- **Savings potential of 572 TWh**
- **30% of reference case**

<table>
<thead>
<tr>
<th>Item</th>
<th>2030 Energy savings (TWh)</th>
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<tbody>
<tr>
<td>Color TV</td>
<td>72</td>
</tr>
<tr>
<td>Lighting</td>
<td>204</td>
</tr>
<tr>
<td>Other uses</td>
<td>170</td>
</tr>
<tr>
<td>Water heating</td>
<td>82</td>
</tr>
<tr>
<td>Space heater</td>
<td>45</td>
</tr>
<tr>
<td>Personal computers</td>
<td>26</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>20</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>12</td>
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<tr>
<td>Space cooling</td>
<td>8</td>
</tr>
<tr>
<td>Freezer</td>
<td>4</td>
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</tbody>
</table>

Carbon Mitigation Potentials & Economics
Energy efficiency reduces costs and carbon emissions

(Energy Future: Think Efficiency, American Physical Society, September, 2008)

Programs to Reduce Energy Use in U.S. Appliances, Lighting and Equipment

- **EnergyGuide Labels** “information”
  - Identify and compare efficiency of models

- **Tax incentives**

- **Utility energy efficiency programs**

- **Minimum Efficiency Standards** “regulation”
  - Require energy performance

- **ENERGY STAR Label** “endorsement”
  - Voluntary branding of more efficient models
EnergyGuide Label

The mandatory EnergyGuide label allows consumers to compare the energy use of different appliances.

Products include:

- clothes washers, dishwashers, refrigerators, freezers,
- water heaters,
- window air conditioners, central air conditioners, heat pumps,
- furnaces, boilers, ceiling fans,
- plumbing products,
- pool heaters
ENERGY STAR

- ENERGY STAR identifies products in more than 60 categories that use less energy without sacrificing quality or performance
  - >2,000 manufacturers labeling
  - >40,000 product models
  - >1,000 retail partners
  - >550 utility partners promoting ENERGY STAR

- Americans with the help of ENERGY STAR prevented 40 million metric tons of GHG emissions - equivalent to 29 million vehicles and saved $19 billion on energy bills in 2008
ENERGY STAR TVs: On Mode Limits

ENERGY STAR TV On Mode Requirements

- Version 3.0
- Version 4.0
- Version 5.0

Comparable Viewable Screen Size (inches)
- 20
- 32"
- 40"
- 46"
- 50"
- 60"

On Mode Power (W)
- 0
- 200
- 400
- 600

Screen Area (square inches)
- 0
- 200
- 400
- 600
- 800
- 1000
- 1200
- 1400
- 1600
- 1800
- 2000
U.S. Efficiency Standards Rulemaking Activities

Six Final Rules in 2009
- 14 Products with standards prescribed by EISA 2007
- Ranges and Ovens
- General Service Fluorescent Lamps (GSFL) and Infrared (IRL) Lamps
- Commercial Package Boilers and Very Large Commercial Package Air-conditioners & Heat Pumps
- Refrigerated Beverage Vending Machines
- Commercial Clothes Washers

Five Final Rules in 2010
- Water Heaters (Residential)(COMPLETED)
- Direct Heating Equipment (COMPLETED)
- Pool Heaters (COMPLETED)
- Small Electric Motors (COMPLETED)
- Refrigerators (12/2010)

Ten Final Rules in 2011
- Microwave Ovens
- Residential Furnaces
- Fluorescent Lamp Ballasts
- Clothes Dryers (Residential)
- Room Air Conditioners
- Central Air Conditioners and Heat Pumps (Residential)
- Battery Chargers
- External Power Supplies (Class A)
- ER, BR, and Small Diameter Incandescent Reflector Lamps
- Residential Clothes Washers
U.S. Energy Efficiency Standards Affect Products Using Most of Buildings’ Primary Energy

**Primary energy savings** = 9% of 2025 residential energy use

**Carbon reductions** = 9% of projected levels
132 million metric tons CO₂/year in 2025

**Peak power savings** = 20% of 2001-2020 growth
Life Cycle Cost (LCC) Analysis

Example: CLOTHES WASHER (12-year life, 7% real discount rate) with Electric Water Heater + Electric Dryer

\[ \text{LCC} = \text{all initial costs plus operating costs} \]

\[ \text{Discount future expenses to the present and sum over lifetime of equipment} \]
U.S. Refrigerator Electricity Use and Size
Unit energy 1974 to 2006 = -4% per year

Average Energy Use per Unit Sold (kWh per year)
Refrigerator Size (cubic feet)


Energy Use per Unit

1978 Cal Standard
1980 Cal Standard
1987 Cal Standard
1990 Federal Standard
1993 Federal Standard
2001 Federal Standard

Refrigerator volume (cubic feet)

0 liters 5 10 15 20 25

566 l 283 l

0 200 400 600 800 1000 1200 1400 1600 1800 2000

Average Energy Use per Unit Sold (kWh per year)
U.S. New Refrigerator kWh/year Decreased 70%  
Annual Drop from 1974 to 2006 = 4% Per Year (average)

Real retail price in 2002 was 40% lower than in 1980
Affordable Energy-Efficiency is a Renewable Resource

-27% -30%

Updated 2001 standards exceeded the maximum technologically feasible level of a few years earlier.

Average standards, % change, effective date:
- 690 kWh/a, -27%, 1993
- 475 kWh/a, -30%, 2001

The maximum technology kWh/a in refrigerators changed 14% in 6 years - from 495 kWh/a (1989) to 425 kWh/a (1995) – and became cheaper to manufacture.
Efficiency improvements have small net effect on TOTAL (Life Cycle) Cost for most consumers

- Example: Residential Electric Storage Water Heaters, 0.95 EF

Average LCC = $3,236 (2009$)
CO₂ Emissions Declined

• Absolute amount of energy consumption – and carbon dioxide emissions – for U.S. household refrigeration decreased

• Technology and policy together achieved this result
• Inflation-adjusted retail prices declined
• Lessons learned can be applied to other energy technologies and services
Standards: Path to Lower Emissions by 2030
Residential Sector, All Countries

Equivalent to 20% of IPCC “zero cost” potential in 2020, 33% in 2030. The rest must be achieved by addressing market failures with building codes, utility programs, incentives, prices, etc.

M. McNeil, V. Letschert, S. de la Rue du Can, LBNL - personal communication, February 27, 2008
Work in progress for Collaborative Labeling and Appliance Standards Programs (CLASP)
Additional Savings from Systems

• From individual technologies to whole building
• Demand response incorporates price signals to deliver automatic reductions
• Digital networks can maximize comfort and utility while minimizing energy
• Efficient (electricity and cooling) data centers

• Combined heat and power can improve efficiency and reduce peak
• Neighborhood systems (e.g., district heating/cooling)
• Micro-grids provide local power, desired power quality

• Energy-efficient wastewater treatment
• Regional integrated resource planning (energy, water)