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Power Sector Transition: GHG Policy and Other Key Drivers

Technical Appendix

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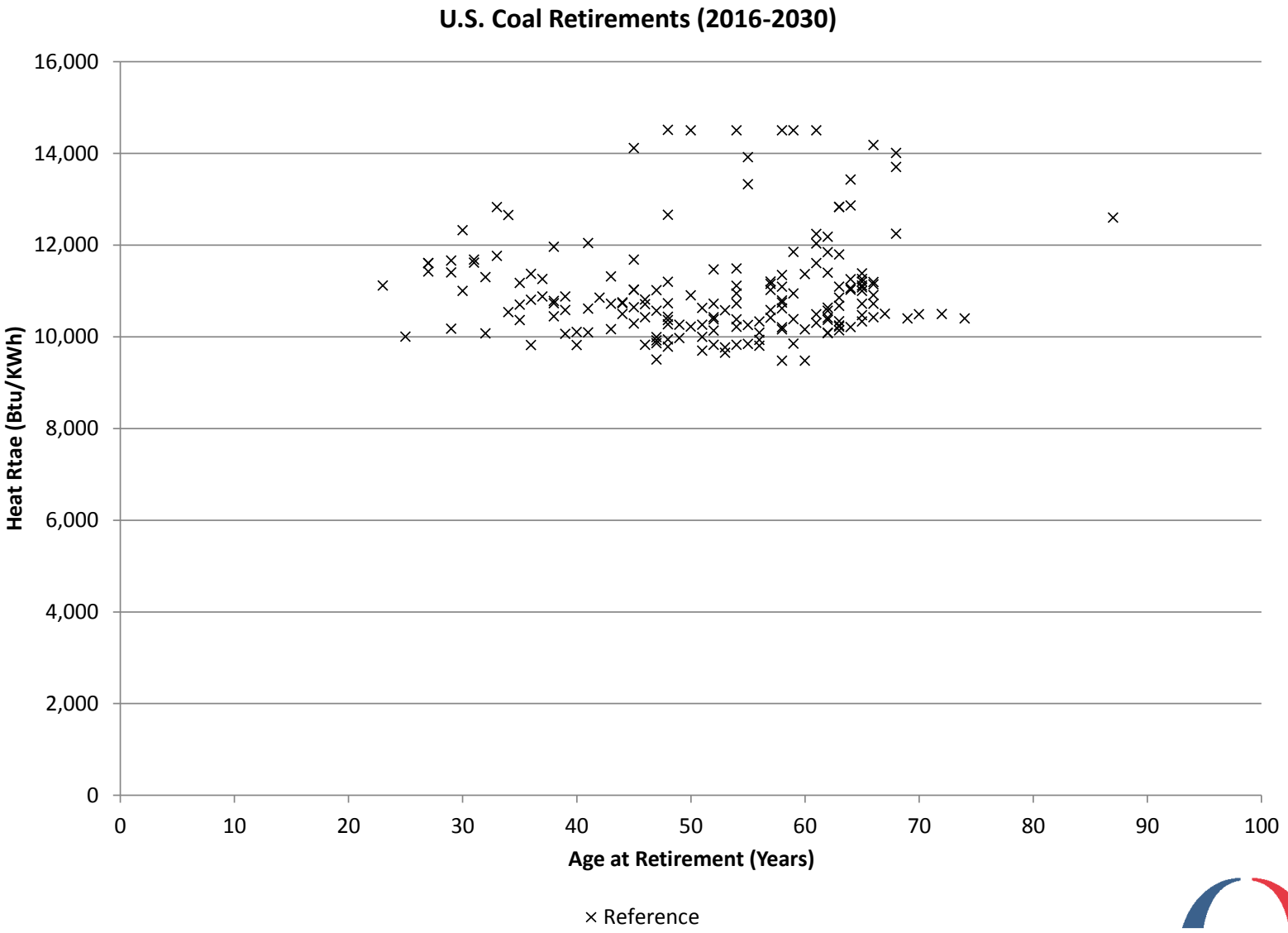
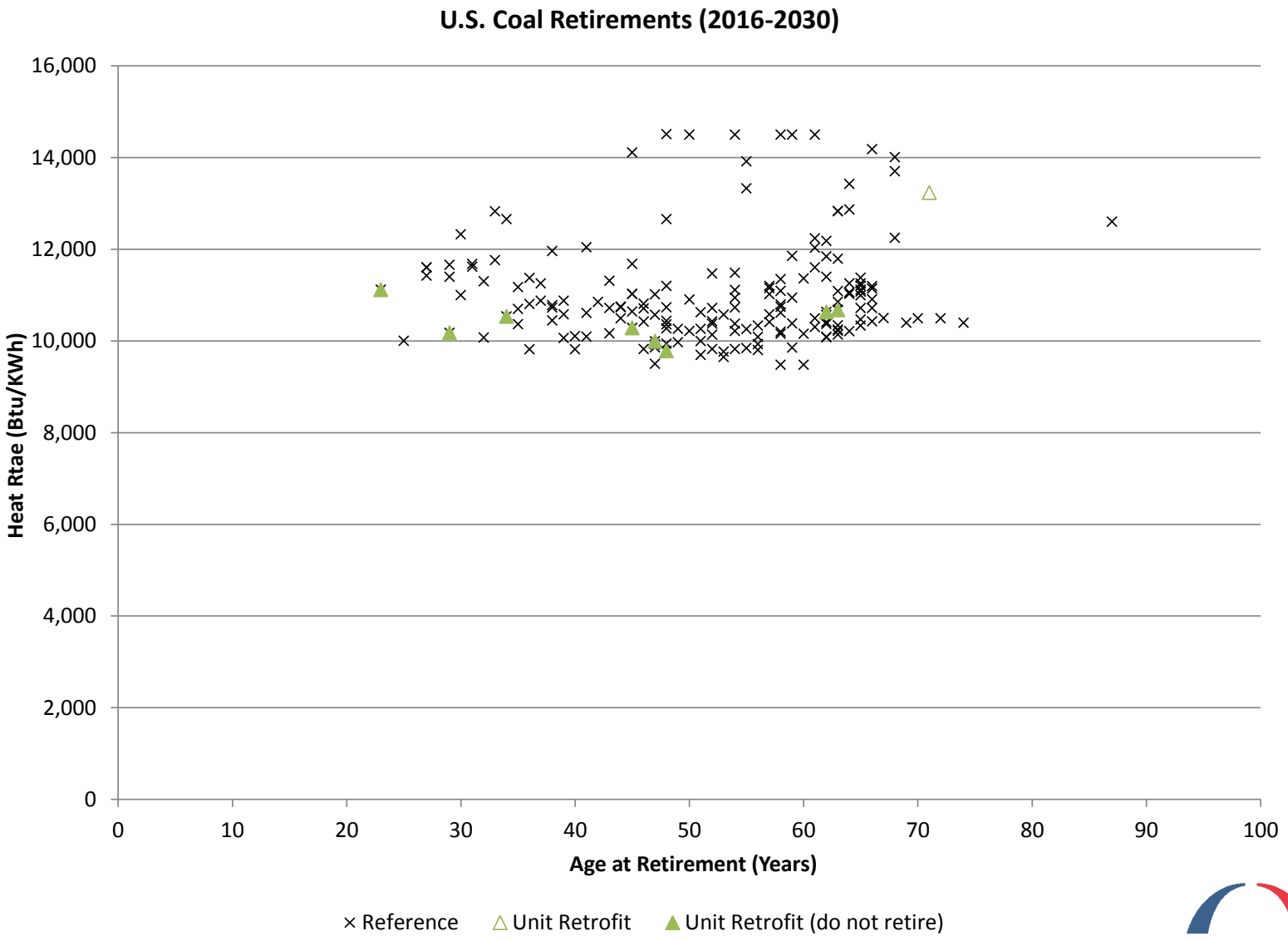
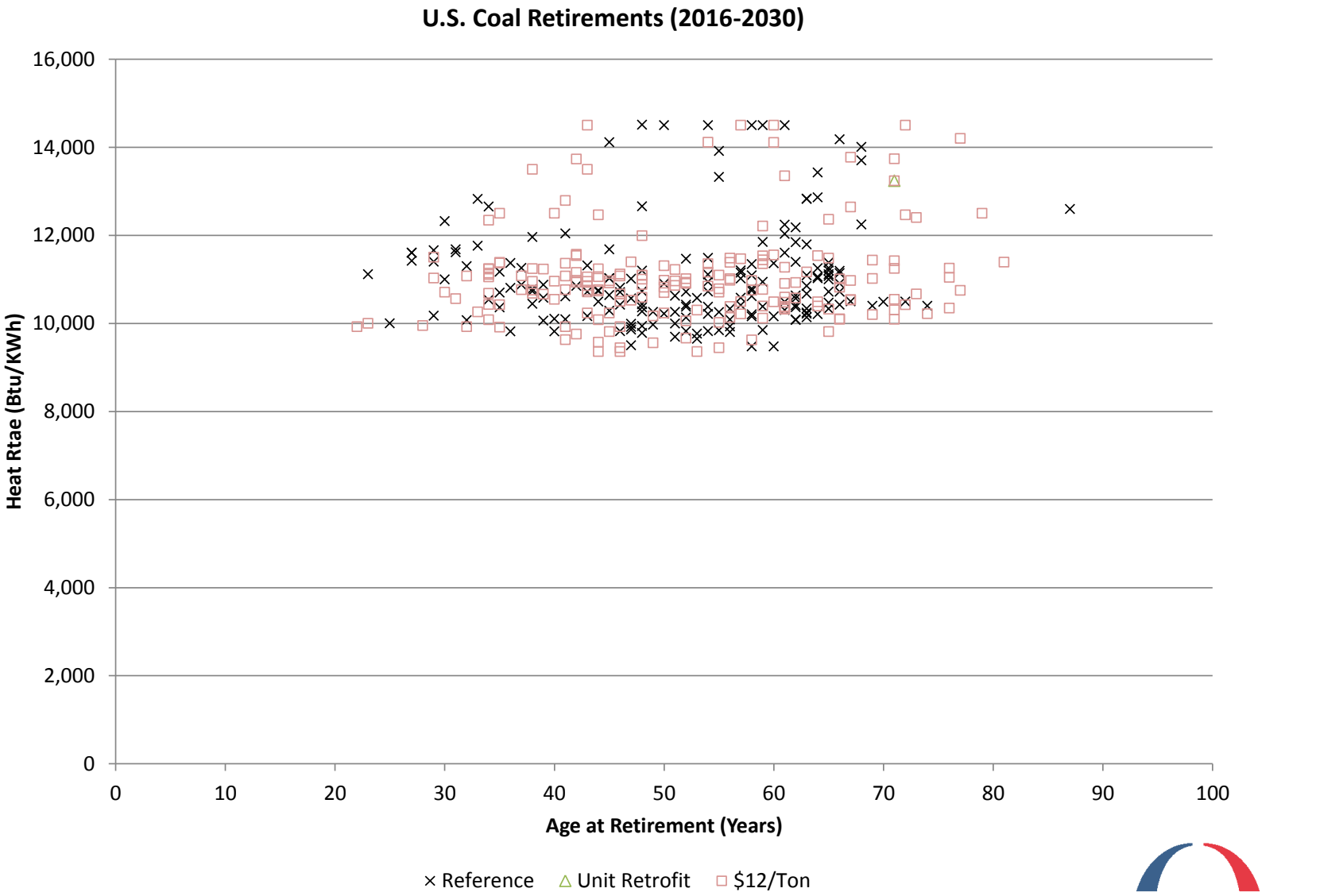
Comparison of Coal Retirement Impacts

For various scenarios
By heat rate and age at retirement


U.S. Coal Retirements (2016-2030)
Heat Rtae (Btu/KWh)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
10
20
30
40
50
60
70
80
90
100
Age at Retirement (Years)
× Reference



*Fewer retirements in Unit Retrofit compared with Reference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16,000
14,000
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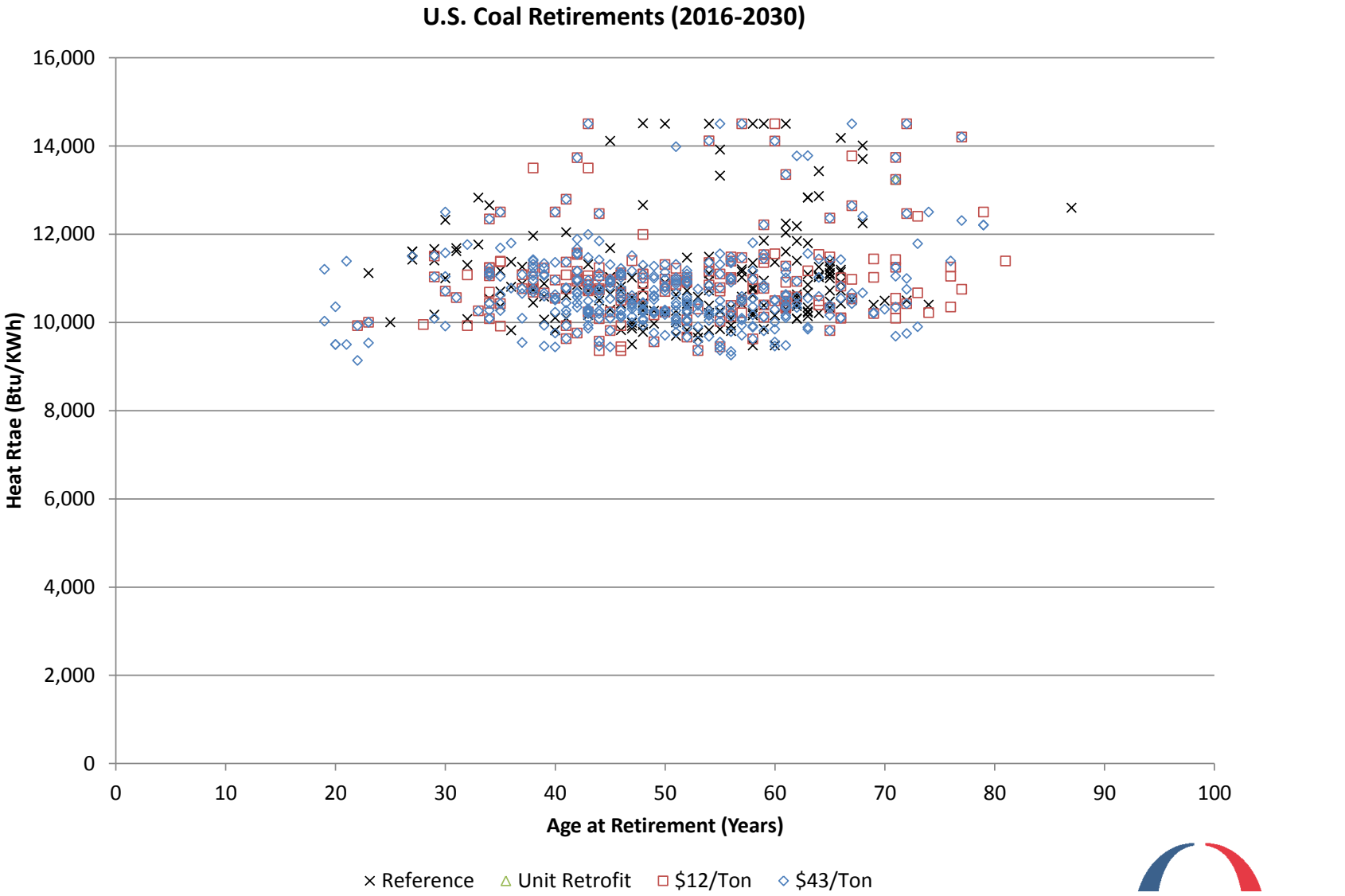
10,000
8,000
6,000
4,000
2,000
0
0
10
20
30
40
50
60
70
80
90
100
Age at Retirement (Years)
× Reference
△ Unit Retrofit
□ $12/Ton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Heat Rtae (Btu/KWh)
16,000
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12,000
10,000
8,000
6,000
4,000
2,000
0
0
10
20
30
40
50
60
70
80
90
100
Age at Retirement (Years)
× Reference
△ Unit Retrofit
□ $12/Ton
◇ $43/Ton

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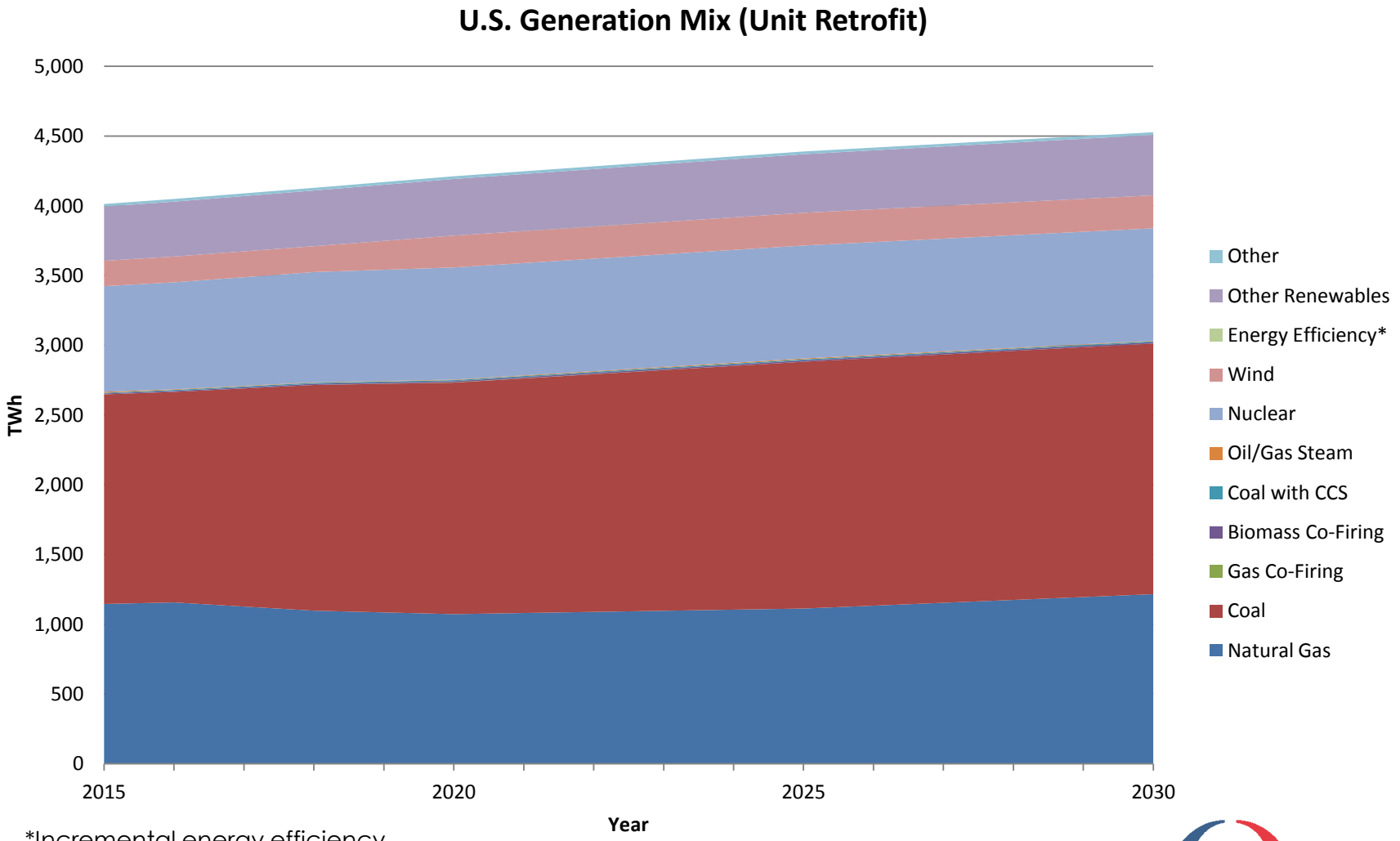
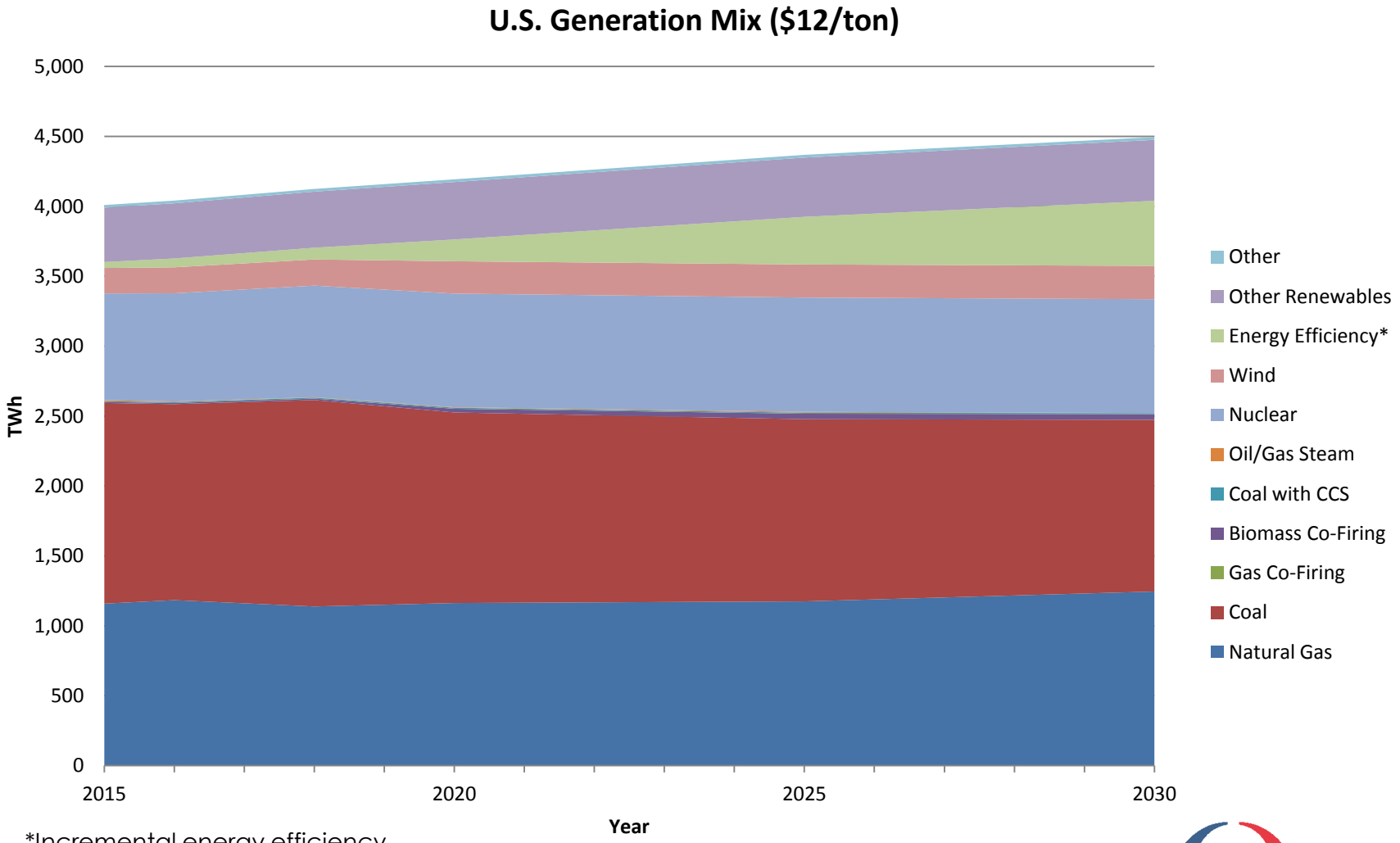
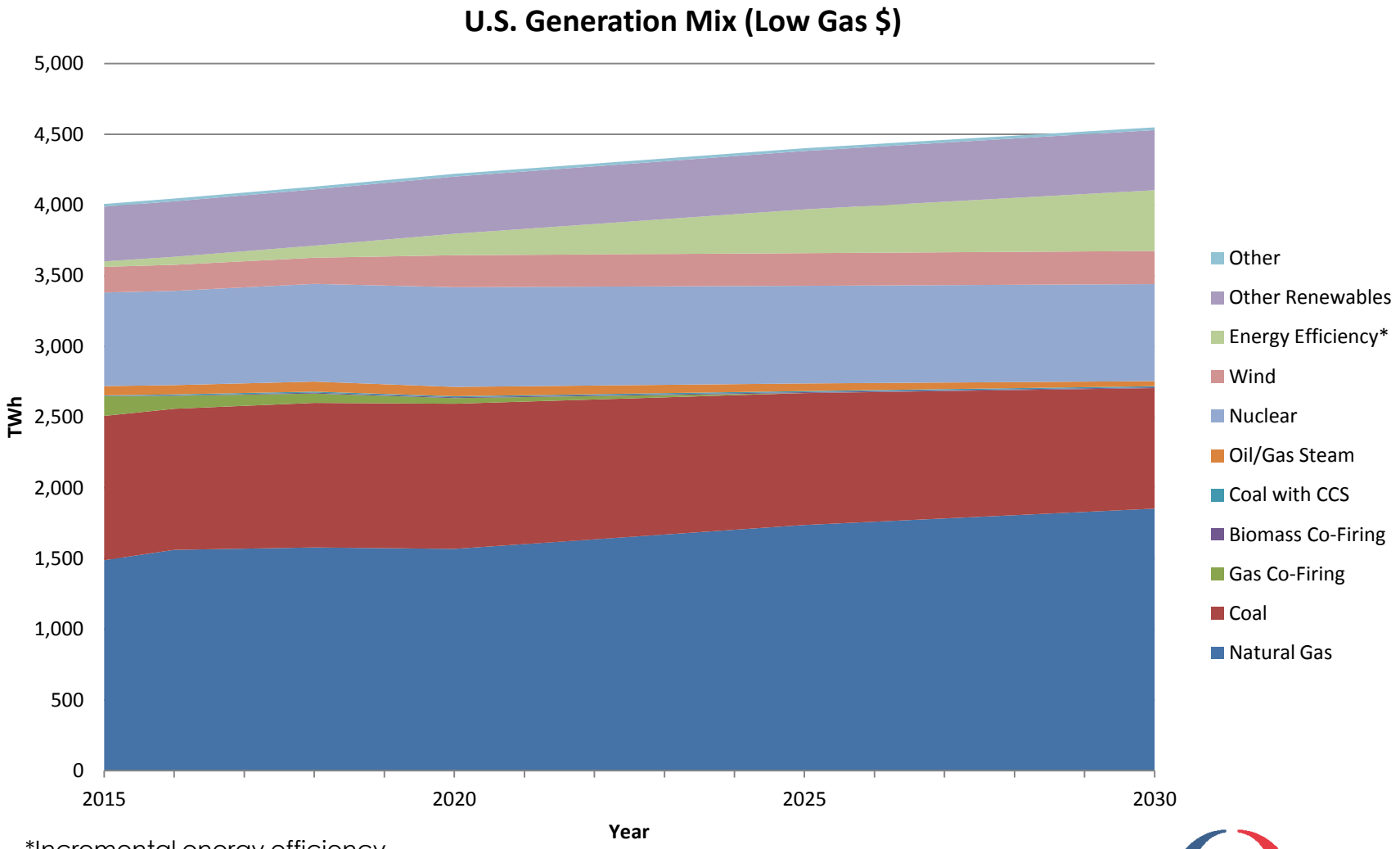
Generation Mix from Modeled Scenarios



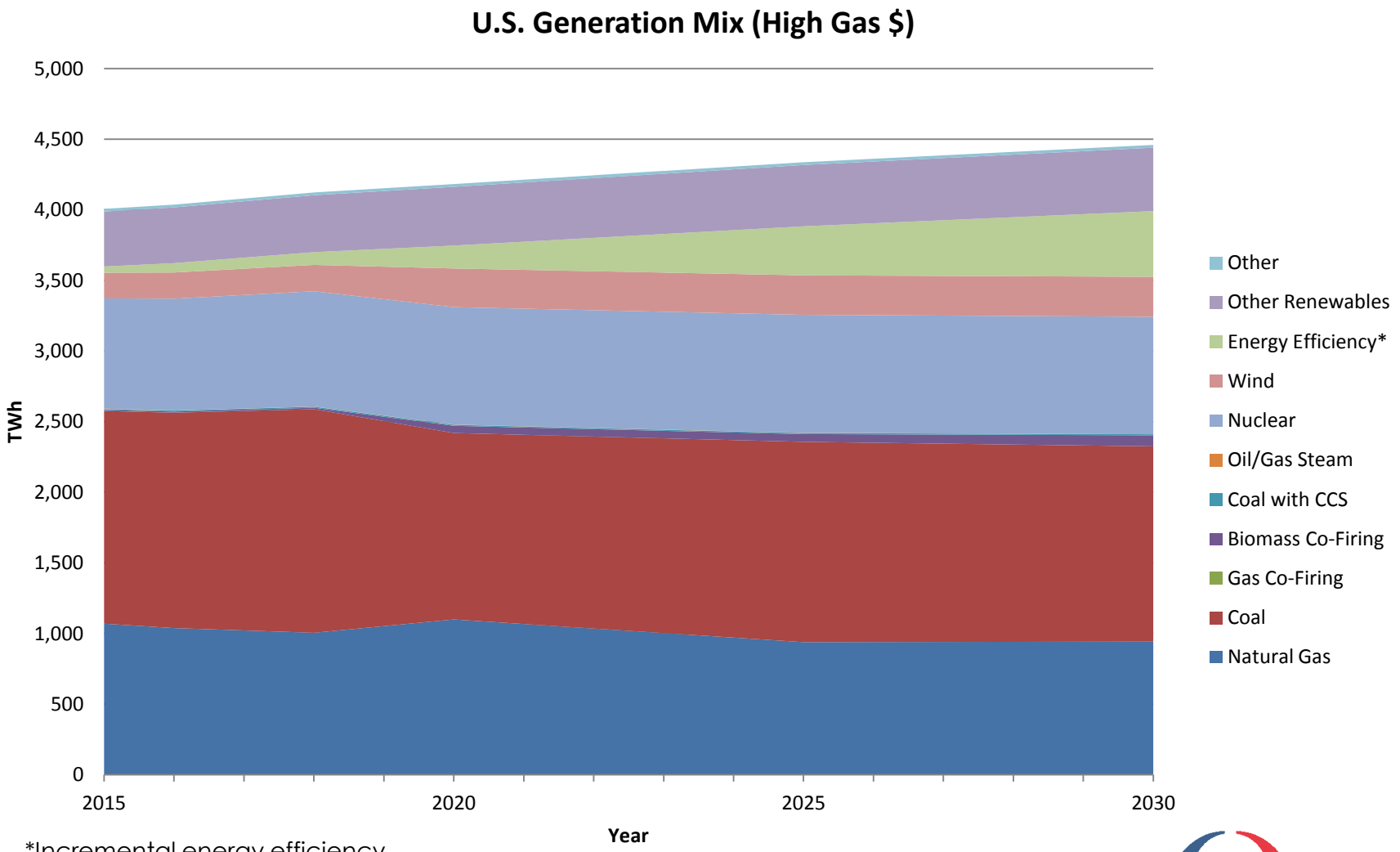
*Incremental energy efficiency



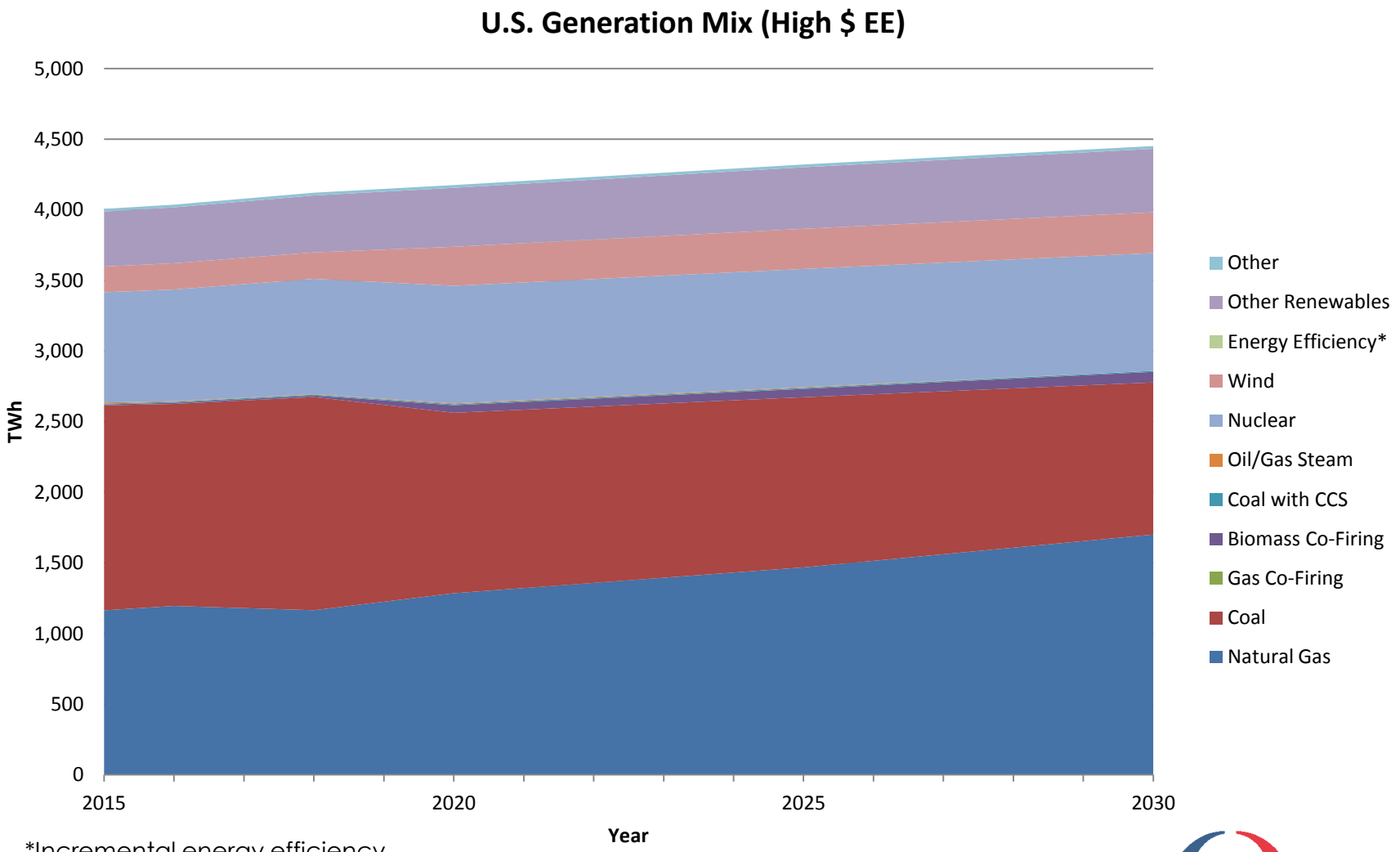
*Incremental energy efficiency



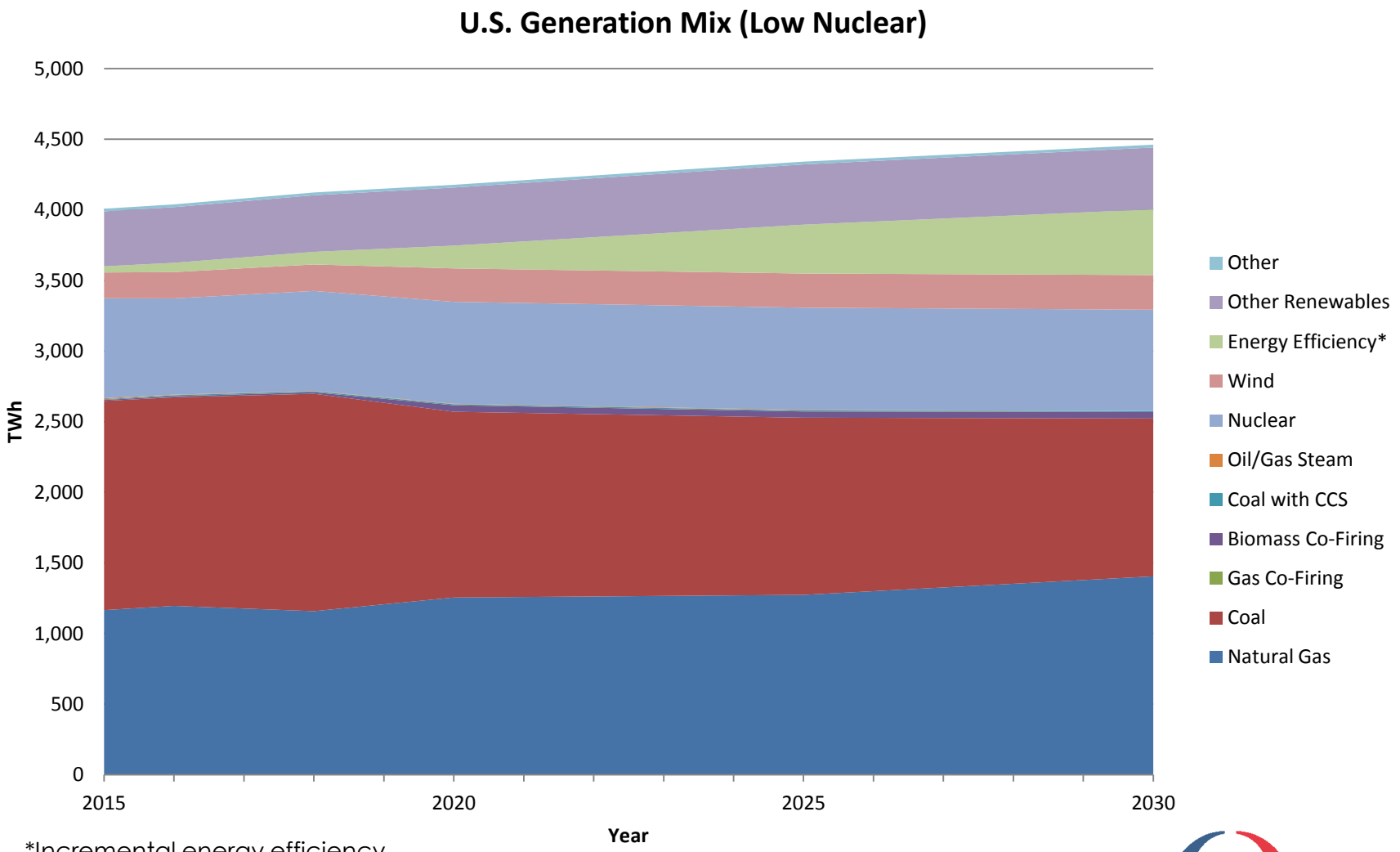
*Incremental energy efficiency



*Incremental energy efficiency



*Incremental energy efficiency



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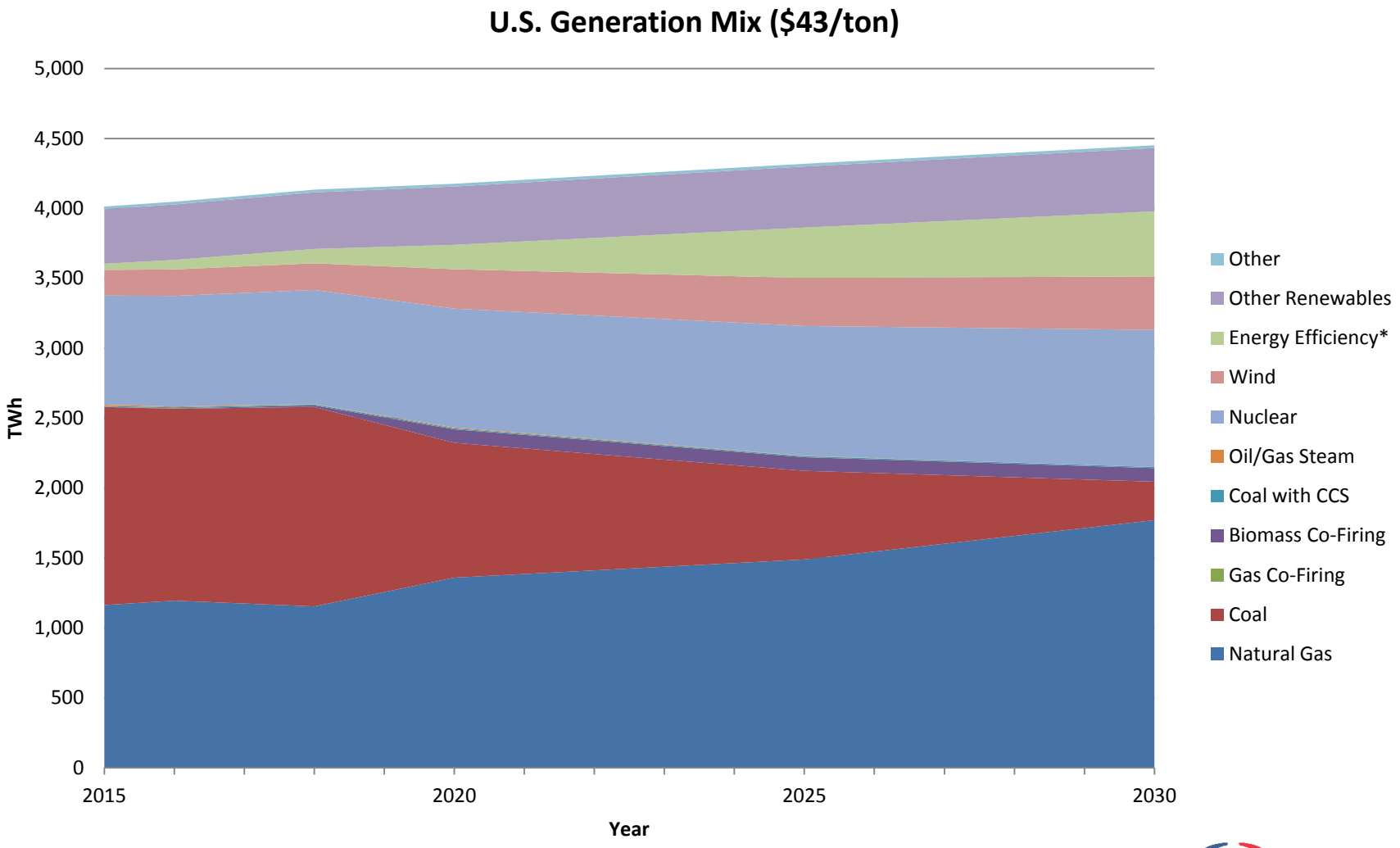

*Incremental energy efficiency

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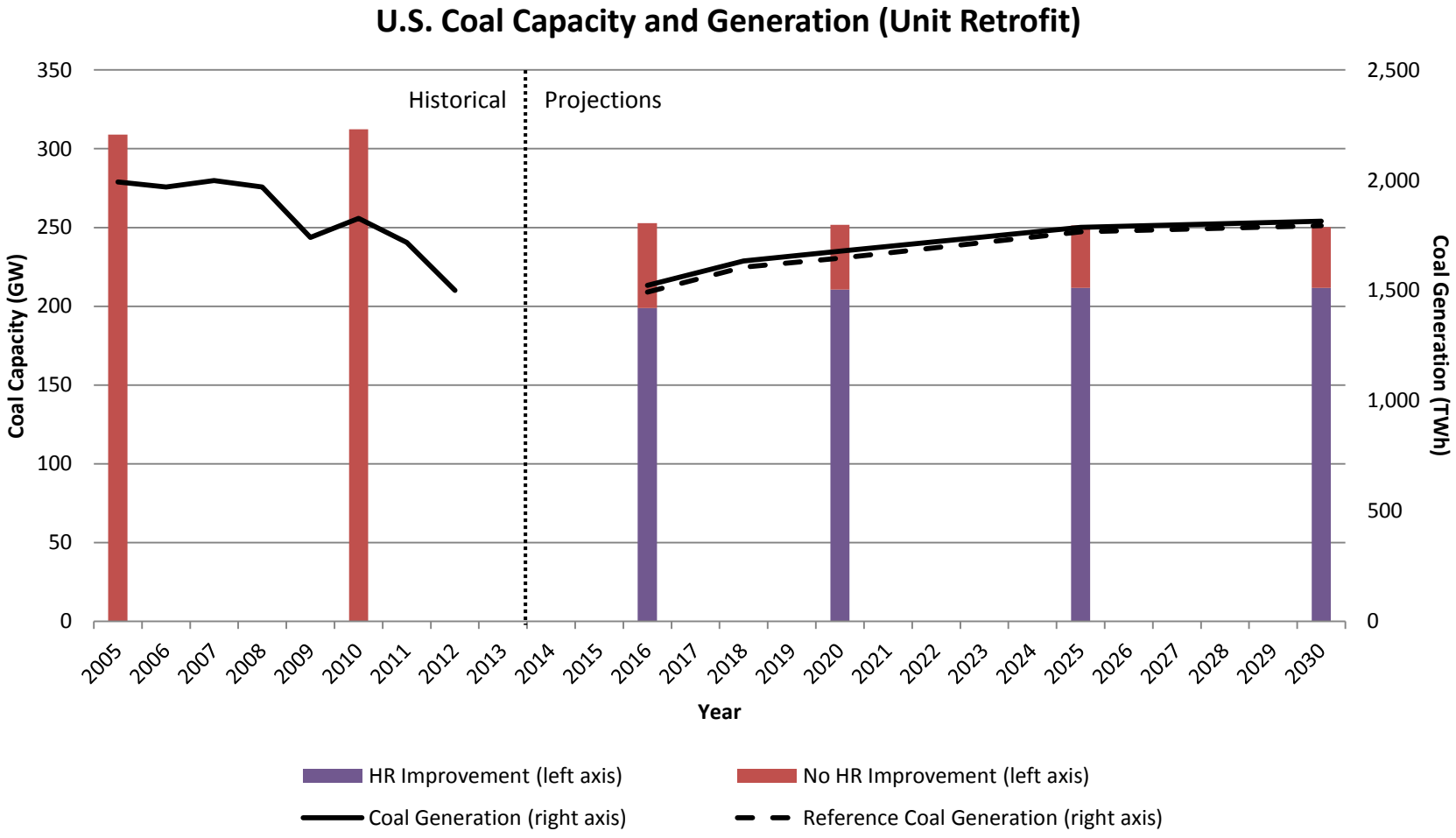
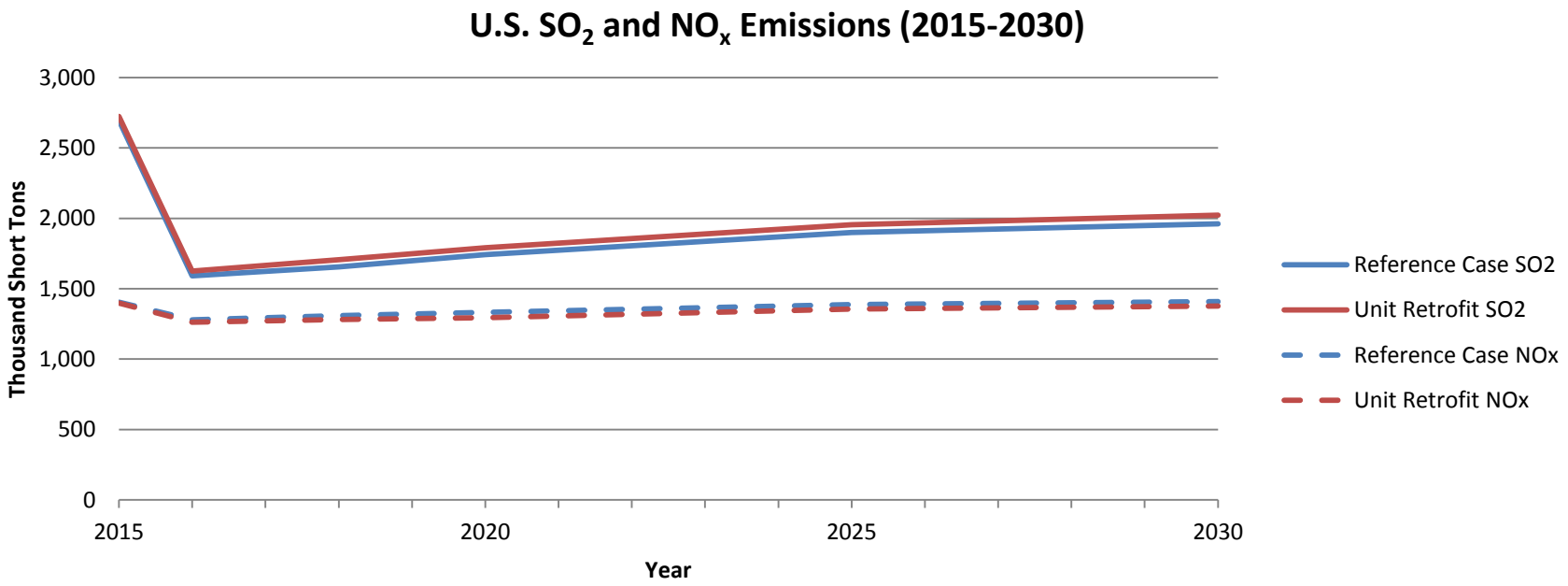
Unit Retrofit: Impact on existing coal


U.S. Coal Capacity and Generation (Unit Retrofit)
Historical
Projections
Coal Capacity (GW)
Coal Generation (TWh)
Year
350
300
250
200
150
100
50
0
2,500
2,000
1,500
1,000
500
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
HR Improvement (left axis)
No HR Improvement (left axis)
Coal Generation (right axis)
Reference Coal Generation (right axis)

Unit Retrofit: could increase SO_2 emissions above Reference case

❖ Modest increase in national SO_2 emissions projected

- Significant increases in some regions
- Due to changes in dispatch of coal generators after plant upgrades
- EPA determinations on New Source Review could limit SO_2 increases
- CO_2 and NO_X emissions are lower than Reference



SO_2: Sulfur Dioxide
CO_2: Carbon Dioxide
NO_x: Nitrogen Dioxide

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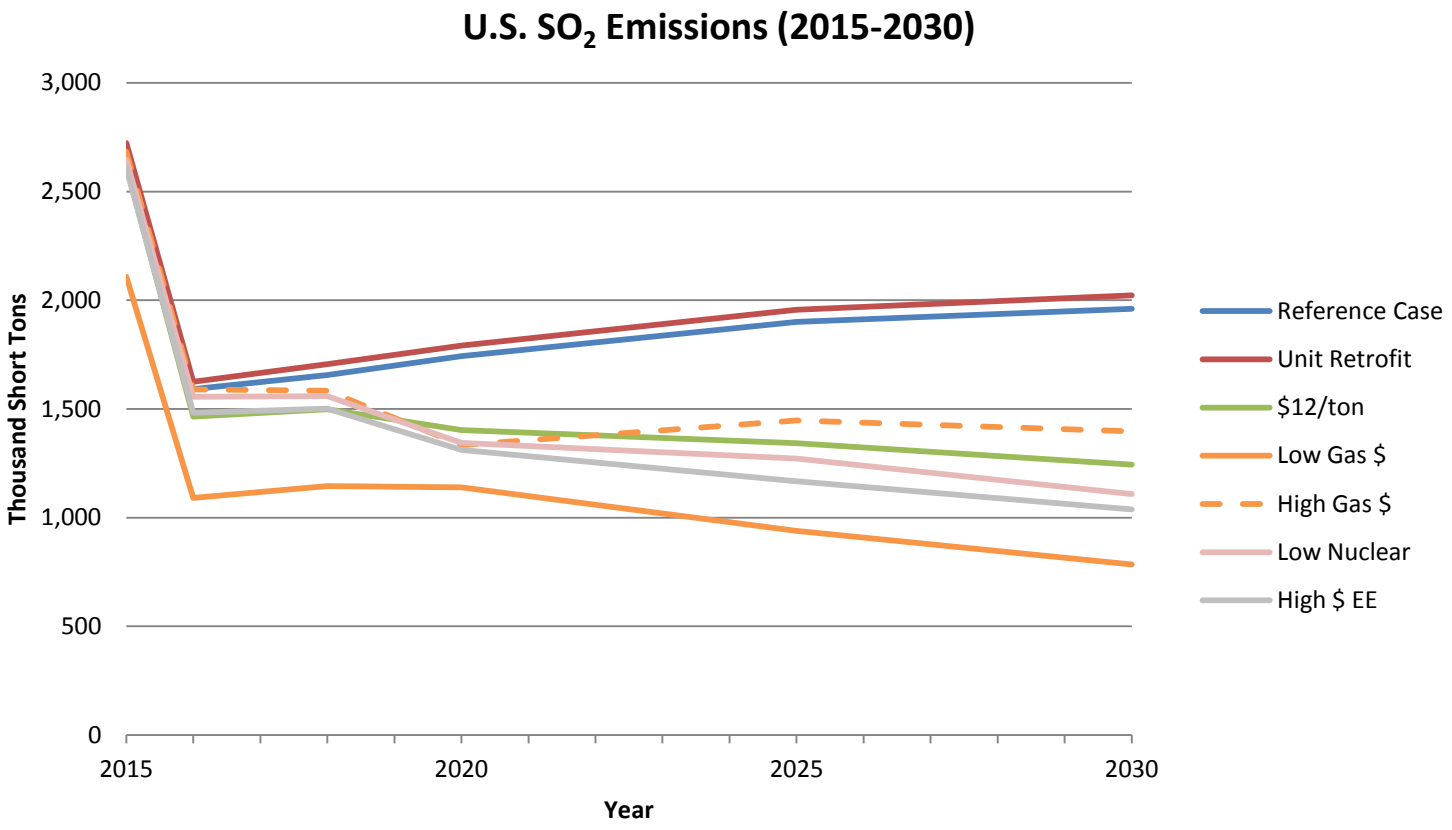
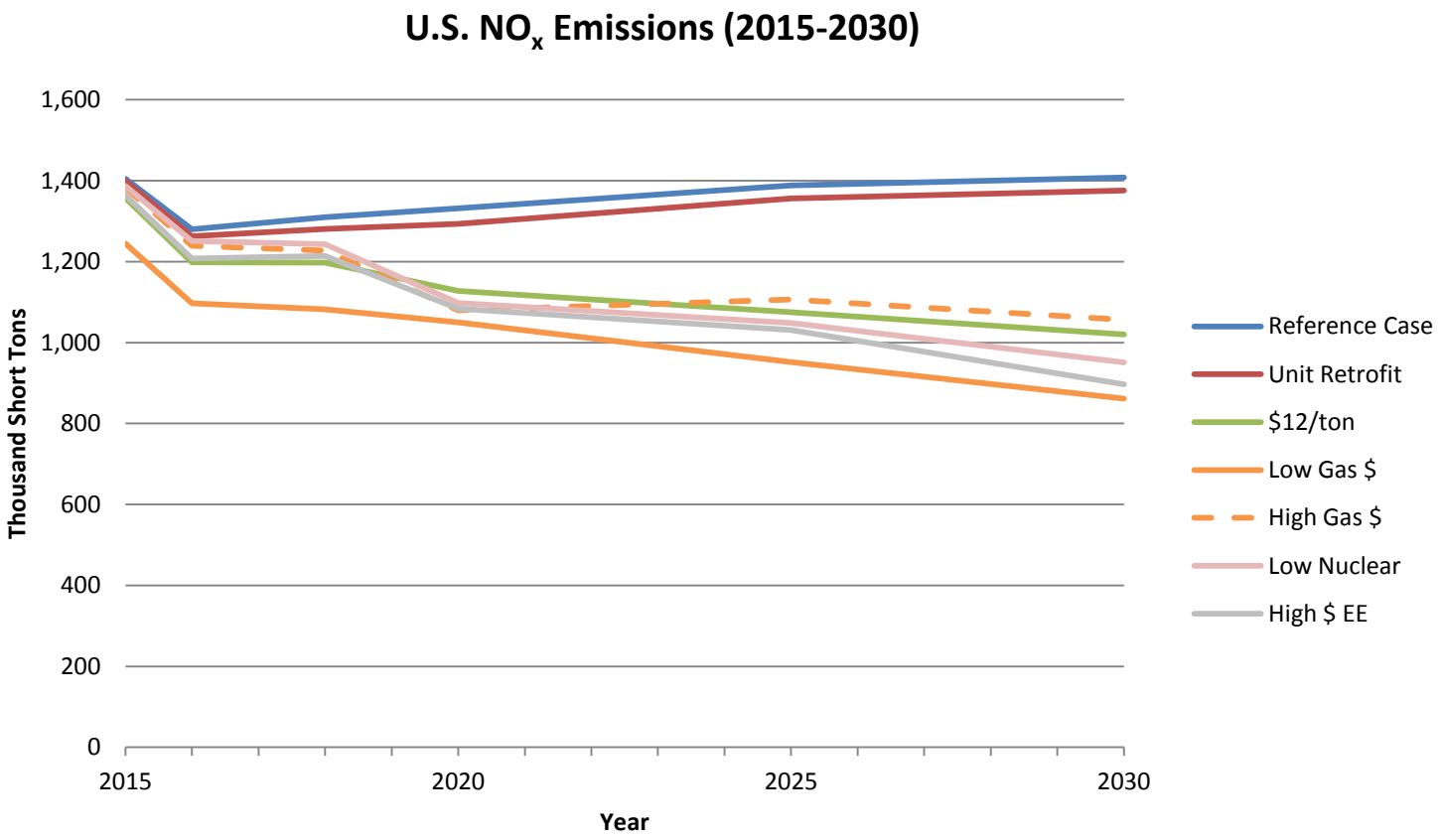
SO_2 and NO_x Emissions



SO_2: Sulfur Dioxide

MODELING RESULTS: NO_X EMISSIONS



NO_x: Nitrogen Dioxide

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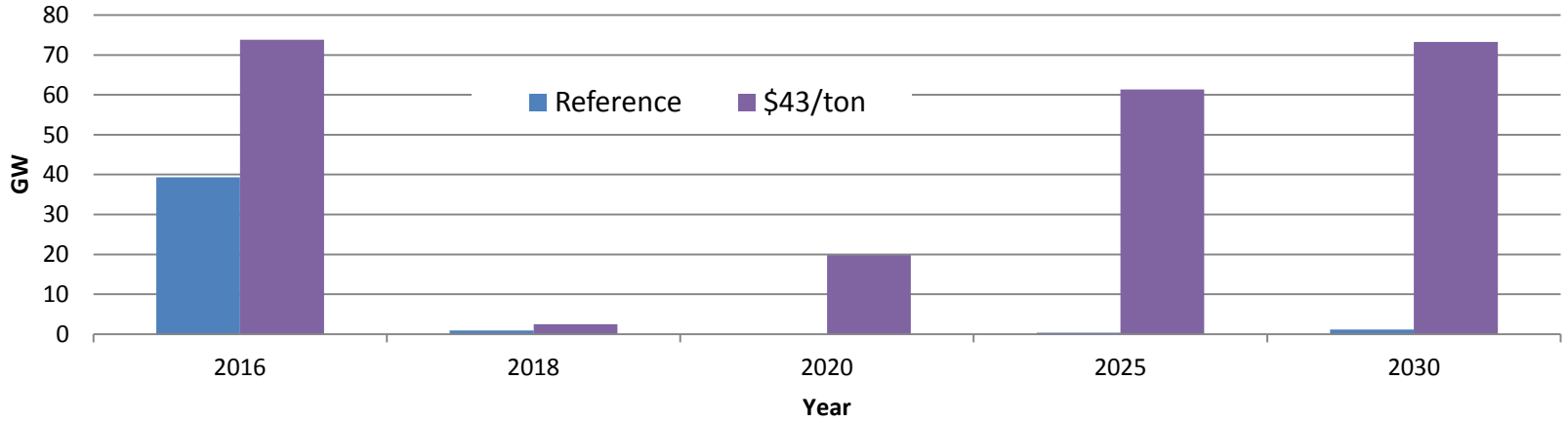
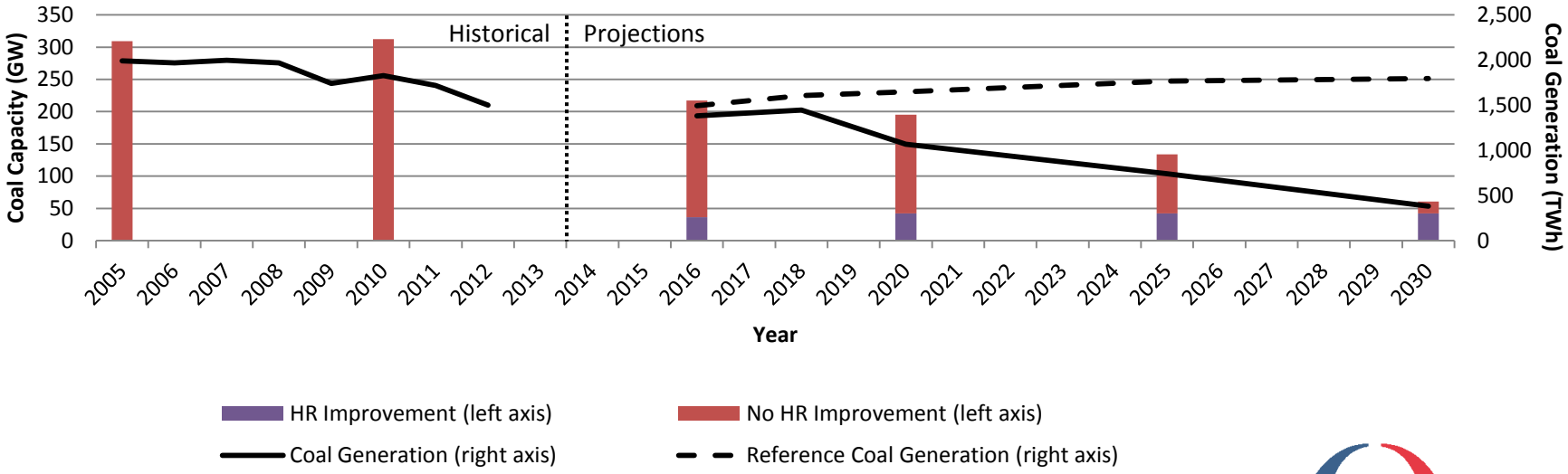
$43/ton: Major impacts on coal

U.S. Coal Retirements (2016-2030)



U.S. Coal Capacity and Generation ($43/ton)



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Assumptions

KEY MODELING ASSUMPTIONS

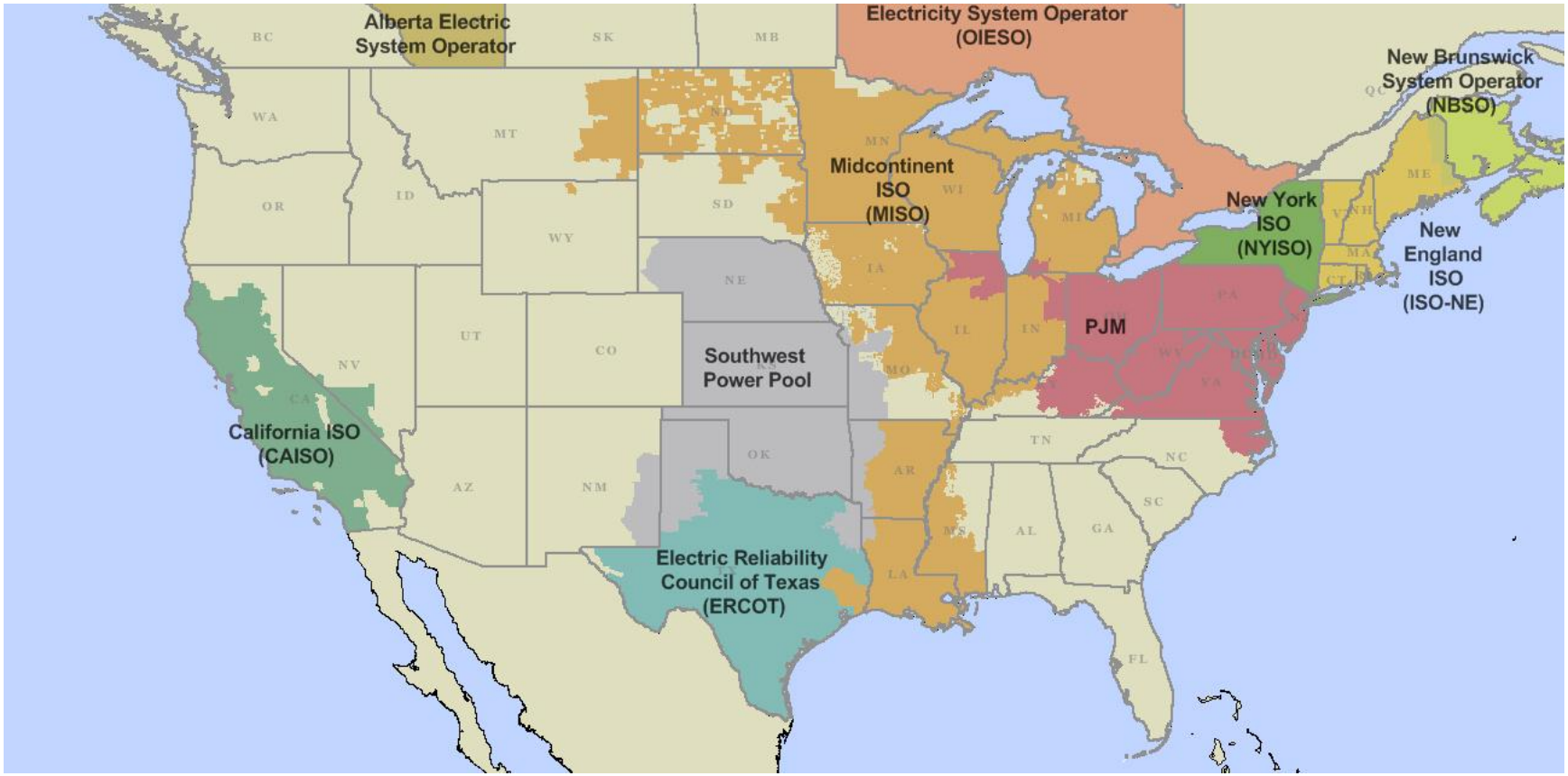
Assumption	Sources	Description
Electric and Peak Demand Growth	AEO 2013	
Capacity Build Costs	AEO 2013 & LBNL	Costs for all technologies come from AEO 2013, except on-shore wind capacity costs come from Lawrence Berkeley National Laboratory's (LBNL) 2012 Wind Technologies Market Report.
Gas Supply/Prices	AEO 2013	Gas supply curves by year are based on AEO 2013 scenarios.
Coal Supply/Prices	AEO 2013	ICF coal supply is calibrated to AEO 2013 average minemouth prices.
Air Pollution Control Costs	EPA, EIA, AEO 2013, & AEO 2013 Early Release	Retrofit costs for most pollution control technologies come from EPA. DSI costs come from EIA. CCS retrofit costs for coal and gas come from AEO 2013 & AEO 2013 Early Release.
Nuclear Power Licensing/Operation	AEO 2013 & BPC	Reference case retirements come from AEO 2013. In addition, Vermont Yankee nuclear power plant retires. Plants are able to relicense at 60 years. In the nuclear sensitivity case, all nuclear power plants must retire at 60 years, along with an additional 7 GW, which retires in 2016.
Biomass Co-firing	EIA, AEO 2013, & BPC	Costs are based on EIA biomass cost curves and AEO 2013 co-firing cost assumptions. Coal units can co-fire up to 15%. Existing subcritical coal units that are 300MW or smaller can repower/retrofit to burn 100% biomass.
Natural Gas Co-firing	EPA & BPC	Coal units that use gas on site can co-fire up to 15% without additional pipeline costs or efficiency degradation penalties. Units that are within 10 miles of a gas pipeline can fully convert to gas. These units incur a pipeline cost and a 5% heat rate penalty.
Demand Side Energy Efficiency	BPC, NRDC, & ACCCE	In policy runs only, energy efficiency is available up to one half of the supply assumed by NRDC in the core case of its March 2014 111(d) analysis. Depending on the scenario, costs are either based on NRDC's March 2014 or ACCCE's March 2014 111(d) analyses.
Heat Rate Improvement	BPC	In policy runs only, coal units can select between two levels of efficiency upgrades based on the unit's capacity, fuel type, steam cycle, and boiler type to close 25% or 40% of the gap between the unit heat rate and the "best in class" heat rate.
Coal with CCS	BPC	BPC assumes both the Kemper plant and the Texas Clean Energy Project will be built as coal-fired generation with CCS. Other CCS generation can come online if it is deemed economical.

EIA: Energy Information Administration
AEO: Annual Energy Outlook
CCS: Carbon Capture and Storage
NRDC: Natural Resources Defense Council
ACCCE: American Coalition of Clean Coal Electricity
DSI: Dry Sorbent Injection

Scenario	Description
Reference	Includes existing state and federal regulations.
Unit Retrofit	Identical to the Reference case, with the addition of a GHG emission rate standard modeled as a requirement for coal plants to either 1) invest in on-site efficiency improvements or 2) co-fire gas or biomass so CO_2 emissions are equivalent to the unit-specific rate achieved by requiring each coal unit to close 40% of the gap between its heat rate and the "best in class" heat rate based on the unit's capacity, fuel type, steam cycle, and boiler type. Any new coal capacity must include CCS.
$12/ton	Identical to the Reference case except for the addition of a GHG policy that requires power sector emission reductions up to $12 per metric ton of CO_2 in 2020 (rising at the rate of the social cost of carbon). The case is representative of national emissions trading under a 111(d)-like policy that allows for investment in demand side energy efficiency at a cost of 2.3-3.2 cents/kWh. Any new coal capacity must include CCS.
$43/ton	Identical to the $12/ton case except the GHG policy requires power sector emission reductions up to $43 per metric ton of CO_2 in 2020 (rising at the rate of the social cost of carbon). Any new coal capacity must include CCS.
Low Gas $	CO_2 emissions are capped at the level from the $12/ton case with banking of allowances permitted. Gas prices from AEO 2013's low gas price sensitivity are imposed. Any new coal capacity must include CCS.
High Gas $	CO_2 emissions are capped at the level from the $12/ton case with banking of allowances permitted. Gas prices from AEO 2013's high gas price sensitivity are imposed. Any new coal capacity must include CCS.
Low Nuclear	CO_2 emissions are capped at the level from the $12/ton case with banking of allowances permitted. In addition to Reference case nuclear retirements, 7 GW of nuclear power is retired in 2016 and no 60-year relicensing agreements are allowed. Any new coal capacity must include CCS.
High $ EE	CO_2 emissions are capped at the level from the $12/ton case with banking of allowances permitted. Demand side energy efficiency is priced at 11 cents/kWh. Any new coal capacity must include CCS.

GHG: Greenhouse Gas
CO_2: Carbon Dioxide
AEO: Annual Energy Outlook
CCS: Carbon Capture and Storage

North American Regional Transmission Organizations



Source: FERC

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