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EVALUATION OF POWER SECTOR EMISSIONS REDUCTION PATHWAYS

The power sector is the second-largest contributor of greenhouse (GHG) emissions in the U.S., accounting for one-quarter of total emissions. Decarbonization of the power sector can play a leading role in cost-effective economy-wide emissions reductions given that deep emissions reductions are projected to cost more in other sectors. Resources for the Future (RFF), with support from the REBA Institute, analyzed decarbonization policy pathways for the power sector through RFF's advanced power sector model, E4ST, to project the tradeoffs and impacts of key options, including:

1. A national clean energy standard (CES)—both a **Fast CES** (100% target by 2035) and a **Slow CES** (100% target by 2050)[1];
2. Utility-led decarbonization—all investor-owned vertically integrated utilities fully decarbonize;
3. A national transmission macrogrid;
4. Expansion of competitive generation via expansion of organized wholesale electricity markets (OWMs);
5. Expansion of supply choice to almost all commercial and industrial customers

Comparison of Power Sector Decarbonization Pathways: Preliminary Takeaways

1 A national CES produces approximately $100B per year in net benefits and larger emission reductions than any other pathway modeled.

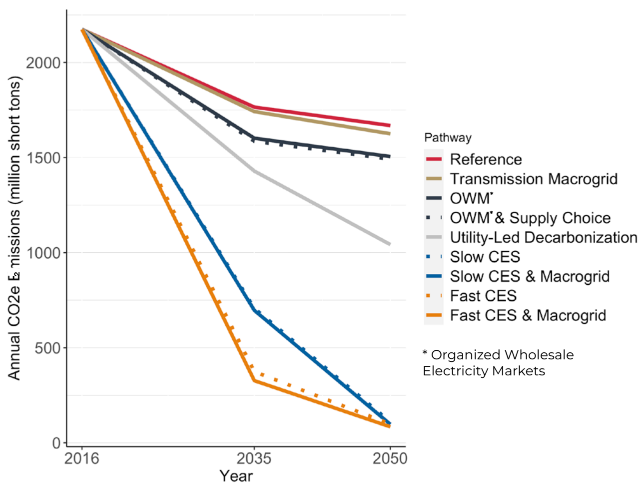


Figure 1. Preliminary modeling results from evaluation of U.S. annual power sector CO_2e emissions through each decarbonization pathway. For some policies, the main projected benefits are in the form of cost savings rather than emission reductions.

2 The ambitiousness of the targets matters. A slower CES can produce disproportionately lower rate effects.

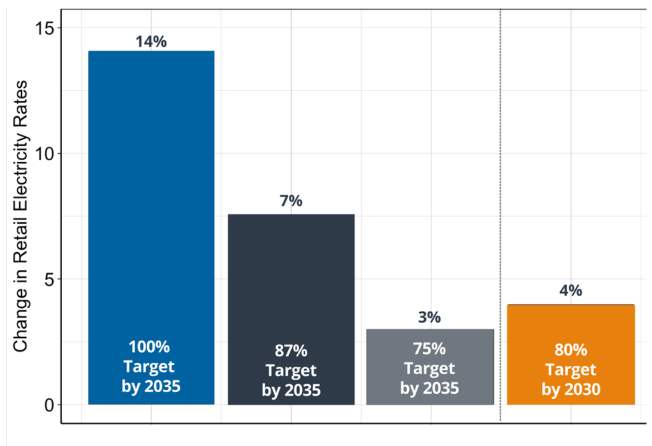
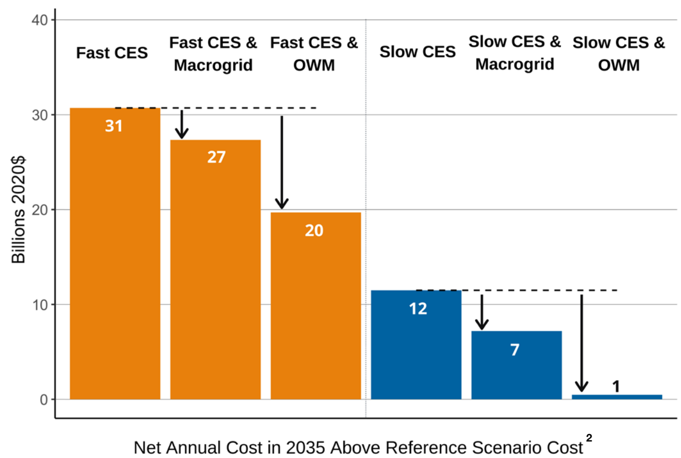


Figure 2. In 2035, a CES with a target of 100% raises retail electricity rates 14%; with a target of 87%, rates increase 7%; and with a target of 75%, rates increase 3%. In 2030, an 80% CES increases rates 4%. Note: Rate effects are relative to reference scenario.

3 Combining a CES with complementary policies would offset some of the cost of a CES.

Figure 3. CES pathway combinations would produce a lower total electricity supply cost than a CES alone. The three Fast CES pathways target 100% by 2035. The three Slow CES pathways target 75% by 2035.



1 The clean percentage targets are percentages of total U.S. generation, not just of retail sales.

2 Cost shown is difference in total cost of electricity compared to reference scenario. Total cost includes operational and amortized capital costs of generation and transmission.

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Summary of Preliminary Results[4]

A national clean energy standard drives the greatest emissions reductions and net benefits.

The net benefits of each of the CESs modeled are on the order of $100 billion per year in both 2035 and 2050, considerably larger than those of any of the other pathways. The benefits largely come from reducing power plant emissions, climate damage, and near-term deaths caused in the U.S.[5]

- The Fast CES modeled would achieve 87% clean generation by 2035 and 97% by 2050 (not 100% in either year because of CES credit price caps[6]). Figure 1 shows the projected greenhouse gas emissions reductions resulting from each pathway.
- The Fast CES has the most significant cost impact to customers of all pathways evaluated. The modeling projects an electricity rate increase of 14% in 2035 and 12% in 2050 without any subsidization or complementary cost-reduction approach.
- **The projected benefits of a Fast CES are more than twice the value of the rate increases.**

A slower clean energy standard could result in disproportionately smaller rate increases.

- A CES with a target of 87% clean generation by 2035 would achieve the same decarbonization level as a Fast CES, and would lower the 2035 rate increase to 7% by eliminating the need for alternative compliance payments to the government.
- A Slow CES, with targets of 75% clean electricity generation by 2035 and 100% by 2050, would result in a 3% rate increase in 2035 and 12% in 2050.
- A CES that achieves 80% clean generation by 2030, as recently proposed in Congress, would increase electricity rates by 4% in 2030. The benefits are approximately six times the value of the rate increase.

Subsidies or emission fee proceeds could help prevent an increase in customer energy costs.

- The modeling results estimate that a government outlay of $40 billion per year in 2035 would cover the electricity bill increase from a Fast CES. An outlay of $17 billion per year in 2035 would cover the electricity bill increase from the Slow CES.
- Policymakers could raise some of the funds to reduce the rate impact of a CES by charging electricity generators for emissions above an established benchmark emission rate. This would also make the policy more efficient at reducing emissions.

A transmission macrogrid and expansion of competitive generation on their own or coupled with a CES, are beneficial as well and can offset costs of a CES, as shown in Figure 3.

- Building a transmission macrogrid would add an estimated $5 billion to $10 billion in annual net benefits for a benefit which is 3-4 times the costs, depending on year and policy design, and would reduce national average retail electric rates by approximately 1-2%.
- Expanding competitive generation through organized wholesale electricity markets to all parts of the country would provide an estimated $11 billion in annual cost savings as of 2035, due to more efficient investment, operation, and retirement decisions. It would also reduce annual emissions and emissions damages by an estimated $10 billion. In the presence of a national CES or emissions cap, it might make emission reductions less costly rather than reducing emissions.
- Having all vertically integrated investor-owned utilities reach 100% decarbonization targets in 2050 would reduce U.S. power sector emissions by 38% in 2050, with a 3% national average retail rate increase in 2050.

3 Additional contributors: Eric O'Shaughnessy (Clean Kilowatts), Jenny Heeter (NREL), Christoph Funke, and Brian Prest (RFF)
4 Data and takeaways presented here are the results of modeling. They are careful projections, but perfect predictions are not possible. All projected effects are relative to outcomes in the same year in a reference scenario with no new national clean energy or environmental policies.
5 We assume climate damage is $61 per short ton of CO_2e in 2035 and $77 per short ton of CO_2e in 2050. All dollars in this document are 2020 dollars.
6 A CES credit price cap limits the cost of the CES by allowing utilities to make alternative compliance payments to the government at the cap price in lieu of producing or acquiring the last few targeted percentage points of required clean generation. Utilities would choose this if that last increment of clean generation would be more costly than the cap price.

Appendix

Decarbonization Pathways Evaluated in the Analysis

1. National Clean Energy Standard (CES)	An ambitious national clean energy standard, as an example of a strong, unifying federal policy. This research models two versions of a CES: 1) Fast CES: Goal of 100% decarbonized electricity generation by 2035. CES credit price caps of $54 in 2035 and $85 in 2050 2) Slow CES: Goals of 75% decarbonized generation by 2035, 100% decarbonized by 2050. CES credit price caps of $46 in 2035 and $85 in 2050 In addition, an 80% CES in 2030 was simulated, which could be part of the Fast CES pathway.
2. Utility-Led Decarbonization	All monopoly investor-owned utilities, which currently serve 42% of U.S. electricity demand, reach 100% decarbonized generation through in-state sources by 2050.
3. National Direct Current Macrogrid	A high voltage direct current macrogrid is built across much of the U.S. 7800 miles of 8-GW lines. Completed by 2035.
4. Expanding Competitive Generation	An expansion of organized wholesale markets into the two parts of the U.S. that do not currently have them: the West and the Southeast. Does not assume that vertically integrated utilities sell the power plants they own, but assumes that they participate in organized wholesale markets.
5. Expanding Supply Choice	An expansion of supply choice (also known as retail choice) to all commercial and industrial (C&I) electricity customers of investor-owned utilities, in addition to competitive generation expansion.

Assumptions and Considerations

- We assume that total U.S. electricity demand in 2035 and 2050 are 19% and 47% higher than 2019 demand, respectively.
- The costs referenced in this document include the cost of all new generators and transmission, levelized over the first 30 years of operation, including cost of financing.
- All dollar values in this document are in 2020 dollars.
- Under a CES, electricity generators earn credit in proportion to how far their emission rates are below a benchmark emission rate, which we assume is 0.4 metric tons of carbon dioxide equivalent (CO_2e) per megawatt-hour (MWh). We assume that each ton of estimated methane emissions from mines, wells, and pipelines is counted as equal to 32 tons of CO_2.
- We assume damage per short ton of CO_2 is $61 if emitted in 2035 and $77 if emitted in 2050 (IAWG, 2021). We use social cost per short ton of methane from Marten and Newbold (2012), which is $2,003 if emitted in 2035 and $2,783 if emitted in 2050. For health damages, we use a linear approximation of the U.S. Environmental Protection Agency's COBRA air pollution model to estimate the number of premature deaths due to emissions (EPA, 2018), and then translate those into costs using values of $13.4 million per infant premature death and $12 million per adult premature death in 2050 and lower in 2035. These mortality valuations are based on (EPA, 2013) updated to 2035 and 2050 in accordance with (EPA, 2014).

Assumptions and Considerations (con't.)

- Our modeling might overstate the cost of a CES, because it is conservative about the affordability of CESs and utility-led decarbonization in several ways. In our modeling, Canadian generation cannot earn CES credits, electricity demand is not affected by electricity prices, natural gas prices are not affected by natural gas use, and the capacities of all transmission lines increase by the same percentage instead of capacity increasing more where it is more valuable. Each of these simplifications omits features of reality that would in fact reduce the cost of a CES and of utility-led decarbonization.

- A more extensive technical analysis will be released by REBA Institute and Resources for the Future in Fall 2021, and will provide an updated evaluation and more detail about results, implications, methods, and assumptions.

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