The Economic Impact of Nuclear Power Generation in Connecticut

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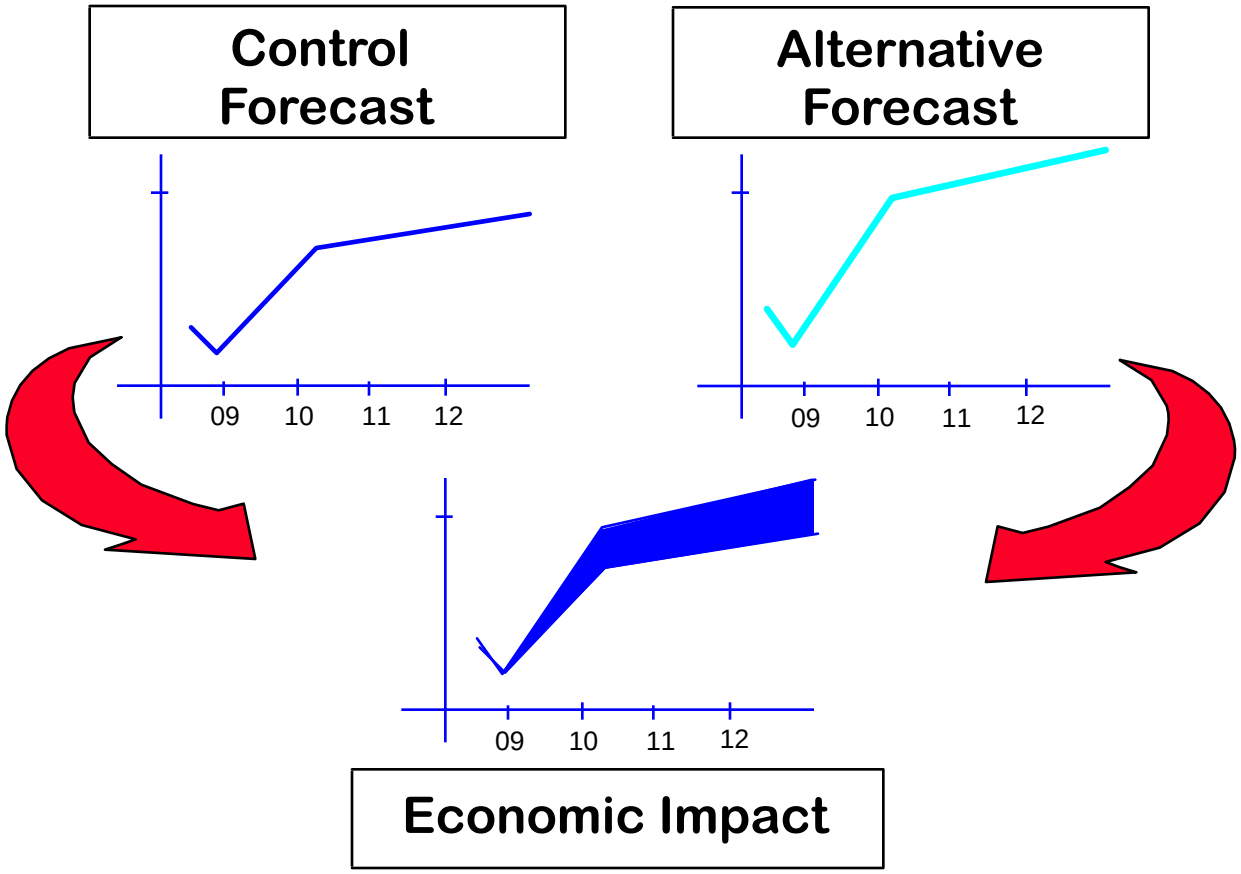
Scope of Study

- Assess the economic and fiscal impacts of replacing or adding baseload generation in CT.
  - Replace existing nuclear unit(s) at Millstone with a 1,000 MWe nuclear or CCGT plant
  - Add 1,000 MWe nuclear or CCGT plant to Millstone or CT Yankee

Estimating Economic Impact



Common Economic Modeling Assumptions

- Each unit receives its LCOE
- No net new job creation
- No net new procurement (B2B activity)
- No net new electricity sales
- Merchant operators
- Decommissioning phase greatly compressed into one year (cost incl. In nuclear LCOE)

Common Modeling Assumptions

- No additional cost for spent fuel storage
- Natural gas pipeline extension included for CCGTs
- Workers receive utility industry average wage
- Workers live in CT
- Modeling time begins in 2009 and ends in 2050

Assumptions: Replacement

- Replacements are large construction projects at the Millstone campus
  - No net new jobs, capacity, procurement (B2B)
  - Use MIT 2009 cost & operational parameters with capacity factor for nuclear increased to 90%.
  - Electricity sales do not change (demand is constant)

Economic Impact Drivers: Replacement

	2009	2010	2011	2012	2013	2014	Total
Nuclear plant construction & nuclear decommission	$405	$1,093	$1,391	$1,159	$456	$887	$5,391
CCGT plant construction & nuclear decommission				$493	$507	$887	$1,887
Pipeline construction				$25	$25		$50
Total CCGT				$543	$557	$887	$1,937

CCGT: Vendor EPC overnight cost = $850 million in 2007$; pipeline extension cost $5 million/mile for 10 miles

AP 1000: Vendor EPC overnight cost = $3.333 billion in 2007$; construction outlays: 10%, 25%, 31%, 25%, 10%

Economic Impacts

Economic Variable		2009	2010	2011	2012	2013	2014
New Total employment	Nuclear	7,993	20,320	24,756	19,249	6,021	12,087
	CCGT	NA	NA	NA	8,685	8,368	13,679
New Construction Jobs	Nuclear	5,708	14,660	18,194	14,636	5,365	9,922
	CCGT	NA	NA	NA	6,263	6,187	10,245
New State GDP (mil nominal $)	Nuclear	$460.5	$1,214.9	$1,495.1	$1,161.2	$313.4	$725.5
	CCGT	NA	NA	NA	$543.5	$531.1	$889.9
New Output (Sales) (mil nominal $)	Nuclear	$780.5	$2,051.6	$2,516.2	$1,948.9	$530.0	$1,207.3
	CCGT	NA	NA	NA	$917.4	$894.6	$1,474.7
New Personal Income (mil nominal $)	Nuclear	$393.6	$1,055.8	$1,400.3	$1,225.8	$556.5	$902.2
	CCGT	NA	NA	NA	$472	$507.80	$867.20
Net New State Revenue (mil nominal $)	Nuclear	$77.78	$190.7	$218.66	$147.7	$0.53	$72.67
	CCGT	NA	NA	NA	$87.65	$77.71	$131.5

Source: The REMI model and author's calculations.

Assumptions: Baseload Addition

- Marginal units are displaced in CT
  - These plants cease operation
  - Released labor & procurement absorbed by new units at Millstone or CT Yankee site.
  - No net new jobs or procurement
  - Electricity sales do not increase b/c demand is constant
  - Wholesale price declines as higher cost marginal units leave the market.

Assumptions: Baseload Addition

- Retail price declines 50% of wholesale decline (2.85%) [ISO-NE, June 2006, White Paper]
- Omit siting & permitting costs & time
- No net new jobs, capacity, procurement
- Use MIT 2009 cost & operational parameters with capacity factor for nuclear increased to 90%.
- Same economic & fiscal impact for Millstone or CT Yankee sites

Economic Impact Drivers: Addition

- Construction expenditure and schedule same as replacement
- CT ratepayers see 2.85% reduction in their electric bills absent other changes
- Decommission occurs in 2074 & lasts for 20+ years (assuming 60-year life)
- No SR/MR change in electricity demand due to price reduction (=> sales flat)

Economic Impact Drivers: Addition

	2009	2010	2011	2012	2013	2014 - 2050
Retail Electricity Price Reduction	NA	NA	NA	NA	NA	-2.85%
Nuclear plant construction & nuclear decommission	$405	$1,093	$1,391	$1,159	$456	NA
CCGT plant construction & nuclear decommission				$493	$507	NA
Pipeline construction				$25	$25	NA
Total CCGT				$543	$557	NA

CCGT: Vendor EPC overnight cost = $850 million in 2007$; pipeline extension cost $5 million/mile for 10 miles

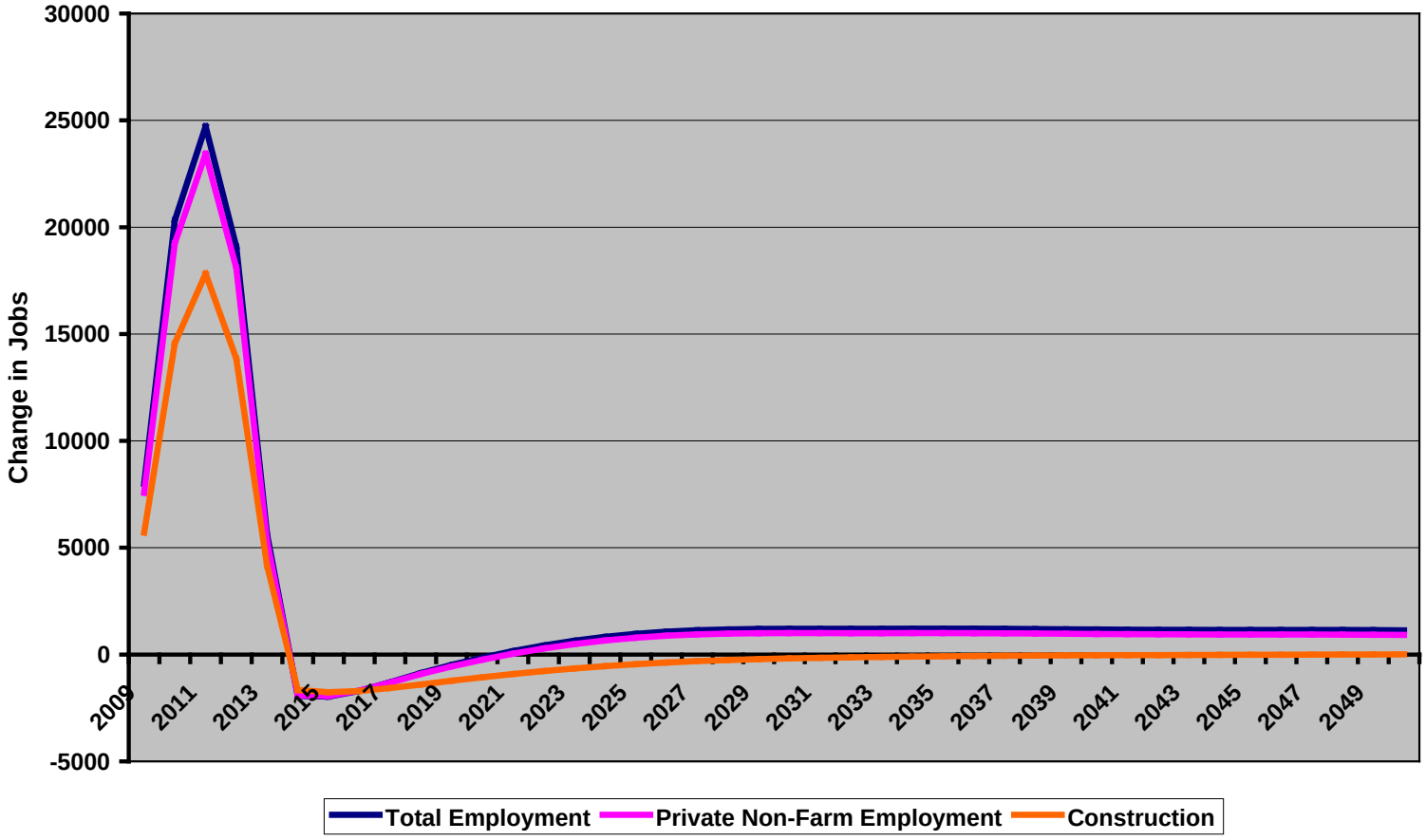
AP 1000: Vendor EPC overnight cost = $3.333 billion in 2007$; construction outlays: 10%, 25%, 31%, 25%, 10%

Economic Impacts

	Annual Average Change from Baseline (2009-2050)			
Economic Variable	Add Nuclear Plant at Millstone or CT Yankee		Add CCGT Plant at Millstone or CT Yankee	
Total New Employment (Persons)	2,420		1,333	
New Construction (Jobs)	957		254	
	Ann. Avg. Change	NPV	Ann. Avg. Change	NPV
New Gross Domestic Product (mil nominal $)	$516.6	$7,594.8	$471.1	$5,768.4
New Output (mil nominal $)	$845	$12,576.3	$773.6	$9,581.7
New Personal Income (mil nominal $)	$363.6	$6,154.1	$247.6	$3,291.8
Net New State Revenue (mil nominal $)	$27.4	$586	$18.6	$306.2

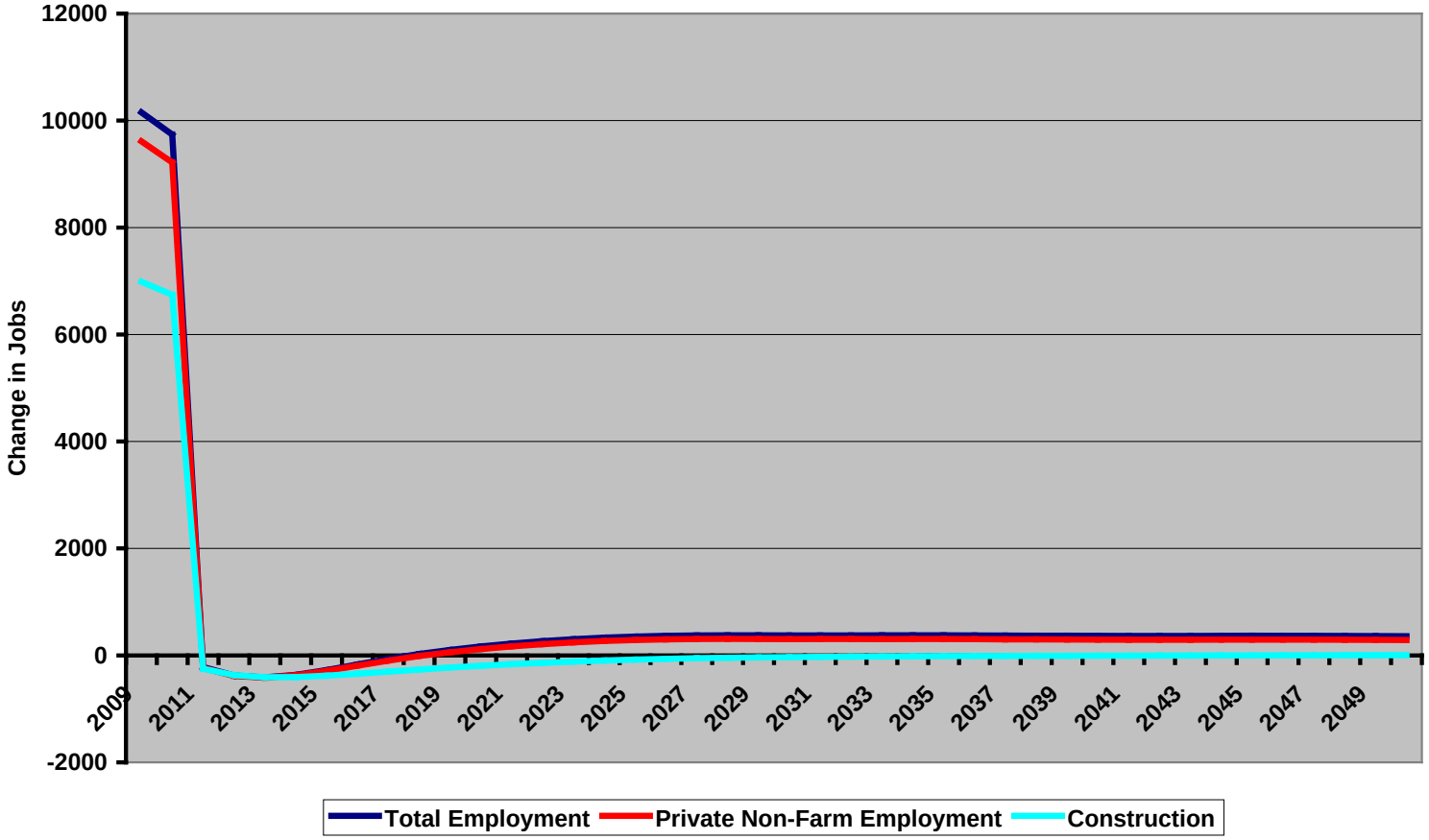
Economic Impacts

Changes in Total, Non-farm & Construction Jobs: New Nuclear Plant at Millstone or CT Yankee



Economic Impacts

Employment Changes in Total Nonfarm and Construction: New CCGT Plant at the CT Yankee Site

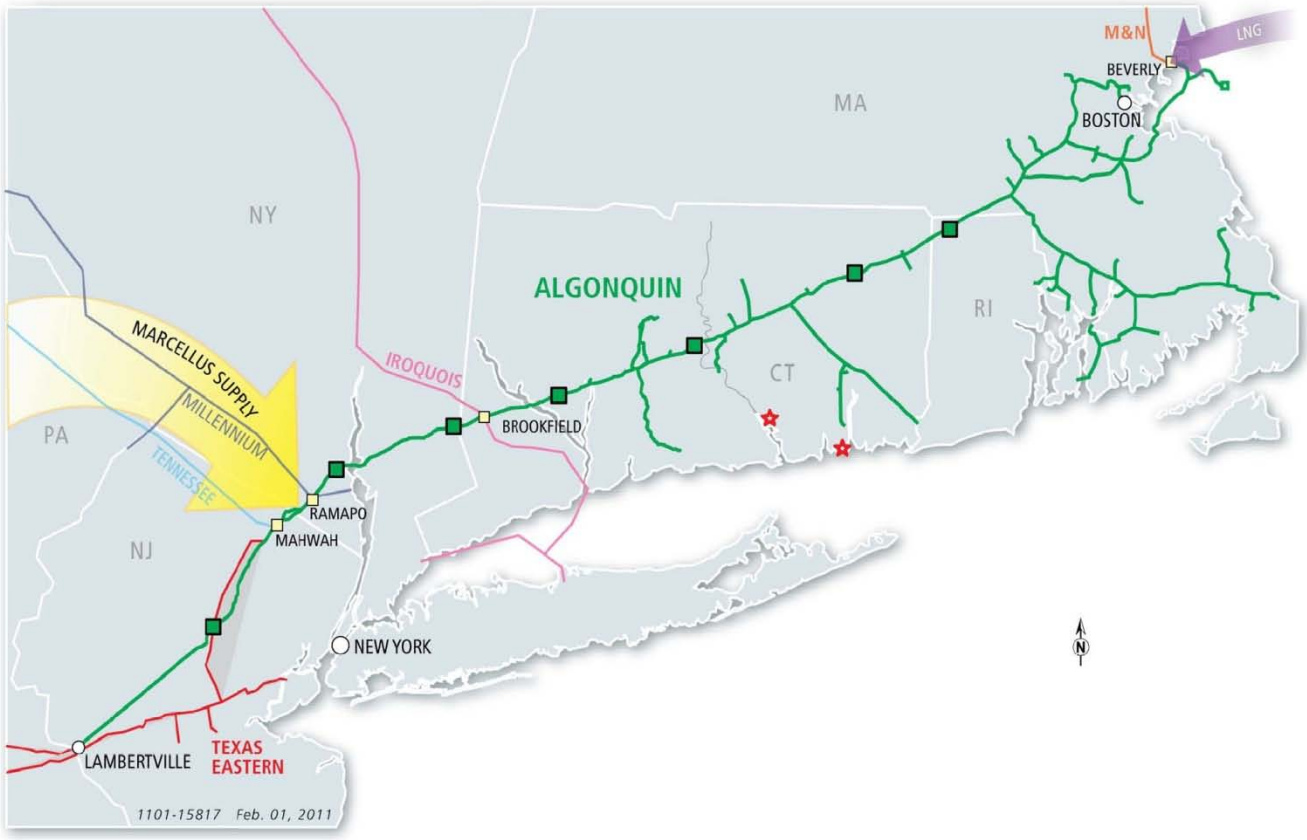


Discussion: Natural Gas

- Natural Gas Pricing
  - Assume ‘national’ price.
  - Changes in price for any reason change the price for everyone.
  - No competitive disadvantage for CT (excl. delivery costs).
  - Adding CCGT increases CT’s CO_2 emission
    - RGGI and RPS targets more difficult to achieve
    - Increased vulnerability to price volatility & supply disruption

Discussion: Natural Gas

- For CCGT plant at Millstone or CT Yankee, need pipeline extension



Regional Electricity Market

- Regional wholesale markets administered by ISO-NE:
  - Day-Ahead
  - Real-Time
  - Forward Capacity
  - Ancillary Services
    - Regulation
    - Forward Reserve
    - Real-Time Reserve Pricing
    - Voltage Support
    - Other Services & Products

Regional Electricity Market

- Energy market pays all generators participating in the day-ahead and real-time markets the price bid by the marginal unit just satisfying the last unit of forecast demand.
- These payments may not cover all costs that generators face and generators may participate in other markets to recoup their average total (fixed plus variable) costs.

Regional Electricity Market

- Because baseload units, especially nuclear units, have low fuel costs relative to inframarginal (natural gas) units, they typically bid zero in the energy markets.
- As baseload capacity is added, it displaces marginal (higher priced generation) units & reduces the wholesale electricity price in the region.

Regional Electricity Market

- Because nuclear power is relatively inexpensive to generate, adding nuclear baseload capacity drives down the prices for capacity and reserve otherwise provided by units that have higher fuel costs.

Levelized Cost of Electricity

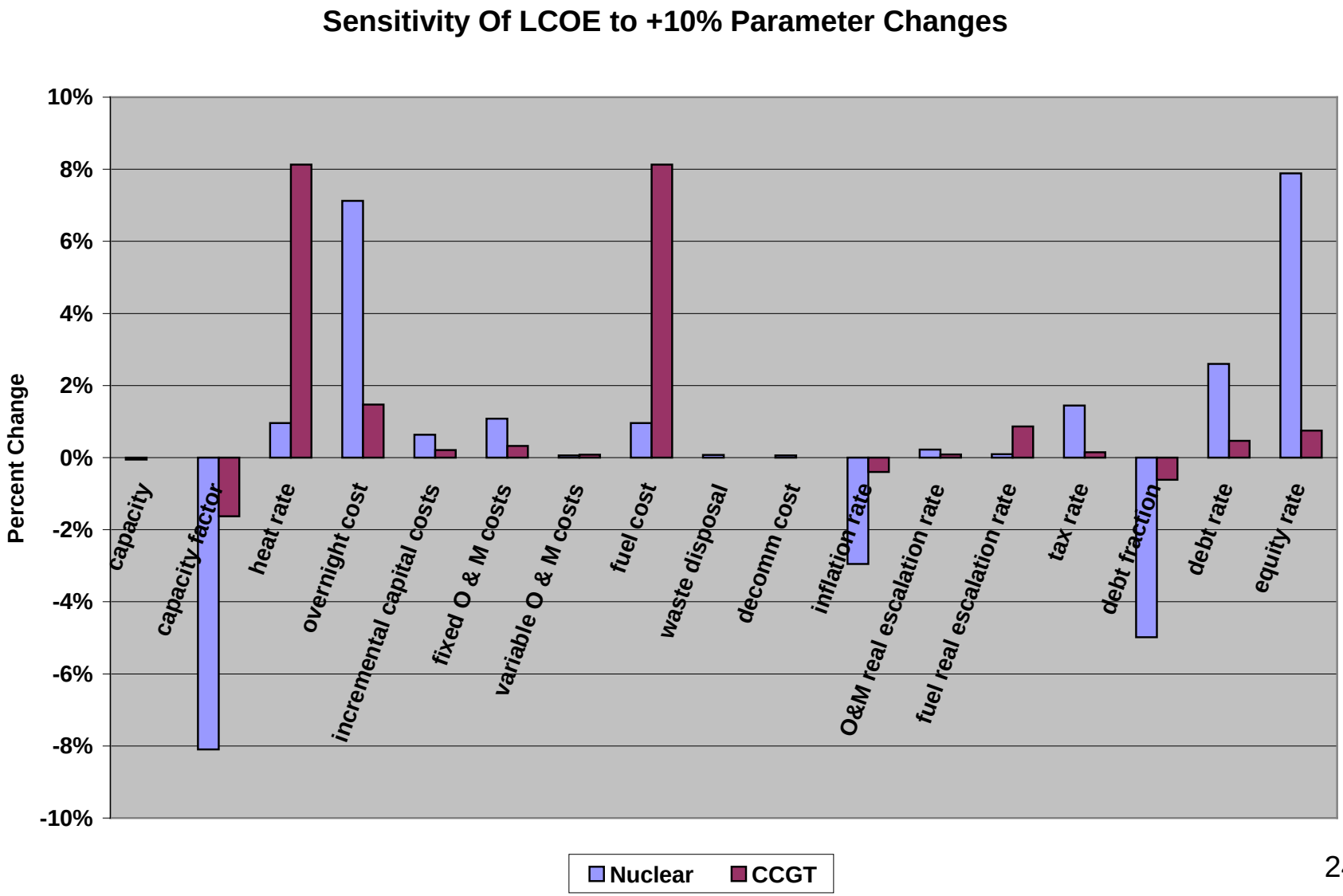
- LCOE represents the constant (level) wholesale price generators receive over the life of a power plant that is necessary to cover all operating expenses including taxes and provide an acceptable return to investors.

- LCOE provides a uniform way to compare the wholesale cost of energy across technologies because it takes into account the installed system price and associated costs such as financing, land, insurance, operation and maintenance and depreciation, among others.

Levelized Cost of Electricity

- LCOE is the net present value of total life cycle costs of the power plant divided by the quantity of energy produced over the plant's life.
- Accounts for carbon costs, inflation, returns to debt & equity (risk) & fuel escalation rates.
- LCOE studies document wide variation

LCOE Sensitivity Analysis



Nuclear Construction & Operational Cost Assumptions

AP1000: Advanced Pressurized Water Reactor

- **Once-through fuel cycle**
- **40-year economic life (see below for a 60-year economic life LCOE estimate)**
- **Capacity factor: 90% (increased from Du and Parsons [2009] study with new information)**
- **Heat rate: 10,400 Btu/kWh**
- **Overnight cost in 2007 dollars: $4,000/kWe**
- **O&M fixed costs: $56.44/kW/yr**
- **O&M variable costs: 0.42 mills/kWh**
- **O&M real escalation rate: 1%/yr**
- **Incremental capital costs: $40/kW/yr**
- **Fuel costs: $0.67/mmBtu**
- **Inflation rate: 3%/yr**
- **Real fuel escalation rate: 0.5%/yr**
- **Tax rate: 37%**
- **Construction period: 5 years**
- **Financing:**
    - **Equity return: 15% nominal net of income taxes**
    - **Debt return: 8% nominal**
    - **Inflation: 3% annual**
    - **Income Tax rate (applied after expenses, interest & tax depreciation): 37%**
    - **Equity: 50%**
    - **Debt: 50%**
    - **Weighted Avg. cost of capital: 10%**
    - **Depreciation: 15-year MACRS schedule**
- **Waste fee: 1 mill/kWh**
- **Decommissioning cost: $700 million in 2007 dollars**
- **Construction schedule: startup year - 5=10%, year - 4=25%, year - 3=31%, year - 2=25%, year - 1=10%**

CCGT Construction & Operational Cost Assumptions

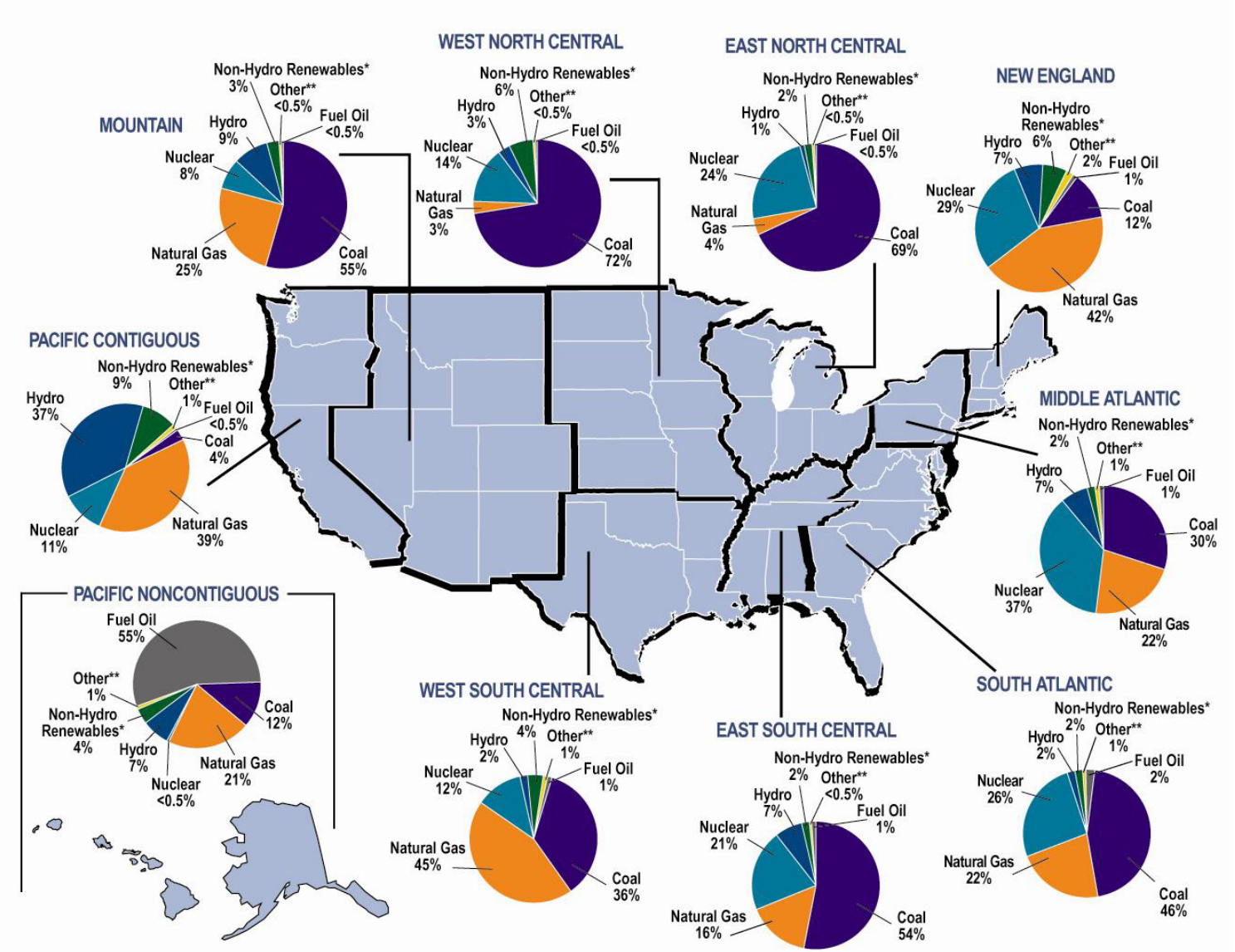
Natural Gas CCGT

- **40-year economic life**
- **Capacity factor: 85%**
- **Heat rate: 6,800 Btu/kWh**
- **Overnight cost in 2007 dollars: $850/kWe**
- **Incremental capital costs: $10.20/kWh/yr**
- **O&M fixed costs: $12.65/kW/yr**
- **O&M variable costs: 0.41 mills/kWh**
- **O&M real escalation rate: 1%/yr**
- **Fuel cost: $7.00/mmBtu**
- **Inflation rate: 3%/yr**
- **Real fuel cost escalation rate: 0.5%/yr**
- **Tax rate: 37%**
- **Construction period: 2 years, half in each year**
- **Financing:**
    - **Equity return: 12% nominal net of income taxes**
    - **Debt return: 8% nominal**
    - **Inflation: 3%/yr**
    - **Income Tax rate: 37%**
    - **Equity: 40%**
    - **Debt: 60%**
    - **Weighted Avg. cost of capital: 7.8%**
    - **Depreciation: 15-year MACRS schedule (identical to the nuclear plant)**
- **Carbon intensity: 14.5 kg-C/mmBtu**
- **Carbon Cost: $0/tCO2**
- **Construction schedule: startup year - 2=50%, year - 1=50%**

LCOE Values & Variations

- These assumptions => \$0.079/kWh for nuclear & \$0.065/kWh for CCGT
- 60-year nuclear economic life => $LCOE_{nuc}$=\$0.076
- 1.64% gas escalation rate => $LCOE_{gas}$ = \$0.079/kWh
- \$41.17/tCO_2 tax => $LCOE_{gas}$ = \$0.079/kWh (RGGI price = \$1.90/tCO_2)

Fuel Diversity



Source: Edison Electric Institute, May 2010.

Fuel Diversity

- Shannon-Weiner Index: $\Delta_a = \sum_{i=1}^{I} - p_i \ln(p_i)$
  - p_i is the proportional representation of option *i* in the portfolio under consideration
- One considers a range of portfolios each with a different combination of fuels &/or technologies
- Taken together, these portfolios form an efficient frontier of diversification choices

Fuel Diversity

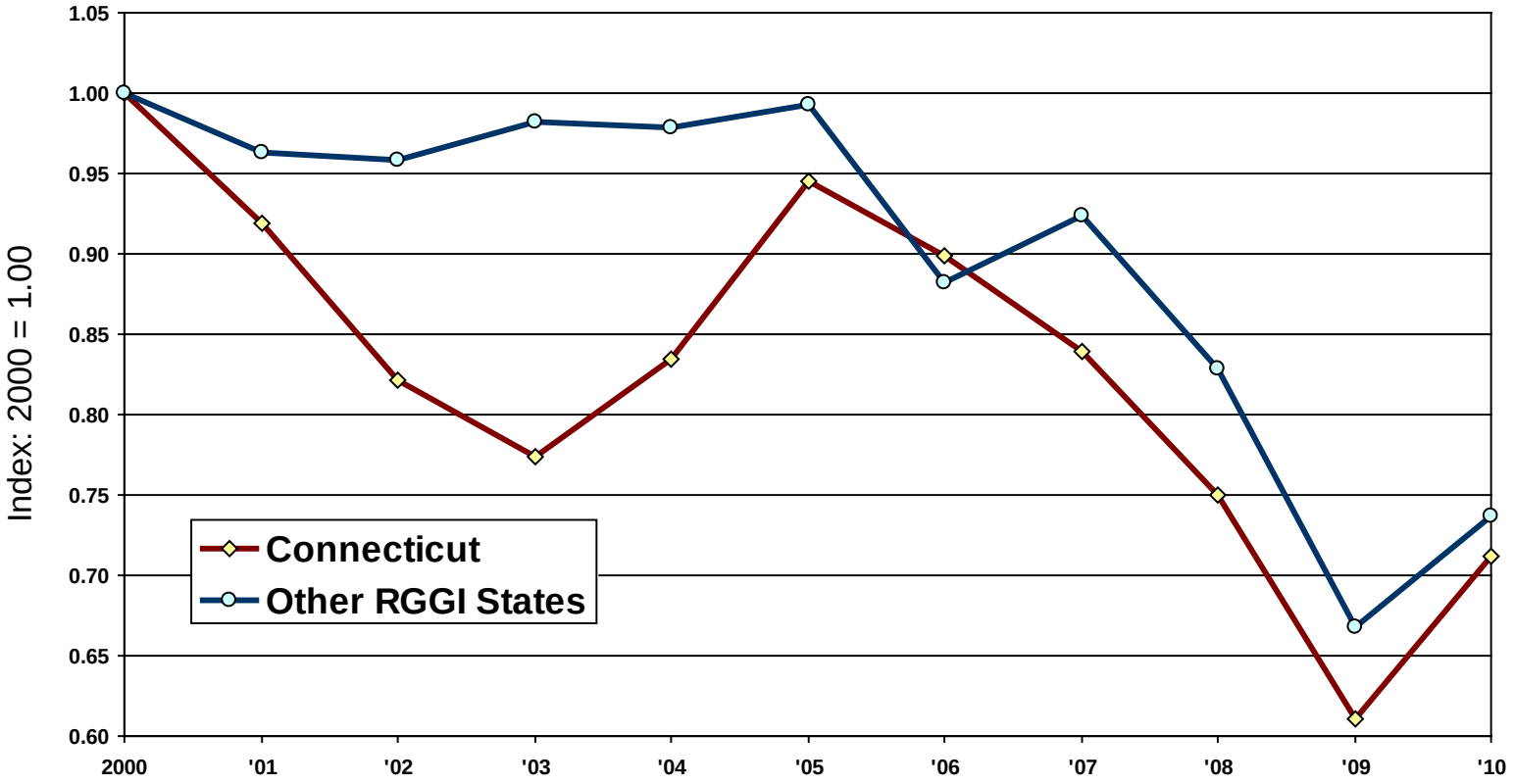
- The efficiency frontier shows a range of possible diversification choices that the region may adopt based on its preferences for certain fuels/technologies and risk.
- ISO-NE's 2007 study shows that adding 5,400 MWe of capacity from a single, non-gas technology does not change the region's disproportionate dependence on gas.

The RGGI

- Ten states in 2005 formed a regional carbon market.
- RGGI capped CO_2 production for 2009 through 2013 that will be reduced from 2014 through 2018 by 2.5% when CO_2 production will be capped 10% below the initial cap.
- Allowances auctioned and sold directly are permission to produce one ton of CO_2

The RGGI

Trend in CO2 Production for Connecticut and Other RGGI States

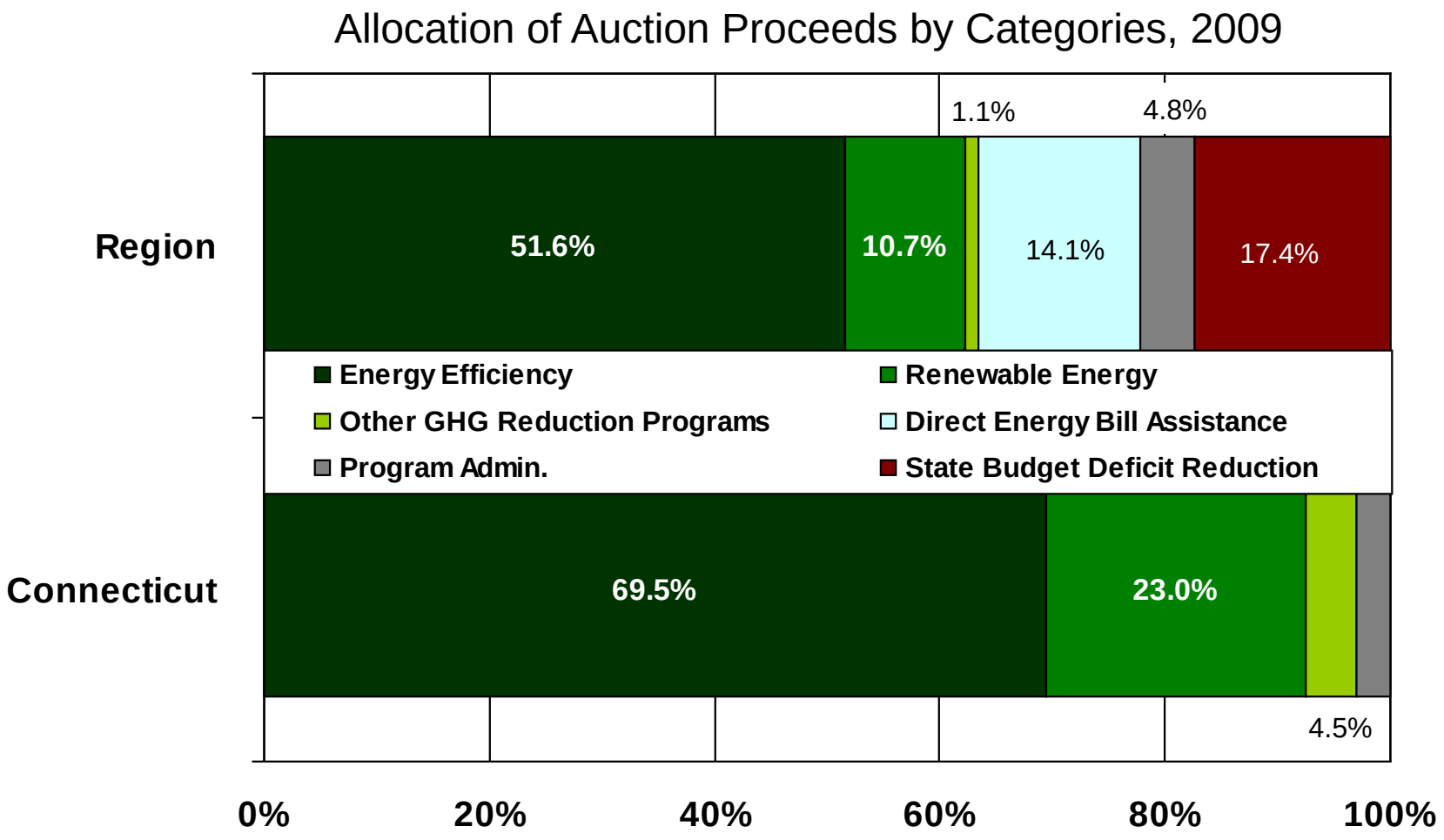


Source: RGGI

The RGGI

- As of the March 2011 auction, 346 million transactions occurred since the 2009 start.
- Cumulative proceeds amount to $860 million in the RGGI states.
- RGGI distributes 91.5% of proceeds from auctions to states.

The RGGI



Source: RGGI, Inc. http://www.rggi.org/docs/Investment_of_RGGI_Allowance_Proceeds.pdf

Takeaways

- LR economic impacts are small (~1%)
  - Large in construction period
  - Most conservative assumptions
- Region's heavy dependence on gas is not changed with a single 1,000 MWe addition.
  - Fuel diversity not impacted until we displace 6,000 Mwe
- Price of gas ↑ makes nuclear relatively attractive.
  - But, no competitive disadvantage to CT
- RGGI raised CT costs but increased efficiency and alt. energy deployment (CCEF & CEEF).

Thank you!

Questions???