

# Summary of Report

# Discussion of Results

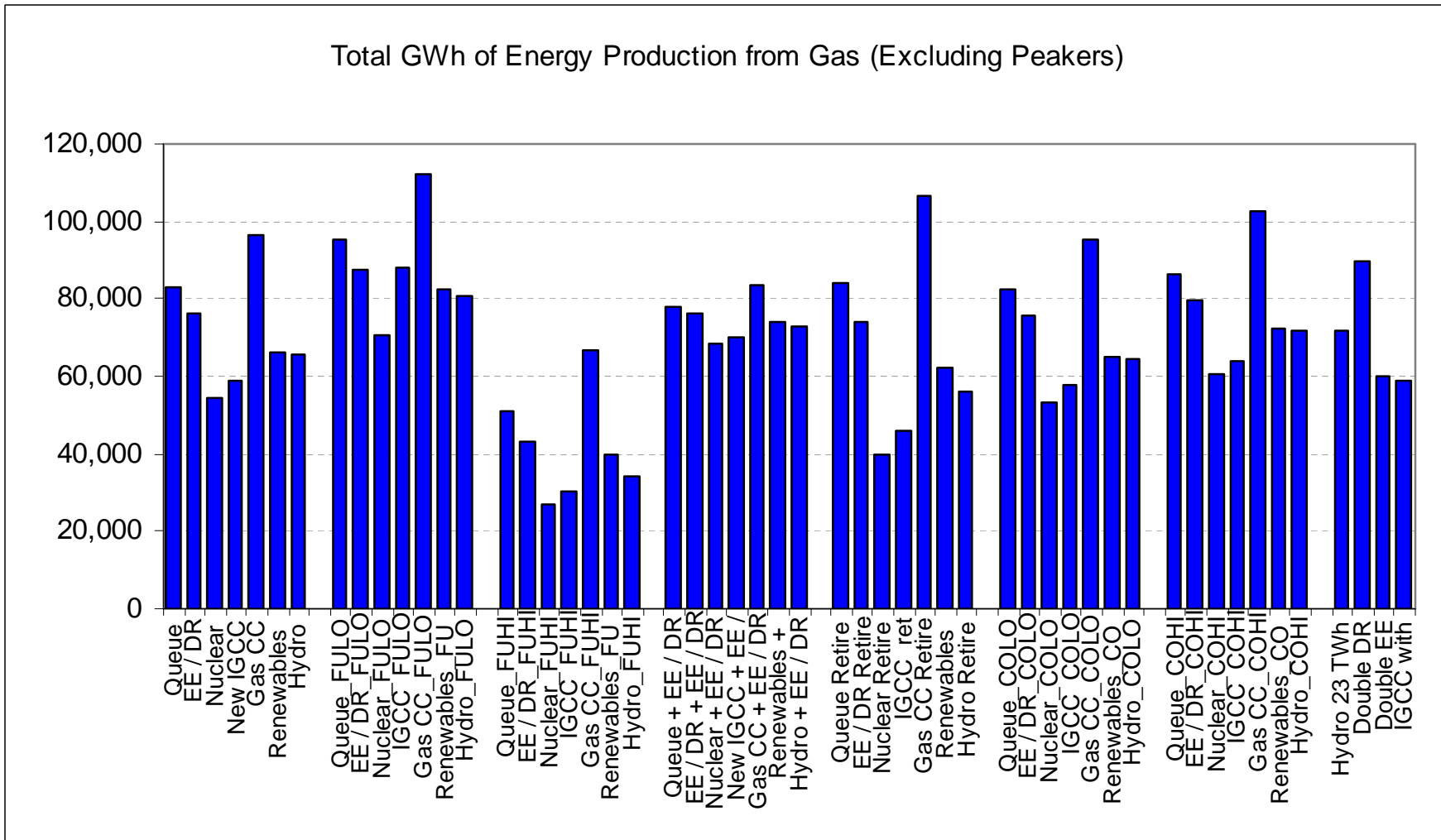
- Key Themes
- Economic Metrics
- Reliability Metrics
- Environmental Metrics
- Summary of Metrics

# Key Themes

- Under all the scenarios, New England will continue to depend on natural gas to supply electricity.
- The prices of fossil fuels, particularly natural gas, drive the region's electric energy mix, costs, electric energy prices, and level of emissions.
- Across all the scenarios and sensitivity cases, gas-fired power plants tend to be among the last plants dispatched (the so-called marginal units) in New England to meet demand.
- Gas-fired plants tend to set electric energy clearing prices in the wholesale electricity markets in most hours of the year – approximately 90% of the time.

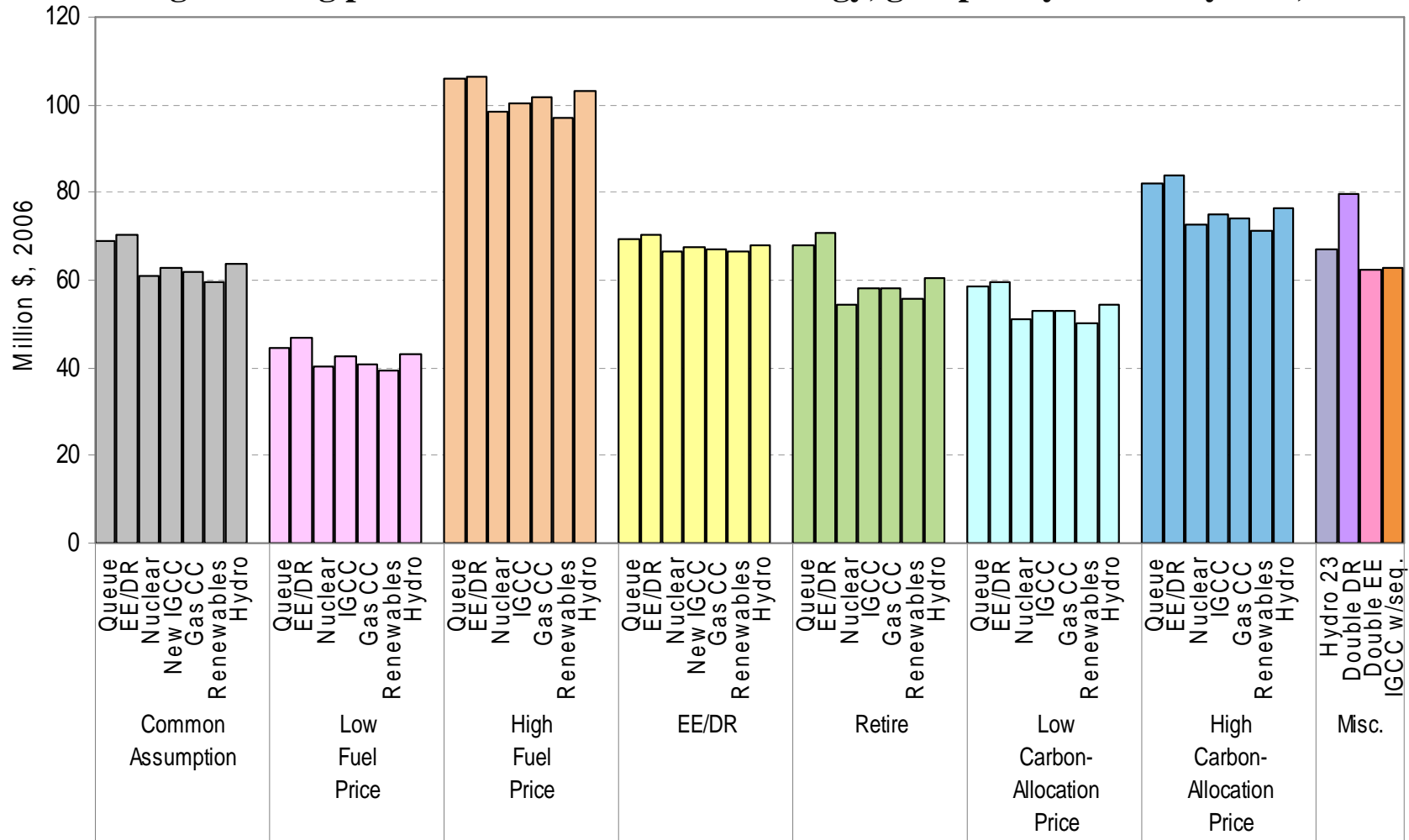
# All Scenarios: New England Continues to Depend on Natural Gas to Supply Electricity

Total GWh of Energy Production from Gas (Excluding Peakers)



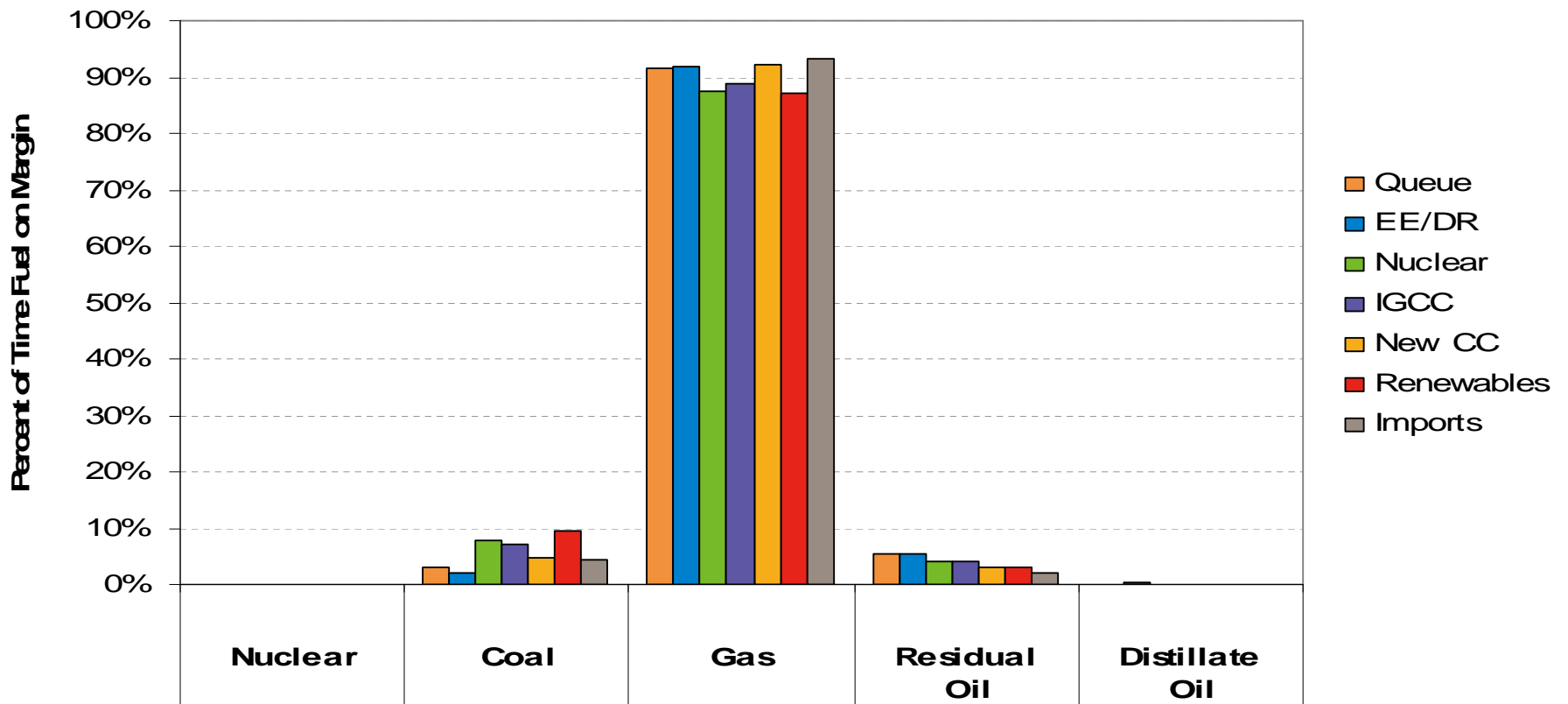
# Fossil Fuel Prices Drive NE's Electric Energy Mix, Costs, Prices, and Level of Emissions

Figure 3: Average clearing price for wholesale electric energy, grouped by sensitivity case, \$/MWh.



# Gas-fired Power Plants Still Tend to be “Marginal Units”

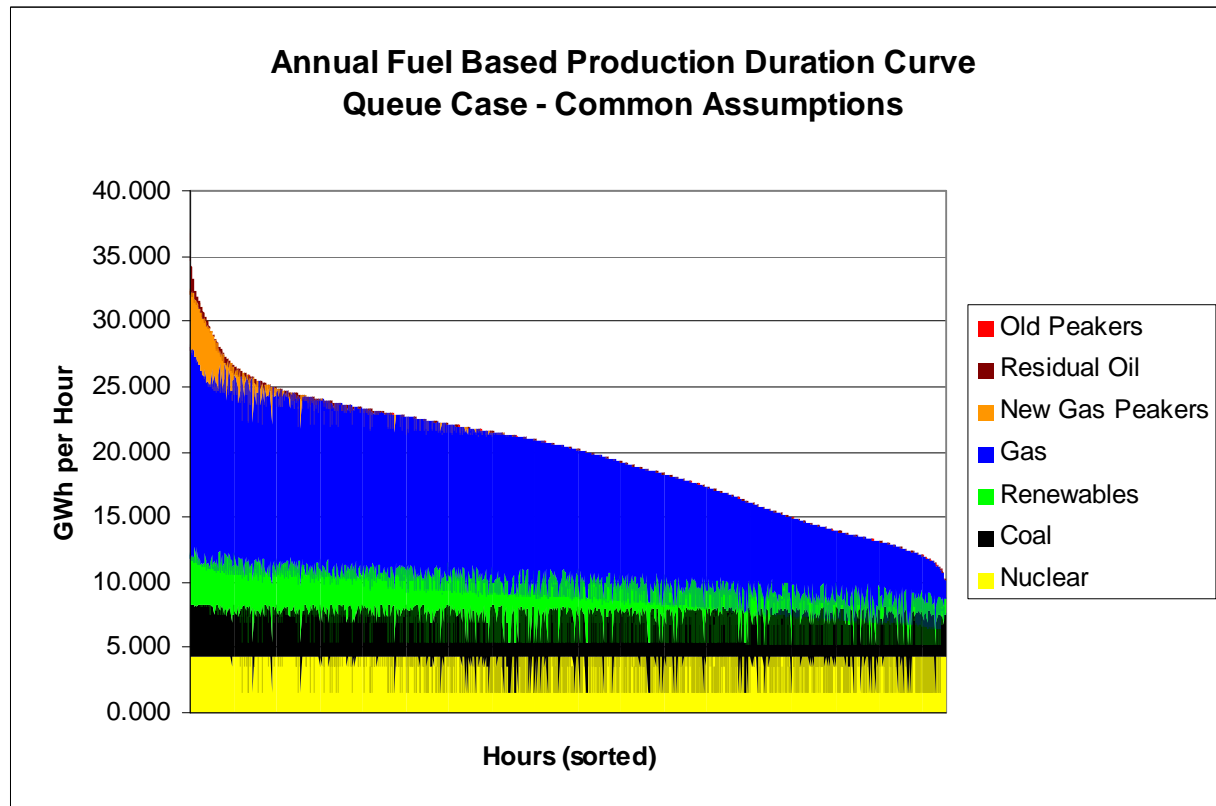
Figure 4: Percent of time fuel is on the margin.



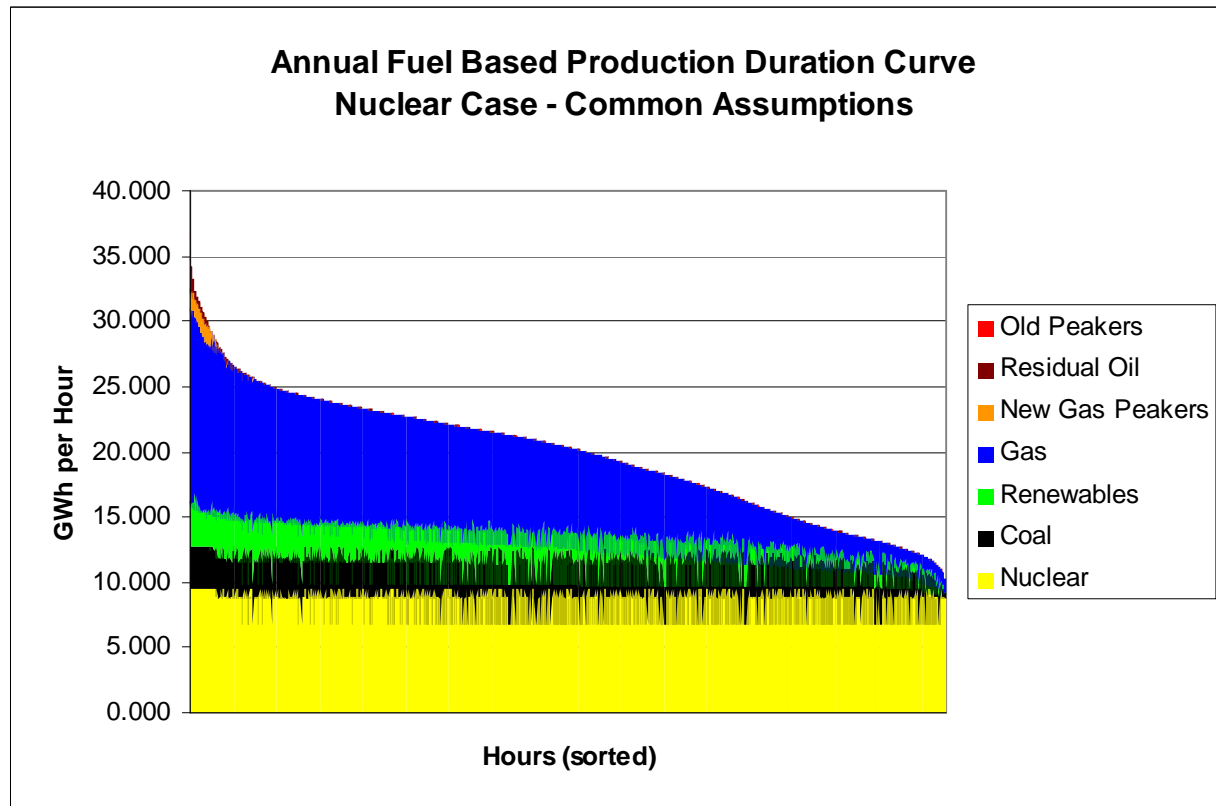
## Key Themes (continued)

- *The scenarios that have low variable cost, low emissions, and medium-to-high energy output (e.g., double energy efficiency, nuclear, hydro imports) will produce electricity more efficiently (i.e., with less overall fossil fuel consumption and lower emissions).*
- *New England's CO<sub>2</sub> emissions from the power sector vary considerably across the scenarios.*
- *The demand-side resources provide capacity and energy to the system at low capital costs and emissions, relative to other resources simulated.*

# Annual Energy Duration Curves: Queue



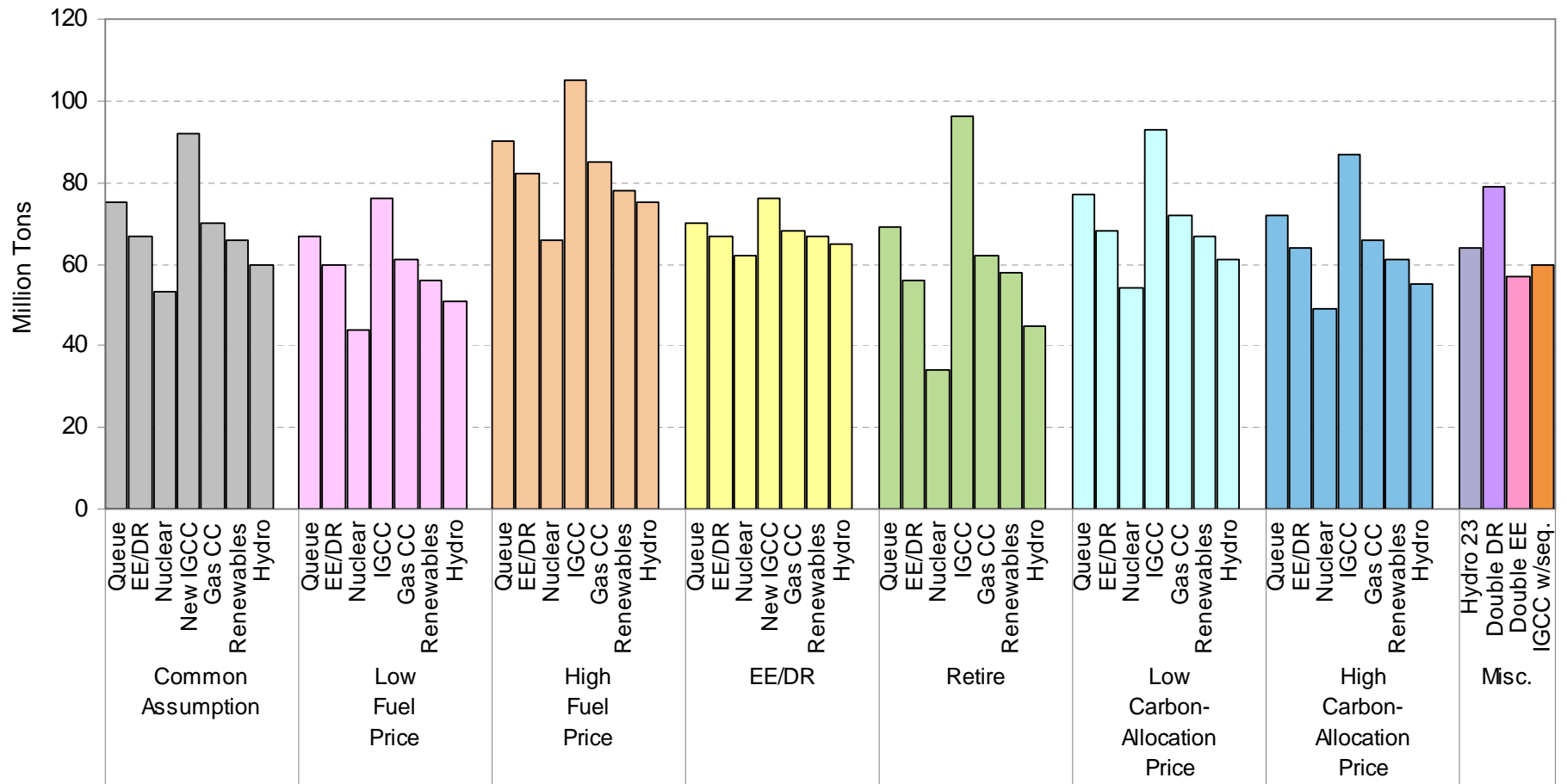
# Annual Energy Duration Curves: Nuclear



# New England's CO<sub>2</sub> Emissions from Power Sector Vary Considerably Across Scenarios

**Figure 11:** Total annual CO<sub>2</sub> emissions, grouped by sensitivity case.

**Note:** Table includes emissions from some small units not covered by RGGI requirements.



# Comparing Scenarios and Cases with RGGI Allocation to New England States

Scenario	Cases with Emissions Below New England's RGGI CO <sub>2</sub> Allocation (50.2 million tons)
1. Queue	None
2. EE/DR	None
3. Nuclear	All cases except the high fuel-price case and the case to replace 3,500 MW with EE and DR
4. IGCC	None
5. NGCC	None
6. Renewables	All except the high fuel-price case
7. Imports	Low fuel-price case; the case to retire 3,500 MW; and the case with the high CO <sub>2</sub> -allowance price

# Economic Metrics

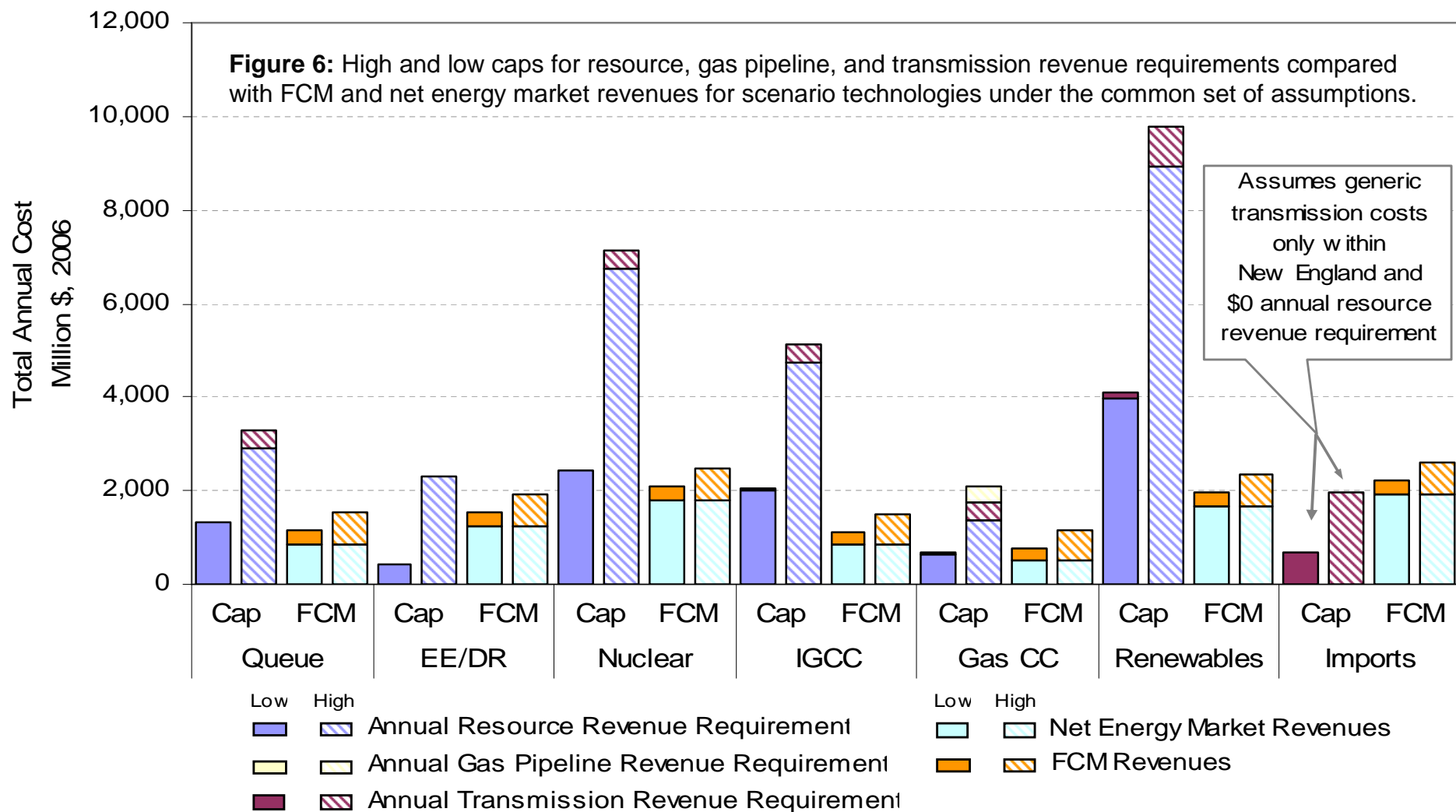
# Themes of Economic Results

- *Adding resources with large amounts of electric energy production, low operating costs, and low emissions will reduce production costs, energy prices, and emissions.*
  - Electric energy clearing prices in all cases except Scenario #2 (demand-side) are lower than the queue case.
  - The simulation results do not reflect dynamic changes, such as lower gas prices that could materialize in a scenario that reduces the demands for natural gas, such as the energy-efficiency cases.

# Themes of Economic Results

- *Adding resources, continued*
  - The new gas-fired resources on the margin are more efficient than in the past and are thus likely to reduce marginal clearing prices compared with existing marginal gas-fired resources that have set average clearing prices in the past.
  - Scenarios, such as Scenario #1 (the queue), which largely depend on peaking and fast-start resources, are likely to lead to higher average marginal energy costs.
- Natural gas appears to remain the marginal fuel.

# Demand-side Resources Provide Capacity and Energy at Relatively Low Capital Costs and Emissions



# Generic Resource Revenues and Costs

- Several expenses were not the result of detailed modeling.
- Broad ranges of expenses were developed for illustrative purposes
- Net electric energy revenues for expansion resources (million \$; \$/kW-year)
  - Results of production simulations
- Other potential revenues:
  - Capacity
    - Assumed range (\$4.50/kw-month to \$10.50/kw-month) included in the FCM settlement agreement)
  - Ancillary services
    - Assumed typical range (1% to 2%) of net electric energy revenues
  - Assume revenue for public policy incentives, such as Renewable Energy Certificates, clean energy funds, tax incentives, subsidies, etc. (amount is unknown to ISO)
- Costs:
  - Used capital cost estimates developed with stakeholders
  - Assumed annual revenue requirements (15%-25%) capture all non-fuel and non-environmental allowance cost requirement costs (e.g. return of and return on investment, taxes, fixed operations and maintenance, and other expenses)

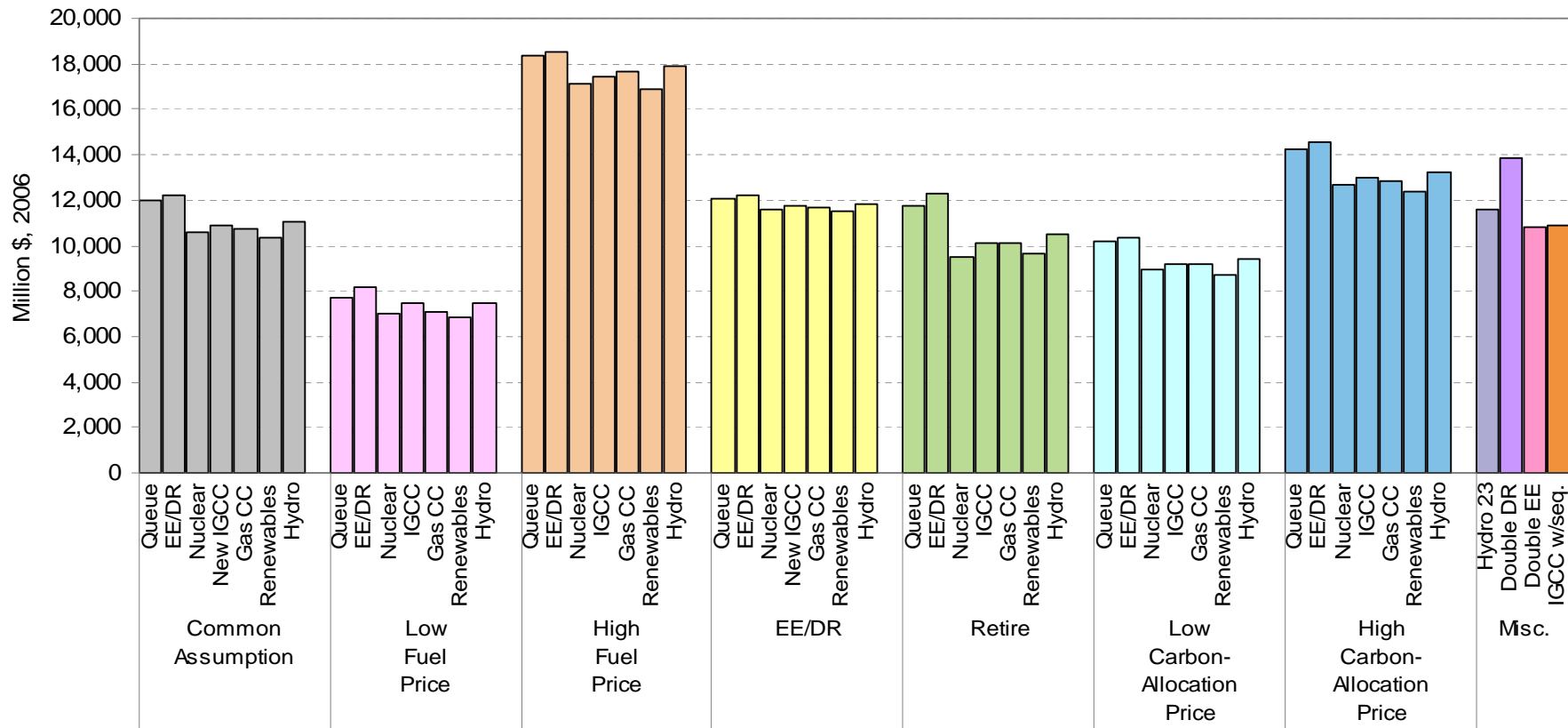
**Table 1**  
**Annual Production and Wholesale Electric Energy Market Costs and**  
**Average Marginal Clearing Prices for the Scenarios Compared with the**  
**Queue Case under the Common Assumptions**

	Prod. Cost (\$ mil)	Change from Queue (\$ mil) <sup>(a)</sup>	% Change from Queue	Avg. Marginal Clearing Price (\$/MWh)	Change from Queue (\$/MWh) <sup>(a)</sup>	% Change from Queue <sup>(a)</sup>	Annual Wholesale Electric Energy Market Cost to LSEs (\$ mil)	Change from Queue (\$ mil) <sup>(a)</sup>	% Change from Queue <sup>(a)</sup>
<b>1. Queue</b>	6,833	-		69	-		11,997	-	
<b>2. EE/DR<sup>(b)</sup></b>	6,298	535	7.8	70	-1	-1.4	12,235	-238	-2.0
<b>3. Nuclear</b>	5,502	1,331	19.5	61	8	11.6	10,566	1,431	11.9
<b>4. IGCC</b>	6,525	308	4.5	63	6	8.7	10,895	1,102	9.2
<b>5. NGCC</b>	6,825	8	0.1	62	7	10.1	10,796	1,201	10.0
<b>6. Renewables</b>	5,569	1,264	18.5	60	9	13.0	10,344	1,653	13.8
<b>7. Imports</b>	5,522	1,311	19.2	64	5	7.2	11,085	912	7.6
<b>All EE<sup>(b)</sup></b>	<b>5,148</b>	<b>1,685</b>	<b>24.7</b>	<b>62</b>	<b>7</b>	<b>10.1</b>	<b>10,811</b>	<b>1,186</b>	<b>9.9</b>

(a) "+" = cost savings; "-" = more costly

(b) Rather than being modeled as a reduction to the load curve, energy efficiency and demand-response resources are modeled in this analysis like supply-side resources. Energy efficiency and demand response are modeled as if they offered "energy" at no cost to the system, and the party that invested in these measures was paid the calculated net energy revenues, which is equivalent to the dollar savings in reduced energy consumption from those resources. The energy efficiency and demand response scenario is assumed to supply 18 Million MWh of no-cost "energy," and the all-energy-efficiency case is assumed to provide 36 million MWh of no-cost "energy," which is comparable to the nuclear and IGCC scenarios.

# Load-serving Entity Annual Expense for Wholesale Electric Energy



# Themes of Economic Results

- *The price for fossil fuels (natural gas and oil) is the most dominant factor affecting the costs and emissions for each of the scenarios.*
- *The economic evaluation of expansion technologies must give full consideration to capital and operating costs as well as sources of revenues for the expansion technologies.*
- *Alternatively, energy efficiency and demand response show sufficient revenues from the electric energy and capacity markets to economically justify investment.*

# Reliability Metrics

# Reliability Results

- Energy mix and fuel-use patterns
  - Natural gas use and power production use
    - Varies with relative fuel prices
    - Is displaced by energy provided by other types of new resources
    - Stays about the same level in retirement cases
    - Increases for high carbon allowances
  - Residual fuel oil use
    - Increases only for retirement cases or when gas prices are high
  - Distillate fuel use increases for
    - The retirement case
    - More demand response
  - Energy response displaces natural gas and oil-fired units

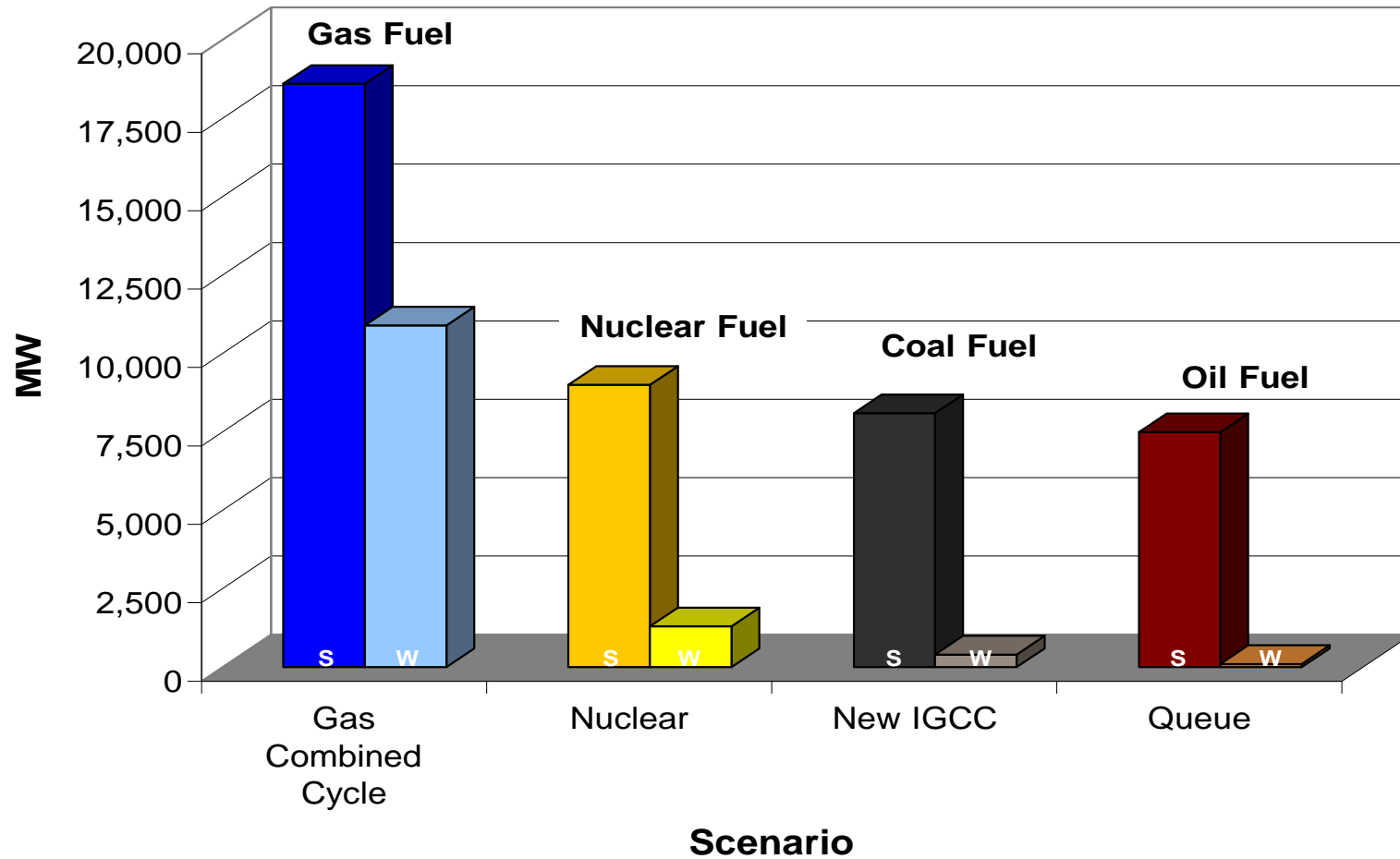
# Themes of Reliability Results

- *The system capacity mix would not alter a high dependency on natural-gas-fired capacity under any scenario.*
- *The greatest changes in the capacity mix tend to occur in the sensitivity cases that assumed that the oldest 3,500 MW of generating capacity in the region would retire and be replaced with that scenario's core technology.*
- *Adding thousands of megawatts of demand-response capacity, as assumed in this Scenario Analysis, could lead to trade offs.*

# Major Results – Operable Capacity Analysis

- Operable Capacity Analysis (OCA) examines the ability to operate the system under peak-load conditions.
- Similar to RSP06 analysis, OCA was used to show the system-wide dependence on various types of capacity.
- Results show that natural gas-fired generation is the largest source of capacity across all scenarios.
- This suggests a continued need for:
  - Alternate sources of capacity and energy
  - Firm natural gas contracts and enhanced natural gas and liquefied natural gas (LNG) infrastructure
  - Dual-fuel capability of natural gas units

# Summer and Winter Operable Capacity Needed by Fuel Source, MW

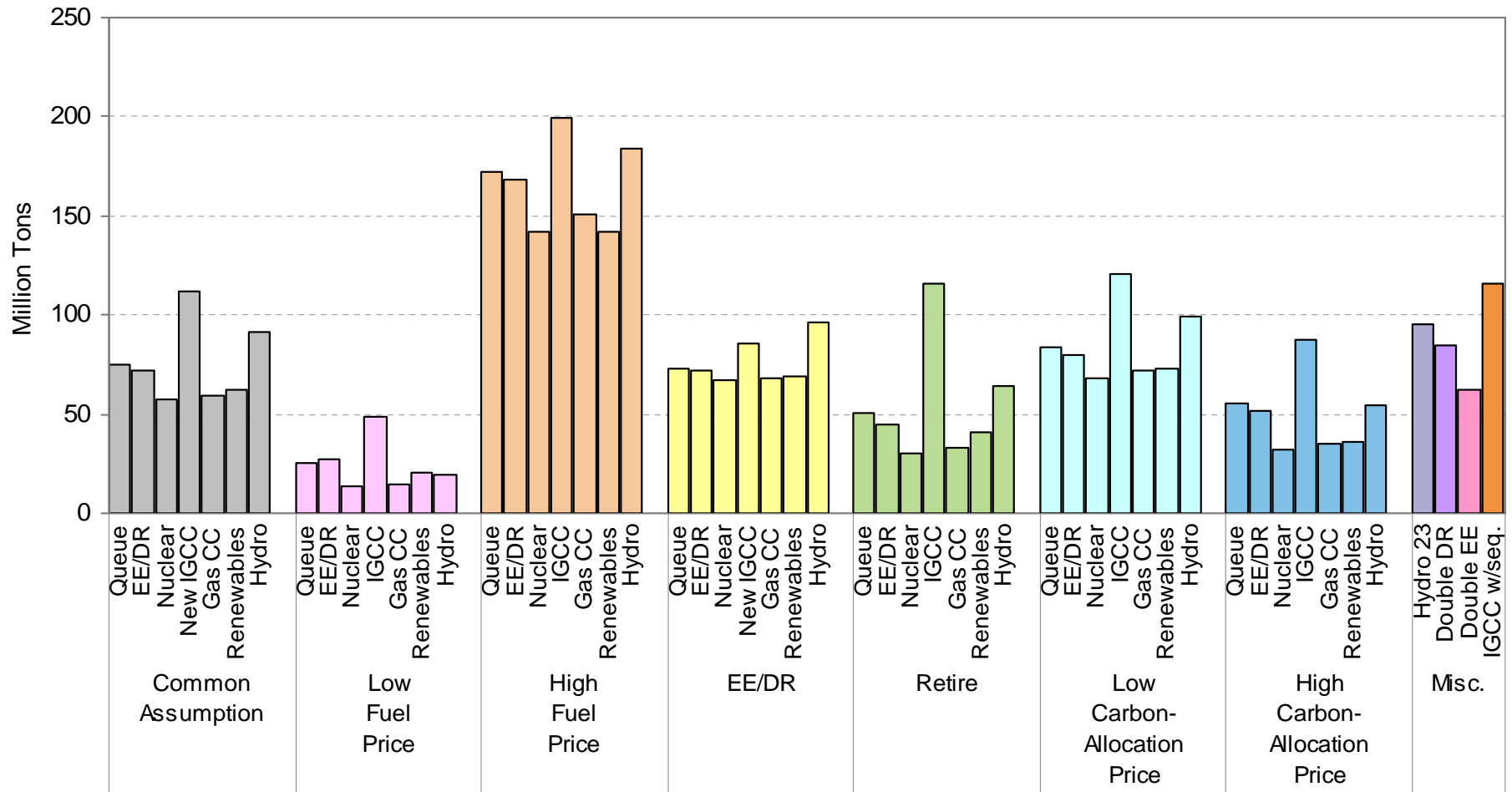


# Environmental Metrics

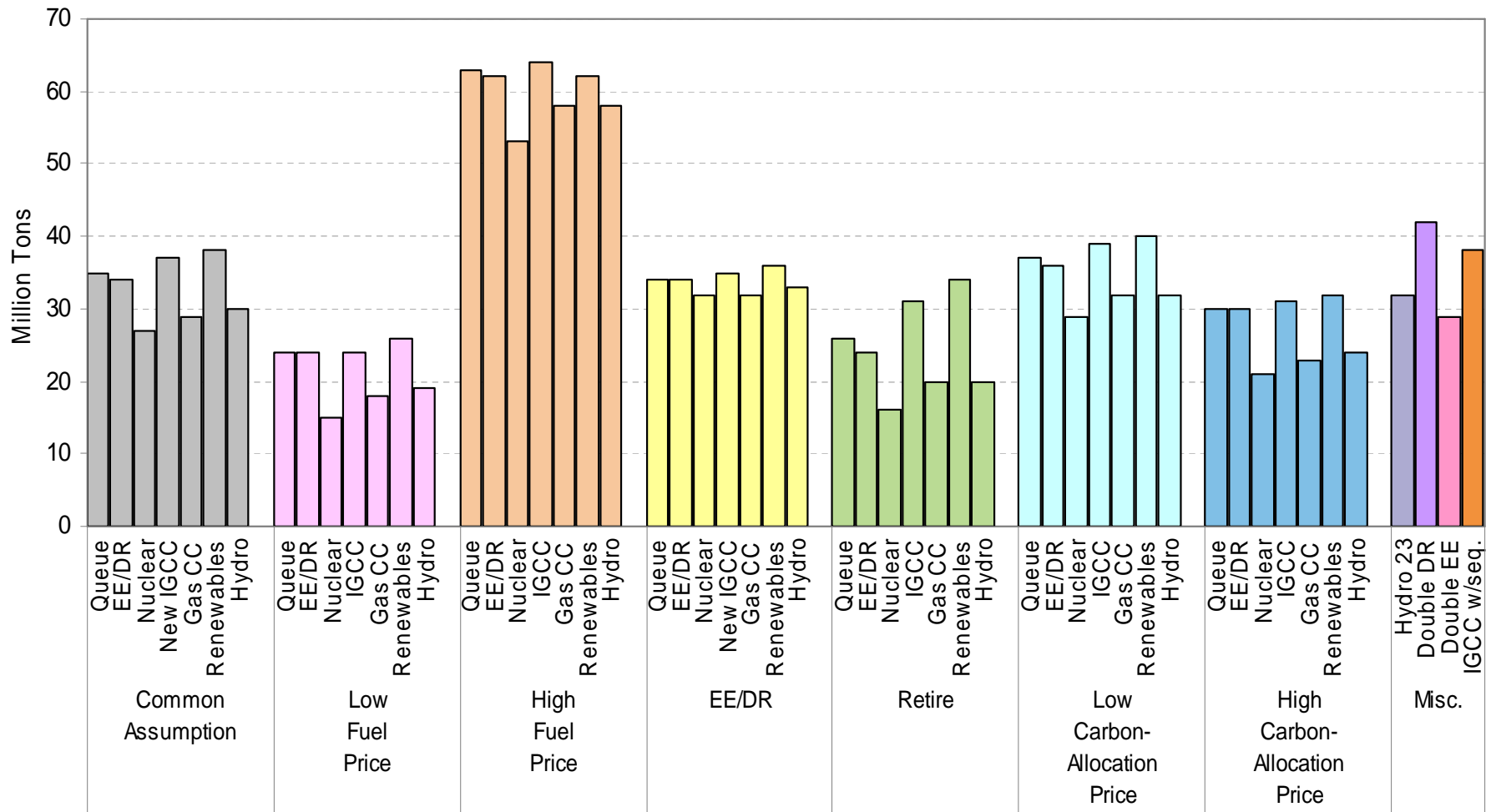
# Themes of Environmental Results

- *With the exception of the Scenario #4 (IGCC), the retirement case results show lower emissions.*
- *Relatively high reliance on fossil-fuel-based peaking resources, even in combination with some form of emission-free demand response, can result in an overall increase in air emissions.*
- *Because CO<sub>2</sub> emissions vary across the scenarios, regional compliance with RGGI will also vary.*

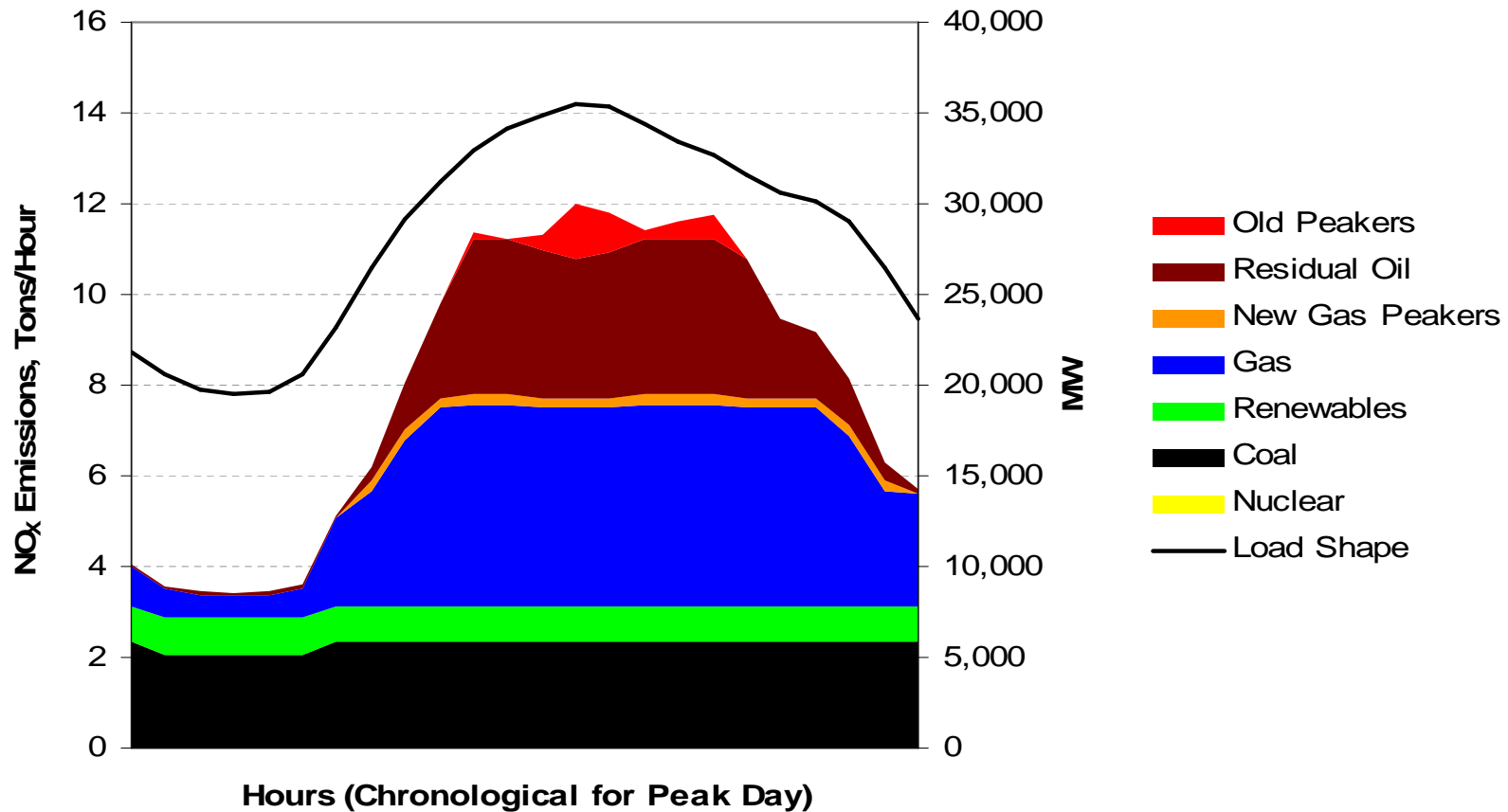
# Total Annual SO<sub>2</sub> Emissions



# Total Annual NO<sub>x</sub> Emissions



# NO<sub>x</sub> Emissions by Fuel Category on the 35,000 MW Peak-load Day for Scenario #2



# Land Requirements (Acres)

Scenario	Generation	Transmission	Total
1. Queue	9,134 – 54,008	238 – 6,019	9,371 – 69,398
2. EE/DR	0	0	0
3. Nuclear	1,038 – 2,025	238 – 6,019	1,276 – 9,320
4. IGCC	378-2,700	238 – 6,019	631 – 9,350
5. NGCC	128 – 128	238 – 950	365 – 1,443
6. Renewables	127,449 – 232,727	2,257 – 13,781	129,706 – 246,507
7. Imports	0	11,880 – 29,462	11,880 – 29,462

# Cooling Water Use for Large Power Plants

- Queue scenario (#1)—12,100 gal/min
- Nuclear scenario (#3)—85,200 gal/min
- IGCC scenario (#4)—65,900 gal/min
- NGCC scenario (#5)—20,700 gal/min
- Other technologies – Little to no cooling water

# Summary of Metrics for Comparing Scenarios

Economic	Reliability	Environmental
Systemwide production costs <sup>(a)</sup> (billion \$)	Systemwide energy mix (MWh; % MWh by fuel)	Total systemwide emissions of SO <sub>2</sub> and NO <sub>x</sub> (1,000 tons) and CO <sub>2</sub> (million tons)
Energy supply duration curves for marginal clearing price	Systemwide capacity mix (MW by fuel)	Total systemwide NO <sub>x</sub> emissions for the 10 highest peak-load summer days (tons)
Annual revenue requirements (ARR) for expansion resources <sup>(b)</sup> (billion \$; \$/kW-year)	Total units of fossil fuel burned (Quadrillion Btus consumed; MWh of production)	Total systemwide emissions of CO <sub>2</sub> (million tons)
Net wholesale electric energy market revenues for expansion resources (million \$; \$/kW-year)	Exposure to fuel-supply disruption (MW) (operable capacity analysis)	CO <sub>2</sub> emissions compared with Regional Greenhouse Gas Initiative allocation <sup>(c)</sup> (million tons; compliance/ noncompliance)
Load-serving entity expenses for wholesale electric energy based on hourly New England marginal clearing prices (billion \$; \$/MWh)		Mercury emissions (lbs)
Generic capital costs for expansion (\$/kW)		Cooling water use (gal/minute)
Generic transmission expansion costs (\$/scenario; \$/MW-hour)		Amount of incremental land used (acres)
Generic distribution expansion costs (\$/MW-hour)		Renewable energy contribution (MWh;% MWh)
Costs for generic expansion of gas-delivery system (\$)		

(a) The systemwide production cost is the sum of the annual production costs (i.e., the fuel and emissions-related operating costs) for every resource to produce power in each hour of the simulated year.

(b) The annual revenue requirement (capital cost X the annual revenue requirement rate) captures all non-fuel-related costs including the recovery of capital costs, other operating costs, taxes, and other expenses.

# Conclusion

- Lower electric energy prices and reduced air emissions are possible by adding resources that provide relatively high amounts of electric energy at low or no fuel costs and that emit few pollutants.
- New England will continue to depend highly on natural gas for power production.
- Energy prices and air emissions will be driven by the relative cost of natural gas to oil.
- CO<sub>2</sub> emissions vary across scenarios.