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Analysis of Current and Pending EPA Regulations on the U.S. Electric Sector

May 31, 2012

PRISM 2.0: Regional Energy and Economic Model Development and Initial Application

- Develop a new energy-economy model of the U.S. with a special focus on the electric power sector:
  - U.S. Regional Economy, Greenhouse Gas, and Energy (US-REGEN) model (completed)

- Develop appropriate sectoral data and detail in electric power production and in energy demand, taking into account regional differences in generating costs and resources, especially for renewables, carbon capture and storage, and land use

- Perform detailed analysis:
  - 1st Phase – Current and Pending Environmental Controls (completed)
  - 2nd Phase – Clean Energy Standard proposals (Summer 2012)
  - 3rd Phase – preliminary analysis on the Impact of CO_2 Constraints on the Electric Power Sector (Fall 2012)

- Communicate results at on-site member briefings and via public reports and presentations

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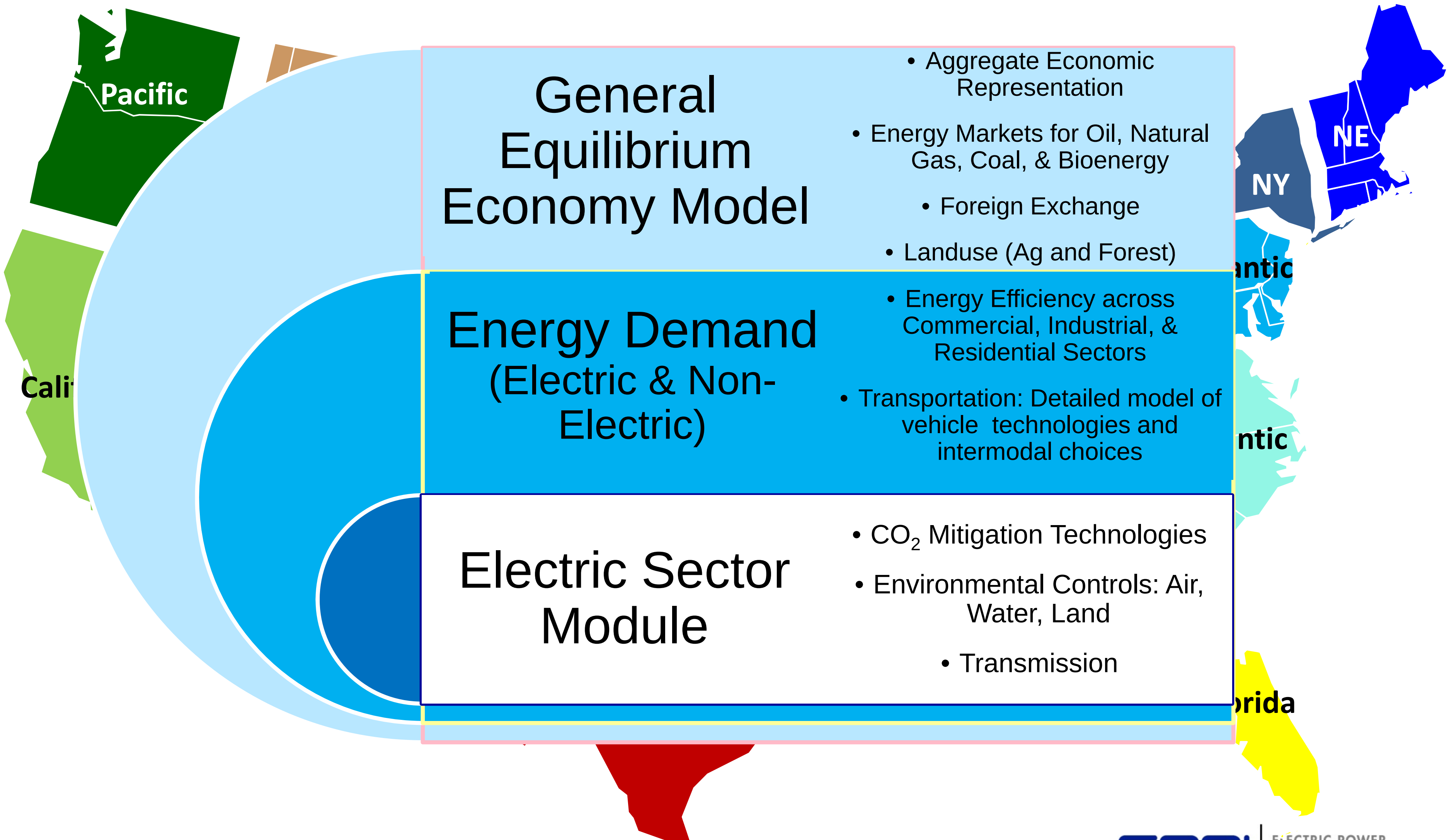
US-REGEN Model Description



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Key Messages

- The confluence of multiple environmental control requirements requiring retrofits on existing coal-fired power plants has significant implications for asset management and generation planning decisions, and substantial effects on electricity generation costs
- Decisions about whether to retrofit or retire existing coal-fired power plants are complex, with multiple uncertainties, interactions, and implications for electricity generators and the broader economy
- With phased compliance more time can facilitate testing and application of new and existing lower-cost technologies with significant savings, and with little change in overall emission reductions

Baseline Scenario

- Economic growth and energy supply and demand based on EIA's Annual Energy Outlook 2011
- Economic and electric power unit data based on 2009 and 2010 datasets, respectively, 2010 is the model's base year
- Electric sector policies, and assumptions:
  - Include state RPS Programs
  - State (CA, RGGI) or federal (CAA) GHG regulations not included
  - Include Cross-State Air Pollution Rule (CSAPR) by 2015 Aims to Reduce SO_2 emissions by 73 percent and NOx emissions by 54 percent from 2005 levels. Final rule.
  - New coal additions limited to units currently under construction

Reference (Environmental Controls) Scenario

- Starting from the Baseline Scenario, then adding
- Electric Sector Policies
  - Mercury and Air Toxics Standard (MATs) Rule by 2015, more stringent SO_2, and SO_3 control by 2018) (Dry/wet scrubbing with increased particulate control)
  - Ozone and haze regulations by 2018 (Stringent NOx control with SCRs for all coal)
  - SO_2 NAAQS, haze regulations by 2018
  - Clean Water Act (CWA) 316(b) Controls by 2018 (closed-cycle cooling on facilities with intake flow > 125)
  - Coal Combustion Residuals (CCRs) Controls by 2020 (RCRA Subtitle D “non-hazardous”)

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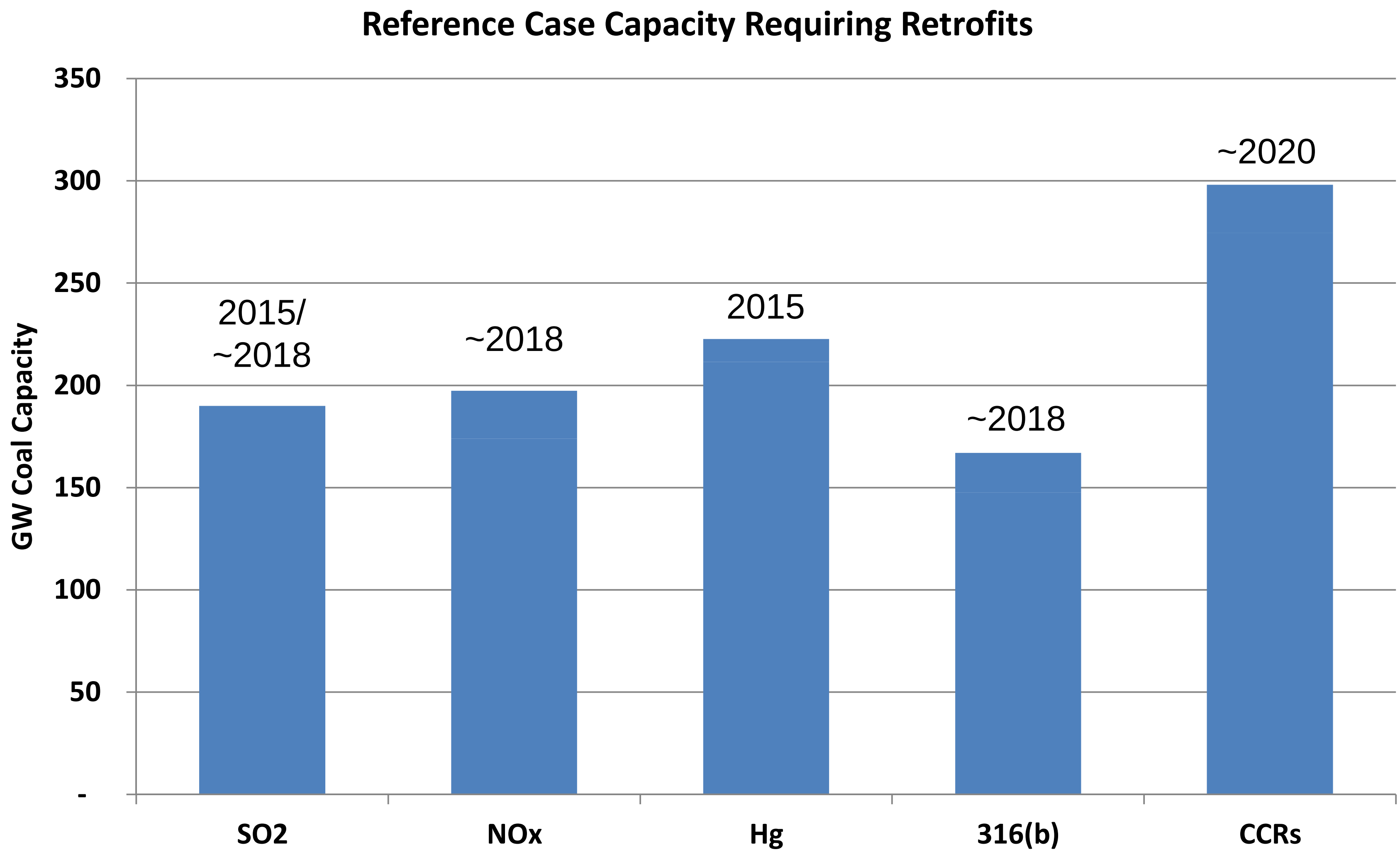
Hundreds of GW of Existing Coal Units Facing Multiple Compliance Obligations by 2015



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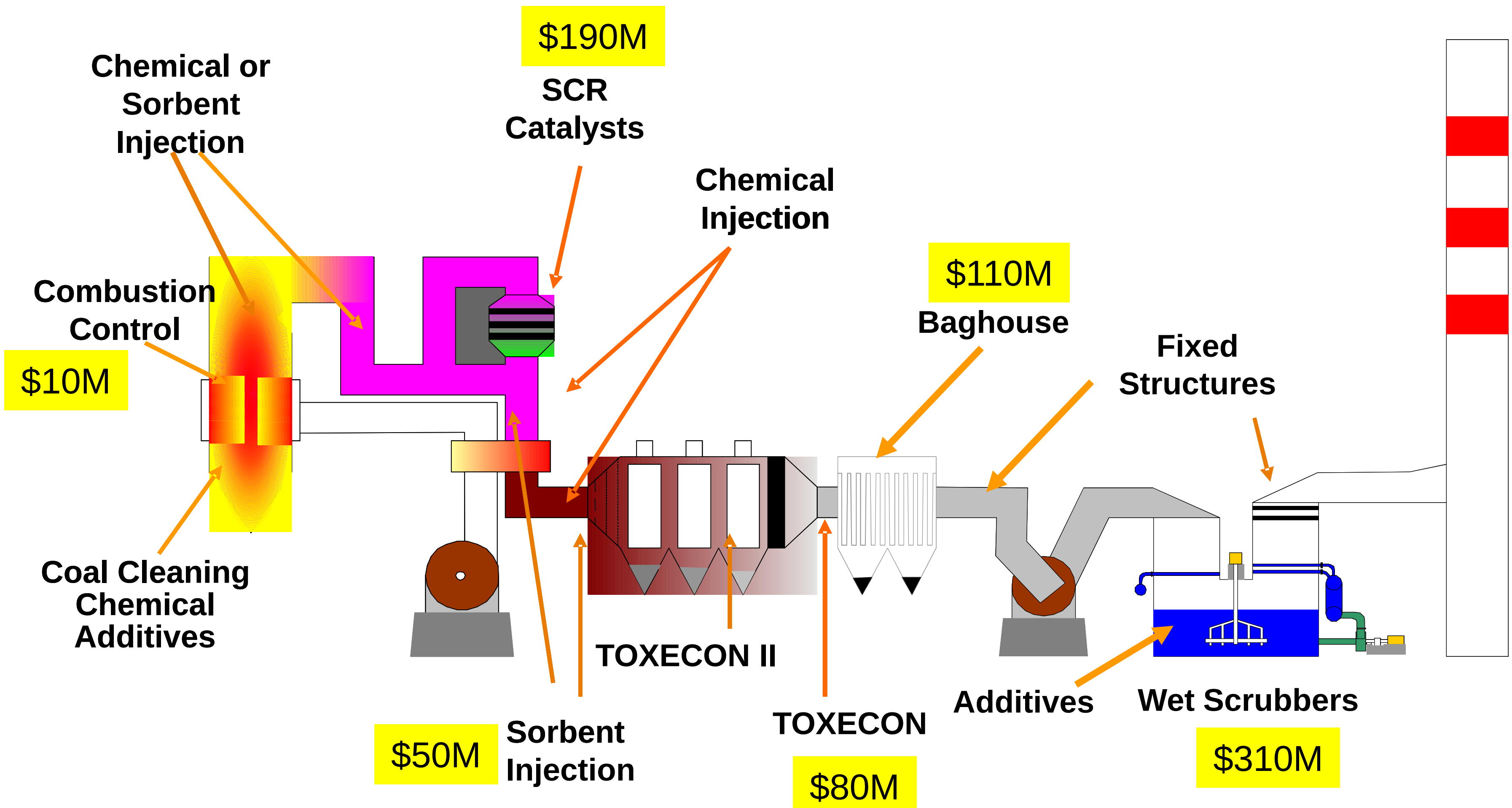
Controlling Emissions from Power Plants

Example Costs – 400 MW, Bituminous Coal



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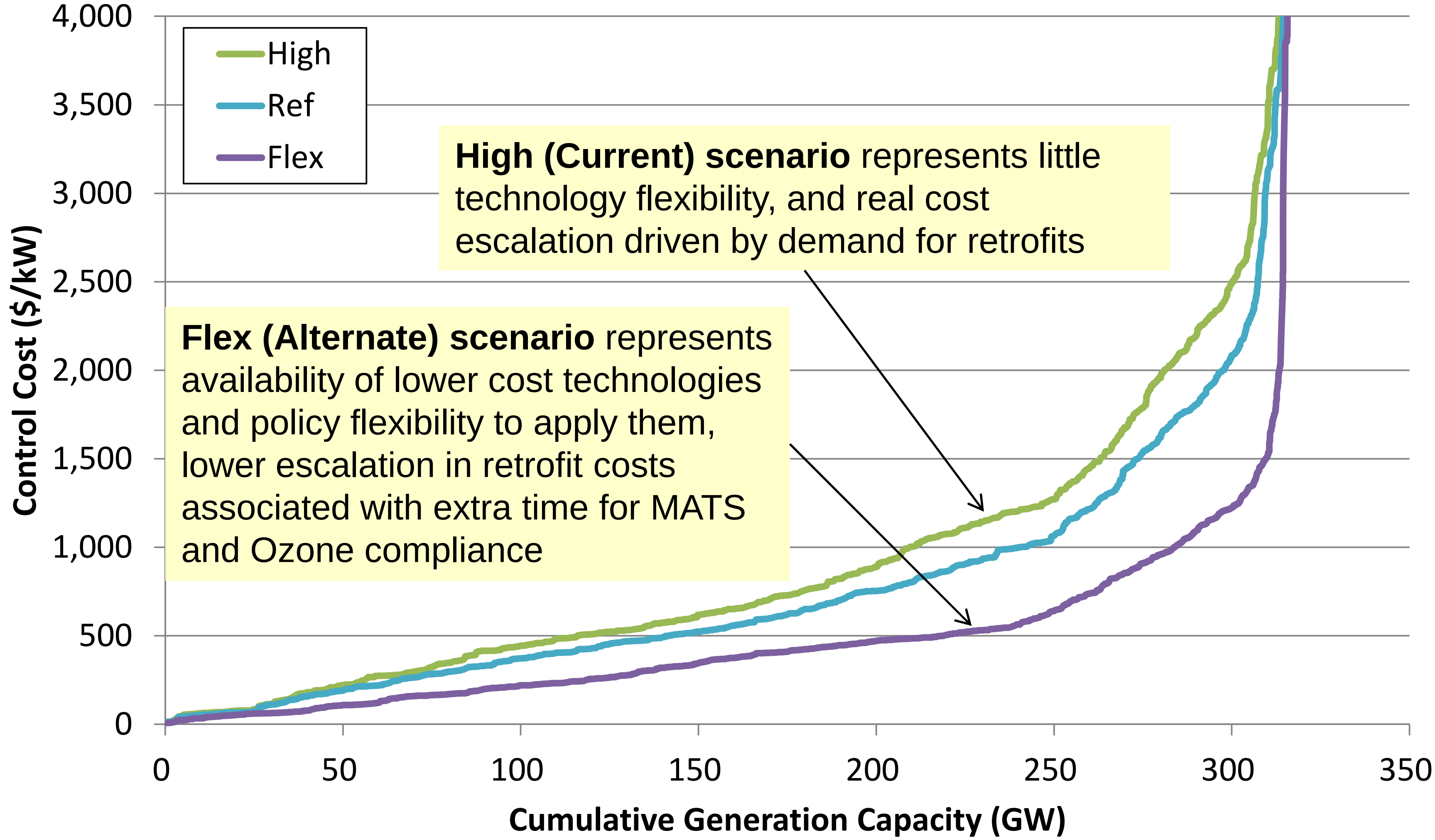
Integrated Analysis of Retrofit Decision in Light of Full Set of Air (non-GHG), Water, Ash Policies

- Full Control policy defined as stringent control of SO_2, NOx, Hg, entrainment (316b), and coal combustion residuals (CCRs) but not recent proposed CO_2 performance standards.
- Assume asset owner make single retrofit-retire decision in 2015 based on full mix of requirements.
- Retrofit cost scenarios reflect broad cost and policy uncertainty:
  – Ref uses reference costs
  – Flex has lower costs, less stringent aquatic entrainment controls, less retrofit cost escalation, and additional time for compliance for SO_2 and NOx to allow for newer control technology options
  – High costs with less policy flexibility to choose low-cost technologies and higher retrofit cost escalation to meet stringent deadlines

Scenarios Represent Uncertainty Ranges in Costs for Technology, Policy, and Escalation



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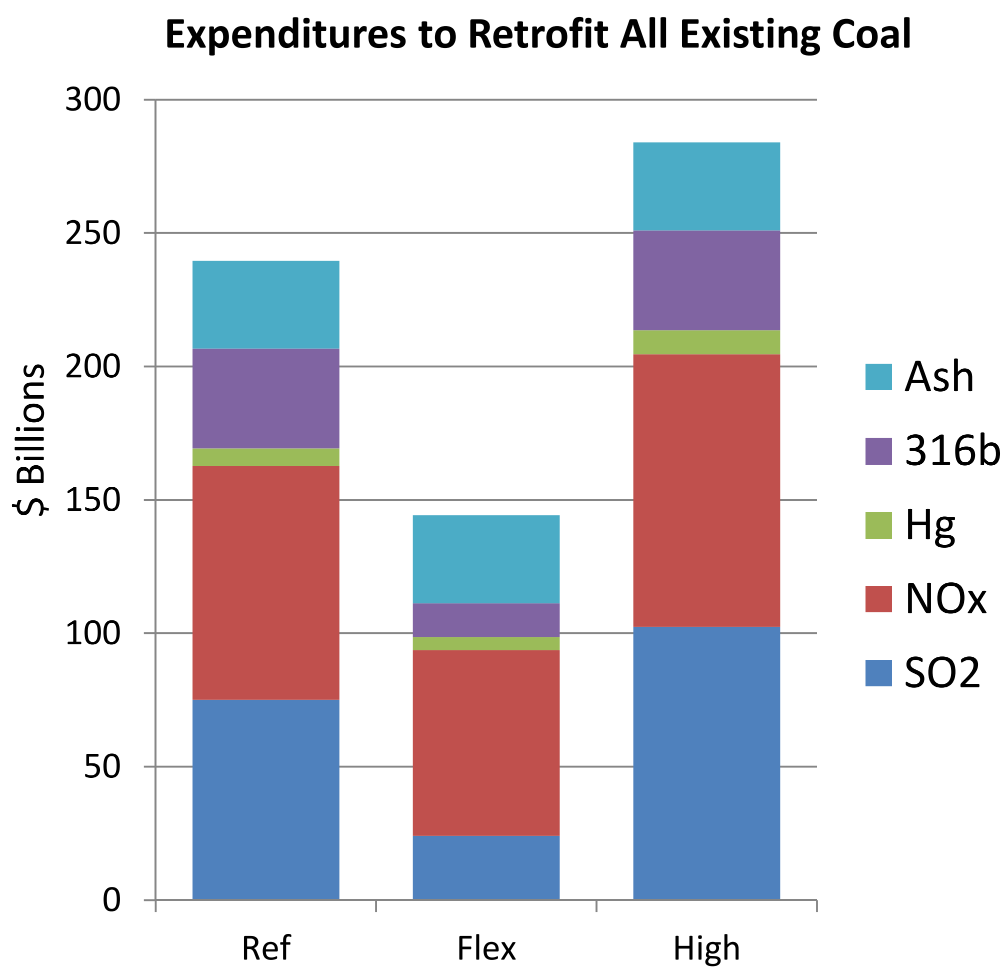
Cost to Retrofit Entire Fleet Uncertain but Several $100 Billions

- Chart show investment cost to retrofit entire existing fleet (sum of unit costs input to model)
- Existing coal
  - 316 GW
  - 40% of electric supply
  - 1,100 generating units
  - Diverse size/age mix
- Age, size, and market impact retrofit/retire decisions
- Many units poor candidates for environmental retrofits
- ~ 40 GW of coal retirements announced to date



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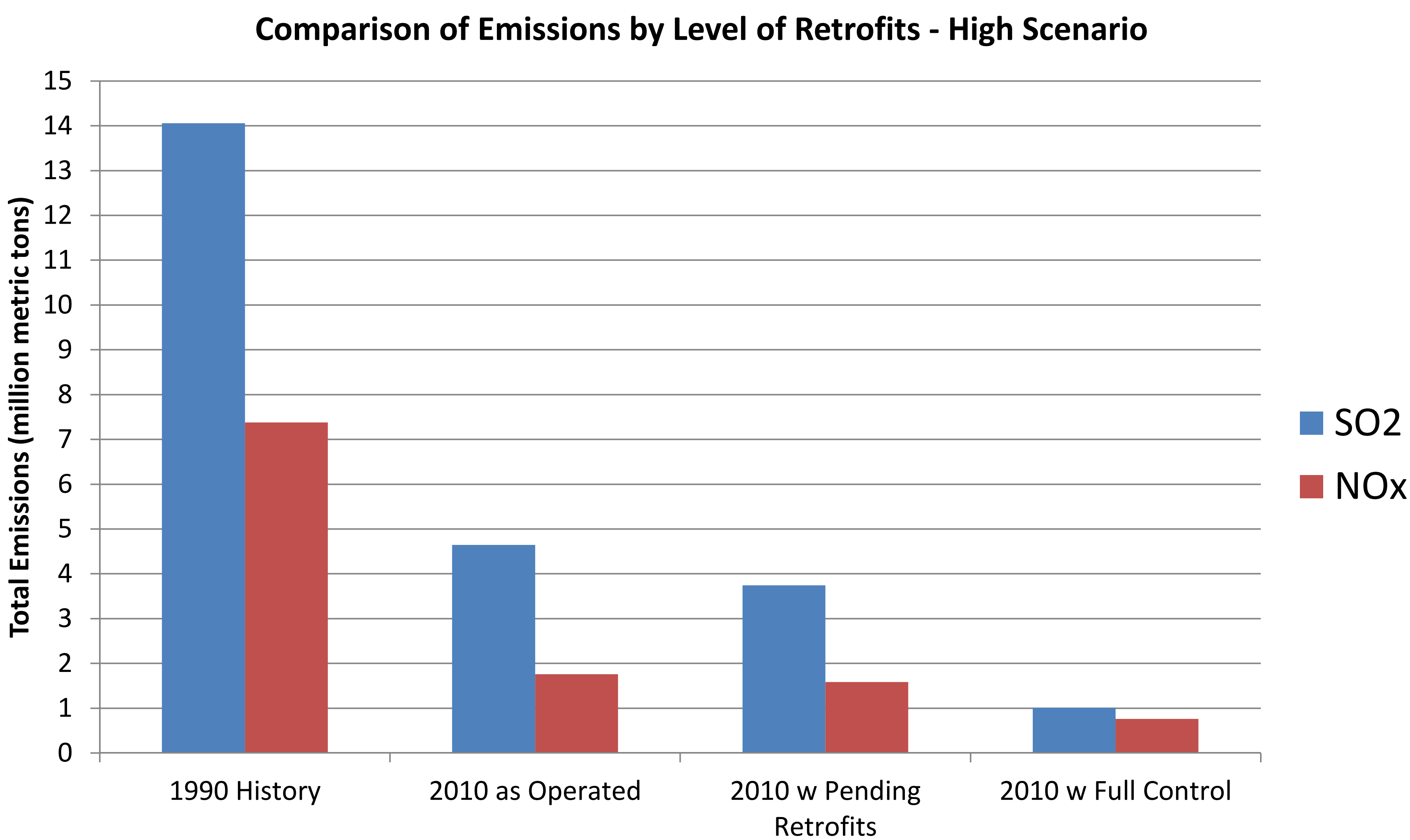
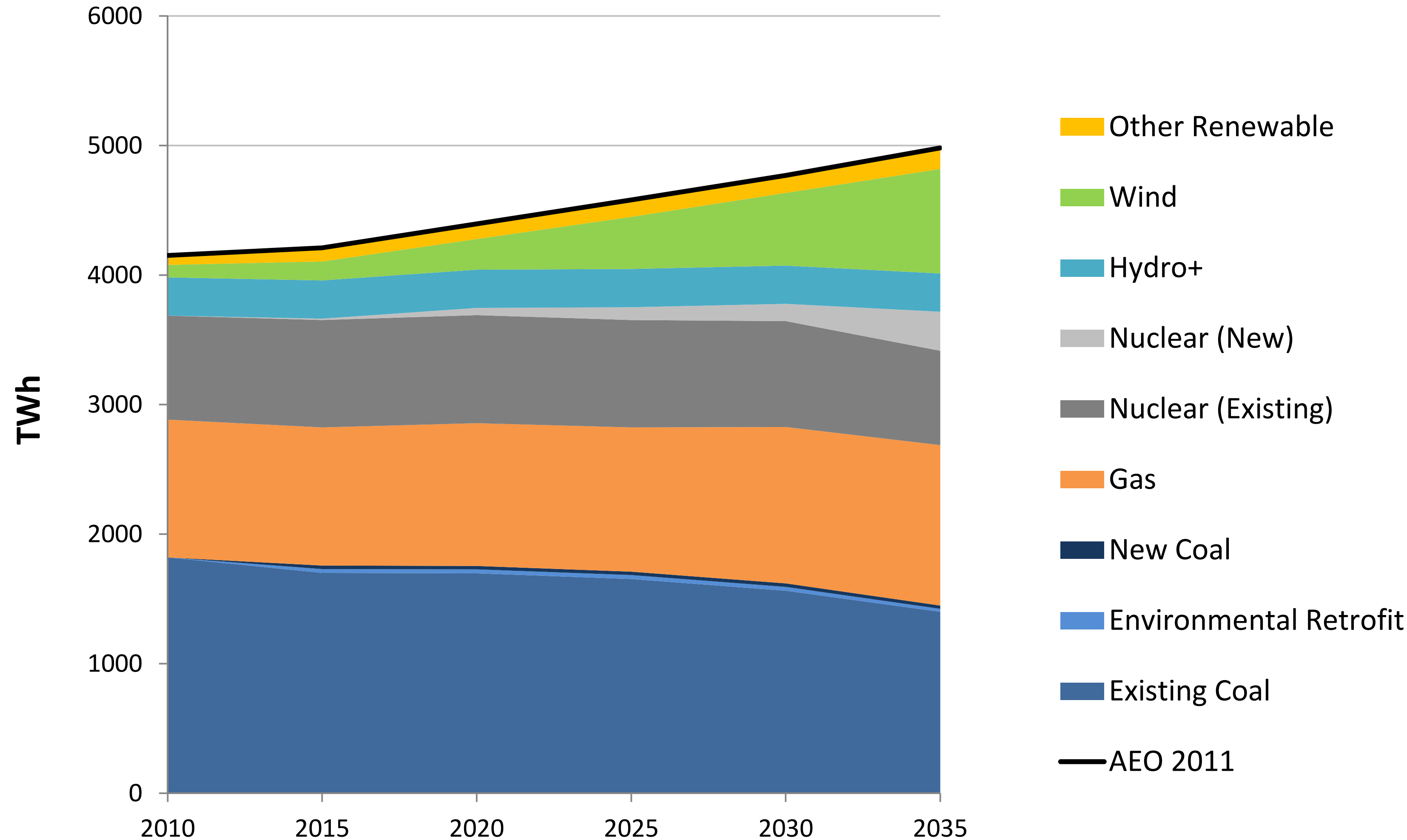
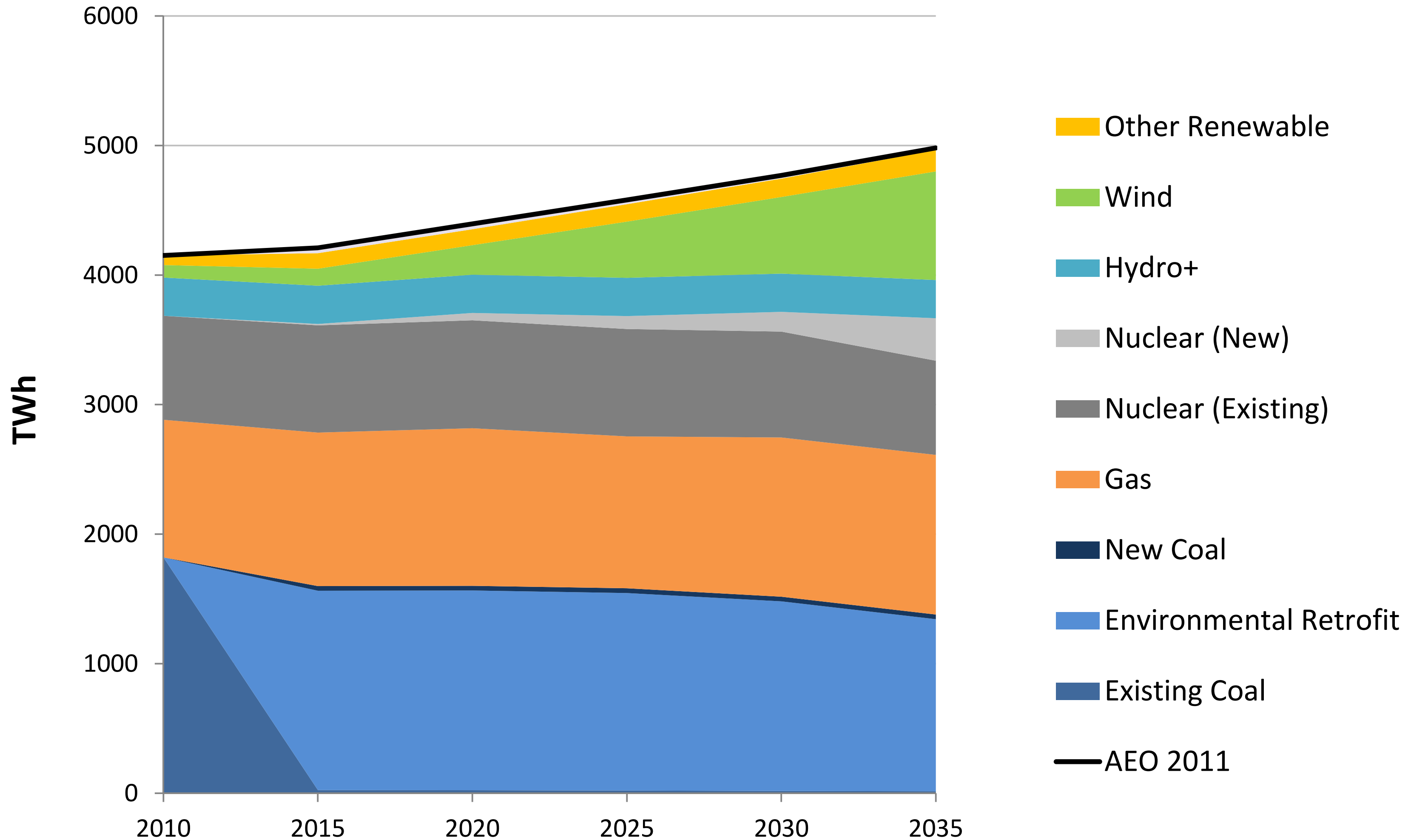
Comparisons Show How Retrofits Will Cut Emissions



U.S. Electric Generation in Baseline



U.S. Electric Generation in Controls (Ref)



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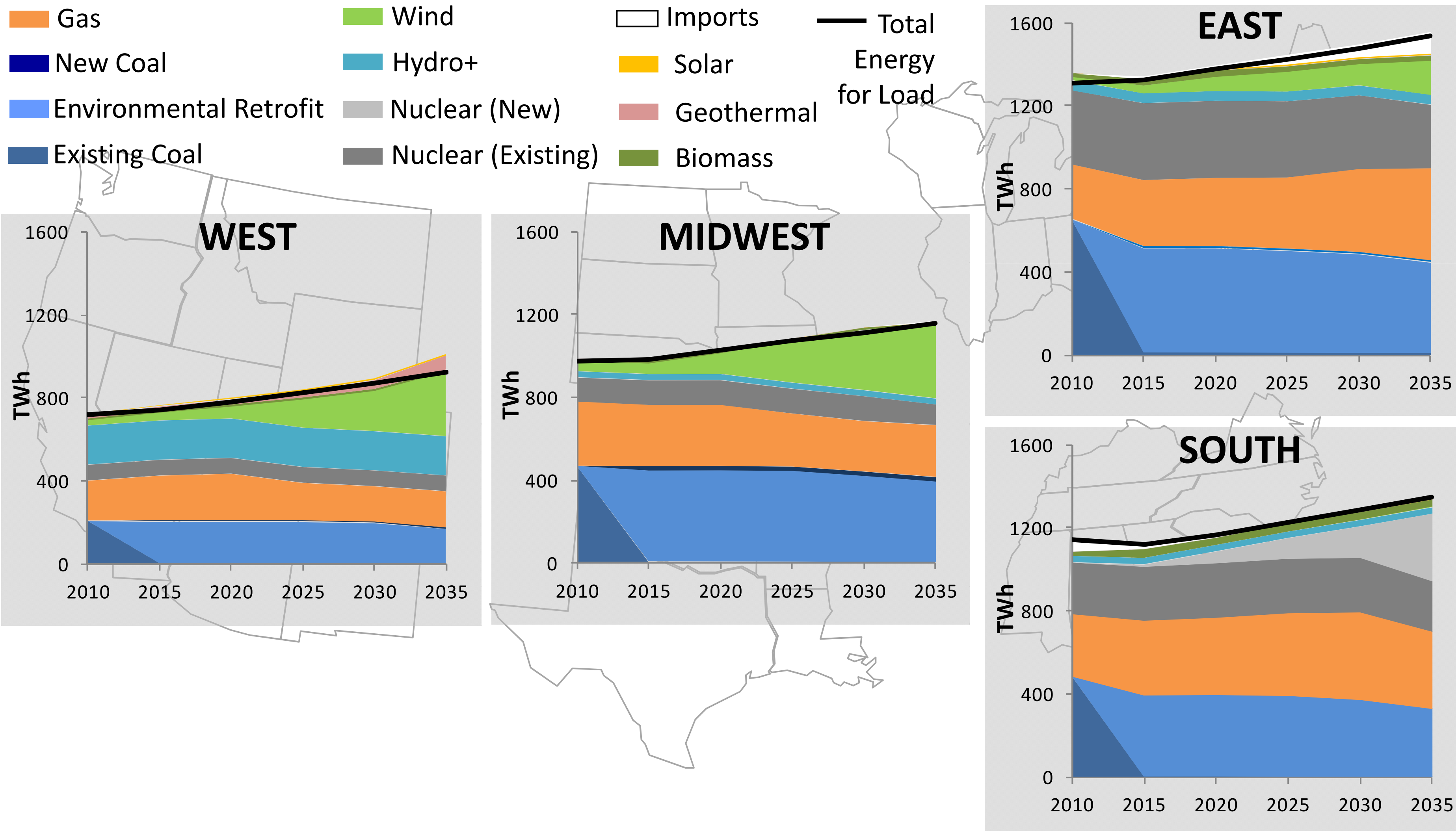
Regional Generation in Controls (Ref)



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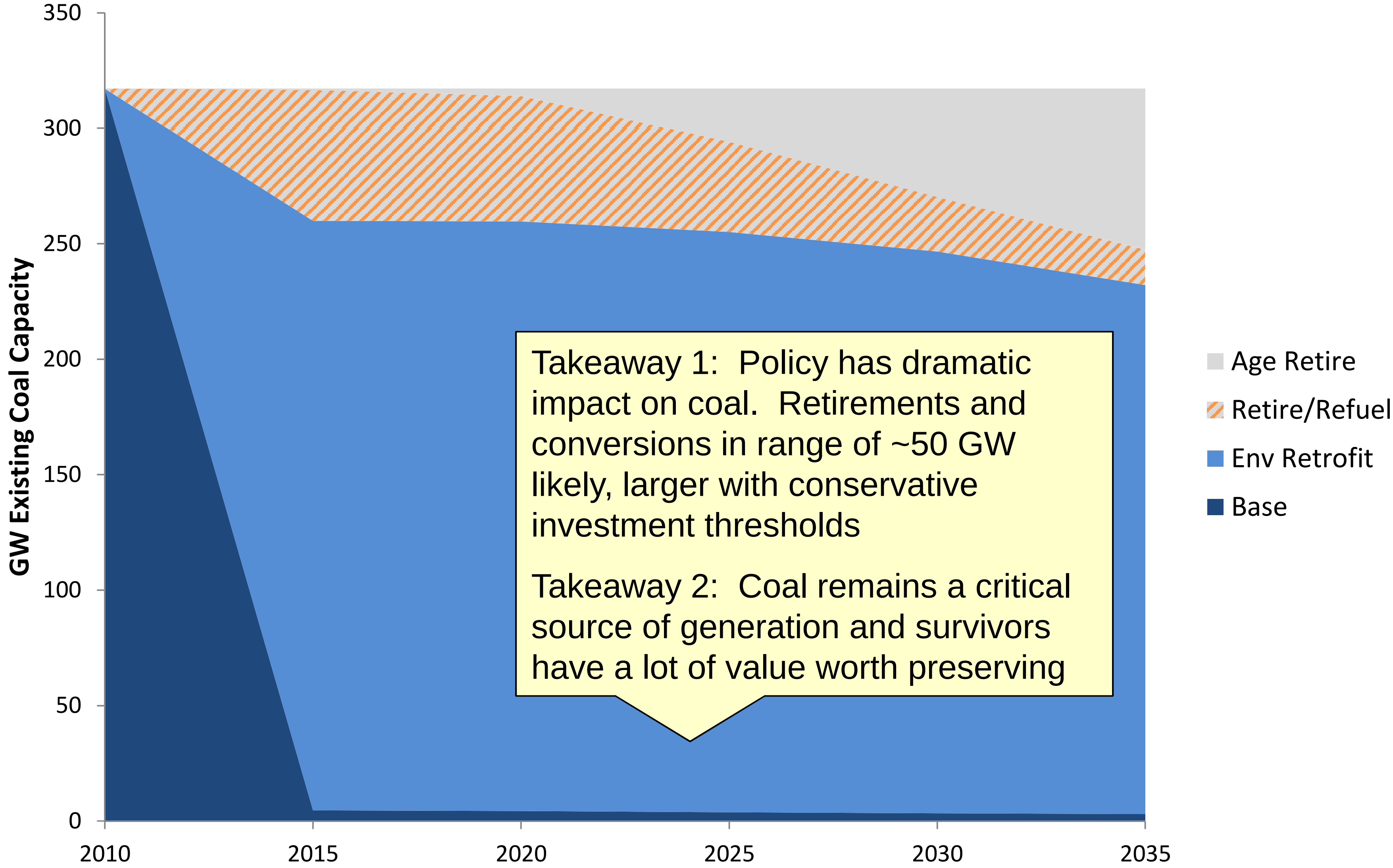
Coal Units May Cease to Operate Coal Due to Retirements as Well as Conversions to Gas

- Economics to retire or convert to gas or biomass can be very close
- Conversions can buy cheap capacity
- Capacity value depends on regional capacity needs and operating limitations of converted capacity
- Cost of conversion to gas can vary widely with distance to gas lines
- Many economically viable gas conversions may prove infeasible (e.g., siting, access to gas)
- As consequence we group units that cease to operate as coal into a Retire/Refuel category

Existing Coal Disposition in Controls (Ref)



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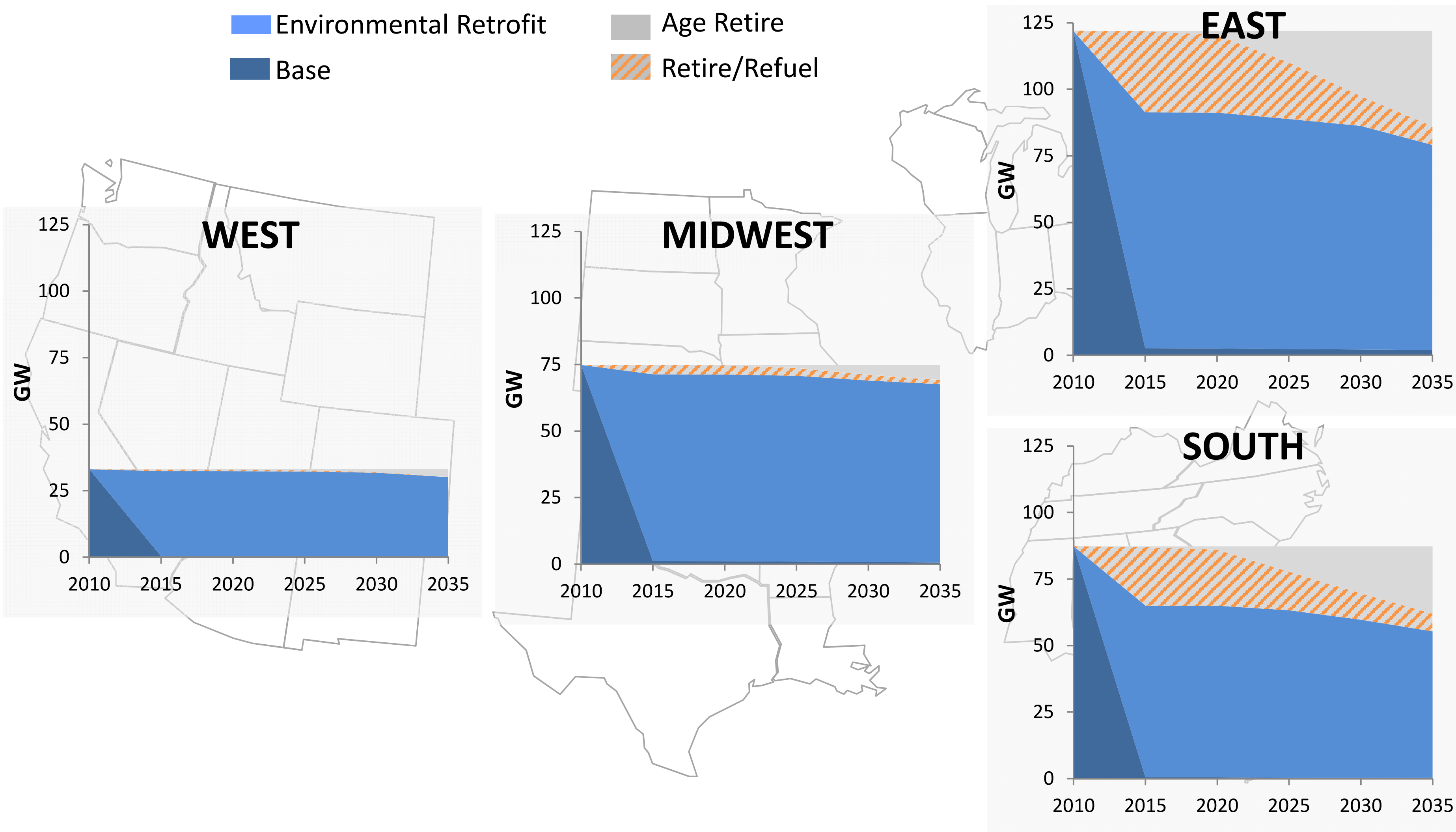
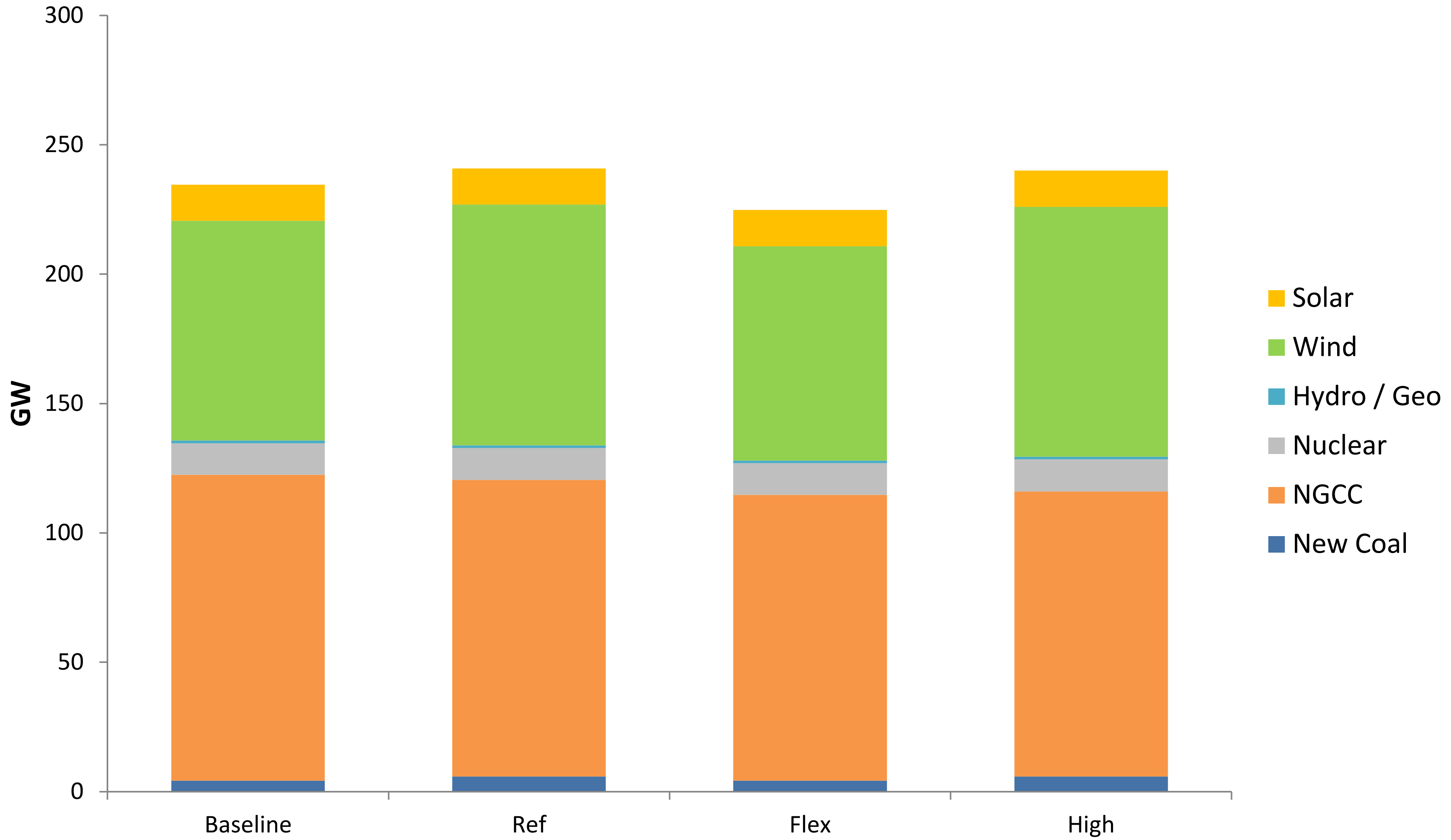
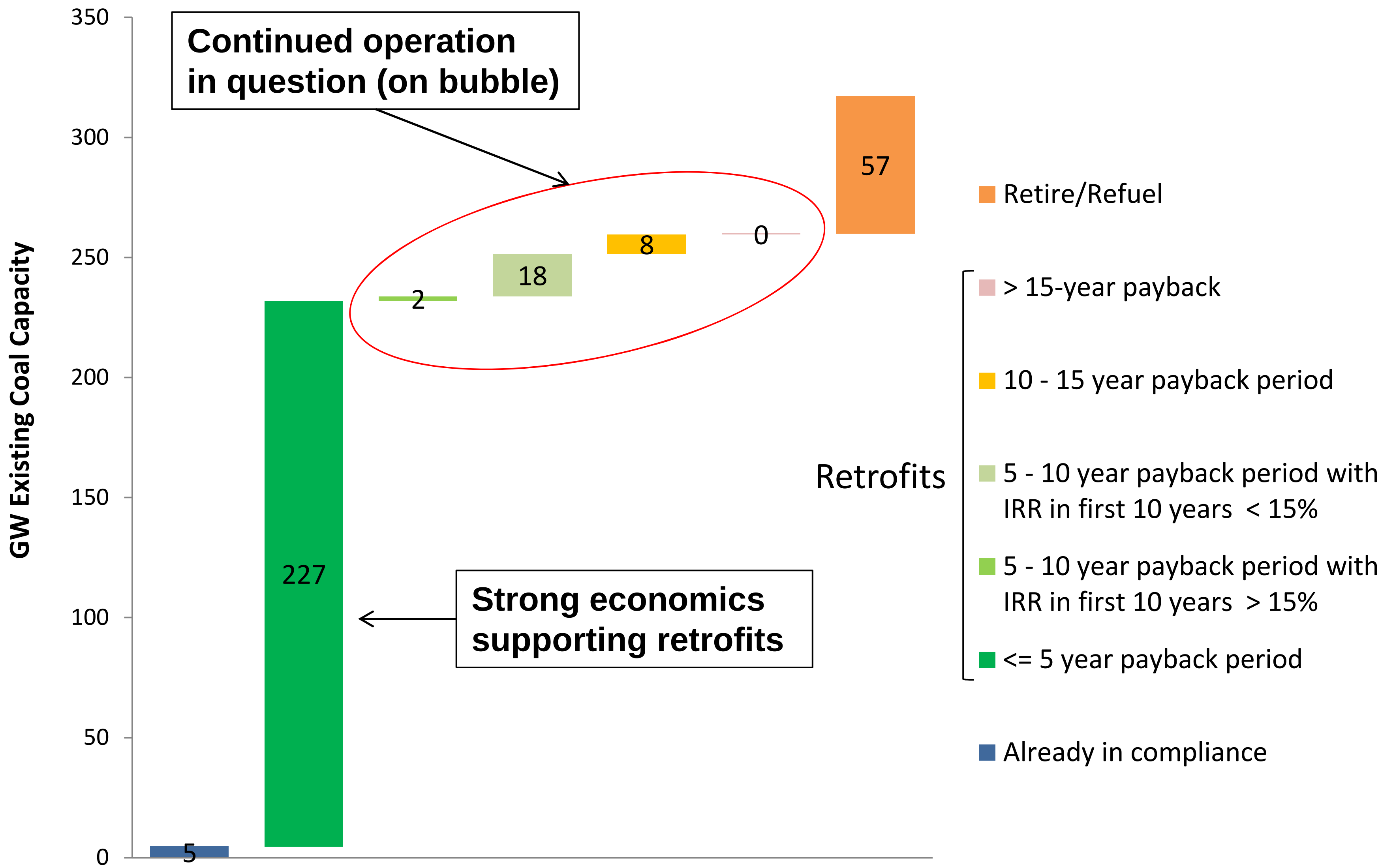
Regional Coal Disposition in Controls (Ref)



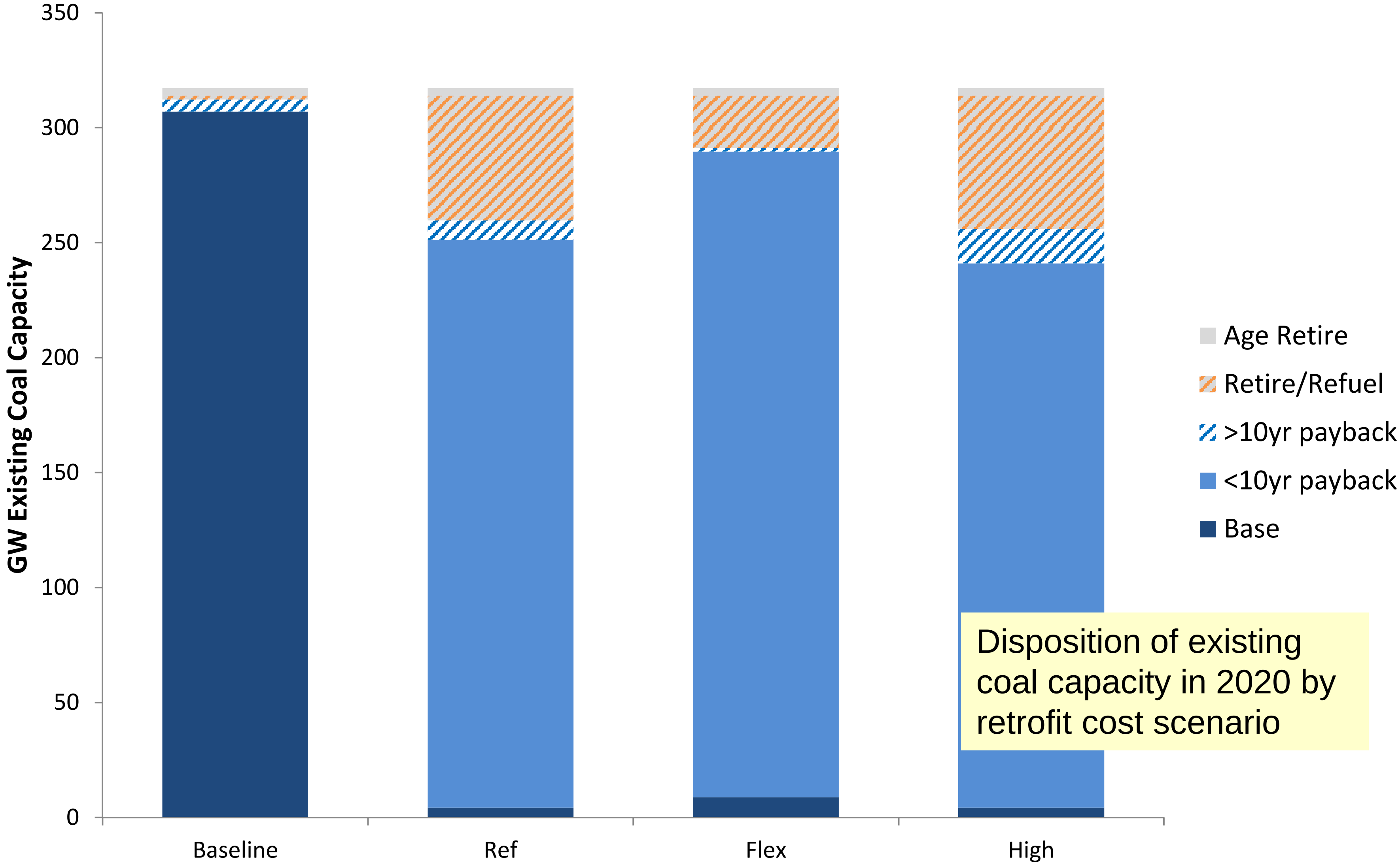
New Capacity Additions Through 2025



Broad Distribution of Pay-offs for Retrofits of Existing Coal (Ref)



Potentially Large Fraction of Existing Coal Fleet May Retire or Refuel with Bio Energy or Gas



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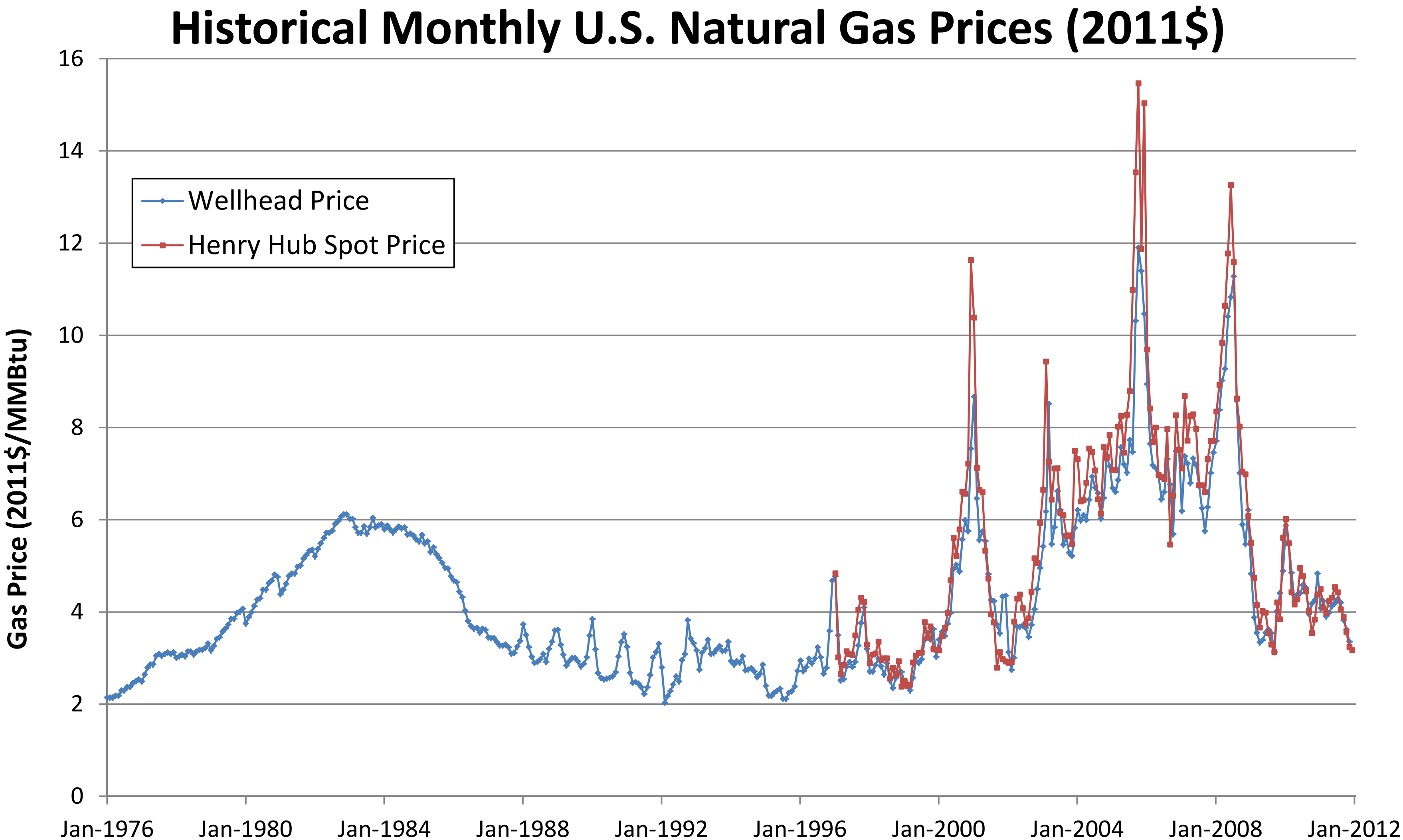
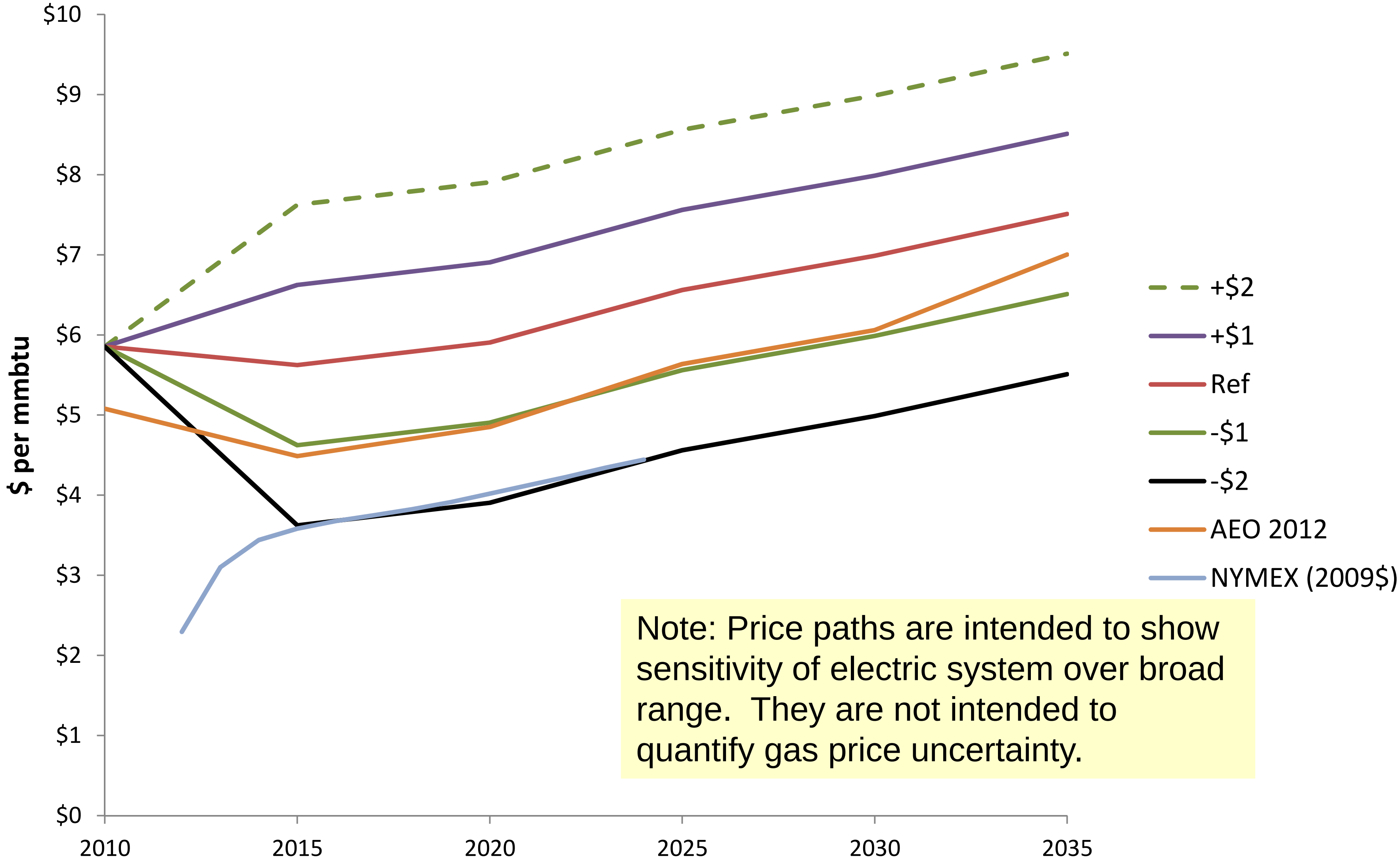
Long-term History of Natural Gas Prices Shows High Level of Variability

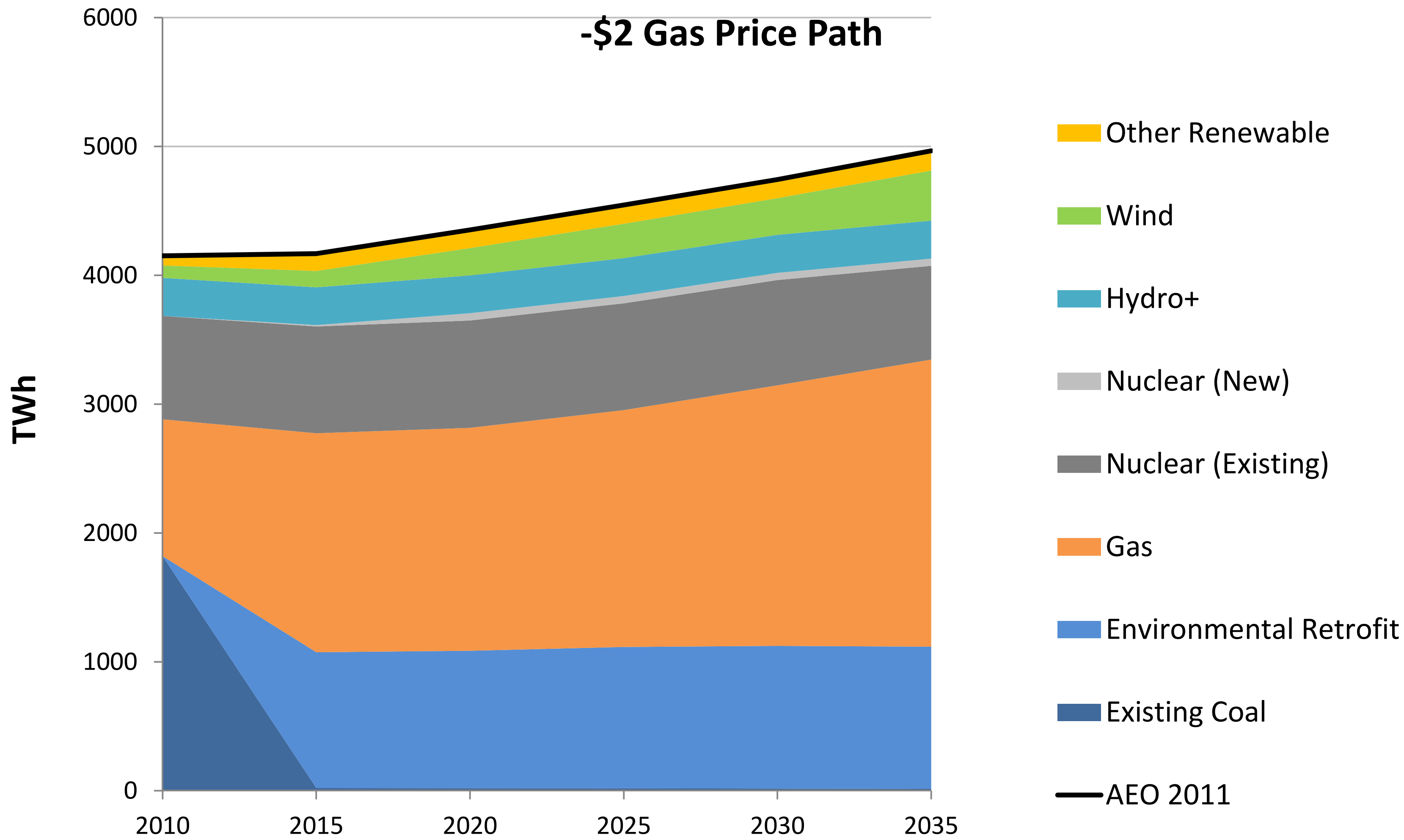


Sensitivity Analysis on Natural Gas Prices



Note: Price paths are intended to show sensitivity of electric system over broad range. They are not intended to quantify gas price uncertainty.

Generation with low gas prices



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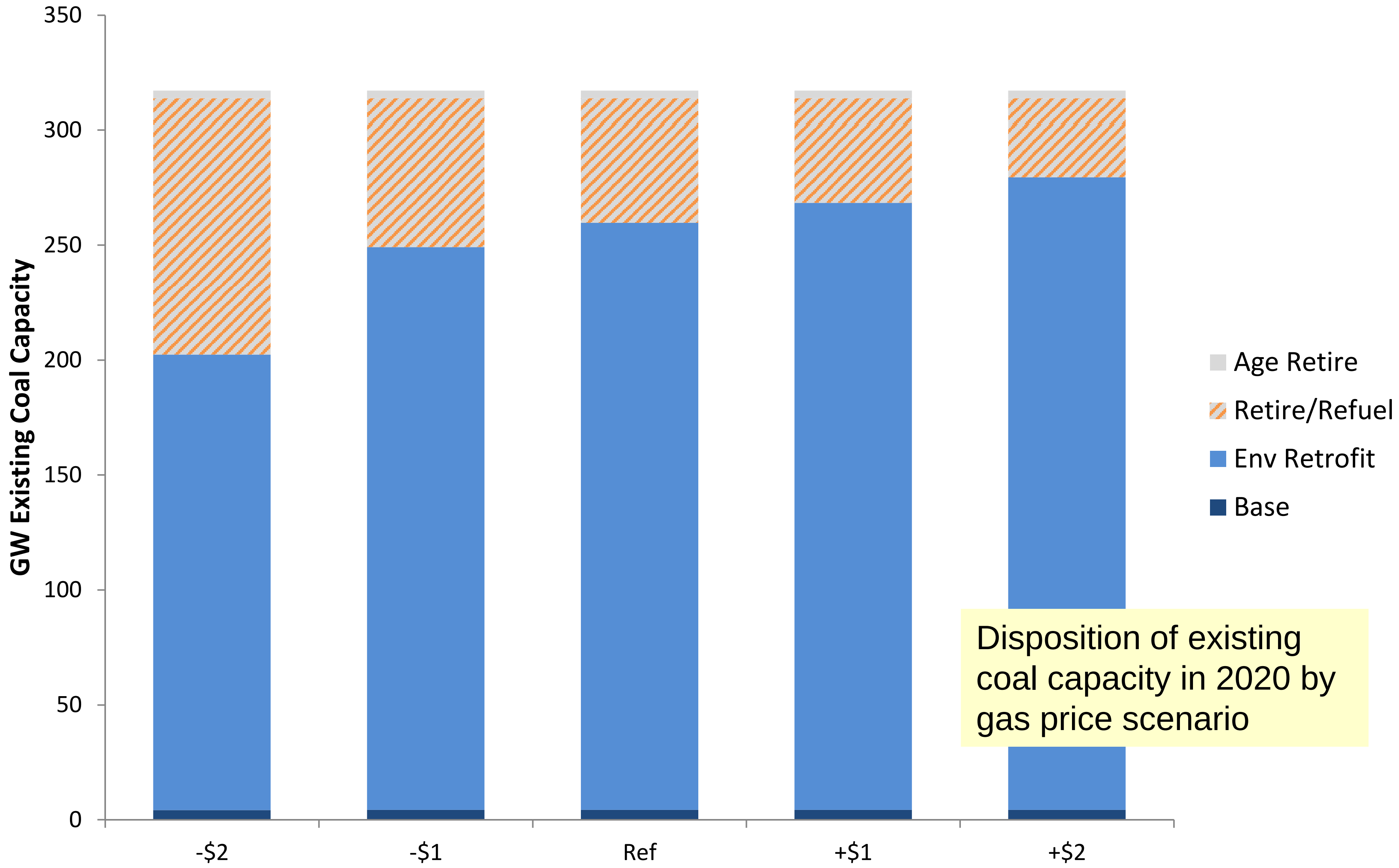
Gas Price Scenarios Show Critical Role of Gas Price Expectations for How Much Coal Survives



Disposition of existing coal capacity in 2020 by gas price scenario

Natural Gas Price is the Dominant Uncertainty

Uncertainty level is very high

- Price range over last decade shows over 5 to 1 ratio
- Are NYMEX futures and AEO 2012 projections going to continue to decline?

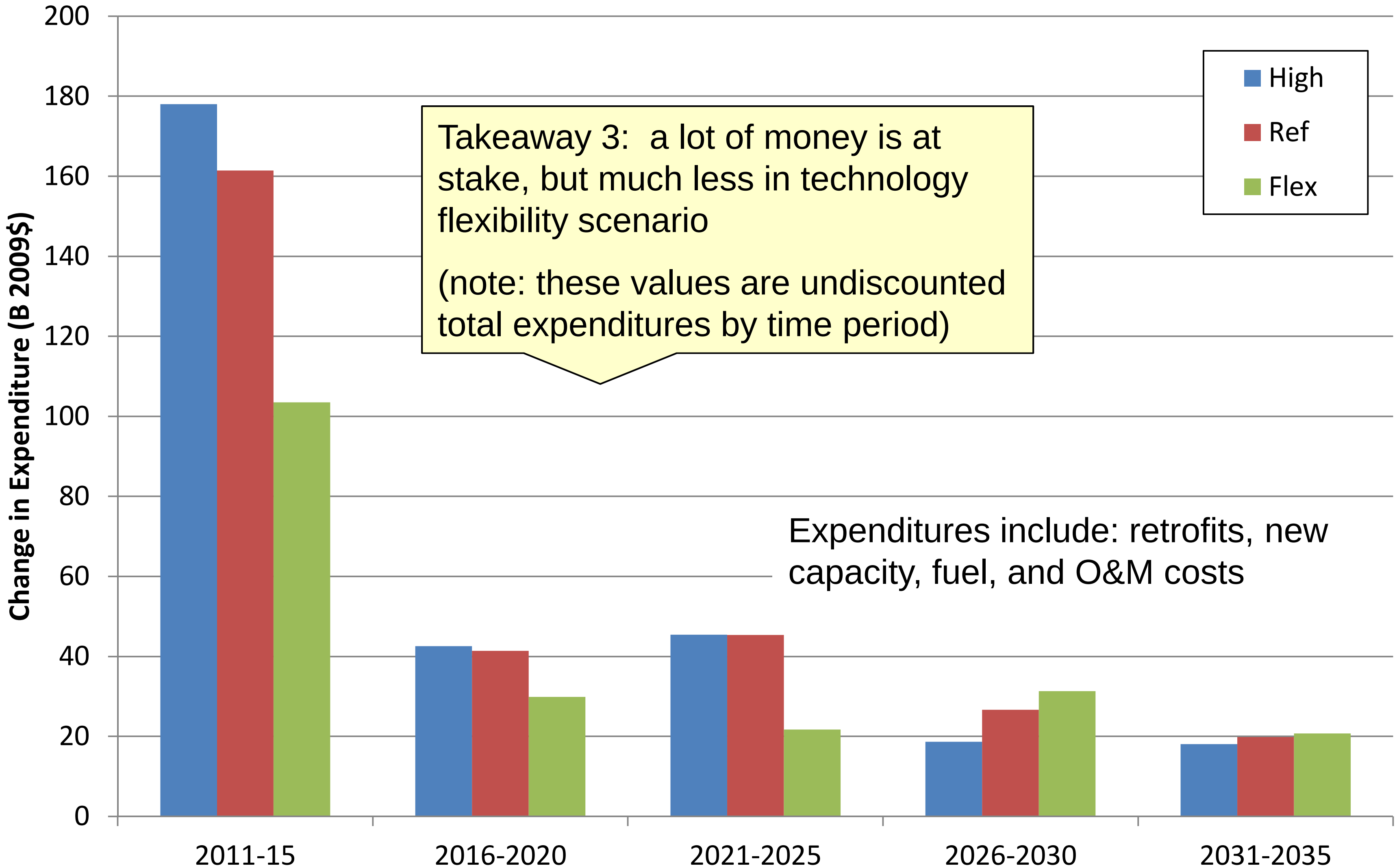
Dramatic consequences

- Average power prices show ~$6/MWh swing for each $1 change in gas prices
- Low price paths have particularly large impact on retrofit vs. retire/refuel decisions

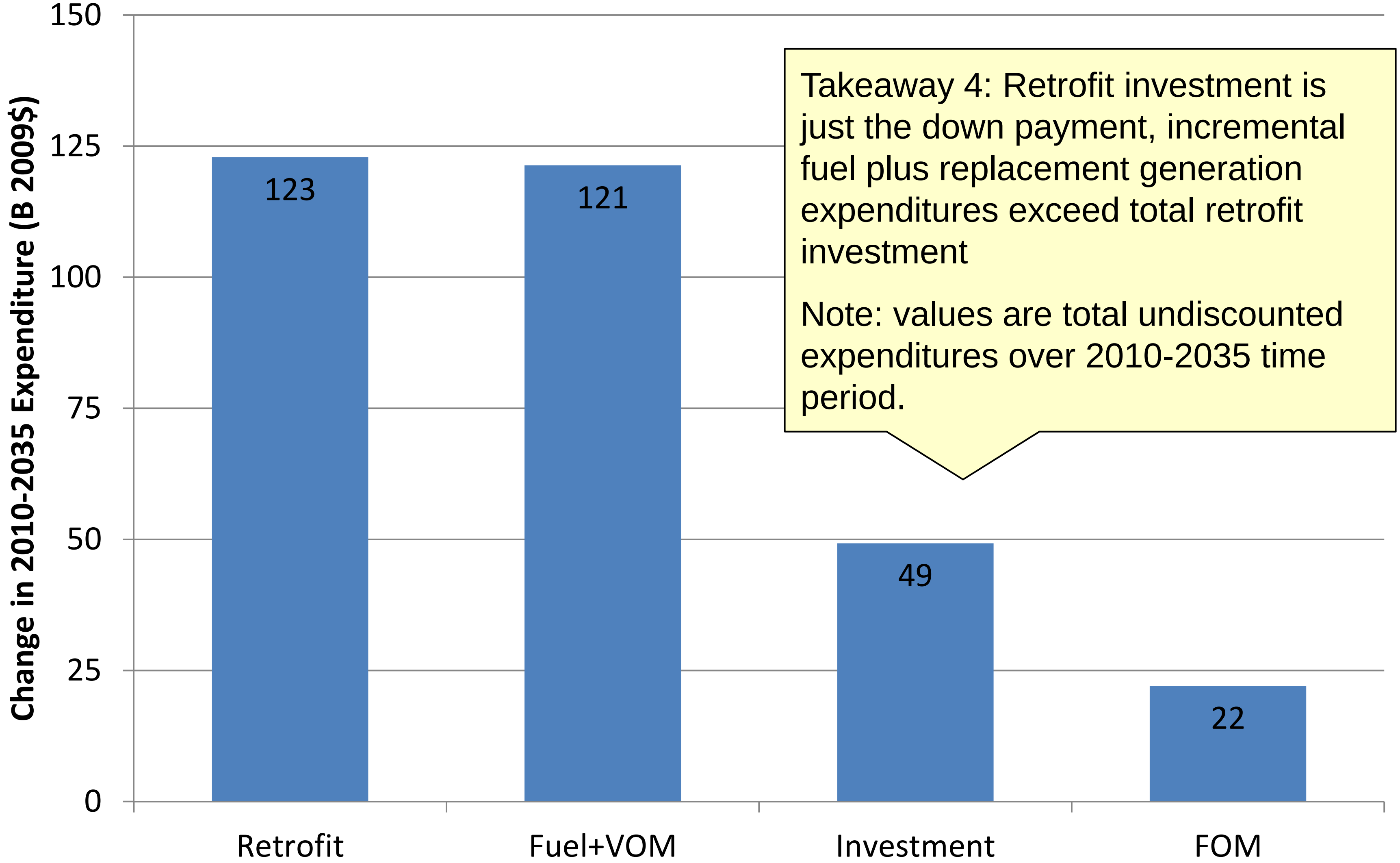
Implications for decisions

- Flexible compliance strategies with lower fixed costs (despite higher operating costs) reduce risk or regrets

100’s of Billions of Dollars in Possible Electric Sector Expenditures



Retrofit Investment is Only Part of Policy Expenditure Costs (Ref)



Takeaway 4: Retrofit investment is just the down payment, incremental fuel plus replacement generation expenditures exceed total retrofit investment

Note: values are total undiscounted expenditures over 2010-2035 time period.

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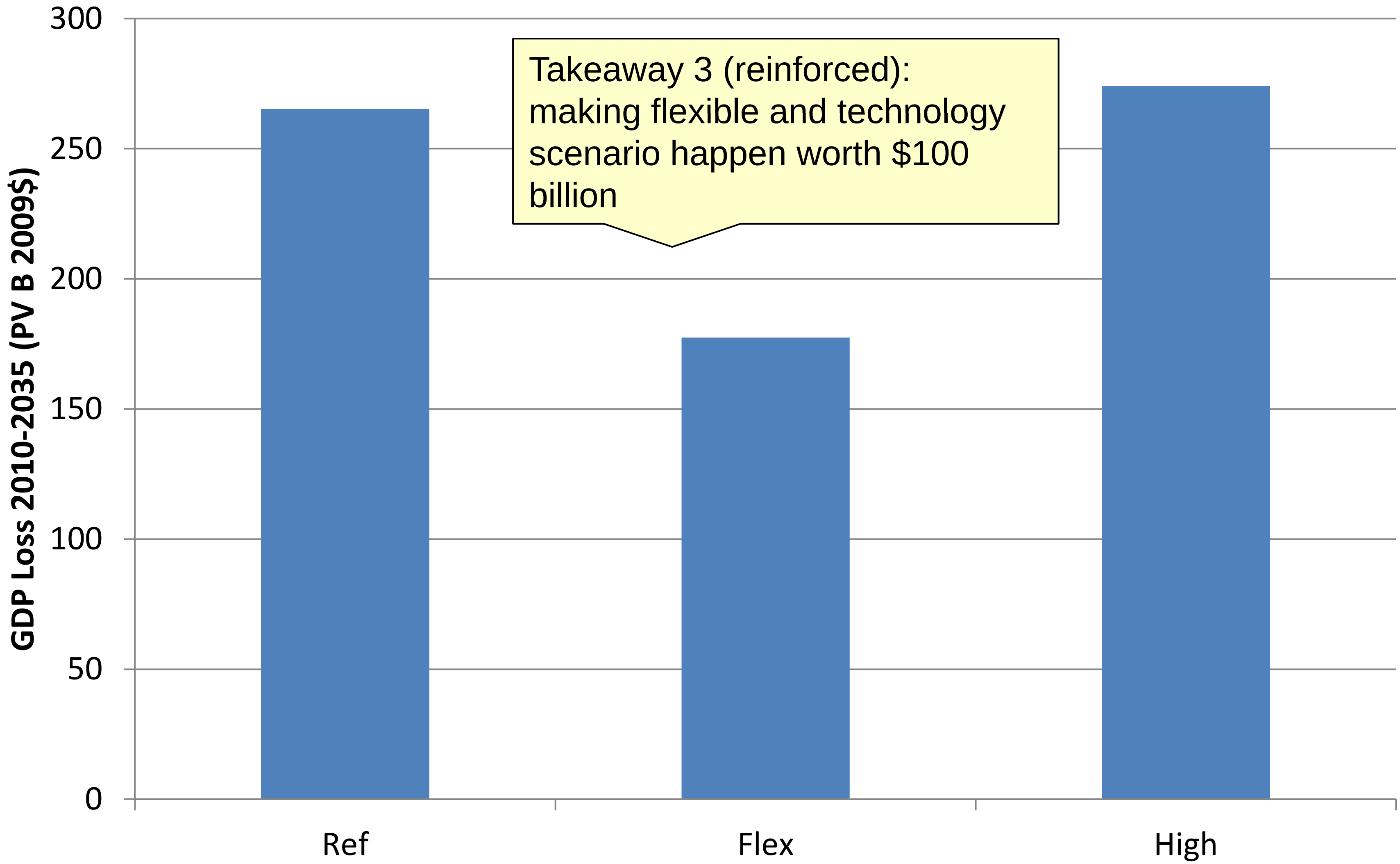
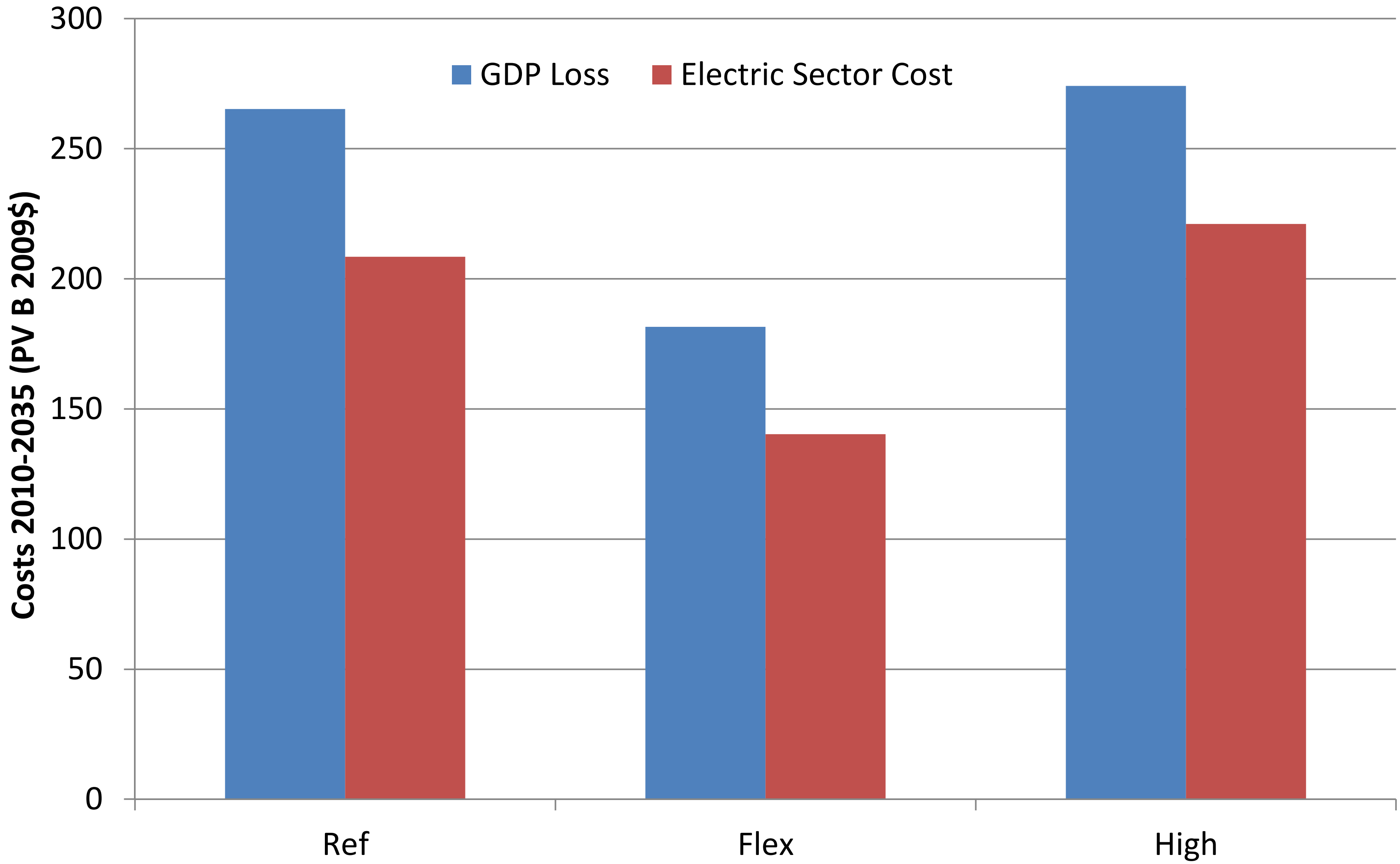
GDP Impacts Show Magnitude of Costs and Opportunity in Flexibility



Note That Total GDP Impacts ~25% Greater Than Increased Cost to Electric Sector



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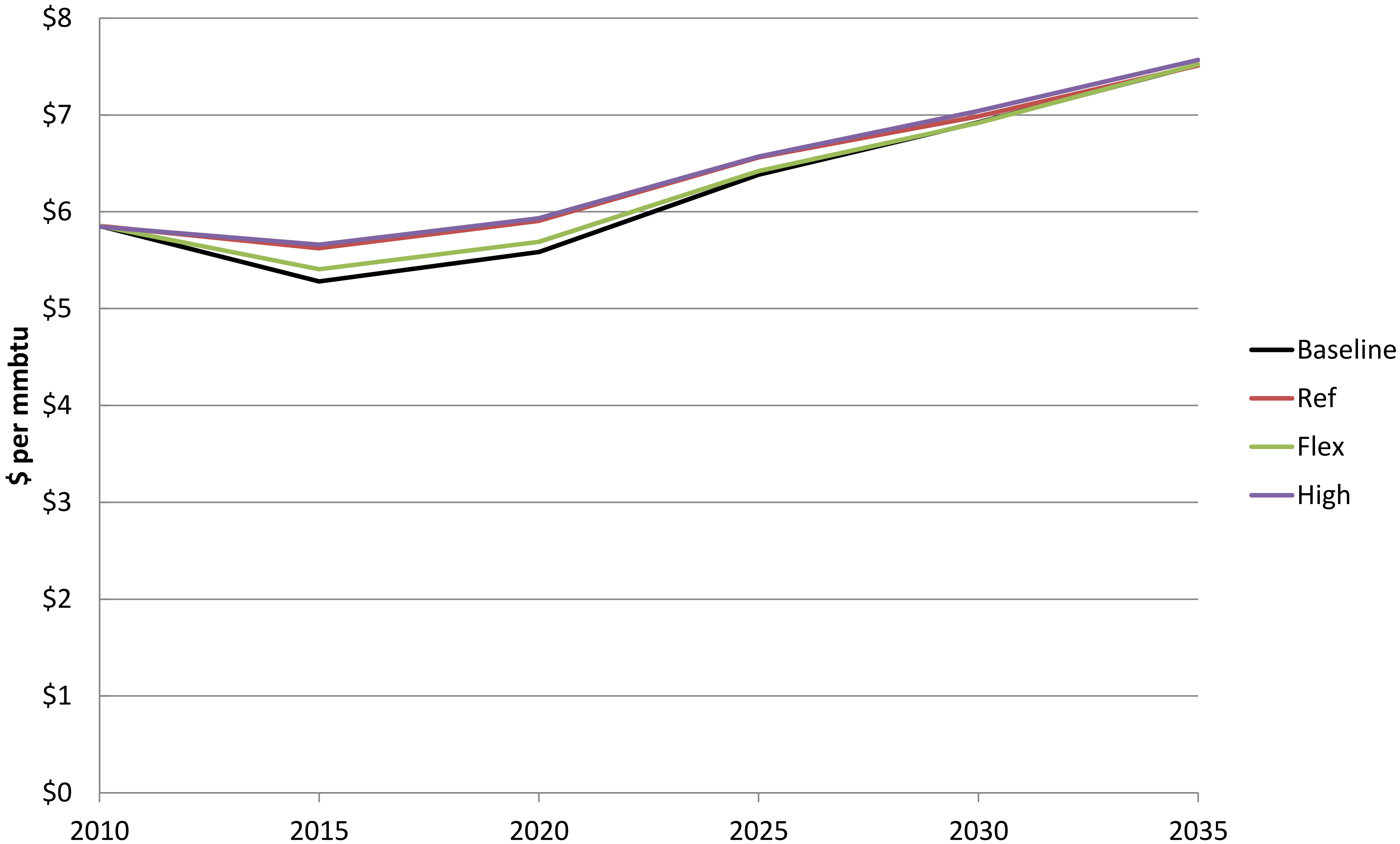
U.S. Average Power Producers' Gas Price



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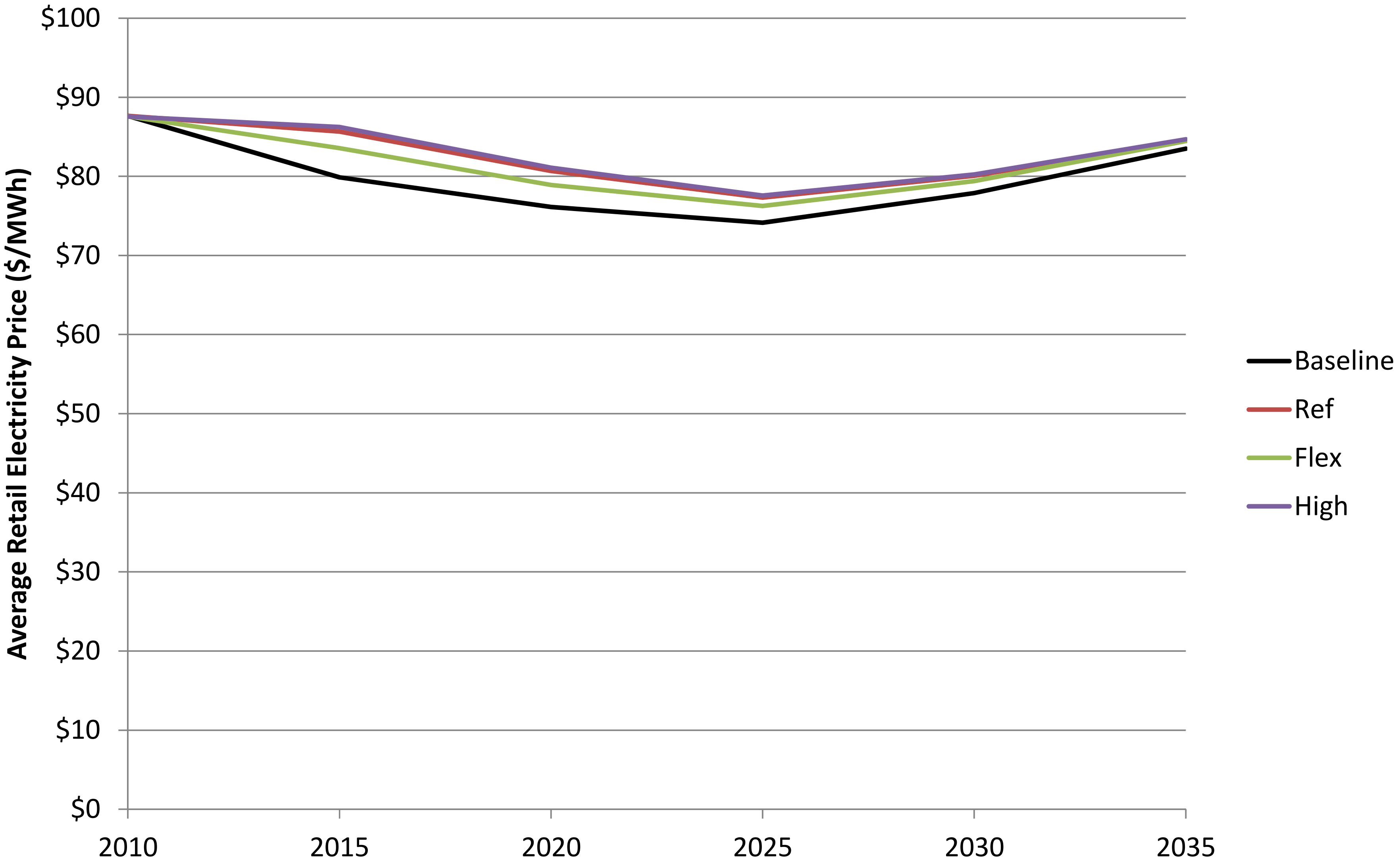
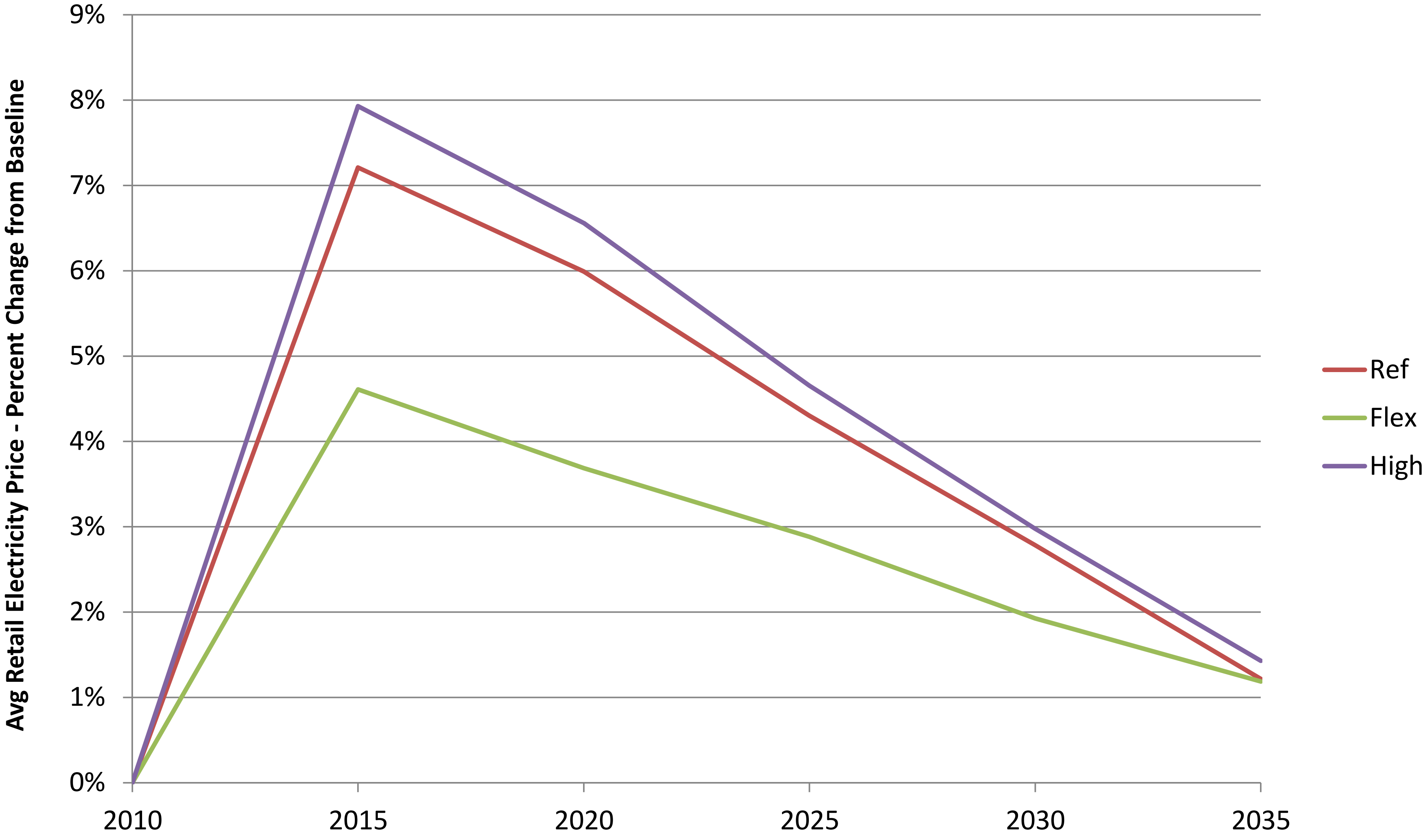
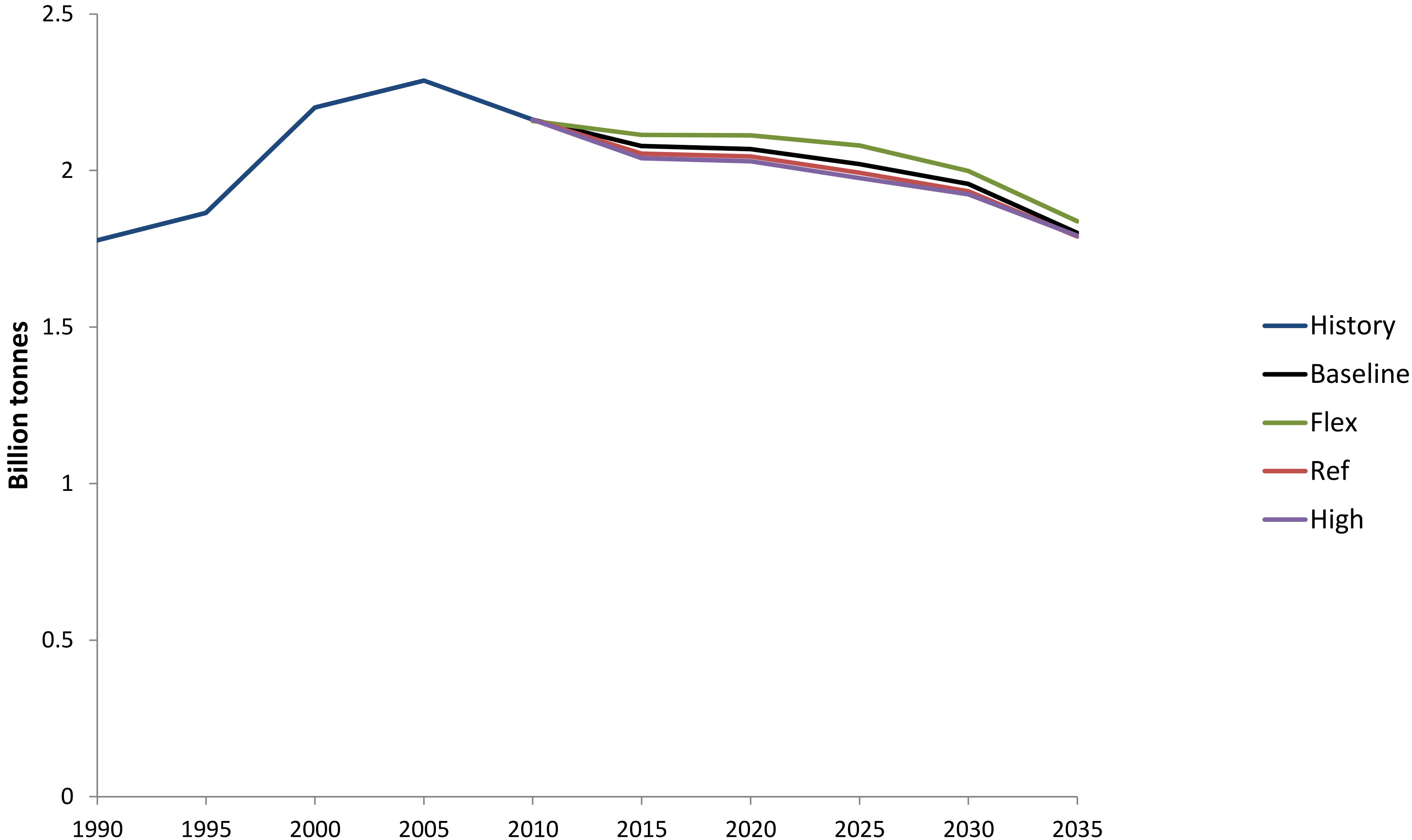
U.S. Average Retail Electricity Price



U.S. Average Retail Electricity Price - Percent Change from Baseline



U.S. Electric Sector CO_2 Emissions



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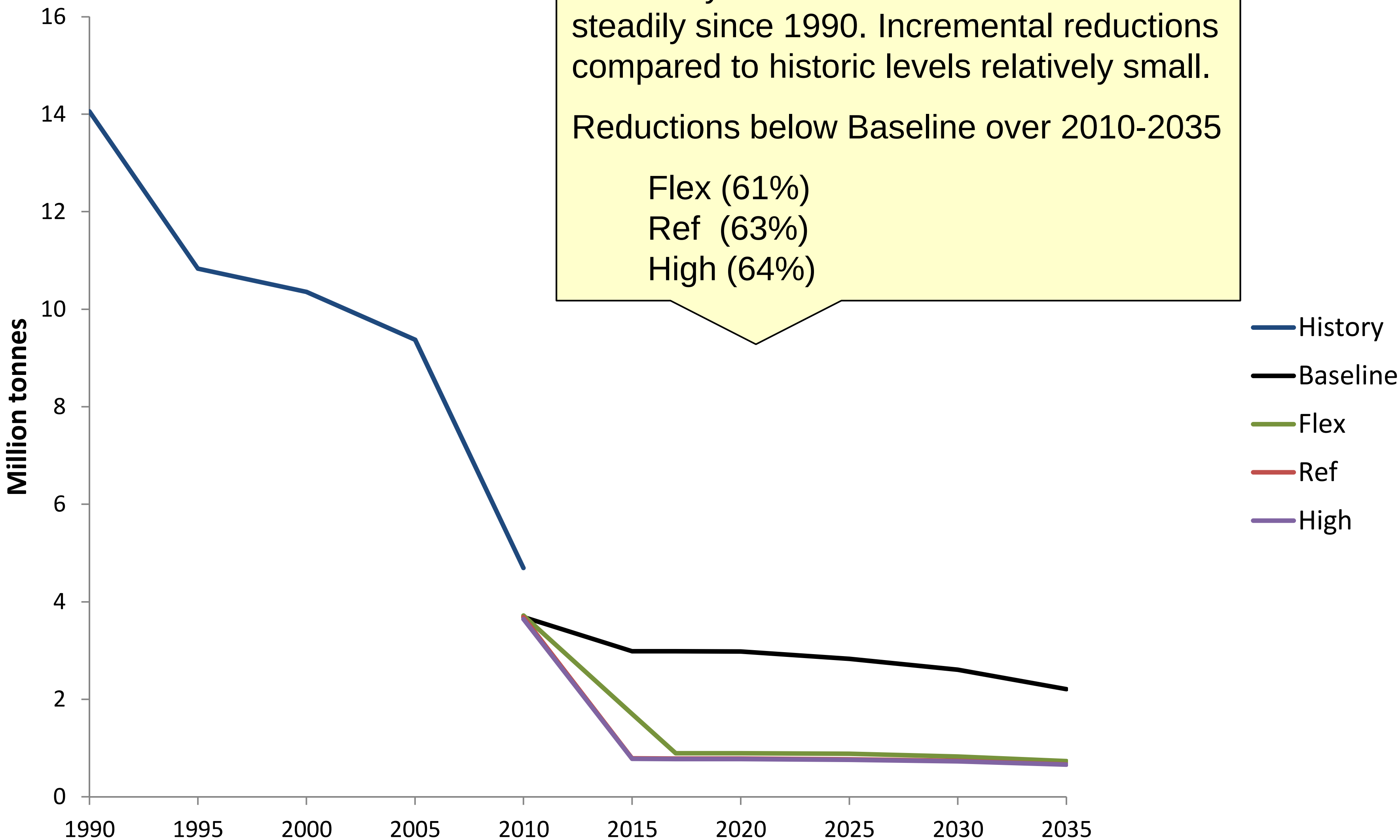
U.S. Electric Sector SO_2 Emissions

Takeaway 5: Emissions have declined steadily since 1990. Incremental reductions compared to historic levels relatively small.

Reductions below Baseline over 2010-2035

Flex (61%)
Ref (63%)
High (64%)

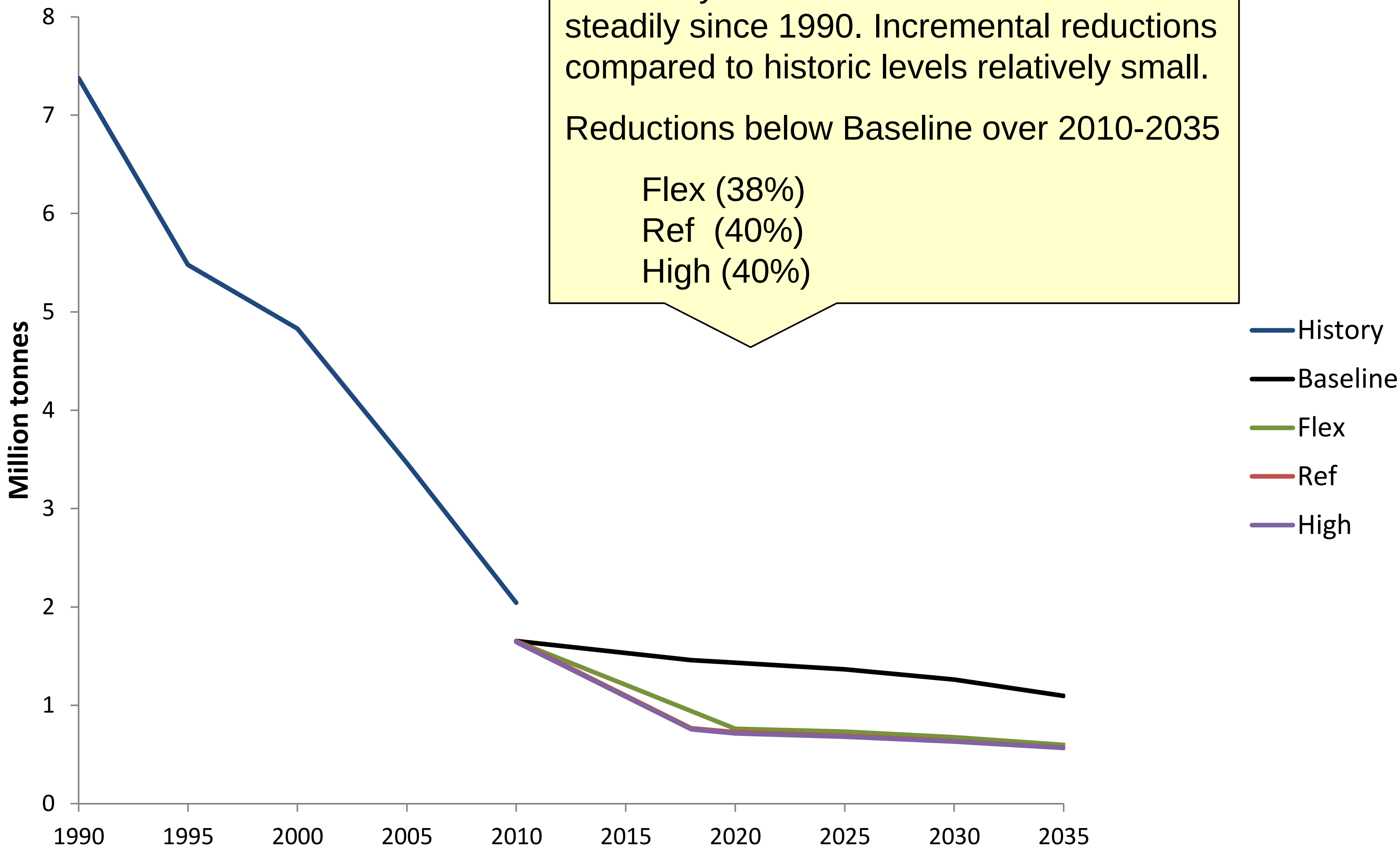


U.S. Electric Sector NO_x Emissions

Takeaway 5: Emissions have declined steadily since 1990. Incremental reductions compared to historic levels relatively small.

Reductions below Baseline over 2010-2035

Flex (38%)
Ref (40%)
High (40%)



Concluding Observations

- Economic cost of full control policy is $175B to $275B (PV 2010-2035)
- Cost range driven by ability to deploy low-cost technologies, which may require policy flexibility and extra time to assess
- Cost impacts greatest in high-coal regions
- Compliance decisions dependent on gas price expectations
- 50 to 100+ GW of coal may retire or convert fuels
- Most of existing coal continues to play key role
- SO_2/NOx emissions drop to less than 30% of 2010 levels
- If emission reductions phased in over an extra two years the relative impact on cumulative emissions is modest

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Together…Shaping the Future of Electricity

Supplemental Material: Details & Assumptions for the Environmental Controls Cases

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Overarching Analysis Framework

- Single near-term decision (by 2015) to retrofit or retire coal units
- Decision informed by full set of ongoing policy and regulatory processes
- Analysis focuses on pollutant control technologies as inputs to the US-REGEN model and not necessarily on the various regulations (e.g., MATS, 316B, RCRA).
- Need to recognize complexities and that the reality faced by sector is not clear cut:
  - Uncertainties resolved over time, not all at once
  - Control decisions staggered over time as well
  - Control technologies interact across emission targets, that is, control of SO_2 and NOx also affects Hg control costs
- Important objective is to develop a *range of costs and technologies* between Flex and High cases to reflect uncertainty:
  - Flex has lower costs, less stringent aquatic entrainment controls, less retrofit cost escalation, and additional time for compliance for SO_2 and NOx to allow for newer control technology options; assumes technologies still need to demonstrate their optimal performance.
  - Ref uses reference costs.
  - High costs with less policy flexibility to choose low-cost technologies and higher retrofit cost escalation to meet stringent deadlines.

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US-REGEN Input Assumptions for SO_2 Control Technologies

Scenario		Ref	Flex	High	
SO2 Control Required		2015	2017	2015	
SO2 Threshold		0.15	0.15	0.15	lb/MMBtu
FGD needed for all units?		no	no	yes	
Cost to upgrade SO2		150	100	200	$/kW
Equation source		IECCost	IECCost	IECCost	
Technology required					
	E. Bit	FGD+WWT	LSD	FGD+WWT	
	Sub Bit	LSD	DSI +	FGD+WWT	
	Lig	SD-FGD	DSI +	FGD+WWT	

- Expenditure ranges also include ranges for retrofit difficulty and market/timing
- Lime Spray Drying (LSD) available for bit coal in Flex scenario
- FGD + WWT = wet flue gas desulfurization
- Dry sorbent injection (DSI)
- Spray dryer – FGD = (SD-FGD)

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US-REGEN Input Assumptions for NOx Control Technologies

Scenario		Ref	Flex	High	
NOx Control Required		2018	2020	2018	
NOx Threshold		0.10	0.10	0.10	lb/MMBtu
SCR Required		yes	yes	yes	
Cost to upgrade NOx		100	50	150	$/kW
Equation source		IECCost	IECCost	IECCost	
Technology required					
	E. Bit	SCR	SCR	SCR	
	Sub Bit	SCR	SCR	SCR	
	Lig	SCR	SCR	SCR	

- SCRs required in all scenarios to meet 0.10 lb/MMBtu (or better)
- Expenditure range reflects retrofit difficulty and market/timing factors

US-REGEN Input Assumptions for Hg Control Technologies

Scenario	Ref	Flex	High	
Hg Control Required	2015	2017	2015	
Cost for FGD+SCR	15	10	25	$/kW
Equation source	IECCost	IECCost	IECCost	
Technology required				
E. Bit w FF or ESP	ACI	ACI	ACI	
Sub Bit w FF or ESP	ACI	ACI	ACI	
Lig w FF or ESP	ACI	ACI	ACI	
E. Bit w other	FF + ACI	Toxecon	FF + ACI	
Sub Bit w other	FF + ACI	Toxecon	FF + ACI	
Lig w other	FF + ACI	Toxecon	FF + ACI	

- Low costs reflect co-benefits of stringent NOx and SO_2 controls (FGD+SCR), final HAPS rules on particulate control
- Activated Carbon Injection (ACI)
- Toxecon™ = EPRI integrated mercury removal processes

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US-REGEN Input Assumptions for 316(b) Controls

Scenario	Ref	Flex	High	
316(b) Cooling Required	2018	2018	2018	
Flow Threshold	125	125	125	MGD
Factor for < threshold	10%	10%	10%	
CCC for O/E/TR & S.Rivers Only	No	Yes	No	

EPA proposed ruling March 2011:

- Cooling towers not Best Available Technology on existing plants
- Plants must retrofit improved impingement protection, larger plants must also retrofit improved entrainment protection
- Assume plants larger than 125 MGD threshold install cooling towers at an investment cost of ~$300/gpm (with plant-specific estimates where available)
- For Flex Scenario assume only ocean, estuary, tidal river, and small river plants will require closed cycle cooling

US-REGEN Input Assumptions for CCR Controls

Scenario	Ref	Flex	High	
CCR Control Required	2020	2020	2020	
RCRA Subtitle	Sub D	Sub D	Sub D	

- EPRI comprehensive survey in 2010 (Veritas Consulting)
- Veritas initially provided equations to Prism 2 for RCRA C costs
- Result is site-by-site quantification of fixed and O&M costs for complying with
- Veritas then undertook adjustment for Subtitle D
  - Dropped RCRA administrative costs, O&M for disposal
  - Kept some wet to dry conversion costs

Comparison of Input Retrofit Costs

Overnight Retrofit Investment Costs (billions) to retrofit entire existing coal fleet (sum of unit costs input to model; data for slide 11)

Cases	Ref	High	Flex	Difference High to Flex	% of Change	Share due to escalation
SO_2	$75	$102	$24	$78	56%	46%
NOx	88	102	70	33	23%	84%
Hg	7	9	5	4	3%	22%
316b	37	37	13	25	18%	0%
Ash	33	33	33	0	0%	
Total	$240	$284	$144	$140	100%	

Final model results are lower given that not all coal units are retrofit.

Analysis focuses on pollutant control technologies as inputs to the US-REGEN model and not necessarily on the various regulations (e.g., MATS, 316B, RCRA).

For example, the difference between the SO_2 retrofits (High minus Flex) was $78B, that was 56% of the difference in total retrofit costs. Of the $78B difference, 46% of that was due to higher escalation for the High case. What isn't escalation can be attributed to different control costs. From this, it is roughly estimated that half the total impact is for savings from lower cost SO2 control technologies, and half of which is for lower escalation. The remaining half is about is roughly split between lower NOx and 316b control costs. Hg control's share is low due to the co-benefits for SO_2 and NOx control.

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