RESOURCES *for the* FUTURE

Emissions Projections for a Trio of Federal Climate Policies

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With the Biden Administration's recent announcement of the American Jobs Plan and nationally determined contribution (NDC) under the Paris Agreement, and as Congress begins to seriously consider legislation to advance clean energy and cut greenhouse gas emissions, RFF researchers have been investigating environmental outcomes under various policy scenarios. In this issue brief, we provide a snapshot from this work—including estimates of energy-related CO_2 emissions and cost-effectiveness.

Policy Scenarios

We compare three prominent proposals being discussed by federal policymakers:

- A simplified version of the recently re-introduced Clean Energy for America Act (CEAA), which provides tax incentives for renewables, energy efficiency, electric vehicles and more
- A Clean Electricity Standard (CES) based on the 2019 Smith-Lujan proposal, which stipulates a schedule for the decarbonization of the electricity sector
- An economy-wide carbon tax starting at $15 per ton and rising at 5 percent real per year (C$15)

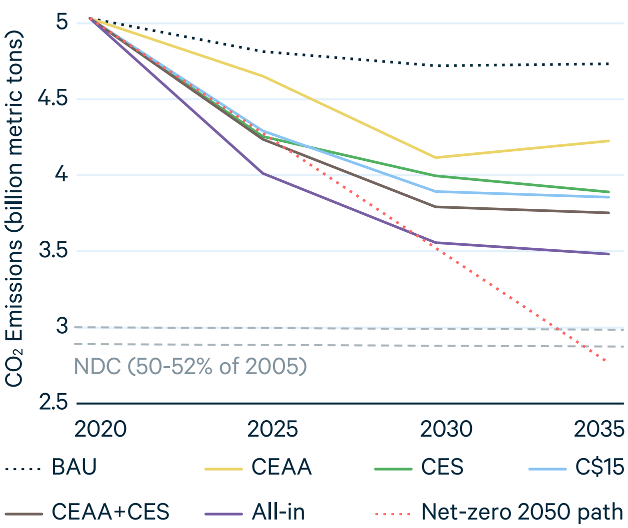
We model energy-related US CO_2 emissions under each of these policies, various combinations thereof, and business-as-usual (BAU) assumptions. In our "All-in" scenario, we also include federal spending on electric vehicle charging infrastructure and residential building weatherization. Table 1 summarizes the policy scenarios included, with more detail in the appendix. Note: this analysis is calibrated to pre-COVID projections (see appendix), which yields conservative emissions estimates.

Table 1. Policy Scenarios Included in This Analysis

Abbreviation	Policy Scenario	Key Features
BAU	Business-as-usual / Reference case	Calibrated to AEO 2019 & 2020
CEAA	Clean Energy for America Act (CEAA)*	Clean electricity and energy storage tax credits, extension of 30D EV incentives, EE tax credits
CES	Clean Energy Standard (CES)	80% clean by 2032, with banking
C$15	Carbon tax	Starting price: $15, gr. rate: 5% real
CEAA+CES	Combined CEAA and CES	See above
All-in	C$15 + CEAA + CES + weatherization and EV charging infrastructure spending	See above

* This is an incomplete representation of the CEAA, see appendix for details.

Figure 1. National CO_2 Emissions by Policy Scenario



Energy-Related Emissions Estimates Under the Various Policy Scenarios

As shown in Figure 1, all policy scenarios make progress cutting emissions from BAU. Across the policy scenarios studied, estimates of economy-wide energy-related CO_2 reductions in 2030 range from roughly 10 to 25 percent from BAU and 30 to 40 percent from 2005 levels.

The CES and $15 carbon tax produce similar emissions trajectories through 2035, with steeper reductions than the CEAA early-on and after 2030. The CEAA and CES combined are an improvement over all individual policies, reducing emissions by approximately 37 percent from 2005 levels in 2030. The All-in scenario, which combines all three policies and federal spending on weatherization and EV charging is estimated to cut 2030 emissions by 41 percent from 2005.

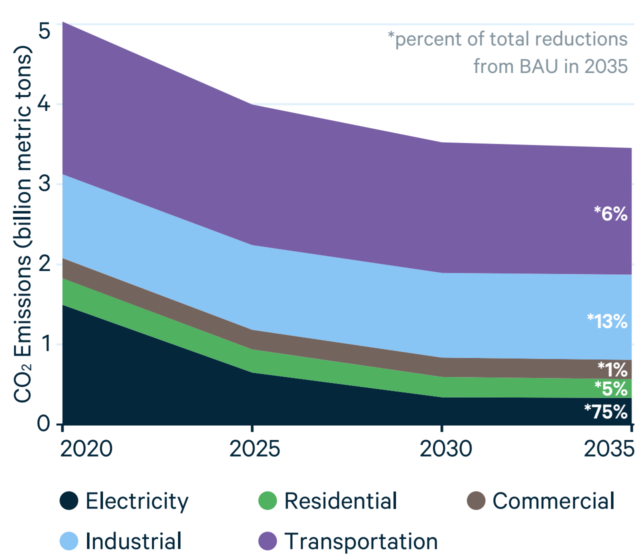
While all scenarios make progress on emissions goals, none hit the NDC target of a 50-52 percent reduction from 2005 levels by 2030, indicating that additional policies and/or greater policy ambition are needed.

Additionally, none of the policy scenarios maintain a reduction path commensurate with what would be needed to reach net-zero by 2050 (as projected linearly from 2020), however a number of scenarios do maintain such a path through 2025 and one (All-in) through 2030. While not shown here, even if a CES were designed to achieve 100% clean by 2035 and combined with all the other policies we study, emissions would still not be on track to hit the midcentury target—policies that substantially cut emissions from sectors other than electricity will be needed as well.

One reason for misalignment with midcentury targets is that almost all policy scenarios hit a plateau around 2030. This is largely because these policies—even when combined—lose effectiveness in the electricity sector over time (discussed below), and the vast majority of emissions reductions come from electricity through 2035.

Indeed, as shown in Figure 2, under the All-in scenario, about 75 percent of 2035 reductions from BAU come from electricity. The next greatest portion (13 percent) comes from the industrial sector, driven exclusively by the carbon tax. Reductions in the transportation sector are mostly driven by existing policy, which includes the national fuel economy/GHG standards for passenger vehicles and the Zero Emission Vehicle (ZEV) program, which sets sales targets for electric vehicles in California and 12 other states. New policy, particularly subsidies for electric vehicles, largely shifts costs of meeting

Figure 2. National CO_2 Emissions by Sector (All-in Scenario)



the national standards and ZEV requirements from automakers and consumers to taxpayers, without substantially reducing national emissions—the All-in scenario only reduces 2035 emissions 6 percent below BAU (driven entirely by the carbon tax). With electricity emissions declining so much (in this and other scenarios), the major challenge going forward will be to reduce emissions from the transportation and industrial sectors—which, under All-in , represent nearly 80 percent of US energy-related CO_2 emissions in 2035.

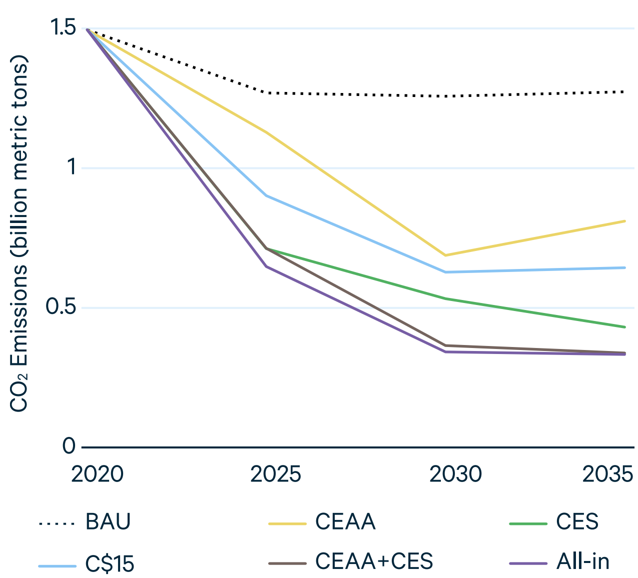
In Figure 3, we take a closer look at the electricity sector. Of the individual policies, the CES reduces emissions most, both in the near- and long-term. And, because the CES and the CEAA together cut electricity emissions so significantly, the addition of the modest $15 carbon tax in the All-in scenario has little to no additional effect on electricity emissions.

None of the policy scenarios studied achieve the Biden goal of net-zero carbon electricity by 2035, but they make solid progress—between a 65 and 85 percent reduction in CO_2 emissions by 2035 (from 2005 levels).

As mentioned above, all policies lose effectiveness over time in the electricity sector—indicated by flattening (and in some cases rising) curves after 2025. Why is this? Both the CES and the CEAA promote clean electricity, which primarily replaces coal in the early 2020s, and natural gas in the late 2020s and 2030s. This declining carbon intensity of the replaced electricity partially accounts for the decreasing emissions slopes. Additionally, by the 2030s, most renewables that are cheaper than natural gas (including tax credits) have been built; and the remaining gas in the system is either cheaper than renewables, or necessary for system balancing.

Post-2030, more stringent carbon pricing, richer tax credits, steeper CES requirements, or policies that target natural gas electricity emissions or promote clean firm resources—such as energy storage—would be necessary to achieve the 100% clean goal by 2035.

Figure 3. Electric Power CO_2 Emissions by Policy Scenario



Cost-Effectiveness of Policy Scenarios in Reducing Electricity Emissions

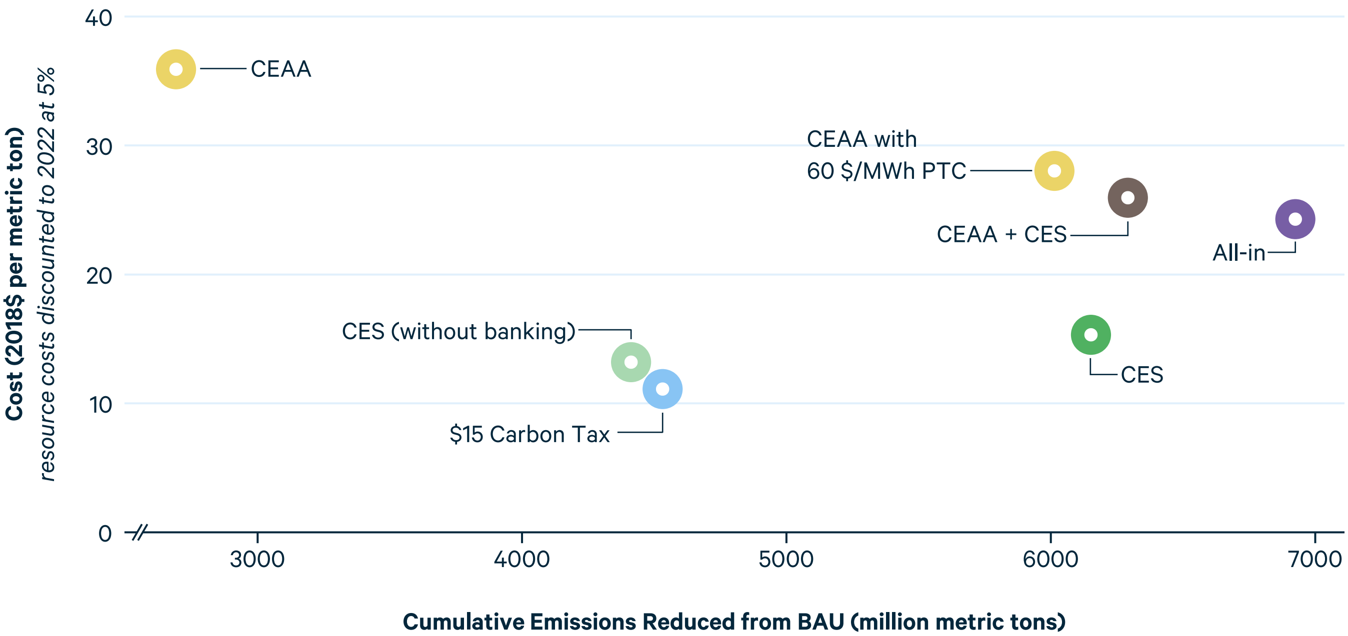
Considering electricity sector effects only, Figure 4 displays cost-effectiveness of the policy scenarios discussed above, along with two additional scenarios—one which assumes a higher tax credit for clean electricity (6 cents per kWh, or $60 per MWh), and a CES with no credit banking.

We measure cost-effectiveness as the change in total resource cost[1] from BAU (discounted over the 10-year budget window) divided by the cumulative emissions reduction from BAU. A lower number on the vertical axis indicates greater economic efficiency in achieving a given emissions reduction.

Policies that provide incentives to pursue numerous options for emissions reductions tend to be more cost-effective than narrowly targeted approaches. The CES is more cost-effective (and more effective at reducing emissions regardless of cost) than the CEAA because it applies to a broader set of clean generators, including existing nuclear, although it also gives credits to existing renewable resources that may not need further incentives

1 Resource costs are the sum of electricity sector fuel costs, variable operations and maintenance costs, fixed operations and maintenance costs, and annualized capital costs.

Figure 4. Cost-Effectiveness of Policy Scenarios (electricity sector effects only)



to generate. It also provides some incentive to move from coal to natural gas by providing partial credits to efficient natural gas plants. The carbon tax is more cost-effective than the CEAA because it increases the market price of all emitting generation, whereas the CEAA simply changes the price of renewables constructed in 2022 or later. We also find the CEAA energy efficiency incentives to be inefficient at reducing emissions, but may be necessary to meet electrification and equity goals. When coupled with a carbon tax or CES, the CEAA amplifies emissions reductions and increases the cost per ton of achieving those reductions.

The CES performs comparably to a modest carbon price and, when credits are bankable, cumulative emissions are reduced by an additional 40 percent below BAU while only increasing the average cost by roughly $2 per ton. Enabling banking for any multipolicy scenario involving a CES also leads to greater reductions in emissions and relative costs. Achieving CES (with banking) levels of emissions reductions using tax credits alone—albeit with less cost-efficiency—would require the CEAA's PTC to be raised by over 150 percent of its current level to $60/MWh.

Conclusion

The policy scenarios discussed in this brief produce reductions in energy-related CO_2 emissions between 10 to 25 percent from BAU—and 30 to 40 percent from 2005—by 2030. None of these scenarios achieve reductions commensurate with the recently announced 2030 NDC, the Biden administration 2035 target for electricity, or midcentury emissions targets identified by IPCC scientists to avoid potentially catastrophic climate change.

One reason for this may be the fact that we calibrate our models to pre-COVID energy and emissions projections (see appendix), which produces conservative estimates in all years of our analysis. Uncertainty remains about the pace and shape of the economic recovery, as well as the extent to which COVID-induced behavior changes (e.g., working from home) will persist even after society restabilizes, and how this may effect emissions in 2030 and 2035.

In any case, greater ambition under this suite of policies is one way to reduce emissions further—for example, by increasing tax credit and/or carbon price levels, or by designing a CES with a more stringent decarbonization path than the one we model here (as **current approaches** indeed propose).

Another approach would be to broaden the set of policy tools beyond what we study here (which we recognize is a small sample of the climate policy ideas being discussed in Washington). With electricity emissions declining 65-85 percent by 2035 (from 2005 levels) under the scenarios we study, leaders will need to devote attention to other sectors, including the transportation and industrial sectors which together account for 70-80 percent of emissions in 2035 under the scenarios we analyze.

Our research also indicates that policies which incentivize a diversity of decarbonization pathways tend to be more cost-effective than more narrowly targeted approaches.

While the policies we study may not achieve the administration's emissions goals, they represent a significant down payment on those goals, and they show that—with additional policy and refinements to existing approaches—these goals are within reach.

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Appendix

In this appendix, we list key assumptions applied in our analysis (organized by reference and policy cases), and we provide brief descriptions of the models used.

Assumptions Regarding the Reference Case

Model reference case (or business-as-usual, BAU) assumptions are calibrated to EIA's Annual Energy Outlook (AEO) 2019 and 2020 reference cases. This means the models do not take into consideration the effects of COVID-19 on the economy or emissions (which are incorporated for the first time in AEO 2021). To give a rough sense of scale, pre-COVID BAU emissions projections are about 10 percent higher in 2020, and 3-4 percent higher in each of 2025, 2030 and 2035, compared to post-COVID projections.

Electricity and Transportation Models – AEO 2019

The electricity and light duty transportation models calibrate to AEO 2019. This implicitly includes the following major policy assumptions (think of these as policies included in the reference case):

- No Clean Power Plan
- Obama CAFE standards still in effect
- ZEV mandate in effect and federal plug-in vehicle tax credit (30D) phases out after manufacturers exceed 200,000 sales

For assumptions about other policies assumed active in AEO 2019: **https://www.eia.gov/outlooks/archive/aeo19/assumptions/pdf/summary.pdf**.

For additional general AEO 2019 assumptions see: **https://www.eia.gov/outlooks/archive/aeo19/assumptions/**.

Economy-Wide Model – AEO 2020

The economy-wide model calibrates to AEO 2020. This implicitly includes the following major policy assumptions:

- No Clean Power Plan
- Obama CAFE standards still in effect
- ZEV mandate not in effect (Trump admin. refusal to renew CAA Sec 209 waiver)

For assumptions about other policies assumed active in AEO 2020: **https://www.eia.gov/outlooks/archive/aeo20/assumptions/pdf/summary.pdf**.

For additional general AEO 2020 assumptions see: **https://www.eia.gov/outlooks/archive/aeo20/assumptions/**.

Assumptions Regarding Modeled Policy Scenarios

Carbon Tax

- Policy start: Jan 1, 2023
- Starting tax rates: $15 per metric ton
- Real annual growth rate: 5%

Clean Energy for America Act (CEAA)

- Electricity generation PTC and ITC
  - Policy start: Jan 1, 2023
  - *PTC*
    - Qualifying Fuels: Wind, Solar, Hydro (Non-buildable), Nuclear (Non-buildable), Geothermal (Non-buildable), Biomass
    - Price: $24 (2020$)/MWh starting in 2023 (assumes full value of tax credit goes to generators, which may not be the case in the context of tax equity market transaction costs and mark-downs)
    - New plants qualify for 10 years of credits
  - *ITC*
    - Qualifying Fuels: Battery Storage
    - Price: 30% discount on capital costs beginning in 2023 (assumes full value of tax credit goes to generators, which may not be the case in the context of tax equity market transaction costs and mark-downs)

        - New plants qualify for 10 years of credits
- Energy efficiency tax credits
    - Policy start: Jan 1, 2022
    - New Homes
        - Whole-home energy reduction
        - 10% more efficient than IECC 2021 -> $2500
    - Home Improvements
        - Replacing heating and cooling systems
            - Min (30% of the replacement, $500) per appliance
            - Up to $800 for air source heat pumps and ductless mini-split heat pumps
            - Up to $10,000 for ground source heat pumps
    - New Commercial Buildings
        - 25% more efficient than ASHRAE 90.1-2016 -> $1.75/sqft
- Electric vehicle tax credits
    - Policy start: Jan 1, 2022 and ends December 31, 2031. Vehicle tax credits are available for all plug-in vehicle purchases, regardless of manufacturer's cumulative sales.

Clean Energy Standard (CES)

- Policy start: Jan 1, 2022
- Starting Requirement: 44% of national retail sales must be clean generation in 2022.
- 1st Segment: linear increase to 80% clean generation by 2032 (3.6% /year)
- 2nd Segment: linear increase to 100% clean generation by 2050 (1.11% per year)
- Benchmark Emission Rate: .4 metric tons / MWh (modeled as .44 short tons / MWh)
- Banking and no-banking scenarios considered

Other

- EV charging infrastructure spending is included in the All-in scenario. Spending assumptions: $1 billion per year from 2022 through 2031. Each charging station costs $50,000, and charging stations are allocated across regions according to the region's share in total new vehicle sales in 2018. The effect of charging stations on EV sales is calibrated based on regional trends from 2015-2018.
- Weatherization spending ($5 billion per year) is included in the All-in scenario.

Model Descriptions

The following models were used for this analysis. Results from each of these three models were combined to produce the estimates discussed above.

E3 Computable General Equilibrium (CGE) Model (Marc Hafstead)

The Goulder-Hafstead Energy-Environment-Economy E3 CGE Model is an economy-wide model of the United States with international trade. The model has two key features that distinguish it from most other CGE models. First, it combines a detailed description of domestic energy supply and demand with a detailed treatment of the US tax system, which allows for a careful examination of the interactions between climate and fiscal policies. Second, the model combines capital adjustment costs and perfect foresight to consider the dynamics of investment and disinvestment in response to climate policy. The current iteration of the model is benchmarked to 2018 data from the BEA and is carefully calibrated to both benchmark year data on energy use by fuel and sector from the EIA and EIA's AEO 2020 projections of energy use and GDP.

Haiku Electricity Sector Model (Karen Palmer, Dallas Burtraw, Maya Domeshek, Nick Roy)

The Haiku model is a detailed dynamic linear programming model of the US electricity sector. The model solves for investment and retirement of generation capacity over a 25-year horizon, with annual operation of the electricity system represented in eight time-blocks in each of three seasons (winter, summer and spring/fall). Electricity market equilibria are solved at the state level, allowing for state-level representations of environmental policies and regulatory practice, with interstate transmission capability calibrated to observed transactions in recent data. The model includes representations of existing power plants categorized by technology and fuel, and new options for investment in both fossil plants and various renewable options that capture costs and performance characteristics including resource availability by location and time block. Forecasted demand for electricity is fixed in any given model solution based on forecasts from EIA and is modified across scenarios to reflect the effects of policies such as vehicle electrification or increased investment in energy efficiency. The model solves for generation by model plant, costs and emissions of CO_2 based on fuel type and heat rates at emitting generators.

Energy Efficiency Model (Kenneth Gillingham, Qinrui Xiahou)

The energy efficiency modeling uses a back-of-the-envelope approach that accounts for four tax credits in the CEAA—those that apply to: new homes, home improvements, weatherization, and new commercial buildings.

For new homes and weatherization, the analysis is conducted at the climate zone level. The total energy saving is the weighted sum of the product of energy intensity savings, the number of new homes, the average floor area and participation rates. Energy intensity savings come from DOE's analyses of building codes; participation rates are estimated based on the energy efficiency distribution from the 2015 RECS Survey and existing WAP practice; and other parameters are acquired from the U.S. Census Bureau.

For home improvements, the calculations use empirical results on the effect of rebate policies on the sales share of Energy Star appliances. Along with efficiency improvement and sales data from the Energy Star website, the total energy saving is the sum of efficiency gains deriving from additional sales over major heating and cooling systems.

For commercial buildings, the parameters are collected and calibrated for each building type. The total energy saving aggregates the participation rates estimated based on the energy efficiency distribution from the 2012 CBECS Survey, the energy intensity savings from DOE's estimations, and the number of buildings and average floor area forecasted with historical data from EIA.

In all the analyses, it is assumed that savings for each energy type (natural gas, petroleum, electricity, etc.) are proportional to their shares of residential/commercial energy consumption at the national level.

Light-Duty Vehicle Model (Josh Linn)

The transportation model embeds a model of the new vehicle market in a representation of the on-road fleet of light-duty passenger vehicles. In the model of the new-vehicle market, vehicle manufacturers maximize profits by choosing the prices and fuel economy of their vehicles while complying with federal fuel economy/ GHG standards and the ZEV program. Consumers in the model choose a vehicle that maximizes their own subjective well-being. All parameters of the model have been estimated or calibrated using a unique data set that is derived from survey data from approximately 1.5 million car-buying households from 2010-2018. For a given set of policy and fuel price assumptions, the model characterizes the equilibrium prices, sales, and GHG emissions rates of new vehicles by year and demographic group from 2017-2035.

Emissions of the on-road fleet are estimated from a model of the stock of light-duty vehicles. The stock evolves over time as new vehicles are purchased and older vehicles are scrapped. Utilization of each vehicle in the fleet depends on total national vehicle miles traveled (VMT), driving preferences of demographic groups, and fuel costs of the vehicle relative to other vehicles. For each scenario, key inputs to the model include a) projected aggregate VMT and fuel prices from the 2019 AEO; b) sales and GHG emissions rates of new vehicles as described above; and c) scrappage rates. Emissions are calculated for each policy scenario and year from 2017-2035.