



MJB&A

Electric Sector Modeling – Summary of Results

October 2019

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Important

Results presented here are based on FACETS model runs of the U.S. electric sector.[1] All policy specifications, inputs, and assumptions were developed by MJB&A at the direction and on behalf of Environmental Defense Fund (EDF), with feedback from participating stakeholder companies.

For questions or comments about this report, please contact:

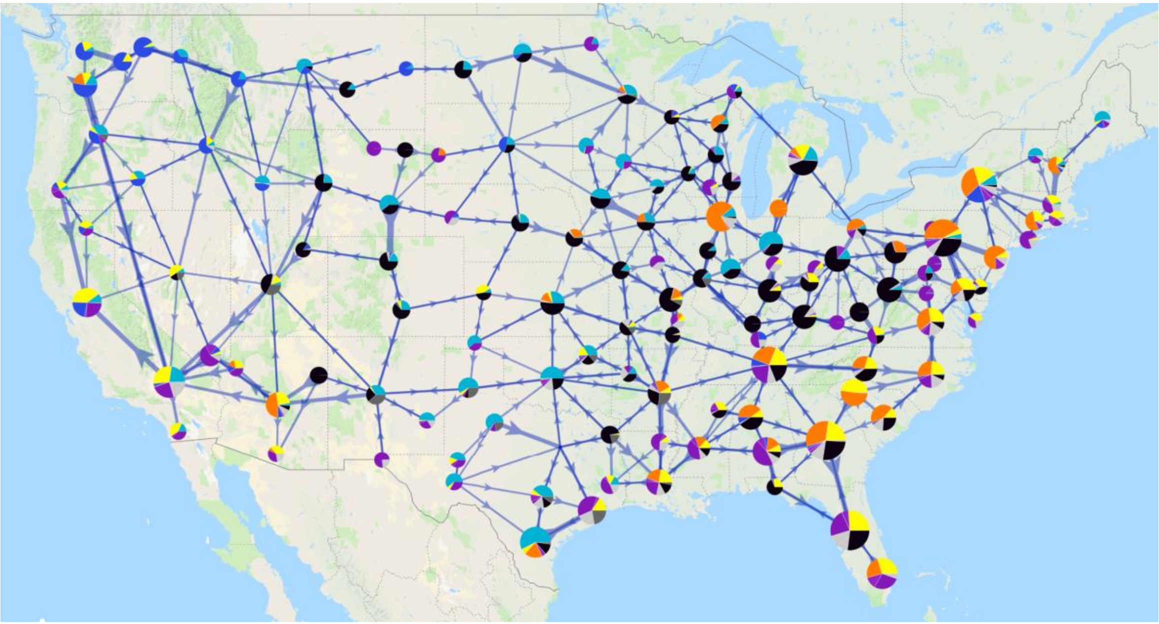
Rama Zakaria
Environmental Defense Fund
1875 Connecticut Ave NW, Ste 600
Washington, DC 20009
Telephone: +1 (202) 387-3500
Email: rzakaria@edf.org

[1]For more information about the FACETS model, please visit www.facets-model.com

Background and Overview

The Framework for Analysis of Climate-Energy-Technology Systems (FACETS) Model

- FACETS is a linear multi-region US energy system model, built in the TIMES bottom-up multi-sector framework
- FACETS integrates federal, regional and state policies, and produces results at the state level. It finds a cost-effective configuration of the US energy system under these assumptions
- More information about FACETS is available at http://facets-model.com

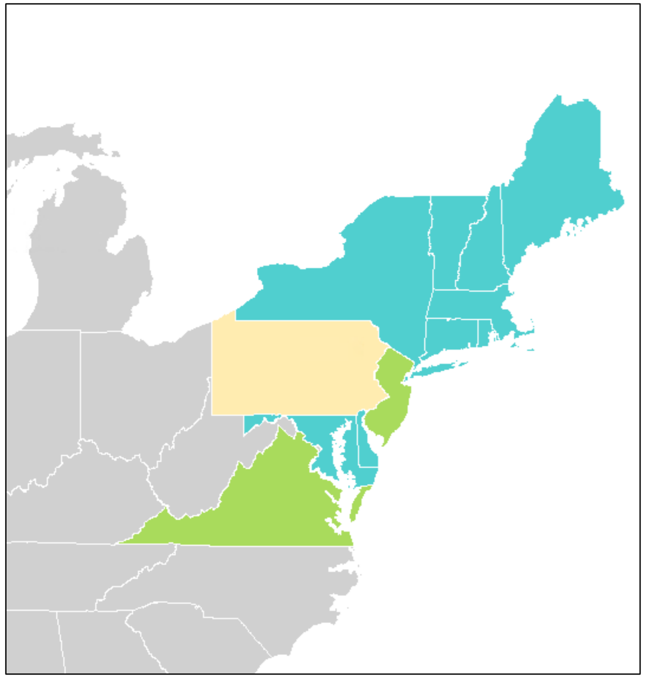


Power sector at the EGU level in 134 regions
Demands at the state or county level

Modeled scenarios and geographic scope

PARAMETER	VARIATIONS
Geographic Scope	• Existing RGGI states (9) • New Jersey • Virginia • Pennsylvania
Emission Budget/Cap Level	• RGGI/RGGI-like trajectory (extended beyond 2030) • Deep Decarbonization
Trading of Allowances	• Unlimited trading within capped region • In-state only trading in certain states
Leakage Mitigation	• No leakage mitigation • Applied to entire capped area • Applied to selected states only
ZEC Payment	• ZEC payments to all nuclear plants in New Jersey and New York • No ZEC payments

40+ scenarios



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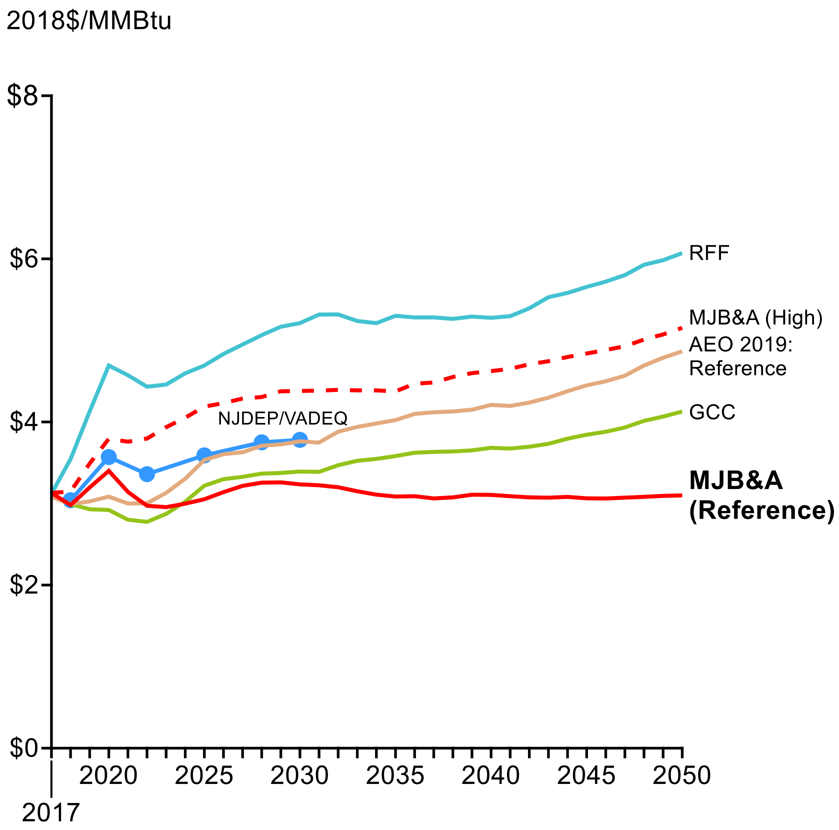
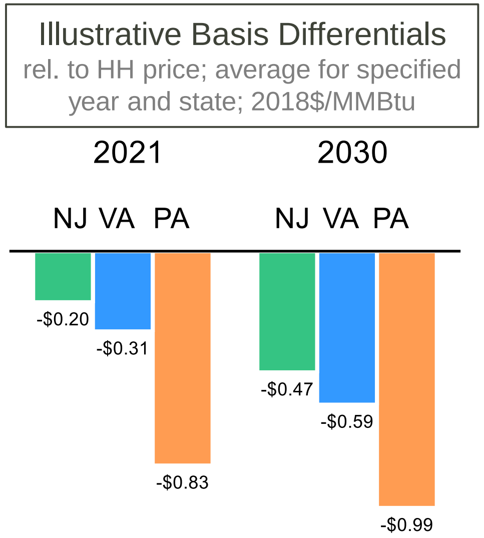
Natural gas price assumptions

- This analysis uses AEO 2018 High Resource gas price as the reference gas price
  - The Henry Hub reference prices are further adjusted with regional basis differentials; differentials are negative in some Marcellus region zones
- Other recent electric sector analyses have assumed relatively higher gas prices (see chart)
- Electric sector projections are generally highly sensitive to gas prices
- Lower gas prices tend to drive wholesale electricity prices down, increase gas-fired generation, reduce profitability of coal and nuclear plants, and result in higher BAU emission projections, all else equal

Henry Hub (HH) Spot Price





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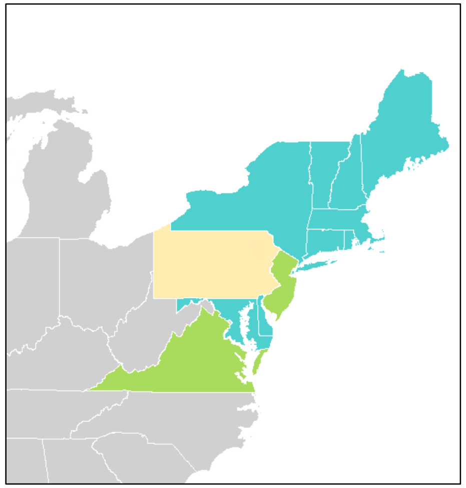
Leakage mitigation mechanism: Imports count toward importing state's cap at exporting state's average emission rate

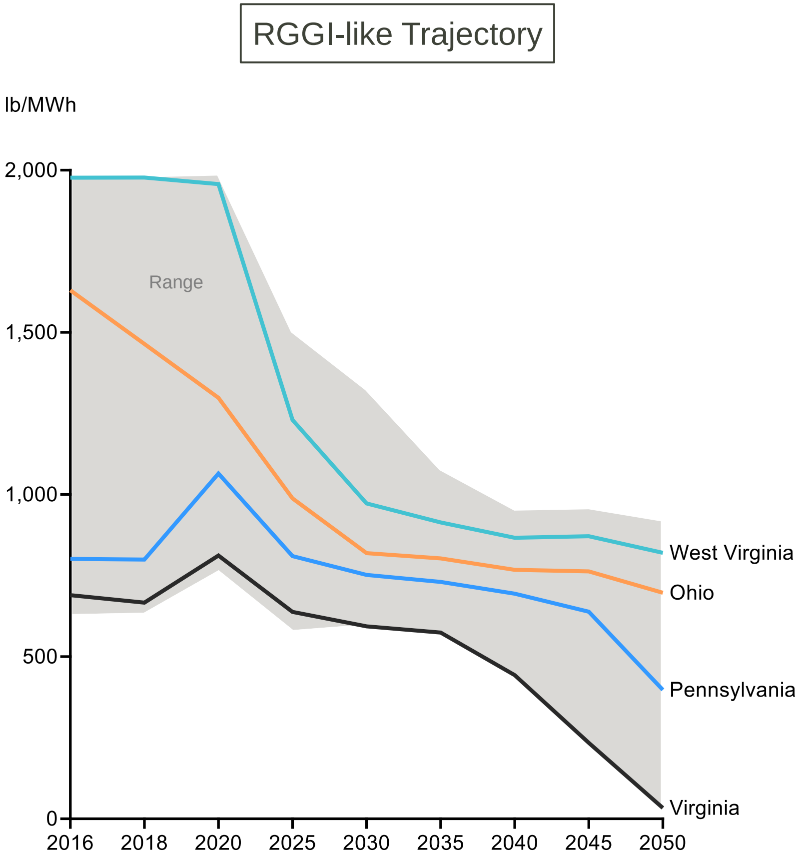
Depending on the scenario, leakage mitigation is either enforced on the entire capped region or on a specific state within the capped region

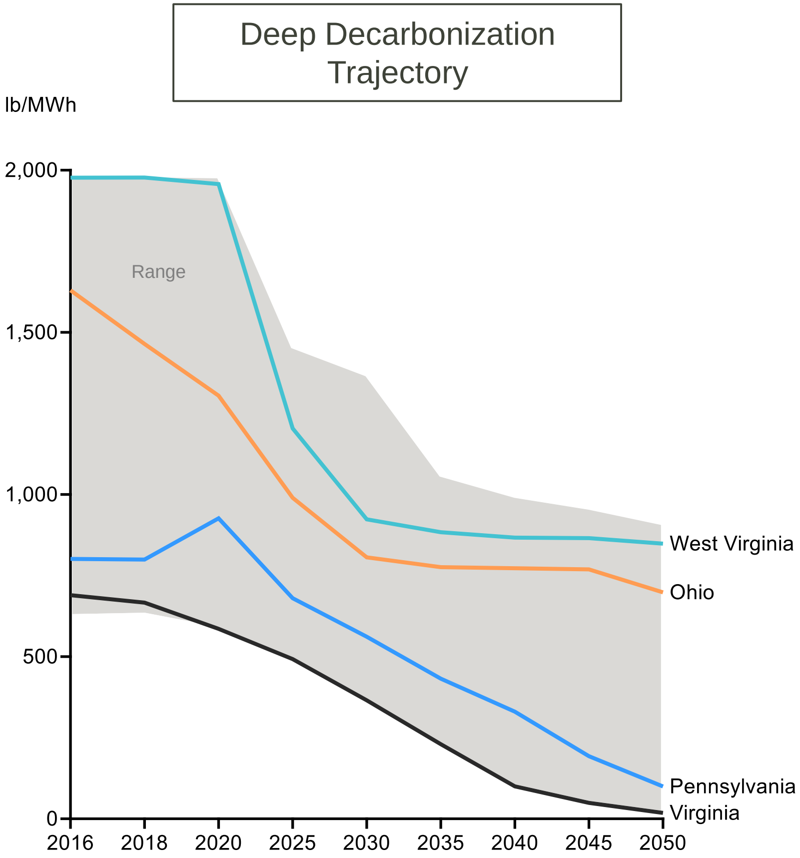
Imports from outside the leakage mitigation enforced area are tagged with emission rates of the exporting state based on modeled emission rate trajectories under the two main cap trajectories through 2050: a) RGGI-like (RGGI extended through 2050); and b) Deep Decarbonization (see adjacent charts)

Import-related emissions are added to the total emissions of leakage mitigation enforced areas and are subject to the applicable emission cap



Average Emission Rate of Exports





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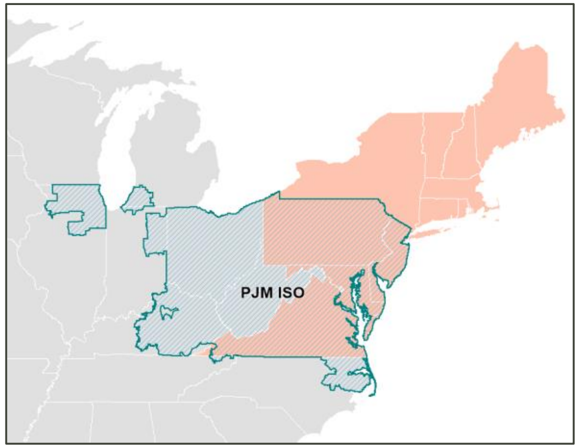
Leakage mitigation mechanism: Illustrative Implementation Strategy

Who	What	How

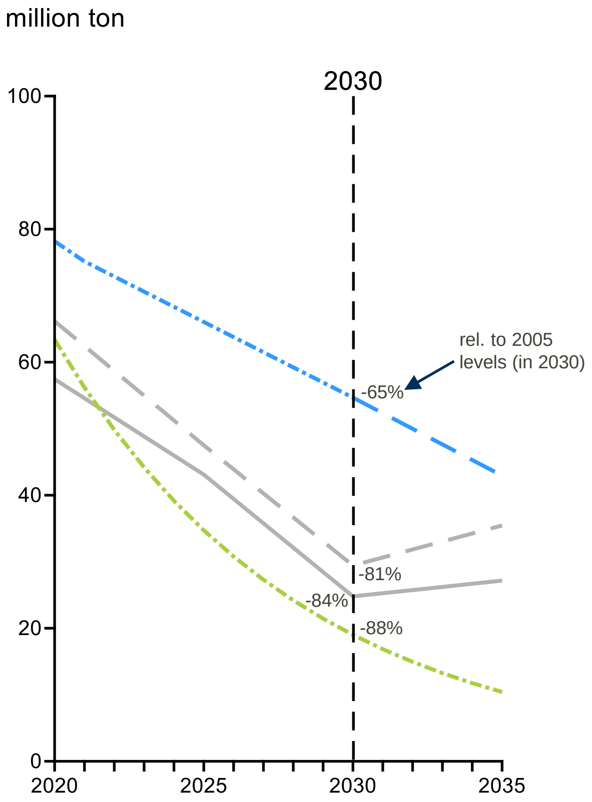
Individual states	Compliance obligation framework	• Implement regulations in capped state to include compliance obligation for emissions associated with in-state generation and imports
		    • In-state generators would continue to have compliance obligation (allowance holding requirement) for emissions associated with their generation—as currently exists in RGGI model rule
		    • In-state load serving entities (LSEs) could have compliance obligation (allowance holding requirement) for emissions associated with imports from any uncapped state

PJM	Enhance technical capabilities to support state policy choices	• Provide states with the information they would need to put emissions associated with imports under the cap (i.e., information associated with out-of-state generation used to serve load in capped state) • Put in place frameworks needed to align dispatch with LSEs compliance obligations • E.g., two-part bid structure where out-of-state generators being dispatched to serve load in the capped state would reflect LSEs compliance costs for imports

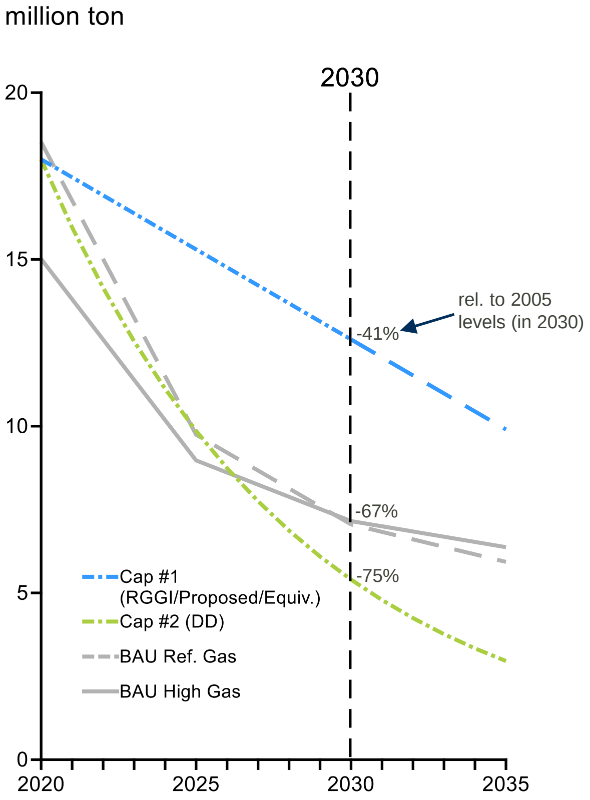


Modeled state budgets: RGGI-like (~30% below 2020 in 2030) and Deep Decarbonization (~70% below 2020 in 2030)

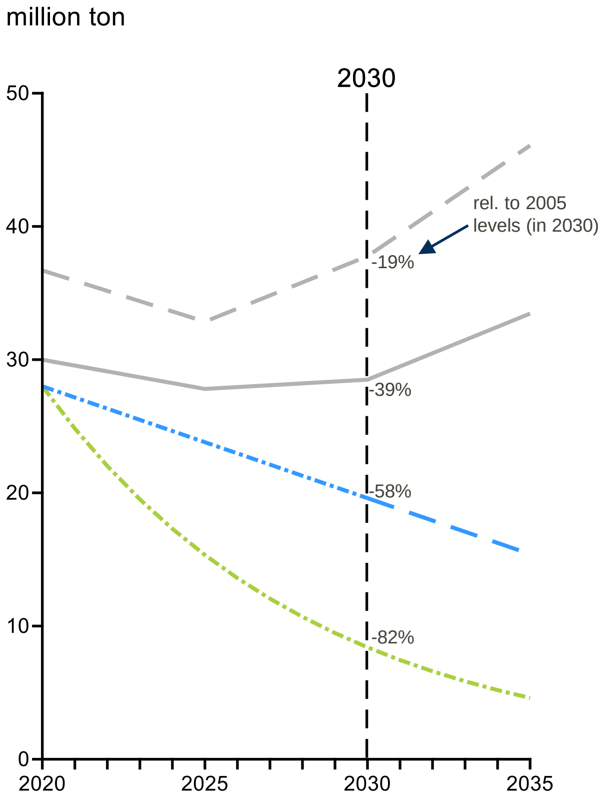
RGGI (9 States)



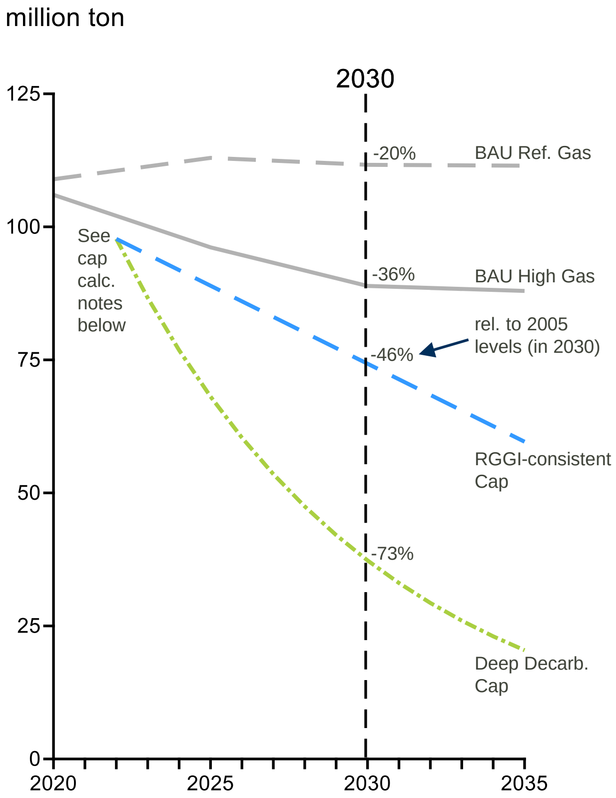
New Jersey



Virginia



Pennsylvania



Notes:

1. BAU reflects emissions from all in-state EGUs including those not covered under RGGI (i.e., those under 25 MW of capacity)
2. RGGI-consistent cap calculation for PA generally follows the methodology used by the states of NJ and VA—i.e., cap starts at projected BAU for the year in which cap goes into effect and declines each year thereafter by 3% of the starting year cap level. As such, starting year cap levels and subsequent trajectories calculated using this methodology are highly dependent on BAU assumptions including natural gas prices
3. This modeling was not designed to explore the level at which PA's CO_2 cap should be set in 2022, but rather to explore power flows and leakage dynamics in the 12-state region

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Key Results – Overview

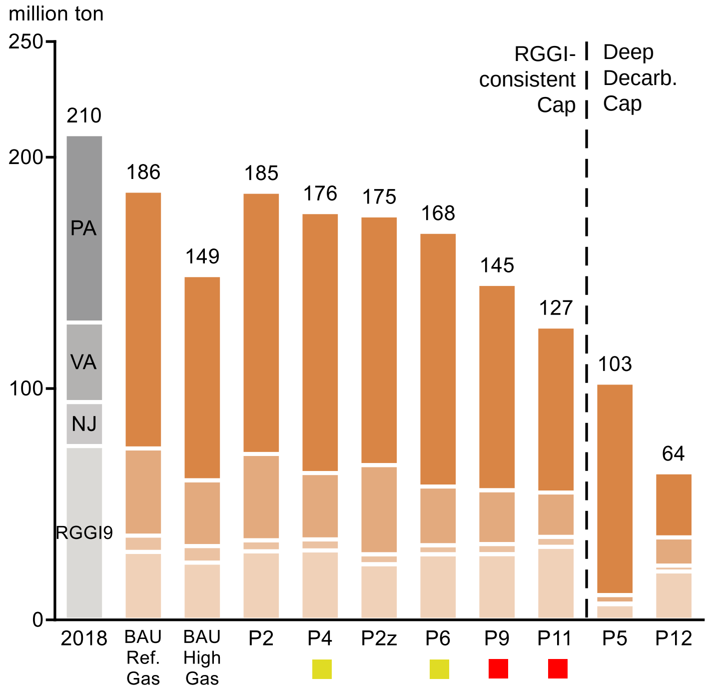
Summary results: Key outputs

CO_2 emissions in the 12-state region decline by up to 70% in 2030 (rel. to 2018) depending on extent of capped area, cap trajectory, and implementation of leakage mitigation measures

Nuclear and gas-fired generation output levels are highly sensitive to gas price assumptions, geographic extent of capped area, cap trajectory, and leakage mitigation measures; coal output declines in all scenarios

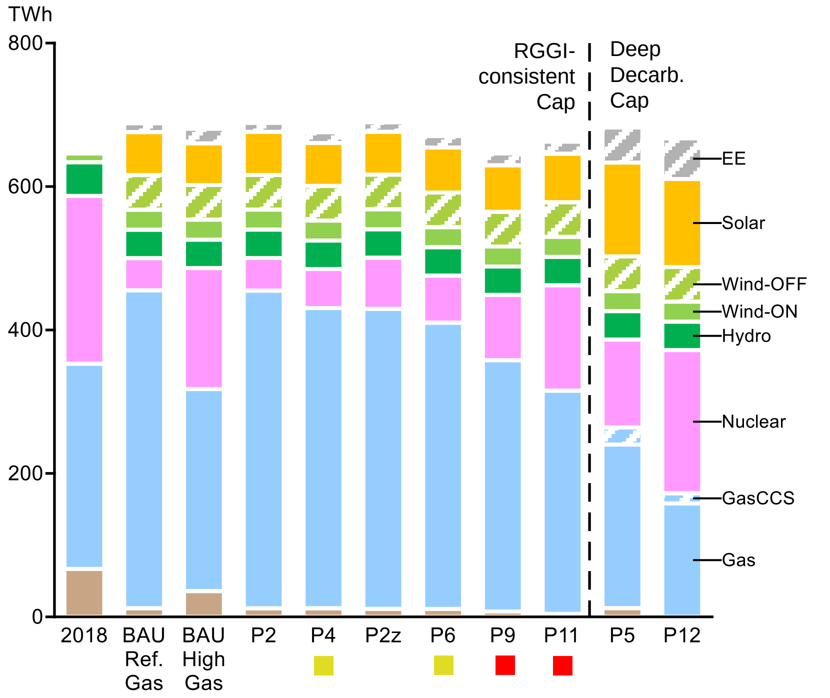
Allowance prices remain under $5/ton through 2030 under most RGGI-consistent trajectories; leakage mitigation and more stringent emission trajectories tend to increase allowance prices

CO_2 Emission - 2030



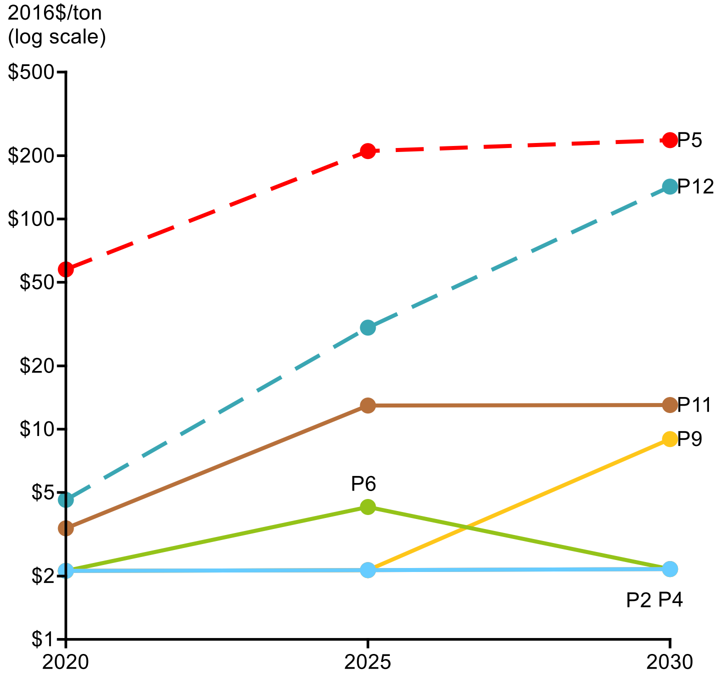
All scenarios result in positive emission reduction benefits (net of any estimated potential leakage); see slide 16 for more details

Generation by Fuel Type - 2030



Code	Scenario
P2	RGGI9+NJ; no LM; RGGI cap
P4	RGGI9+NJ+VA; no LM; RGGI cap
P6	RGGI9+NJ+VA; with LM (NJ only); RGGI cap
P9	RGGI9+NJ+VA+PA; no LM; RGGI cap
P11	RGGI9+NJ+VA+PA; with LM; RGGI cap
P5	RGGI9+NJ+VA; with LM; DD cap #1
P12	RGGI9+NJ+VA+PA; with LM; DD cap #1
+z	+ZEC Payments (NY, NJ)

Allowance Price 2020-30



Higher allowance prices may not necessarily imply higher total electric system costs due to fewer existing nuclear fleet retirements

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Electricity flows depend on states included in capped area, leakage mitigation, and ZEC payments

- Imports from PA into NJ increase when NJ is brought under the cap and there is no leakage mitigation

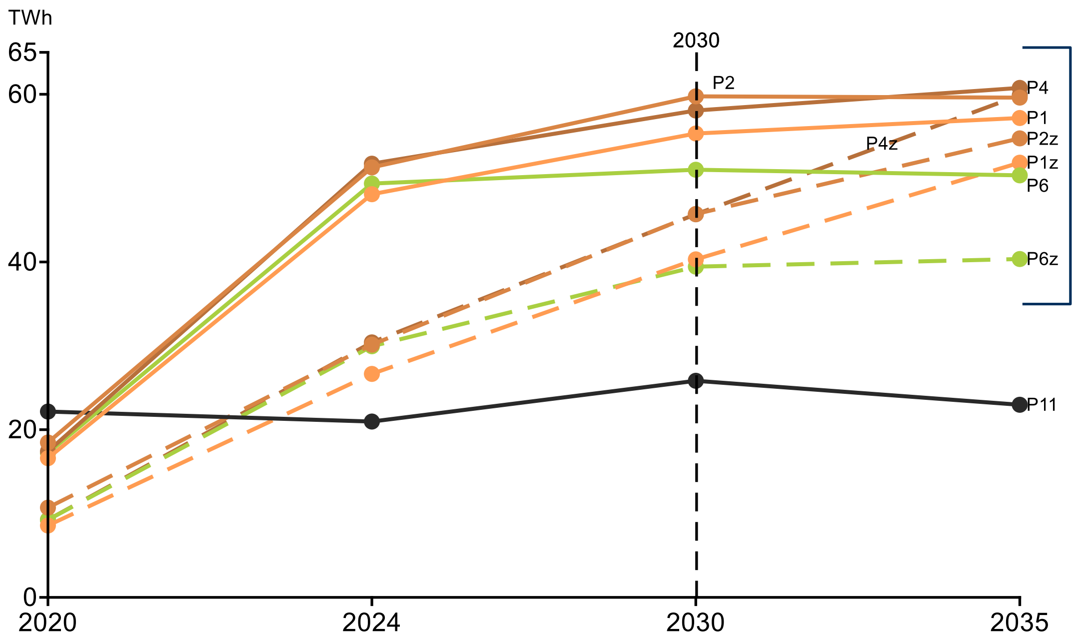
- Adding leakage mitigation reduces imports from PA into NJ

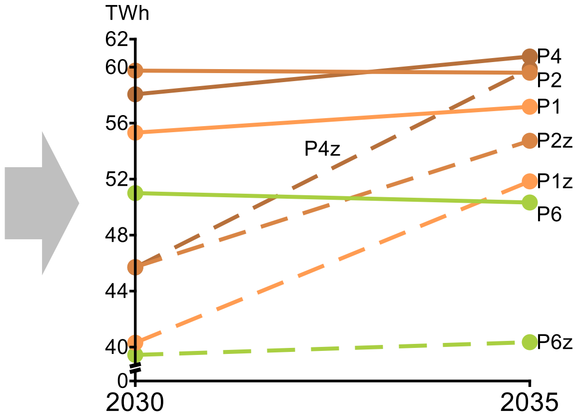
- Imports from PA into NJ under leakage mitigation measures decline regardless of whether or not NJ's nuclear fleet receives ZEC payments

- Including PA under the cap and implementing leakage mitigation on the entire enlarged capped area results in even lower imports from PA into NJ

Illustrative Example: New Jersey

Est. Imports from PA into NJ





Code	Scenario
P1	RGGI9; no LM; RGGI cap
P2	RGGI9+NJ; no LM; RGGI cap
P4	RGGI9+NJ+VA; no LM; RGGI cap
P6	RGGI9+NJ+VA; with LM (NJ only); RGGI cap
P11	RGGI9+NJ+VA+PA; with LM; RGGI cap
+z	+ZEC Payments (NY, NJ)

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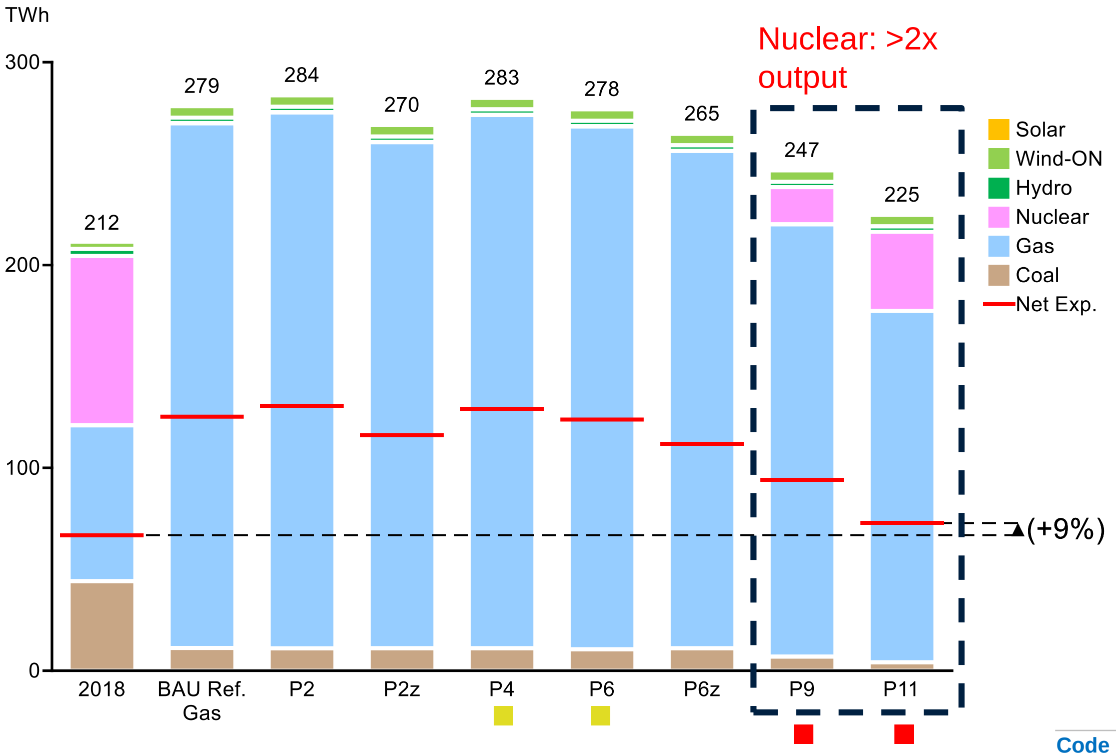
Linking with RGGI helps achieve states' environmental objectives and supports existing nuclear fleet; leakage mitigation increases these benefits significantly and reduces need for out-of-market payments

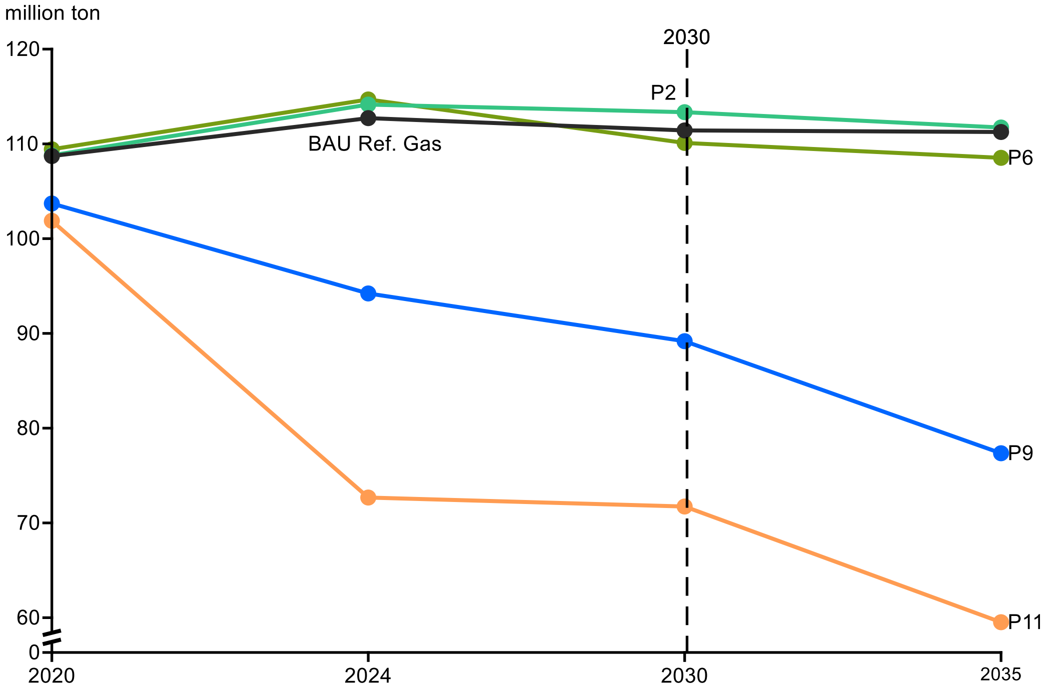
Illustrative Example: Pennsylvania

In-state Generation Mix and Est. Exports
2030



In 2030, total output from PA's existing NGCC units remain largely unchanged from their actual 2018 levels when PA is included under a RGGI-like cap; implementing leakage mitigation tends to increase their output levels slightly

CO_2 Emission
Pennsylvania



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Notes:

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2. RGGI-consistent cap calculation for PA generally follows the methodology used by the states of NJ and VA—i.e., cap starts at projected BAU for the year in which cap goes into effect and declines each year thereafter by 3% of the starting year cap level. As such, starting year cap levels and subsequent trajectories calculated using this methodology are highly dependent on BAU assumptions including natural gas prices
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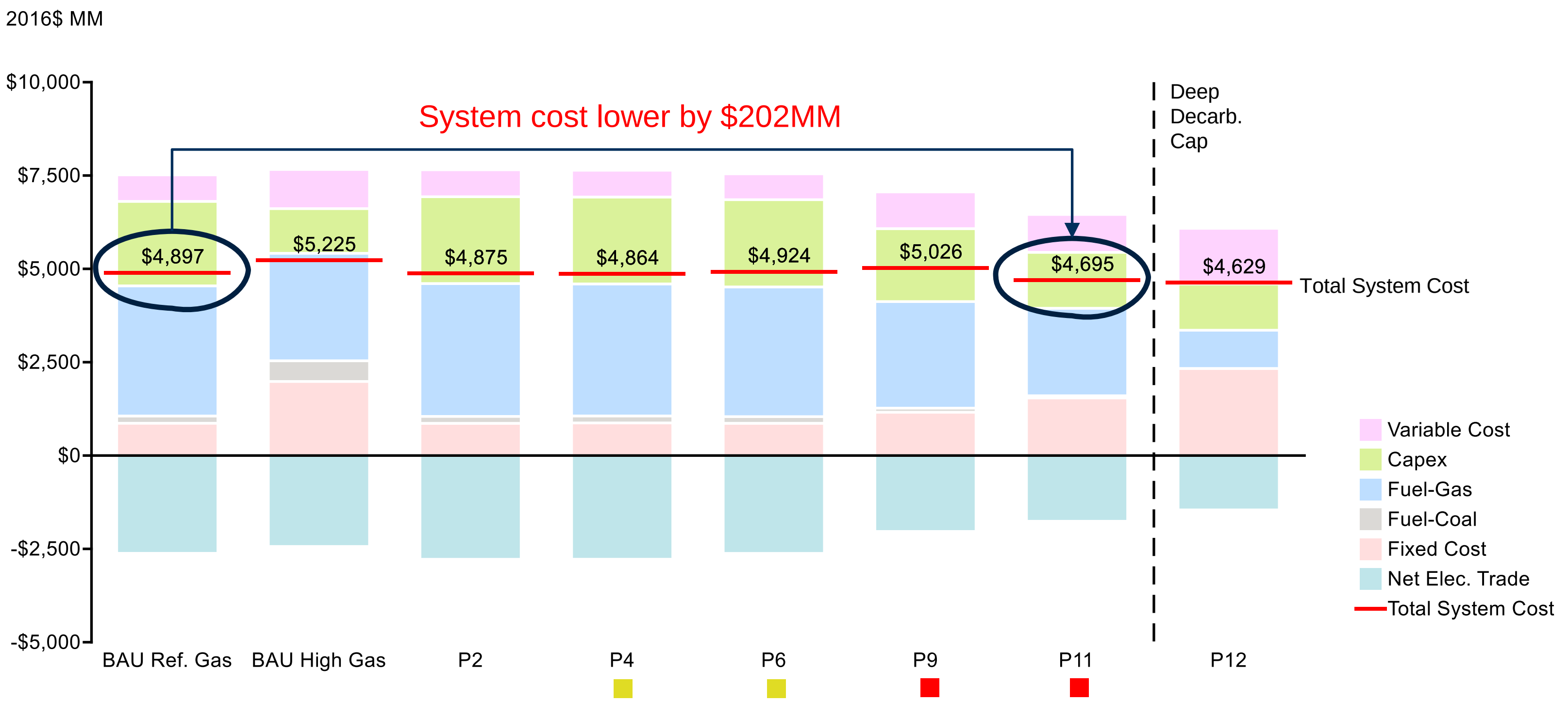
Leakage mitigation and more ambitious emission caps result in lower overall system costs in Pennsylvania

- A RGGI-consistent cap with leakage mitigation produces net savings (~$200MM lower than BAU; ~$331MM lower than capped scenario without leakage mitigation)
- More stringent cap results in even lower total system costs
- Costs are lower mainly due to reduced new build capex and declining fossil fuel costs, both driven by more of the existing nuclear fleet remaining in operation
- This modeling did not consider the spending of allowance revenues, which could determine how different electric sector stakeholders are affected by system cost changes

System Cost Components

Pennsylvania (2030)



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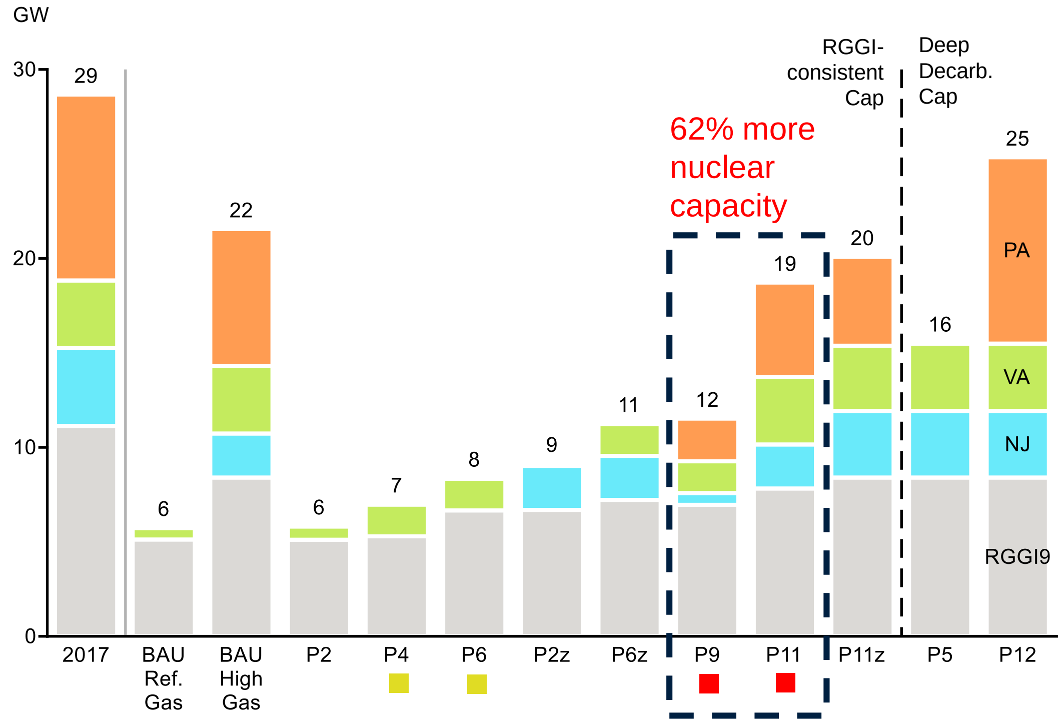
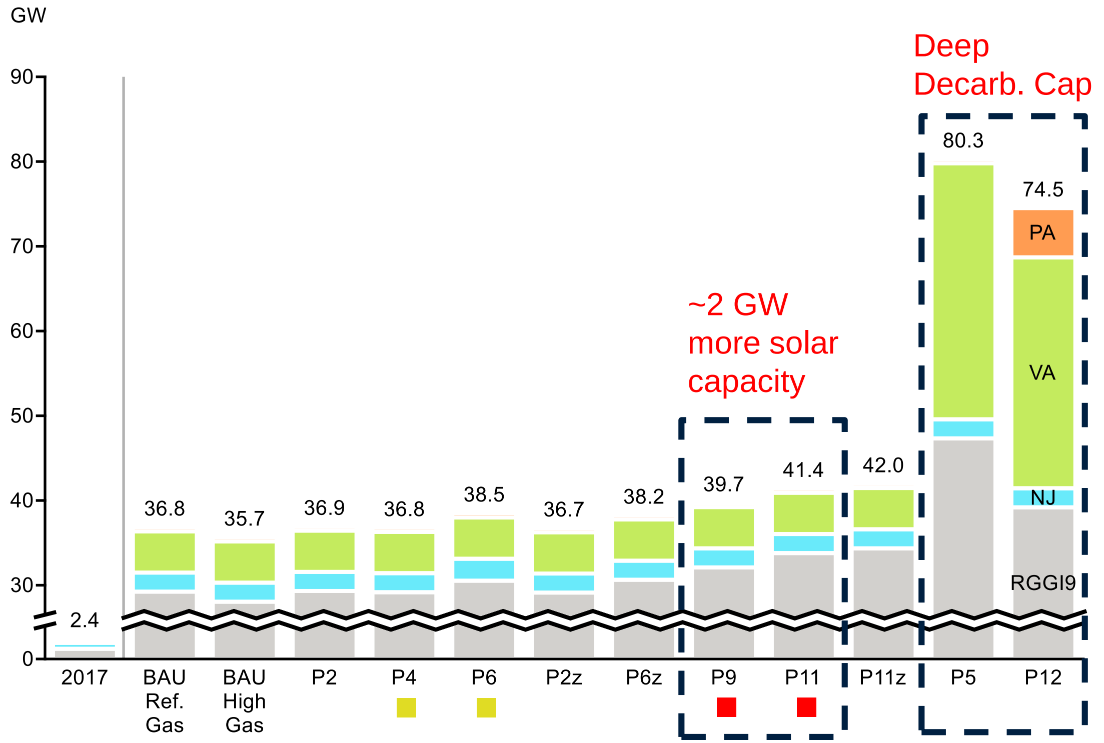
Effective leakage mitigation and more ambitious emission caps (in line with deep decarbonization trajectories) provide benefits for the existing nuclear fleet and support solar new builds





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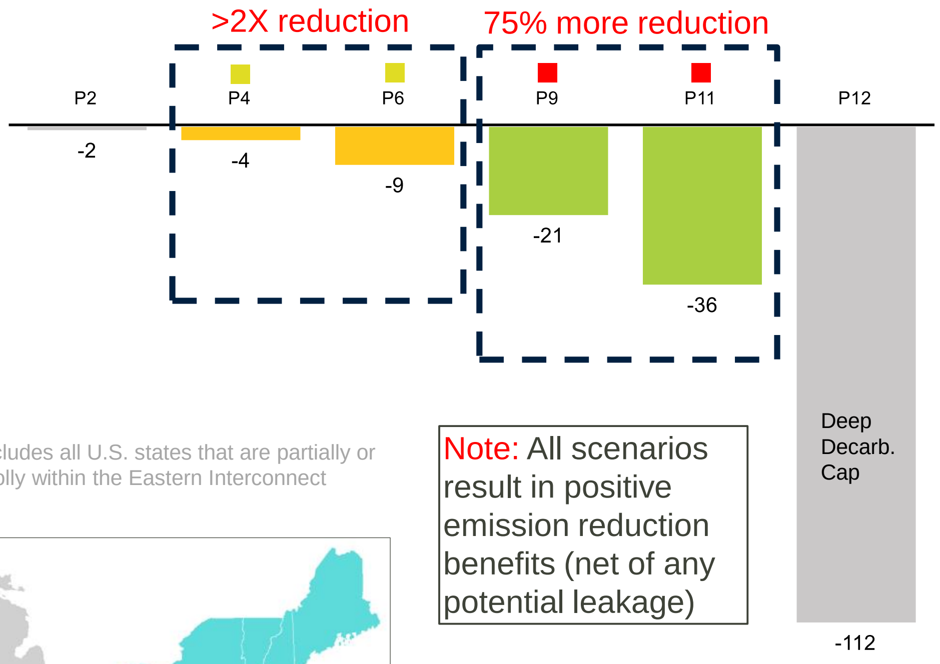
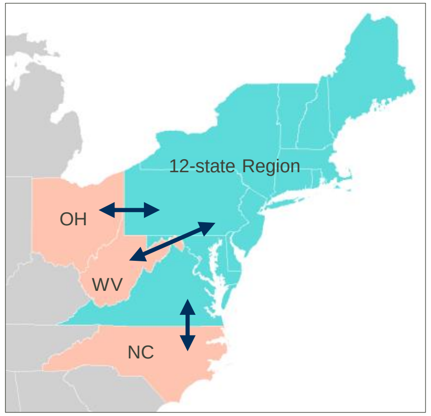
Effective leakage mitigation results in lower overall emissions; larger “leakage mitigated” areas produce greater reductions

Eastern Interconnect*: Reduction in CO_2 Emission Rel. to BAU
(million ton in 2030)



*includes all U.S. states that are partially or wholly within the Eastern Interconnect



Note: All scenarios result in positive emission reduction benefits (net of any potential leakage)

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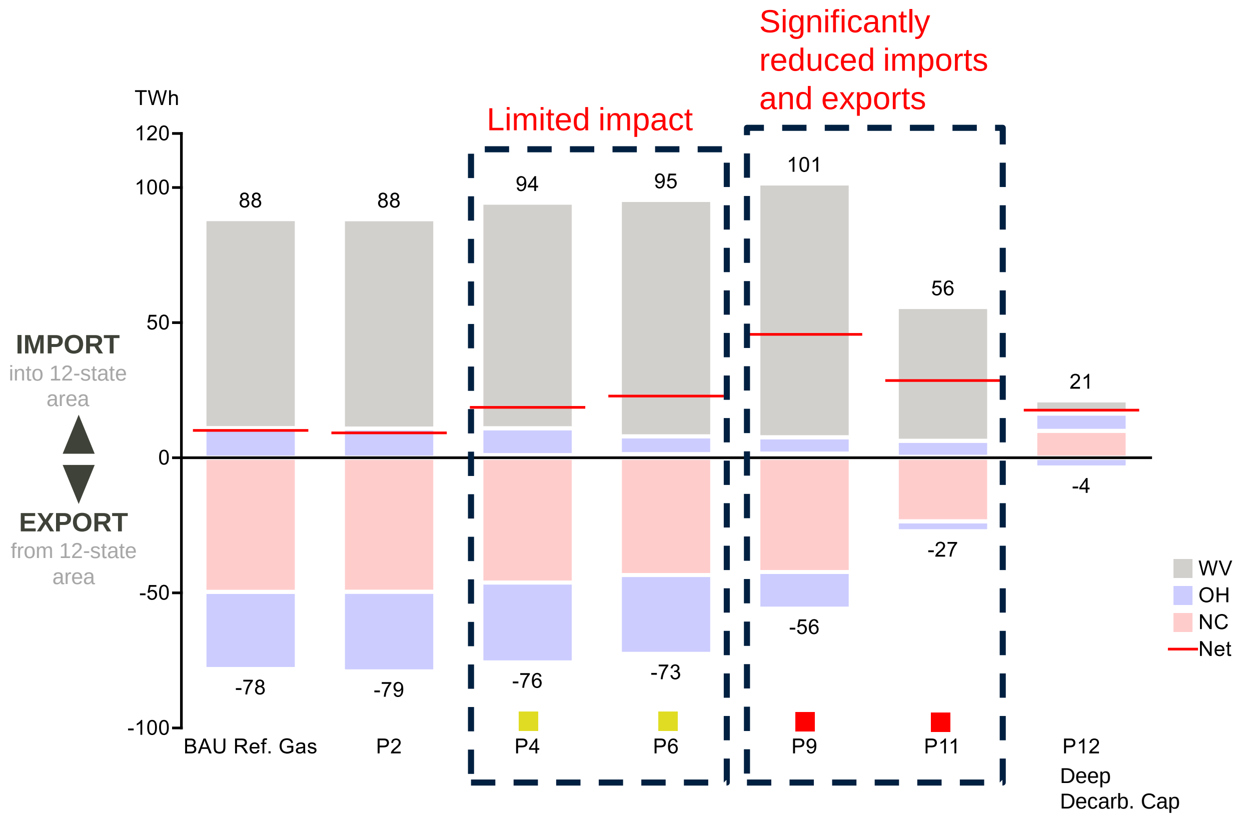
Twelve-State Region Electricity Import and Export
(2030)



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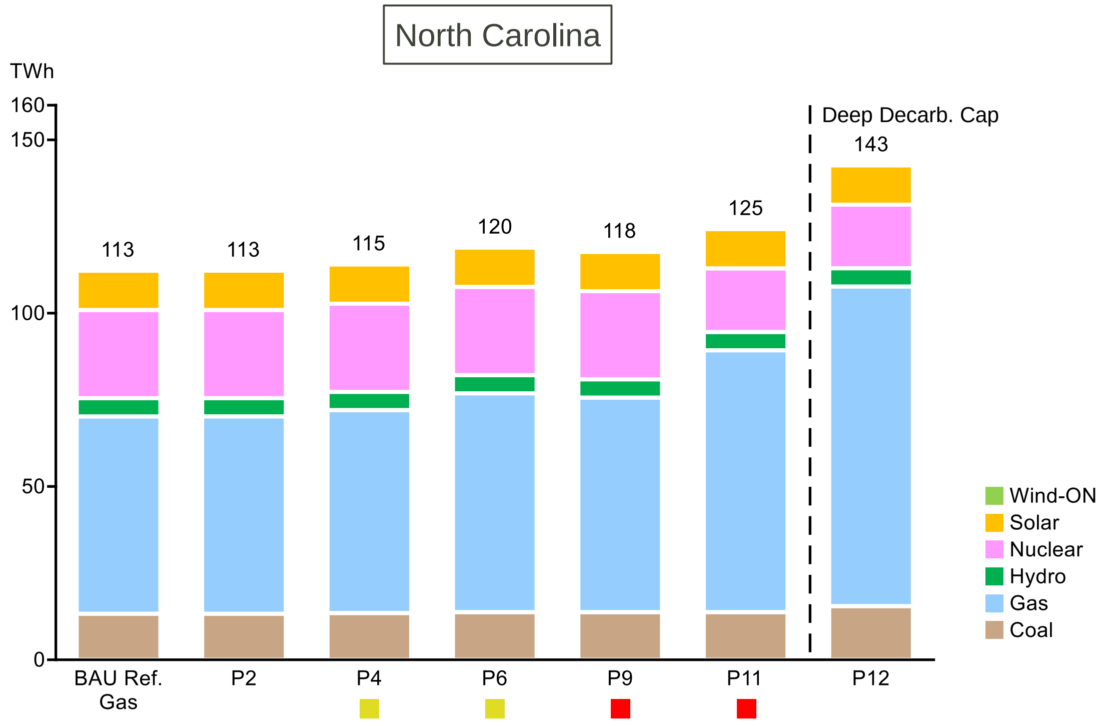
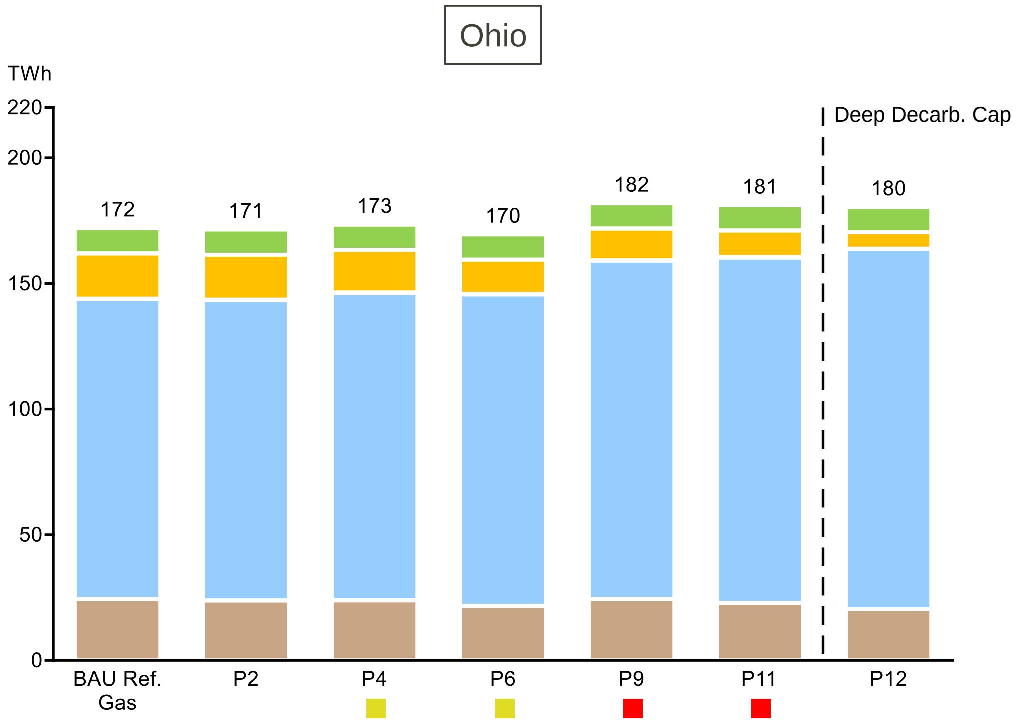
All scenarios result in positive net emission reduction benefits; however, lower exports from capped to uncapped states, if replaced with fossil, may reduce magnitude of overall emission reduction

Generation Mix in 2030





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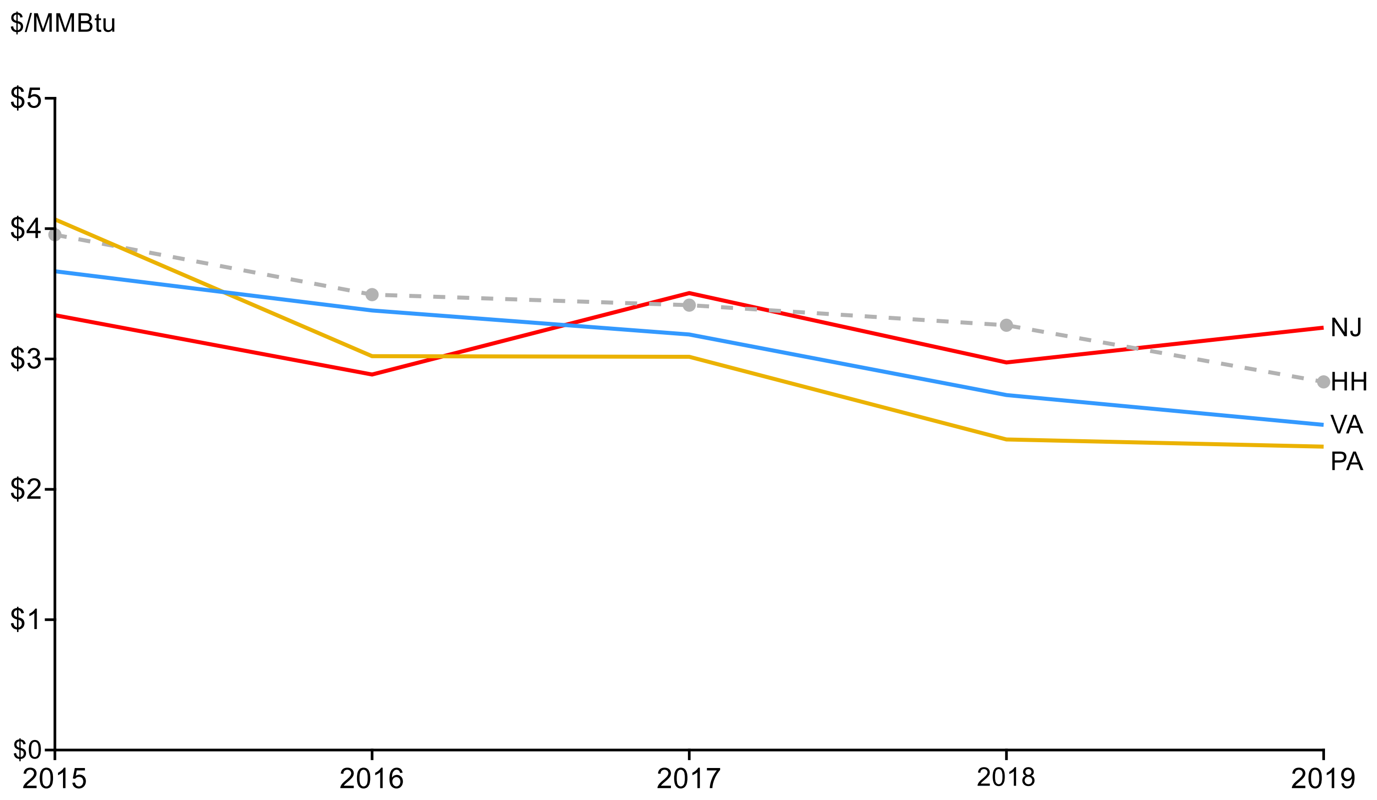
Appendices

Historic Natural Gas Prices

Historic Natural Gas Prices at Select Commodity Pricing Locations*

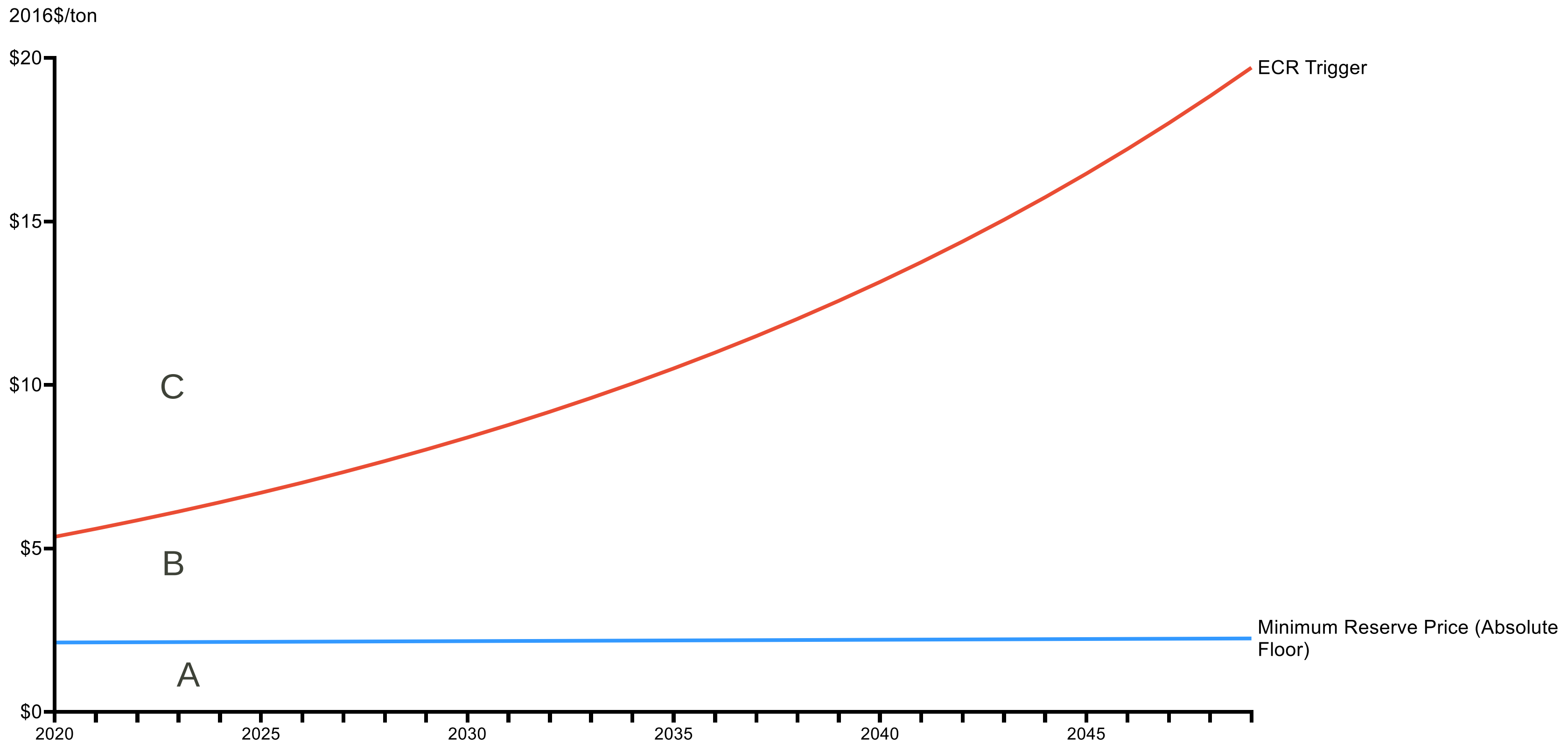


*Commodity Price Points

NJ	Texas Eastern Zone M 3 (TETCO)
HH	Henry Hub
VA	Columbia Gas Transmission Corp Appalachia (TCO)
PA	Dominion Transmission Inc Appalachia (border of WV and PA)

Source: MJB&A Analysis and ABB Velocity

ECR and Absolute Floor



M.J. Bradley & Associates, LLC

Concord, MA

Headquarters

47 Junction Square Drive
Concord, MA 01742
USA

T: +1 978 369 5533
F: +1 978 369 7712

Washington, DC

1225 Eye Street, NW, Suite 200
Washington, DC 20005
USA

T: +1 202 525 5770
F: +1 202 315 3402

For more information, visit www.mjbradley.com