# Detailed Preliminary Results (Metrics)

# Scenario Analysis – Update on Metrics

April 2, 2007

# Presentation of Metrics

- Extensive list of metrics makes presentation format critical
  - Many metrics must be presented
  - Metrics convey important information about each scenario
  - Metrics include
    - Direct results of simulations
    - Simulation results combined with other information
    - Implications of input assumptions
  - Metrics' ability to provide useful information to stakeholders depends, in part, on having the information be clear and reasonably easy to read
- All metrics expected to be quantified, but certain metrics may require additional time and effort

# Plenary Session Review of Metric Formats

- There are many potential ways to present metrics.
  - ISO has attempted to develop some approaches.
  - Stakeholders may have other good / better ideas.
  - ISO seeks input on how to present the information in subsequent meetings and in the final report
- Following are examples of potential metric formats
  - Focus on communication of relative merits
  - Identifying “winners” and “losers” not the objective of these metrics

# Metrics Overview Summary

| Economic | Reliability | Environmental |
|---|---|---|
| Systemwide production costs[a] (billion $) | Systemwide energy mix (MWh; % MWh by fuel) | Systemwide emissions of $SO_X$ and $NO_X$ (1000 tons) |
| Energy supply duration curve for marginal clearing price | Systemwide capacity mix (MW by fuel) | Total systemwide $NO_X$ emissions for the 10 highest peak-load summer days (tons) |
| Annual revenue requirement for expansion resources[b] (billion $; $/kW-year) | Total units of fossil fuel burned (Quadrillion Btus consumed; MWh of production) | Total systemwide emissions of $CO_2$ (million tons) |
| Net electric energy revenues for expansion resources (million $; $/kW-year) | Exposure to fuel-supply disruption (MW) (operable capacity analysis) | Mercury emissions—(lbs) |
| Load-serving entity (LSE) expense for wholesale electric energy based on hourly New England marginal clearing price (billion $; $/MWh) | | Cooling water use (gal/minute) |
| Generic capital cost for expansion ($/kW) | | Amount of incremental land used (acres) |
| Generic transmission expansion cost ($/scenario; $/MW-hour) | | Renewable energy contribution (MWh;% MWh) |
| Generic distribution expansion cost ($/MW-hour) | | |
| Cost 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.

# Energy Duration Curves

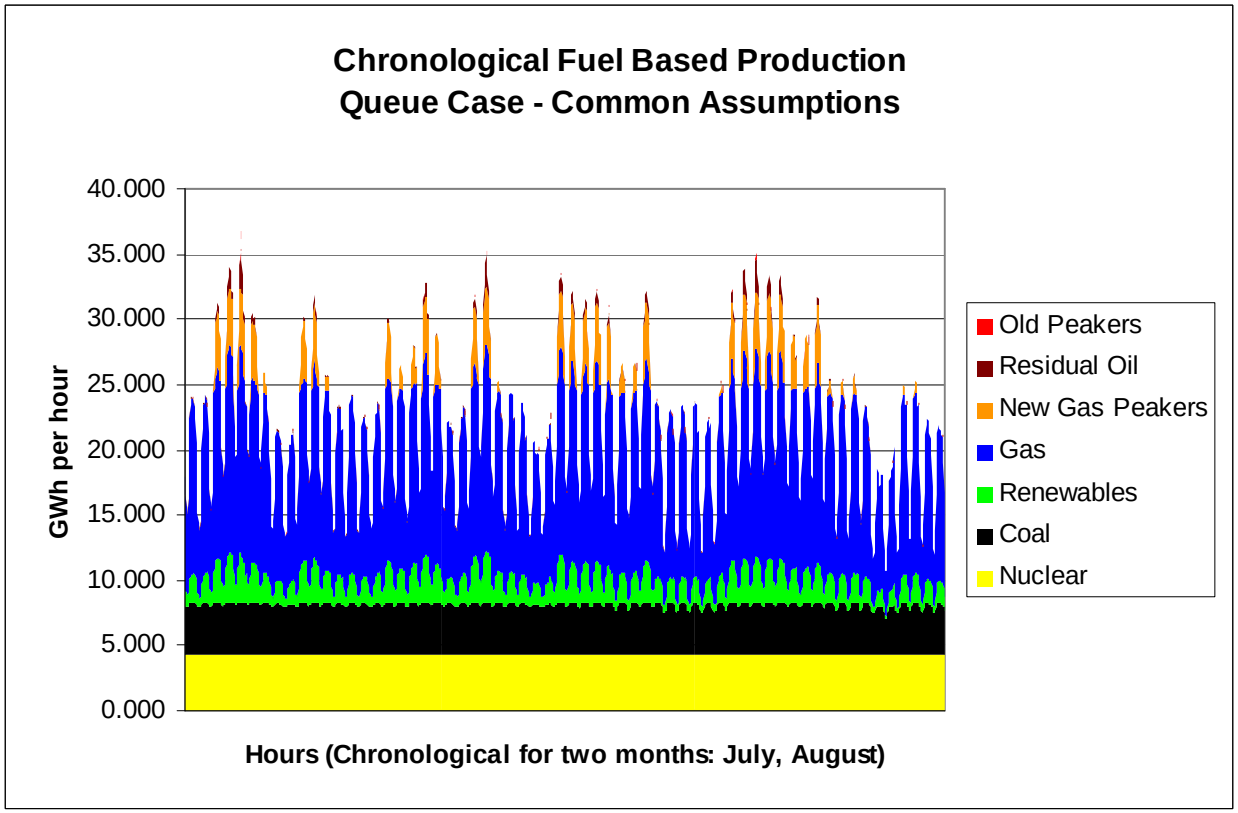
# Energy Production Graphs

- Following graphs show energy production by fuel category
  - Hourly chronological for two months July and August
  - Annual energy production duration curves
- All seven scenarios shown with “common assumptions”
- Order is arranged in conceptual dispatch order
  - Lowest dispatch cost toward bottom
  - Highest dispatch cost toward top
  - Renewables are shown between the coal and gas categories
- Annual energy production duration curves are not chronological
  - Effect of maintenance outages can be seen
  - Hourly details (8760 hours) are blurred on these powerpoint slides

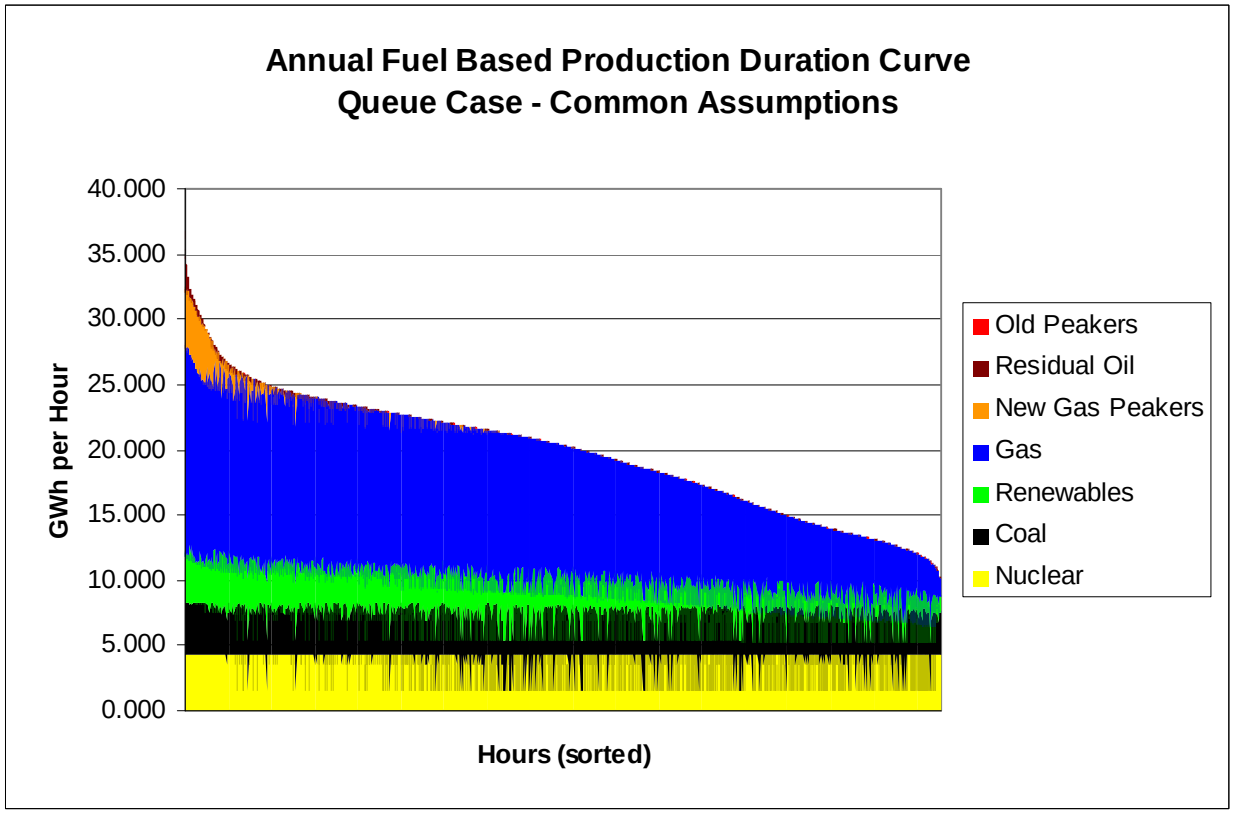
# Fuel Categories Shown

| | |
|---|---|
| Nuclear | All nuclear units |
| Coal | All coal units |
| Renewables | Hydro, Wind, Photovoltaics, Biomass, EE/DR |
| Gas | All natural gas (except new gas peakers)<br>This includes renewable resources that use gas (CHP, fuel cells, landfill gas) |
| New Gas Peakers | All new gas peakers |
| Residual Oil | All residual oil fired resources |
| Other | Mostly old peakers fueled by distillate oil |

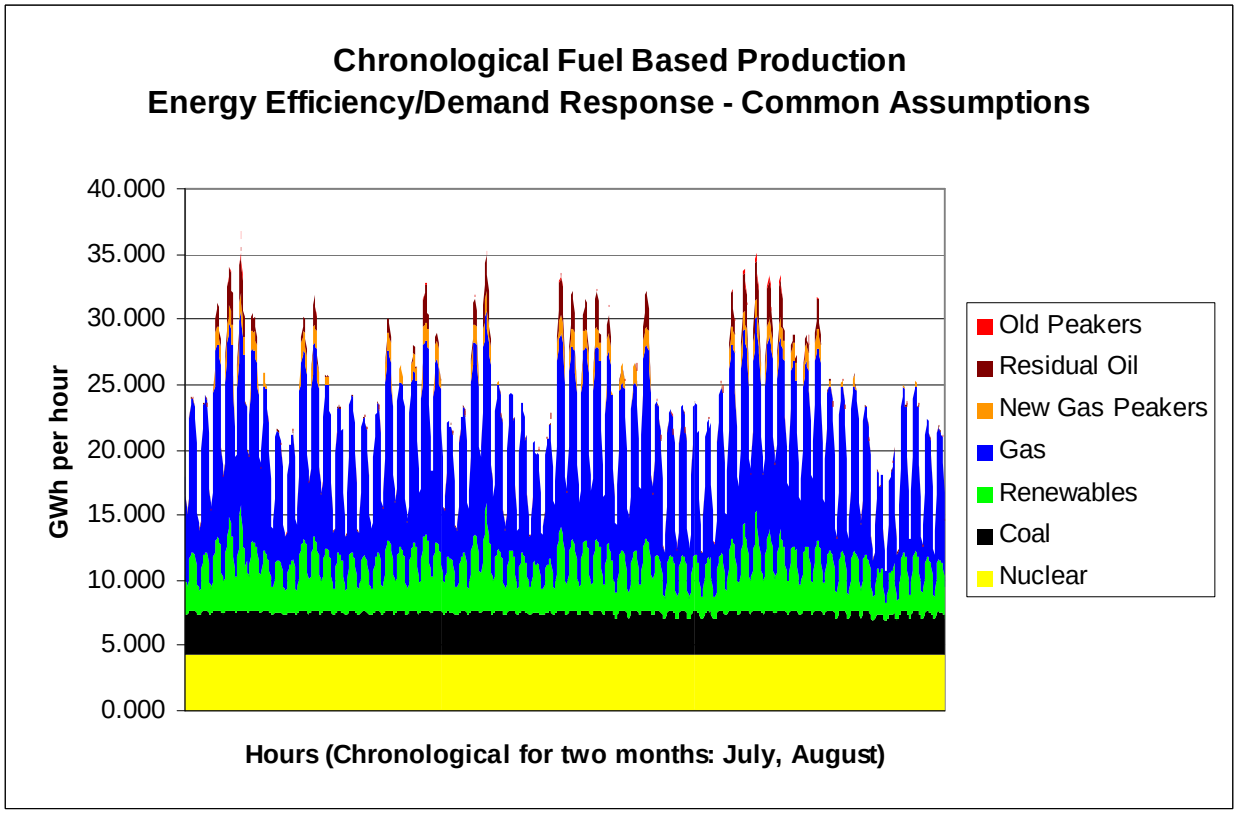
# Summer Chronological GWh: Queue



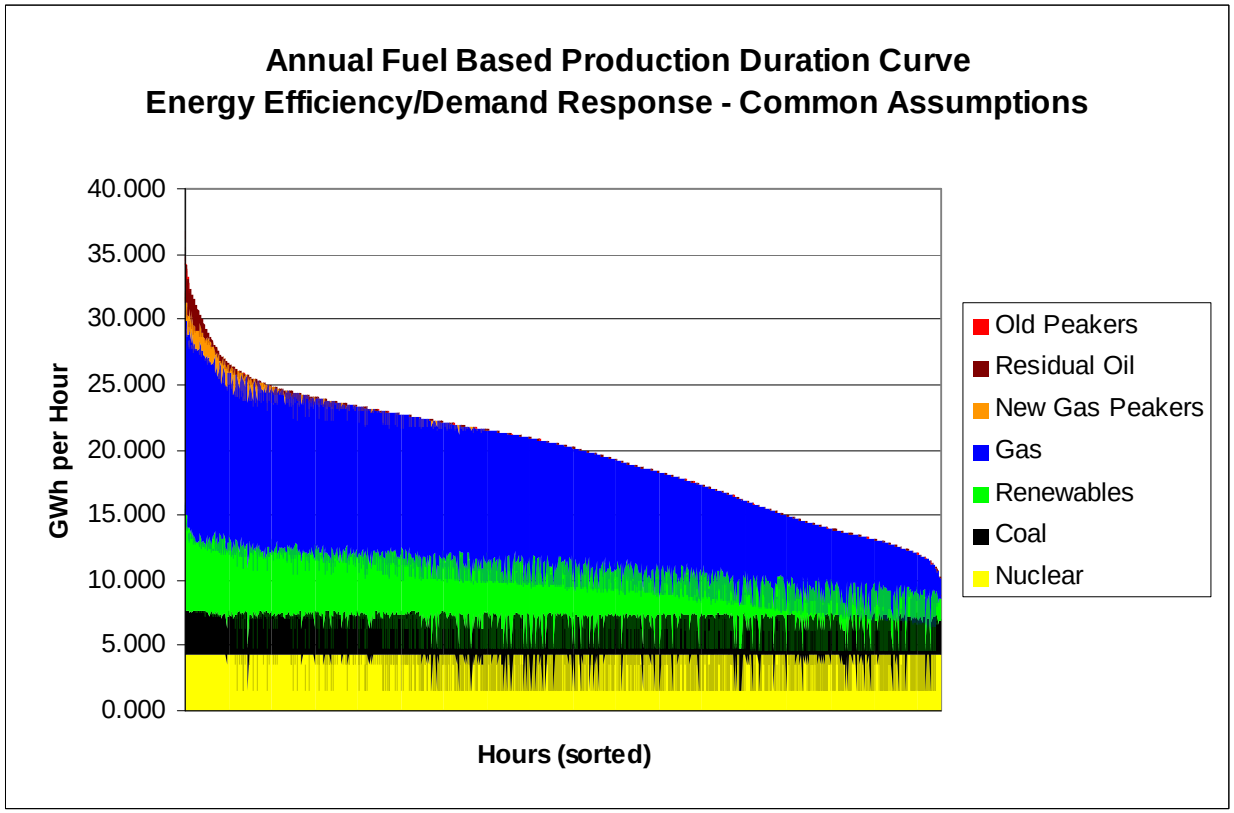
# Annual Energy Duration Curves: Queue



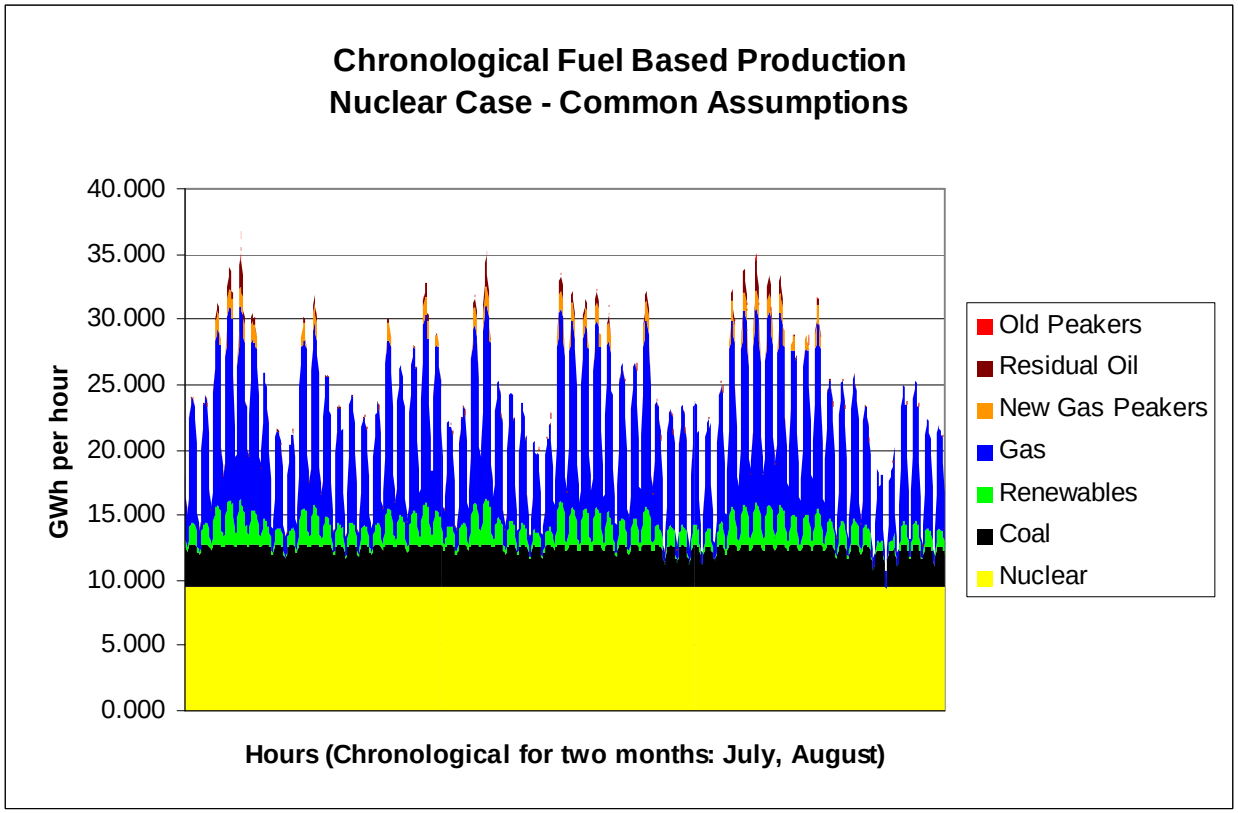
# Summer Chronological GWh: EE / DR



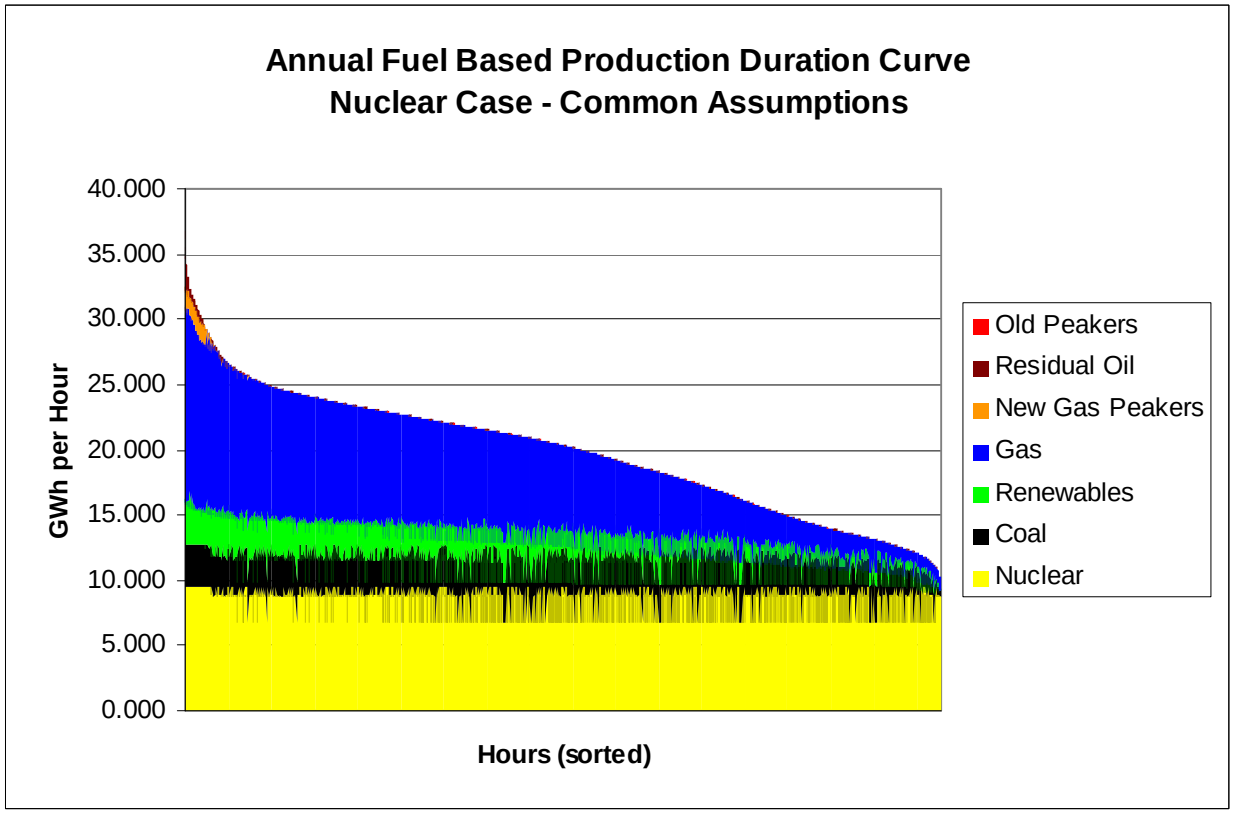
# Annual Energy Duration Curves: EE / DR



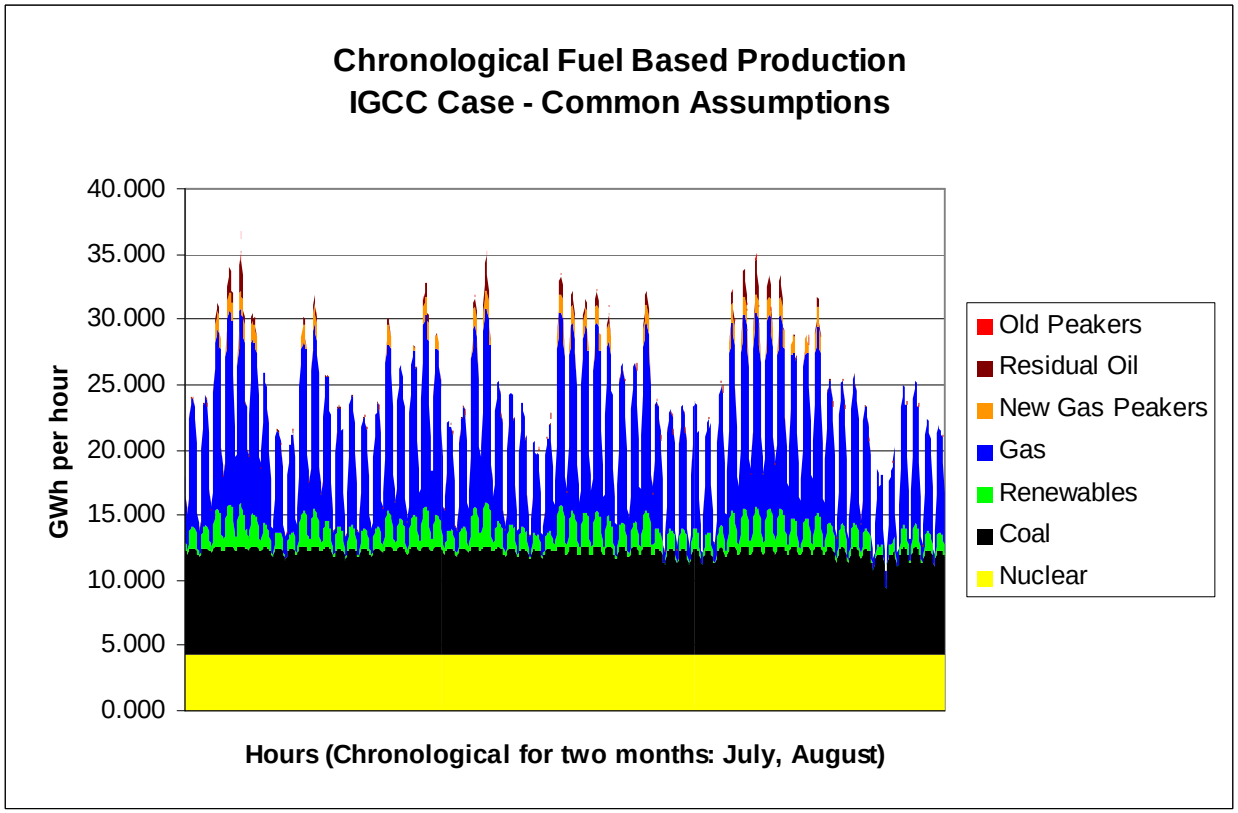
# Summer Chronological GWh: Nuclear



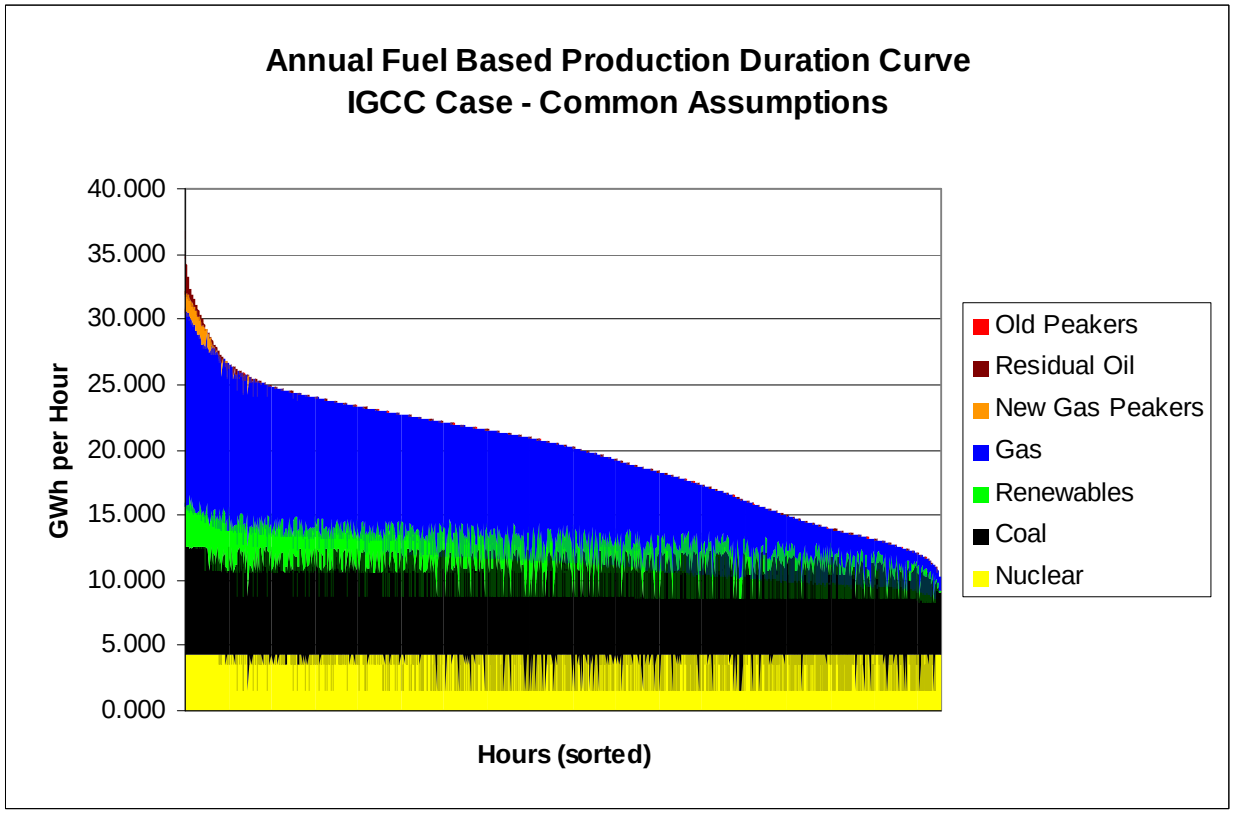
# Annual Energy Duration Curves: Nuclear



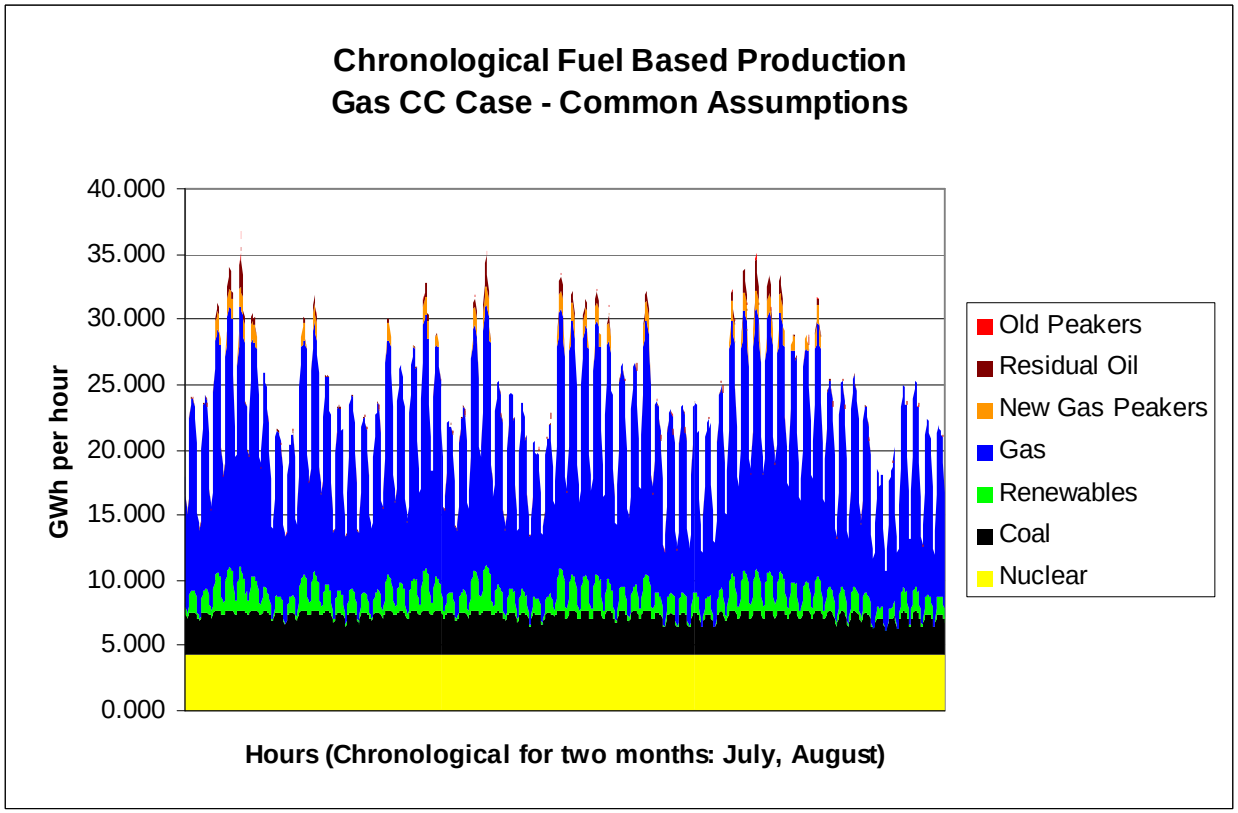
# Summer Chronological GWh: IGCC



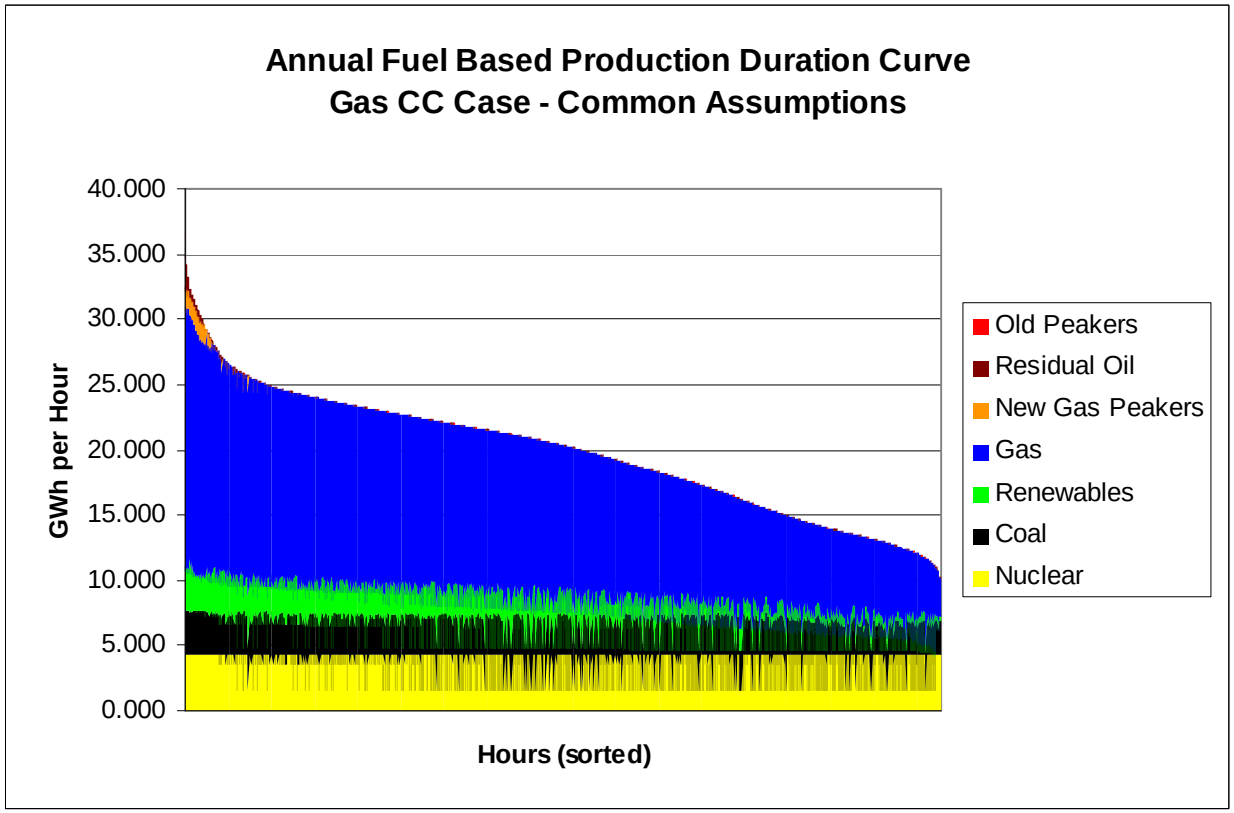
# Annual Energy Duration Curves: IGCC



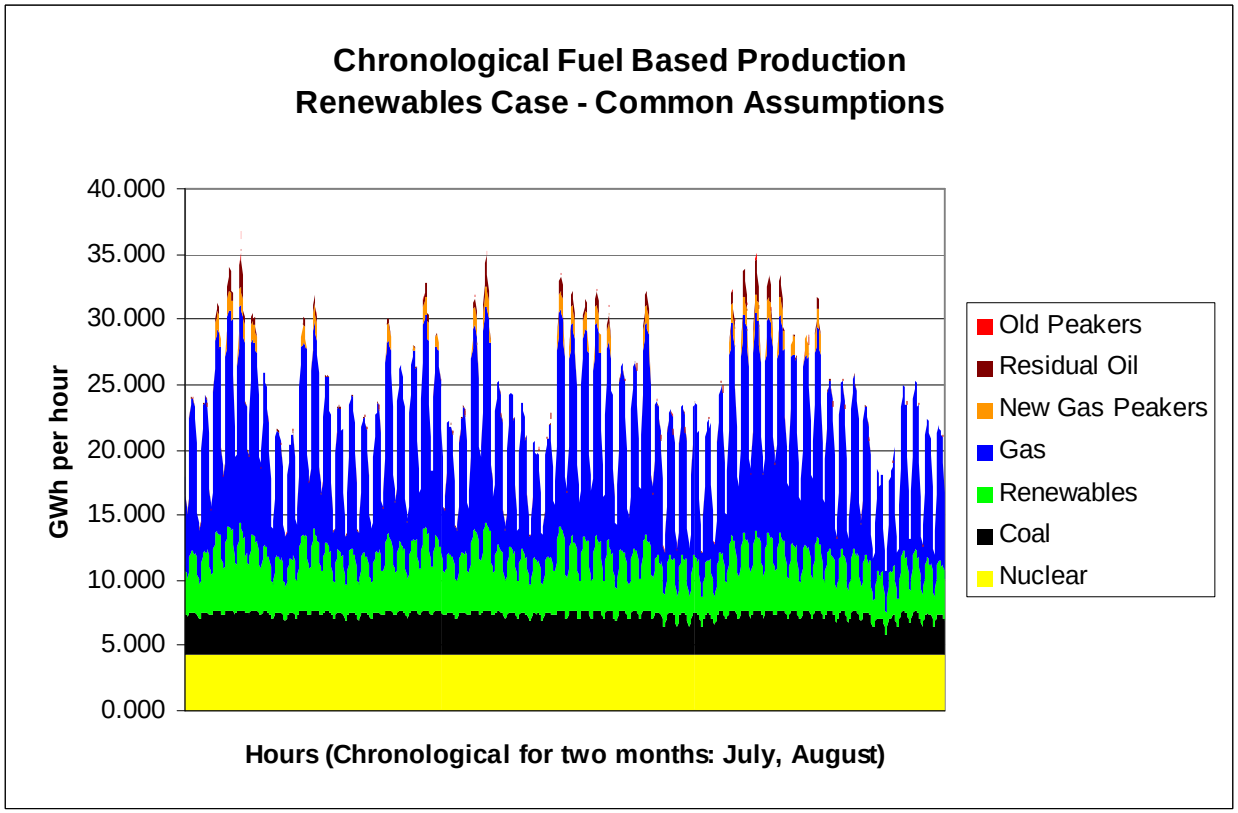
# Summer Chronological GWh: Gas CC



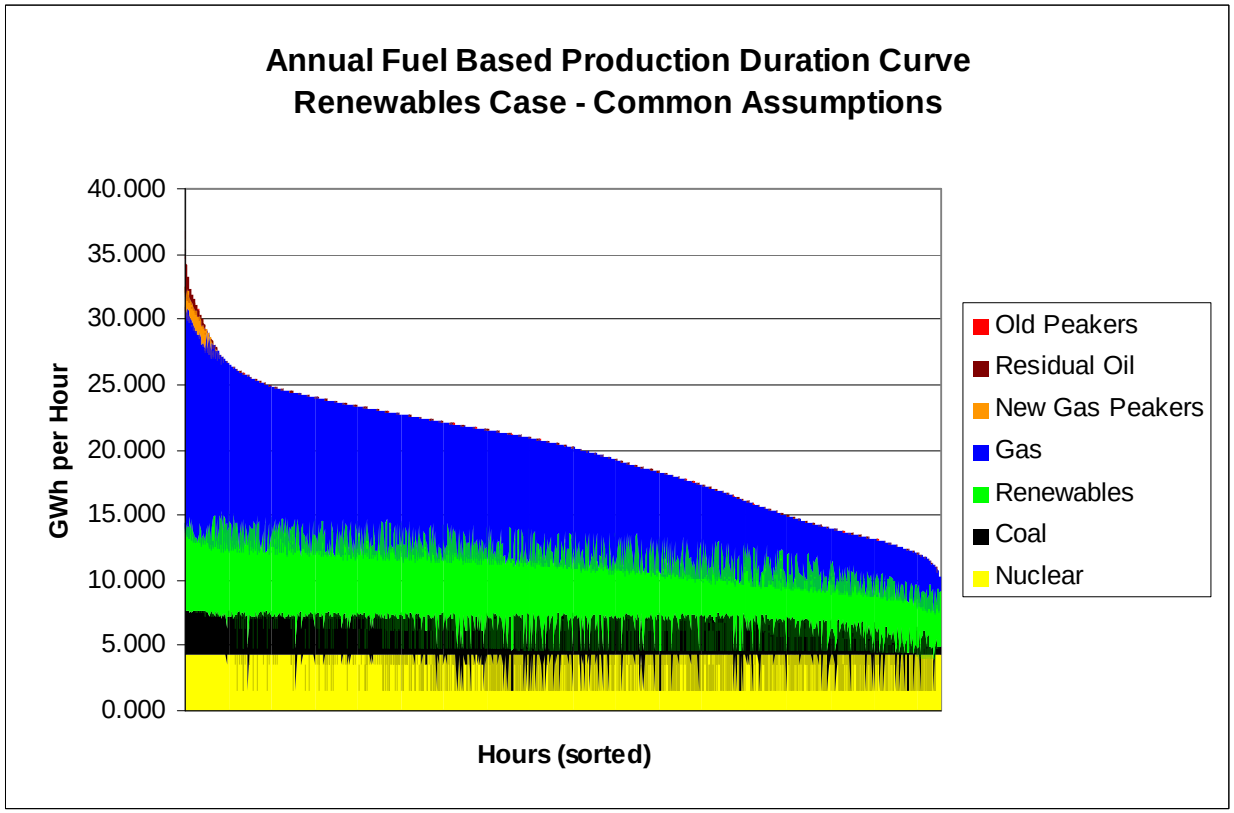
# Annual Energy Duration Curves: Gas CC



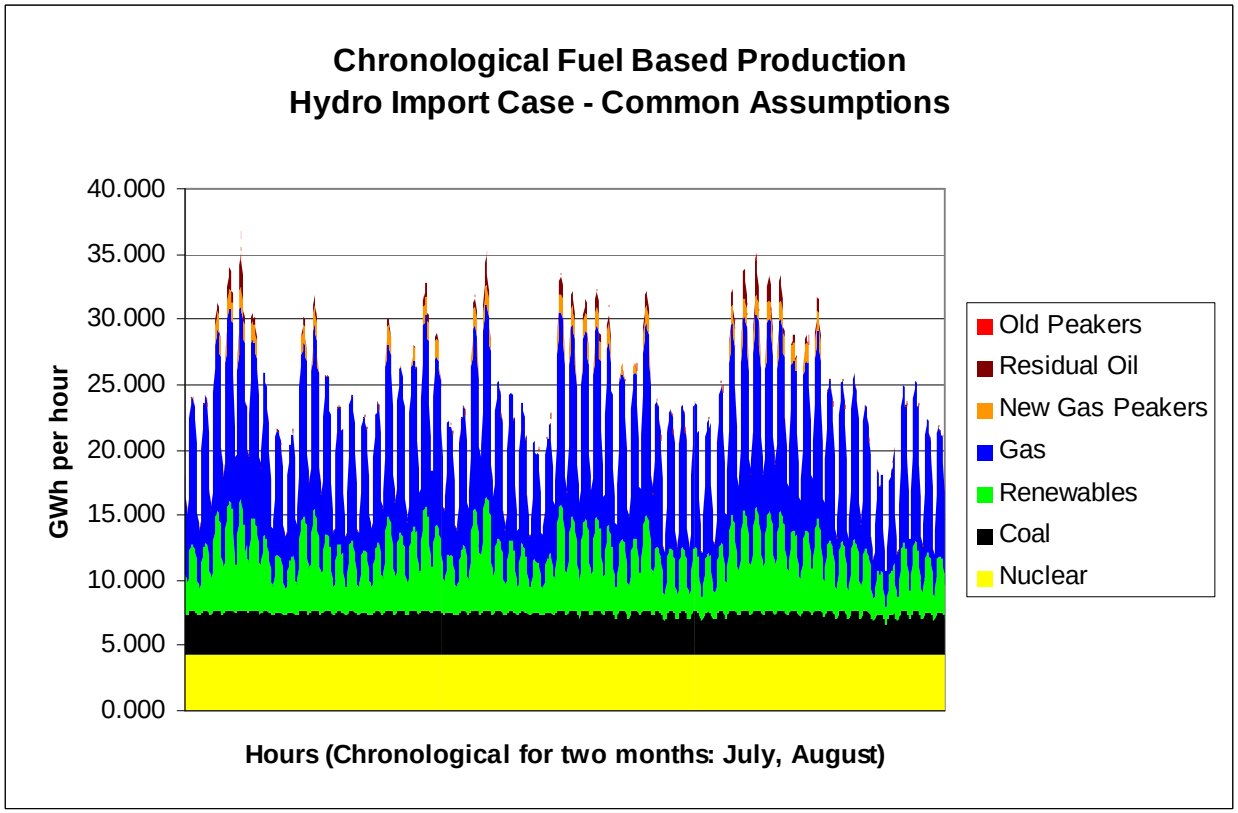
# Summer Chronological GWh: Renewables



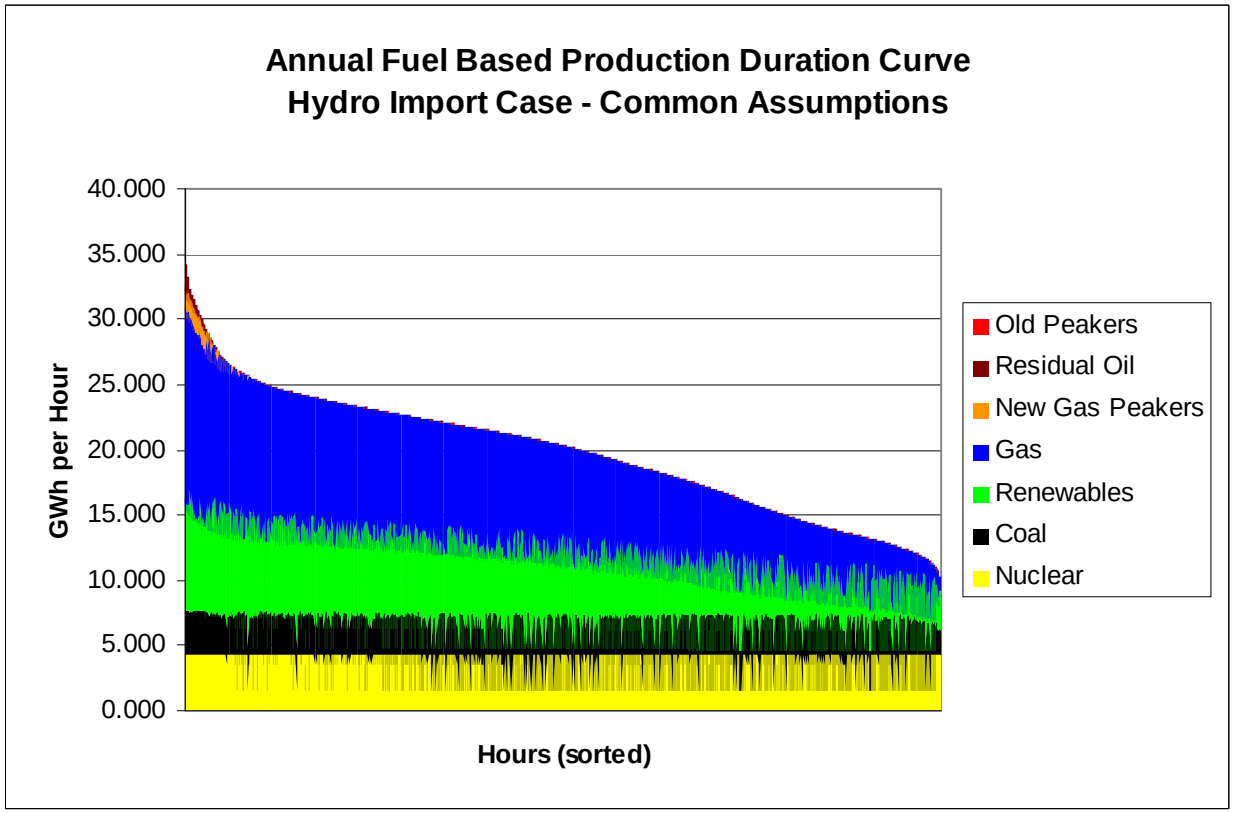
# Annual Energy Duration Curves: Renewables



# Summer Chronological GWh: Hydro Import



# Annual Energy Duration Curves: Hydro Import



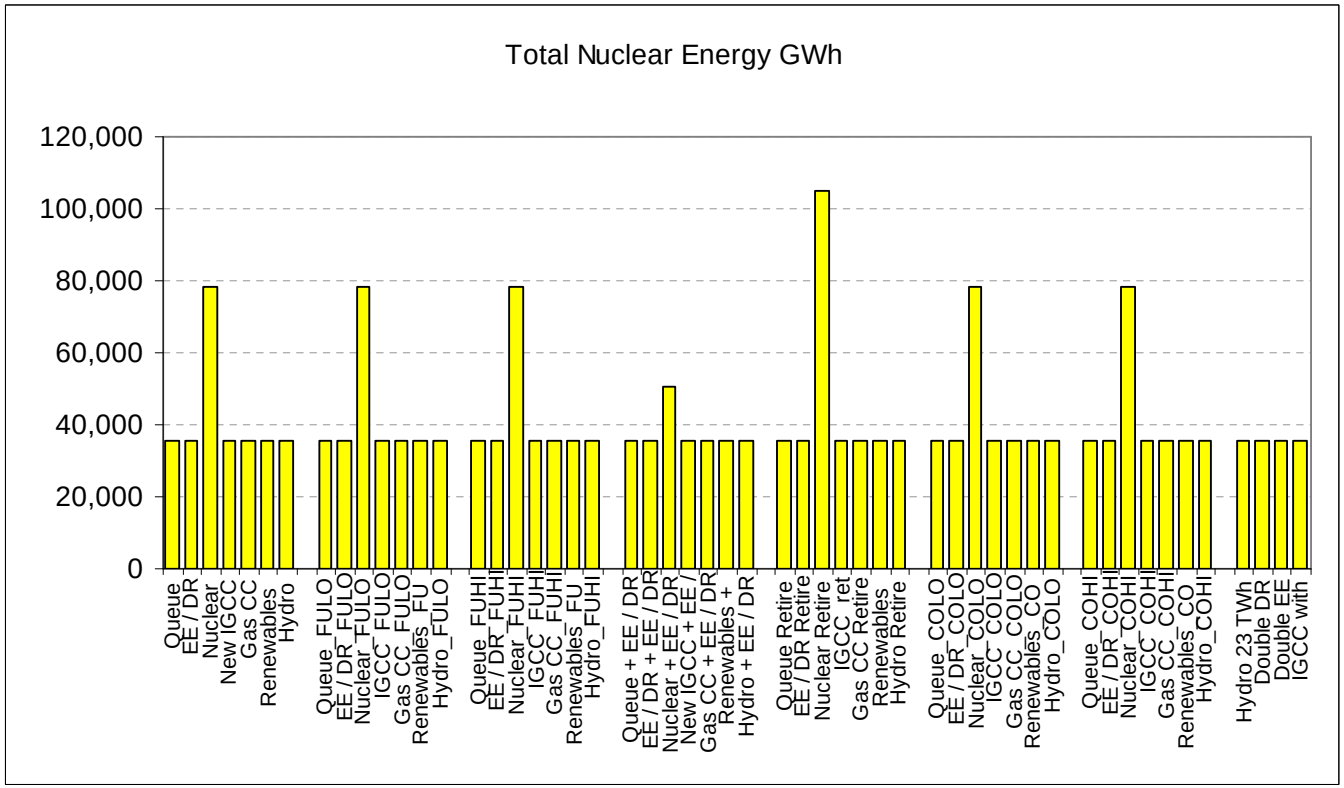
# Energy Production by Fuel Category or Load Response Category (GWh)

# GWh Energy Production by Fuel Category

- Following slides show the energy production in each scenario and sensitivity case.
  - Seven scenarios
  - Seven common sensitivity cases for each scenario
  - Four miscellaneous sensitivity cases
  - Total 53 cases for each metric (or category)

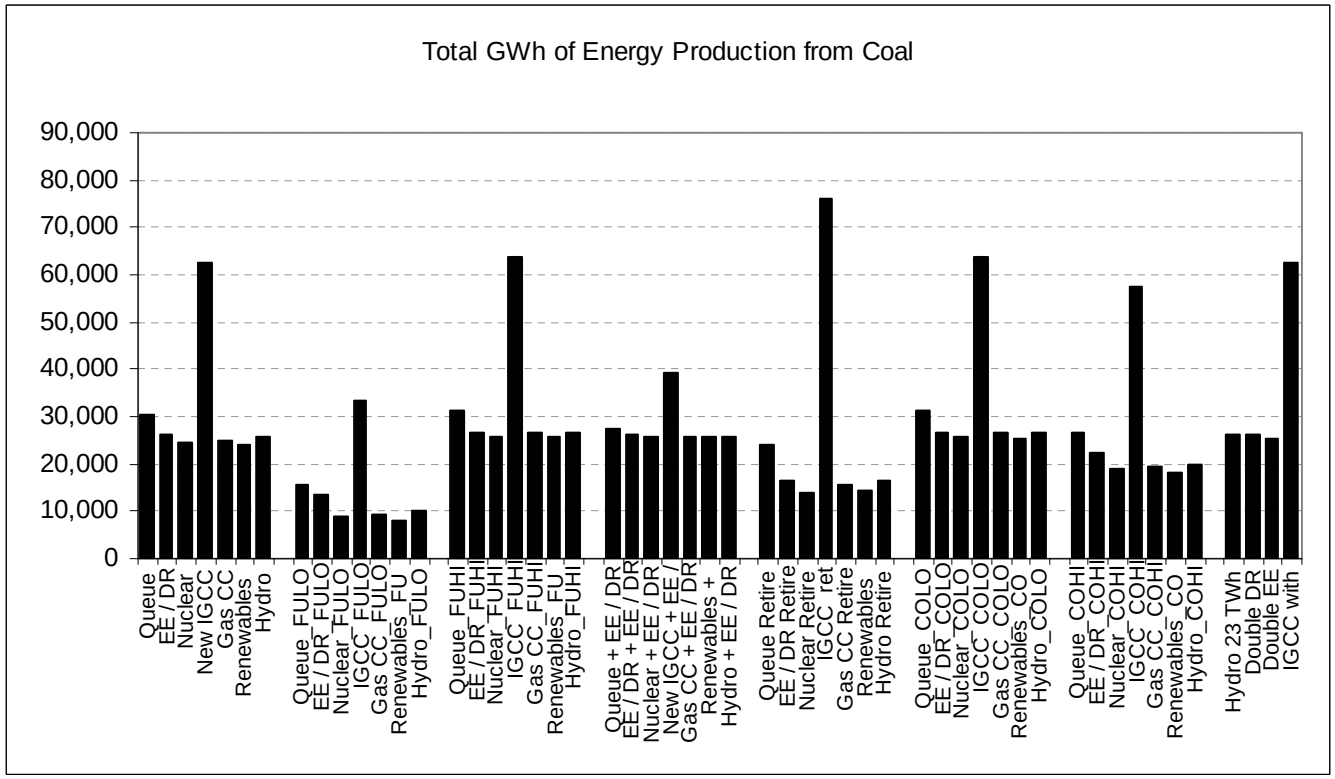
# Total GWh: Nuclear

## Grouped by Sensitivity



# Total GWh: Coal

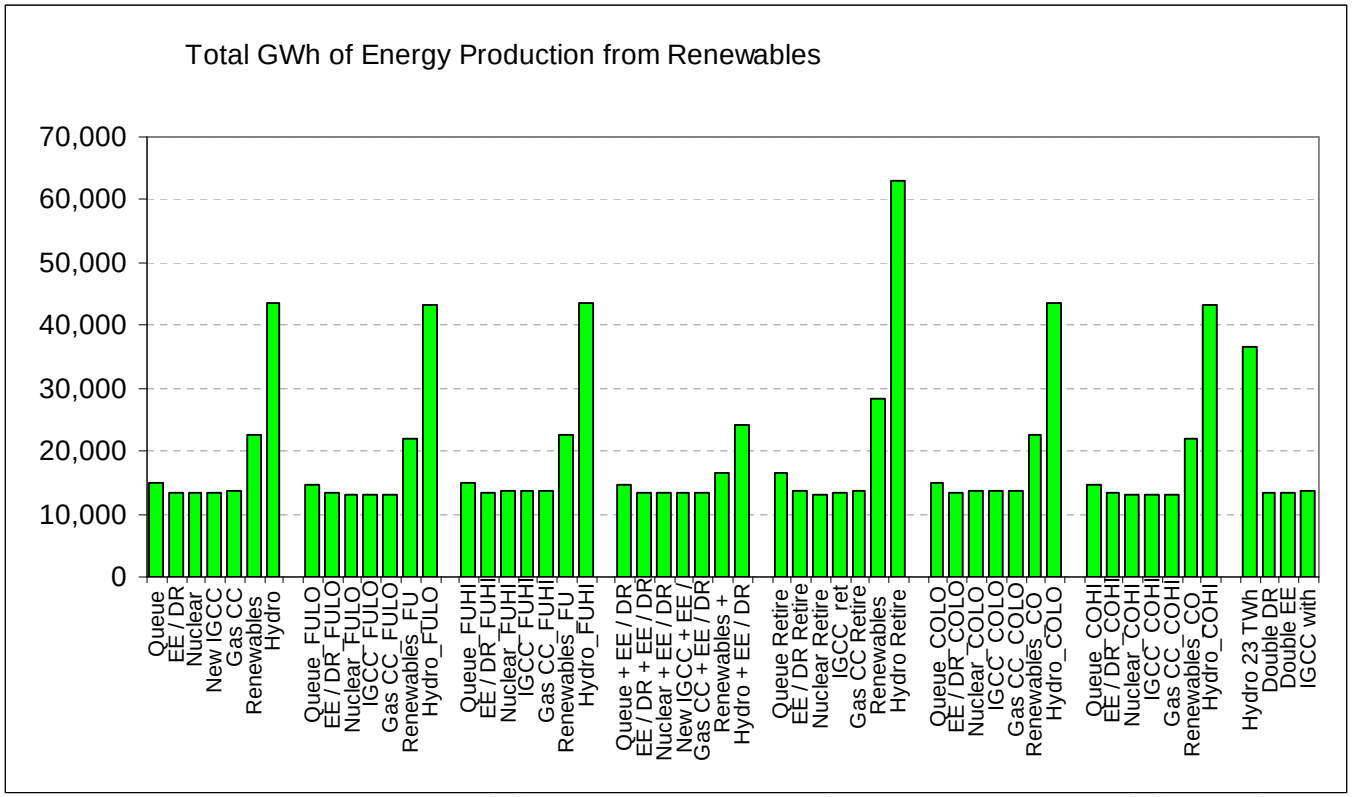
## Grouped by Sensitivity




**Common Assumptions** | **Low Fuel** | **High Fuel** | **More EE / DR Less Scenario Technology** | **Retire 3,500 MW** | **Low $CO_2$ Emission Values** | **High $CO_2$ Emission Values** | **Misc. Sensitivity Cases**

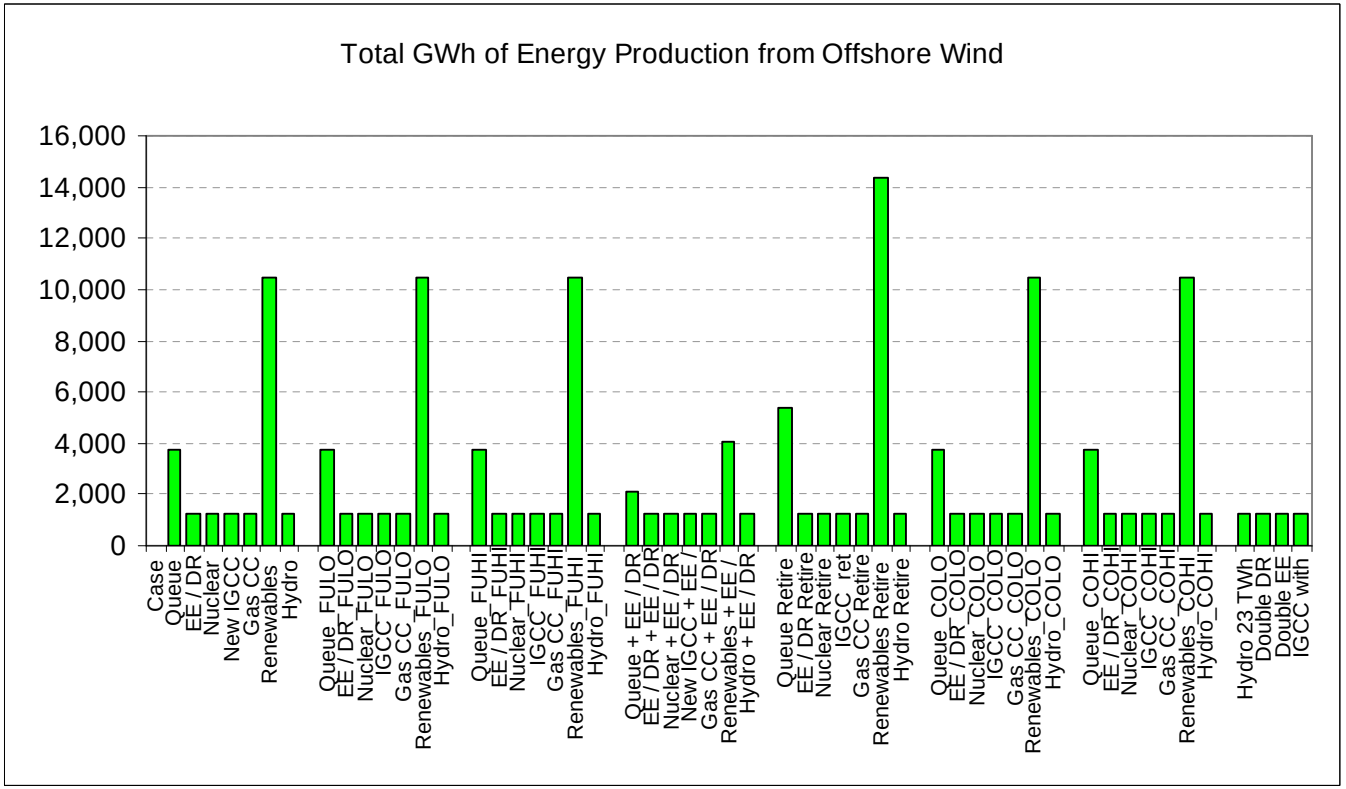
# Total GWh: Biomass and Hydro

## Grouped by Sensitivity



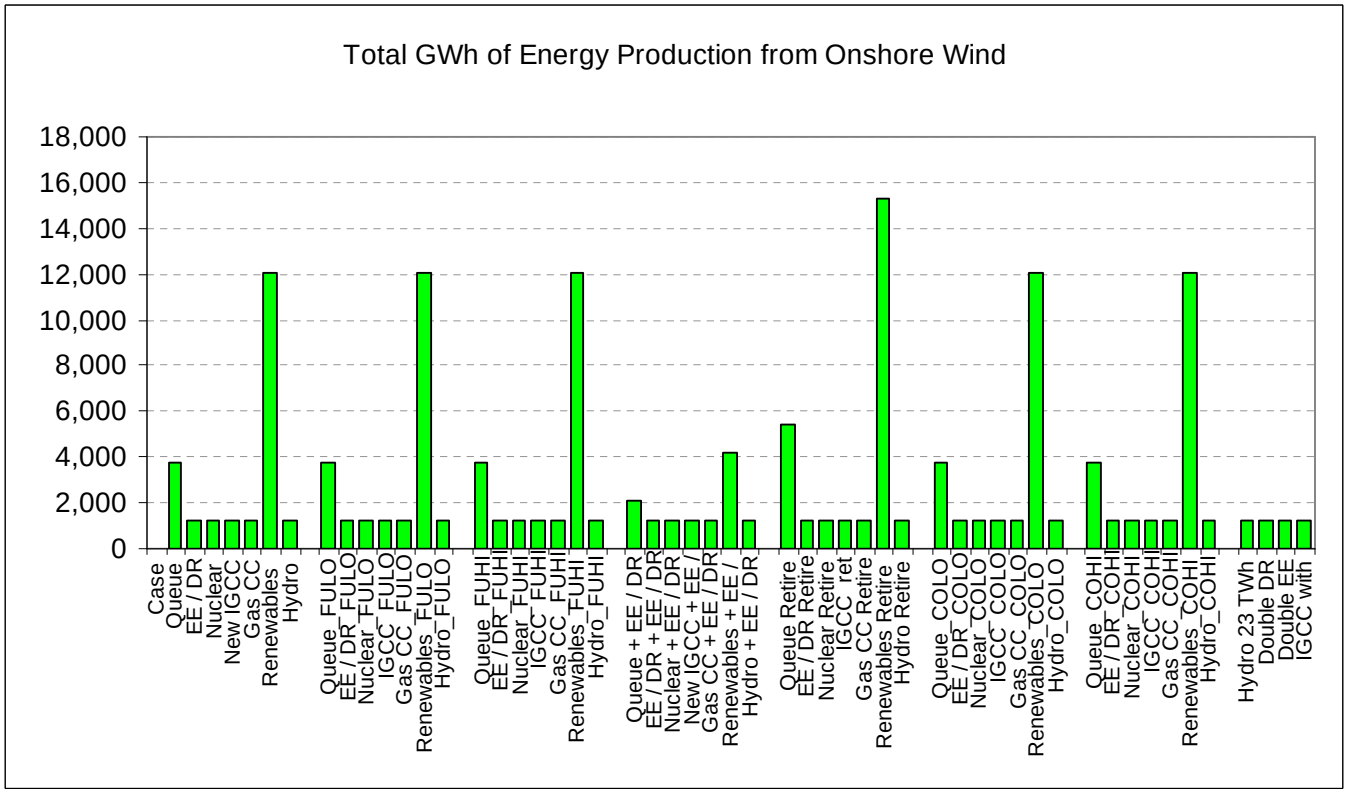
# Total GWh: Offshore Wind

## Grouped by Sensitivity



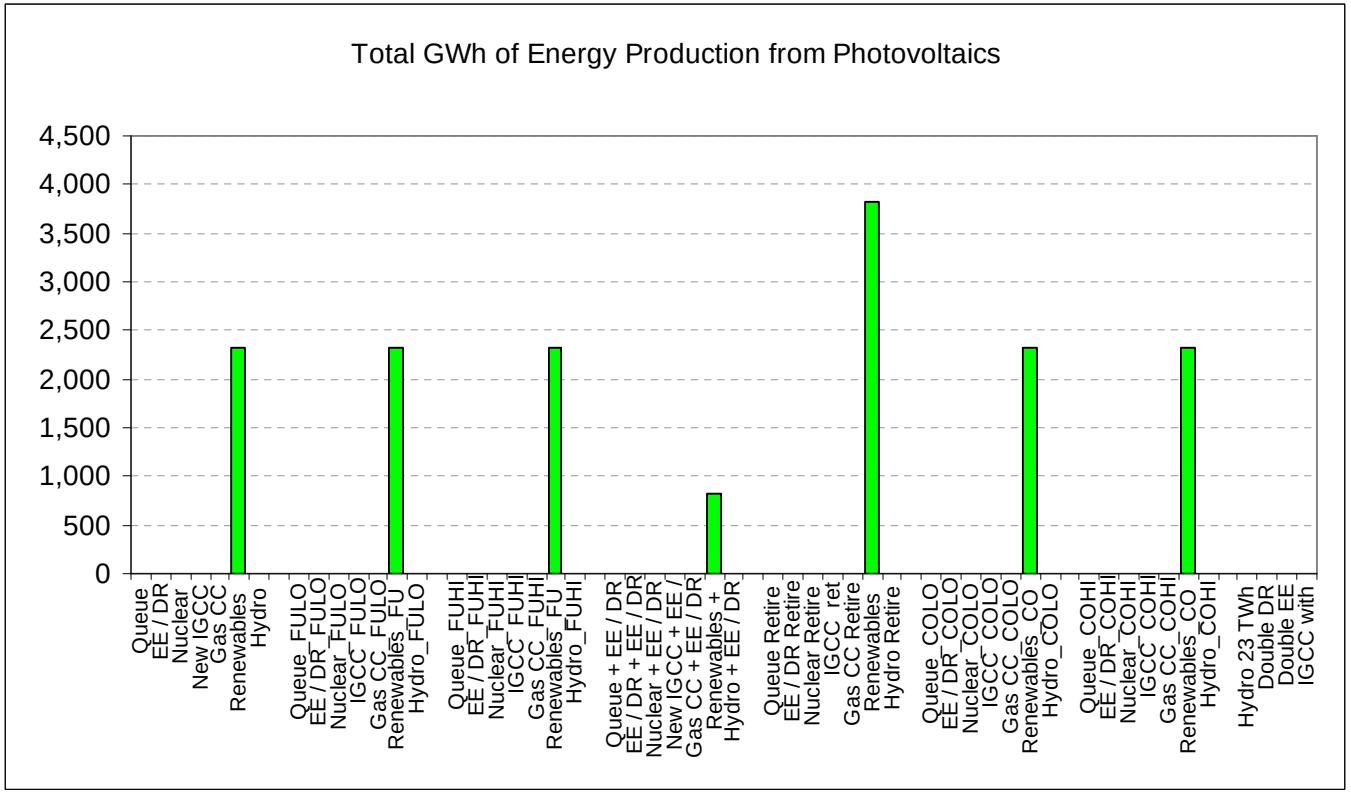
# Total GWh: Onshore Wind

## Grouped by Sensitivity



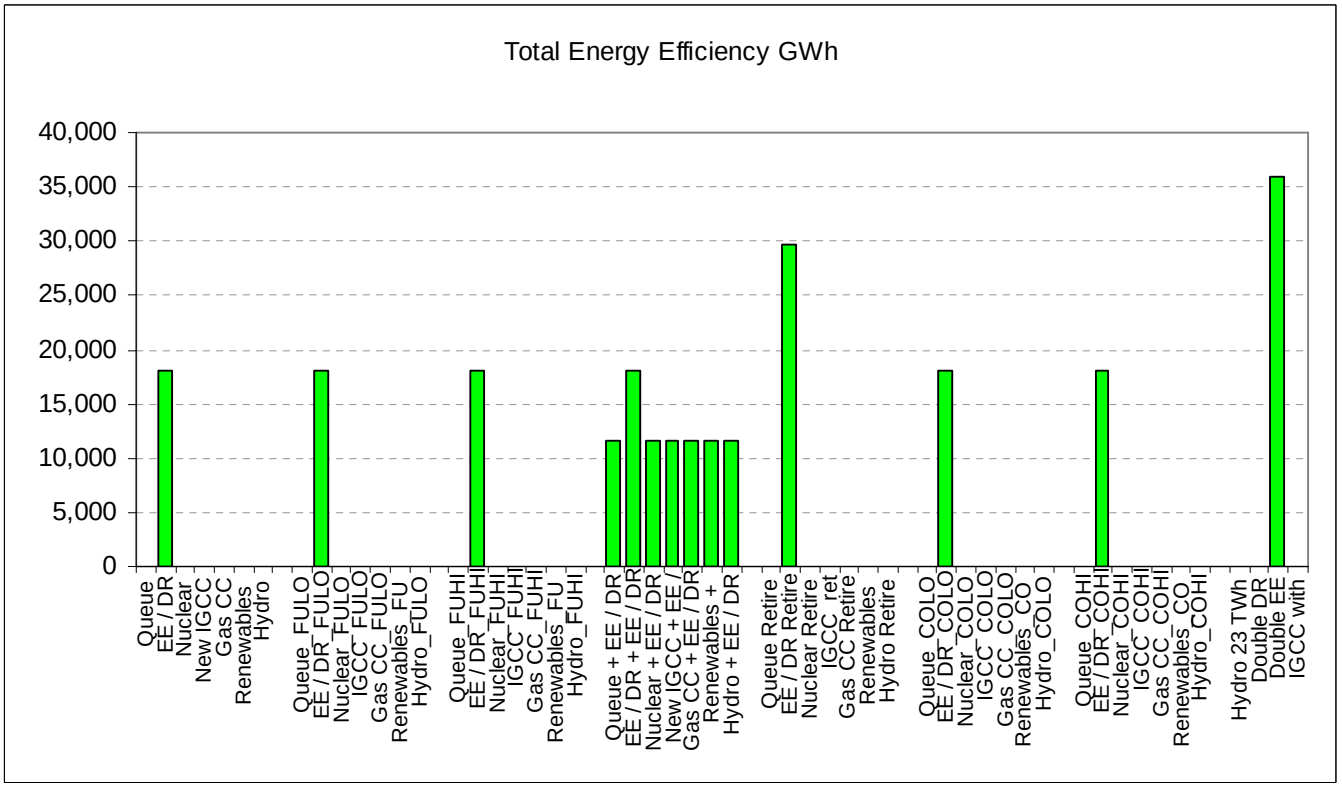
# Total GWh: Photovoltaics

## Grouped by Sensitivity



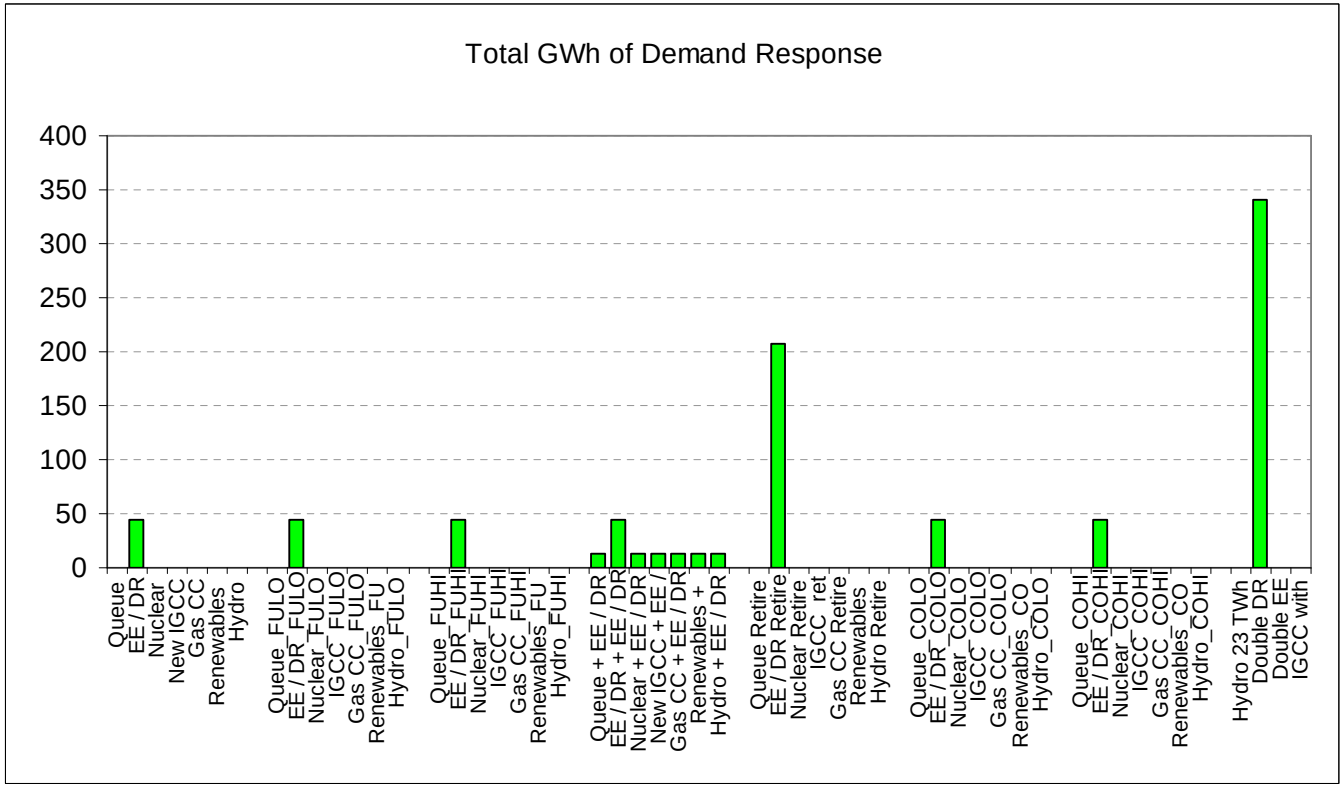
# Total GWh: Energy Efficiency

## Grouped by Sensitivity



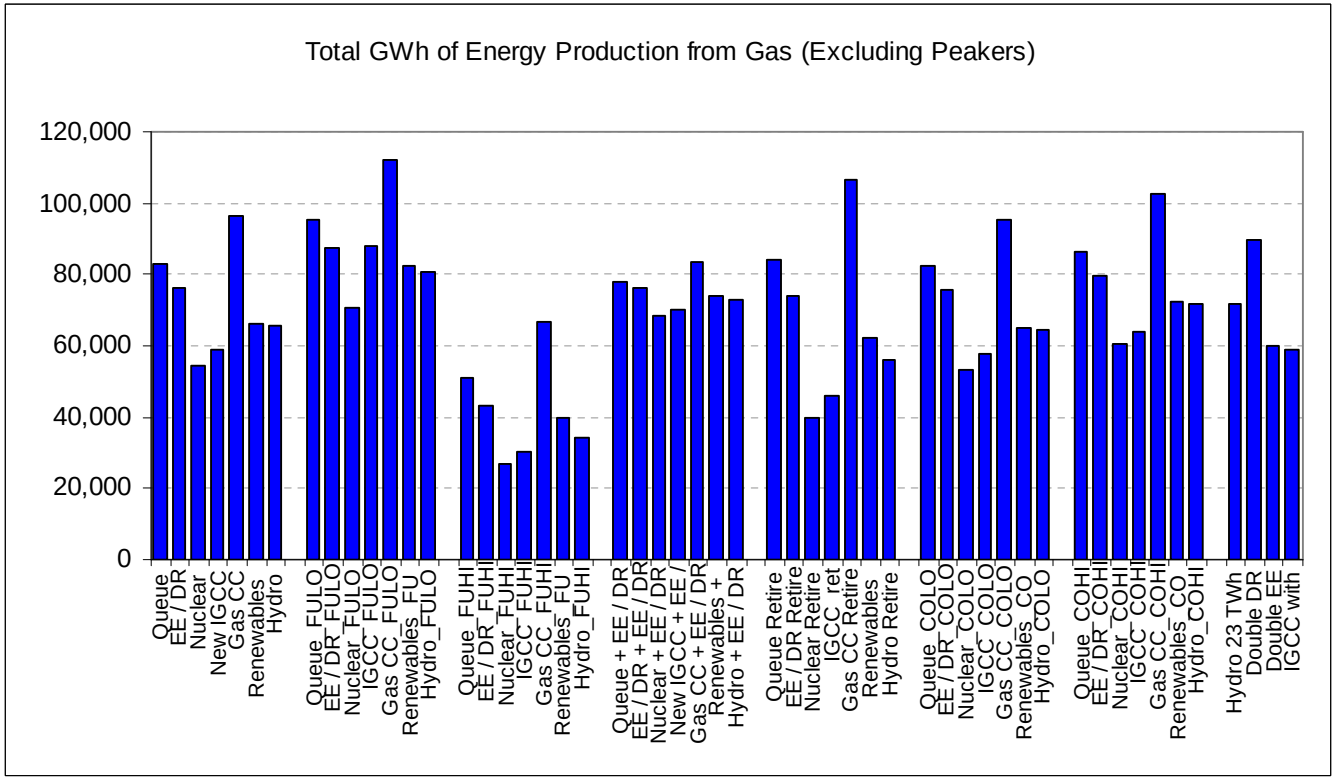
# Total GWh: Demand Response

## Grouped by Sensitivity



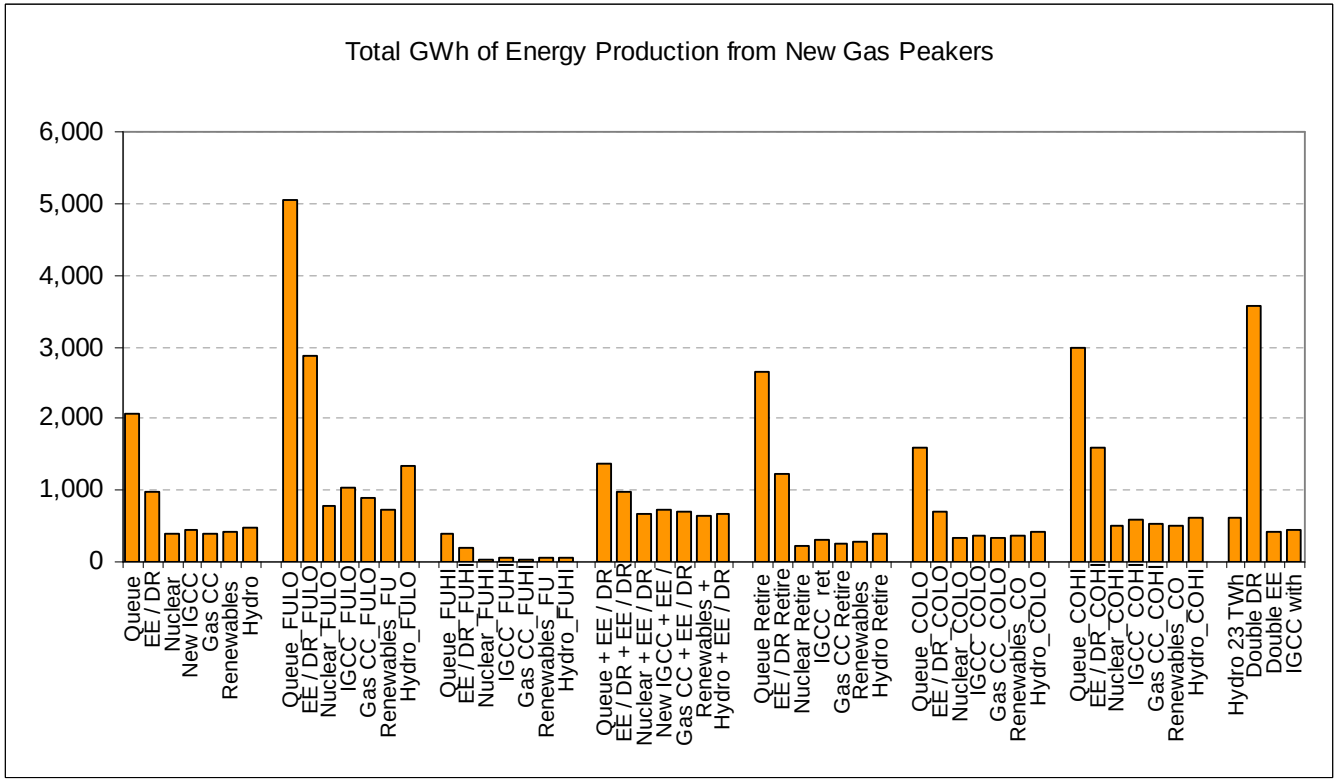
# Total GWh: Gas

## Grouped by Sensitivity



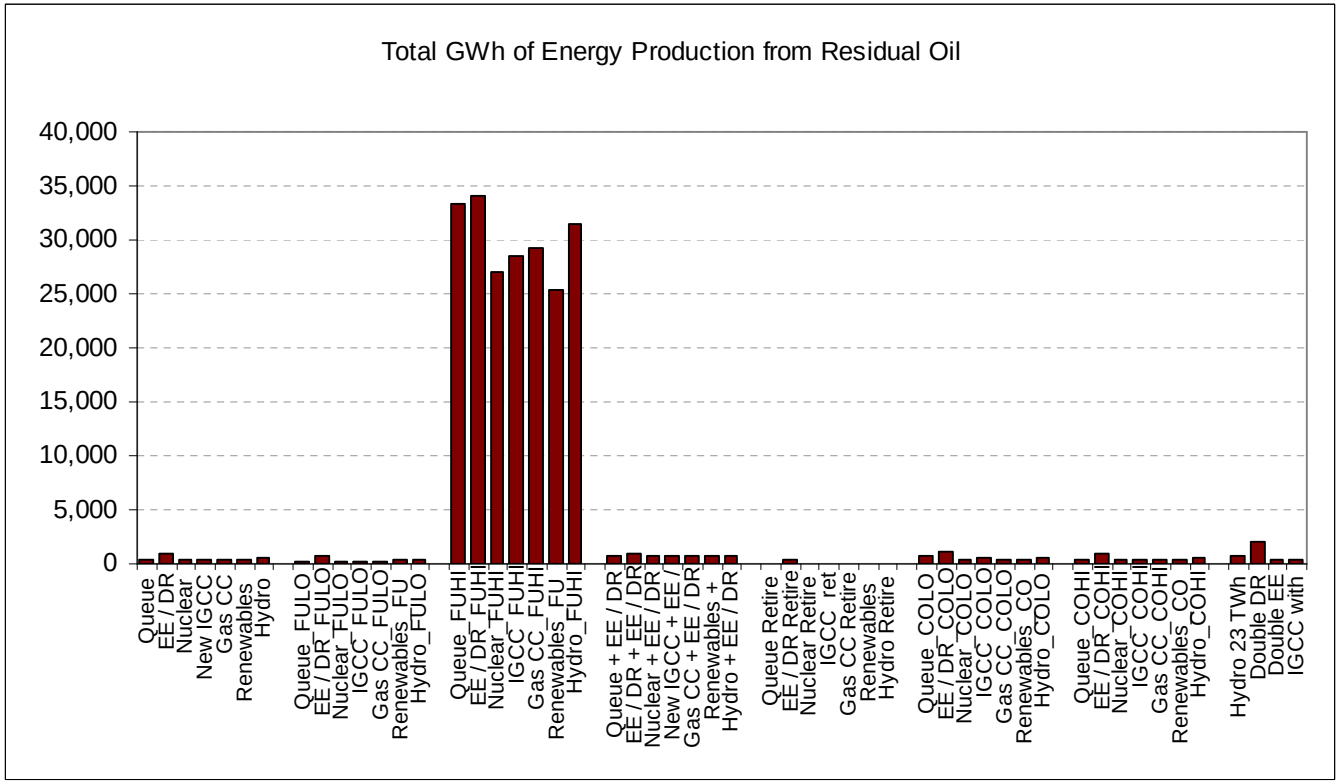
# Total GWh: From New Gas Peakers

## Grouped by Sensitivity



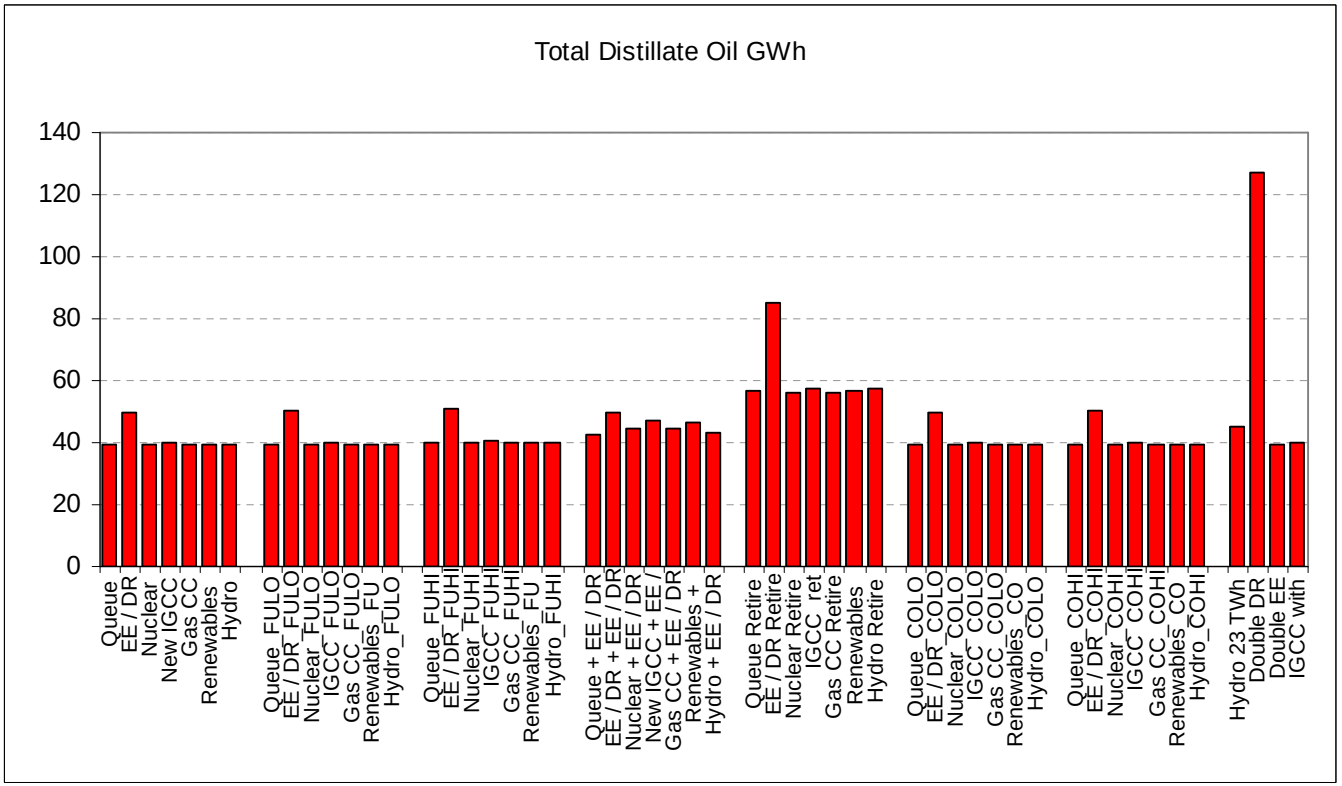
# Total GWh: Residual Oil

## Grouped by Sensitivity



# Total GWh: Distillate Fuel Oil

## Grouped by Sensitivity



# Total GWh: Nuclear

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 35,596 | 35,596 | 35,596 | 35,596 | | | 35,596 | 35,596 | 35,596 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 35,596 | 35,596 | 35,596 | 35,596 | 35,596 | 35,596 | 35,596 | 35,596 | 35,596 | | |
| 3 | **Nuclear —** 5,400 MW | 78,191 | 78,190 | 78,190 | 50,585 | | | 104,837 | 78,179 | 78,194 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 35,596 | 35,596 | 35,596 | 35,596 | | | 35,596 | 35,596 | 35,596 | 35,596 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 35,596 | 35,596 | 35,596 | 35,596 | | | 35,596 | 35,596 | 35,596 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 35,595 | 35,564 | 35,595 | 35,596 | | | 35,566 | 35,591 | 35,596 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 35,596 | 35,596 | 35,596 | 35,596 | | | 35,596 | 35,596 | 35,596 | | 35,596 |

# Total GWh: Coal

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 30,482 | 15,817 | 31,131 | 27,600 | | | 24,009 | 31,178 | 26,773 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 26,056 | 13,411 | 26,625 | 26,056 | 25,491 | 26,313 | 16,686 | 26,671 | 22,362 | | |
| 3 | **Nuclear —** 5,400 MW | 24,502 | 8,820 | 25,610 | 25,755 | | | 13,989 | 25,660 | 19,054 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 62,716 | 33,491 | 63,730 | 39,095 | | | 76,194 | 63,792 | 57,673 | 62,679 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 25,011 | 9,325 | 26,493 | 25,805 | | | 15,711 | 26,516 | 19,502 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 23,942 | 7,826 | 25,674 | 25,766 | | | 14,178 | 25,285 | 18,217 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 25,767 | 9,974 | 26,521 | 25,978 | | | 16,337 | 26,595 | 20,030 | | 26,016 |

# Total GWh: Renewables w/o Wind and PV

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 14,918 | 14,648 | 14,914 | 14,588 | | | 16,690 | 14,902 | 14,636 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 13,505 | 13,245 | 13,491 | 13,505 | 13,489 | 13,510 | 13,530 | 13,497 | 13,225 | | |
| 3 | **Nuclear —** 5,400 MW | 13,484 | 13,110 | 13,577 | 13,494 | | | 12,917 | 13,527 | 13,050 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 13,516 | 13,135 | 13,589 | 13,512 | | | 13,478 | 13,535 | 13,125 | 13,540 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 13,541 | 13,143 | 13,611 | 13,518 | | | 13,589 | 13,560 | 13,102 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 22,534 | 22,074 | 22,639 | 16,686 | | | 28,326 | 22,595 | 22,035 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 43,575 | 43,250 | 43,571 | 24,082 | | | 63,139 | 43,564 | 43,196 | | 36,553 |

# Total GWh: Offshore Wind

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 3,771 | 3,771 | 3,771 | 2,119 | | | 5,415 | 3,771 | 3,771 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 1,226 | 1,226 | 1,226 | 1,226 | 1,226 | 1,226 | 1,226 | 1,226 | 1,226 | | |
| 3 | **Nuclear —** 5,400 MW | 1,226 | 1,226 | 1,226 | 1,226 | | | 1,226 | 1,226 | 1,226 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 1,226 | 1,226 | 1,226 | 1,226 | | | 1,226 | 1,226 | 1,226 | 1,226 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 1,226 | 1,226 | 1,226 | 1,226 | | | 1,226 | 1,226 | 1,226 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 10,495 | 10,495 | 10,495 | 4,035 | | | 14,376 | 10,495 | 10,495 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 1,226 | 1,226 | 1,226 | 1,226 | | | 1,226 | 1,226 | 1,226 | | 1,226 |

# Total GWh: Onshore Wind

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 3,771 | 3,771 | 3,771 | 2,119 | | | 5,415 | 3,771 | 3,771 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 1,226 | 1,226 | 1,226 | 1,226 | 1,226 | 1,226 | 1,226 | 1,226 | 1,226 | | |
| 3 | **Nuclear —** 5,400 MW | 1,226 | 1,226 | 1,226 | 1,226 | | | 1,226 | 1,226 | 1,226 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 1,226 | 1,226 | 1,226 | 1,226 | | | 1,226 | 1,226 | 1,226 | 1,226 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 1,226 | 1,226 | 1,226 | 1,226 | | | 1,226 | 1,226 | 1,226 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 12,022 | 12,022 | 12,022 | 4,227 | | | 15,288 | 12,022 | 12,022 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 1,226 | 1,226 | 1,226 | 1,226 | | | 1,226 | 1,226 | 1,226 | | 1,226 |

# Total GWh: Photovoltaics

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 3 | **Nuclear —** 5,400 MW | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 2,321 | 2,321 | 2,321 | 815 | | | 3,825 | 2,321 | 2,321 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | | 0 |

# Total GWh: Energy Efficiency

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 0 | 0 | 0 | 11,669 | | | 0 | 0 | 0 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 18,005 | 18,005 | 18,005 | 18,005 | 36,009 | 0 | 29,674 | 18,005 | 18,005 | | |
| 3 | **Nuclear —** 5,400 MW | 0 | 0 | 0 | 11,669 | | | 0 | 0 | 0 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 0 | 0 | 0 | 11,669 | | | 0 | 0 | 0 | 0 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 0 | 0 | 0 | 11,669 | | | 0 | 0 | 0 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 0 | 0 | 0 | 11,669 | | | 0 | 0 | 0 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 0 | 0 | 0 | 11,669 | | | 0 | 0 | 0 | | 0 |

# Total GWh: Demand Response

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 0 | 0 | 0 | 13 | | | 0 | 0 | 0 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 45 | 45 | 45 | 45 | 0 | 342 | 207 | 45 | 45 | | |
| 3 | **Nuclear —** 5,400 MW | 0 | 0 | 0 | 13 | | | 0 | 0 | 0 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 0 | 0 | 0 | 13 | | | 0 | 0 | 0 | 0 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 0 | 0 | 0 | 13 | | | 0 | 0 | 0 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 0 | 0 | 0 | 13 | | | 0 | 0 | 0 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 0 | 0 | 0 | 13 | | | 0 | 0 | 0 | | 0 |

# Total GWh: Gas (Except New Peakers)

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 82,916 | 95,122 | 51,061 | 78,162 | | | 84,165 | 82,329 | 86,100 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 76,318 | 87,568 | 43,379 | 76,318 | 60,023 | 89,957 | 74,168 | 75,773 | 79,756 | | |
| 3 | **Nuclear —** 5,400 MW | 54,640 | 70,483 | 27,174 | 68,633 | | | 39,610 | 53,449 | 60,455 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 58,877 | 87,989 | 30,153 | 70,172 | | | 45,987 | 57,763 | 64,205 | 58,895 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 96,666 | 112,422 | 66,631 | 83,530 | | | 106,451 | 95,115 | 102,521 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 66,265 | 82,634 | 39,849 | 73,764 | | | 62,152 | 64,888 | 72,432 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 65,528 | 80,904 | 34,294 | 72,719 | | | 56,002 | 64,711 | 71,523 | | 72,023 |

# Total GWh: Gas for New Peakers

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 2,057 | 5,049 | 387 | 1,354 | | | 2,664 | 1,590 | 2,987 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 990 | 2,878 | 200 | 990 | 406 | 3,568 | 1,234 | 705 | 1,589 | | |
| 3 | **Nuclear —** 5,400 MW | 381 | 782 | 32 | 663 | | | 235 | 325 | 489 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 438 | 1,024 | 42 | 734 | | | 296 | 359 | 589 | 438 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 398 | 886 | 32 | 688 | | | 243 | 329 | 532 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 408 | 737 | 42 | 631 | | | 292 | 355 | 491 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 477 | 1,331 | 49 | 667 | | | 389 | 413 | 618 | | 603 |

# Total GWh: Residual Oil

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 437 | 153 | 33,319 | 712 | | | 17 | 796 | 336 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 962 | 718 | 34,124 | 962 | 462 | 2,119 | 369 | 1,178 | 917 | | |
| 3 | **Nuclear —** 5,400 MW | 323 | 138 | 27,033 | 662 | | | 20 | 392 | 302 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 384 | 202 | 28,495 | 698 | | | 36 | 485 | 365 | 387 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 330 | 153 | 29,243 | 677 | | | 20 | 433 | 304 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 393 | 282 | 25,400 | 714 | | | 36 | 437 | 385 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 542 | 422 | 31,458 | 754 | | | 43 | 594 | 544 | | 682 |

# Total GWh: Distillate Fuel Oil

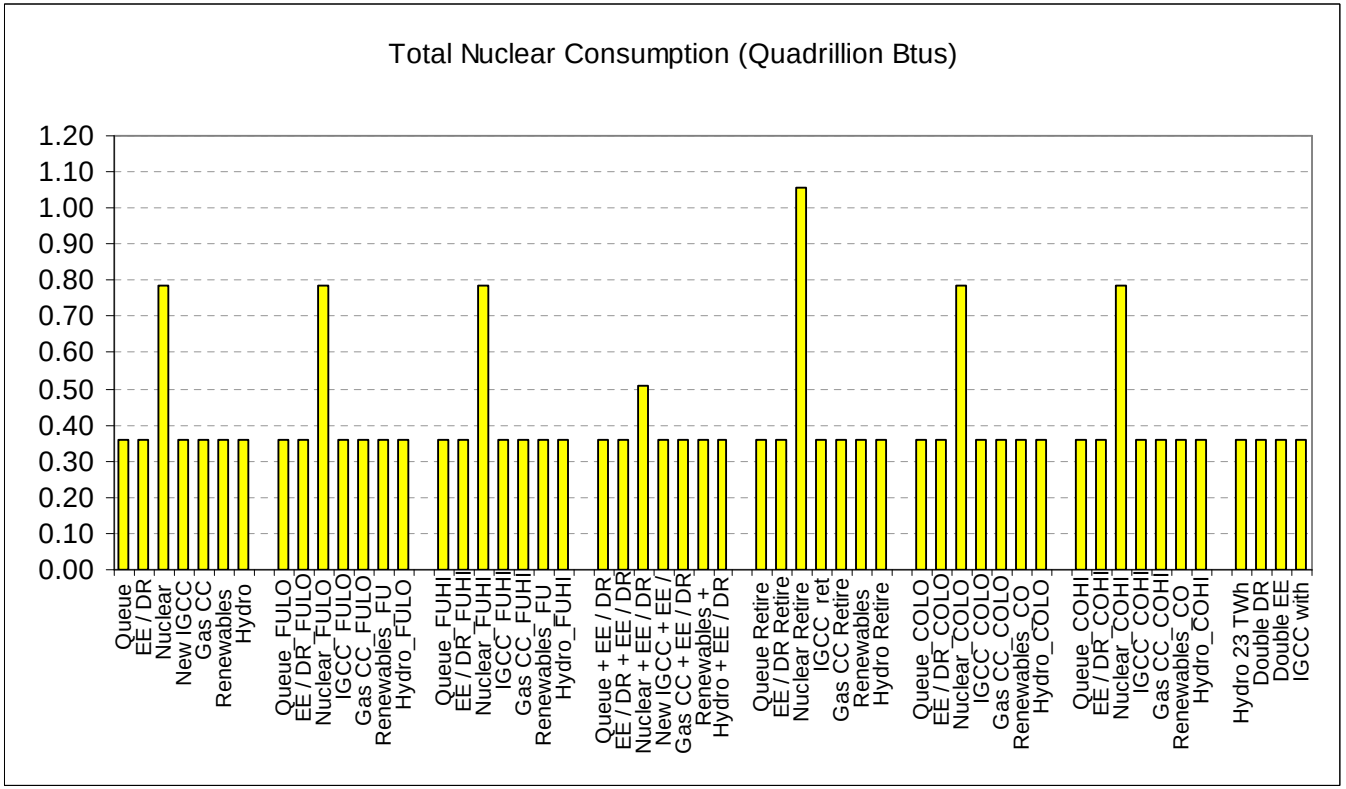
| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 40 | 39 | 40 | 43 | | | 57 | 40 | 40 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 50 | 50 | 51 | 50 | 39 | 127 | 85 | 50 | 50 | | |
| 3 | **Nuclear —** 5,400 MW | 39 | 39 | 40 | 44 | | | 56 | 39 | 39 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 40 | 40 | 41 | 47 | | | 57 | 40 | 40 | 40 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 40 | 39 | 40 | 44 | | | 56 | 40 | 39 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 39 | 39 | 40 | 47 | | | 57 | 39 | 39 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 39 | 39 | 40 | 43 | | | 57 | 39 | 39 | | 45 |

# Fuel Consumption
# (Quads – Billion MBtu Consumed)

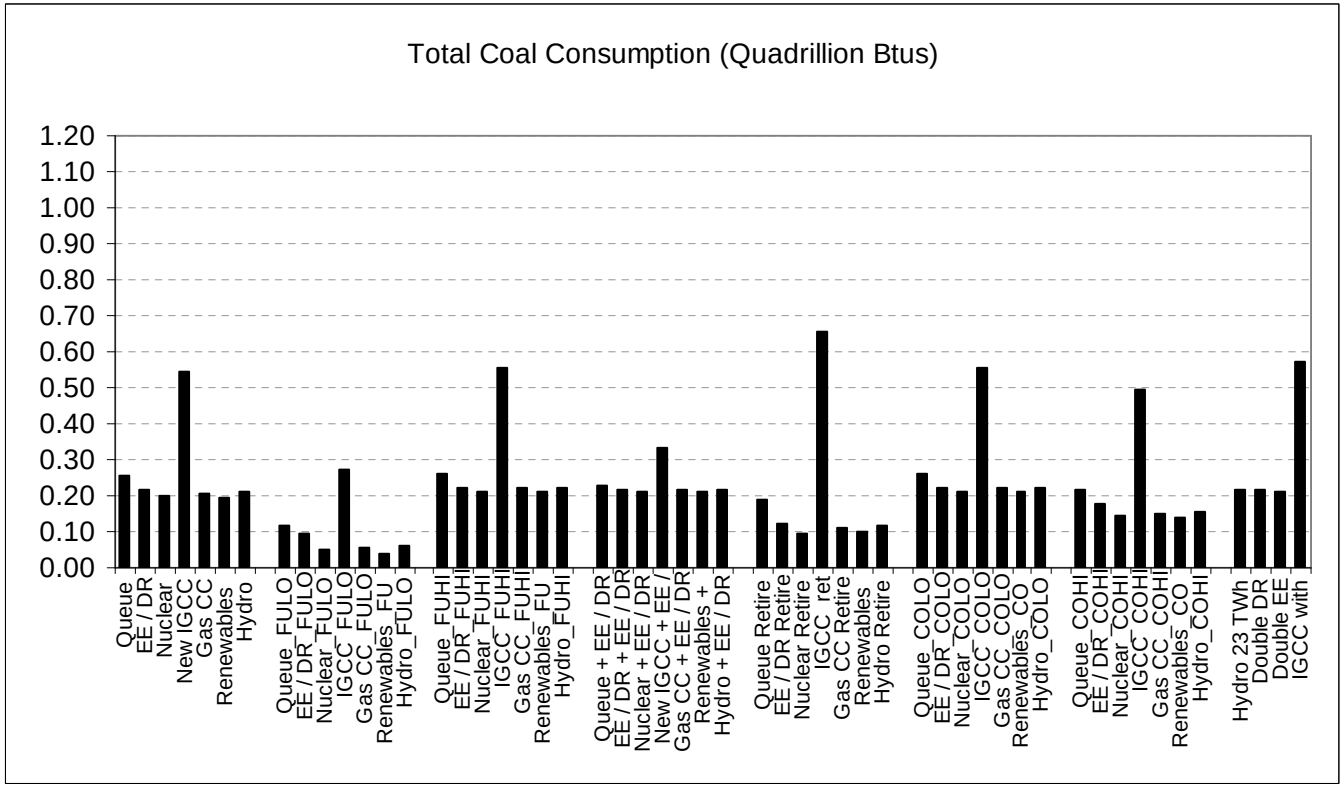
# Fuel Consumption for Energy Production

- Previous section showed MWh
- This shows similar composite information in terms of fuel consumption
  - Fuel consumption expressed in terms of Quads (Quadrillion Btus)
  - One Quad = One Billion MBtus
  - One Quad ~= 45 Million tons of coal
  - One Quad ~= 160 Million BBL of Oil
- Takes into account heat rate differences between resources

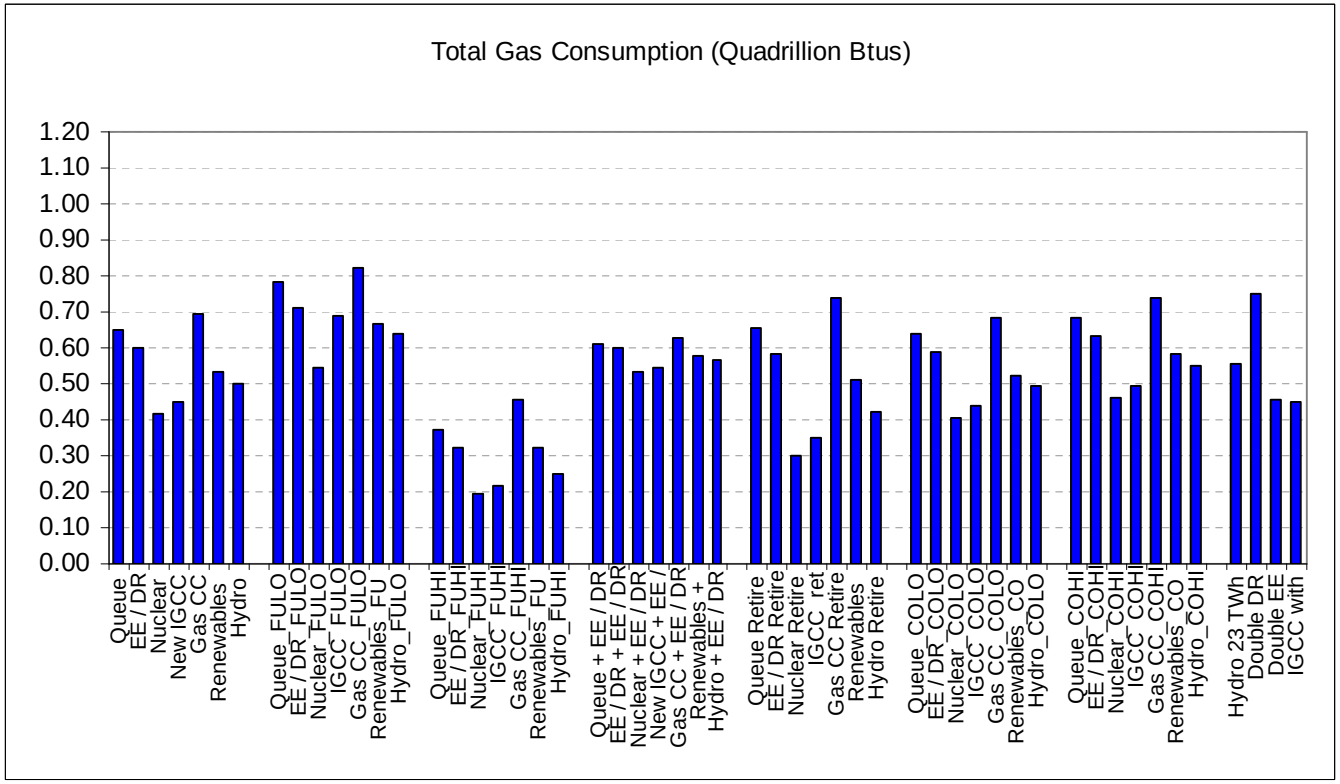
# Total Nuclear Energy Consumed Quads



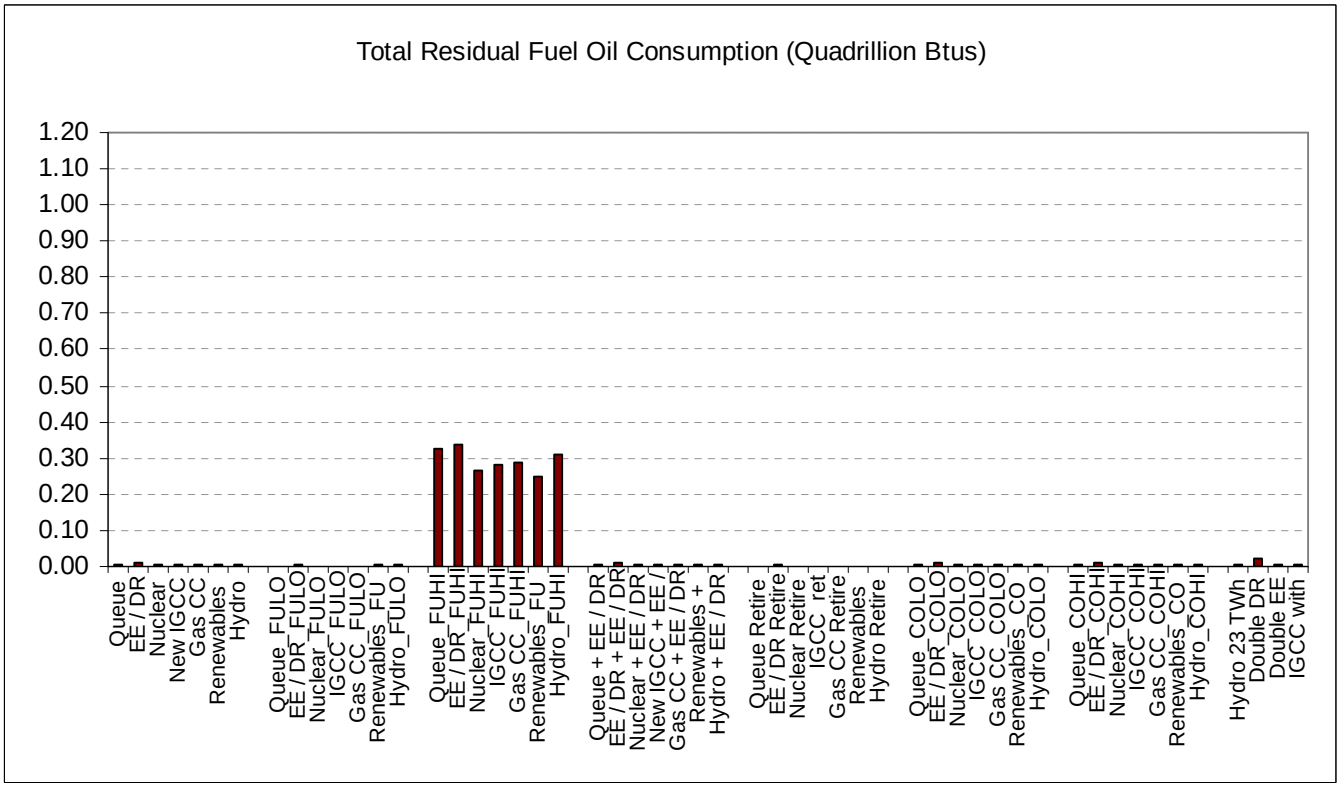
# Total Coal Energy Consumed Quads



# Total Gas Energy Consumed Quads



# Total Residual Fuel Oil Consumed Quads



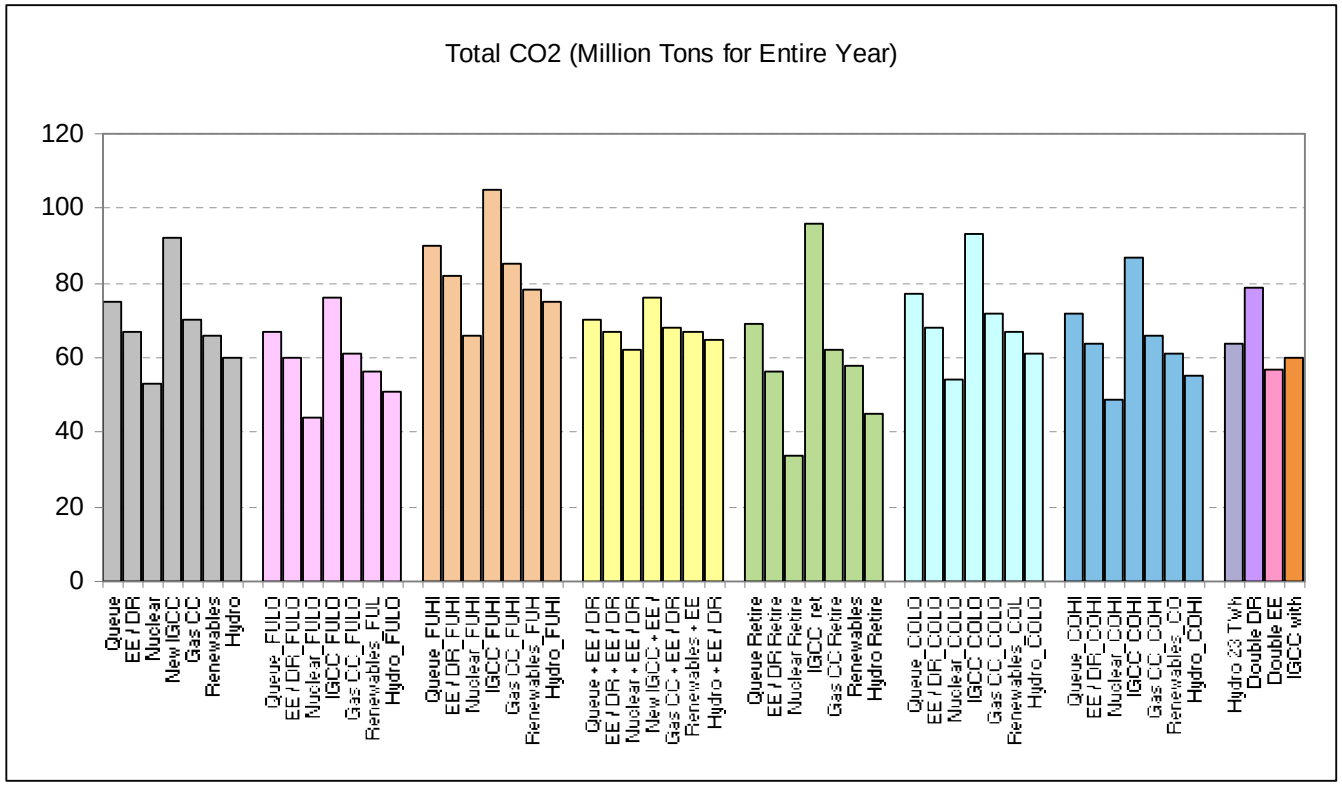
# Environmental Emissions

# Overview

- NOx, $CO_2$ and $SO_2$ emissions shown for New England
- NOx emissions are a critical concern to air regulators
- NOx emissions are typically
  - Disproportionately higher on high load days
  - Difficult to control for short term excursions
- Emission by fuel type used is informative
  - Gas subdivided into “Gas” and “Gas for Only New Peakers”
- Analysis provided here includes
  - Chronological NOx emissions for July and August
    - Peak load months
    - Excursions easily seen due to narrow spikes
  - Peak Day NOx Emission Profile
    - Shows trend across all hours of peak NOx day

# CO2 Emissions (Million Tons)

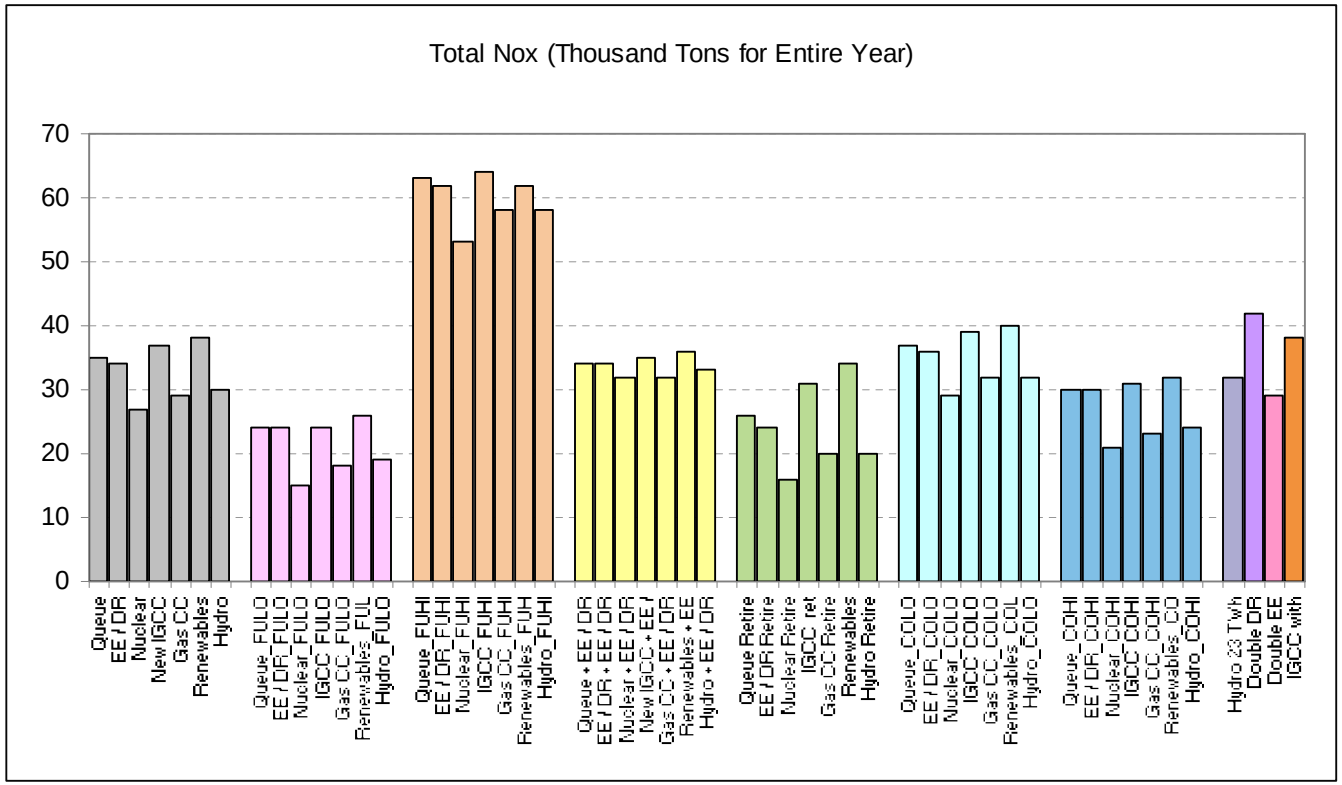
## Grouped by Sensitivity




**Common Assumptions** | **Low Fuel** | **High Fuel** | **More EE / DR Less Scenario Technology** | **Retire 3,500 MW** | **Low $CO_2$ Emission Values** | **High $CO_2$ Emission Values** | **Misc. Sensitivity Cases**

# SO2 Emissions (Thousand Tons)

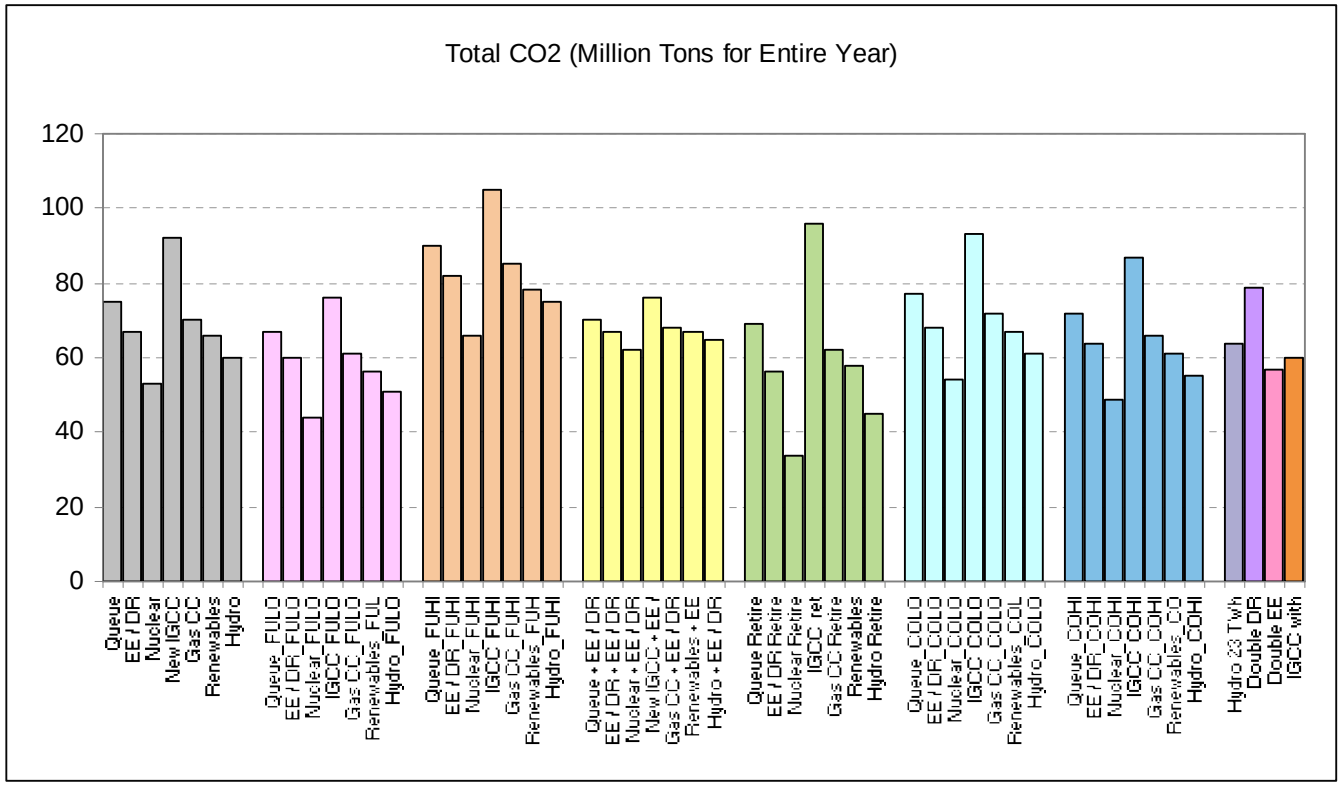
## Grouped by Sensitivity




**Common Assumptions** | **Low Fuel** | **High Fuel** | **More EE / DR Less Scenario Technology** | **Retire 3,500 MW** | **Low $CO_2$ Emission Values** | **High $CO_2$ Emission Values** | **Misc. Sensitivity Cases**

# NOx Emissions (Thousand Tons)

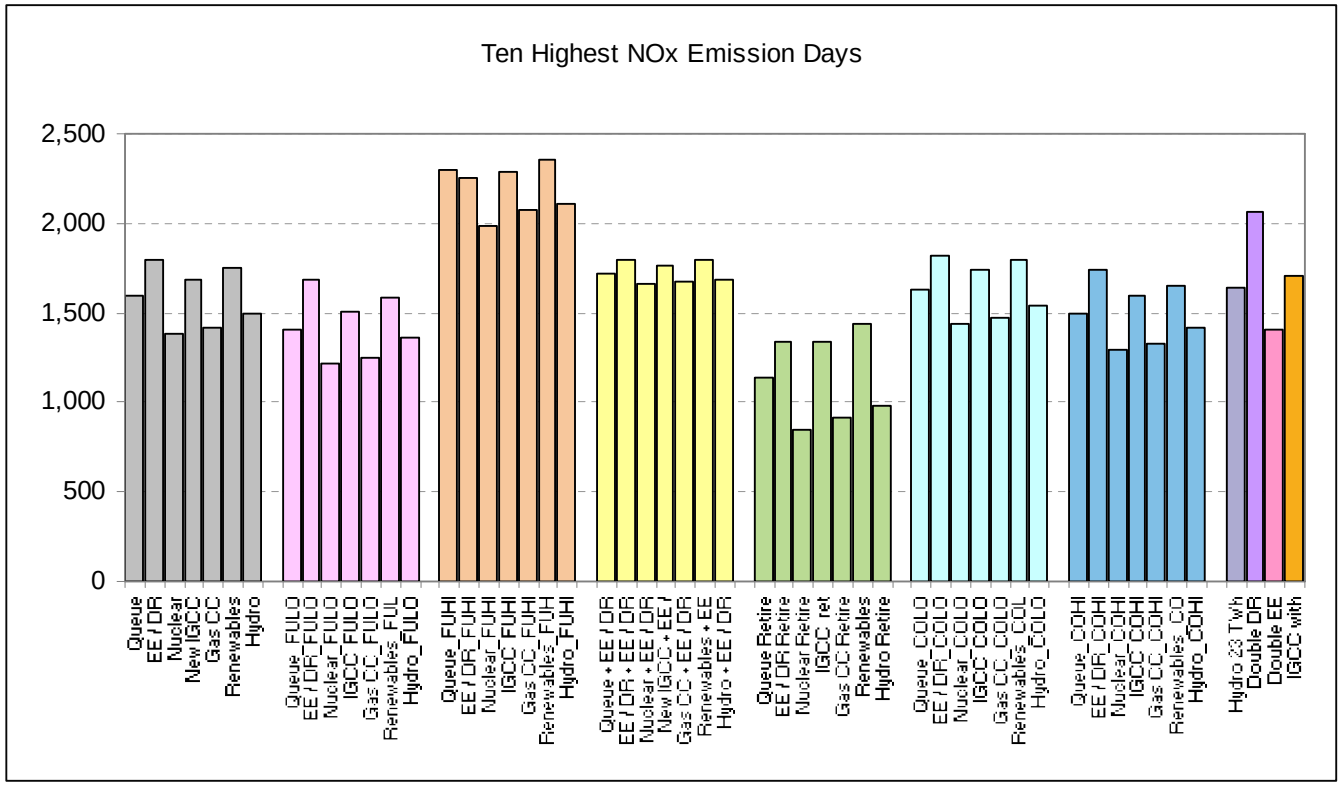
## Grouped by Sensitivity




**Common Assumptions** | **Low Fuel** | **High Fuel** | **More EE / DR Less Scenario Technology** | **Retire 3,500 MW** | **Low $CO_2$ Emission Values** | **High $CO_2$ Emission Values** | **Misc. Sensitivity Cases**

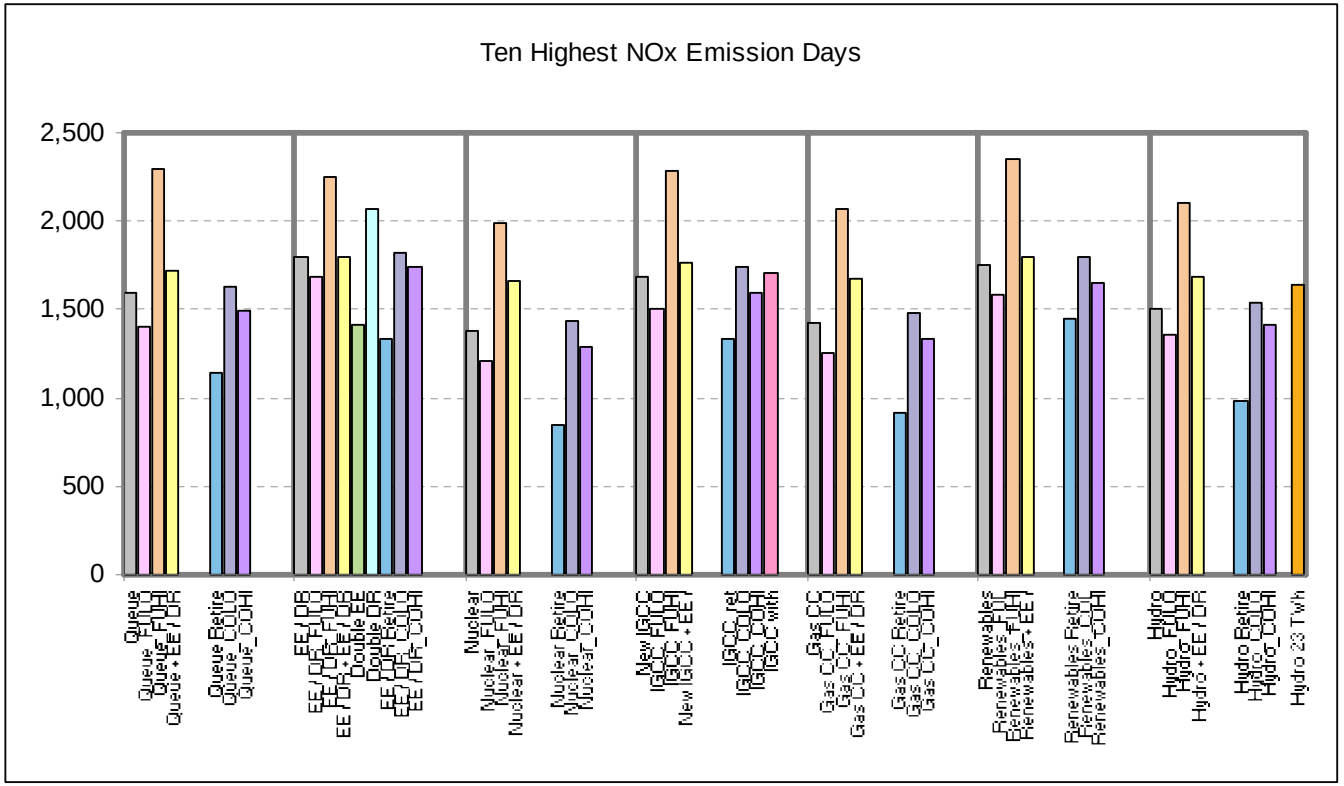
# Sum of Top Ten Days NOx Emissions (Tons)

## Grouped by Sensitivity



# Sum of Top Ten Days NOx Emissions (Tons)

## Grouped by Scenario



# Total Emission: $CO_2$ (Million Tons)

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 75 | 67 | 90 | 70 | | | 69 | 77 | 72 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 67 | 60 | 82 | 67 | 57 | 79 | 56 | 68 | 64 | | |
| 3 | **Nuclear —** 5,400 MW | 53 | 44 | 66 | 62 | | | 34 | 54 | 49 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 92 | 76 | 105 | 76 | | | 96 | 93 | 87 | 60 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 70 | 61 | 85 | 68 | | | 62 | 72 | 66 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 66 | 56 | 78 | 67 | | | 58 | 67 | 61 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 60 | 51 | 75 | 65 | | | 45 | 61 | 55 | | 64 |

# Total Emissions: $SO_2$ (Thousand Tons)

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 75 | 25 | 172 | 73 | | | 51 | 84 | 55 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 72 | 27 | 168 | 72 | 62 | 85 | 45 | 80 | 52 | | |
| 3 | **Nuclear —** 5,400 MW | 57 | 14 | 142 | 67 | | | 30 | 68 | 32 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 112 | 49 | 199 | 86 | | | 116 | 121 | 88 | 116 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 59 | 15 | 151 | 68 | | | 33 | 72 | 35 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 62 | 20 | 142 | 69 | | | 41 | 73 | 36 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 91 | 19 | 184 | 96 | | | 64 | 99 | 54 | | 95 |

# Total Emissions: $NO_x$ (Thousand Tons)

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 35 | 24 | 63 | 34 | | | 26 | 37 | 30 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 34 | 24 | 62 | 34 | 29 | 42 | 24 | 36 | 30 | | |
| 3 | **Nuclear —** 5,400 MW | 27 | 15 | 53 | 32 | | | 16 | 29 | 21 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 37 | 24 | 64 | 35 | | | 31 | 39 | 31 | 38 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 29 | 18 | 58 | 32 | | | 20 | 32 | 23 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 38 | 26 | 62 | 36 | | | 34 | 40 | 32 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 30 | 19 | 58 | 33 | | | 20 | 32 | 24 | | 32 |

# Sum of Top Ten Days NOx Emissions

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 1,592 | 1,404 | 2,296 | 1,715 | | | 1,142 | 1,629 | 1,499 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 1,798 | 1,683 | 2,252 | 1,798 | 1,410 | 2,064 | 1,335 | 1,824 | 1,737 | | |
| 3 | **Nuclear —** 5,400 MW | 1,383 | 1,213 | 1,989 | 1,658 | | | 849 | 1,437 | 1,293 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 1,685 | 1,508 | 2,285 | 1,767 | | | 1,334 | 1,737 | 1,597 | 1,708 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 1,423 | 1,253 | 2,072 | 1,672 | | | 915 | 1,477 | 1,333 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 1,748 | 1,584 | 2,351 | 1,794 | | | 1,444 | 1,795 | 1,657 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 1,501 | 1,359 | 2,107 | 1,682 | | | 988 | 1,535 | 1,413 | | 1,644 |

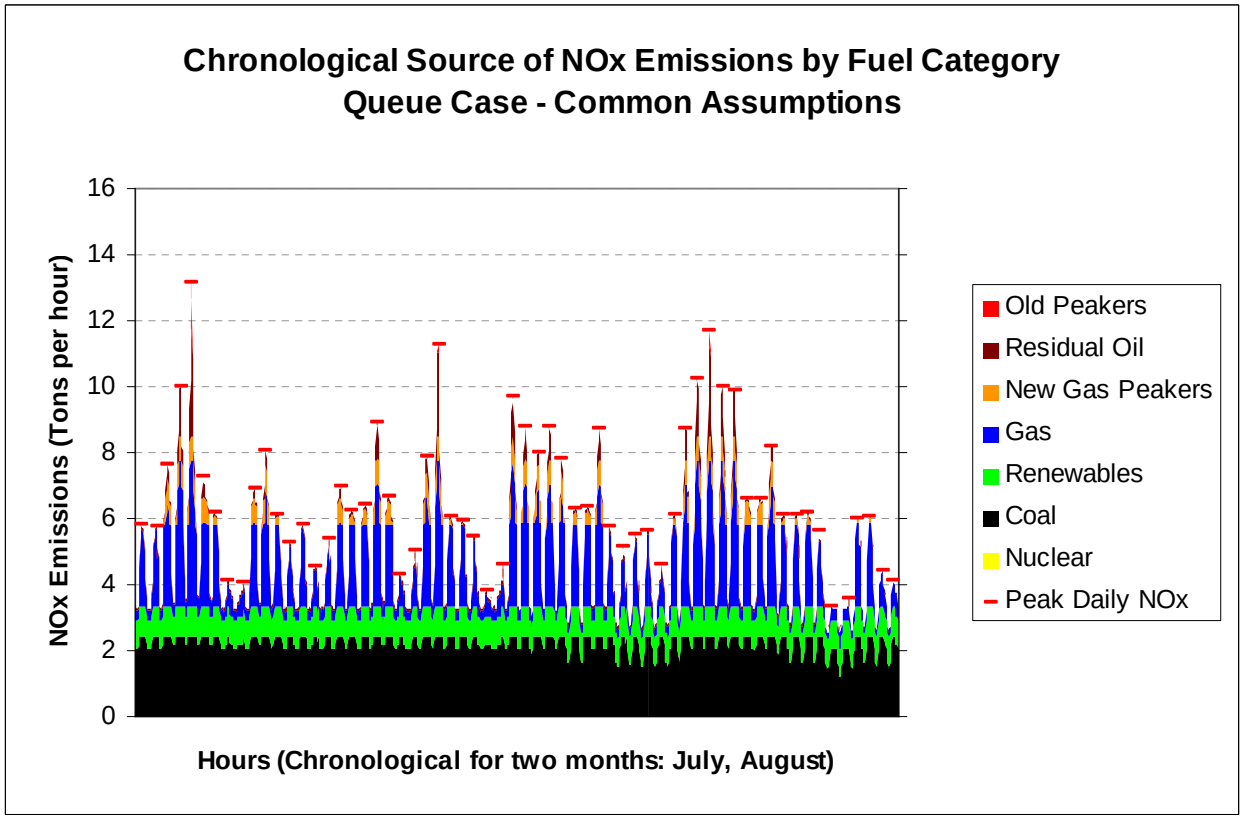
# Total Emissions: Mercury (pounds)

| | | A | C | B | D | E | F | G | I | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon-Allowance Prices** | **High Carbon-Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low-Emission Resources (-7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 1,403 | 627 | 1,441 | 1,260 | | | 1,029 | 1,441 | 1,205 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 1,188 | 506 | 1,221 | | 1,150 | 1,199 | 671 | 1,221 | 985 | | |
| 3 | **Nuclear —** 5,400 MW | 1,095 | 270 | 1,161 | 1,172 | | | 534 | 1,166 | 803 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 2,992 | 1,485 | 3,053 | 1,832 | | | 3,608 | 3,053 | 2,712 | 3,146 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 1,128 | 297 | 1,210 | 1,177 | | | 622 | 1,210 | 825 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on- and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 1,067 | 215 | 1,161 | 1,172 | | | 539 | 1,150 | 754 | | |
| 7 | **Increased imports of hydro and other low-emission resources —** 30 TWh of imports | 1,172 | 330 | 1,216 | 1,183 | | | 649 | 1,221 | 858 | | 1,183 |

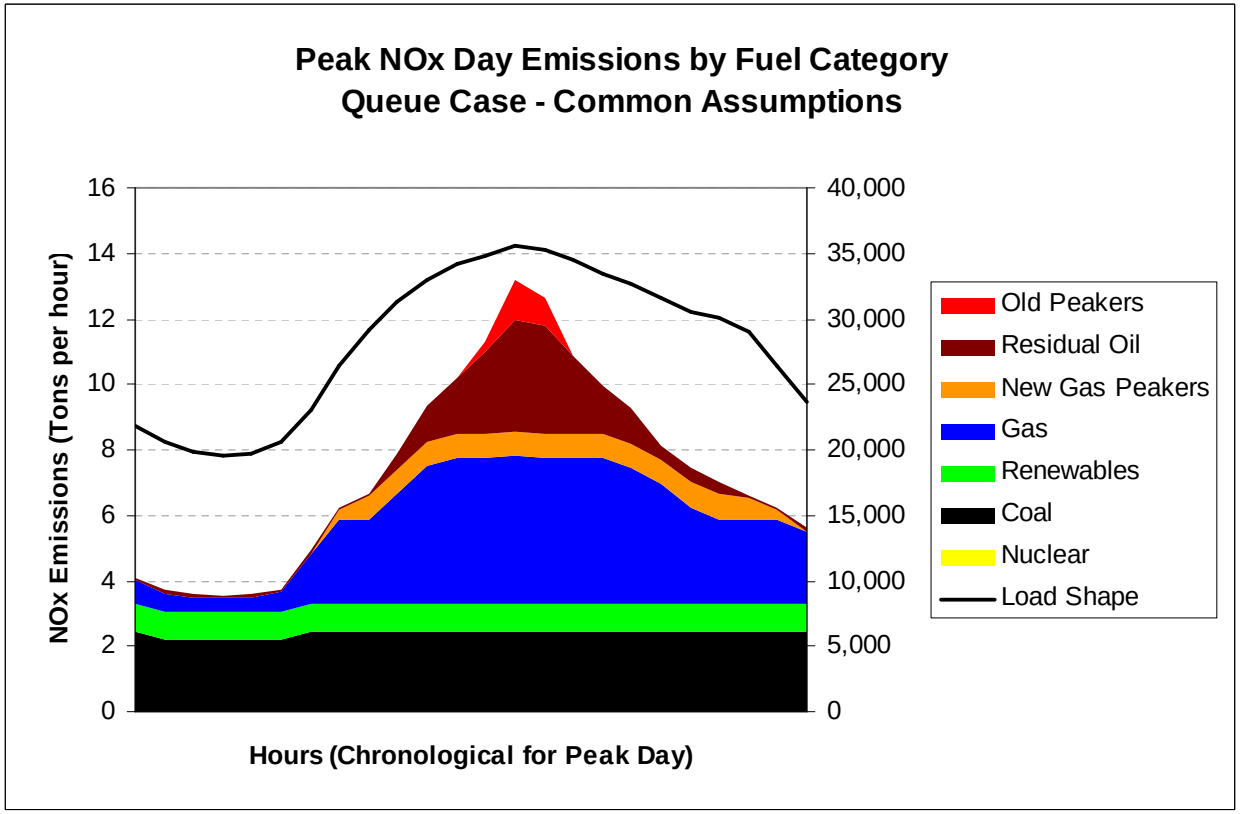
Based on Coal Consumption and 5.5 lb of Mercury per Trillion Btus (or 5500 lb per "Quad" of coal consumed)

# Summer Hourly NOx: Queue Case

Graphs do not show narrow, short duration excursions well. Red line used to show peak hourly NOx for each day

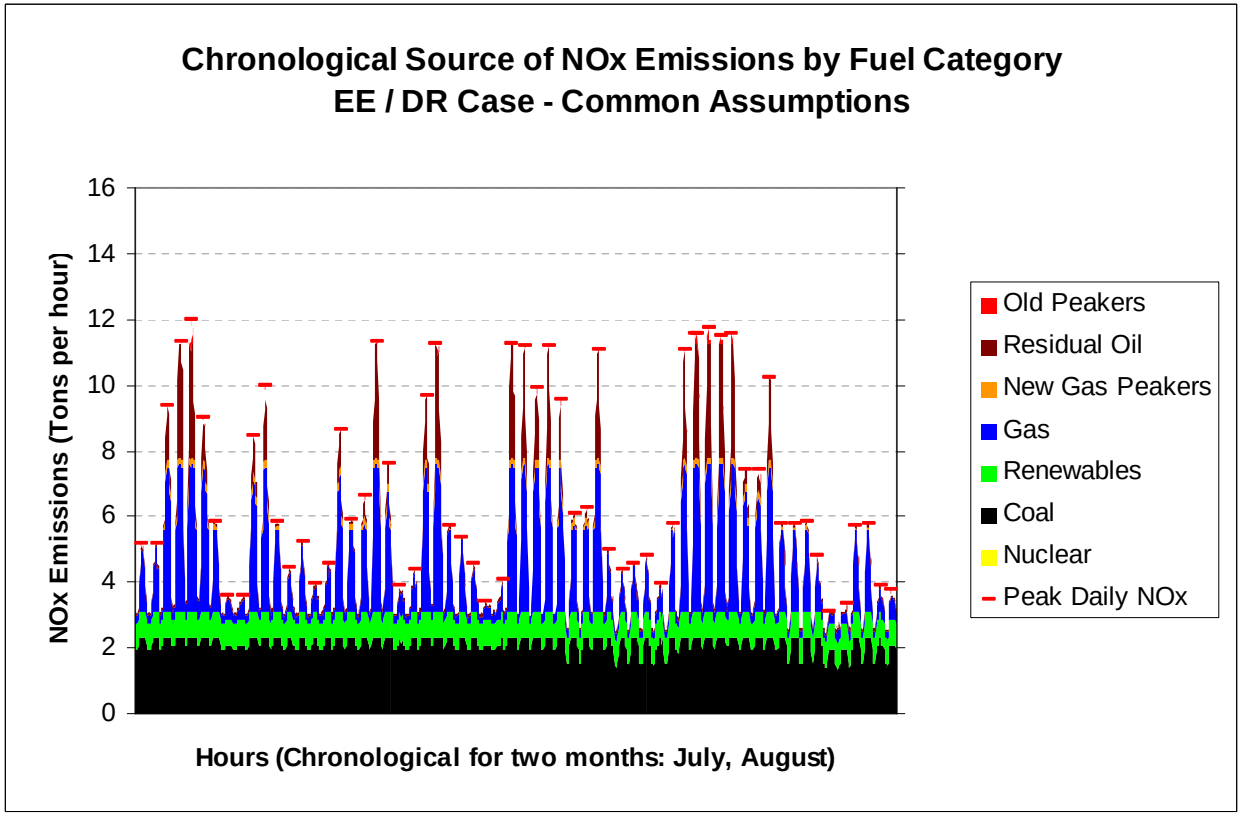


# Peak NOx Day: Queue Case

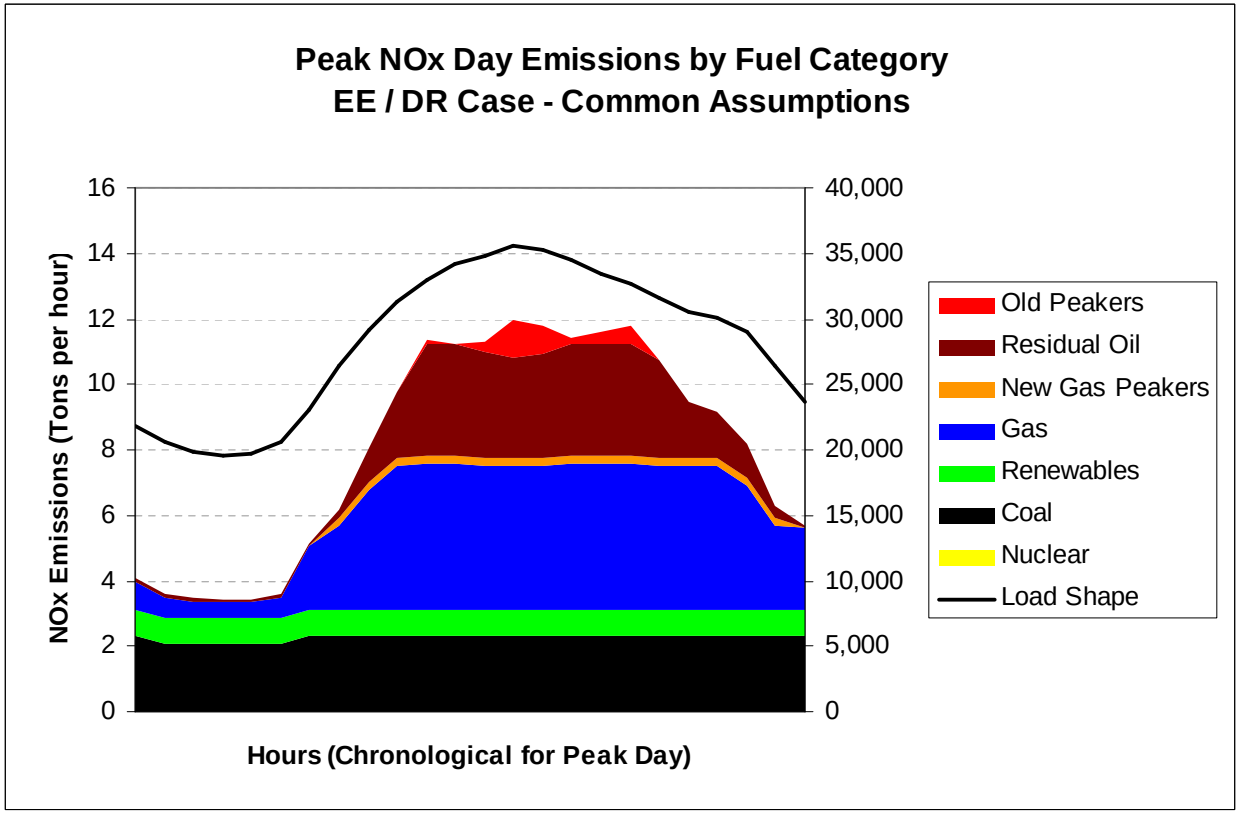


# Summer Hourly NOx: EE / DR Case

Graphs do not show narrow, short duration excursions well. Red line used to show peak hourly NOx for each day

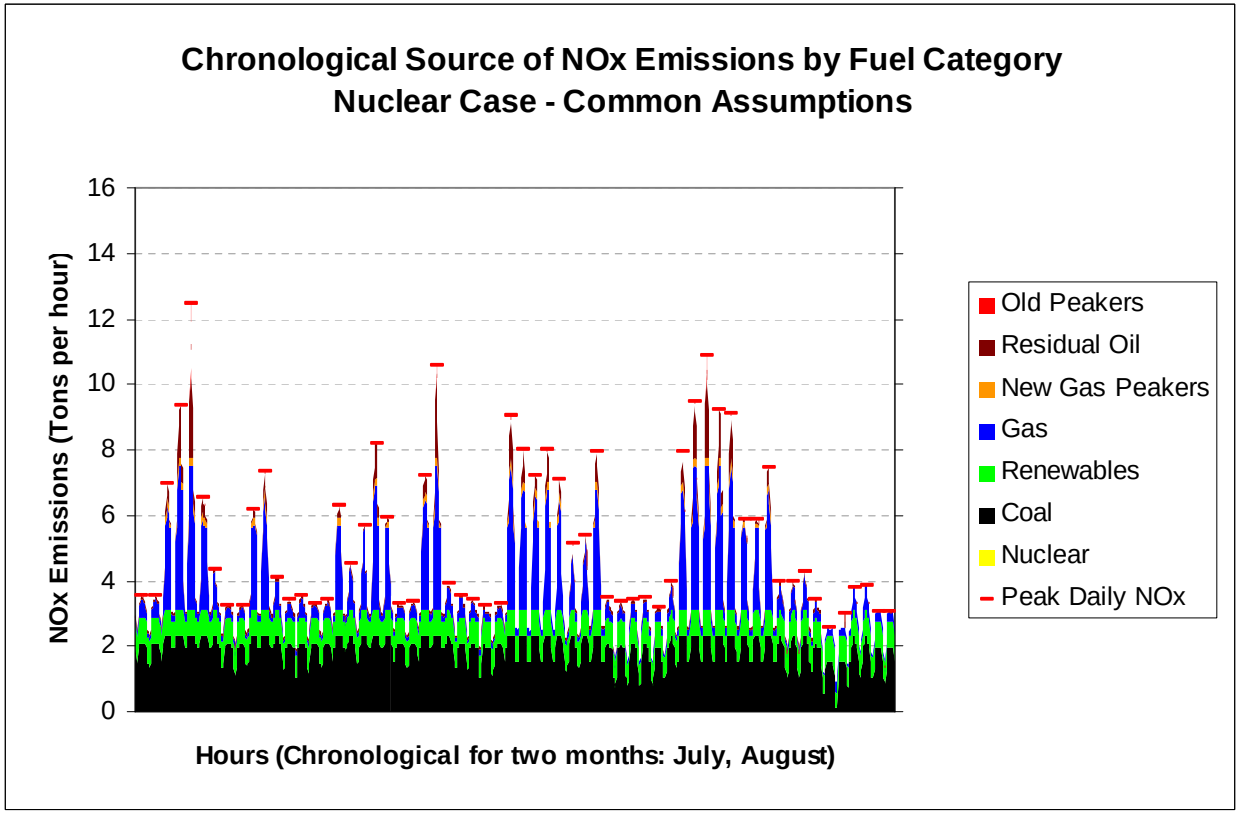


# Peak NOx Day: EE / DR Case

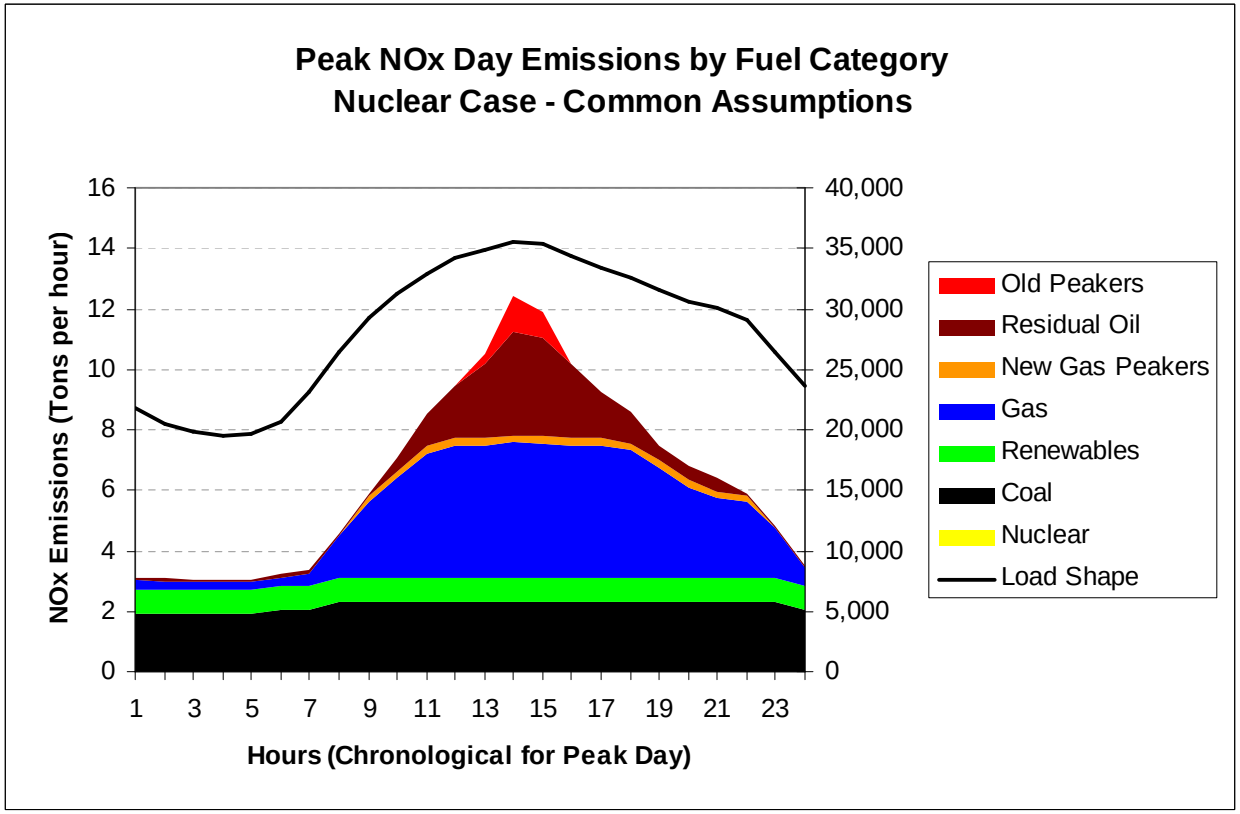


# Summer Hourly NOx: Nuclear Case

Graphs do not show narrow, short duration excursions well. Red line used to show peak hourly NOx for each day

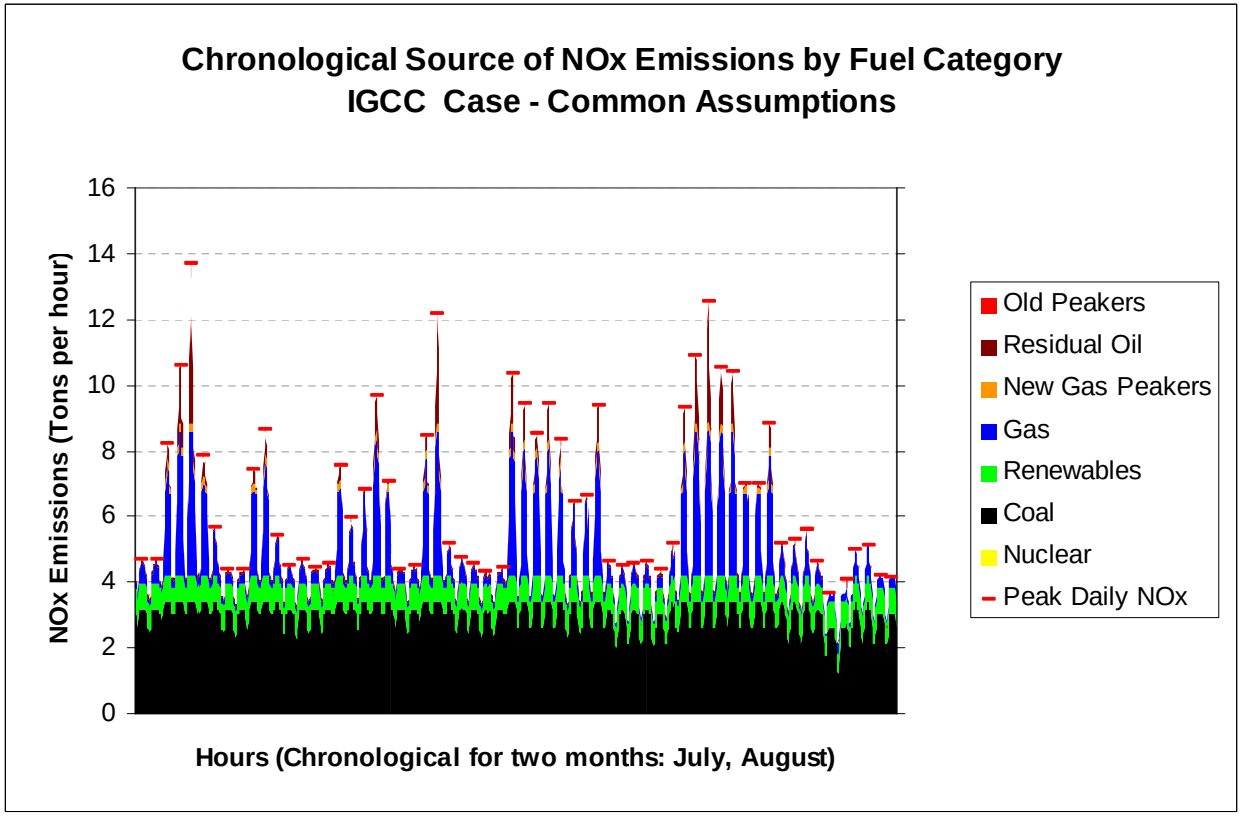


# Peak NOx Day: Nuclear Case

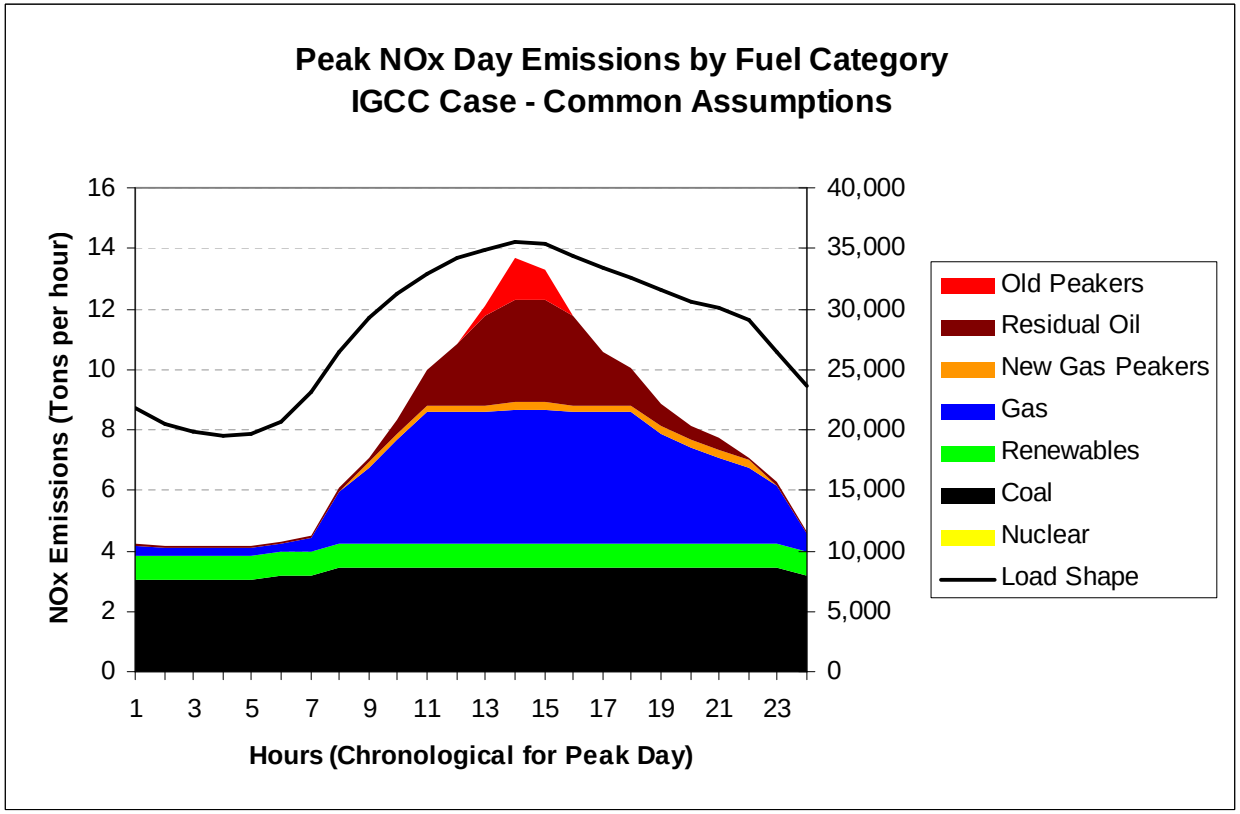


# Summer Hourly NOx: IGCC Case

Graphs do not show narrow, short duration excursions well. Red line used to show peak hourly NOx for each day

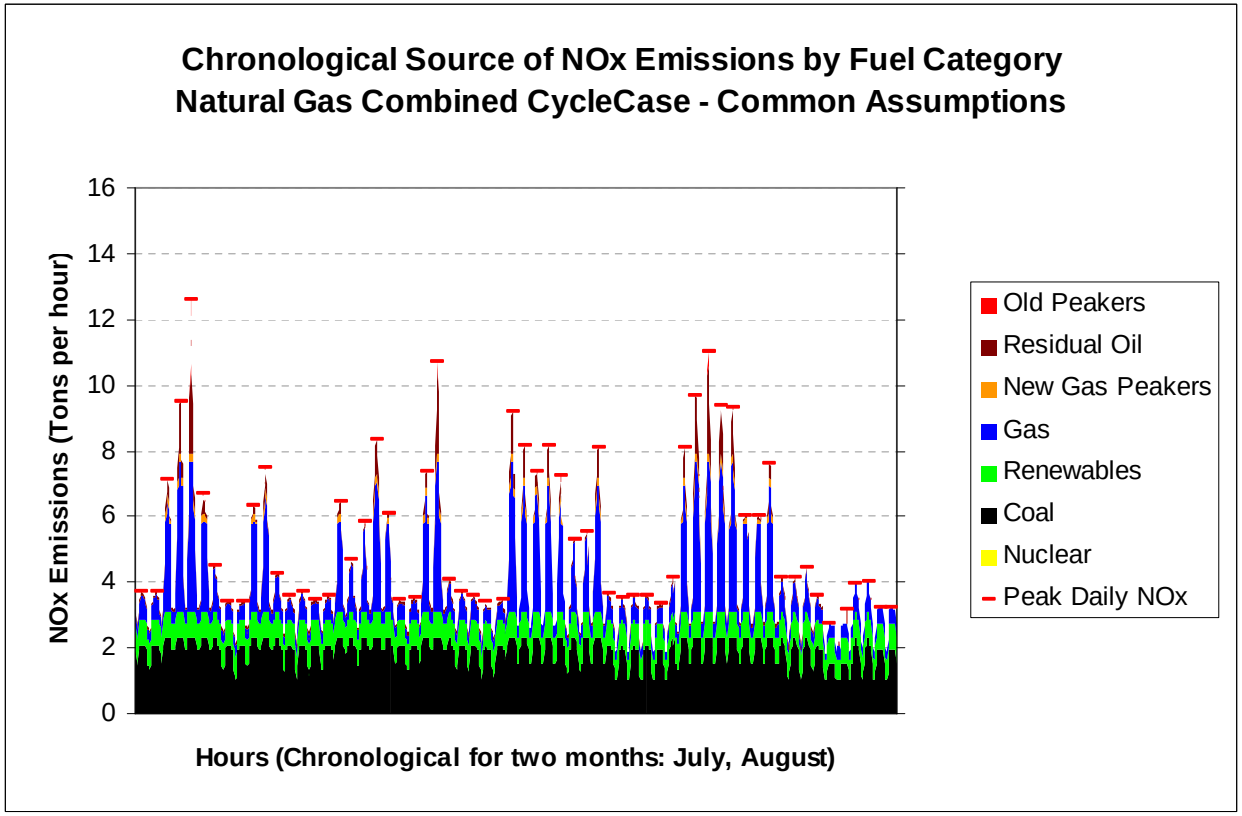


# Peak NOx Day: IGCC Case

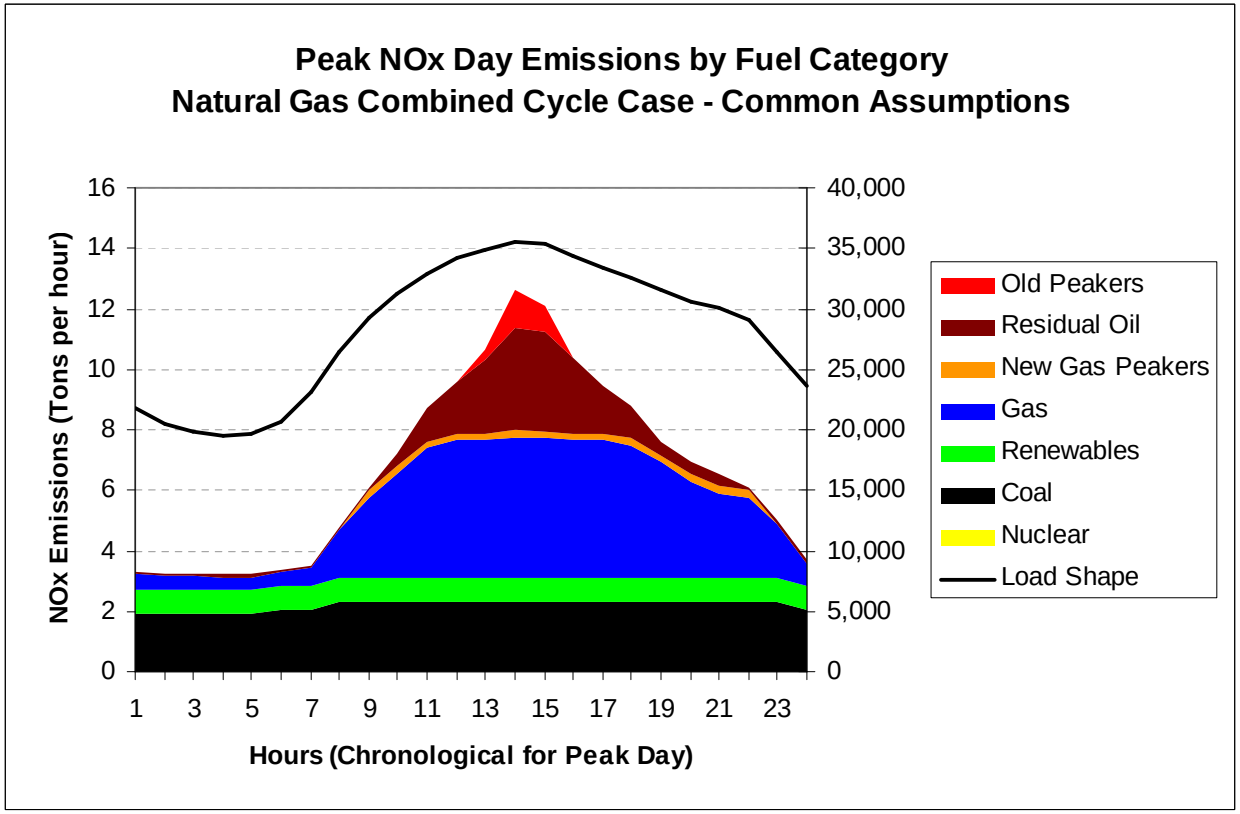


# Summer Hourly NOx: Gas CC Case

Graphs do not show narrow, short duration excursions well. Red line used to show peak hourly NOx for each day

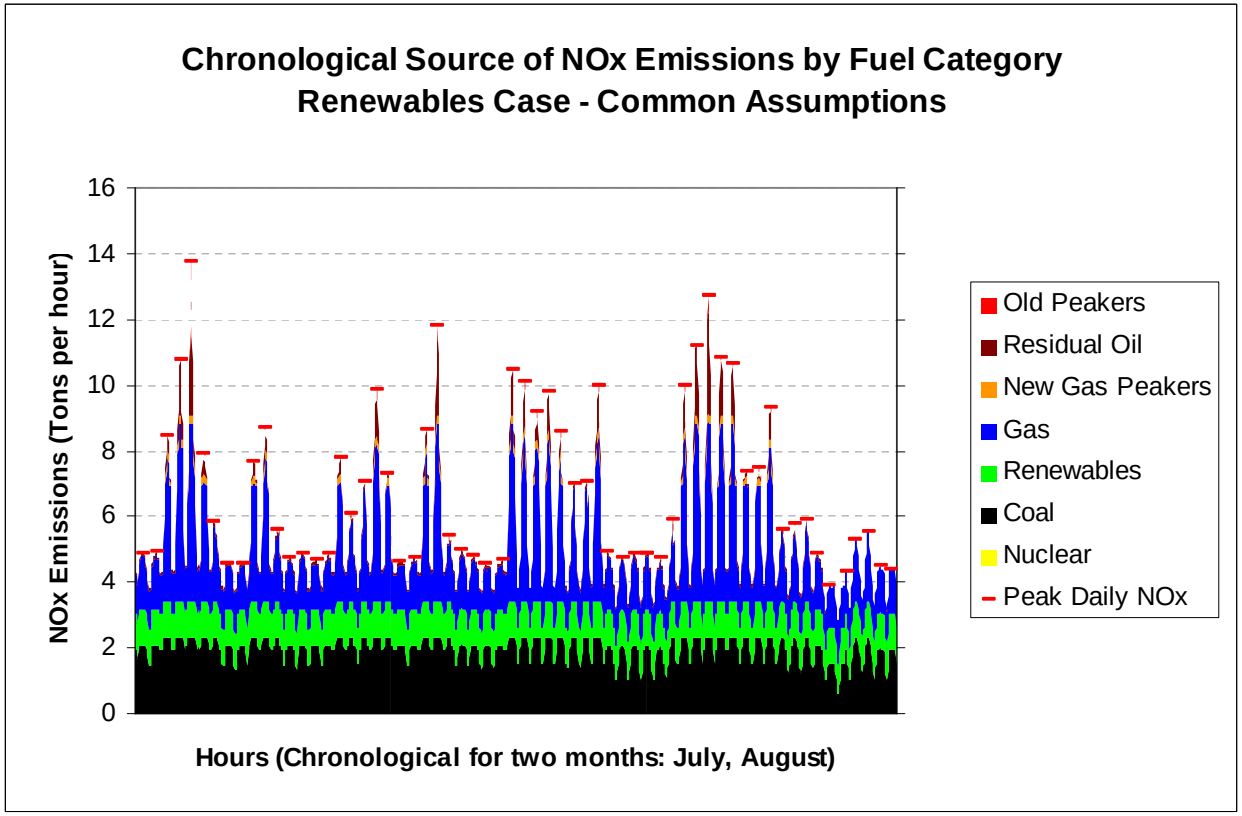


# Peak NOx Day: Gas CC Case

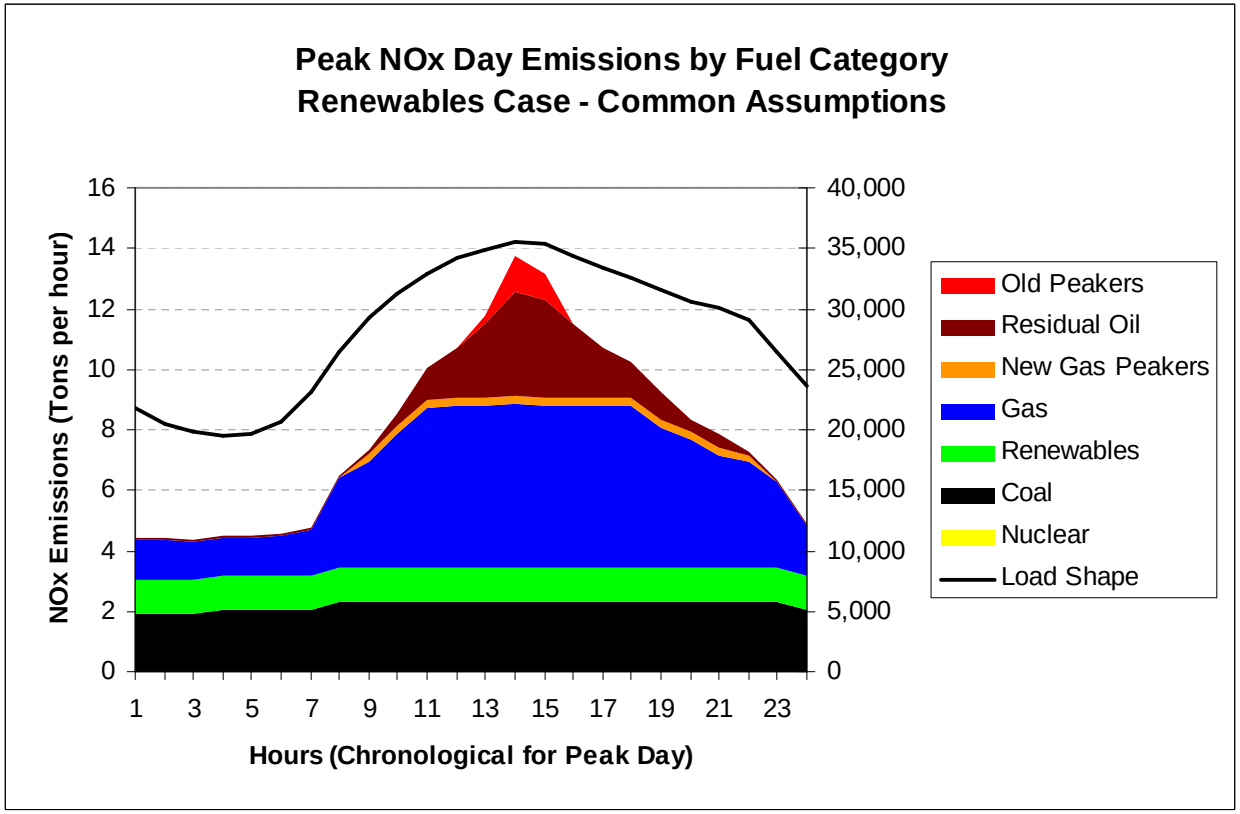


# Summer Hourly NOx: Renewables Case

Graphs do not show narrow, short duration excursions well. Red line used to show peak hourly NOx for each day

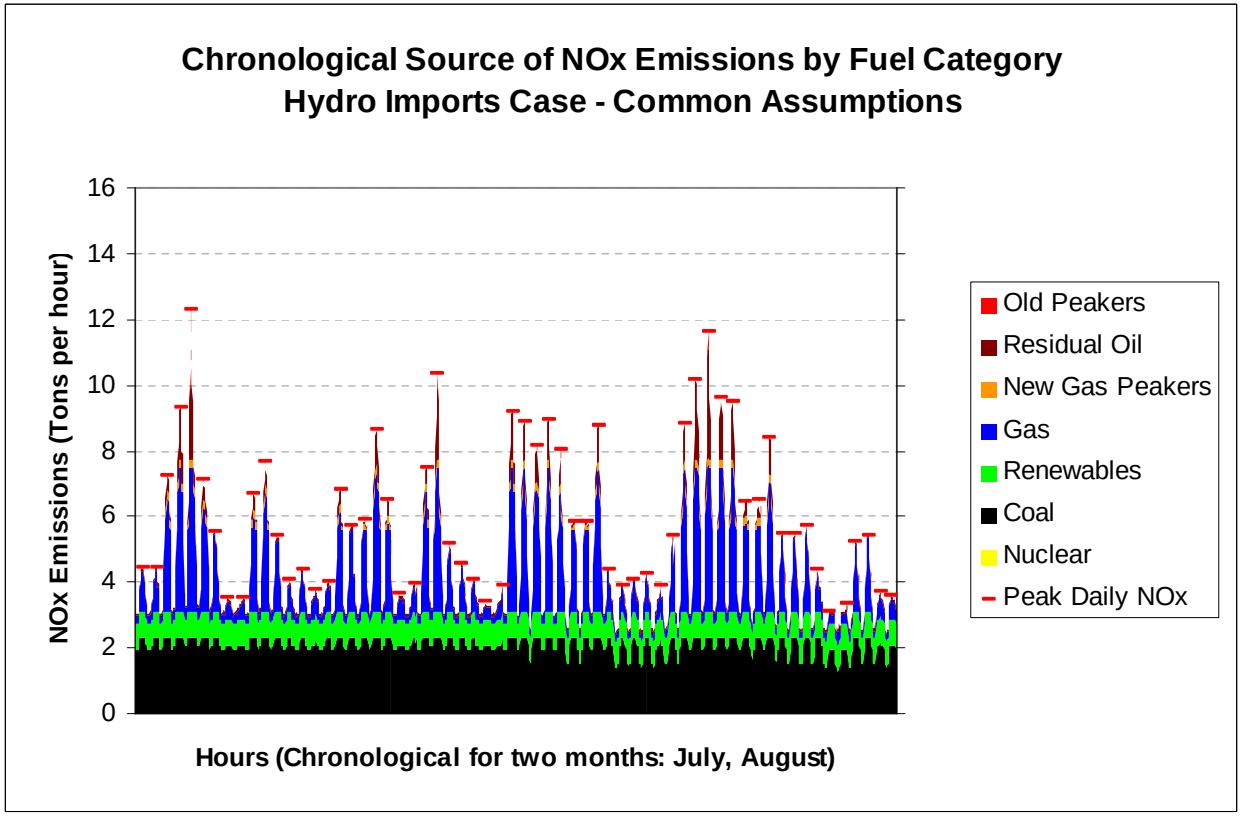


# Peak NOx Day: Renewables Case

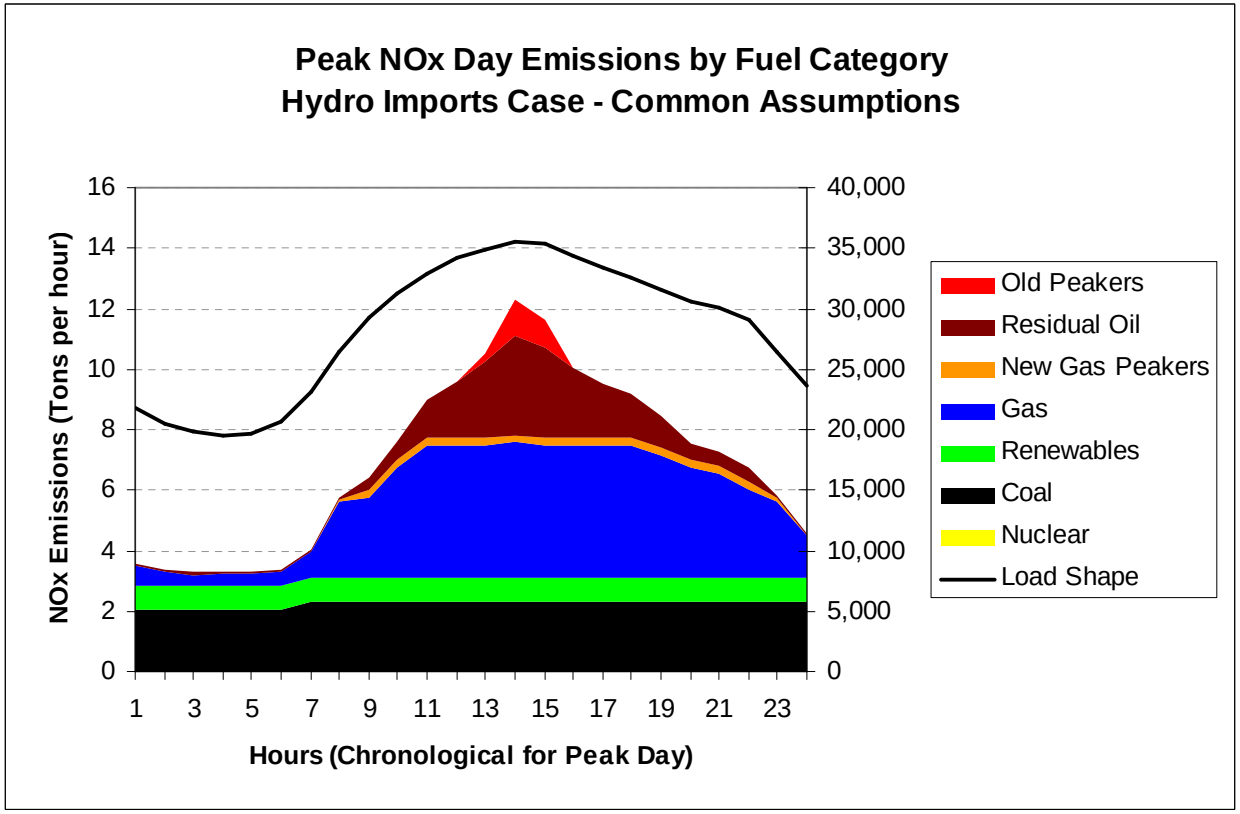


# Summer Hourly NOx: Hydro Import Case

Graphs do not show narrow, short duration excursions well. Red line used to show peak hourly NOx for each day



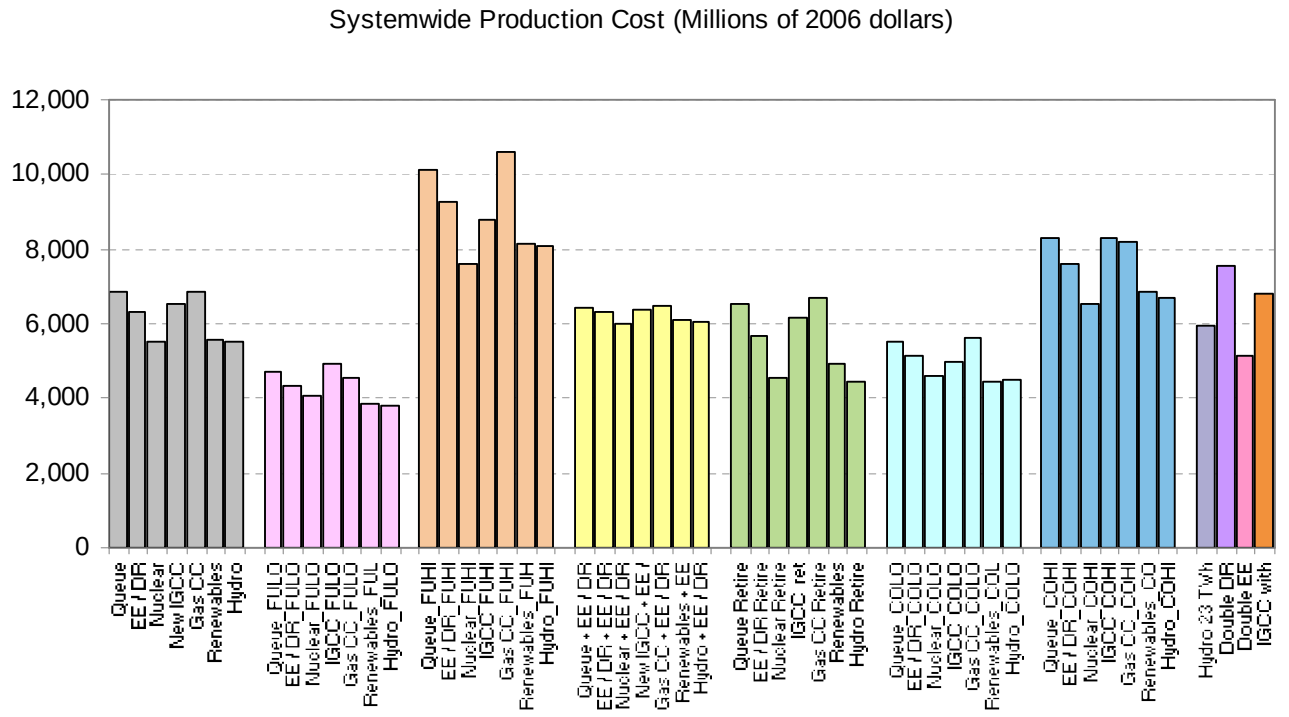
# Peak NOx Day: Hydro Import Case



# Economic Metrics

# Systemwide Production Cost ($ Million)

## Grouped by Sensitivity




**Common Assumptions**

**Low Fuel**

**High Fuel**

**More EE / DR Less Scenario Technology**

**Retire 3,500 MW**

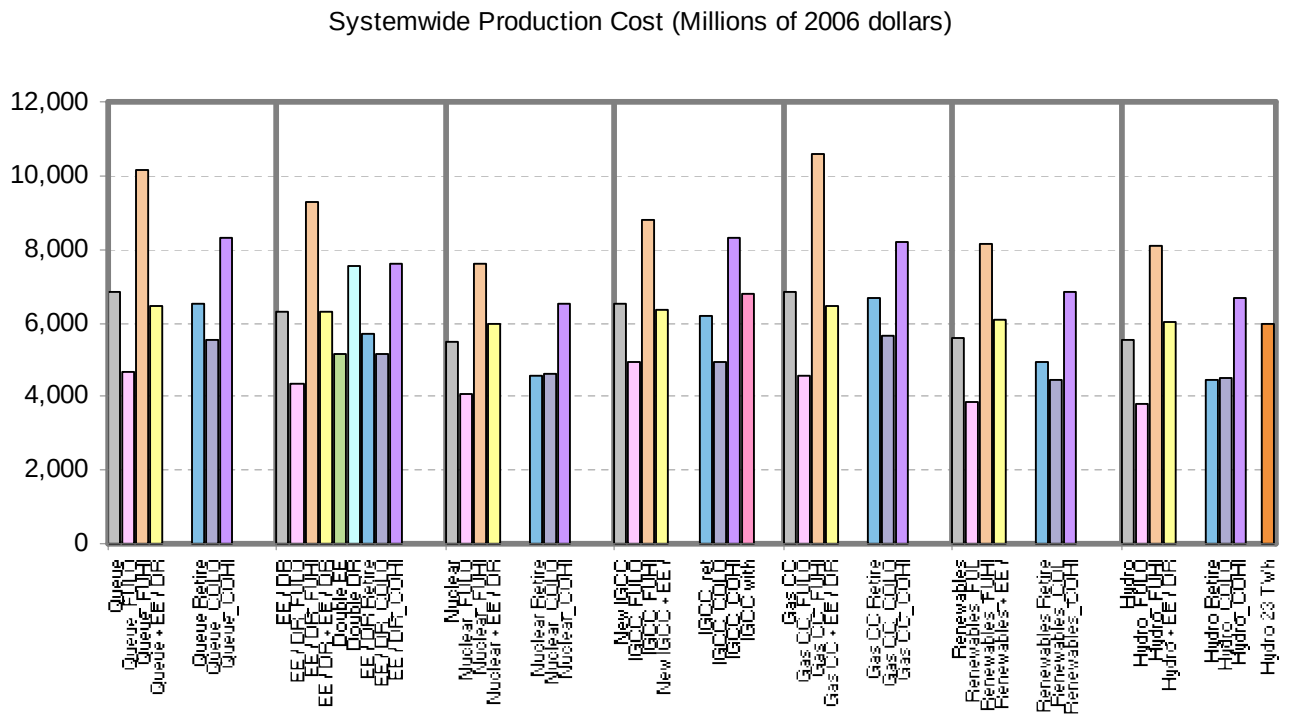
**Low $CO_2$ Emission Values**

**High $CO_2$ Emission Values**

**Misc. Sensitivity Cases**

# Systemwide Production Cost ($ Million)

## Grouped by Scenario




**Queue**

**Half Demand Response Half Energy Efficiency**

**Nuclear**

**Integrated Gasification Combined Cycle**

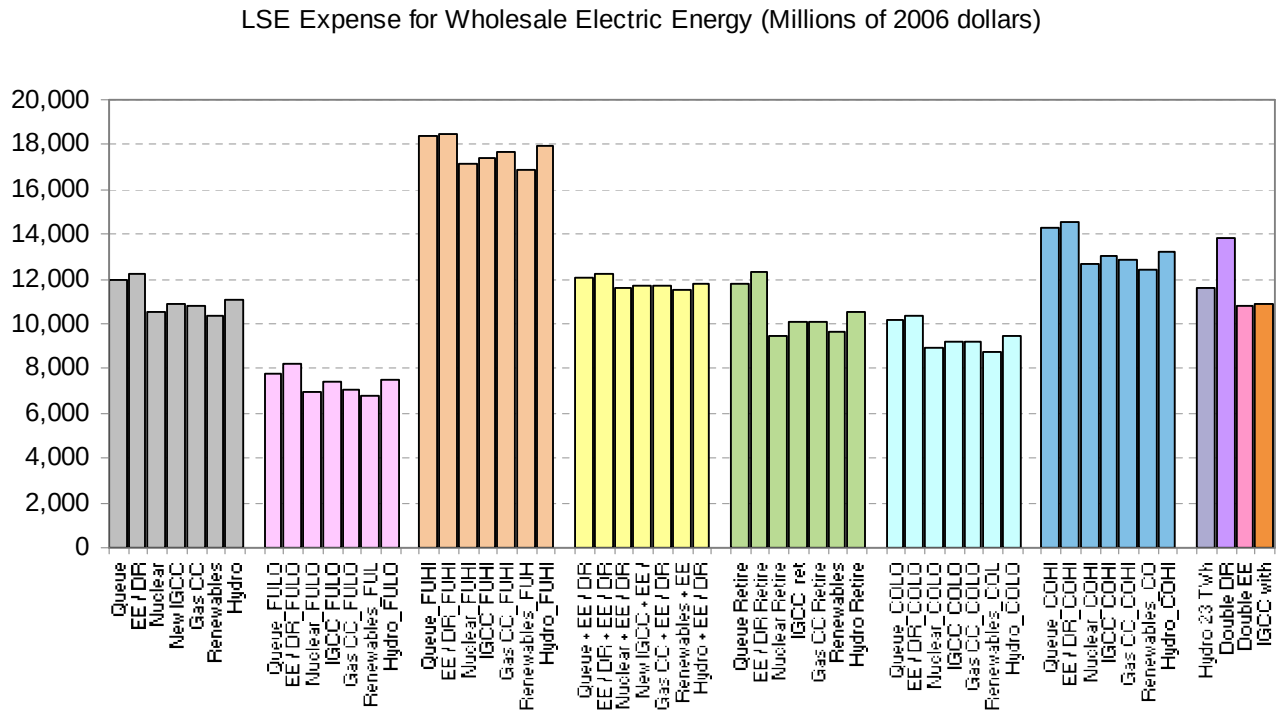
**Gas Combined Cycle**

**Renewables**

**Hydro Imports**

# LSE Expense For Wholesale Electric Energy ($ Million)

## Grouped by Sensitivity




**Common Assumptions**

**Low Fuel**

**High Fuel**

**More EE / DR Less Scenario Technology**

**Retire 3,500 MW**

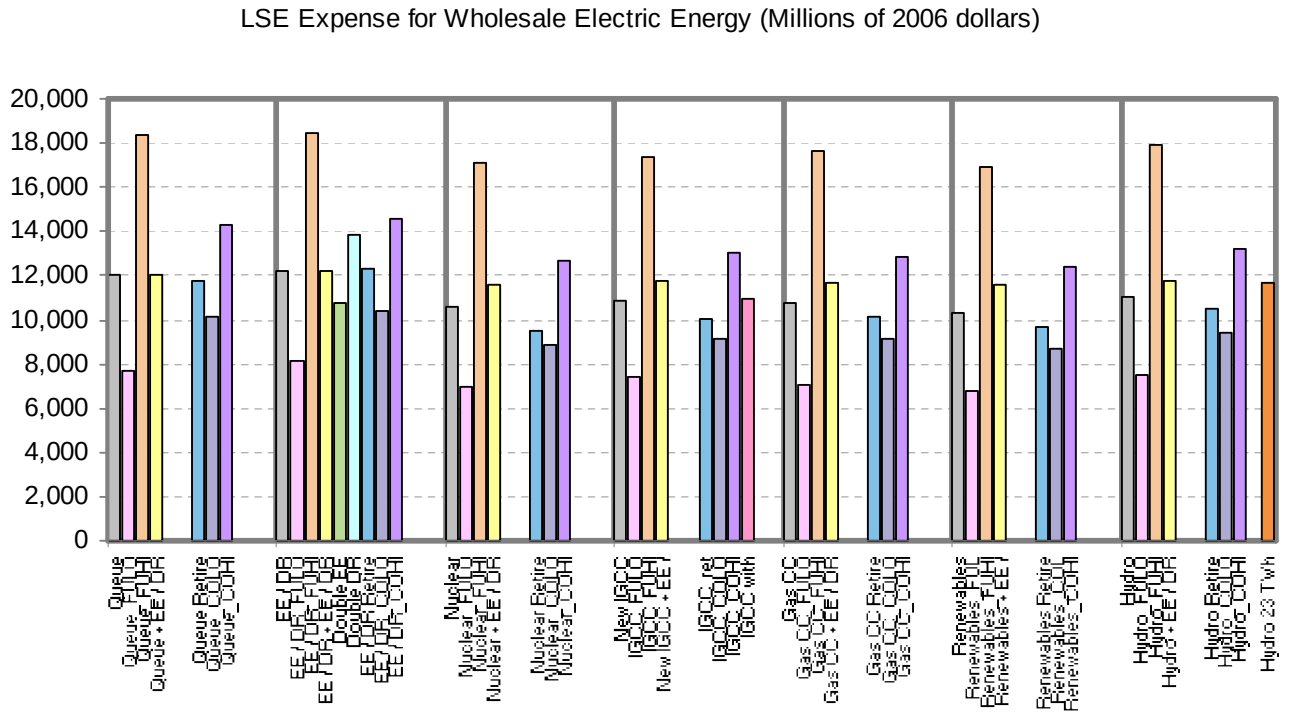
**Low $CO_2$ Emission Values**

**High $CO_2$ Emission Values**

**Misc. Sensitivity Cases**

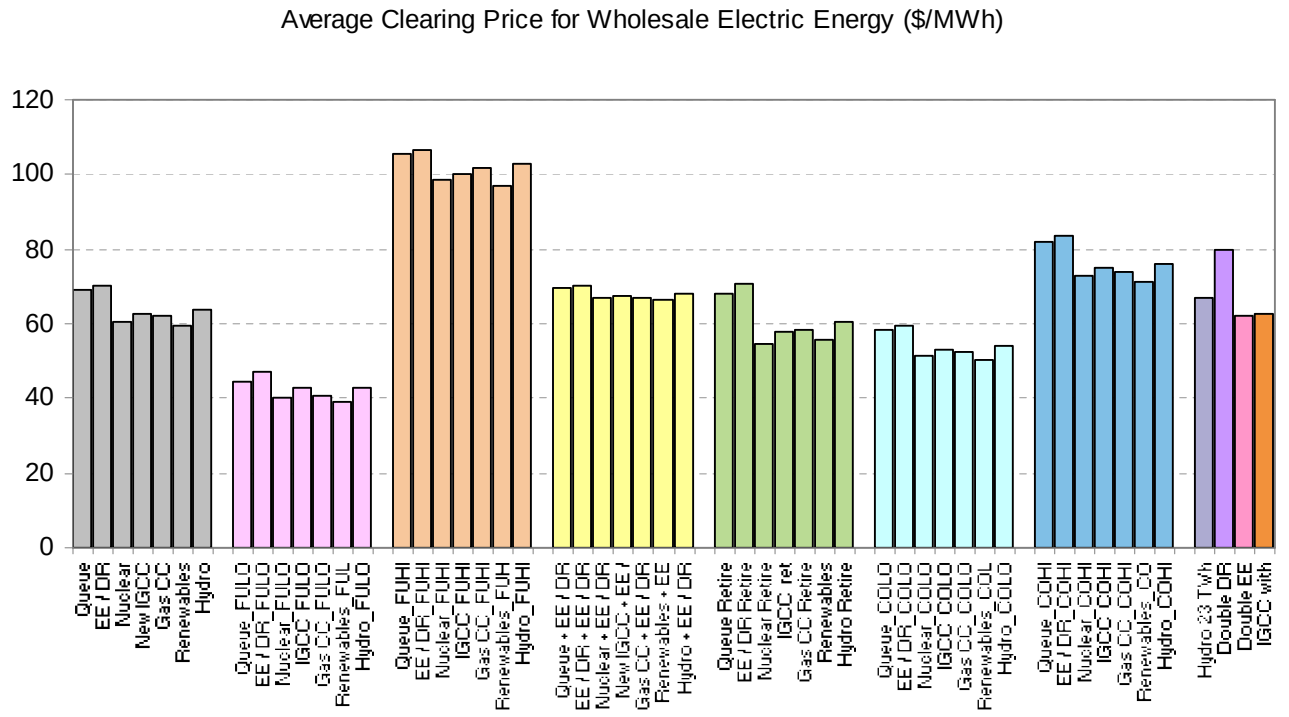
# LSE Expense For Wholesale Electric Energy ($ Million)

## Grouped by Scenario



# Average Clearing Price For Wholesale Electric Energy ($/MWh)

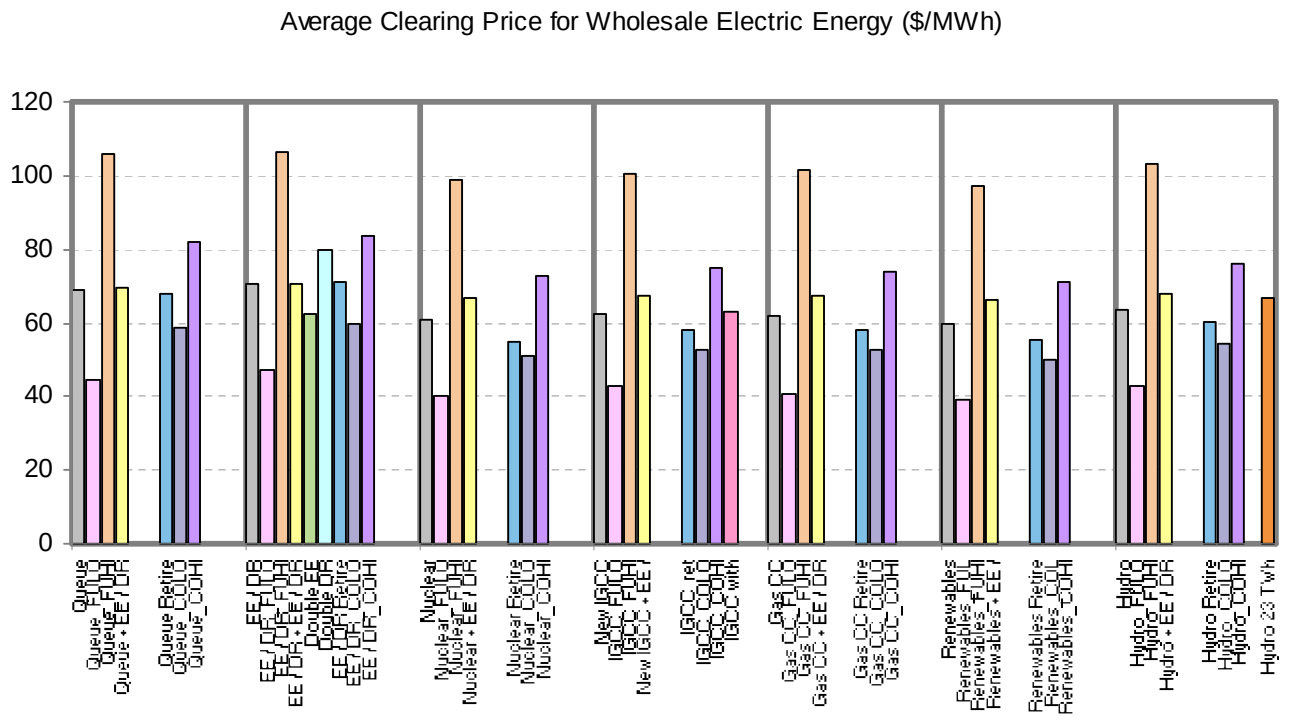
## Grouped by Sensitivity




**Common Assumptions** | **Low Fuel** | **High Fuel** | **More EE / DR Less Scenario Technology** | **Retire 3,500 MW** | **Low $CO_2$ Emission Values** | **High $CO_2$ Emission Values** | **Misc. Sensitivity Cases**

# Average Clearing Price For Wholesale Electric Energy ($/MWh)

## Grouped by Scenario




**Queue**

**Half Demand Response Half Energy Efficiency**

**Nuclear**

**Integrated Gasification Combined Cycle**

**Gas Combined Cycle**

**Renewables**

**Hydro Imports**

# Average Clearing Price For Wholesale Electric Energy ($/MWh)

| | | A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon-Allowance Prices** | **High Carbon-Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low-Emission Resources (-7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 69 | 45 | 106 | 69 | | | 68 | 58 | 82 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 70 | 47 | 106 | 70 | 62 | 80 | 71 | 60 | 84 | | |
| 3 | **Nuclear —** 5,400 MW | 61 | 40 | 99 | 67 | | | 55 | 51 | 73 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 63 | 43 | 100 | 68 | | | 58 | 53 | 75 | 63 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 62 | 41 | 102 | 67 | | | 58 | 53 | 74 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on- and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 60 | 39 | 97 | 66 | | | 56 | 50 | 71 | | |
| 7 | **Increased imports of hydro and other low-emission resources —** 30 TWh of imports | 64 | 43 | 103 | 68 | | | 60 | 54 | 76 | | 67 |

# Systemwide Production Cost ($ Million)

| | | A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 6,833 | 4,693 | 10,131 | 6,443 | | | 6,540 | 5,543 | 8,310 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 6,298 | 4,330 | 9,292 | 6,298 | 5,148 | 7,563 | 5,693 | 5,146 | 7,613 | | |
| 3 | **Nuclear —** 5,400 MW | 5,502 | 4,054 | 7,593 | 5,995 | | | 4,554 | 4,591 | 6,519 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 6,525 | 4,917 | 8,791 | 6,362 | | | 6,167 | 4,959 | 8,316 | 6,798 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 6,846 | 4,550 | 10,595 | 6,473 | | | 6,699 | 5,639 | 8,207 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 5,569 | 3,882 | 8,152 | 6,084 | | | 4,946 | 4,438 | 6,841 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 5,522 | 3,814 | 8,069 | 6,029 | | | 4,457 | 4,495 | 6,681 | | 5,963 |

# LSE Expense For Wholesale Electric Energy ($ Million)

| | | A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Scenarios —** incremental 8,000 MW All cases have the same 2,600 MW of resources reflecting proposals in the ISO queue as of 9/30/06. | **Common Assumptions** | **Low Gas/Oil Fuel Prices** | **High Gas/Oil Fuel Prices** | **Replace 3,500 MW of the Scenario Technology with 1,750 MW of Energy Efficiency (EE) and 1,750 MW of Demand Response (DR)** | **Replace 2,700 MW of DR with 2,700 MW of EE** | **Replace 2,700 MW of EE with 2,700 MW of DR** | **Retire 3,500 MW and Replace with Scenario Technology** | **Low Carbon−Allowance Prices** | **High Carbon−Allowance Prices** | **For Coal with Carbon Sequestration** | **Decreased Imports of Low−Emission Resources (−7 TWh)** |
| 1 | **Queue Mix —** combination of currently proposed resources; 5,400 MW blend reflecting the fuel mix exhibited recently by the market | 11,997 | 7,736 | 18,380 | 12,074 | | | 11,783 | 10,162 | 14,261 | | |
| 2 | **Demand-side resources —** an additional 2,700 MW of DR and 2,700 MW of EE | 12,235 | 8,174 | 18,496 | 12,235 | 10,811 | 13,878 | 12,321 | 10,363 | 14,554 | | |
| 3 | **Nuclear —** 5,400 MW | 10,566 | 6,998 | 17,134 | 11,602 | | | 9,488 | 8,911 | 12,648 | | |
| 4 | **Advanced technology coal (IGCC) —** 5,400 MW without carbon sequestration | 10,895 | 7,451 | 17,420 | 11,740 | | | 10,090 | 9,184 | 13,030 | 10,909 | |
| 5 | **Natural gas (combined cycle) —** 5,400 MW | 10,767 | 7,098 | 17,689 | 11,669 | | | 10,124 | 9,165 | 12,847 | | |
| 6 | **Renewables —** 5,400 MW, including a combo of on− and offshore wind, hydro, biomass, landfill gas, combined heat and power, fuel cells, photovoltaics; 1/8 each | 10,344 | 6,826 | 16,890 | 11,547 | | | 9,669 | 8,721 | 12,387 | | |
| 7 | **Increased imports of hydro and other low−emission resources —** 30 TWh of imports | 11,085 | 7,474 | 17,917 | 11,800 | | | 10,494 | 9,425 | 13,239 | | 11,630 |

# Annual Revenue Comparisons

# Purpose of Comparison

- Purpose is to show
  - Range of contributions to annual revenue requirements from net revenues from energy production
    - Comparison to range of annual total non-fuel and non-environmental allowance cost requirements that a “scenario technology” may need
    - Annual revenue requirement rate provides allowances for
      - Return of, and return on, investment
      - Taxes
      - Fixed O&M (except nuclear where this was included as “fuel” cost)
      - Other
  - Revenue shortfalls for “scenario technologies” deployed is an indicator of need for other sources of revenue
- Not a definitive economic comparison
- Not a simulation of market dynamics over multiple years

# Annual Revenue Comparisons

- Net Energy Market Revenues are:
  Hourly clearing price minus
  - Fuel cost
  - Environmental emissions adders
- Excluded revenue streams
  - Forward Capacity Markets revenues
  - Forward Reserve Markets revenues
  - Ancillary Services Market revenues
  - Renewable Energy Credit (REC) revenues
  - Clean Energy Funds
  - Tax Incentives
  - Subsidies

# What's included

- Capital cost ranges for scenario technology
  - Lower Bound
    - Lower capital cost estimate
    - With the 15 percent Annual  Revenue Requirement Rate factor
  - Upper Bound
    - Higher capital cost estimate
    - With the 25 percent Annual  Revenue Requirement Rate factor
  - Transmission interconnection included as part of technology capital cost
- Major scenario transmission expansion was considered a network expansion cost to the Load Serving Entities

# Capital Cost Estimates

- Range of capital cost for each technology
  - Based on stakeholder input
  - Uncertainty in cost of new construction in New England
- Wind capital cost for 675 MW of “needed capacity”
  - Initial assumption is 100 percent mechanical availability
  - Assume one MW of FCM “qualified capacity” provides one MW of “needed capacity”
  - Must install 4 or 5 MWs to get one MW of “needed capacity”
    - 19 percent FCM “qualified capacity” for offshore
    - 26 percent FCM “qualified capacity” for offshore
    - Based on analysis of 2005 historical wind patterns
  - Final adjustment to estimate the number of “nameplate” MW to be bought accounts for assumed 90 percent mechanical availability
  - Similar approach for photovoltaics

# Queue Case: Small Hydro

**Queue Case Technologies**

**=> Small Hydro**

Biomass

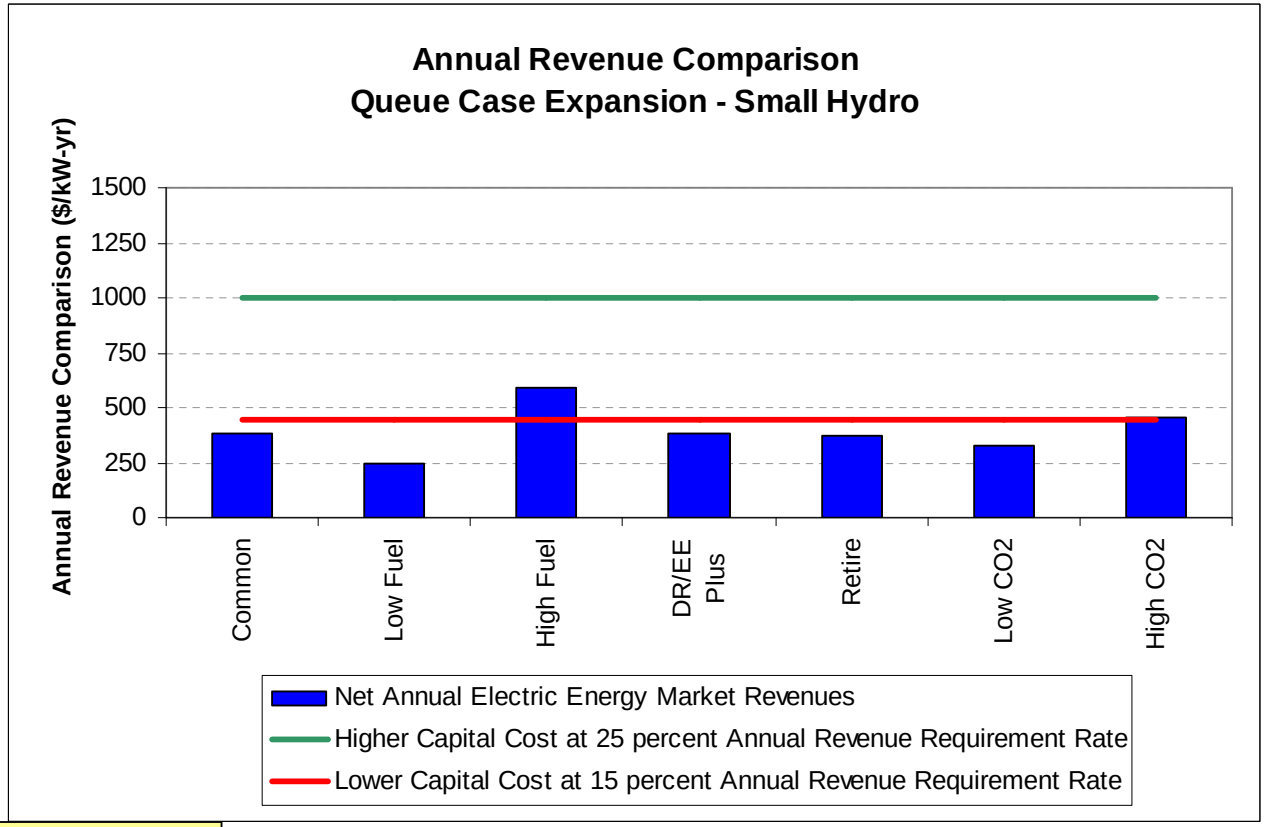
Gas CC

IGCC

New CT

Fuel Cell

Queue Wind

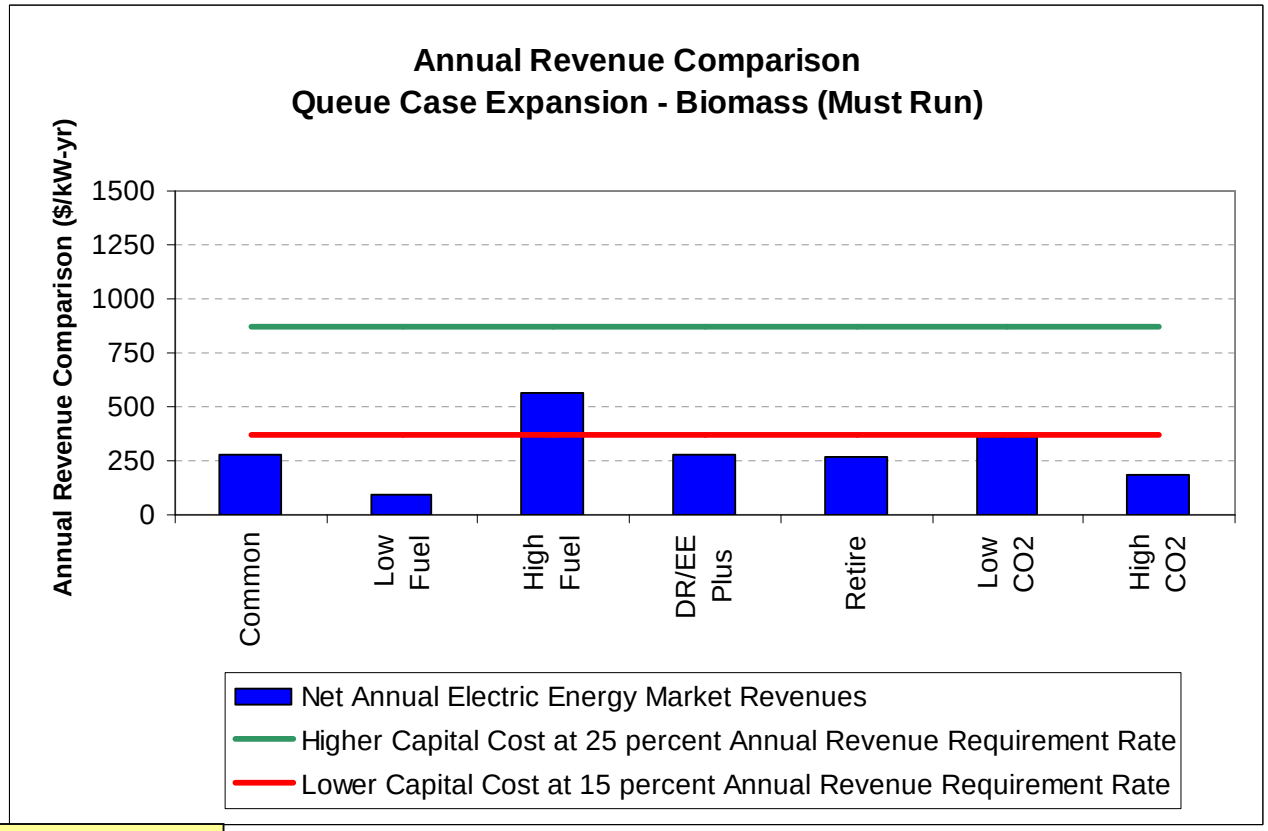



**Lower Capital Cost: $3000/kW**
**Higher Capital Cost: $4000/kW**

# Queue Case: Biomass

**Queue Case Technologies**

Small Hydro
**=> Biomass**
Gas CC
IGCC
New CT
Fuel Cell
Queue Wind

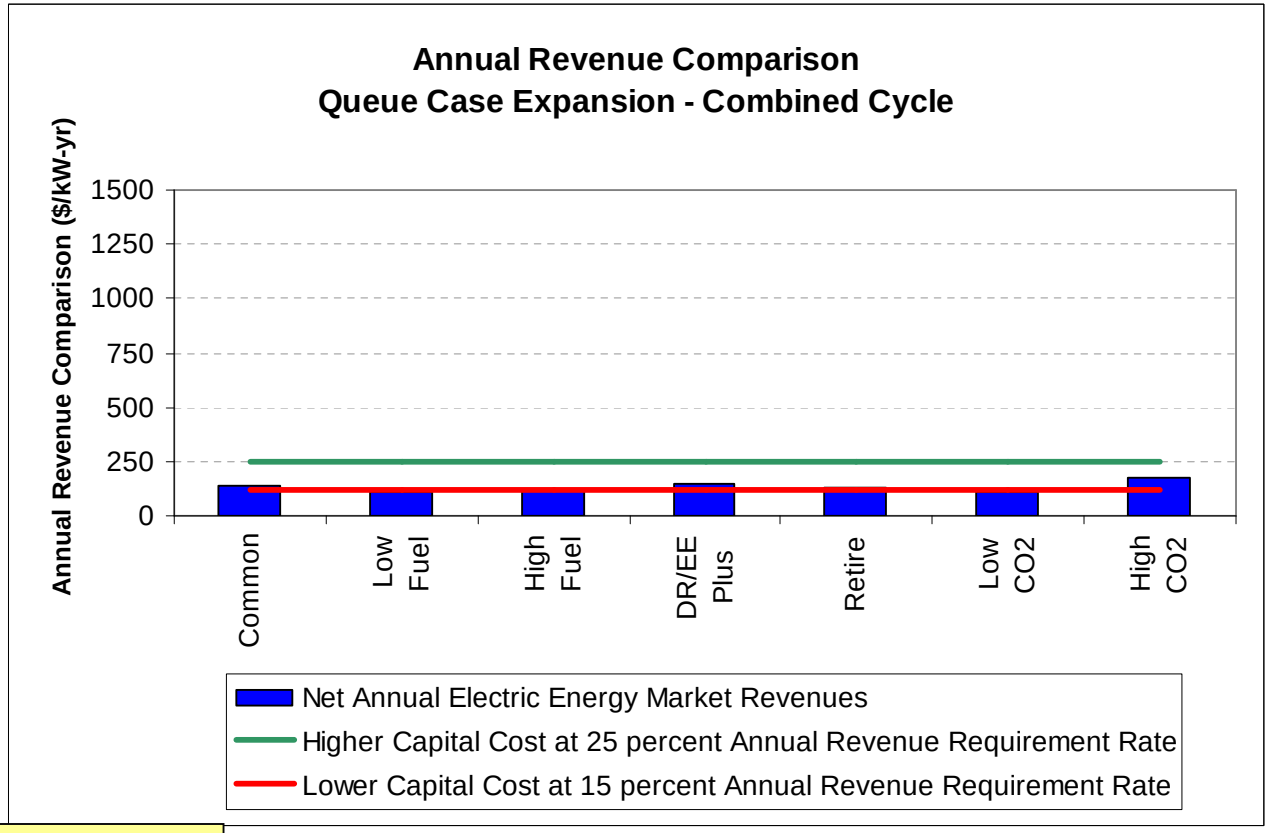



**Lower Capital Cost: $2500/kW**
**Higher Capital Cost: $3500/kW**

# Queue Case: Combined Cycle

**Queue Case Technologies**

Small Hydro
Biomass
**=> Gas CC**
IGCC
New CT
Fuel Cell
Queue Wind

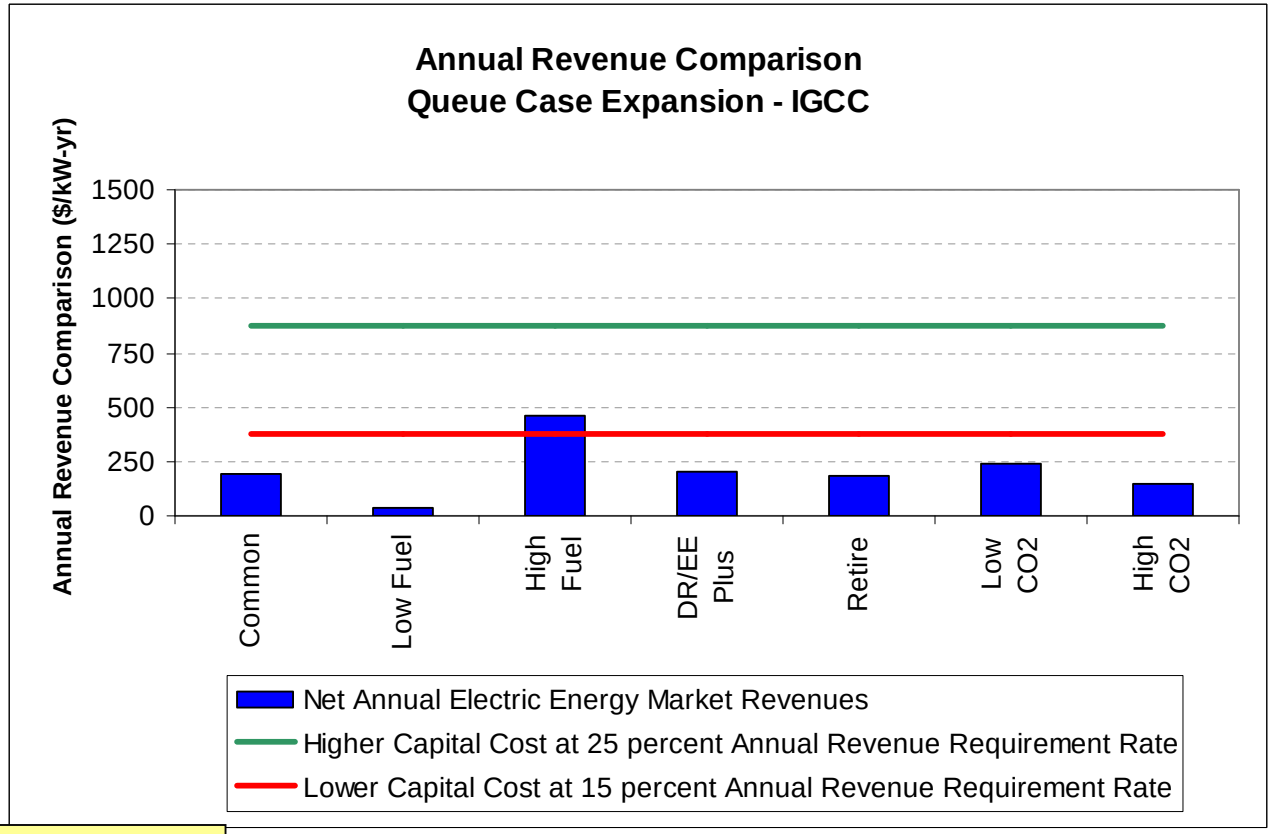



**Lower Capital Cost: $ 800/kW**
**Higher Capital Cost: $1000/kW**

# Queue Case: IGCC Resource

**Queue Case Technologies**

Small Hydro
Biomass
Gas CC
**=> IGCC**
New CT
Fuel Cell
Queue Wind

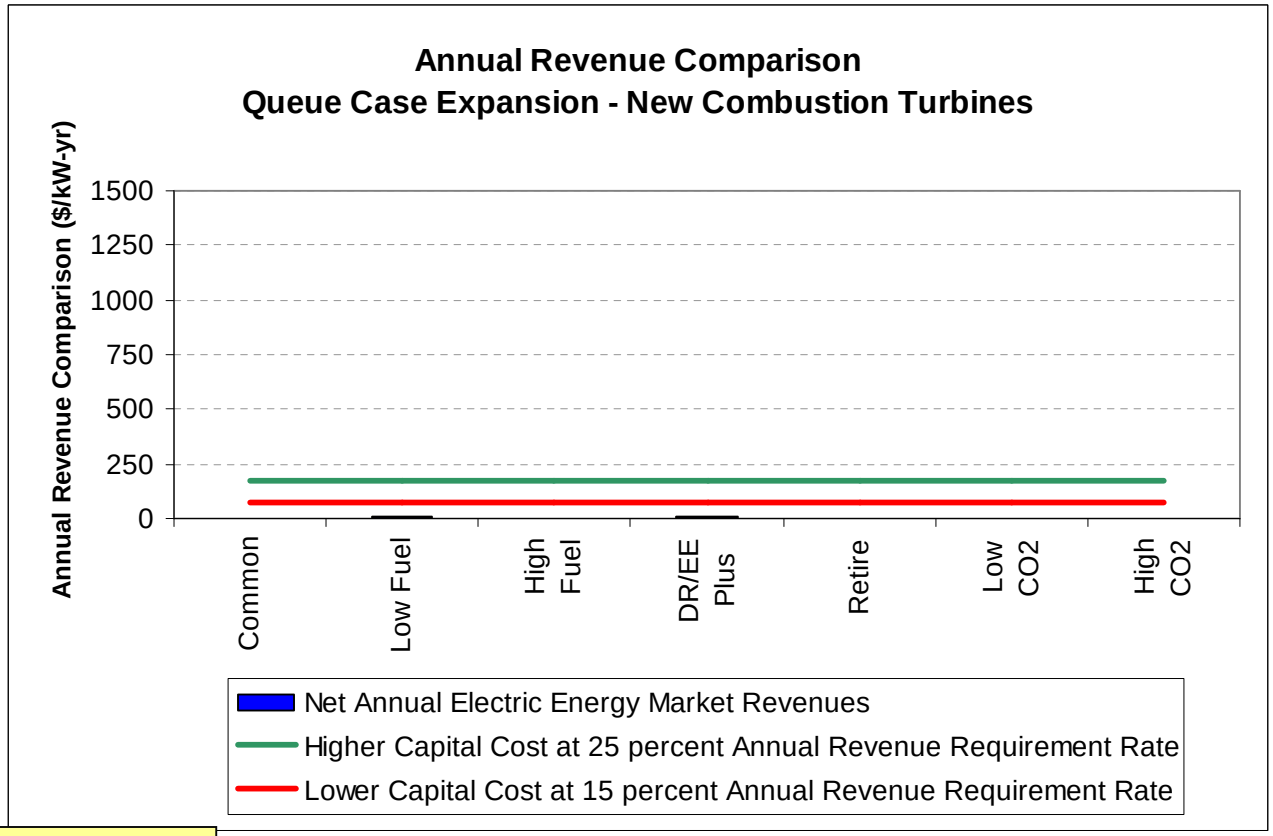



**Lower Capital Cost: $2500/kW**
**Higher Capital Cost: $3500/kW**

# Queue Case: Combustion Turbines

**Queue Case Technologies**

Small Hydro
Biomass
Gas CC
IGCC
**=> New CT**
Fuel Cell
Queue Wind

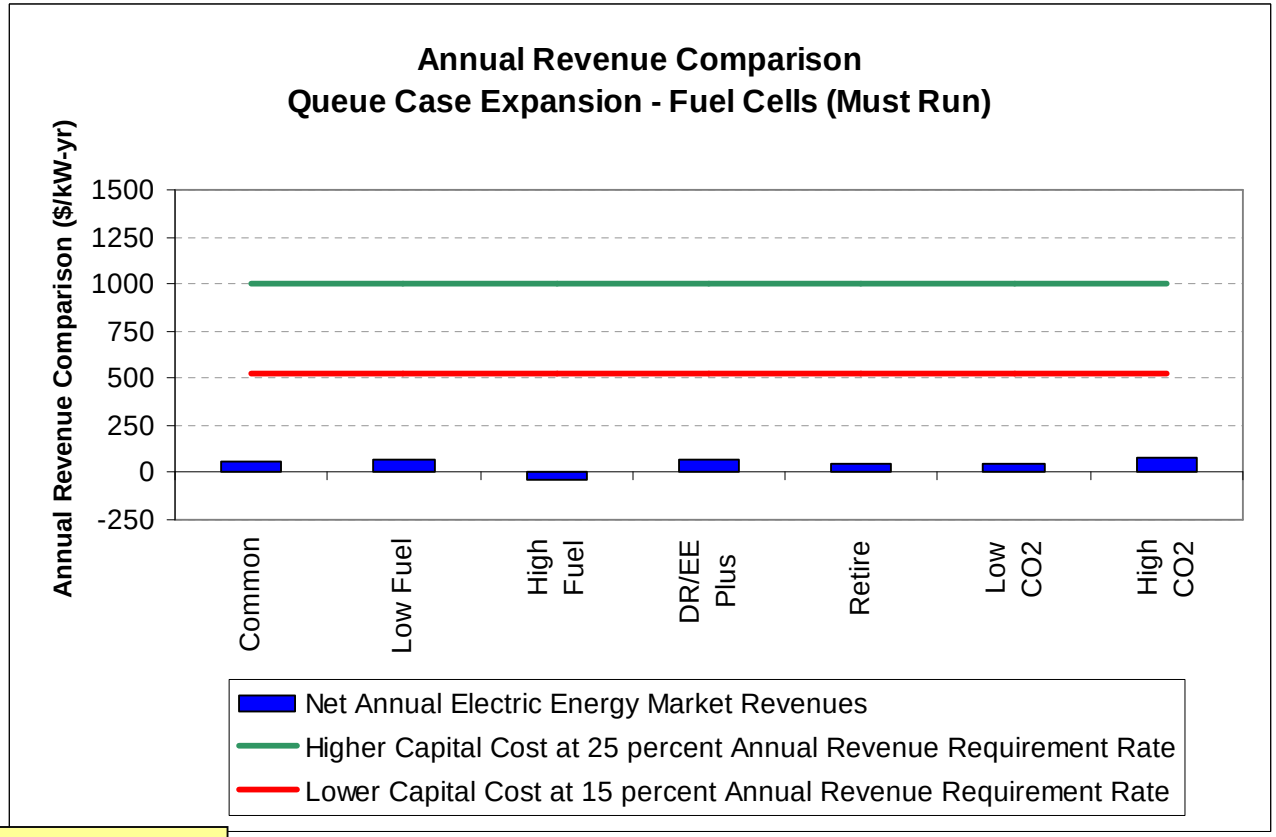



**Lower Capital Cost: $ 500/kW**
**Higher Capital Cost: $ 700/kW**

# Queue Case: Fuel Cells

**Queue Case Technologies**

Small Hydro
Biomass
Gas CC
IGCC
New CT
**=> Fuel Cell**
Queue Wind

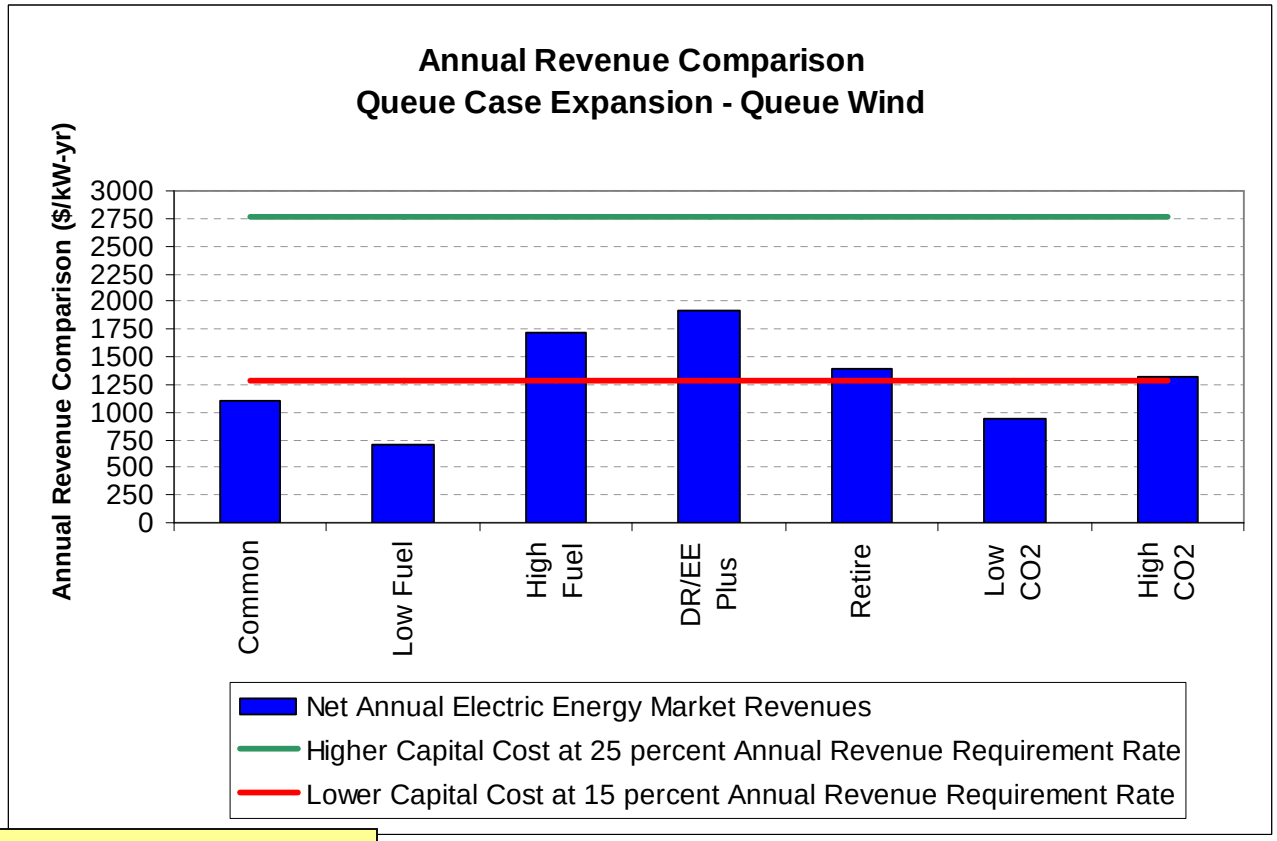



**Lower Capital Cost: $3500/kW**
**Higher Capital Cost: $4000/kW**

# Queue Case: Queue Wind

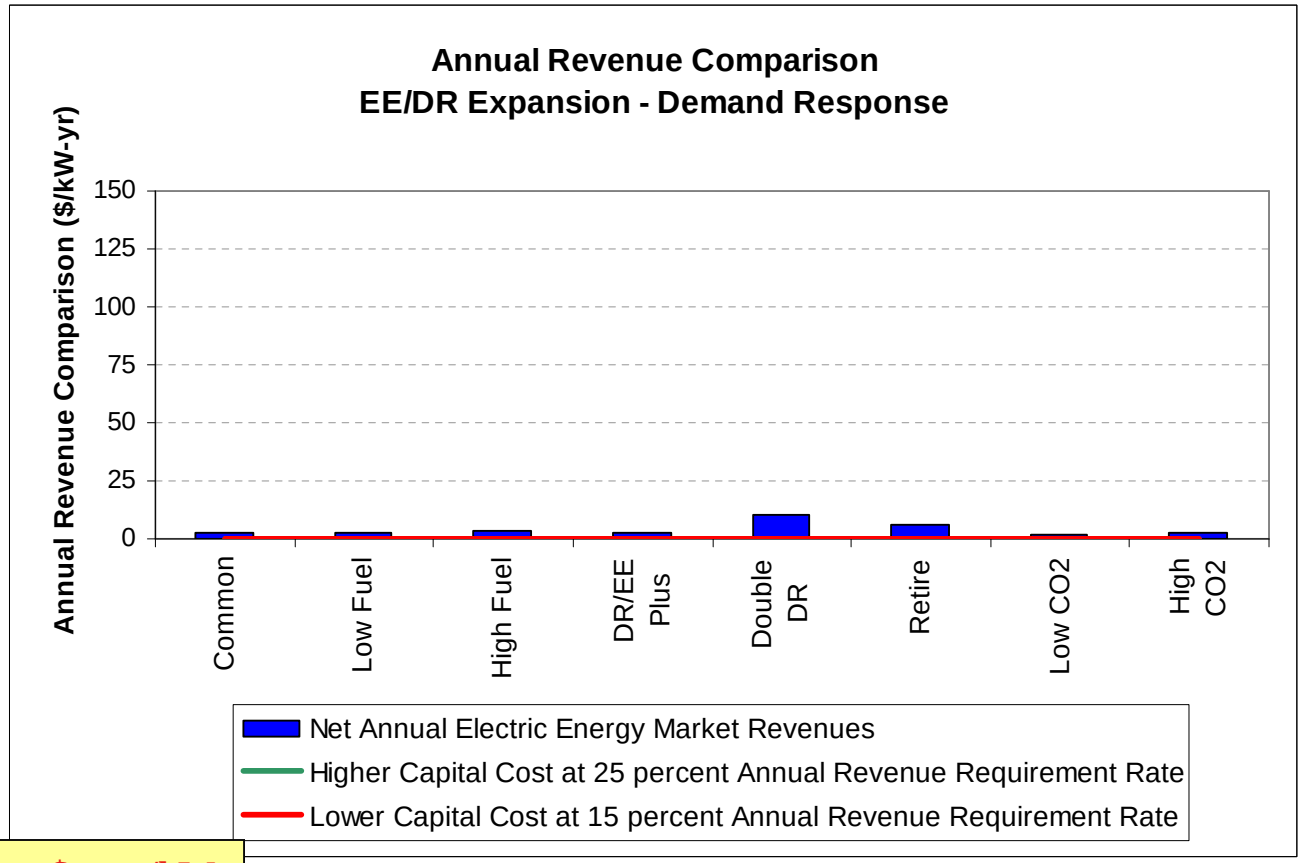
**Queue Case Technologies**

Small Hydro
Biomass
Gas CC
IGCC
New CT
Fuel Cell
**=> Queue Wind**



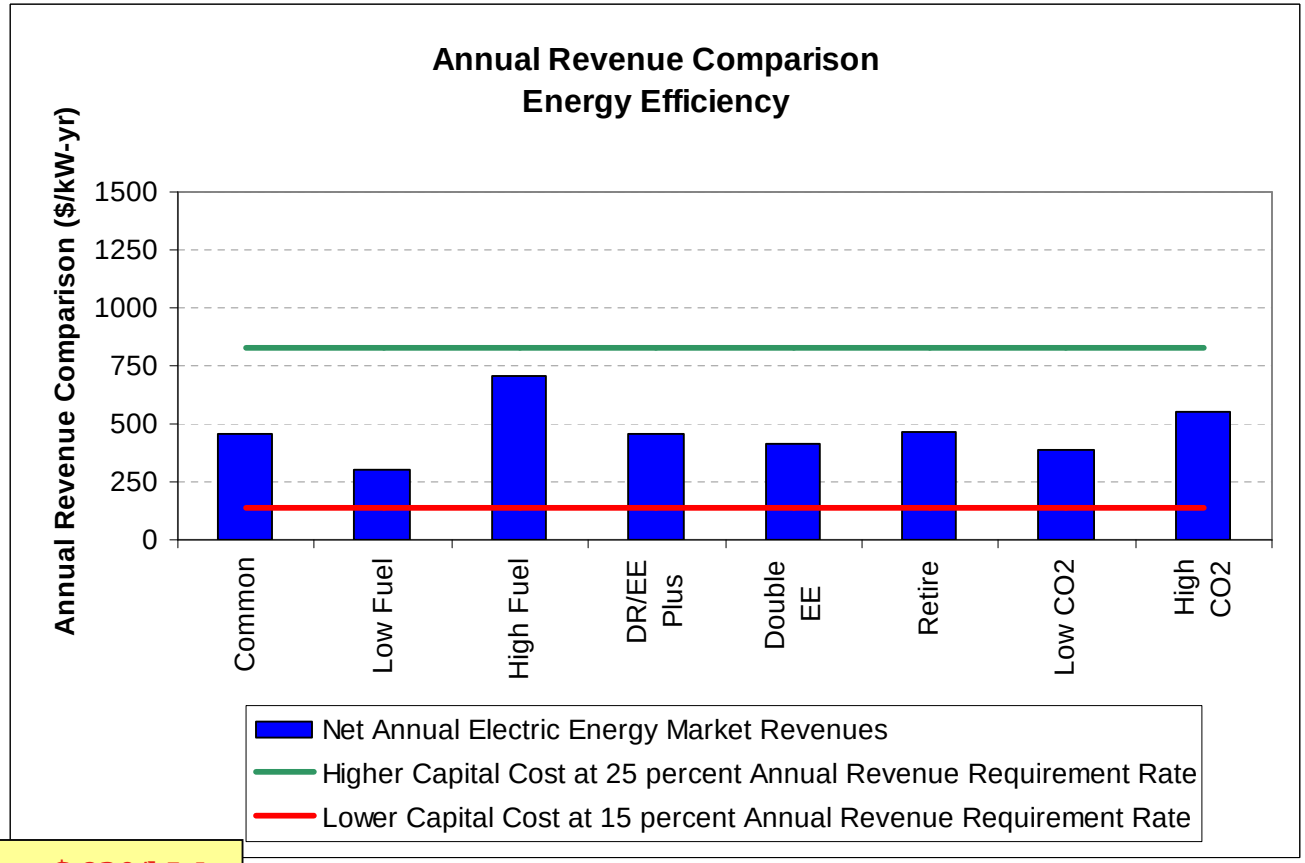

**Lower Capital Cost: $ 8577/Needed-kW**
**Higher Capital Cost: $11080/Needed-kW**

# EE/DR Expansion: Demand Response



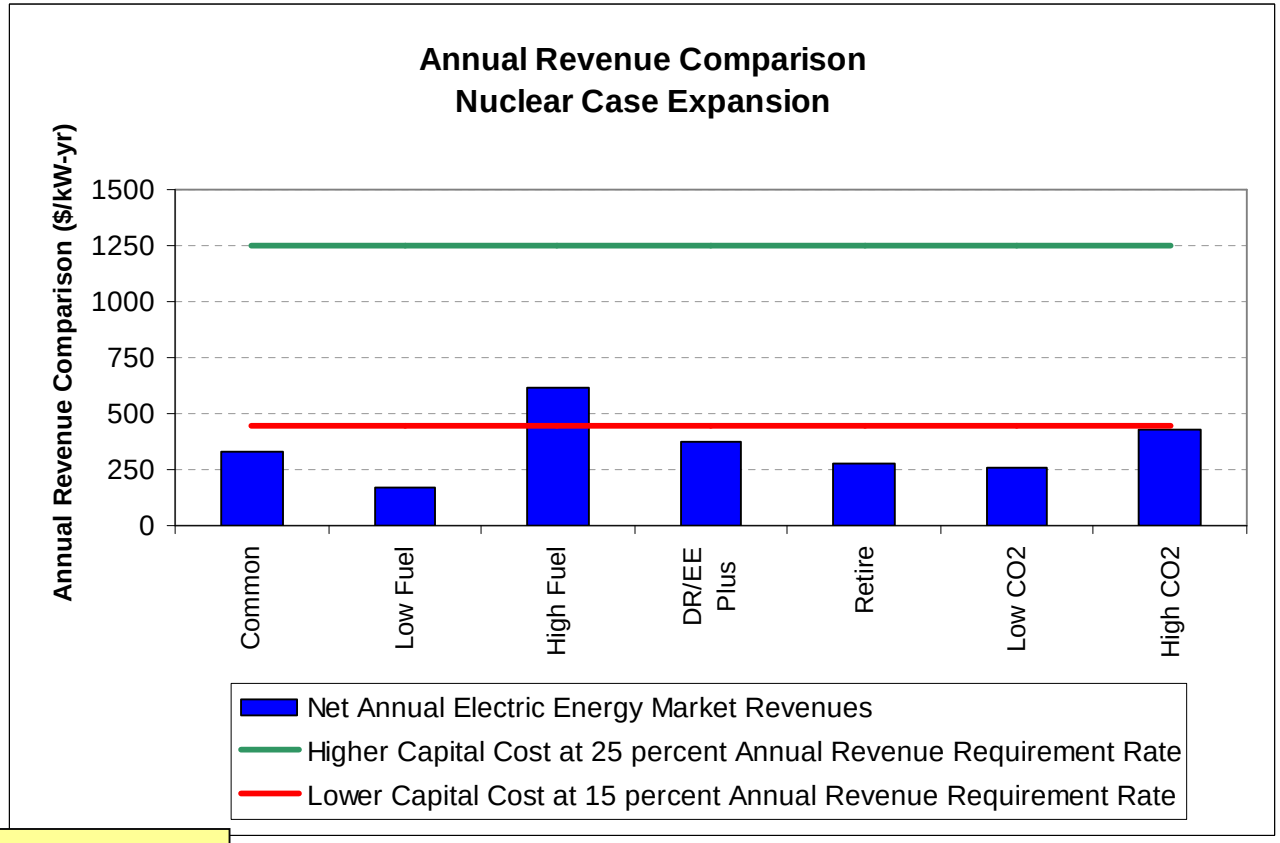

**Lower Capital Cost: $ zero/kW**
**Higher Capital Cost: $ zero/kW**

# EE/DR Expansion: Energy Efficiency



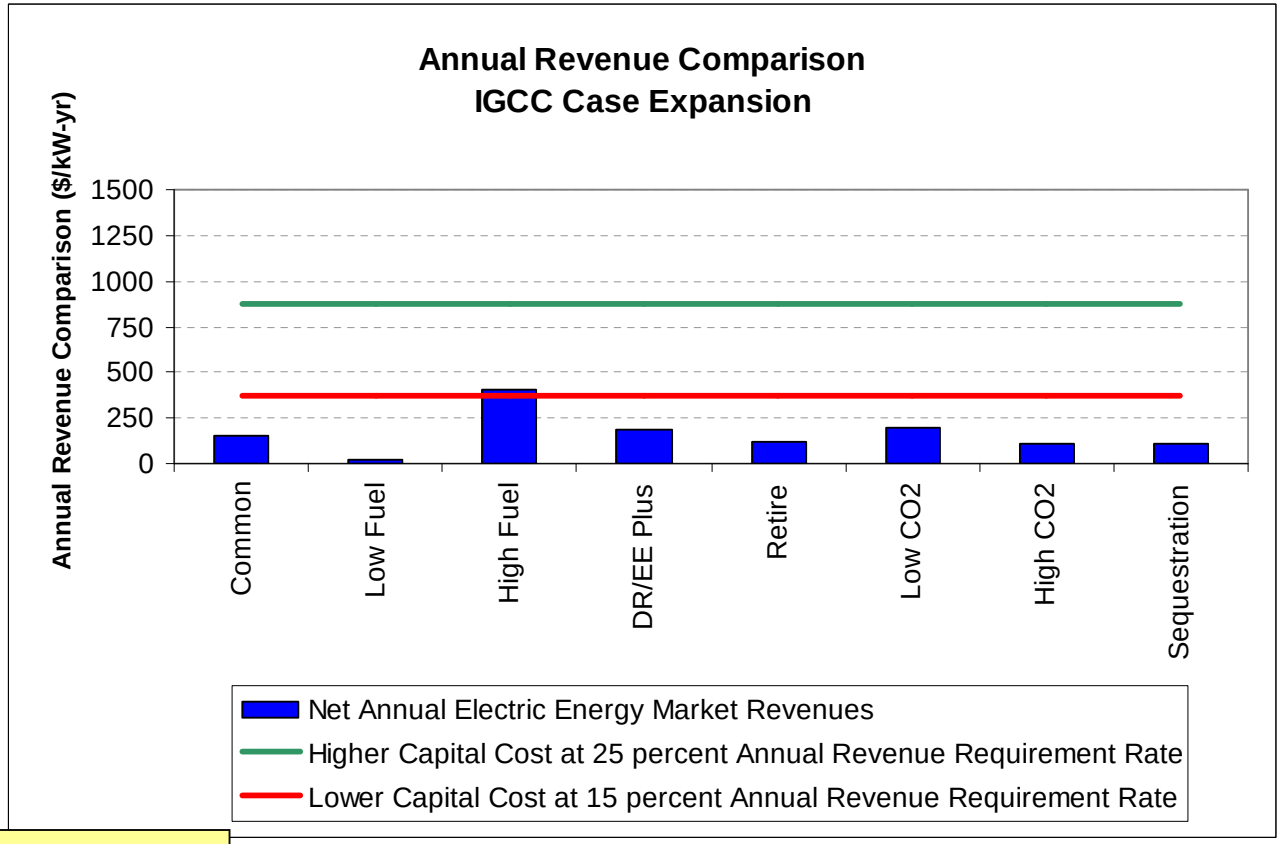

**Lower Capital Cost: $ 920/kW**
**Higher Capital Cost: $3300/kW**

# Nuclear Expansion: Nuclear



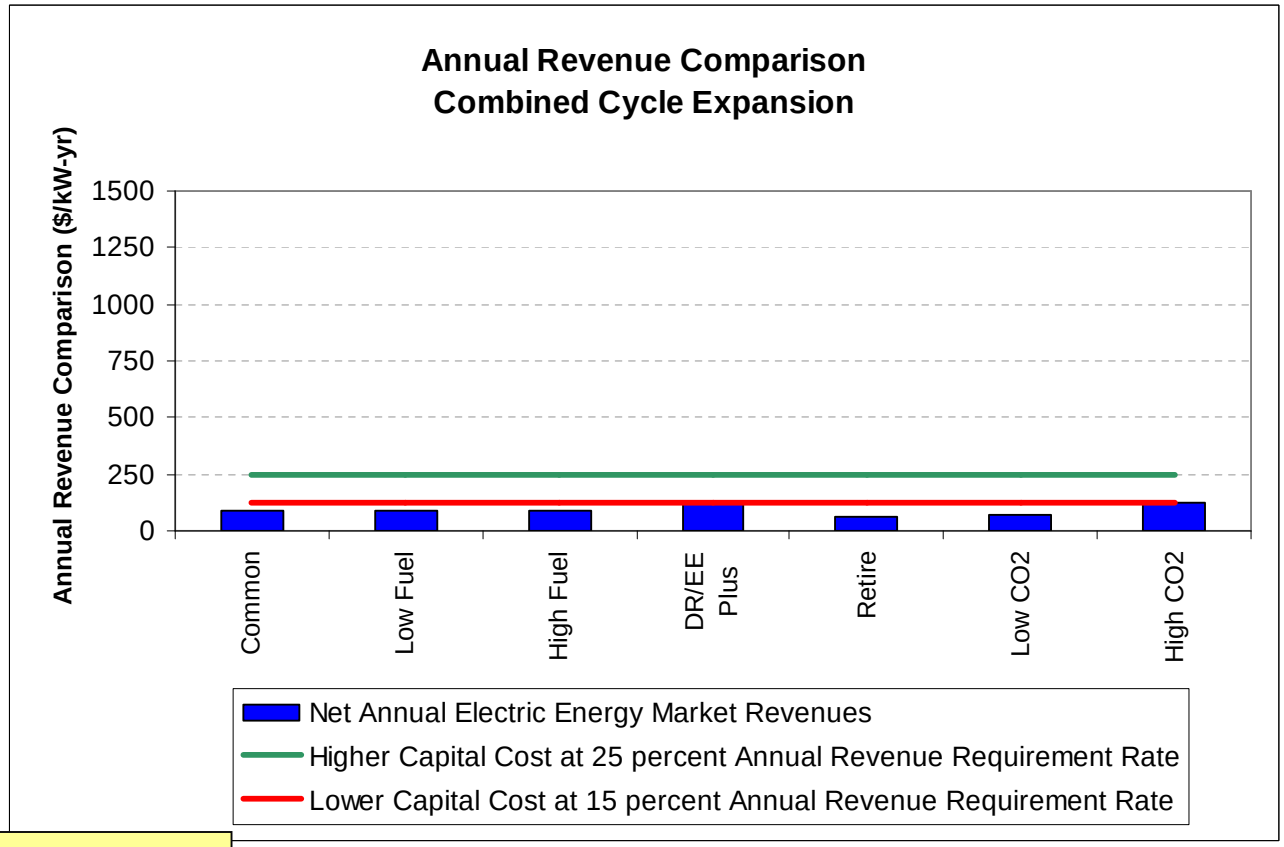

**Lower Capital Cost:$3000/kW**
**Higher Capital Cost: $5000/kW**

# IGCC Expansion Case: IGCC




**Lower Capital Cost: $2500/kW**
**Higher Capital Cost: $3500/kW**

# Combined Cycle Expansion




**Lower Capital Cost: $ 800/kW**
**Higher Capital Cost: $1000/kW**

# Renewable Resources: Small Hydro

**Renewable Case Technologies**

**=> Small Hydro**

CHP

Biomass

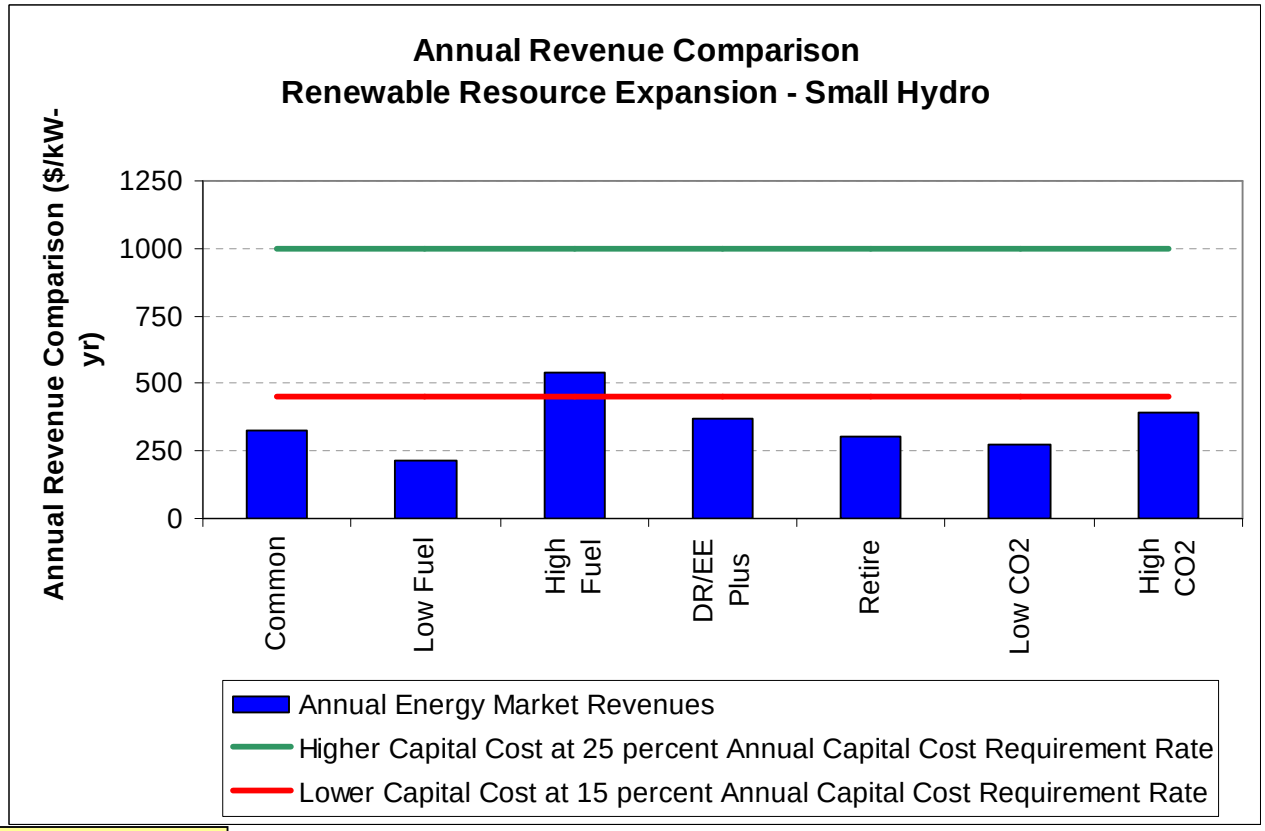
Fuel Cells

Landfill Gas

Photovoltaic

Onshore Wind

Offshore Wind

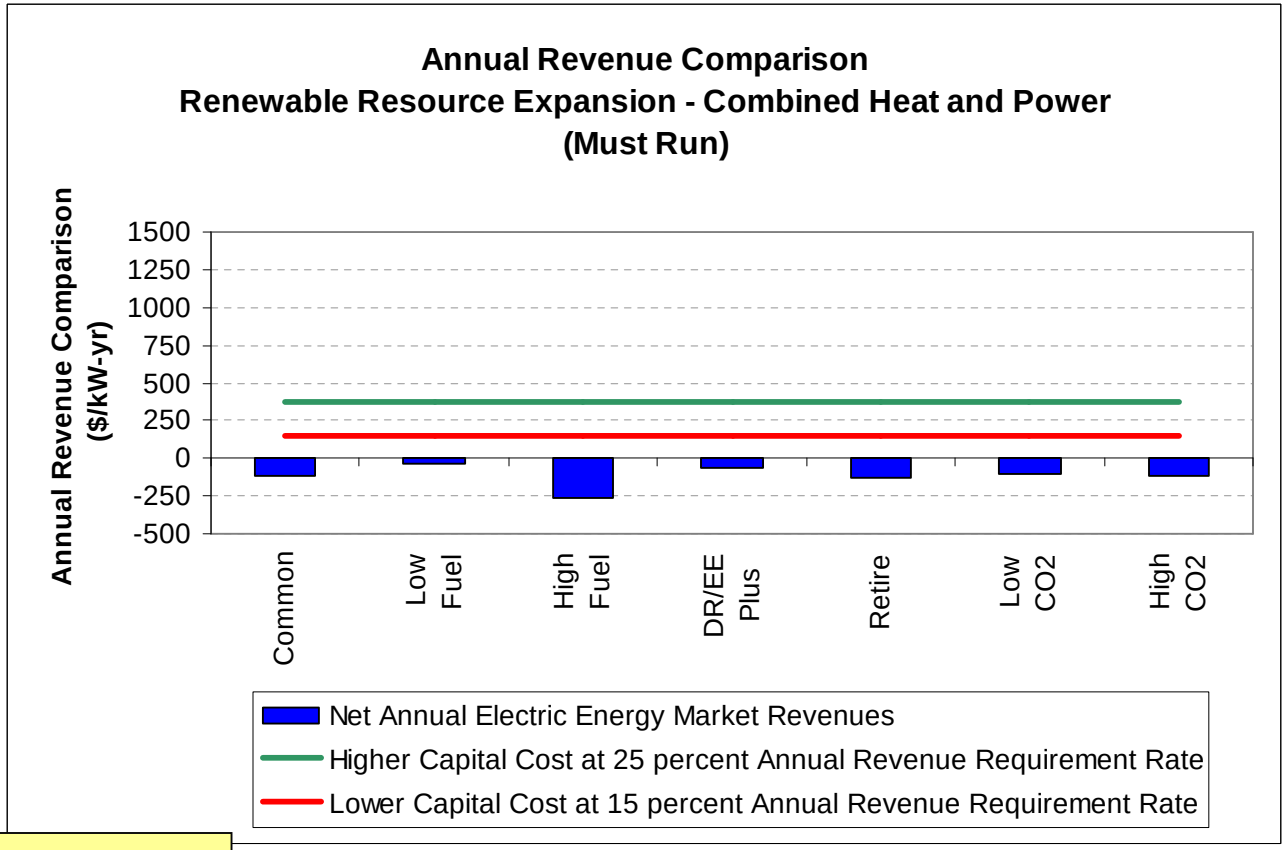



**Lower Capital Cost: $3000/kW**
**Higher Capital Cost: $4000/kW**

# Renewable Resources: CHP

**Renewable Case Technologies**

Small Hydro
=> CHP
Biomass
Fuel Cells
Landfill Gas
Photovoltaic
Onshore Wind
Offshore Wind

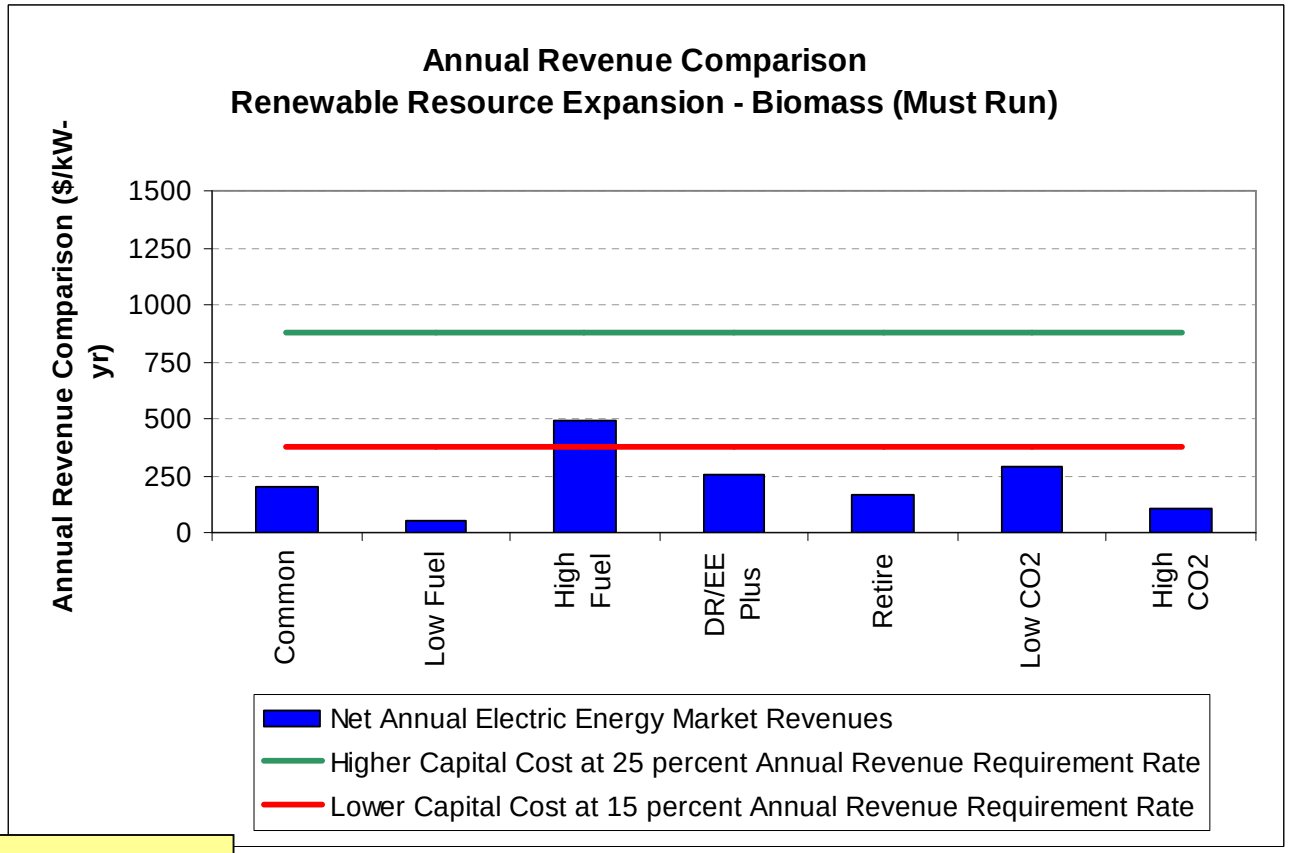



**Lower Capital Cost: $1000/kW**
**Higher Capital Cost: $1500/kW**

# Renewable Resources: Biomass

**Renewable Case Technologies**

Small Hydro
CHP
**=> Biomass**
Fuel Cells
Landfill Gas
Photovoltaic
Onshore Wind
Offshore Wind

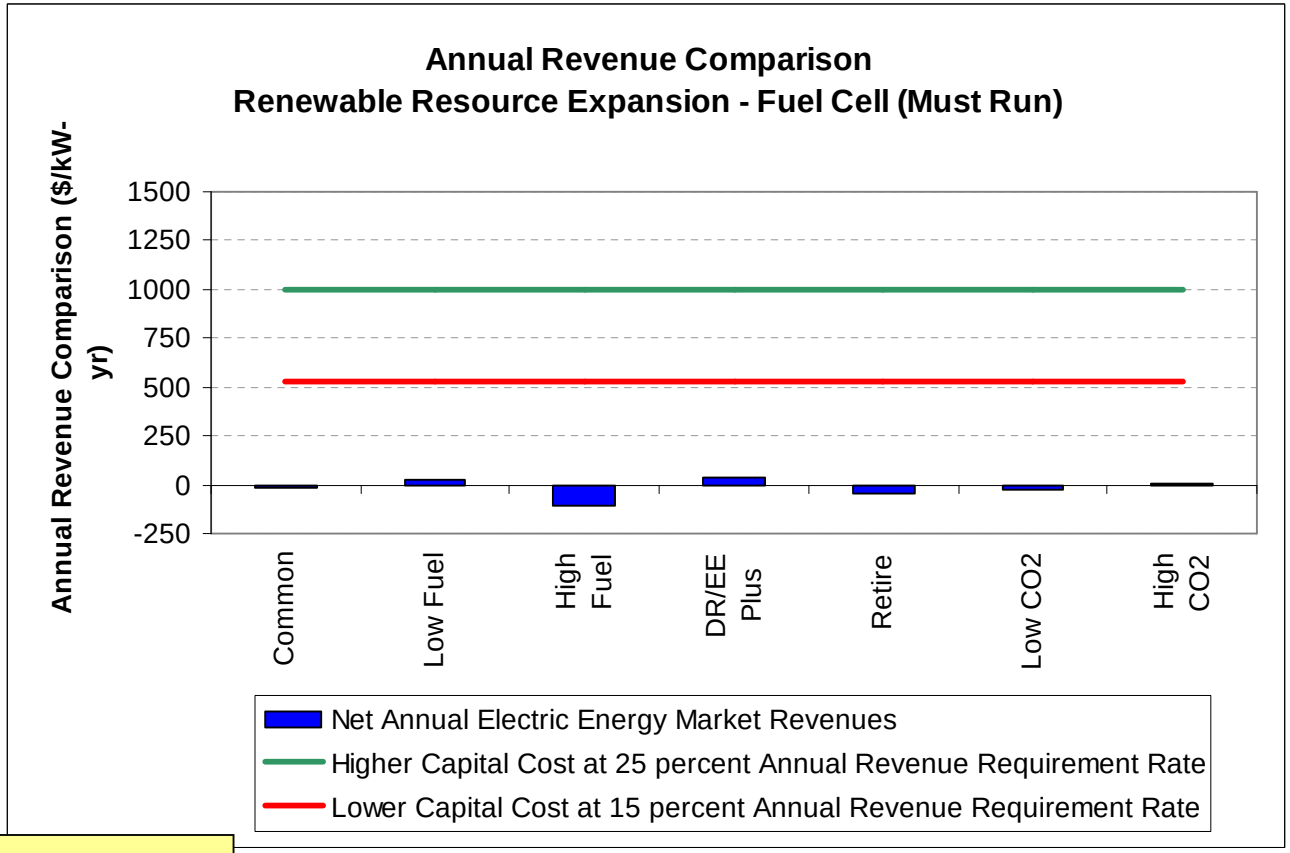



**Lower Capital Cost: $2500/kW**
**Higher Capital Cost: $3500/kW**

# Renewable Resources: Fuel Cells

**Renewable Case Technologies**

=>Small Hydro
CHP
Biomass
**=> Fuel Cells**
Landfill Gas
Photovoltaic
Onshore Wind
Offshore Wind

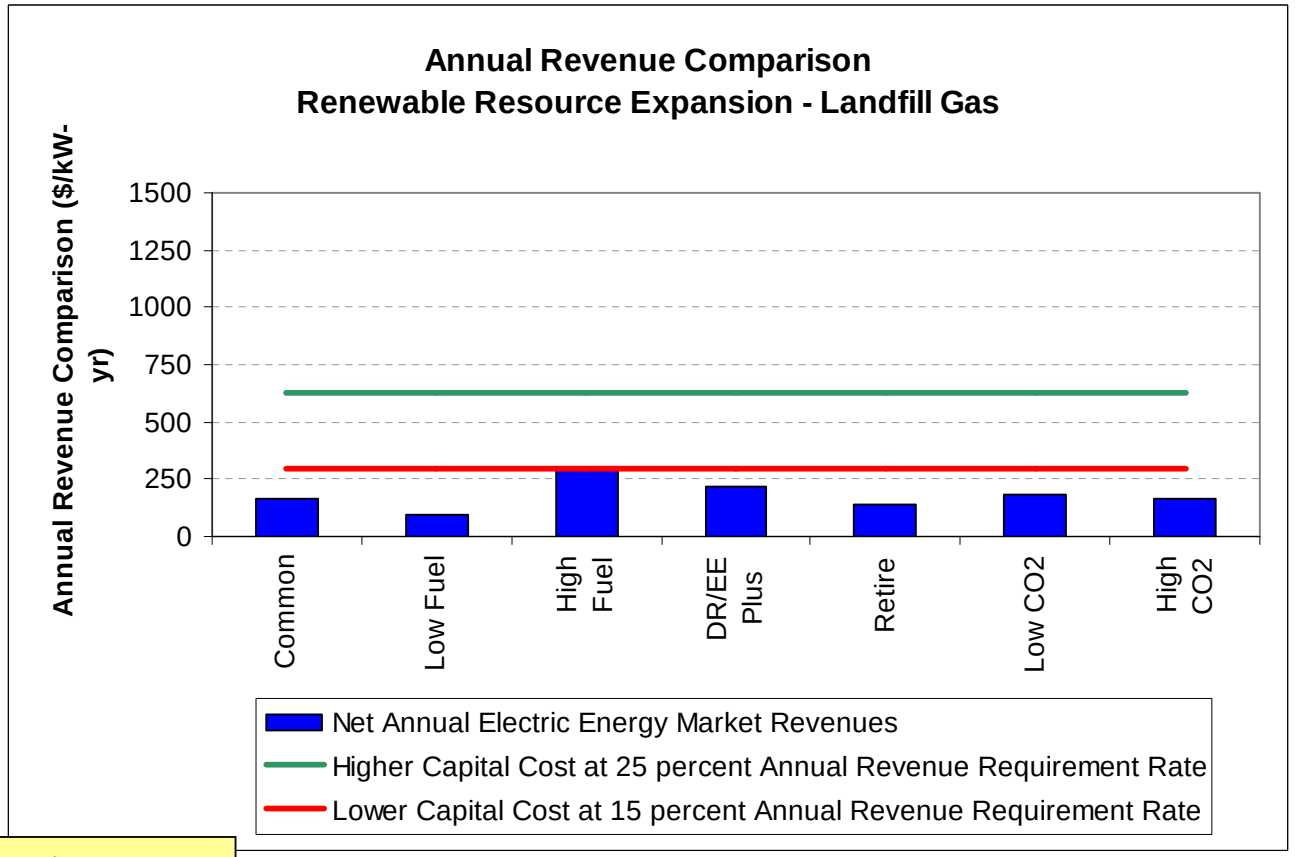



**Lower Capital Cost: $3500/kW**
**Higher Capital Cost: $4000/kW**

# Renewable Resources: Landfill Gas

**Renewable Case Technologies**

=>Small Hydro
CHP
Biomass
Fuel Cells
**=> Landfill Gas**
Photovoltaic
Onshore Wind
Offshore Wind

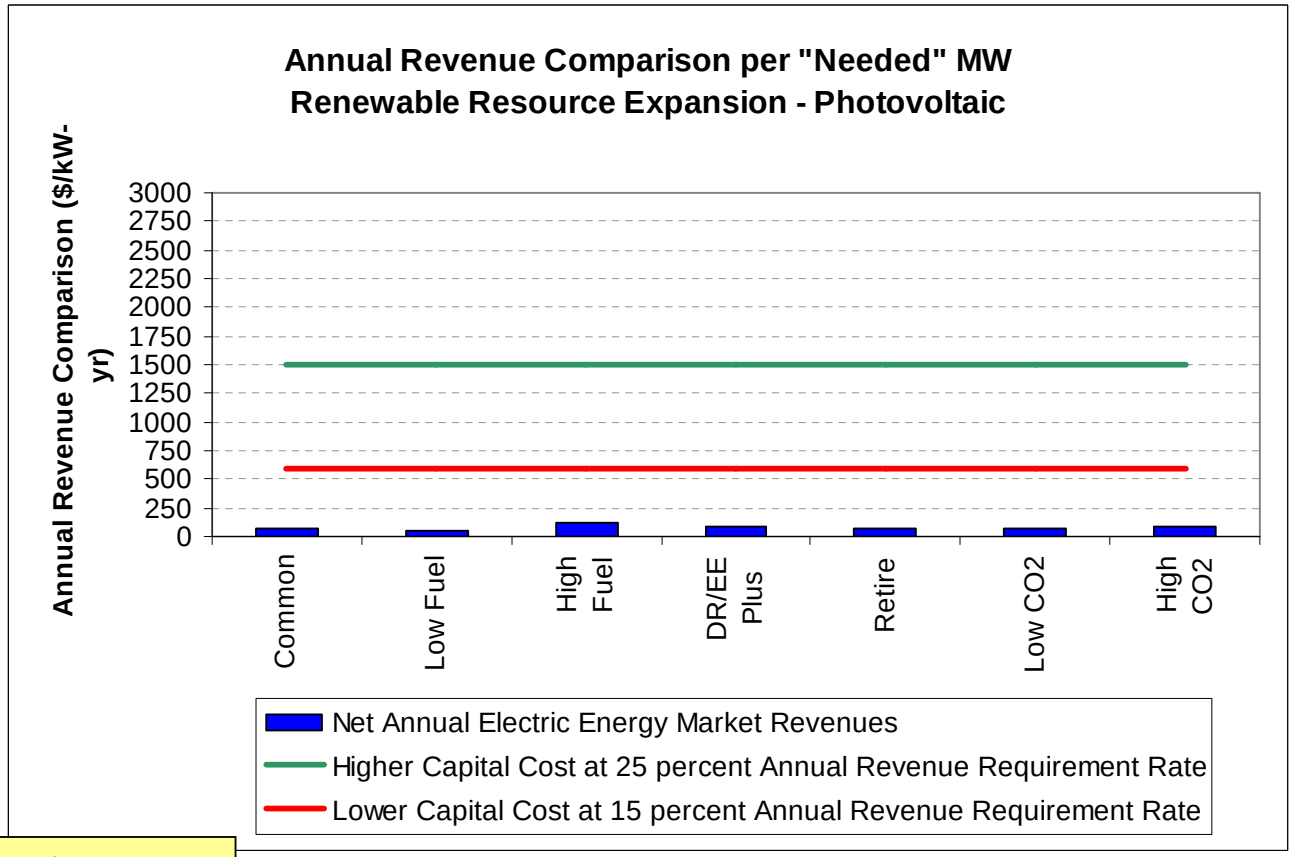



**Lower Capital Cost: $2000/kW**
**Higher Capital Cost: $2500/kW**

# Renewable Resources: Photovoltaic

**Renewable Case Technologies**

=>Small Hydro
CHP
Biomass
Fuel Cells
Landfill Gas
**=> Photovoltaic**
Onshore Wind
Offshore Wind

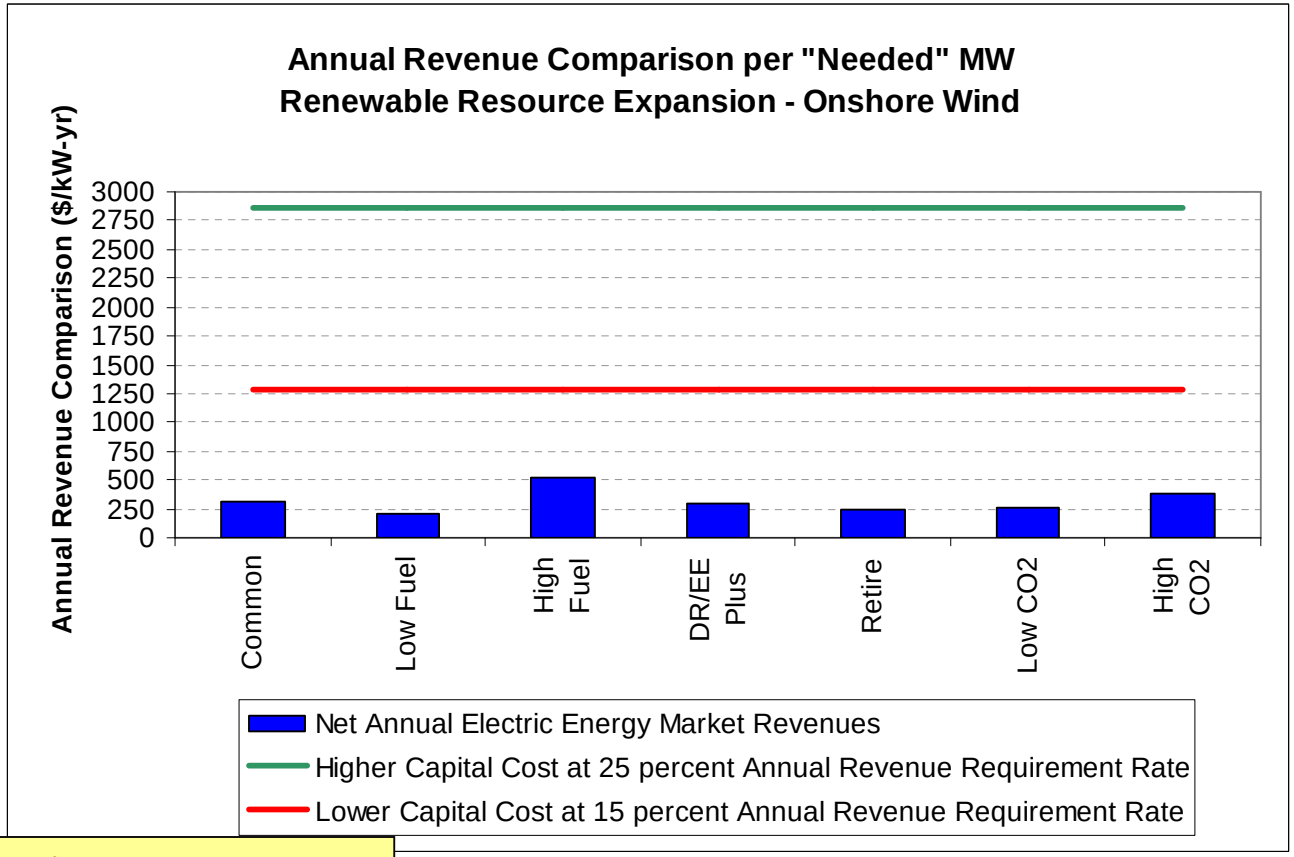



**Lower Capital Cost: $4000/kW**
**Higher Capital Cost: $6000/kW**

# Renewable Resources: Onshore Wind

**Renewable Case Technologies**

Small Hydro
CHP
Biomass
Fuel Cells
Landfill Gas
Photovoltaic
**=> Onshore Wind**
Offshore Wind

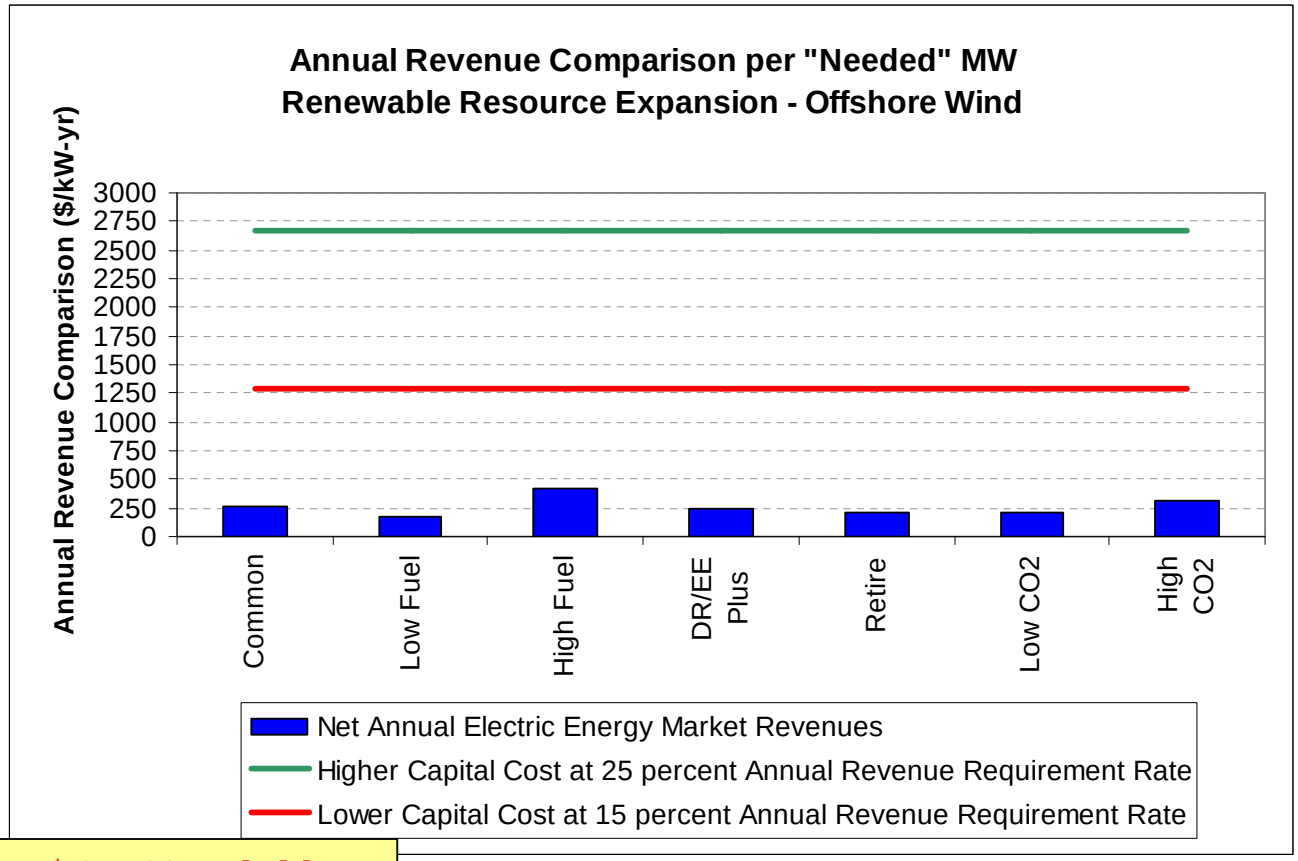



**Lower Capital Cost: $ 8,601/Needed-kW**
**Higher Capital Cost: $11,468/Needed-kW**

# Renewable Resources: Offshore Wind

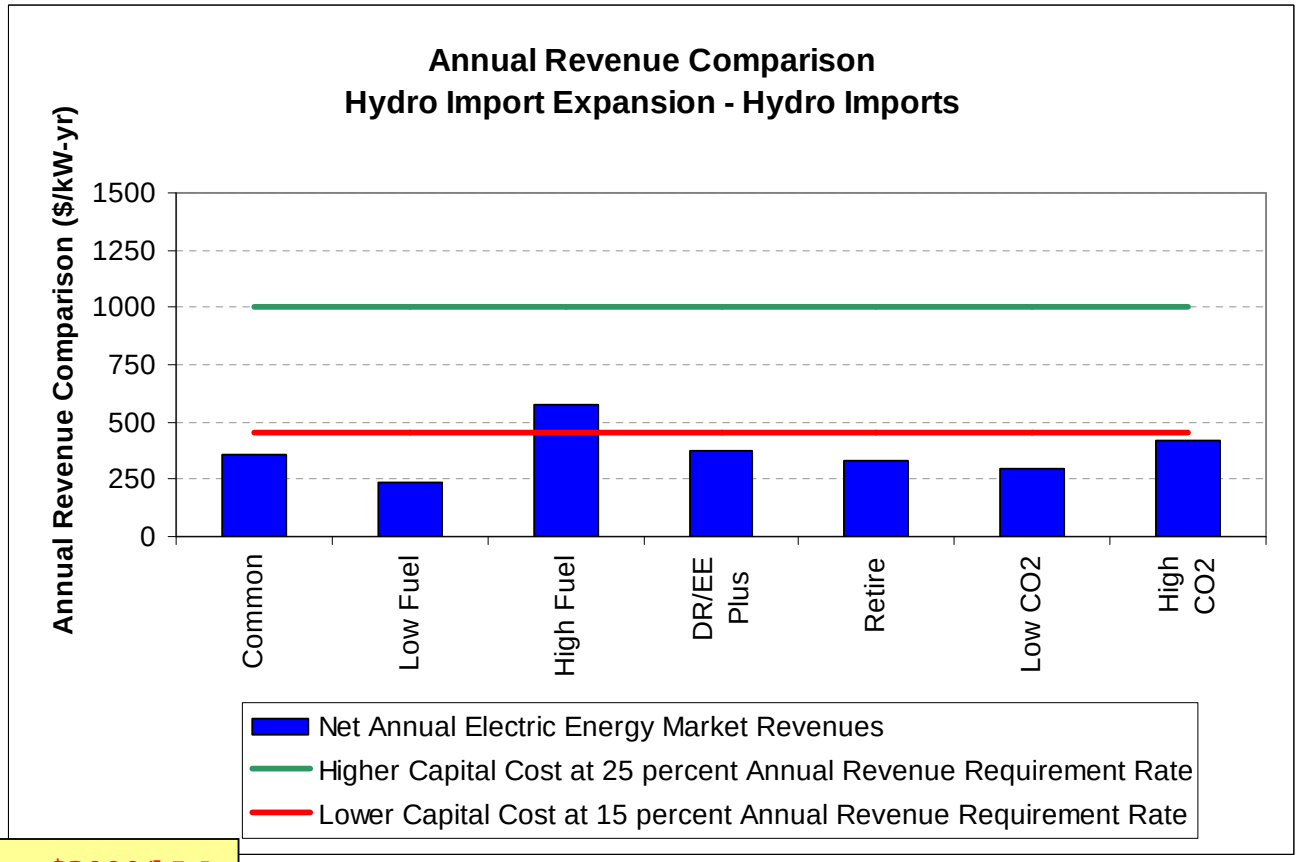
**Renewable Case Technologies**

Small Hydro
CHP
Biomass
Fuel Cells
Landfill Gas
Photovoltaic
Onshore Wind
**=> Offshore Wind**




**Lower Capital Cost: $ 8,553/Needed-kW**
**Higher Capital Cost: $10,691/Needed-kW**

# Hydro Import Case: Hydro Imports




**Lower Capital Cost: $3000/kW**
**Higher Capital Cost: $4000/kW**