About the Climate Change Policy Partnership

University – corporate partnership

- Nicholas Institute
- Nicholas School
- Center on Global Change
- Corporate partners
  - Duke Energy, ConocoPhillips and MeadWestvaco

Natural Gas Modeling Project

- Concerns about natural gas prices under climate change legislation
  - Will we see fuel switching from coal to natural gas in the near-term in response to a carbon cap?
  - Will natural gas prices escalate as a result?
- Goal is to present a range of forecasts given potential technology development scenarios

Climate Change Policy

- Based on Lieberman-Warner (S.2191) cap and trade bill
  - Other cap and trade bills would create similar results
  - We selected S.2191 because EIA developed this scenario for NEMS

Revised Inputs for All Scenarios

- Additional unconventional natural gas reserves
  - Haynesville shale in Louisiana
- Restricted LNG imports to reflect large uncertainties about future availability
- Added ability to retrofit existing coal plants with post-combustion capture technology – from NETL
- Updated power plant construction costs to reflect current overnight plant costs, driven largely by recent increases in primary material prices

CCPP Scenario Matrix: Scenario Numbers

	High NG Extract Tech	Ref NG Extract Tech	Low NG Extract Tech
High Elec Tech	4		7
Ref Elec Tech	3	2	6
Low Elec Tech	5		8
Low Elec Tech, No IGCC CCS or Nuc until 2020			9
Low Elec Tech, No Retro CCS ever, No IGCC CCS or Nuc 2020			9b

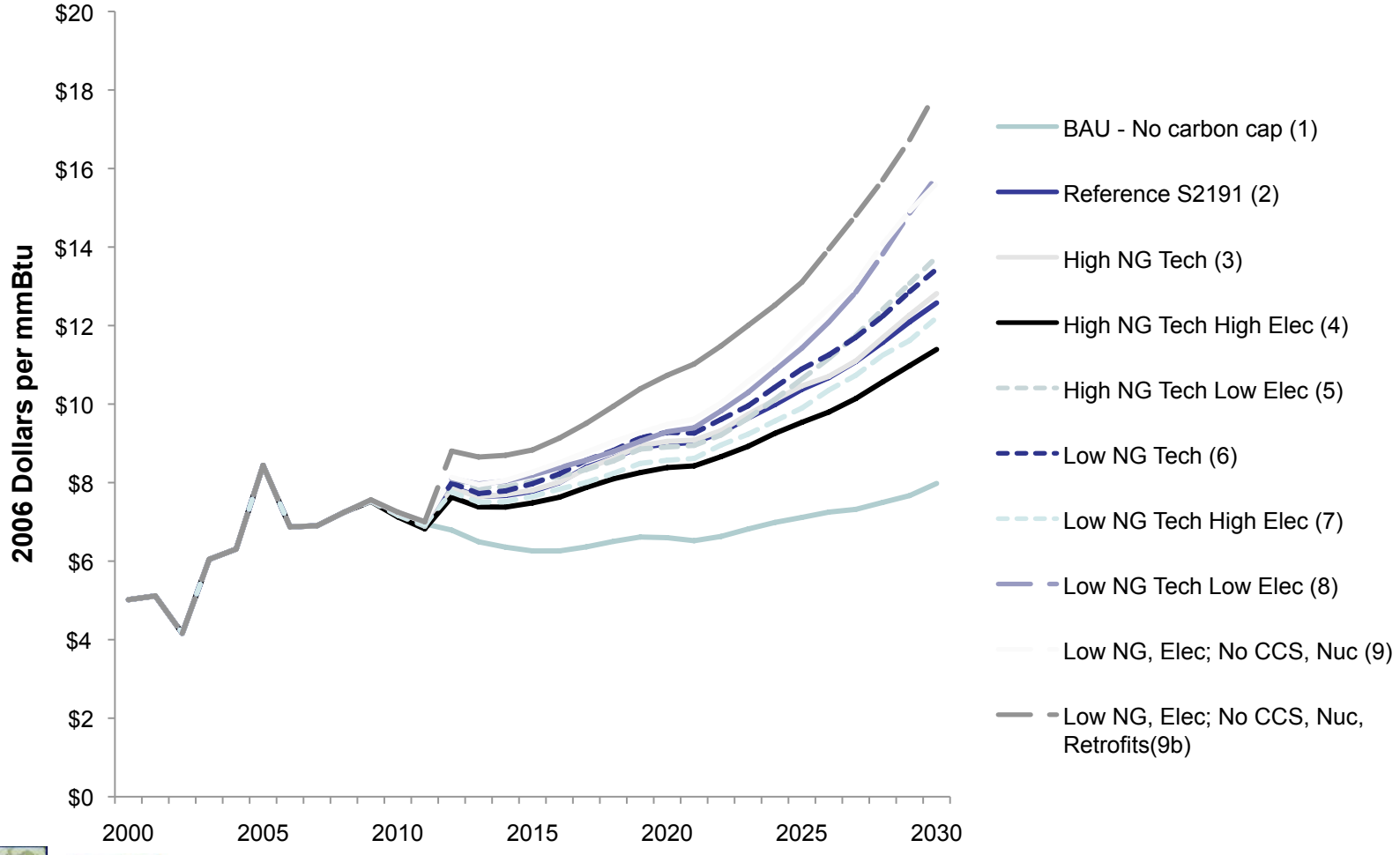
Note: Business as usual scenario 1 has no carbon cap (not shown)

Changing energy world

- Model assumes real GDP growth rate 2.4%
- Likely underestimate unconventional NG resources
  - AEO 2009 includes Haynesville shale and Marcellus shale
  - Navigant: Total U.S. gas resource 1,680 Tcf (88 years)
  - CERA: North America NG supplies no longer constrained (until at least 2018)
- Construction costs?

Natural Gas Market Results

Delivered Natural Gas Prices for Electricity Generation – includes cost of carbon



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Percent Change in Natural Gas Demand from Reference Scenario

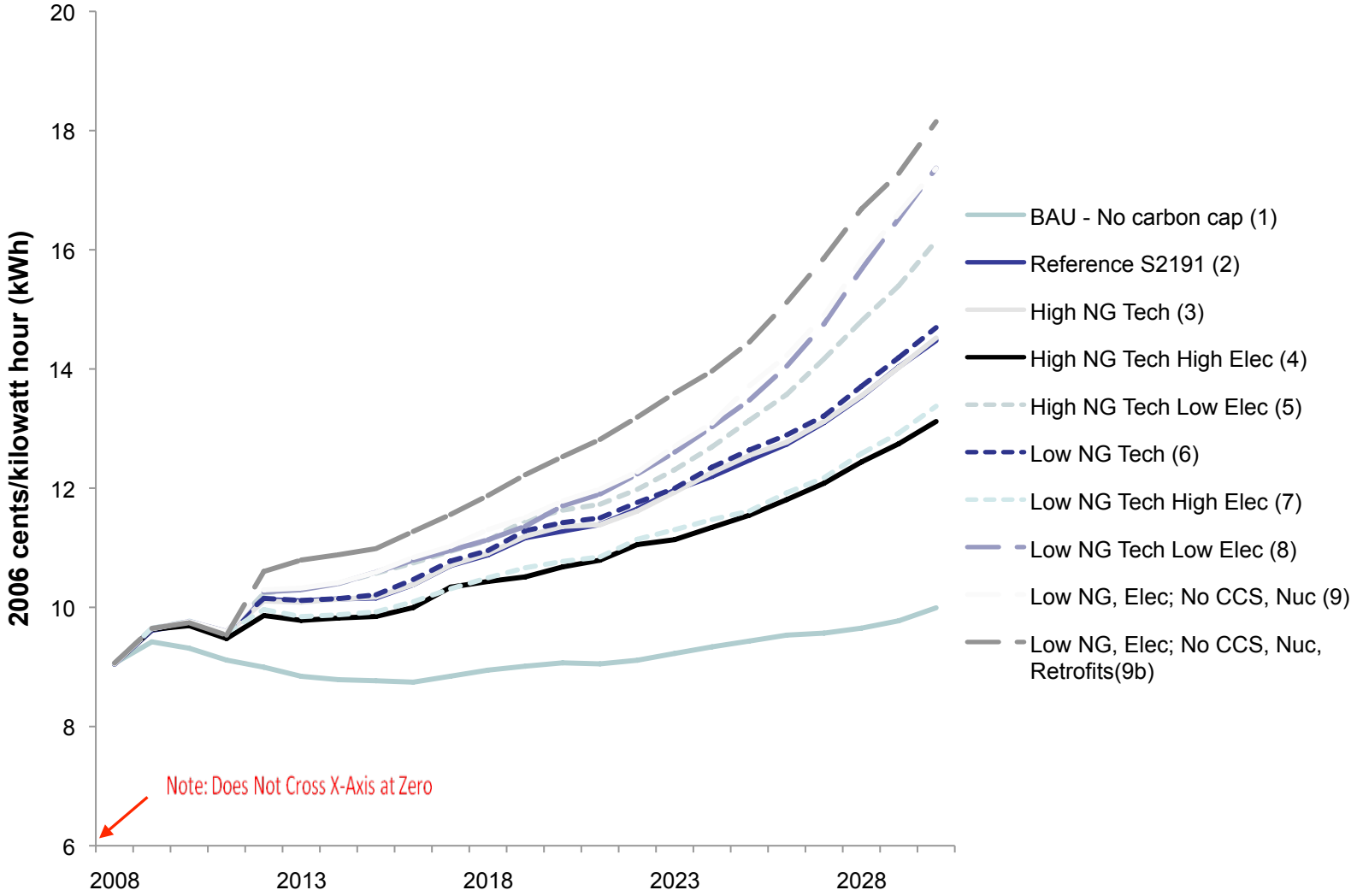
	2000	2005	2010	2020	2030
BAU - No carbon cap (1)			0%	1%	4%
Reference S2191 (2)	23.32	22.01	23.17	24.23	23.86
High NG Tech (3)			0%	0%	1%
High NG Tech High Elec (4)			0%	-3%	-6%
High NG Tech Low Elec (5)			0%	-1%	8%
Low NG Tech (6)			0%	-3%	-9%
Low NG Tech High Elec (7)			-1%	-7%	-14%
Low NG Tech Low Elec (8)			0%	-3%	0%
Low NG, Elec; No CCS, Nuc (9)			0%	-2%	0%
Low NG, Elec; No CCS, Nuc, Retrofits(9b)			0%	-4%	-3%

Summary of Natural Gas Results

- Delivered natural gas prices steadily increase with carbon cap
- Prices highly dependant on electricity sector technology development
- Natural gas demand stable across scenarios

Electricity Sector Results

Average Electricity Price



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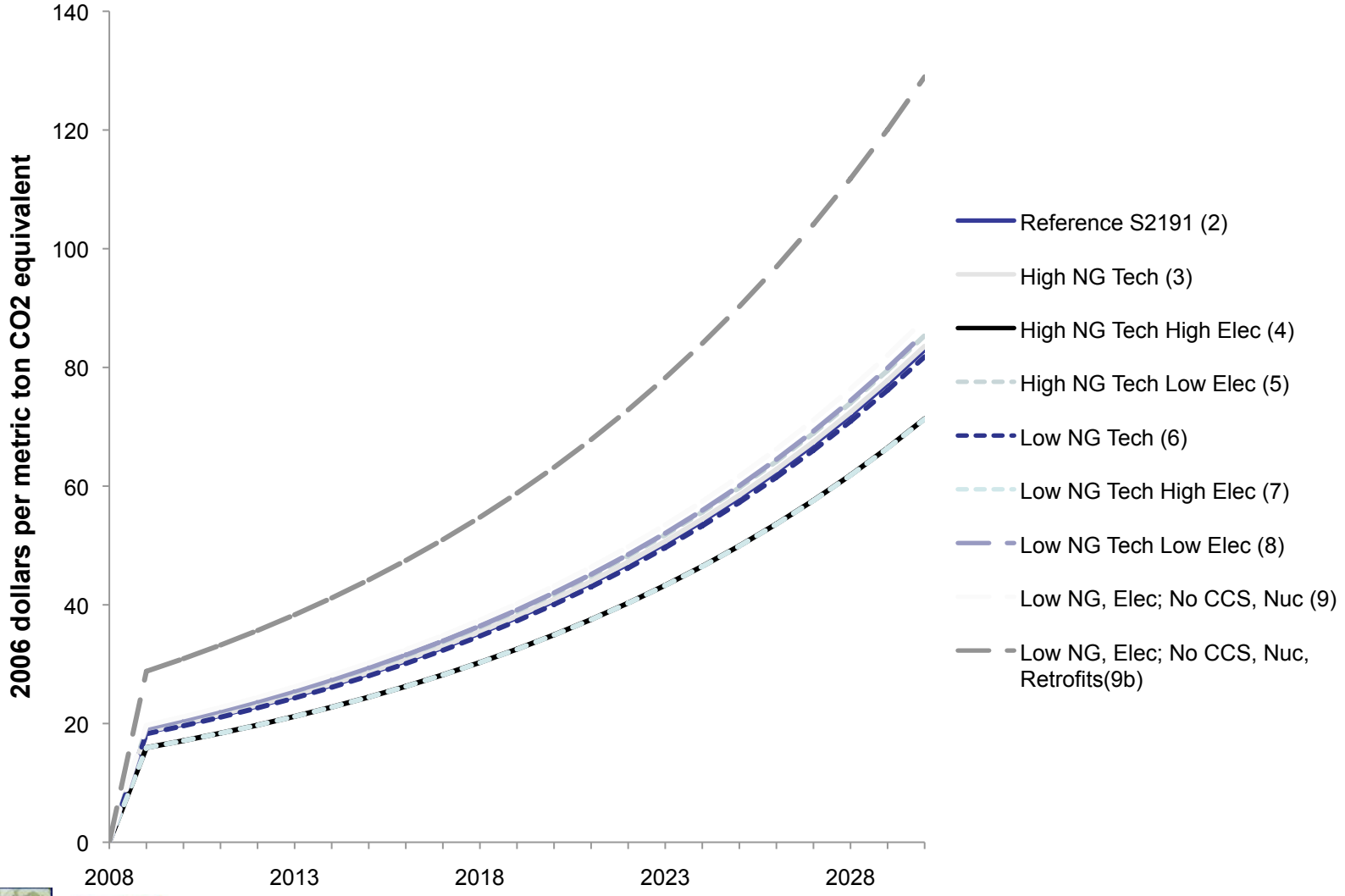
Average Allowance Price



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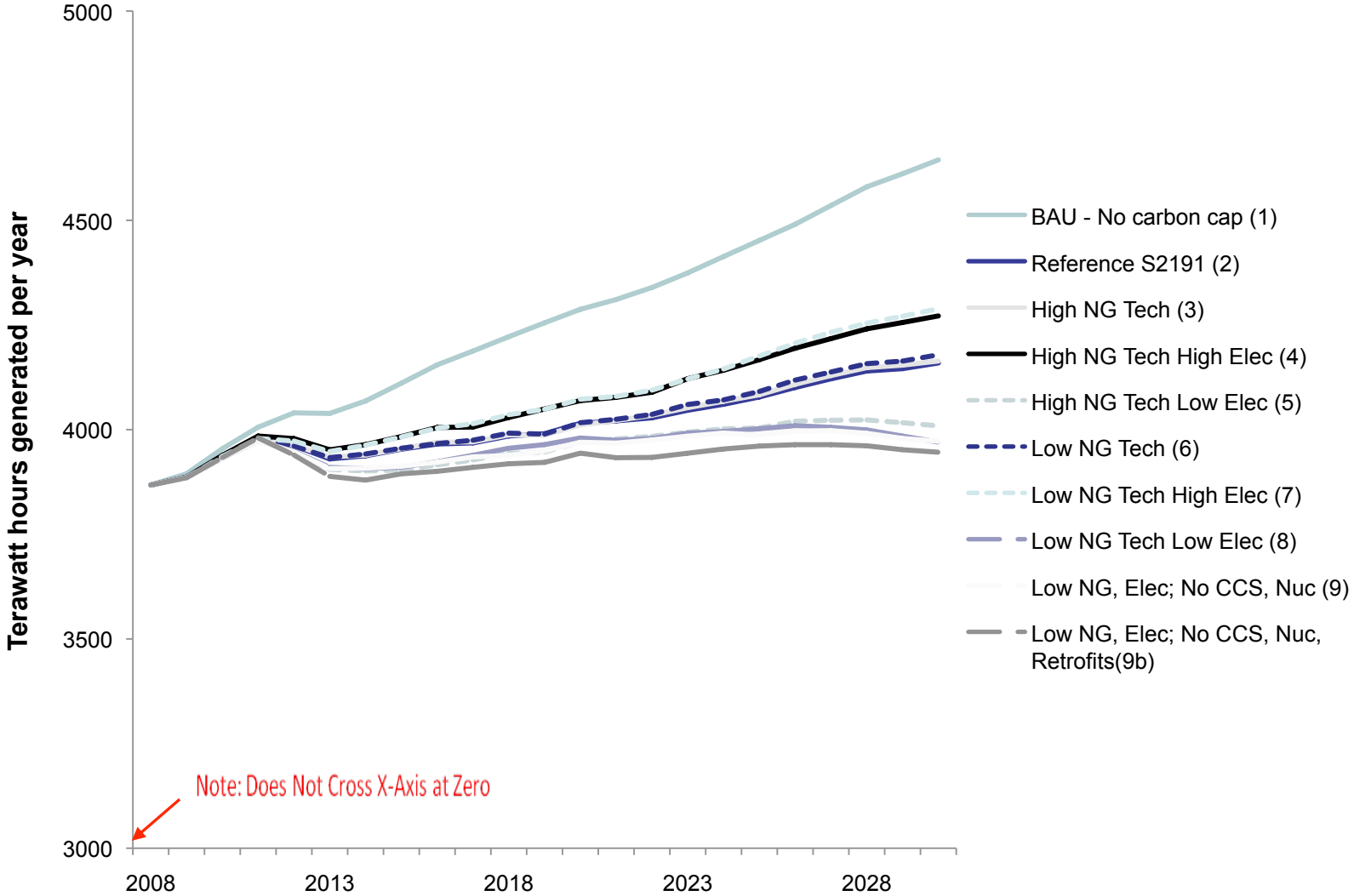
Percent change in Average Electricity Price from Reference Scenario (2)

	2010	2020	2030
BAU - No carbon cap (1)	-4%	-20%	-31%
Reference S2191 (2)	9.72	11.28	14.48
High NG Tech (3)	0%	1%	0%
High NG Tech High Elec (4)	0%	-5%	-9%
High NG Tech Low Elec (5)	0%	3%	12%
Low NG Tech (6)	0%	1%	1%
Low NG Tech High Elec (7)	0%	-5%	-8%
Low NG Tech Low Elec (8)	0%	4%	20%
Low NG, Elec; No CCS, Nuc (9)	0%	4%	20%
Low NG, Elec; No CCS, Nuc, Retrofit(9b)	0%	11%	25%

Total Electricity Generation



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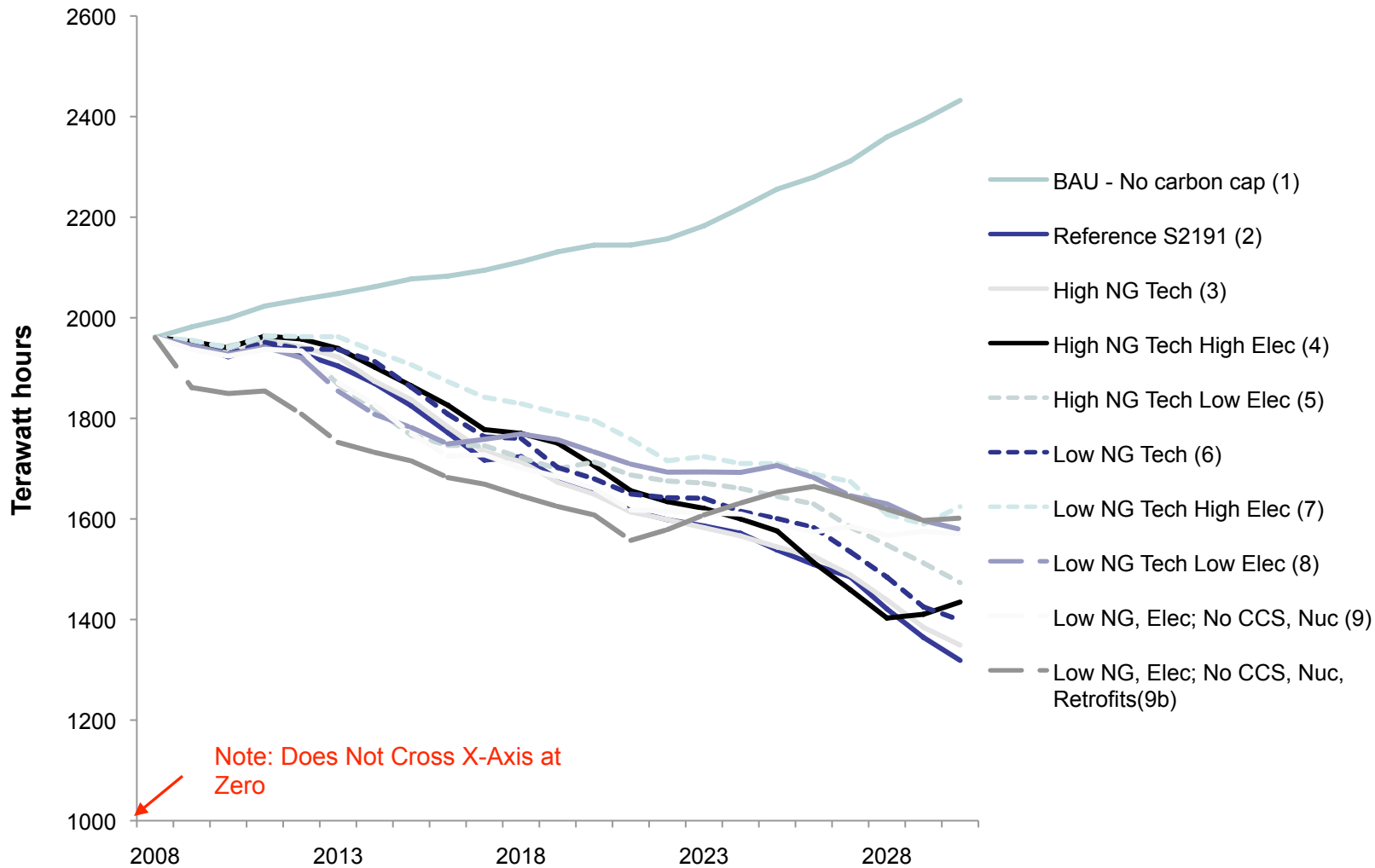
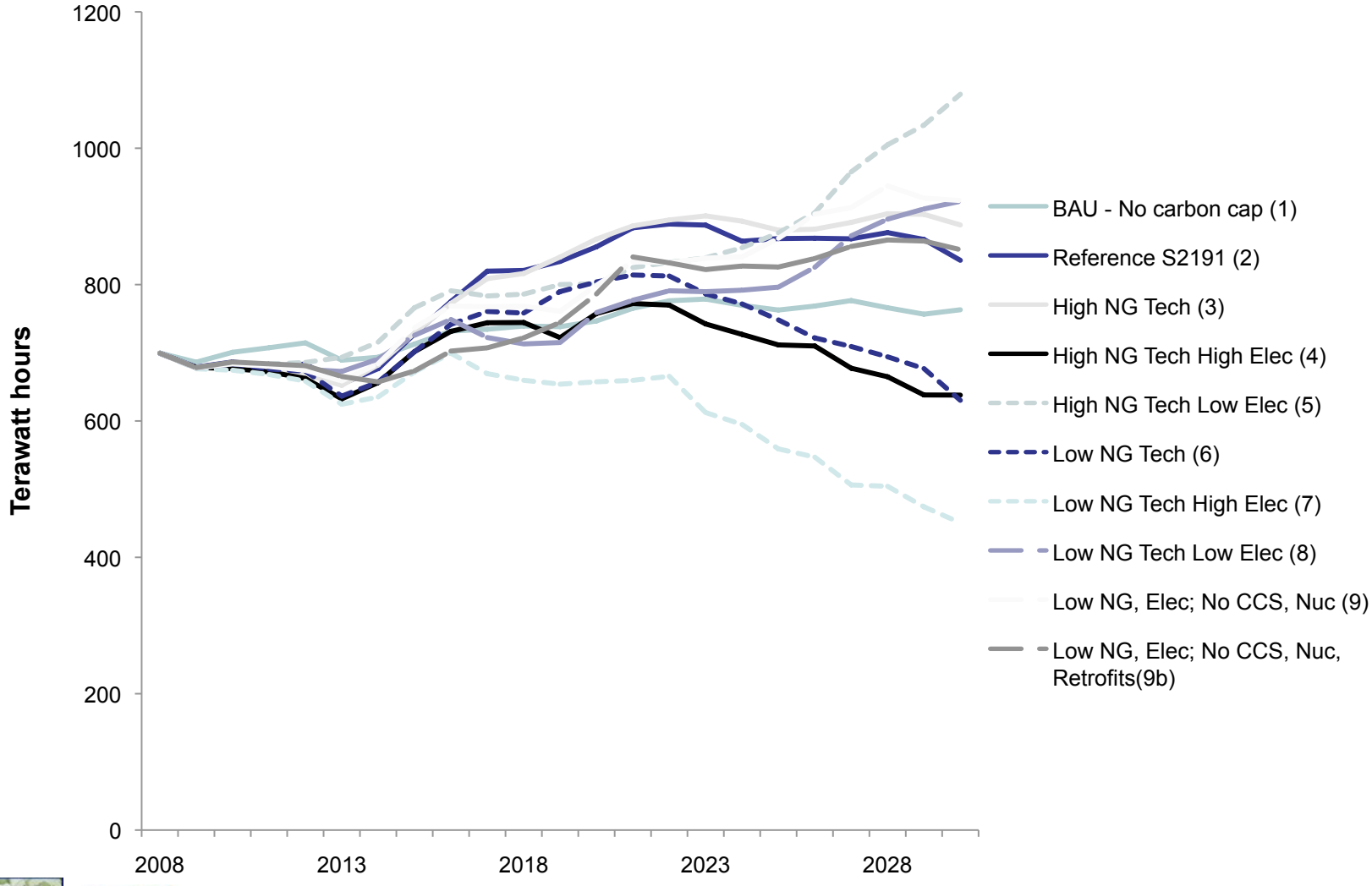
Coal Electricity Generation



Natural Gas Electricity Generation



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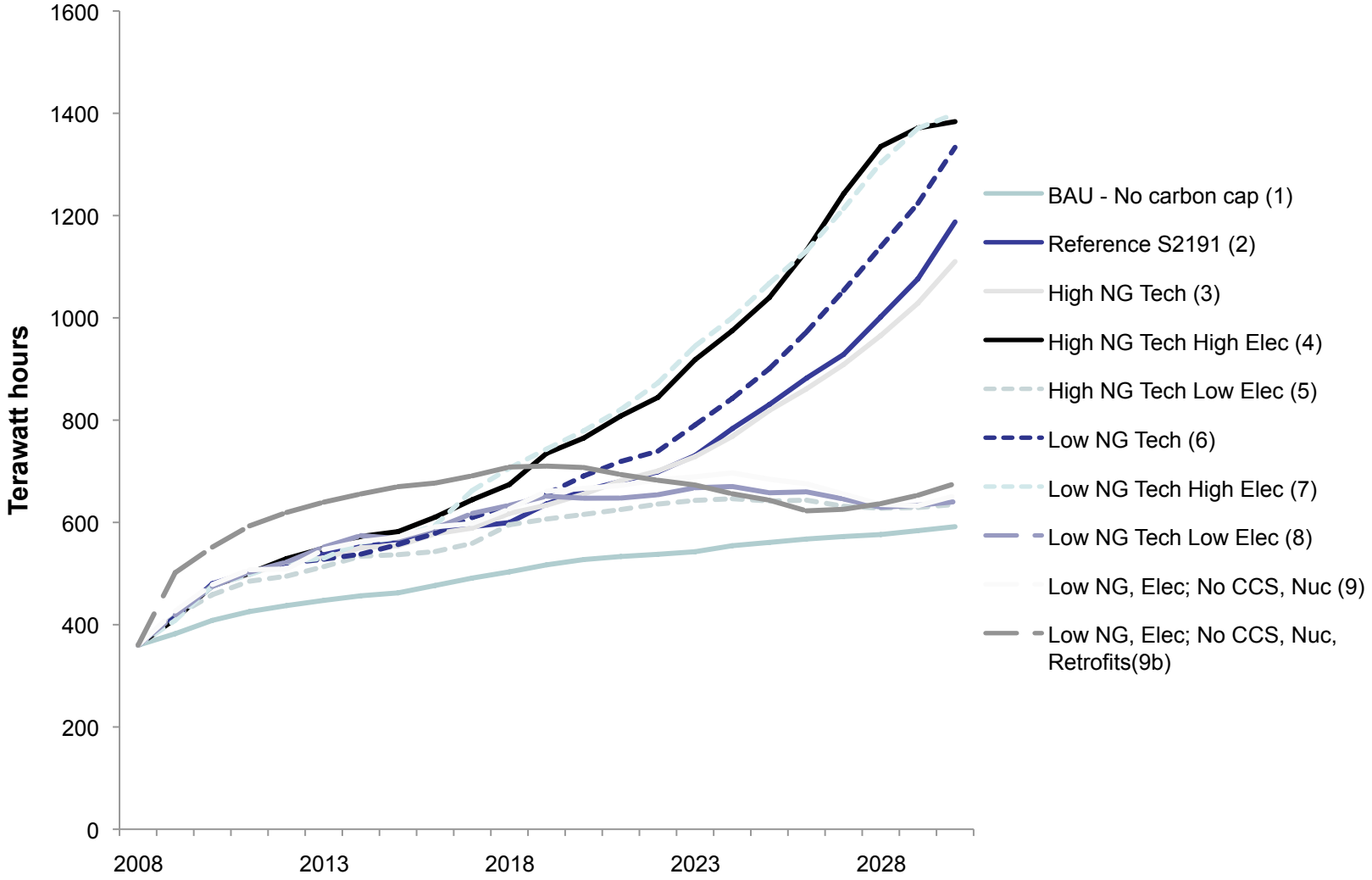
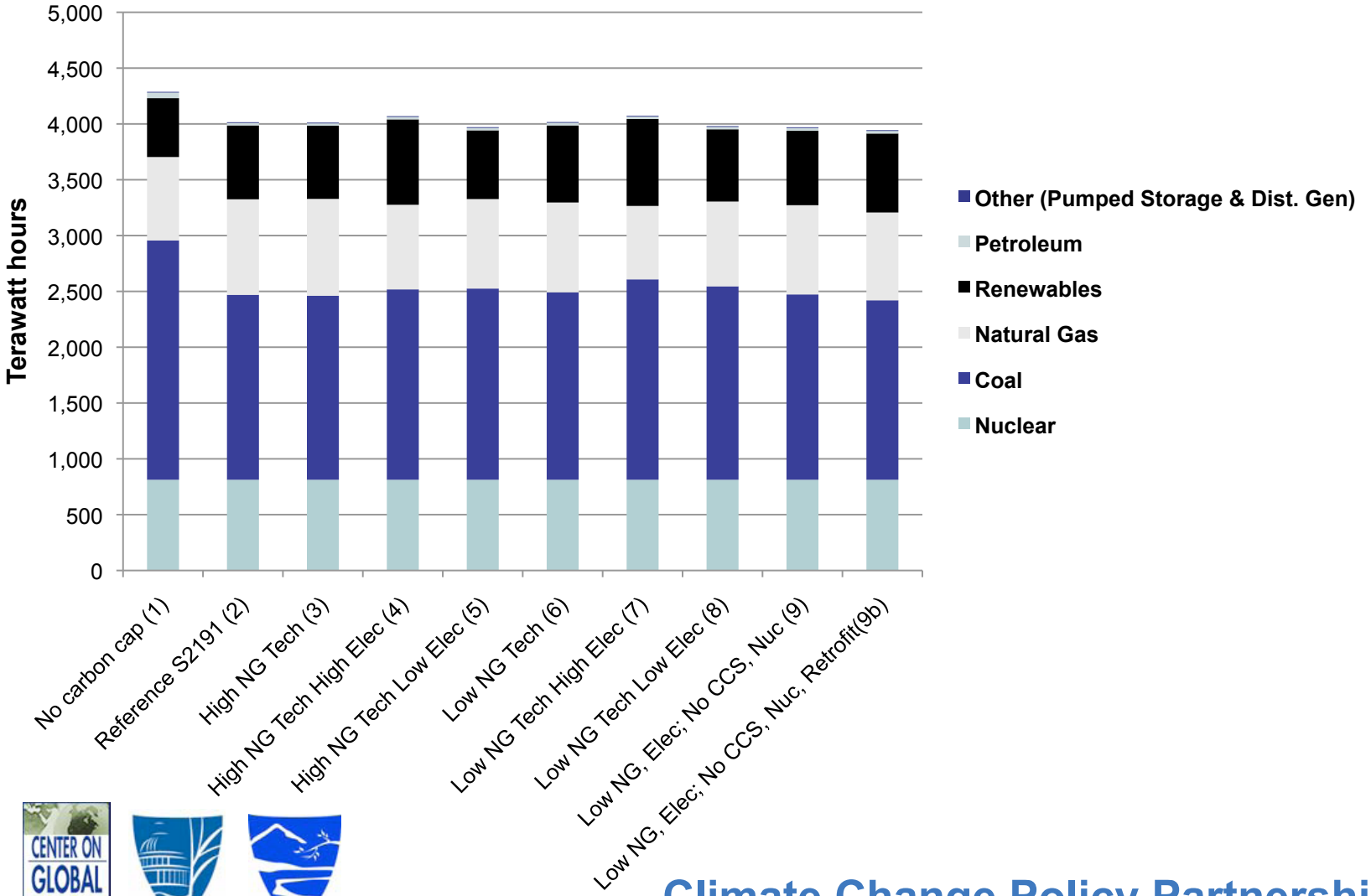
Renewable Electricity Generation



Electricity Generation by Source 2020 (TWh)



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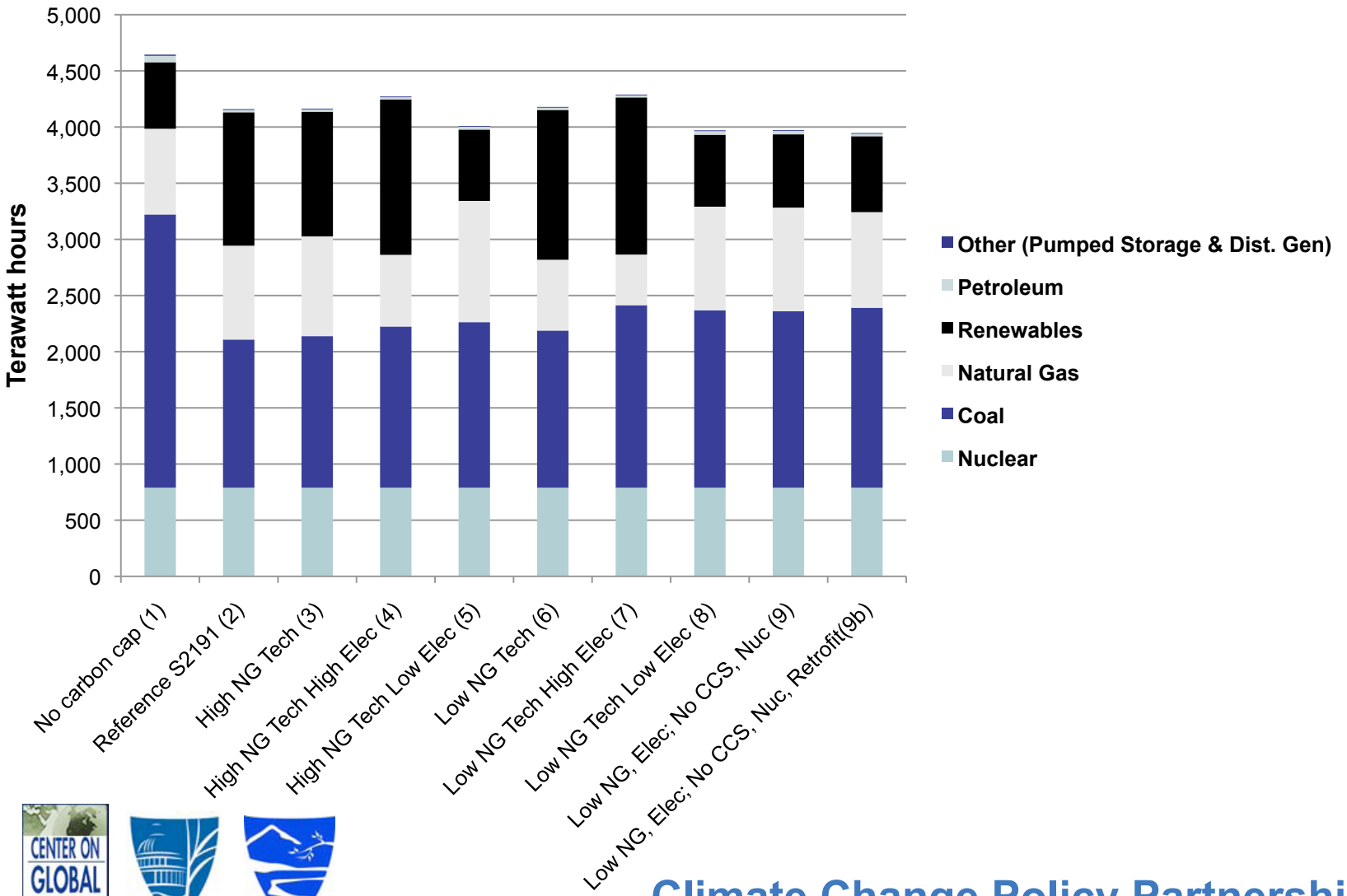
Electricity Generation by Source in 2030 (TWh)



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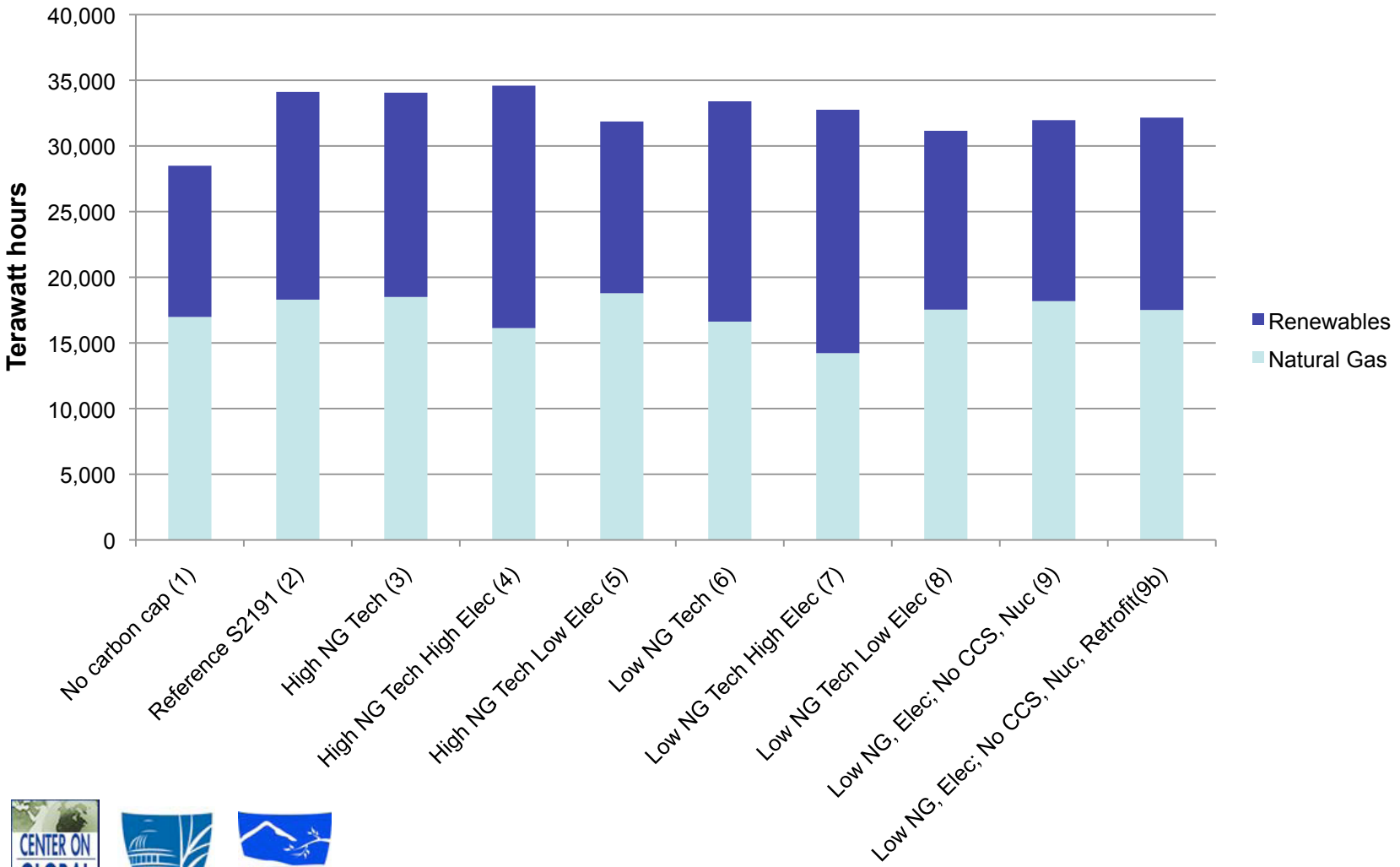
Cummulative Natural Gas and Renewable Electricity Generation 2008 - 2030



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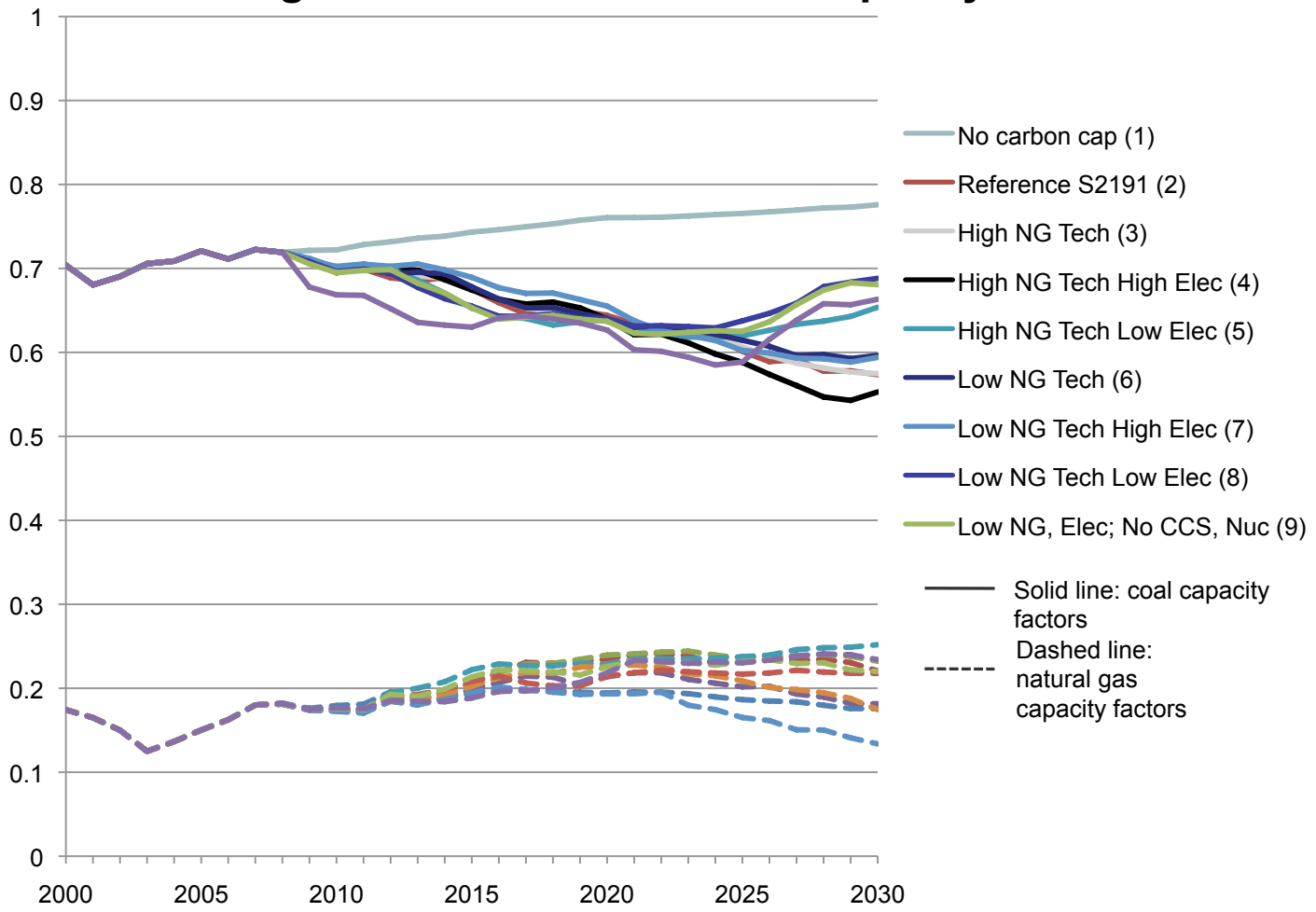
Average Coal and Natural Gas Capacity Factors



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Electricity Results Summary

- Coal generation relatively constant across scenarios
- Taken separately, large variability in renewable and natural gas generation across scenarios
  - Taken together, the sum of natural gas and renewable generation is fairly constant across scenarios
- For scenarios with high electricity sector development, renewable generation exceeds natural gas generation
- IGCC w/CCS and CCS retrofit restrictions do not decrease coal generation, but restrictions do increase prices

Discussion

- For CCPP scenarios coal remains primary baseload generation
- Natural gas is *not a substitute for coal generation* under carbon cap
  - Coal capacity factors approximately double that of NG
  - Coal fuel input costs are lower than NG for all scenarios
- Renewables, NG are substitutes
- Ability to retrofit is critical

Conclusion

- If policy makers are concerned about natural gas prices under a carbon cap
  - Fund Research, Development, Demonstration and Deployment of IGCC CCS and CCS retrofits
  - Support renewable generation through policy and RDD&D

Questions?

Report Available online:

http://www.nicholas.duke.edu/ccpp/publications.html

AEO 2009 Lieberman-Warner Scenario

	2010		2020		2030	
	AEO 2009 LW	CCPP Ref Scenario (2)	**AEO 2009 LW**	CCPP Ref Scenario (2)	**AEO 2009 LW**	CCPP Ref Scenario (2)
Delivered NG prices Electricity Sector ($ 2006/mmBtu)	**$ 6.71**	$ 7.17	**$ 9.02**	$ 8.98	**$ 12.53**	$ 12.58
Delivered coal prices Electricity Sector ($ 2006/mmBtu)	**$ 1.80**	$ 1.83	**$ 5.11**	$ 5.53	**$ 8.49**	$ 9.55
Allowance price ($ 2007/ton CO2 equiv.)			**$ 35.09**	$ 40.65	**$ 71.66**	$ 83.01

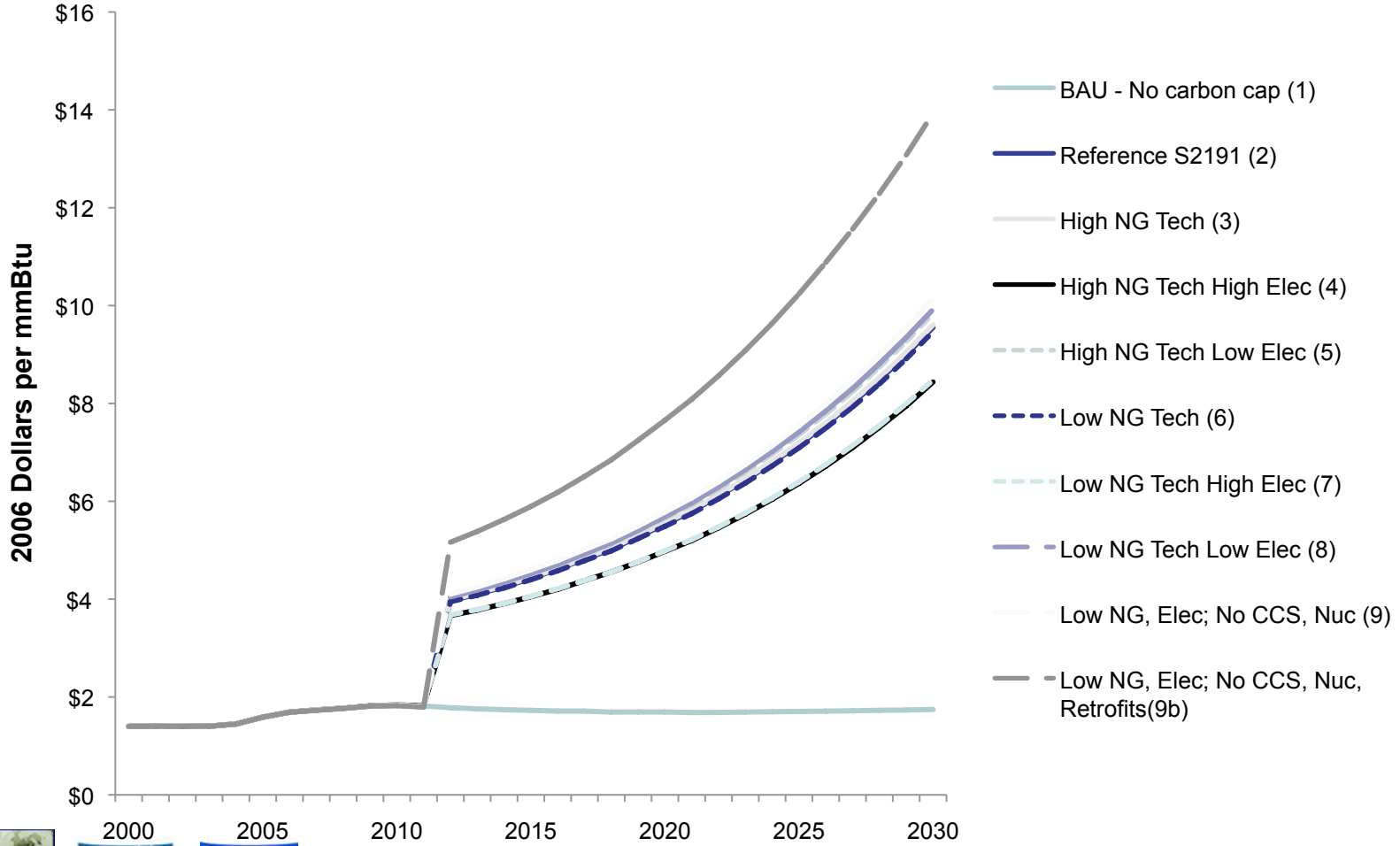
Coal and Natural Gas Fuel Input Costs 2006 $/mmBtu

	2008	2010	2020	2030
Business-as-usual - No carbon cap (1)	1.77	1.84	1.69	1.75
	7.24	7.23	6.60	7.98
Reference S2191 (2)	1.77	1.83	5.53	9.55
	7.24	7.17	8.98	12.58
High NG Tech (3)	1.77	1.84	5.56	9.61
	7.24	7.17	9.05	12.82
High NG Tech High Elec (4)	1.77	1.84	4.98	8.44
	7.24	7.13	8.38	11.39
High NG Tech Low Elec (5)	1.77	1.84	5.66	9.84
	7.24	7.17	8.91	13.75
Low NG Tech (6)	1.77	1.83	5.49	9.47
	7.24	7.23	9.28	13.44
Low NG Tech High Elec (7)	1.77	1.84	4.99	8.48
	7.24	7.18	8.57	12.20
Low NG Tech Low Elec (8)	1.77	1.84	5.68	9.92
	7.24	7.24	9.30	15.80
Low NG, Elec; No CCS, Nuc (9)	1.77	1.83	5.78	10.14
	7.24	7.24	9.48	15.63
Low NG, Elec; No CCS, Nuc, Retrofits(9b)	1.77	1.82	7.66	13.93
	7.24	7.25	10.73	17.97

coal

natural gas

Delivered Coal Prices for Electricity Generators - includes cost of carbon



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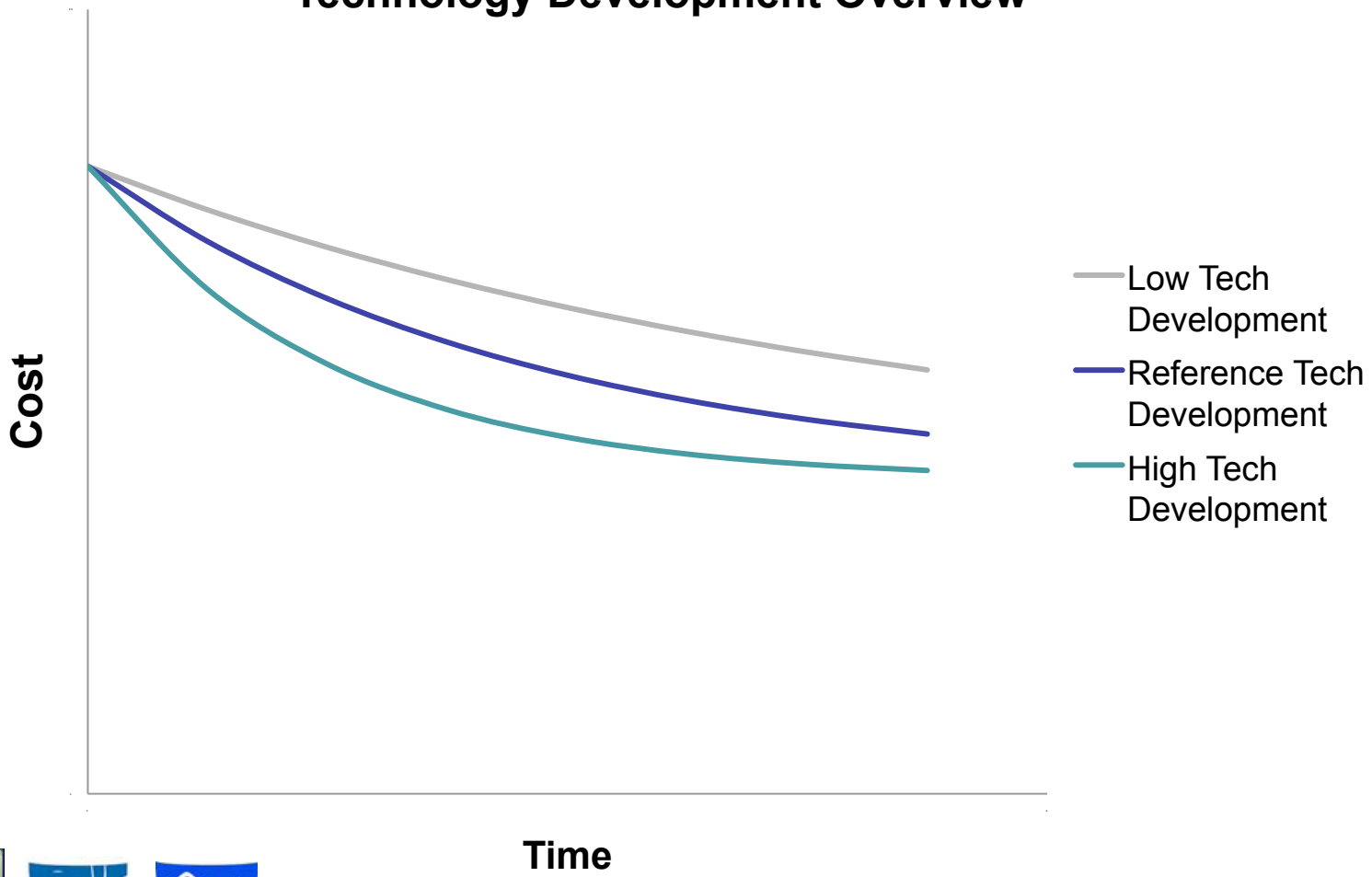
Natural Gas Extraction and Electricity Sector Technology Development Overview



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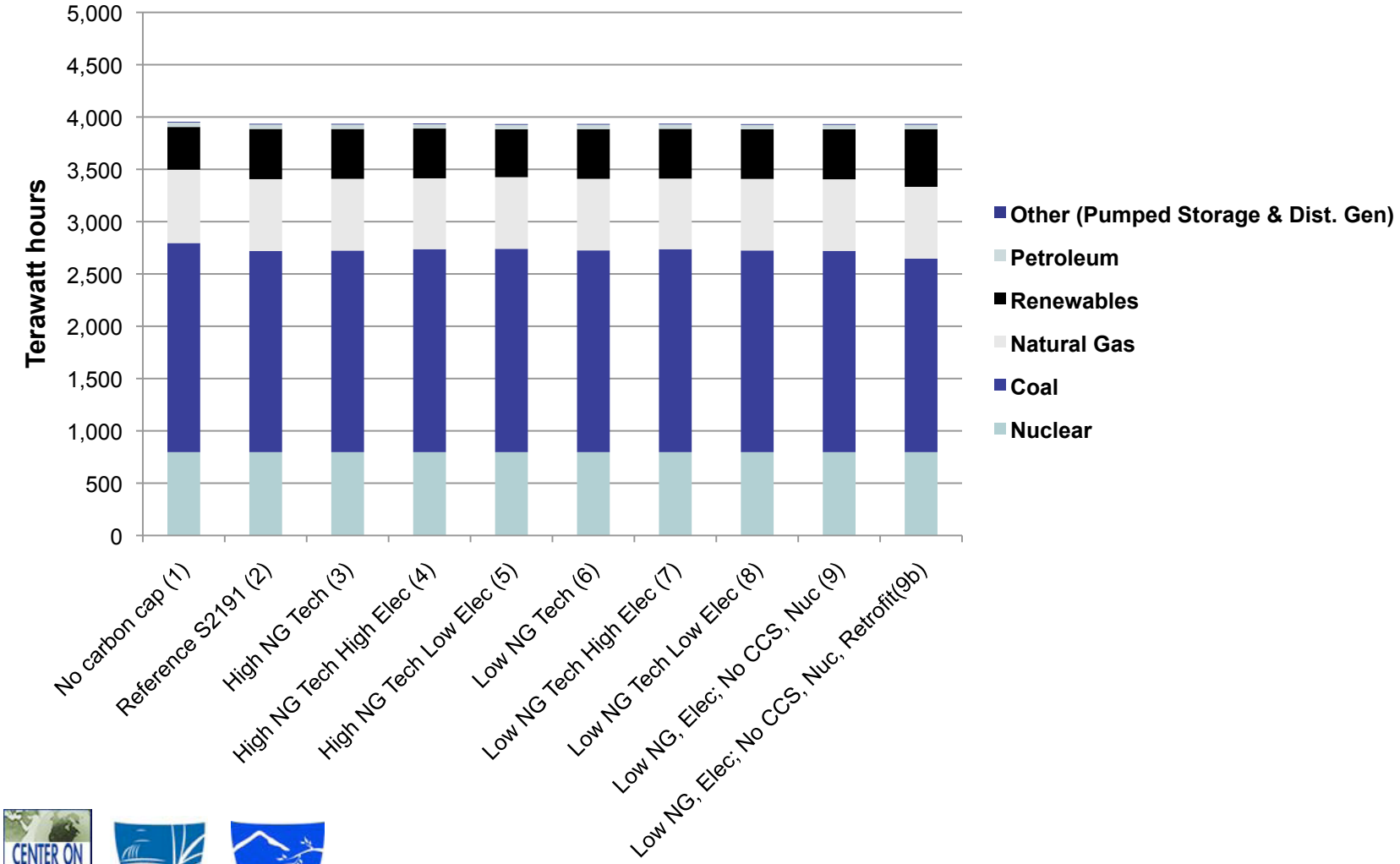
Comparison of EIA and CCPP Overnight Construction Costs

Overnight Cost $ 2006/kW Generation Capacity

	EIA AEO 2008 ($ 2006)	CCPP 2008 ($ 2006)	Percent Increase
Scrubbed Coal	1,534	2,178	42%
IGCC	1,773	2,525	42%
IGCC w/ CCS	2,537	3,332	31%
Adv Gas/Oil Comb Cycle (CC)	706	1,048	48%
Adv CC w/CCS	1,409	1,854	32%
Adv Combustion turbine	473	794	68%
Advanced Nuclear	2,475	4,928	99%
Biomass	2,809	2,872	2%
Conventional Hydropower	1,551	1,586	2%
Wind	1,434	1,776	24%

CCPP NI-NEMS Modeling Process

- Conduct literature review
- Review EIA's assumptions for AEO 2008
- Adjust NEMS inputs and assumptions
- Create 10 scenarios that cover a range of technology pathways for natural gas extraction and for electricity generation
- Run model and analyze results

Electricity Generation by Source 2010 (TWh)