Emissions Sensitivities and Incentives to Generation under Clean Power Plan Compliance Pathways: An Analysis in FACETS

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Introduction and Methodology

A key principle of EPA's Clean Power Plan (CPP) design process has been to provide states with maximum flexibility to design implementation approaches consistent with state priorities and policies. In the final rule, EPA provided states with four alternative compliance pathways – two "rate-based" and two "mass-based" approaches – along with the opportunity to use complementary state measures to achieve their goals.

The four pathways can be expected to have different impacts in different states, depending on conditions including state resource mix, gas prices, load growth and energy efficiency levels, and the choices of other states. In this paper we explore the impacts of each pathway at the state and national levels, identifying the sensitivities of each pathway to several of these these factors.

We used the Framework for Analysis of Climate-Energy-Technology Systems (FACETS) energy systems model to analyze a wide variety of CPP implementation scenarios. FACETS contains a unit-level depiction of the US electricity system, with detailed emissions and emissions control technology modeling and the ability to impose CPP policies directly at the state level.

The results presented here are not intended to be predictions of the future. Instead, modeling studies like this one serve to illuminate key relationships within the energy system, identify the incentives that policy designs create, and explore the key factors to which outcomes can be expected to be sensitive.

Accordingly, the FACETS modeling approach employs many more runs than has been typical in energy modeling studies, to systematically explore the policy design space and identify which findings are robust to uncertainty and which are quite sensitive to it. We use an automated scenario matrix generator to parametrically combine key policy and uncertainty dimensions, run multiple scenarios in parallel on cloud servers, and analyze the results using sophisticated data visualization tools.

In total, 106 scenarios are presented in this paper, exploring CPP compliance design variations, levels of incentives to renewable and existing gas generators under the various pathways, gas prices, and energy efficiency accomplishment.

Key Findings

- The Clean Power Plan is an achievable and affordable policy. Average net present value costs of emissions reductions range from less than $2 per metric ton up to only $11 per ton in the cases with very high gas prices. Interstate compliance trade and energy efficiency can both help keep costs low.
- The emissions results of the four pathways vary under different scenarios because of the different incentives they create for generation resources. Only the **Mass with New Source Complement** pathway reliably delivers emissions reductions at EPA's benchmark of 32 percent below 2005 levels across all sensitivities and implementations.
- The **Rate** standard pathways are particularly sensitive to natural gas prices, delivering greater reductions when gas prices are low, and less when gas prices are high. Pathways also vary in the extent to which they provide incentives for additions of new renewable and natural gas combined cycle (NGCC) capacity.
- The risk of leakage when a **Mass** cap covers **Existing Sources Only** is significant if the program does not include effective leakage-control measures. Our findings agree with those of several other modeling teams: While EPA outlined a number of useful tools to address leakage in the proposed model trading rules, the specific formulation EPA proposed is unlikely to be sufficient. In particular, the other pathways create greater incentives for new renewable generation than the proposed set-aside provides. Higher levels of incentives, such as from a larger proportion of output-based allowance allocation, are needed to bring outcomes closer in line with those of the other pathways.
- Like other modeling teams, we find that **energy efficiency** (EE) can play a large role in reducing new source leakage, and a combination of EE and allowance allocation methods is more effective than either alone.
- The four pathways also have different impacts in different regions of the country, depending on existing capacity and resource mixes. States with strong renewable potential, under-utilized existing gas capacity, and/or low gas prices may find that they can export low carbon electricity, allowances/emissions rate credits (ERCs), or both. States with more limited compliance options may especially benefit from interstate trade.

The FACETS Model

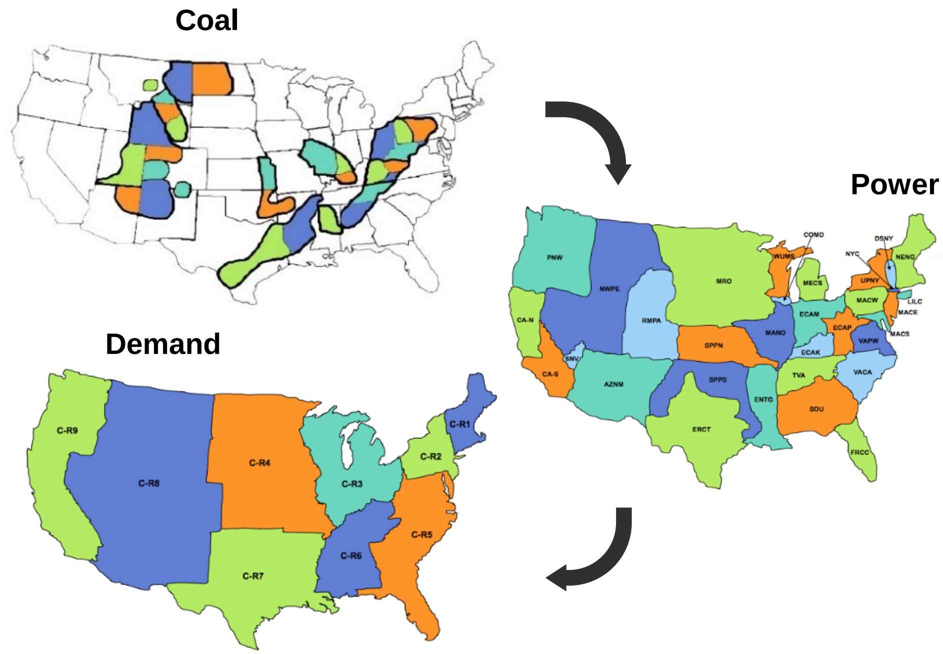
FACETS is a technologically-detailed, multi-region US energy system model. FACETS integrates federal, regional and state policies, and produces results at the state level. The level of geographic and technology detail is fully flexible as analysis needs dictate. The current version models electricity generation in 32 NERC sub-regions and end use demands in the 9 Census divisions. Clean Power Plan budgets are applied at the state level.

FACETS represents 11,000 individual electricity generating units in the continental US. All units except hydro dispatch individually. Coal units can be retrofitted with a combination of SCR, FGD, DSI, and ACI. Units can choose to retire when their going-forward costs are not covered by their generation earnings.

The model solves to find the least cost way of meeting all demands, subject to physical, operating, and policy constraints.

FACETS can be run in two modes: a full sector mode, in which demands for electricity and other fuels are built bottom-up from fuel and device competition to meet end use service demands in buildings, industry, and transport sectors, and a power sector only mode, which models only electricity generating units and their fuel supplies and inter-regional transmission.

For this analysis, the power sector only mode was used, with electricity demands driven by the Annual Energy Outlook 2015 regional loads.



Data for existing units is based on the EPA NEEDS dataset, version 5.15. New power plant cost and performance from AEO 2015, with the exception of wind and solar PV, which come from the NREL 2015 ATB mid case. Full data details are in the Appendix.

Scenarios modeled: Four pathways, three uncertainties, plus OBA variations

Four CPP compliance pathways are modeled:

- **Subcategory** and **state rate** pathways
- A **mass** cap covering **existing units only**. This pathway was modeled with and without mechanisms to inhibit leakage to new sources, as discussed further on the next slides.
- A mass cap covering existing and new units, using EPA's published **new source complement**

Three sensitivity dimensions were tested:

- **Natural gas resource/price**. Here the *high* resource case has *low* gas prices and vice versa.
- State **energy efficiency** program accomplishment. For the EE-Yes sensitivity, the state-level EE estimates used by EPA in the CPP Regulatory Impact Assessment modeling were imposed as exogenous load reductions.
- Interstate CPP compliance **trade**

In all, a total of 106 scenarios are analyzed.

Code	Dimension and Options
T	**T**rade in interstate compliance "credits"
	No: all states individually comply
	X: No CPP
	Yes: full trading within participating states
Sh	**Sh**ale gas supplies
	Reference: Annual Energy Outlook (AEO) 2015 Reference
	High: AEO 2015 High resources (low gas prices)
	Low: AEO 2014 Low resources (high gas prices)
Ee	**E**nergy **e**fficiency
	Yes: EPA RIA state estimates are exogenously imposed load reductions.
	No: No additional EE beyond AEO 2015 levels.
Pt	**P**a**t**hway
	RB: Subcategory rate
	RS: State rate
	MEX: Mass existing only – No leakage mitigation incentives
	ME1: Mass existing only – OBA-simulation level 1 (see next slide)
	ME2: Mass existing only – OBA-simulation level 2 (see next slide)
	MN: Mass with new source complement
	X: No CPP

All of the CPP scenarios modeled here assume that all states choose the same CPP compliance pathway, except those – the Regional Greenhouse Gas Initiative (RGGI) states and California – that have an already established carbon policy covering the power sector. These states are assumed to use the Mass with New Source Complement (Mass+NSC) pathway in all CPP scenarios.

All scenarios include the extension of the production and investment tax credits for some renewable technologies enacted in December 2015.

Scenario Details

No CPP: The No CPP case is based on AEO 2015, with the exception that we follow EPA in retiring nuclear units after their 60-year lifetimes expire. Six No CPP scenarios are modeled, permuting gas resource/price and EE accomplishment. All CPP compliance comparisons (including cost and emissions reductions achieved) are then made from the corresponding No CPP case.

Subcategory rate pathway: This pathway requires that fossil steam units and gas combined cycle (NGCC) units each collectively meet the emissions rate standard published by EPA. Units can comply when their emissions divided by the sum of their generation plus purchased emission rate credits (ERCs) are less than or equal to the subcategory target rate. We have modeled full *intrastate* trading, so that units in each participating state comply collectively within their respective subcategories. Three types of ERCs are modeled:

1. Covered unit ERCs: Within each subcategory, units trade ERCs amongst themselves to achieve compliance in aggregate. Units whose emissions rate is below the rate target earn partial ERCs for each MWh generated in proportion to how far their emissions rate is below the target rate. These can be traded to other units. ERCs may be banked for use in future compliance periods.

2. ERCs from qualifying renewable generation and energy efficiency programs (EERE ERCs) may be sourced from any state participating in the subcategory rate pathway, even in Trade-No scenarios, and may be used in either the fossil steam or NGCC rate constraint.

3. Gas shift ERCs are based on the redispatch from steam to NGCC units. All covered NGCC generation earns gas shift ERCs, according to the following formula:

   *Gas shift ERCs = NGCC unit generation MWh * (1 - NGCC unit emission rate/Steam Standard) * Incremental Generation Factor*

   The incremental generation factor, calculated by EPA, is designed to capture the portion of NGCC generation that is incremental beyond business as usual. It varies over time between 20-30%. Gas shift ERCs may only be used by fossil steam units.

Under Trade-No scenarios, each state's generating fleet complies individually with state-specific constraints, whereas under Trade-Yes scenarios, all participating states comply with region-wide constraints.

State rate pathway: Each state's covered sources are subject to EPA's state rates in each of the interim and final compliance periods. As in the subcategory rate scenarios, EERE ERCs may be sourced from any state participating in the state rate pathway in all such scenarios. In Trade-Yes scenarios, participating states may trade covered unit ERCs by averaging their state rate targets, so that the trading region is complying with a single blended rate constraint.

Mass with new source complement (Mass+NSC) pathway: In this pathway, states comply with mass targets including EPA's published new source complement. For all mass pathways, under Trade-No scenarios, states comply with their goals individually. Under Trade-Yes scenarios, participating states comply collectively, meeting the sum of their individual budgets, with full interstate trading.

Mass existing only (MassExO) pathway: We ran several versions of this pathway, each using EPA's published state goals. We simulated allowance allocation mechanisms to inhibit emissions leakage from increased new source generation through parametric sets of runs directing incentives to existing gas and new renewable generation. These are detailed on the next slide.

Additional scenarios test the response of generation and emissions to allowance allocation strategies designed to reduce new source leakage

Previous modeling by MJ Bradley, Natural Resources Defense Council, and Resources for the Future has showed that, while output based allocation (OBA) strategies can reduce leakage to new sources when a mass cap covers existing units only, the precise recipe set out by EPA in the proposed model rule is unlikely to mitigate the vast majority of new source leakage.

For this analysis, we evaluate the response of existing and new gas and renewable generation to varying levels of generation incentives that could potentially be provided by allowance allocation programs.

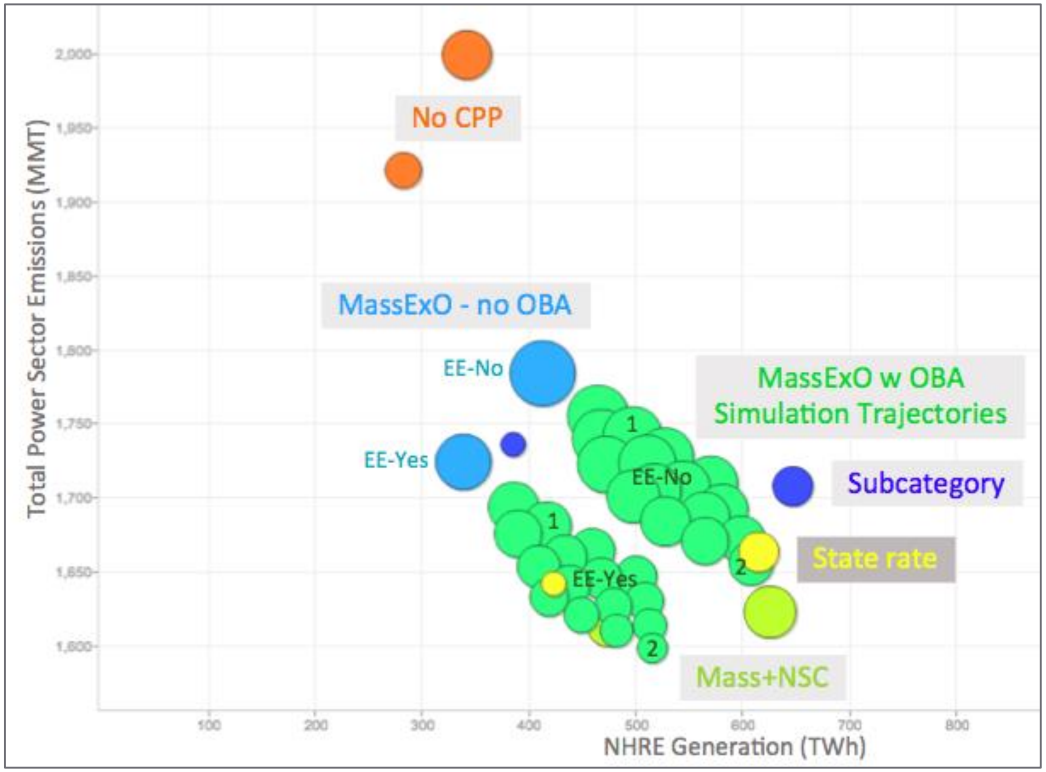
We simulated these incentives by testing four different levels of direct payments to existing gas and new renewable generation. The trajectories simulate the price trajectories of allowance values under banking over time. Incentives to gas and renewable generation were varied separately, yielding 16 trajectories.

The full suite of 16 OBA simulation runs was tested under a limited set of uncertainty dimensions: Reference gas prices and full interstate compliance trade. Both EE-Yes and EE-No versions were tested, for a total of 32 runs. These results are explored on slides 16-18.

From these 16 trajectories, two were selected and included in the full package of sensitivity runs:

- OBA simulation **Level 1** scenarios have incentive levels closest to those estimated in the model rule proposal: trajectory 2 for gas and 1 for renewables.
- OBA simulation **Level 2** scenarios have the highest level of incentive tested: trajectory 4 for both.

	Generation incentive (2011$/MWh)			
Trajectory	2023	2026	2028	2032
1	2.5	2.9	3.2	3.9
2	5	5.8	6.4	7.8
3	7.5	8.7	9.6	11.6
4	10	11.6	12.8	15.5



The pathways achieve a range of emissions reductions, depending on assumptions

No CPP: 2030 emissions without the Clean Power Plan range from 1781 to 1966 million metric tons (MMT), or 18-26% below 2005 levels.

The **Mass with New Source Complement** (Mass+NSC) pathway provides the most consistent levels of abatement, reducing emissions 32% below 2005 levels by 2030 across all uncertainty scenarios.

The **Rate** pathways have a wide range of 2030 emissions. As shown in the next slide, much of the variation is due to sensitivity to gas prices.

The **Mass Existing Only** (MassExO) scenarios do not reach the 32% emissions reduction level unless they are complemented with robust leakage prevention measures. Without such measures, a cap on existing units only creates an incentive to substitute generation from new units for existing gas, creating more "room" under the cap for additional coal generation, and raising emissions.

Simulated **OBA incentives** to new renewable and existing gas generation help reduce emissions leakage. OBA incentive **Level 1**, most similar to the levels in the proposed model rule, reaches the 32% level only when gas prices are high *and* EE is achieved, two factors that reduce new source leakage. OBA incentive **Level 2**, the highest level of support we tested, reaches this level *except* when EE is not achieved *and* gas prices are at low or Reference levels.

	No CPP	State Rate	Subcategory Rate	MassExO No OBA	MassExO OBA Level 1	MassExO OBA Level 2	Mass+NSC
2030 Emissions Range	1781-1966	1546-1701	1560-1780	1646-1816	1624-1769	1567-1697	1602-1625
% Below 2005	18%-26%	29%-36%	26%-35%	24%-31%	26%-32%	29%-35%	32%-33%
% Below 2012	3%-12%	16%-24%	12%-23%	10%-19%	13%-20%	16%-23%	20%-21%

Gas prices and energy efficiency affect the time course of emissions

In the **No CPP** scenarios (and in CPP scenarios in the pre-compliance years), emissions are notably lower under low gas prices through the mid 2020s, as the current redispatch from coal to gas accelerates. Under Reference and high gas prices, we see a slight increase in emissions as more coal is dispatched through 2017, before emissions level out.

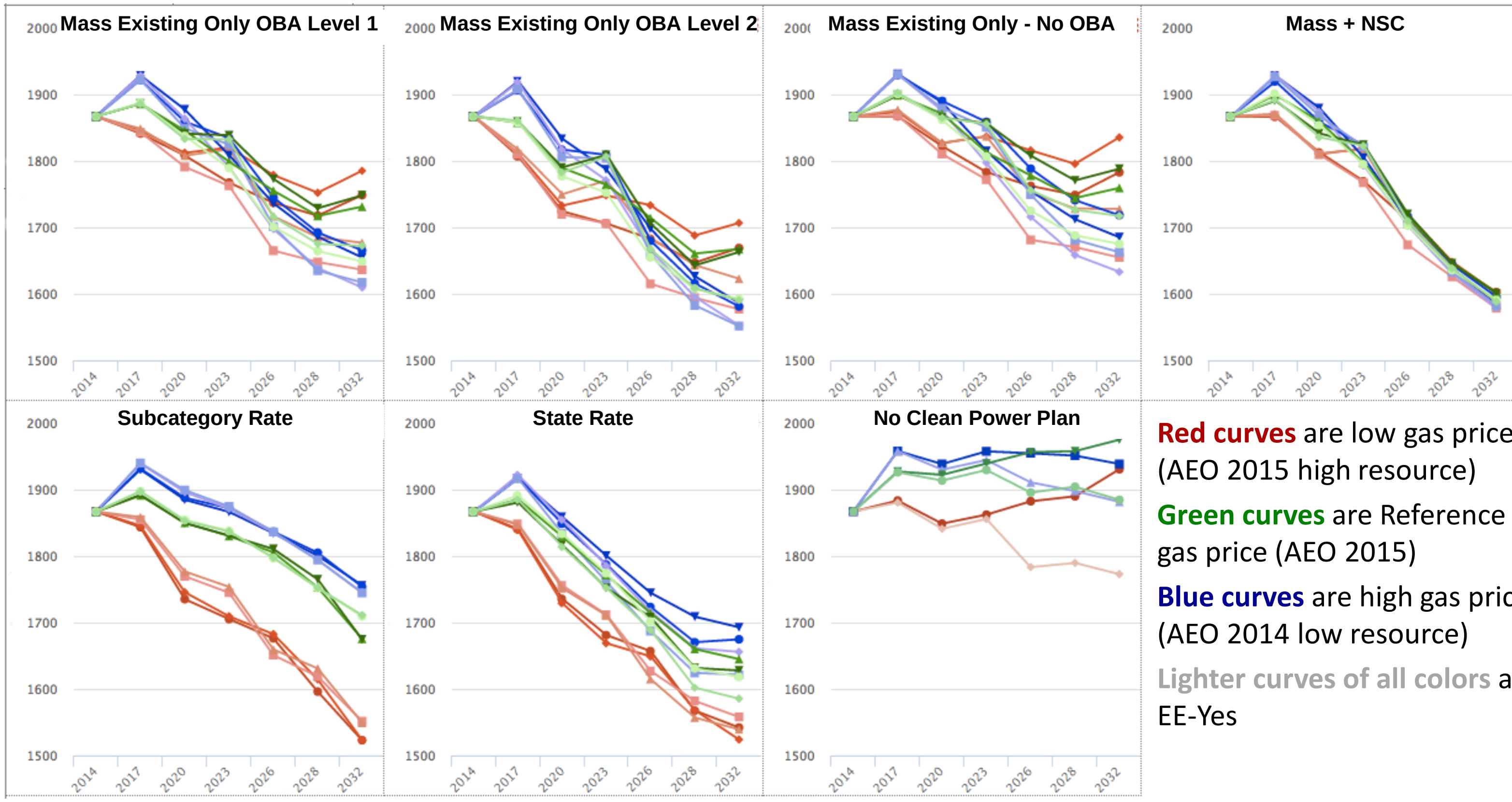
After a similar spread in the early years, the **Mass with New Source Complement** (Mass+NSC) pathway provides very consistent emissions across uncertainty scenarios.

Both **Rate** pathways are highly sensitive to gas prices, with lower emissions when gas prices are low. (This sensitivity may explain much of the variation among other modeling results presented for rate pathways.)

By contrast, low gas prices *increase* emissions under **Mass Existing Only** (MassExO) by improving the cost effectiveness of new gas units, creating a greater incentive to new generation. EE-Yes versions of this pathway have lower emissions than EE-No. Simulated **OBA incentives** to existing gas and renewable generation reduce emissions under this pathway.

In the No CPP scenarios we see a greater emissions impact from energy efficiency accomplishment (a 7% reduction in 2030) when gas prices are low and EE offsets mostly new gas builds.

Emissions reductions are smaller when gas prices are high and EE mostly offsets new renewable generation.



Red curves are low gas price (AEO 2015 high resource)

Green curves are Reference gas price (AEO 2015)

Blue curves are high gas price (AEO 2014 low resource)

Lighter curves of all colors are EE-Yes

The cost of the CPP is modest in all scenarios
Good design can further reduce costs

The average net present value cost of emissions reductions in our CPP runs range

- $1-5/ton when gas prices are low
- $5-11/ton when gas prices are high
- In between, under AEO 2015 Reference gas prices

Interstate compliance trade and energy efficiency reduce costs. In the table below, the Trade-No rows show the range of allowance/ERC prices across states when they comply alone, while Trade-Yes shows the common traded price.

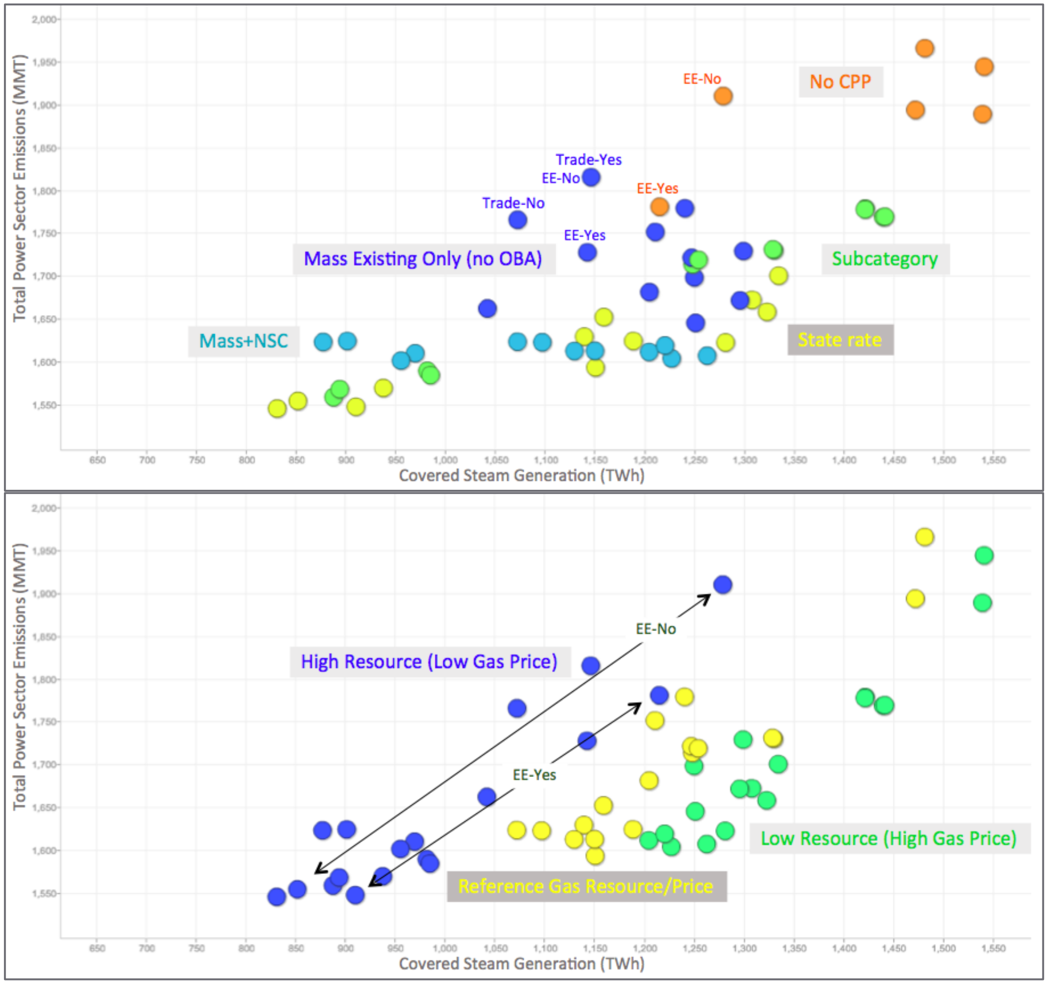
In mass pathways, trade reduces the highest end of the state price range by 30-80%. Trade has less impact in rate pathways, because we have assumed EERE ERCs are traded nationally in all cases.

EE reduces allowance prices by one-quarter to one-third in Mass+NSC and Subcategory scenarios. It has less impact on allowance prices in the MassExO case due to new source leakage. (Only the No OBA version of this pathway is shown, because OBA incentives change allowance prices, making them less informative to compare.)

2028 allowance/ERC prices (2011$/ton)

Scenario		Hi Shale EE-No	Hi Shale EE-Yes	Lo Shale EE-No	Lo Shale EE-Yes	Ref Shale EE-No	Ref Shale EE-Yes
Mass Existing Only (No OBA)	Trade-No	2-30	2-27	2-52	3-44	7-43	6-39
	Trade-Yes	7	5	31	27	20	19
Mass + New Source Complement	Trade-No	6-32	5-27	13-61	4-60	2-53	9-40
	Trade-Yes	18	12	42	32	32	25
Subcategory Rate	Trade-No	0-26	0-20	0-27	0-18	0-29	0-20
	Trade-Yes	25	18	25	18	28	20

The pathways set up different incentives to different forms of generation



The next several slides explore the impacts of the various pathways and sensitivities of different generation types. The primary visual tool here is an interactive scatterplot of scenario outcomes, known as a *motion chart.*

As the name implies, these charts can be animated by the user to "play" scenario outcomes forward in time. They can also be colored in different ways to reveal patterns in scenario outcomes.

Readers are strongly encouraged to explore these charts for themselves at the FACETS website. A video explaining their use and walking through the results described here is also available.

In these plots, each colored "bubble" is a scenario. Here they scatter covered steam (mostly coal) generation versus total power sector emissions in 2030.

- In the top panel, the scenarios are colored by compliance pathway, as indicated by the color-coded labels.
- The bottom plot is identical, except that the scenarios are colored by gas resource/price sensitivity.

The orange bubbles in the upper right-hand corner are the **No CPP** scenarios, appearing as three pairs, corresponding to low, Reference, and high gas prices. The upper scenario in each pair is EE-Yes, and the lower EE-No.

Rate scenarios are highly sensitive to gas price. The **Subcategory** pathway requires independent compliance of steam and NGCC units with their own rate standards, allowing full flexibility to the share of generation in each subcategory, creating a wide range of steam generation and emissions across scenarios. The **State Rate** scenarios have lower emissions than the Subcategory scenarios because the blended state rate induces more shift from steam to gas generation. In both Rate pathways, when gas prices are low, more new gas replaces covered generation, leading to a lower emissions intensity of the entire fleet.

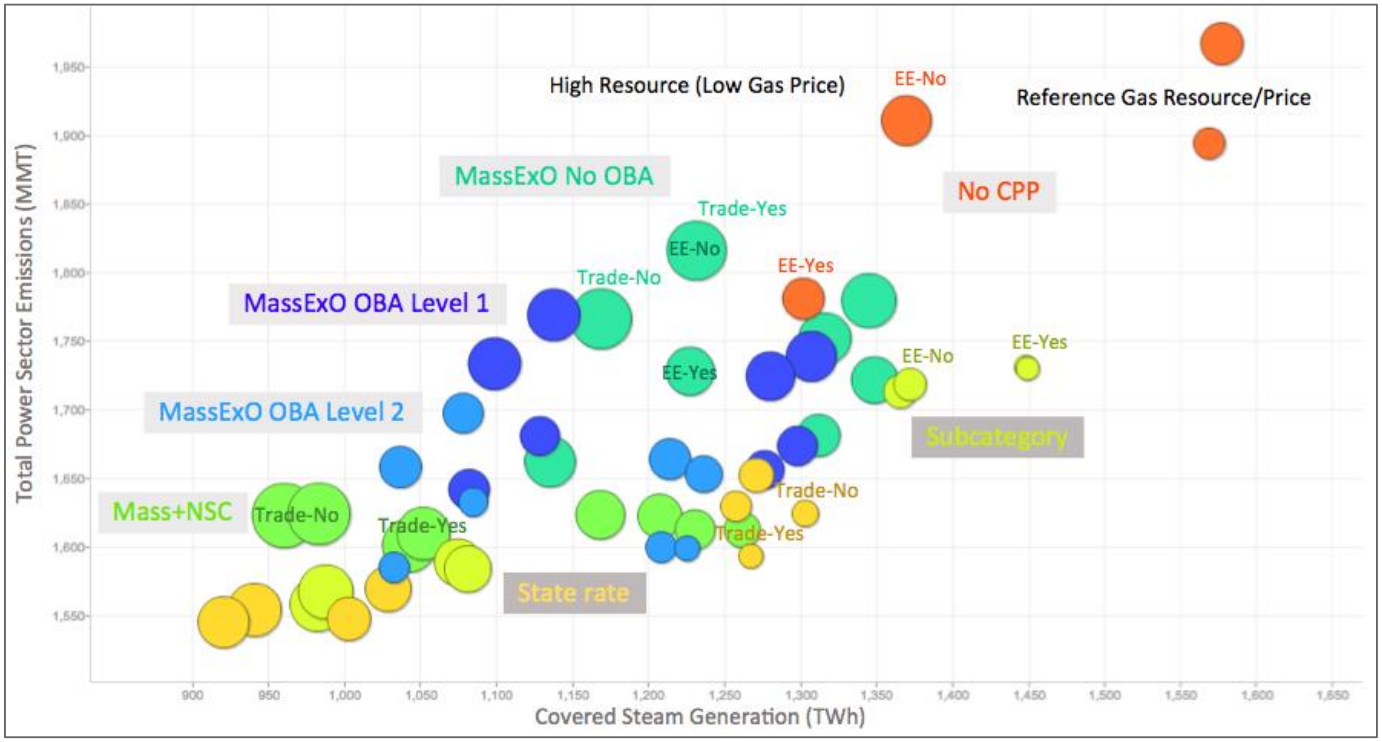
The **Mass+NSC** scenarios have stable emissions across sensitivities, with greater steam generation at higher gas prices. Without any OBA correction for leakage, emissions are much higher when a mass cap covers **existing sources only**. Here, EE reduces leakage by 50-100 MMT/year. Low gas prices and interstate compliance trade both increase it.

Steam generation varies across pathways and in response to energy efficiency and gas price

On this and the next two slides, only the Reference and High Resource/low gas price scenarios are shown, so that pathway dynamics may be better explored. In each of these graphs, scenarios are visually grouped in left-to-right bands by gas price scenario, as shown in the previous slide. Here, the low gas price scenarios are on the left, with lower steam generation. (The order is reversed in some of the other graphs.)

Scenarios here include the OBA simulation Level 1 and 2 runs, where Level 1 is closest to the level of incentives in the proposed pathway model rule, and Level 2 has the highest incentives we tested.

In these figures, bubble size scales with generation from new gas units, allowing for easy identification of the EE-Yes scenarios. They have less new gas than their EE-No counterparts, and hence smaller bubble size. Note that the colors in these figures are different from those in the previous slide because of the additional pathways.



Under both low and Reference gas prices, the highest emissions CPP pathway is **Mass Existing Only** without EE and without any leakage mitigation measures. This design also has the highest amount of new gas generation (largest bubble size). EE reduces the emissions from this pathway 3-5 percent. Adding the **Level 1** incentives to existing gas and new RE reduces emissions only modestly, while the **Level 2** incentives bring emissions near the level of the Mass+NSC pathway.

As noted in the previous slide, the **Rate** pathways are very sensitive to gas prices. The **Subcategory** rate pathway has emissions 5-6 percent higher than the blended **State** rate pathway under Reference gas prices, but nearly identical under lower gas prices. EE has a much less dramatic effect on emissions under these pathways, leading to a slight decrease in some scenarios and a slight increase in others. (It can play an important role in reducing compliance costs, however.)

In all designs except MassExO, EE allows for increased steam generation relative to the corresponding EE-No scenarios. In the rate pathways, this happens because avoided MWh generate ERCs that can be used in the rate denominators, allowing the remaining generation to have a higher emissions intensity. The increase in coal generation is greater under the subcategory rate pathway because the EE ERCs may be purchased by either the steam or NGCC subcategory constraint markets, and they go overwhelmingly to the steam market. In the **MassExO** design, EE reduces emissions substantially by decreasing the incentive to build new gas units.

The pathways affect existing and new gas generation differently

Our results suggest that most of the CPP pathways do not result in a substantial shift to existing gas generation (upper panel).

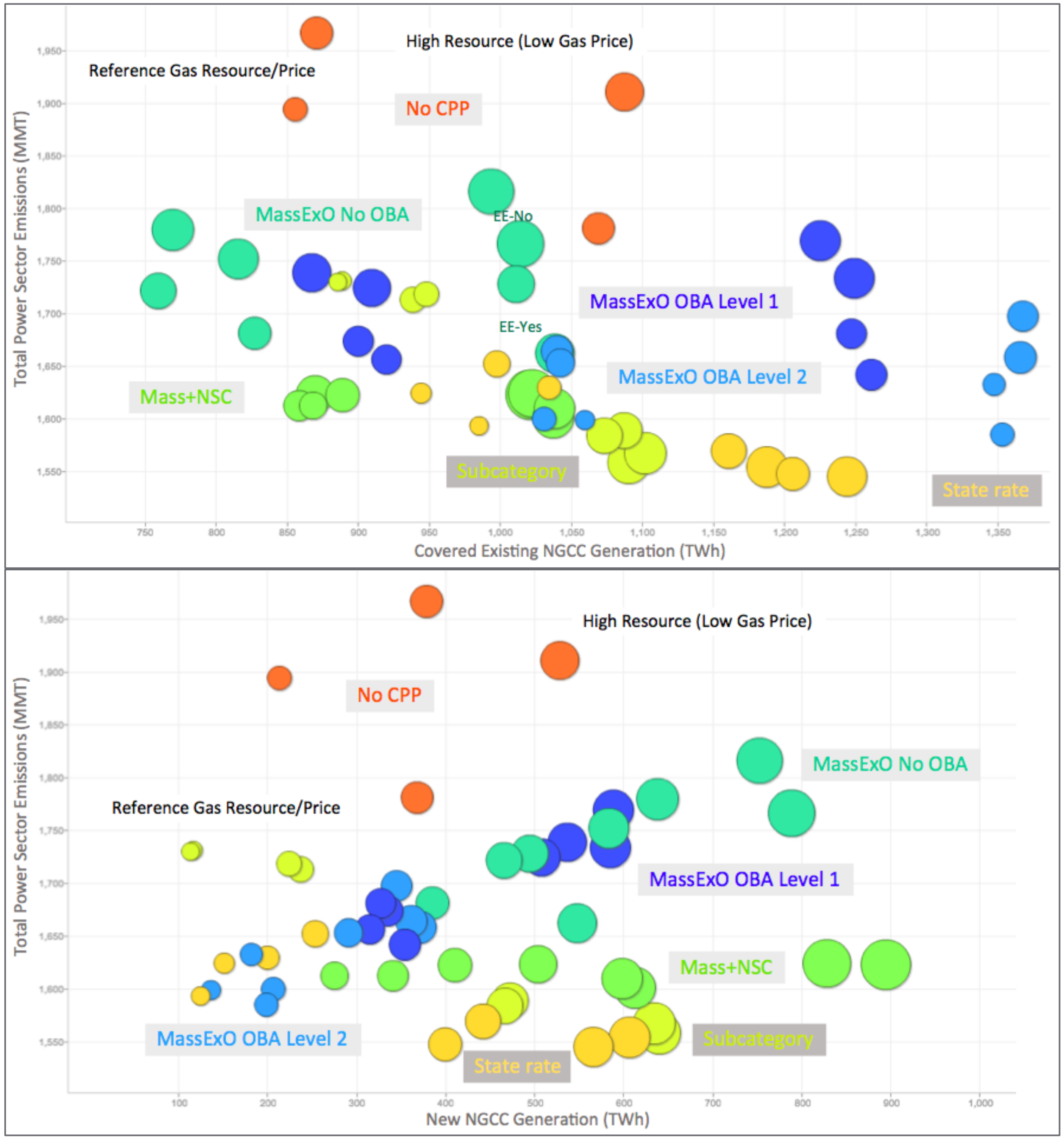
The **State** rate design increases existing NGCC generation 15-18 percent over No CPP under Reference gas prices, and 9-12 percent under low gas prices. The **Subcategory** rate design produces much less gas shift at 4-8 percent under Reference prices, and less than 2 percent under low prices.

Existing NGCC generation is similar to business-as-usual (BAU) under **Mass+NSC**, while **MassExO** without OBA reduces it in favor of generation from new NGCC. The **Level 1** OBA simulation incentives bring it back to BAU levels at Reference gas prices, and push it to the higher State rate levels under low gas prices. The **Level 2** incentives increase it to or beyond the State rate levels in both gas price scenarios.

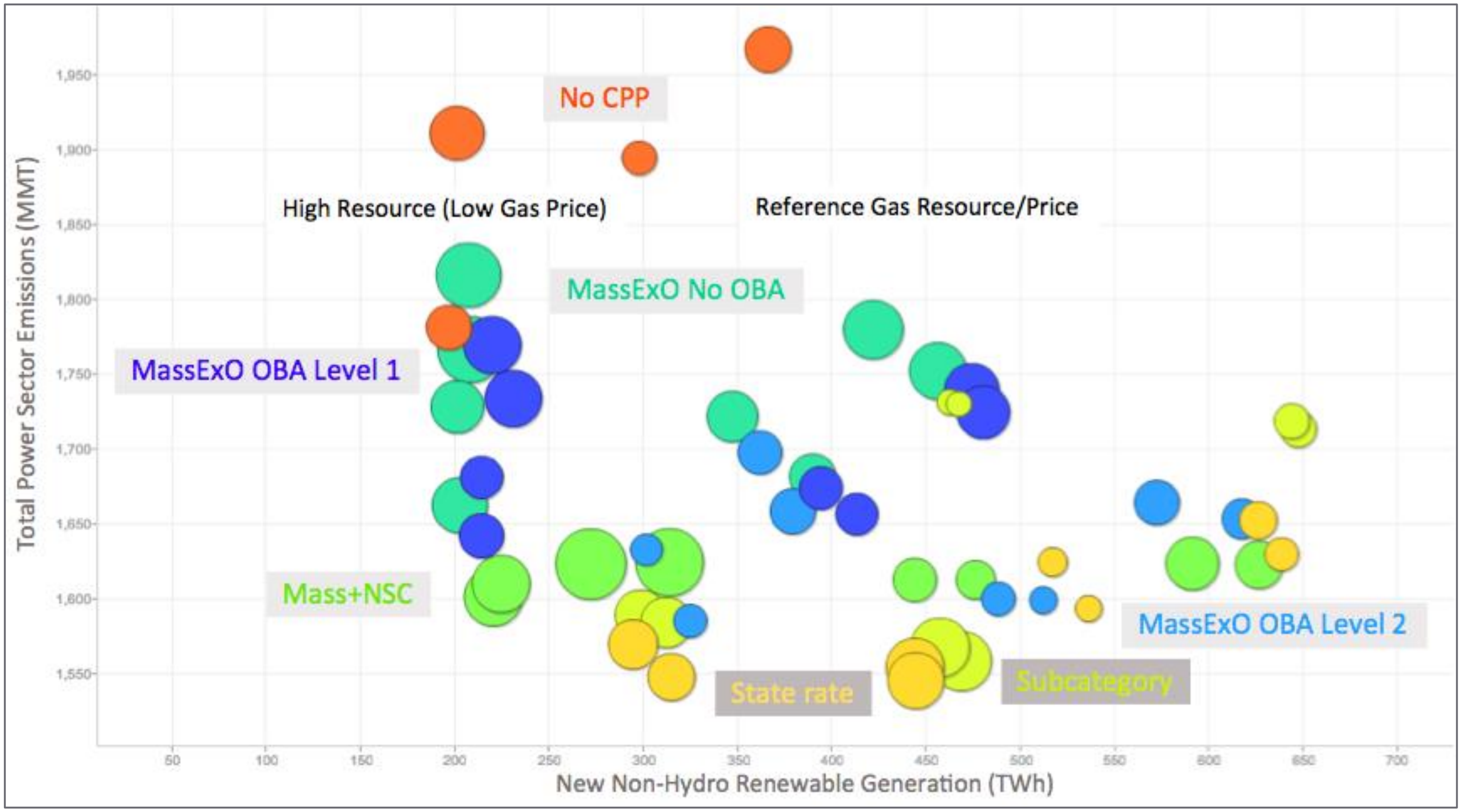
Pathway outcomes are largely inverted for new gas generation (lower panel). The **Rate** pathways reduce new gas, relative to BAU, at Reference gas prices, and keep it roughly the same as BAU when gas prices are lower.

MassExO stimulates an increase in new gas of 20 up to 120 percent. This increase is moderated in proportion to the strength of OBA-type incentives to existing gas and renewables. Our **Level 2** incentives reduce new gas generation to BAU levels or below.

In all pathways, energy efficiency reduces new gas capacity additions, so the EE-Yes scenarios are to the left of their EE-No counterparts.



The pathways stimulate renewables to different degrees



New renewable additions are sensitive to gas prices and energy efficiency achievement. **No CPP** new RE generation is 30-50 percent lower under low gas prices than under Reference prices.

At Reference gas prices, all the CPP pathways increase renewable generation beyond No CPP levels, but by widely different amounts. Renewable generation is lowest in **MassExO** without OBA leakage mitigation mechanisms, where new gas additions displace much of the renewable generation added in other pathways. In the Trade-Yes version of this pathway, the increase in RE is limited to 15 percent over No CPP levels, and it reaches 25 percent in the Trade-No version.

OBA-type incentives increase new renewables, but only with the **Level 2** incentives – the highest level we tested – does RE generation reach that of the other pathways. The performance of these incentives in decreasing emissions is highly correlated with their impact on renewable generation. (See more on this in slides 16-18.)

The other pathways increase renewable generation by 50 percent or more. In all scenarios, EE increasingly offsets new renewable builds as time goes on, so EE-Yes scenarios have less renewable generation than their EE-No counterparts.

When gas prices are low, several pathways stimulate little additional renewable generation, including the **MassExO** pathway with no leakage mitigation mechanism and with only **Level 1** incentives, along with the **Mass+NSC** pathway when EE is achieved. In these scenarios, the increase is limited to 15 percent or less. Under the **Level 2** incentives with EE, **Mass+NSC** without EE, and the **Rate** pathways with EE, the increase reaches 35-60 percent, while the Rate pathways without EE lead to a doubling of new RE.

EERE ERCs provide the bulk of Subcategory compliance

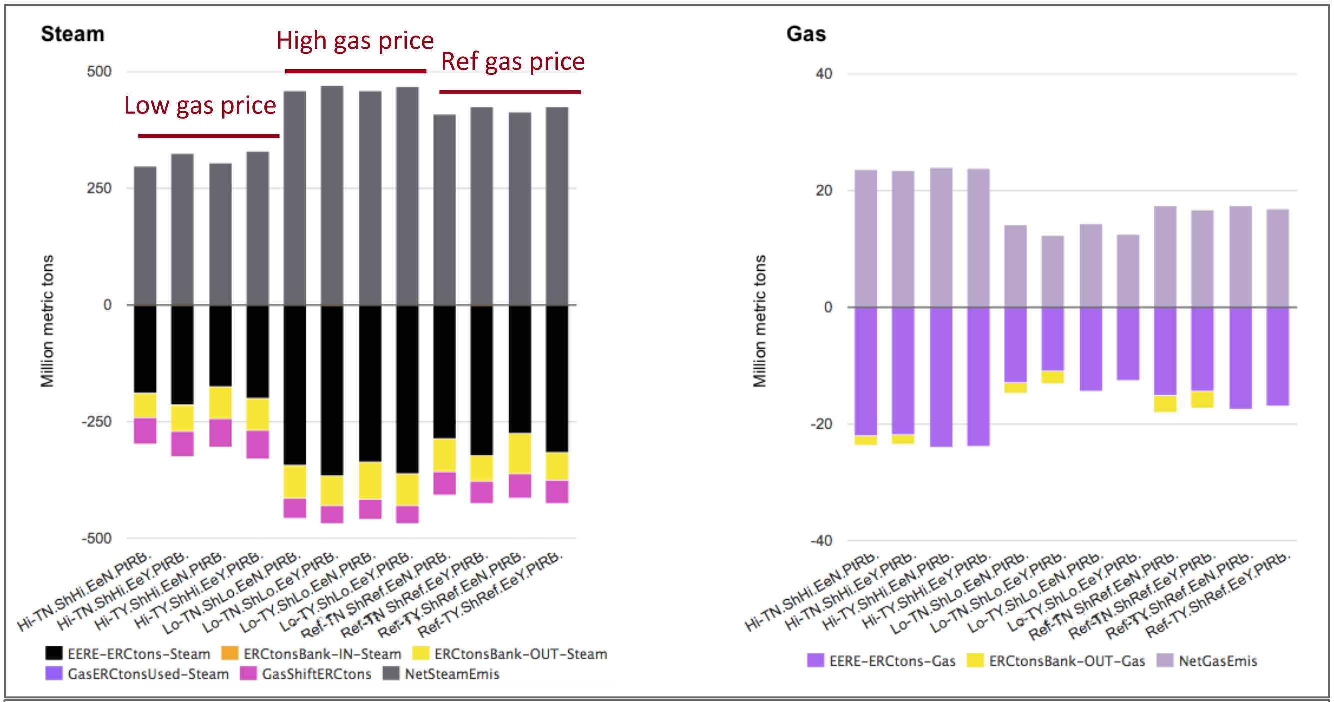
The upper panel shows how the steam and natural gas combined cycle subcategory constraints are met in 2028.

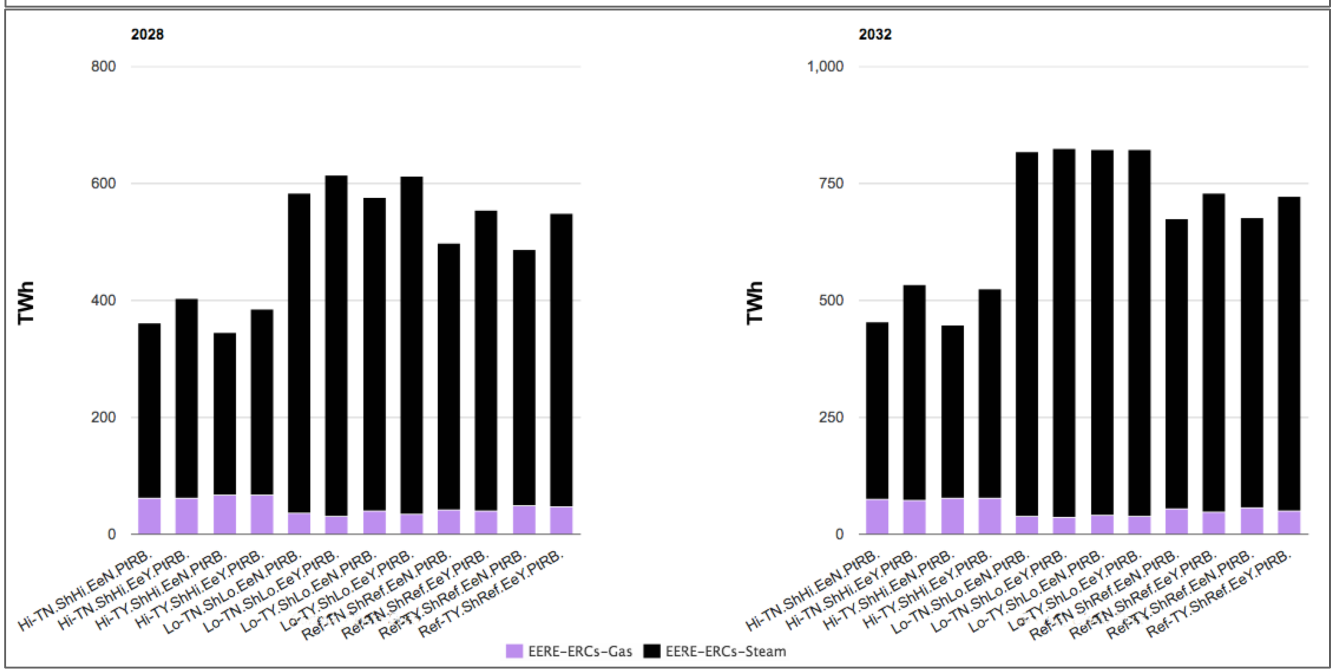
The (gray and light purple) positive bars show excess emissions from covered units above their subcategory rate constraint. Negative bars show emissions rate credits (ERCs), converted into tons, illustrating the contribution of different compliance mechanisms.

ERCs from energy efficiency and renewable generation (EERE ERCs) are the main compliance route (shown in black in the steam market and dark purple in the gas market). The fractions of compliance from gas-shift ERCs (pink) and ERCs banked in previous years (yellow) are much smaller.

The lower panel reorganizes this information to show the relative shares of EERE ERCs going to the steam and gas markets in 2028, as well as in 2032. The share to the steam market ranges 81-95% in 2028, and 83-96% in 2032 across scenarios. Shares to gas are higher when gas prices are low, and lower when they are high.

The shares of EERE ERCs to steam are far higher than fraction of renewable generation offsetting steam assumed by EPA in the rate calculation. It appears to be more cost effective for EERE ERCs to go directly to the steam market, than for existing gas units to increase their dispatch, consume more EERE ERCs, and send more gas shift ERCs to the steam market. We believe this accounts for the small role for gas shift we see in the subcategory pathway results.





Scenarios simulating incentives to existing gas and renewable generation show the response of generation and emissions to potential allocation strategies

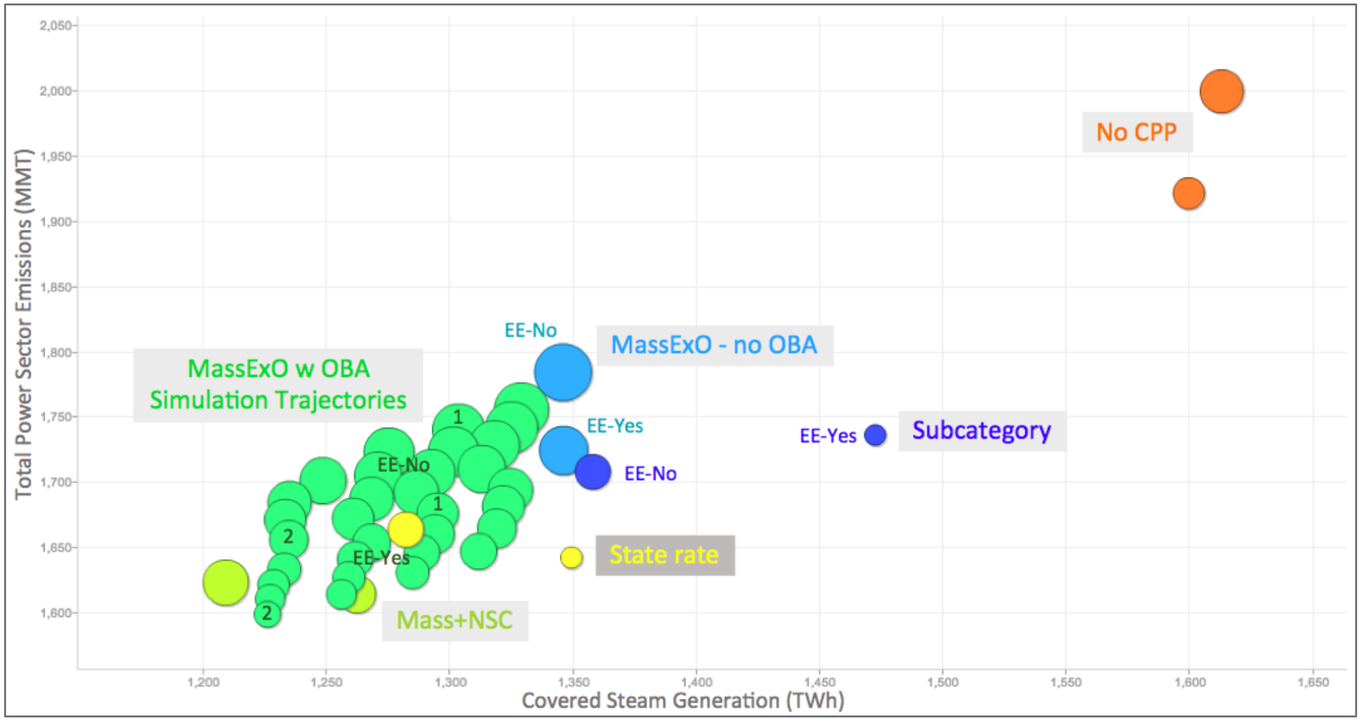
The full suite of 32 OBA incentive simulation runs – 16 EE-No and 16 EE-Yes – are shown in motion charts on this and the next two slides.

Each group of 16 scenarios are seen here grouped into four diagonal bands. Working right to left, the four bands are the four levels of gas incentive. The rightmost bands has the lowest level of gas incentive, and hence the largest amount of existing steam generation. Within each band, the level of RE incentive increases as we move downwards, with higher RE incentives corresponding to lower emissions.

In the **EE-No** case, the incentive scenarios stretch roughly between the MassExO scenario without any incentive and the Mass+NSC scenario, not quite achieving Mass+NSC emissions reductions even at the highest incentive level.

Energy efficiency plays an important role in addressing leakage. Under **EE-Yes**, the emissions difference between MassExO without any incentive and Mass+NSC is roughly two-thirds of the size of the gap without EE. Here the Level 1 incentive closes almost one half of the gap, while several of the highest incentive scenarios achieve emissions at or below the Mass+NSC level.

We also see that emissions are more sensitive to incentives to renewables than to gas (steeper slope down the bands than across them).



	Generation incentive (2011$/MWh)			
Trajectory	2023	2026	2028	2032
1	2.5	2.9	3.2	3.9
2	5	5.8	6.4	7.8
3	7.5	8.7	9.6	11.6
4	10	11.6	12.8	15.5

Scenarios labeled "1" receive incentives closest to those in the set-aside program in the proposed model rule: trajectory #2 for gas and #1 for renewables. Note however that these scenarios are not identical to this program. Most notably, these scenarios do not include the 50 percent capacity factor threshold for existing gas units to receive generation incentives. In all these runs, incentives go to *all* existing covered gas and qualifying renewable generation.

Scenarios labeled "2" the highest incentives we tested: trajectory #4 for both gas and renewables.

Existing and new gas generation are highly sensitive to incentive levels

In the upper panel, the diagonal bands from the previous slide are now reversed right-to-left, with the greatest existing gas generation under the highest trajectory of gas incentive. We see that the **Level 1** scenarios match the amount of existing gas generation in the Mass+NSC runs fairly well, although they fall short of the gas shift induced by the Rate pathways in the EE-No cases.

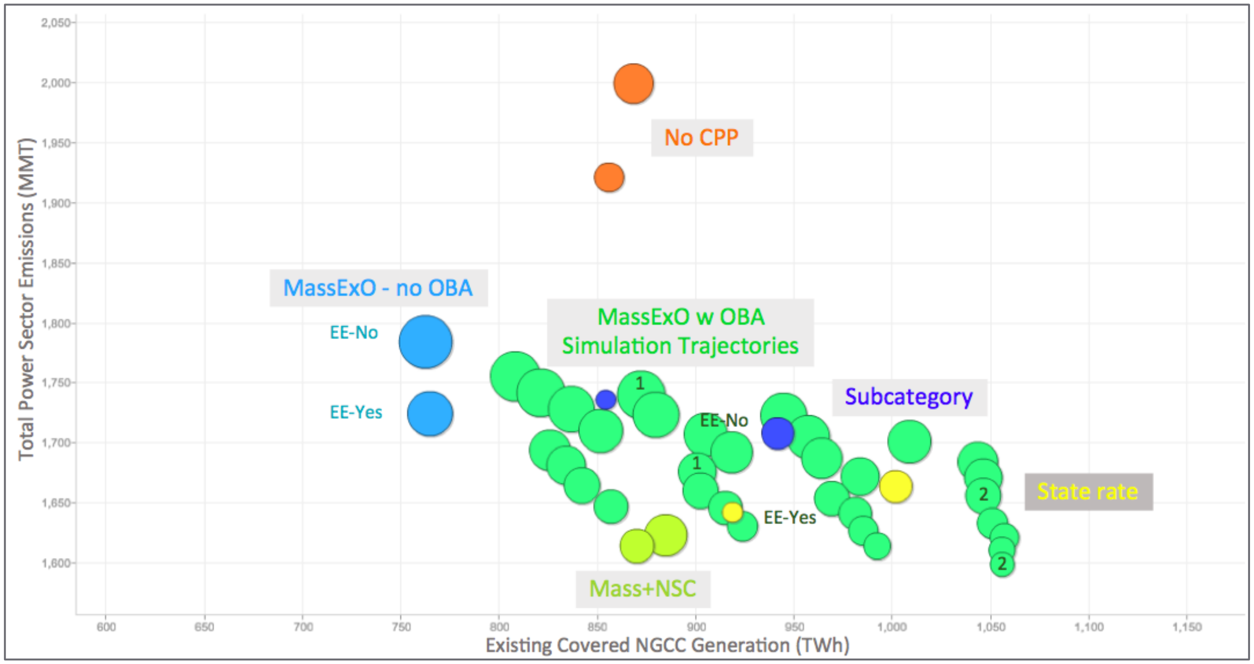
However, matching existing gas generation levels does not lead to matching emissions performance. Consideration of new gas (lower panel) and renewable generation (next slide) helps to explain this.

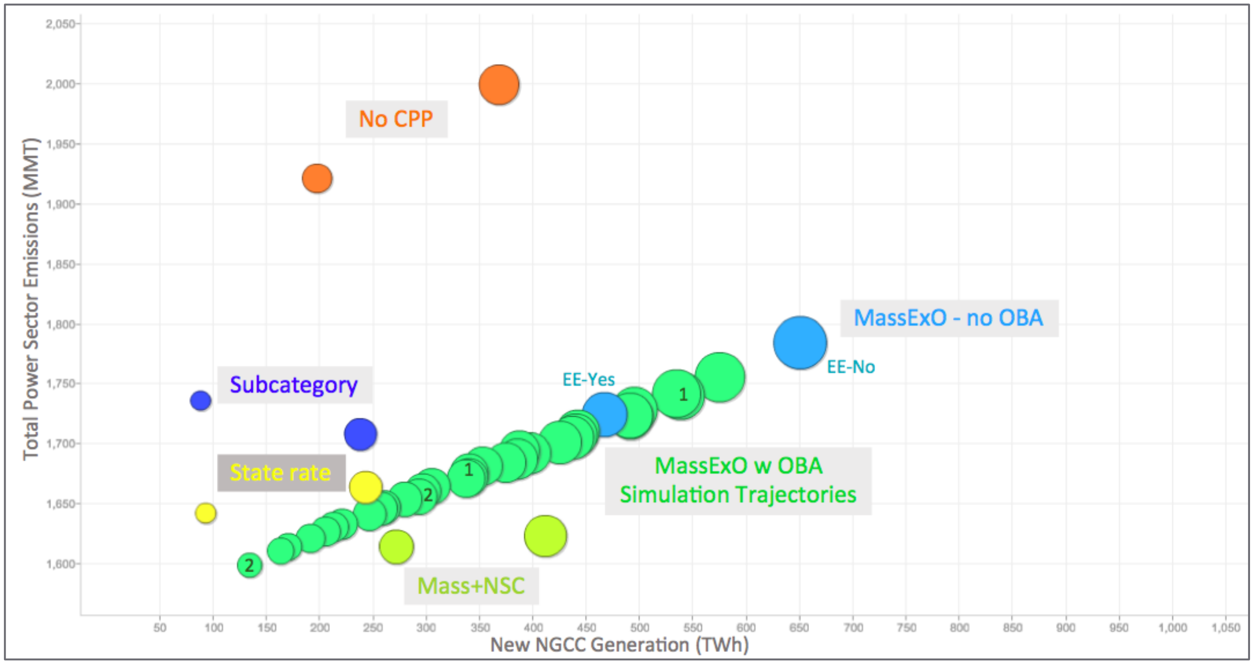
We see a very tight relationship between emissions and new gas generation for the MassExO runs, with increasing new gas generation and emissions as incentive levels fall.

Despite their performance in stimulating existing gas, the **Level 1** scenario still has new gas generation that exceeds all other pathways under both EE-Yes and EE-No. The **Level 2** scenarios have new gas generation closer to that of the Rate pathways.

Because all emissions from new gas generation are uncovered in this pathway, stimulating existing gas generation to or beyond the levels of the other pathways may be necessary to bring emissions down to the levels achieved when all sources are included under the cap.

The level of incentive for renewable generation is crucial for this tradeoff (see next slide).



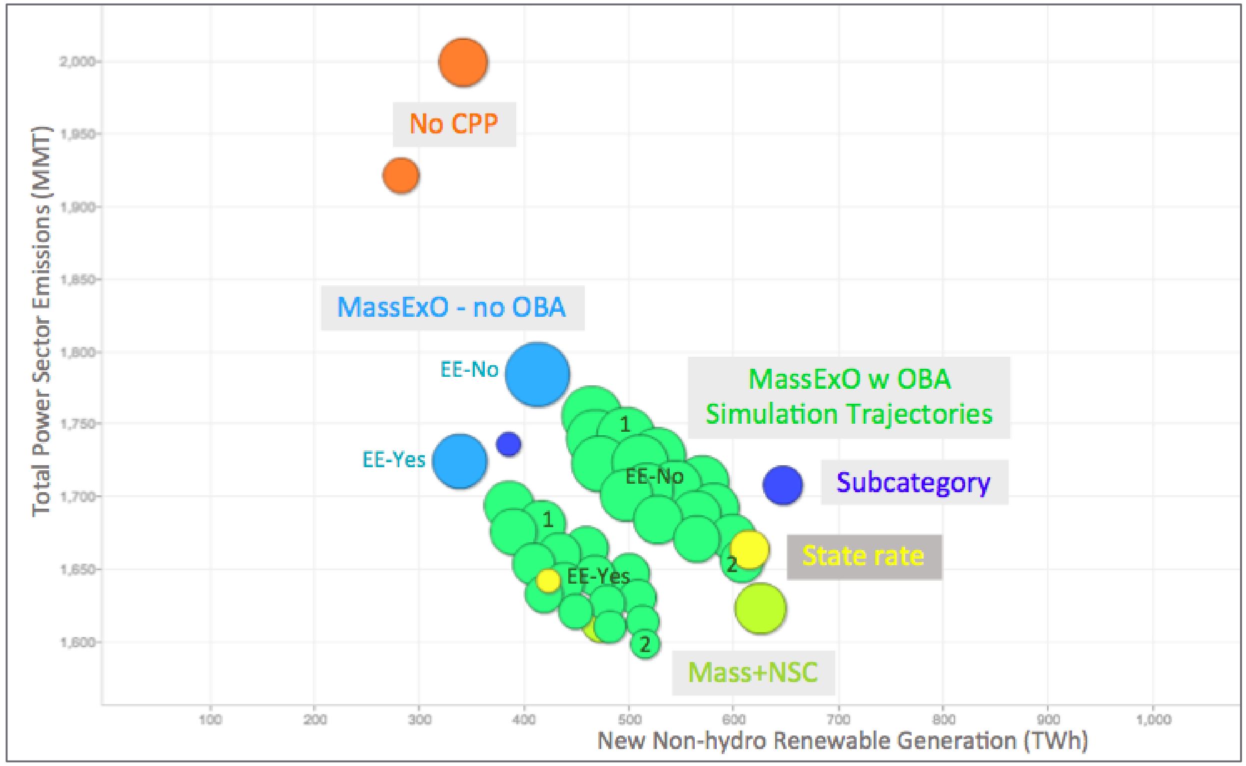


Most of the incentive levels tested do not achieve the incentives for renewables created by the other pathways

The Rate and Mass+NSC pathways create differential incentives for renewables and new gas, due to their source coverage. MassExO without any allowance allocation or other direct support mechanism to renewable generation does not provide such differential incentives. (Both RE and new gas are untouched by the cap, and so experience the same incentives relative to covered generation.)

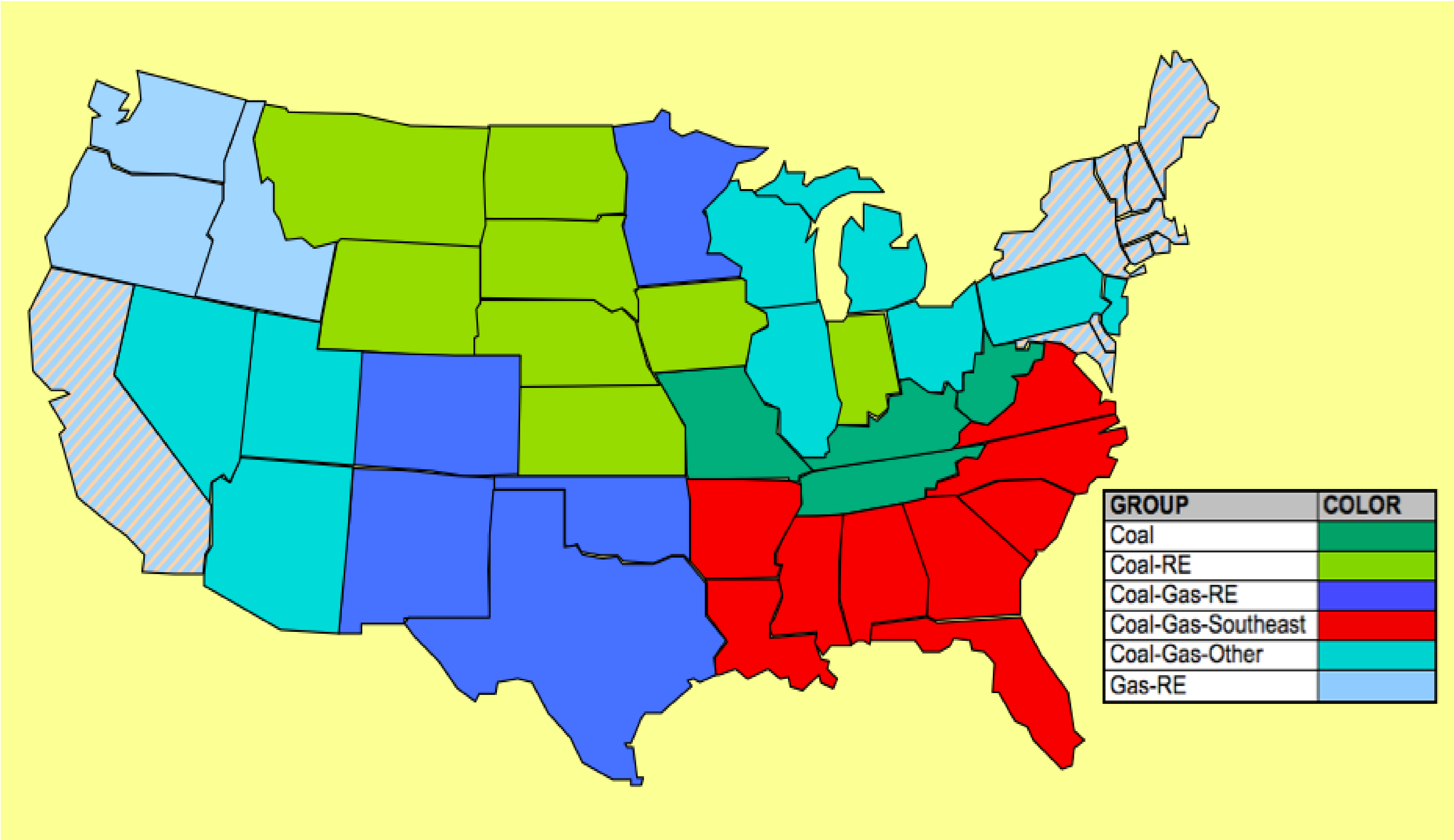
The value of the incentives provided by the Rate and Mass+NSC pathways in the full suite of FACETS runs are summarized in the table below, based upon ERC and allowance prices. The renewable incentive level from the proposed set aside, as estimated by EPA, falls far short of these values, as do most of the incentive trajectories tested in FACETS.

Except at the highest levels tested here, renewable generation (and hence emissions) do not reach the levels of the other pathways. When EE is not achieved, it is additionally necessary to increase existing gas generation beyond the levels achieved by the other pathways, in order to bring renewable generation in line with the other pathways.



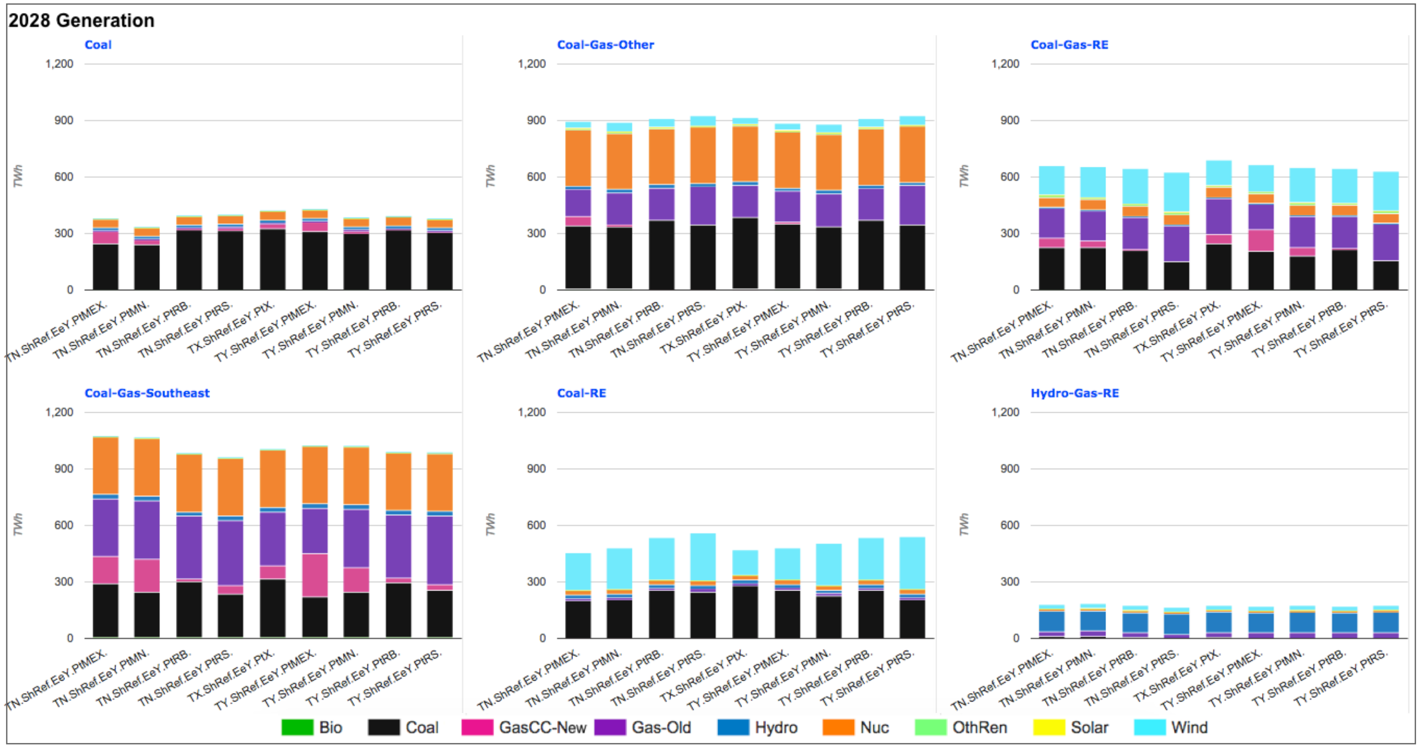
Pathway	Mechanism	Relevant 2028 FACETS Price	Value to RE
Rate	RE earns ERCs; new gas does not	ERC = $11-18/MWh	$11-18/MWh
Mass + New Source Complement	New gas must pay allowance price; RE does not	Allowance = $12-42/ton	$4.5-15/MWh
MassExO: Proposed RE set-aside	Allowances allocated to RE	As estimated in EPA's renewable set-aside documentation:	$2.48-3.73/MWh
MassExO with generation incentive: Levels tested in FACETS			$2.5-10/MWh

To explore state-level impacts, we grouped states by resource mix



In order to explore the impacts of CPP pathways at the state level, we grouped states based upon their primary generation mix in our runs: a combination of some or all of coal, gas and renewables. In our runs, we find that most new gas capacity is added in a broad Southeastern region stretching from Texas through Southern Appalachia into Virginia, where gas prices tend to be lower and load growth tends to be higher than in other regions, creating favorable economics for new gas additions. We therefore divided the very diverse Coal-Gas states into Southeast and Other groupings.

Abatement strategies differ across state groupings



The graph shows the 2028 generation mix in the EE-Yes, Reference gas price scenarios for the four pathways. The middle scenario in each graph is No CPP. Trade-No scenarios are on the left, Trade-Yes on the right. The MassExO version without any leakage mitigation measure has been chosen to represent this pathway here, in order to further explore the dynamics of this issue.

The states in the **Coal** group have little or no existing gas and, under the technology and cost assumptions we used, more costly RE potential than other regions. Heat rate improvements at existing coal units, energy efficiency, and construction of new gas units are the most cost effective in-state compliance strategies. These states particularly benefit from interstate trade, importing ERCs under rate pathways or allowances under mass pathways, which allows the bulk of the region's existing coal capacity to keep operating close to BAU levels when they engage in interstate compliance trade.

The **Coal-RE** states have coal-heavy systems with strong renewable potential. With limited opportunity to redispatch to existing gas, major renewable expansion represents most of the CPP response strategy. This group increases its generation above No CPP levels in most CPP scenarios. Depending on the pathway, it can supply low carbon electricity, ERCs, or excess mass allowances to other regions. Additions of wind generation more than offset decreases in coal-fired generation.

The **Coal-Gas-RE** states are a diverse group of states with mixed systems and strong potential to add renewables. In these states, renewable additions tend to offset existing gas under most CPP pathways. Like the Coal-Gas-Southeast group, this group expands new gas generation under the Trade-Yes MassExO pathway, exporting excess allowances to other states.

States in the **Coal-Gas-Southeast** group have mixed systems within the southeast where redispatch to existing gas and addition of new gas are major response strategies. Along with the Coal-Gas-RE group, this group is the primary site for new gas builds.

The **Coal-Gas-Other states** are a diverse group of states with mixed systems where redispatch to existing gas is a major response strategy, and renewable additions are more limited. This group experiences smaller fluctuations in total generation between scenarios than other groups.

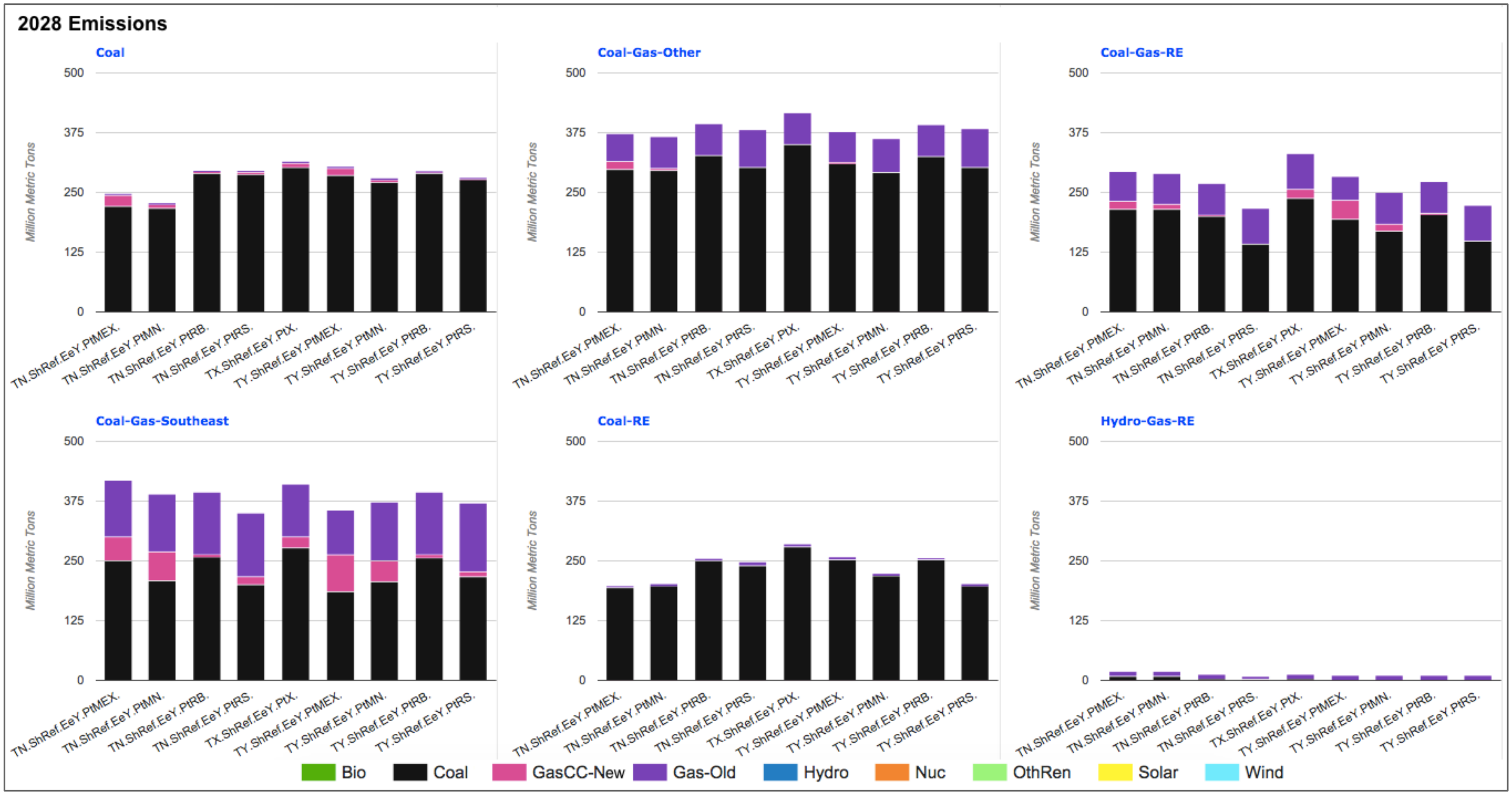
The **Hydro-Gas-RE** group contains hydro-dominated systems in the northwest with limited existing coal capacity. Coal plays a lesser role here in most scenarios, as the region has numerous cost effective opportunities to generate low carbon power for itself and other regions.

Emissions results show the importance of leakage mitigation measures, particularly when states trade

Interstate compliance trade has an important role to play in increasing flexibility for states and decreasing compliance costs. However, when the Mass Existing Only pathway is not accompanied by a robust leakage solution, interstate trade can also amplify new source leakage.

To observe this effect, compare emissions results for the MassExO and Mass+NSC pathways in the Coal-Gas-Southeast region, under Trade-No and Trade-Yes conditions. (Columns 1-2 and 6-7, in the graph, respectively.) When all states comply individually, this region adds *more* new gas under Mass+NSC than MassExO, using it to lower the overall emissions intensity. When interstate compliance trade is added to Mass+NSC, new gas usage shrinks, as this region cuts emissions and exports allowances.

Under the Mass Existing Only pathway shown here, without any leakage mitigation measures, the deployment of new gas is reversed. When interstate compliance trade is added, the region expands new gas generation, increasing it to more than 80 percent over Mass+NSC levels. However, its overall emissions fall as it also cuts back on coal generation, indicating that the excess allowances generated through new source leakage are of higher value outside the region and have been exported.



Conclusions

The Clean Power Plan is an achievable and affordable policy that creates incentives to accelerate the ongoing shift of the US electricity system in the direction of cleaner generating sources. The way in which this shift occurs will vary depending on the specific CPP implementation pathway chosen.

Net present value emissions reduction costs range from less than $2 per metric ton to only $11 per ton in the highest gas price, most costly cases. Interstate compliance trading can provide significant cost benefits, particularly to regions with fewer compliance options. Energy efficiency also reduces costs, decreasing allowance/ERC prices by up to one-third.

The emissions results of the four pathways vary under different scenarios because of the different incentives they create for generation resources. Such variation is not surprising in a program that gives states considerable flexibility in the design of their state plans. One implication, however, is that only one pathway - the mass cap with new source complement (**Mass+NSC**) covering all emitting sources - delivers emissions reductions meeting EPA's benchmark of 32 percent below 2005 levels across all sensitivities and implementations.

In particular, without a robust approach to mitigating new source leakage, the **Mass Existing Only** pathway runs the risk instead of incenting over-development of new gas capacity at the expense of other low- and zero-carbon generation sources. Our findings agree with those of several other modeling teams: While EPA outlined a number of useful tools to address leakage in the proposed model trading rules and federal implementation plan, the specific formulation EPA proposed is unlikely to be sufficient, because it does not match the level of differential incentives to new renewable versus new gas generation that the other pathways create.

Some commentators have suggested that EPA require the new source complement with mass pathways, for this reason. If EPA continues to allow mass caps to cover only existing sources, enhanced allocations to low- and zero-carbon generation beyond what EPA has suggested in the proposed model rule, coupled with strong measures to support energy efficiency, can bring this pathway's outcome more in line with the others.

We find that modeled emissions under the **Rate** pathways are highly sensitive to assumptions on gas resource/price and energy efficiency accomplishment. (In other runs, not presented here, we found similar sensitivity to renewable costs and ERC supply and trading.) We believe this sensitivity accounts for the considerable variation in modeling results that have been reported on the relative “stringency” of rate versus mass pathways.

This sensitivity to input assumptions has implications for the use of modeling to guide compliance plan development and equivalency demonstration: a wide variety of gas prices and other sensitivity assumptions should be tested and well documented.

Much of the data presented here can be explored interactively at http://facets-model.com/cpp

For more information about FACETS see http://facets-model.com or contact Evelyn.L.Wright@gmail.com

Appendix: FACETS Data Sources

Sector	Source	Comments
Biomass Supply	AEO supply curves	16 supply regions
Coal Supply	EPA IPM	31 supply sources, 3 types, 6 sulfur grades
Coal Transportation	EPA IPM	Matrix of 80 coal types to 135 power plant groupings
Natural Gas	AEO	Reference and Low and High Resource
Existing Power Plants	EPA IPM NEEDS	32 NERC subregions 11000 plants, indexed by state and county
New Power Plants	AEO, NREL (wind and PV)	Indexed by state
Renewable Potential	EPA IPM and AEO	
Transmission Capacity	EPA IPM	Among 32 NERC subregions
Pollution Control Retrofit Costs	EPA IPM	FGD, DSI, SCR, and ACI
Electricity Demand	Endogenous/AEO	Census divisions or state level
Load curve	EPA IPM/AEO	6 times of day in two seasons based on historical load, or endogenous