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Energy Efficiency and the Benefits for Carbon Dioxide Reduction in the United States – An Analysis Using the MARKAL Model

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Outline

- Background
- Energy Efficiency Analysis
- Electric Sector Low Carbon Portfolio and Energy Efficiency

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Background

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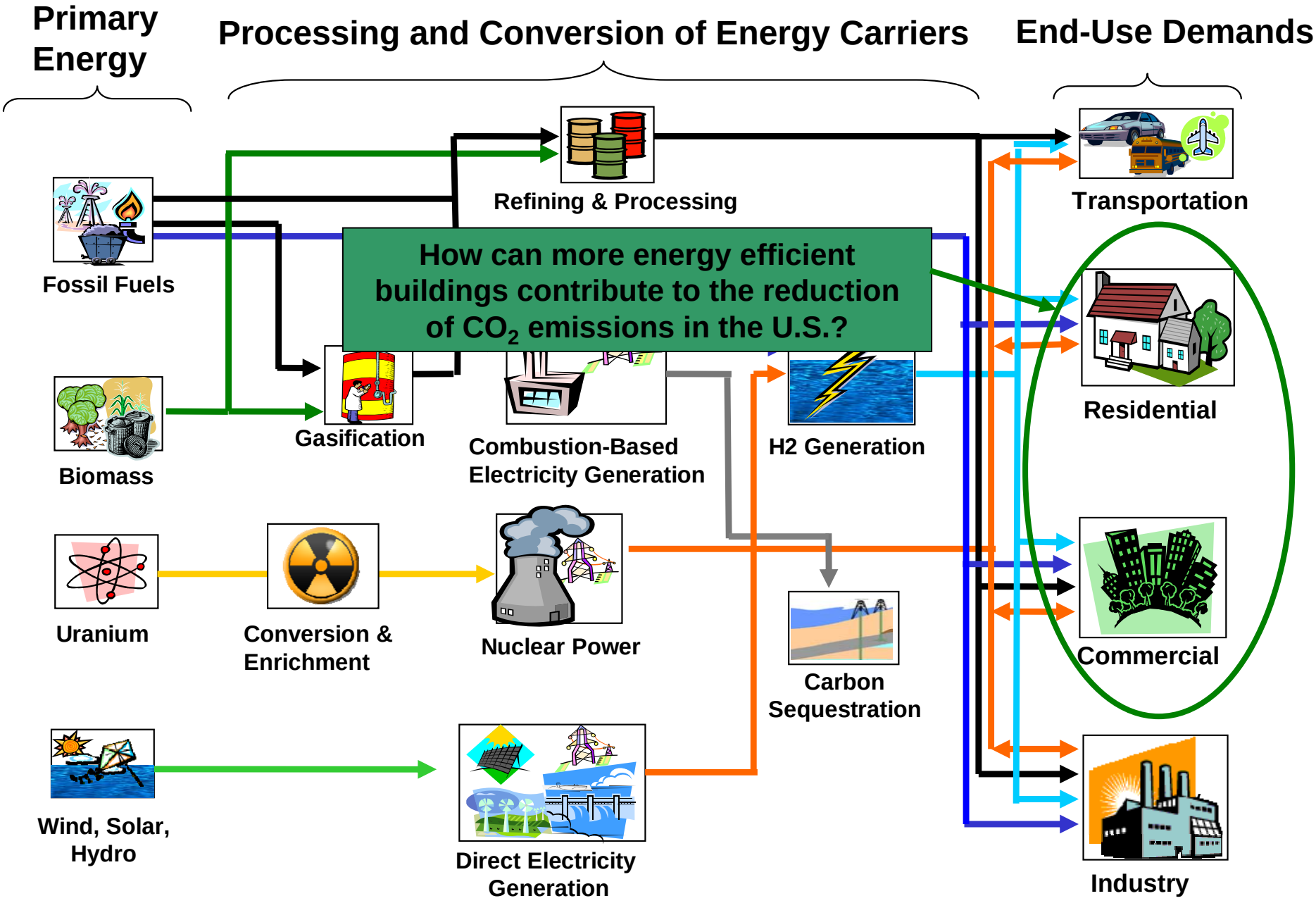
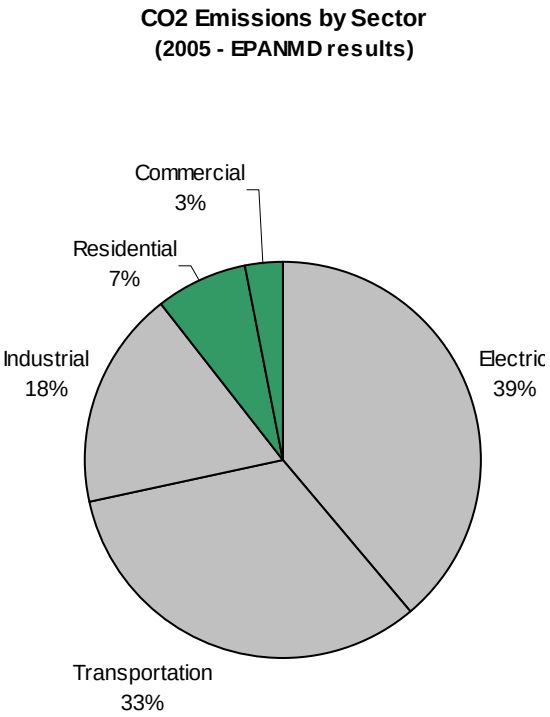
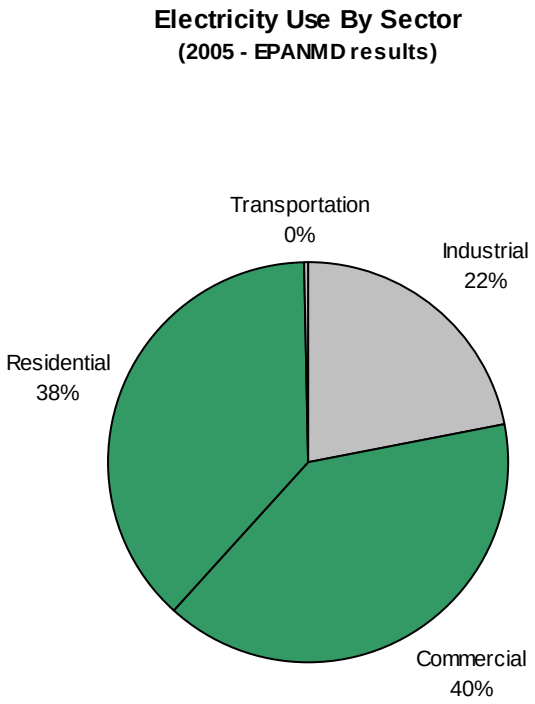
The U.S. Energy System



Residential and Commercial Sector Contribution to CO_2 Emissions





~40% CO_2 Emissions from Residential and Commercial Sector

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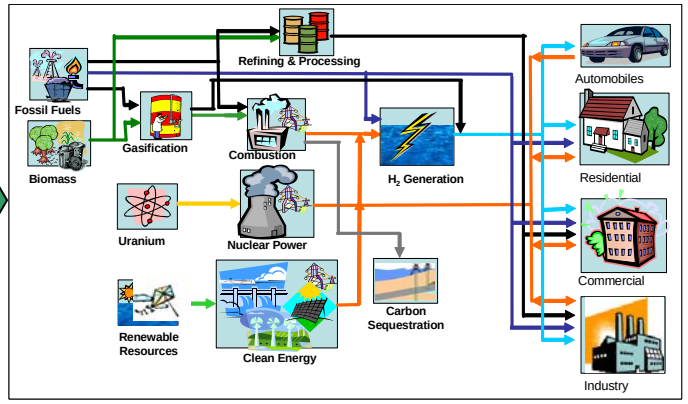
Modeling Technology Change with MARKAL

MARKAL Inputs:

- Future-year energy service **demands**
- Primary energy resource **supplies**
- Current and future **technology characteristics**
- Energy and environmental **policies**



Minimize net present value of capital and O&M by selecting the optimal mix of technologies and fuels at each time step

MARKAL Outputs:

- **Technology penetrations** for meeting industrial, residential, commercial, and transportation demands
- **Fuel use** by type
- Sectoral and system-wide **emissions** of criteria pollutants and GHGs
- **Marginal fuel prices** and emissions reduction costs

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U.S. EPA MARKAL National Database (EPANMD)

- **Coverage**: U.S. energy system
- **Spatial resolution**: National
- **Modeling horizon**: 2000 to 2050 in 5-yr increments
- **Sectors**:

  Electricity production, Transportation, Industrial, Residential, Commercial
- **Main data source:** Annual Energy Outlook (2006 and 2008)
- **Pollutants**: For all sectors: CO_2, NOx, SO_2, PM_{10}

  For some sectors: $PM_{2.5}$, VOC, CO, CH_4, N_2O
- **Additional Database Version**: EPAUS9r (9-region)

U.S. EPA MARKAL Database

End-Use Energy Demands

Industrial
Electrochemical
Feedstock
Machine Drive
Process Heat
Steam
Other

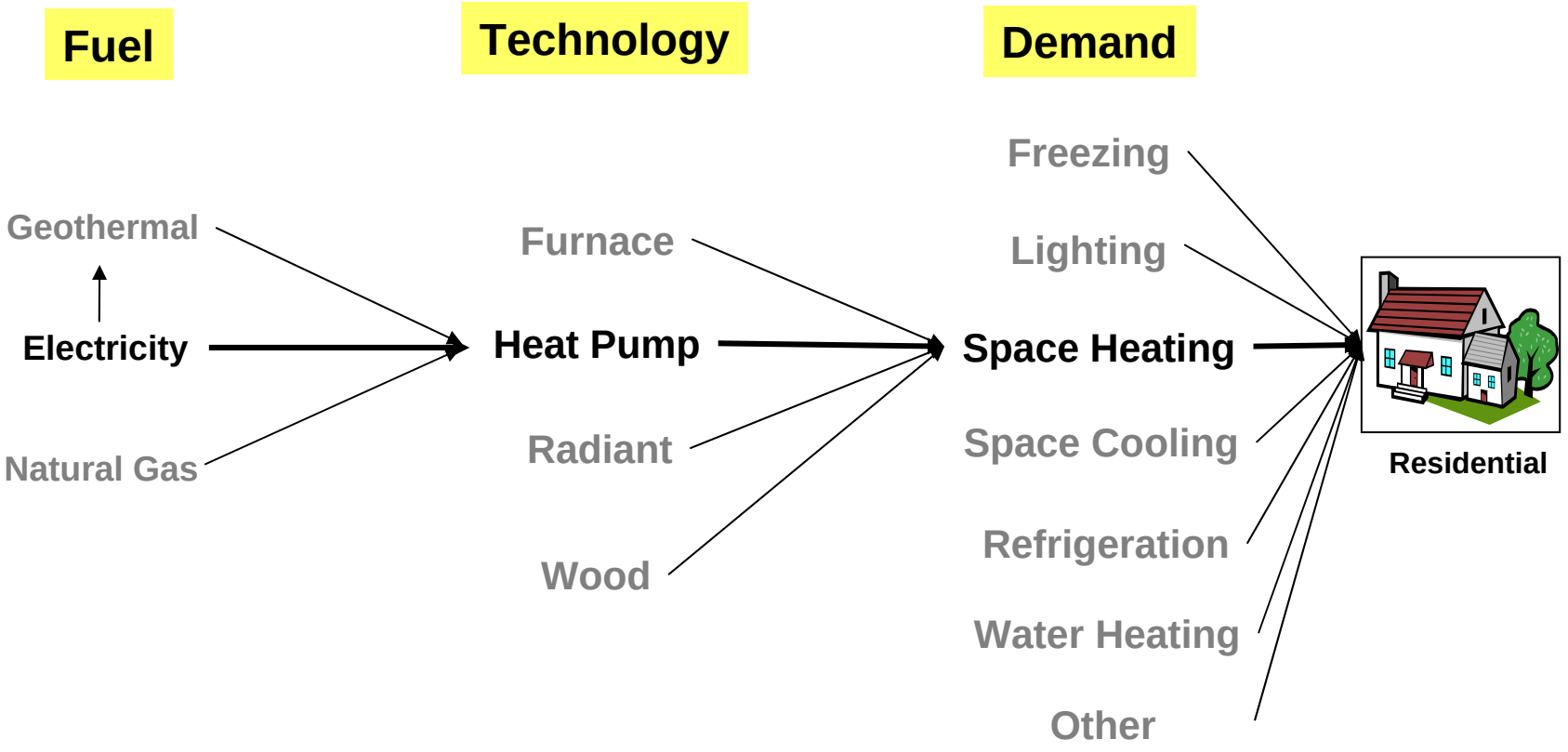
For:
Chemical
Food
Primary metals
Non-metals
Pulp and paper
Transportation equip.
Other Manufacturing
Non-manufacturing

Commercial
Cooking
Lighting
Office Equipment
Refrigeration
Cooling
Heating
Ventilation
Water Heating
Other

Residential
Freezing
Lighting
Refrigeration
Cooling
Heating
Water Heating
Other

Transportation
Light duty
Heavy duty
Bus
Off-road
Passenger rail
Freight rail
Air
Marine

Technology Detail – Residential Space Heating



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Energy Efficiency Analysis: Residential and Commercial Buildings

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Scenarios

Energy Efficiency Scenario (EE)

Increased usage of higher efficiency technologies, voluntary conservation, and shell improvements for new buildings.

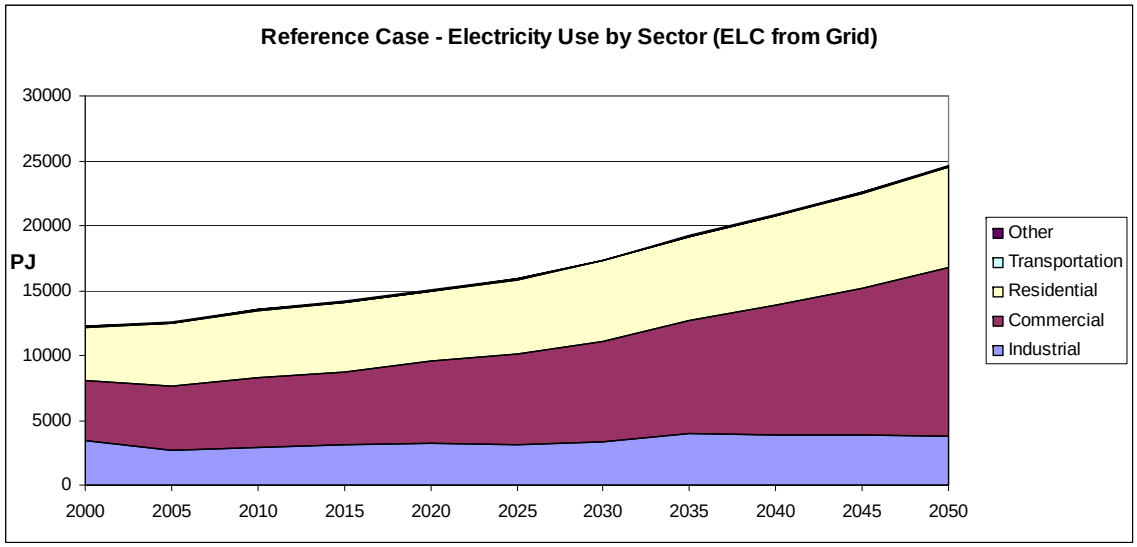
Carbon Neutral Scenario (CN)

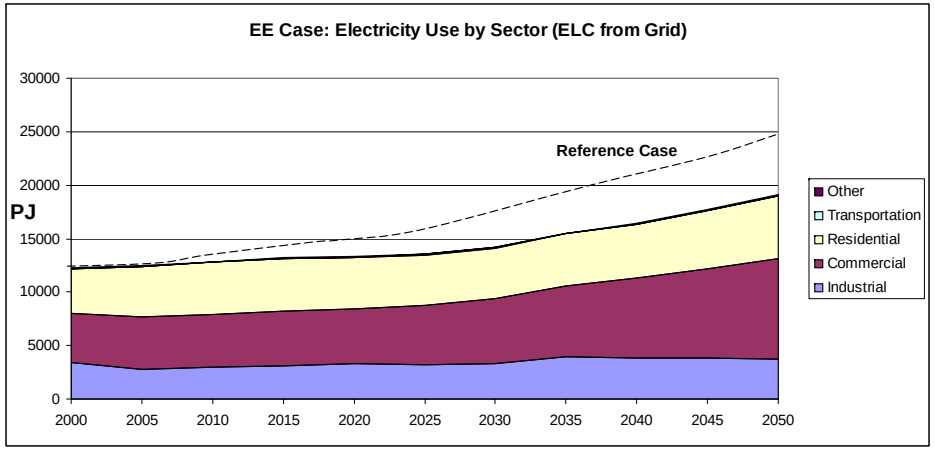
All demands for new buildings starting in 2030 are met by some combination of energy efficiency, building shell improvements, and on-site electricity generation with renewables all leading to zero emissions. In our model application these are “dummy” technologies which currently have no cost.

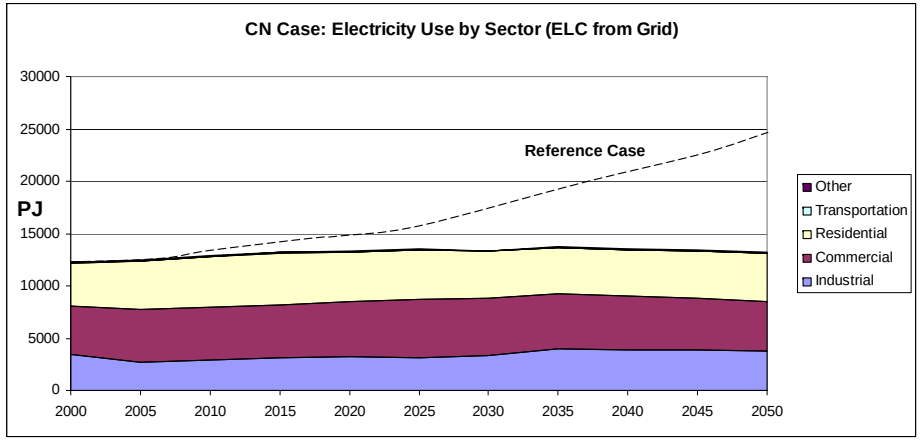
How We Got There – Energy Efficiency

- Shell improvements in new buildings reduces residential and commercial heating and cooling demands and water heating demands starting in 2010.
- Residential lighting largely compact fluorescents and LEDs by 2020.
- Commercial lighting largely efficient fluorescent and LEDs by 2020.
- Energy conservation efforts begin in 2010, for example:
  - Programmable thermostats
  - Energy management systems
  - Low flow shower heads
  - Home weatherization
- Starting in 2015, only highest efficiency technology choices are available for both new buildings and for replacement of retired technologies in old buildings.
- Ground source heat pumps penetrate the market reaching 2% of demand for space heating by 2015, increasing to 5% by 2030.

Total System Electricity Use







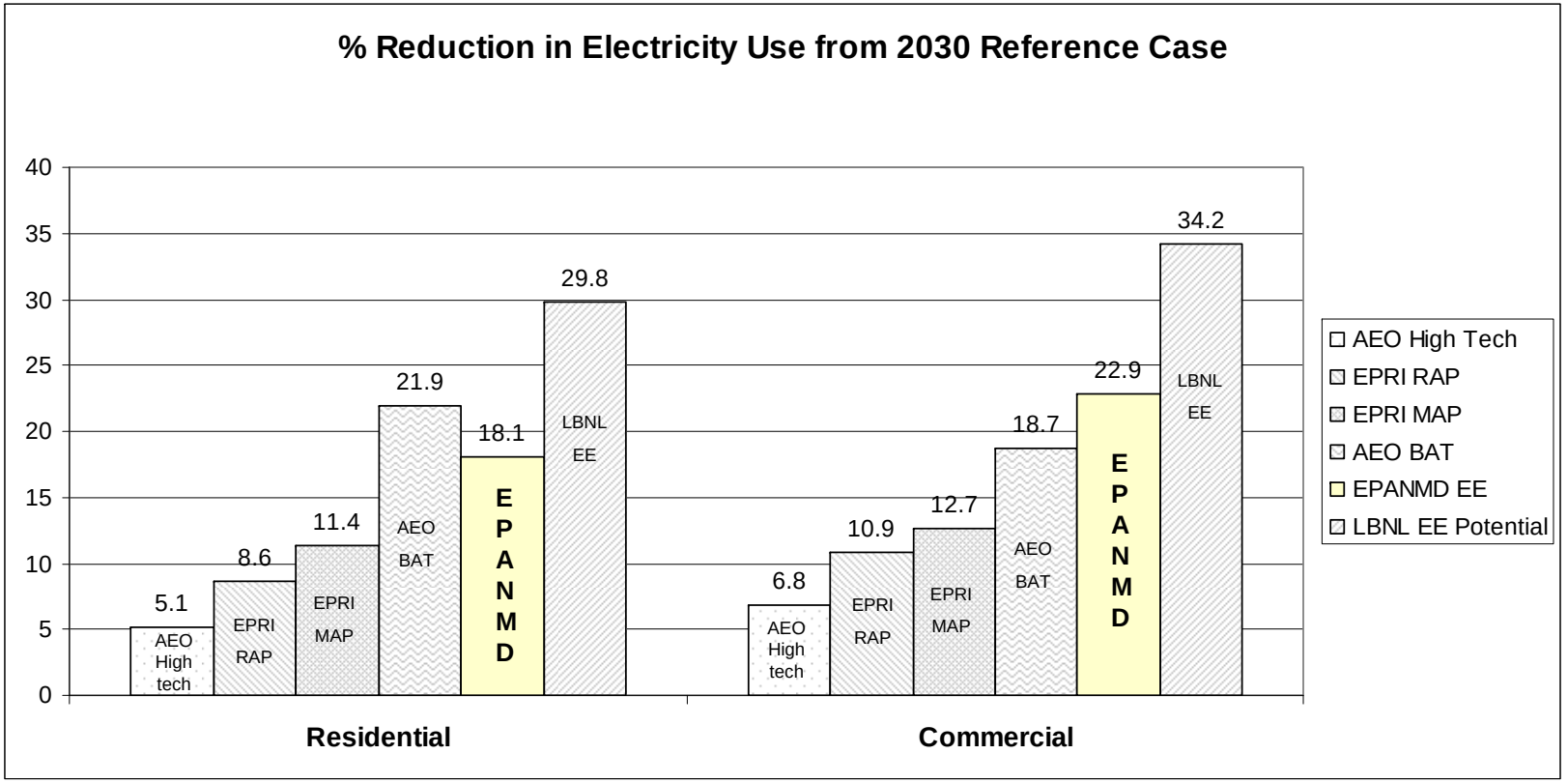
18.1% Reduction from Reference Case in 2030

22.6% Reduction from Reference Case in 2050

22.9% Reduction from Reference Case in 2030

46.4% Reduction from Reference Case in 2050

Comparison to Other Studies



AEO High Tech (High Technology Case, AEO2009): Assumes earlier availability, lower costs, and higher efficiency for more advanced equipment and building shell efficiency improvements.

EPRI RAP (Realistic Achievement Potential, *"Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S."*): Represents a forecast of likely consumer behavior, taking into account existing market, financial, political, and regulatory barriers.

EPRI MAP (Maximum Achieveable Potential , *"Assessment of Achievable Potential from Energy Efficiency and Demand Response Programs in the U.S."*): Represents a forecast under an ideal set of conditions, taking into account barriers that limit customer participation under a scenario of perfect information and utility programs.

AEO BAT (Best Available Technology, AEO2009): Assumes consumers will install only the most efficient technology regardless of cost, at normal replacement intervals, and that new buildings will meet the most energy efficient specifications available

LBNL EE Potential (Lawrence Berkeley National Laboratory, "*U.S. Building-Sector Energy Efficiency Potential*"): Applies annual percentage savings estimates by end use drawn from several prior efficiency potential studies, including the U.S. Department of Energy's *Scenarios for a Clean Energy Future*.

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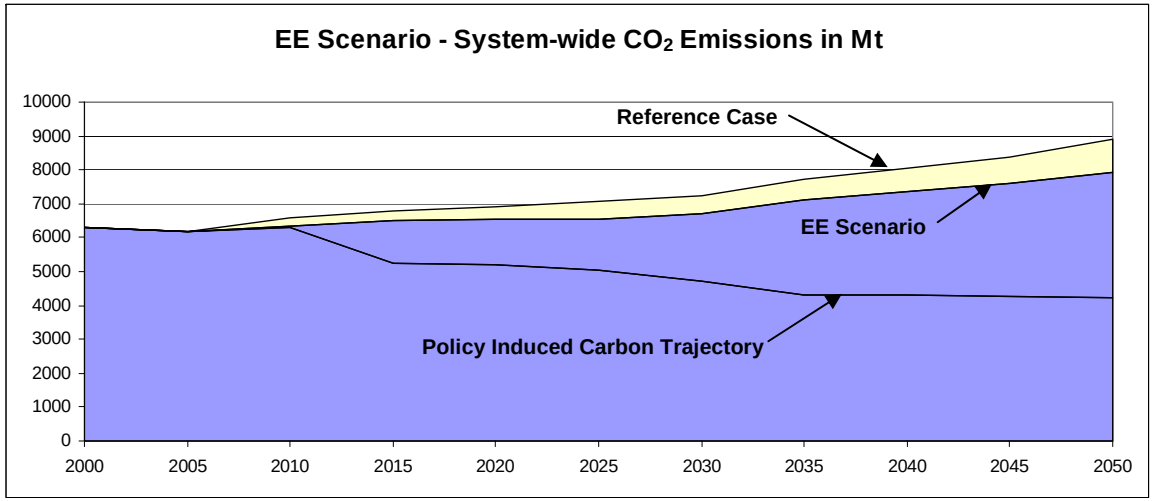
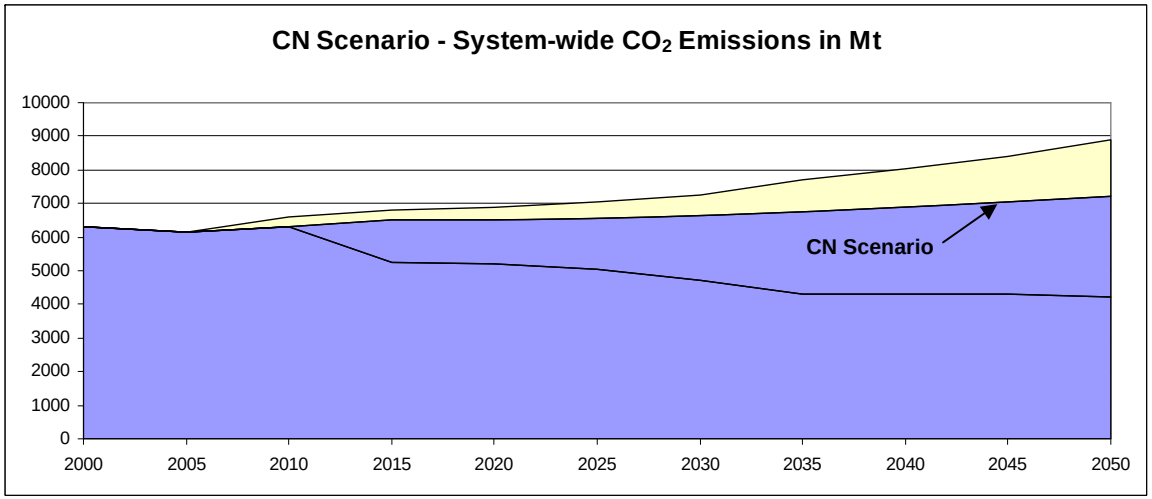
CO_2 Emissions Reduction Wedges



EE achieves 21% of Policy Induced Carbon Trajectory

Cumulative CO_2 Emissions Reductions from Reference Case (2000-2050)	
EE	6.2%
CN	9.0%



CN achieves 30% of Policy Induced Carbon Trajectory

The policy induced carbon trajectory is representative of the level of CO_2 emissions reductions that have been targeted by various proposed U.S. carbon mitigation policies.

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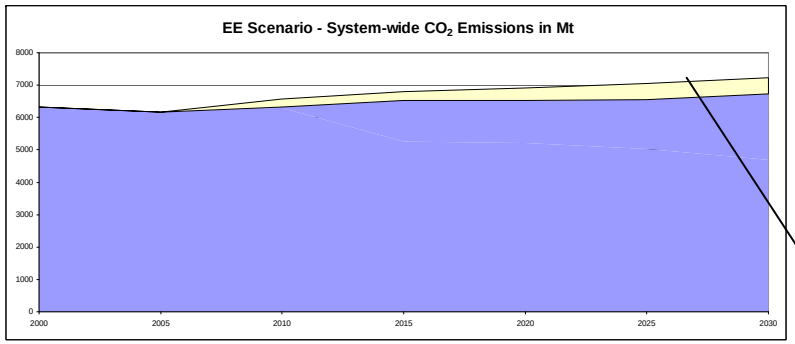
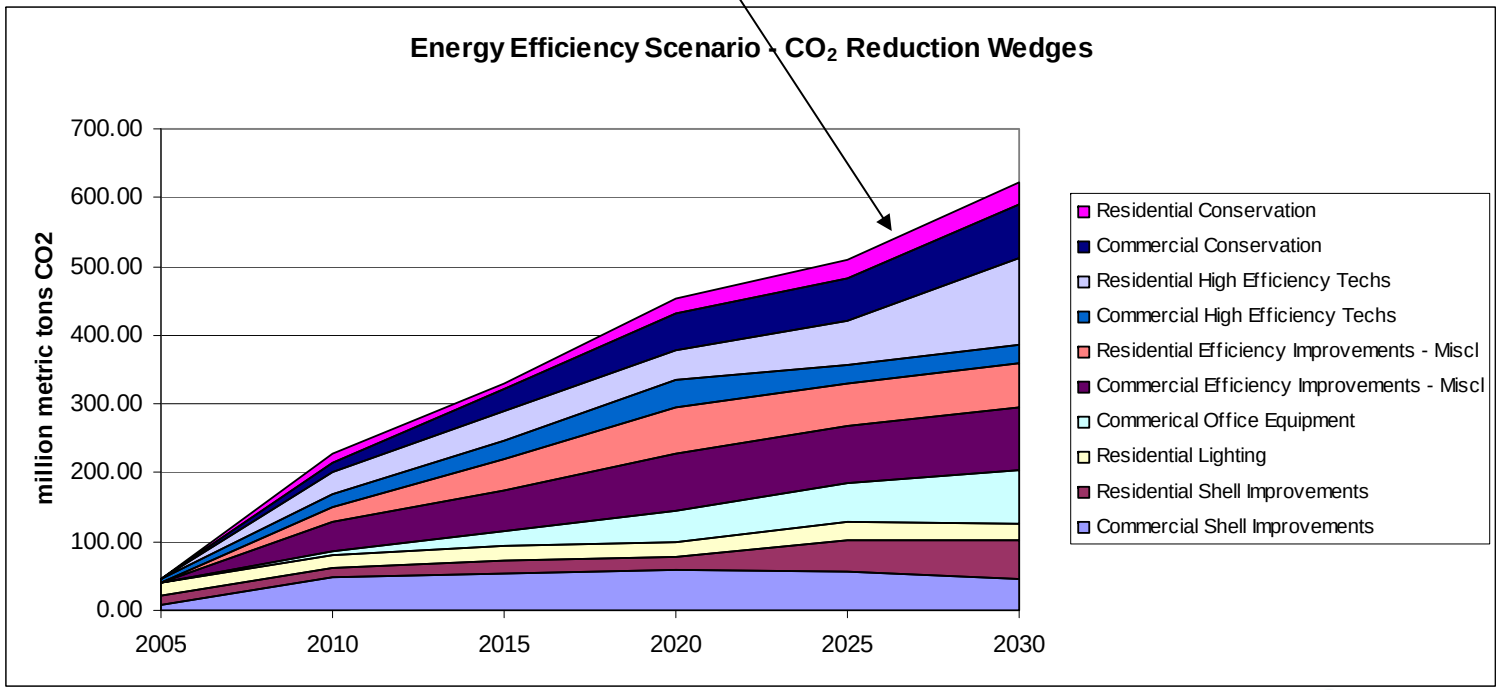
Where does the benefit come from?





This is an example of one possible outcome when more efficient technologies are aggressively introduced into the system, consumer conservation efforts begin immediately and grow over time, and new buildings employ the latest methods to conserve energy.

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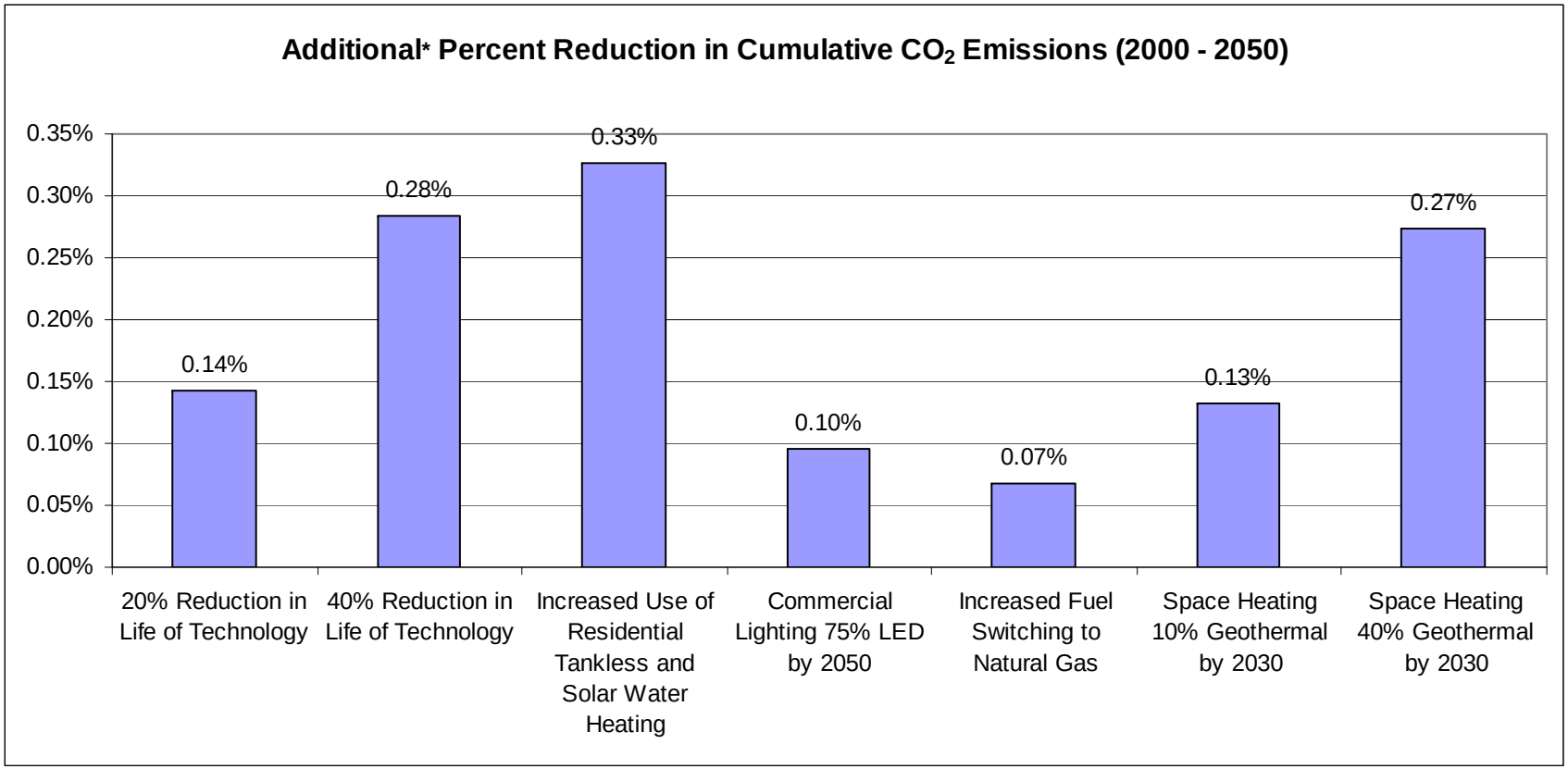
Sensitivity Runs



*** In addition to the 6.2% reduction from the reference case achieved by the EE scenario.**

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Key Insights

- A variety of technology efficiency improvements and conservation measures are needed.
- Need a widespread and rapid deployment of the most efficient available technologies
- Need a broad adoption of substantial conservation measures in existing buildings
- Need significant shell improvements in new buildings

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Benefits of Low Carbon Portfolio in Reducing CO_2 in Energy Efficiency Scenario and Carbon Neutral Scenario

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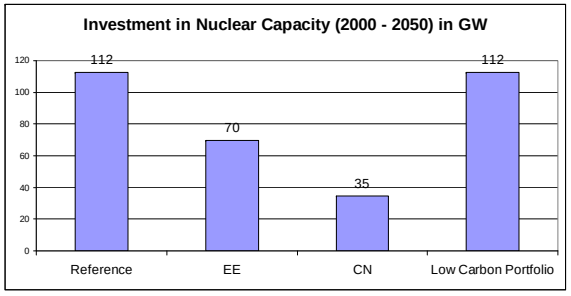
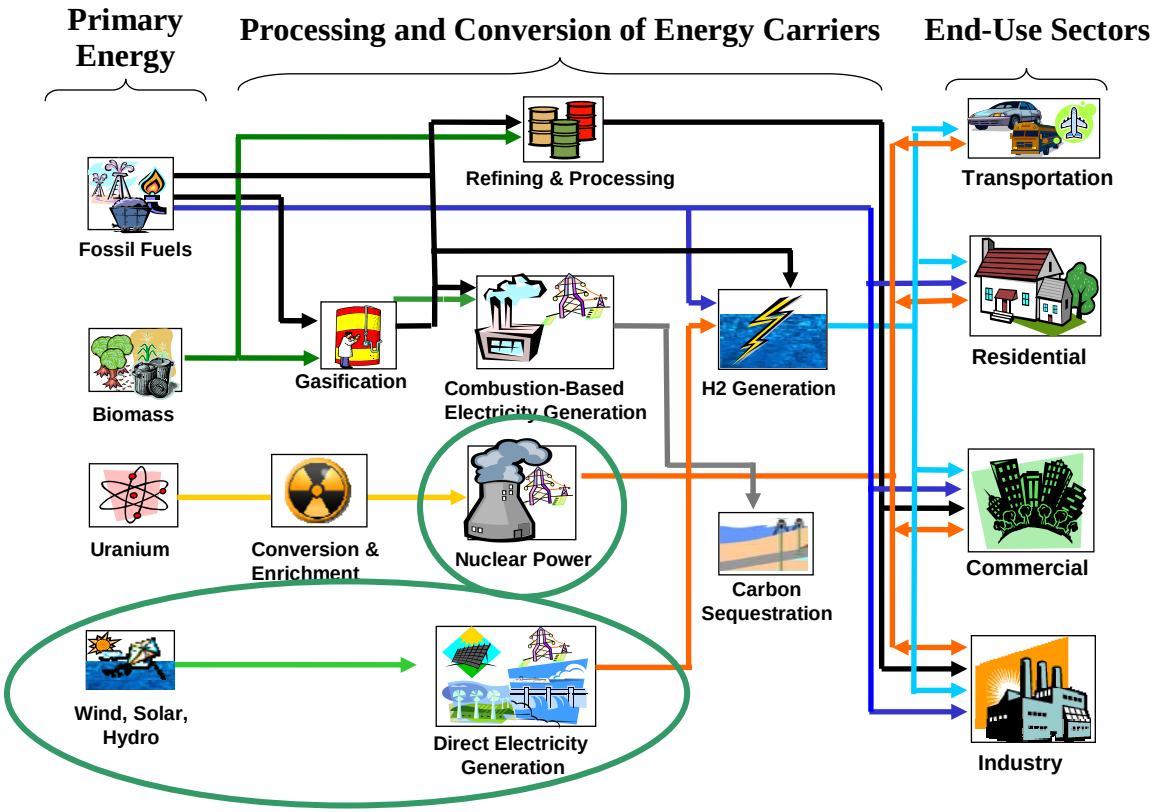
Electric Sector Low Carbon Portfolio (LCP)

- In 2020, 20% of electricity generation met by renewables growing to 30% by 2050.
- New nuclear power plants are invested in at the same level as the reference case.





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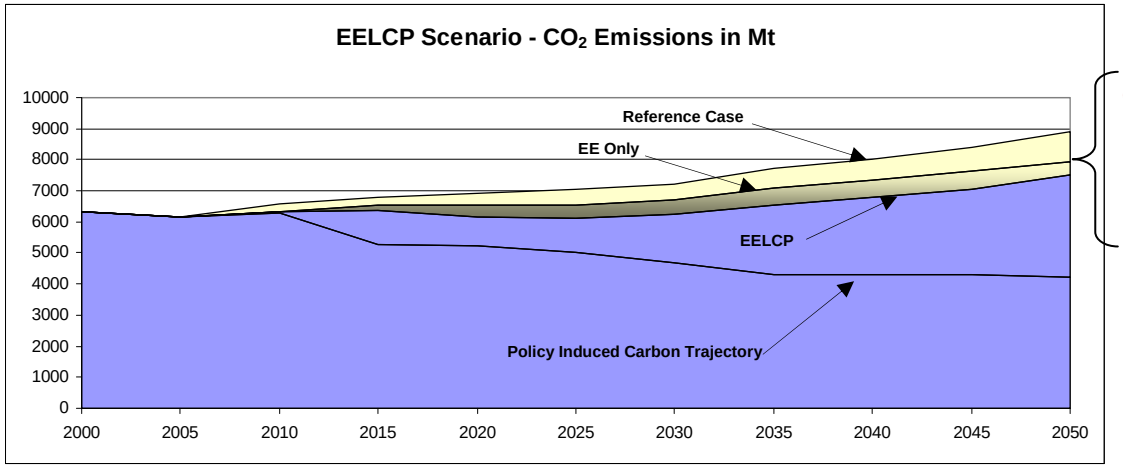
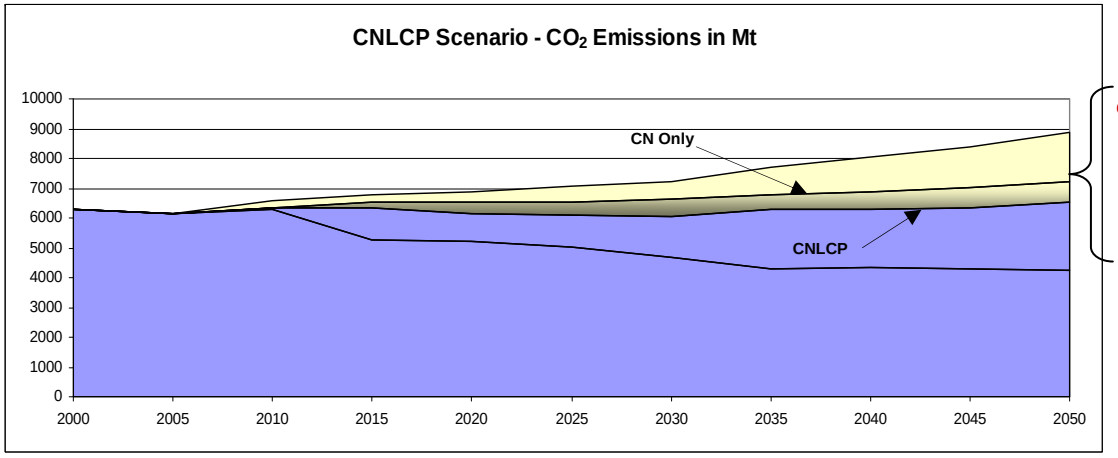
CO_2 Emissions Reduction



% of Policy Induced CO_2 Reduction

21% - EE Only

35% - EELCP +



% of Policy Induced CO_2 Reduction

35% - CN Only

46% - CNLCP +

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Key Insight

- The benefits of energy efficiency improvements in the residential and commercial sectors are significantly improved by the introduction of a low carbon portfolio in the electric sector. Without this standard, electricity reductions from energy efficiency improvements are more likely to result in less investment in new nuclear and new renewable power generation.

Next Steps

- Add costs and detailed options for conservation measures
- Add detailed carbon neutral technology options and choices
- Regionalize analysis (using EPAUS9r)

Thank You

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