# Investing in American Energy:

## Impacts of the Inflation Reduction Act and Bipartisan Infrastructure Law on the U.S. energy economy and emissions reductions

## Technical Appendix

## Background

### OP-NEMS

OP-NEMS is a version of the National Energy Modeling System (NEMS) developed by the DOE Office of Policy (OP). NEMS is the primary model used for economy-wide energy system modeling for the U.S. government and is used to develop key analyses including the U.S. Energy Information Administration (EIA) Annual Energy Outlook.

Details on OP-NEMS model development can be found at Office of Policy - National Energy Modeling System (OP-NEMS) | Department of Energy. Details on the NEMS framework can be found at Model Development - U.S. Energy Information Administration (EIA).

Several sections of OP-NEMS are based on the DOE Office of Fossil Energy and Carbon Management (FECM-NEMS) version of NEMS developed by OnLocation, Inc, and supported by FECM. OP-NEMS represents new and modified carbon capture, transport, and storage (CCS) technologies that are not covered by the EIA NEMS model including ethanol, natural gas processing, hydrogen in refineries, and cement in industry, and biomass cofiring in power plants (BECCS). OP-NEMS also represents applications of clean hydrogen production and uses with exogenous inputs developed by the DOE Office of Energy Efficiency and Renewable Energy (EERE).

### Model Scenarios

This analysis uses two scenarios to evaluate the possible impacts of both laws on the U.S. energy system:

- **Moderate Scenario:** Assumes moderate technology costs and assumptions around IRA and BIL implementation
- **Advanced Scenario:** Assumes more aggressive technology cost reductions and higher impact from the IRA and BIL provisions

Both scenarios are based on a Pre-IRA/BIL baseline scenario (**No BIL/IRA**). The No BIL/IRA scenario is built in OP-NEMS to be analogous to the EIA Annual Energy Outlook 2022 (AEO2022), the most updated publicly available version of the AEO available at the time of modeling, with a few notable additions. First, the No BIL/IRA scenario adjusts macroeconomic assumptions to reflect updated assumptions used in the AEO2023. The No BIL/IRA Policy scenario also includes policies other than IRA and BIL that were

finalized after the publication date for AEO2022, as well as modified technological assumptions, including:

(1) Updated EPA/NHTSA Corporate Average Fuel Economy (CAFE) standards from 2023 to 2026[i,ii]
(2) Updated state-based zero-emission vehicle (ZEV) requirements to reflect the end of the moratorium on state programs in 16 states[1,iii]
(3) Updated technology costs and characteristics for power sector renewable and carbon capture technologies based on the 2022 Annual Technology Baseline (ATB) from the National Renewable Energy Lab (NREL)[2,iv]
(4) Updated technology costs for electric light-duty vehicles and fuel economy for electric medium-heavy-duty vehicles based on Argonne National Laboratory (ANL)[3,v]

## Representing BIL and IRA in OP-NEMS

The results of this analysis will differ from the EIA's AEO 2023, which also modeled portions of IRA, for two key reasons. First, this analysis applies a fuller representation of IRA than AEO 2023. The EIA explicitly did not model IRA provisions that: i) did not have policy guidance available at the time of analysis, ii) required significant model modifications, and iii) required more granular geographic resolution. Second, the underlying technology assumptions and NEMS module structure in OP-NEMS differs from that of the AEO, using technology costs from the Annual Technology Baseline produced by the National Renewable Energy Laboratory (NREL) and vehicle costs produced by Argonne National Laboratory (ANL). This analysis leverages DOE experts' best judgment on policy implementation to represent key IRA provisions, including a series of new and extended tax credits for clean power supply and infrastructure, tax credits for transportation electrification, several grant and loan programs, and other non-credit policies. Some provisions are still not modeled due to limitations in the NEMS modeling structure. Modeled provisions are listed in Table 1. More specific implementation is outlined in Table 2.

**Table 1. Comparison of IRA provisions modeled in OP-NEMS 2023 and AEO 2023.** This table is not an exhaustive list of provisions in IRA. Rather, it is a list of all provisions modeled in OP-NEMS and a cross check of whether they were also modeled for AEO 2023. Rows shaded grey are provisions that have diverging implementation. Note that provisions that are implemented in both OP-NEMS and AEO 2023 may have been implemented differently.

| Sector | Section | Tax Code | Provision | OP-NEMS 2023 | AEO 2023 |
|---|---|---|---|---|---|
| Electricity | 13101 | 45 | Production Tax Credit for Electricity from Renewables | Yes | Yes |
| Electricity | 13102 | 48 | Investment Tax Credit for Energy Property | Yes | Yes |
| Electricity | 13701 | 45Y | Clean Electricity Production Tax Credit | Yes | Yes |
| Electricity | 13702 | 48D | Clean Electricity Investment Tax Credit | Yes | Yes |

[1] California, Colorado, Connecticut, Delaware, Maine, Maryland, Massachusetts, Minnesota, New York, New Jersey, Nevada, Oregon, Rhode Island, Washington, Vermont, and Virginia have ZEV requirements.
[2] NREL (National Renewable Energy Laboratory). 2022. 2022 Annual Technology Baseline. Golden, CO: National Renewable Energy Laboratory.
[3] ANL (Argonne National Laboratory) 2022, U.S. DOE VTO/HFTO Transportation Decarbonization Analysis

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|---|---|---|---|---|---|
| Electricity | 13105 | 45U | Zero-Emission Nuclear Power Production Credit | Yes | Yes |
| Electricity | 13703 | 168(e)(3)(B) | Cost Recovery for Qualified Facilities, Qualified Property, and Energy Storage Technology | Yes | Yes |
| Electricity | 22001 | | Electric Loans for Renewable Energy | Yes | No |
| Electricity | 22002 | | Rural Energy for America Program | Yes | No |
| Electricity | 22004 | | USDA Assistance for Rural Electric Cooperatives | Yes | No |
| Transportation | 13401 | 30D | Clean Vehicle Credit | Yes | Exogenous |
| Transportation | 13403 | 45W | Commercial Clean Vehicles Credit | Yes | No |
| Transportation | 70002 | - | U.S. Postal Services Clean Fleets | Exogenous | No |
| Transportation | 60102 | - | Grants to Reduce Air Pollution at Ports | Exogenous | No |
| Transportation | 60101 | - | Clean Heavy Duty Vehicles | Exogenous | No |
| Transportation | 11402 | - | Port Infrastructure Development Program | Exogenous | No |
| Fuels and Refineries | 13201 | 40A, 6426(c),6427(e) | Extension of Tax Credits for Biodiesel and Renewable Diesel | Yes | Yes |
| Fuels and Refineries | 13202 | 40 | Extension of Second Generation Biofuel Incentives | Yes | Yes |
| Fuels and Refineries | 13203 | 40B | Sustainable Aviation Fuel Credit | No | Yes |
| Fuels and Refineries | 13704 | 45Z | Clean Fuel Production Credit | Yes | Yes |
| Fuels and Refineries | 13204 | 45V | Clean Hydrogen Production Tax Credit | Exogenous | No |
| Buildings | 13301 | 25C | Energy Efficient Home Improvement Credit | Yes | Yes |
| Buildings | 13302 | 25D | Residential Clean Energy Credit | Yes | Yes |
| Buildings | 13304 | 45L | New Energy Efficient Homes Credit | Yes | Yes |
| Buildings | 13303 | 179D | Energy Efficient Commercial Buildings Deduction | Yes | No |
| Buildings | 50121 | - | Home Energy Performance Based, Whole House Rebates (HOMES) | Yes | No |
| Buildings | 50122 | - | High Efficiency Electric Home Rebate Program | Yes | No |
| Buildings | 50131 | - | Assistance for Latest and Zero Building Energy Code Adoption | Yes | No |
| Buildings | 60502 | - | Assistance for Federal Buildings | Yes | No |
| Buildings | 40502 | - | Energy Efficiency Revolving Loan Fund Capitalization Grant Program | Yes | No |
| Buildings | 40551 | - | Weatherization Assistance Program | Yes | No |
| Buildings | 40109 | - | State Energy Program | Yes | No |
| Buildings | 40552 | - | Energy Efficiency and Conservation Block Grant Program | Yes | No |
| Buildings | 40554 | - | Assisting Federal Facilities with Energy Conservation Technologies Grant Program | Yes | No |

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|---|---|---|---|---|---|
| Industry | 50161 | | Advanced Industrial Facilities Deployment Program | Yes | No |
| Industry | 13501 | 48C | Advanced Energy Project Credit | Yes | No |
| Industry | 60503 | - | Use of Low Carbon Materials | Partial [4] | No |
| Industry | 60506 | - | Low Carbon Transportation Materials Program | Yes | No |
| Cross-cutting | 13104 | 45Q | Credit for Carbon Oxide Sequestration | Yes | Yes |
| Cross-cutting | 50144 | - | 1706 Program (Energy Infrastructure Reinvestment Financing) | Yes | No |
| Cross-cutting | 50261 | | Offshore Oil and Gas Royalty Rate | Yes | Yes |
| Cross-cutting | 50262 | | Mineral Leasing Act Modernization | Yes | Yes |
| Cross-cutting | 60114 | | Climate Pollution Reduction Grants | Yes | No |
| Cross-cutting | 60201 | | Environmental and Climate Justice Block Grants | Yes | No |
| Cross-cutting | 60103 | | Greenhouse Gas Reduction Fund | Yes | No |

**Table 2: Implementation of key IRA and BIL provisions in OP-NEMS.** This table is not an exhaustive list of provisions in IRA.

| Electricity Sector | | | | |
|---|---|---|---|---|
| **Policy** | **Section** | **Tax Code** | **Provision** | **Implementation** |
| IRA | 13101 | 45 | Production Tax Credit for Electricity from Renewables | Both scenarios: Assume prevailing wage and apprenticeship requirements can be met; credits applied to facilities built in 2022-2024, at which point the technology-neutral 45Y credit takes over<br>Moderate scenario: Assume 10% bonus credit achieved either by meeting domestic content or energy communities requirements.<br>Advanced scenario: Assume average of 15% bonus credit achieved |
| IRA | 13102 | 48 | Investment Tax Credit for Energy Property | Both scenarios: Assume prevailing wage and apprenticeship requirements can be met; credits applied to facilities built in 2022-2024, at which point the technology-neutral 48E credit takes over<br>Moderate scenario: Assume 10 percentage point bonus credit achieved either by meeting domestic content or energy communities requirements.<br>Advanced scenario: Assume average 15 percentage point bonus credit achieved |
| IRA | 13701 | 45Y | Clean Electricity Production Tax Credit | Both scenarios: Assume prevailing wage and apprenticeship requirements are met<br>Moderate scenario: Assume 10% bonus credit achieved either by meeting domestic content or energy communities requirements. Credits continue through |

[4] This is modeled as an enabling policy in OP-NEMS, by increasing demand for low-carbon cement

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| | | | | 2050 because target emissions (75% below 2022 levels) are not met<br>Advanced scenario: Assume average of 15% bonus credit achieved and credits phase out after 2034 because target emissions (75% below 2022 levels) are met |
| IRA | 13702 | 48E | Clean Electricity Investment Tax Credit | Both scenarios: Assume prevailing wage and apprenticeship requirements are met<br>Moderate scenario: Assume 10 percentage point bonus credit achieved either by meeting domestic content or energy communities requirements. Credits continue through 2050 because target emissions (75% below 2022 levels) are not met<br>Advanced scenario: Assume average 15 percentage point bonus credit achieved and credits phase out after 2034 because target emissions (75% below 2022 levels) are met |
| IRA | 13105 | 45U | Zero-Emission Nuclear Power Production Credit | Both scenarios: Assume prevailing wage and apprenticeship requirements can be met to achieve bonus credit of up to $15/MWh for at-risk nuclear plants through end of 2032 |
| IRA | 13703 | 168(e)(3)(B) | Cost Recovery for Qualified Facilities, Qualified Property, and Energy Storage Technology | Both scenarios: All technologies that qualify under the Clean Electricity Credits provisions (45Y, 48D) are eligible for 5-year accelerated depreciation |
| IRA | 22001 | | Electric Loans for Renewable Energy | Both scenarios: USDA programs 22001 and 22002 were combined to fund new wind and solar PV power plants |
| IRA | 22002 | | Rural Energy for America Program | Both scenarios: USDA programs 22001 and 22002 were combined to fund new wind and solar PV power plants |
| IRA | 22004 | | USDA Assistance for Rural Electric Cooperatives | Both scenarios: Assumed to fund new wind, solar PV, and carbon capture power plants. |

| **Transportation** | | | | |
|---|---|---|---|---|
| **Policy** | **Section** | **Tax Code** | **Provision** | **Implementation** |
| IRA | 13401 | 30D | Clean Vehicle Credit | Moderate scenario: Average credit amounts are limited based on MSRP and annual gross income qualifications using assumptions in Slowik et al. (2023), as well as not all manufacturers meeting the battery and critical material requirements.<br>Advanced scenario: Similar to the Moderate scenario, except that vehicle credits are assumed to be greater due to an interplay with 45W, which increases the share of leased electric light-duty vehicles. |
| IRA | 13403 | 45W | Commercial Clean Vehicles Credit | Moderate scenario: Assume that the credit reduces incremental costs of clean vehicles, with a maximum credit amount of $7500 for Class 2b-3 vehicles and $40,000 for Class 4-8 vehicles |

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| | | | | Advanced scenario: EV sales shares are based on national adoption of Advanced Clean Truck (ACT) rule, representing target adoption<br>Both scenarios: Zero-emission bus shares are added exogenously based on outputs from Slowik et al. (2023) as NEMS does not model economic competition for buses |
| IRA | 50142 | - | Advanced Technology Vehicle Manufacturing | Advanced Scenario: Provide loans to develop domestic supply chains for battery components and critical minerals used in clean vehicle batteries. |
| IRA | 50143 | - | Domestic Manufacturing Conversion Grants | Advanced Scenario: Provide grants to develop domestic supply chains for battery components and critical minerals used in clean vehicle batteries. |
| IRA | 70002 | - | U.S. Postal Services Clean Fleets | Both scenarios: Assume zero-emission vehicle purchases based on the USPS public purchase schedule |
| IRA | 60102 | - | Grants to Reduce Air Pollution at Ports | Moderate scenario: Assume that most of the program is used to provide funding for direct measures with the remainder used for planning, permitting, and climate action plans. funding for zero-emission vehicles at ports based on exogenous DOE modeling<br>Advanced scenario: See 45W |
| IRA | 60101 | - | Clean Heavy Duty Vehicles | Moderate scenario: Assume program is used to replace Class 6 and Class 7 vehicles based on a schedule from exogenous DOE modeling<br>Advanced scenario: See 45W |
| BIL | 11402 | - | Port Infrastructure Development Program | Moderate scenario: Provides additional funds to scale the implementation of 60102<br>Advanced scenario: See 45W |

| **Fuels and Refineries** | | | | |
|---|---|---|---|---|
| **Policy** | **Section** | **Tax Code** | **Provision** | **Implementation** |
| IRA | 13201 | 40A, 6426(c),6427(e) | Extension of Tax Credits for Biodiesel and Renewable Diesel | Both scenarios: Extend credit for biodiesel and renewable diesel, alternative fuels, and alternative fuel mixtures through 2024 |
| IRA | 13202 | 40 | Extension of Second Generation Biofuel Incentives | Both scenarios: Extend credit for second generation biofuels through 2024 |
| IRA | 13704 | 45Z | Clean Fuel Production Credit | Both scenarios: Assume that the base credit is multiplied by the lifecycle greenhouse gas emissions of each fuel production process; assume that the prevailing wage requirements are met |

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| IRA | 13204 | 45V | Clean Hydrogen Production Tax Credit | Moderate scenario: Clean hydrogen demand is exogenously set to 2MMT H2 in 2030, or 20% of the Base case scenario in the U.S. National Hydrogen Strategy<br>Advanced scenario: Clean hydrogen demand is exogenously set to 10MMT H2, which is consistent with the Base case scenario in the U.S. National Hydrogen Strategy |

| **Buildings** | | | | |
|---|---|---|---|---|
| **Policy** | **Section** | **Tax Code** | **Provision** | **Implementation** |
| IRA | 13301 | 25C | Energy Efficient Home Improvement Credit | Both scenarios: Increase credit for home energy efficiency improvements to 30% and extend it through 2032 |
| IRA | 13302 | 25D | Residential Clean Energy Credit | Both scenarios: Extend the credit for qualified residential renewable energy |
| IRA | 13304 | 45L | New Energy Efficient Homes Credit | Both scenarios: Extend the new energy efficient home tax credit through 2032, modeling as a credit for new home shell packages. |
| IRA | 13303 | 179D | Energy Efficient Commercial Buildings Deduction | Both scenarios: The cost of high efficiency HVAC technologies is reduced to represent the impact of tax credits |
| IRA | 50121 | - | Home Energy Performance Based, Whole House Rebates (HOMES) | Both scenarios: The $4.3 billion made available through this program through FY2031 is assumed to go toward raising building shell indices to achieve estimated energy savings<br>Moderate scenario: Half of the estimated energy savings are attributed to shell improvement<br>Advanced scenario: Full energy savings are attributed to shell improvement |
| IRA | 50122 | - | High Efficiency Electric Home Rebate Program | Both scenarios: The $4.275 billion available through FY2031 is assumed to lower switching costs to electric heat pumps in the model |
| IRA | 50131 | - | Assistance for Latest and Zero Building Energy Code Adoption | Both scenarios: The $1 billion available through September 2029 is assumed to eliminate the two lowest tiers of residential building shell packages and assumed to adjust commercial new shell indices |
| IRA | 60502 | - | Assistance for Federal Buildings | Both scenarios: This program is combined with the AFFECT Program (BIL 40554) to improve efficiency based on DOE analysis |
| BIL | 40502 | - | Energy Efficiency Revolving Loan Fund Capitalization Grant Program | Both scenarios: This provision is assumed to result in energy saving through shell improvement in the same portion as the HOMES program (IRA Section 50121) |
| BIL | 40551 | - | Weatherization Assistance Program | Both scenarios: This provision is modeled to increase shell improvements in existing homes by scaling up the pre- |

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| | | | | existing weatherization program from 2023 through 2032, together with 40109 and 40522 |
| BIL | 40109 | - | State Energy Program | Both scenarios: Combined with 40551 and 40552 |
| BIL | 40552 | - | Energy Efficiency and Conservation Block Grant Program | Both scenarios: Combined with 40551 and 40109 |
| BIL | 40554 | - | Assisting Federal Facilities with Energy Conservation Technologies Grant Program | Both scenarios: This program is combined with IRA Section 60502 to improve efficiency based on DOE analysis |

| **Industry** | | | | |
|---|---|---|---|---|
| **Policy** | **Section** | **Tax Code** | **Provision** | **Implementation** |
| IRA | 50161 | | Advanced Industrial Facilities Deployment Program | Both scenarios: This funding is assumed to go toward additives in cement, carbon capture and sequestration and electrification options in cement, steel, glass, paper, and aluminum facilities |
| IRA | 13501 | 48C | Advanced Energy Project Credit | Both scenario: This 30% investment tax credit is assumed to combine with IRA Section 50161 in supporting industrial decarbonization at energy intensive facilities |
| IRA | 13102 | 48 | Investment Tax Credit for Energy Property | Both scenarios: The 48D tax credit is assumed to go toward natural gas combined heat and power facilities. Note that the IRA requires combined heat and power to be net-zero after 2025 |
| IRA | 60506 | - | Low Carbon Transportation Materials Program | Advanced scenario only: Assume funding used to enable green cement manufacturing |

| **Cross-cutting** | | | | |
|---|---|---|---|---|
| **Policy** | **Section** | **Tax Code** | **Provision** | **Implementation** |
| IRA | 13104 | 45Q | Credit for Carbon Oxide Sequestration | Both scenarios: Assume prevailing wage and apprenticeship requirements can be met to achieve bonus credits of $60/ton CO2 used for enhanced oil recovery (EOR) and $85/ton CO2 sent to saline storage. The credit is extended for power and industrial facilities that commence construction before 2032. Industrial carbon capture technologies include ethanol, hydrogen at refineries, natural gas processing, cement, and steel facilities with options for CO2 to EOR or saline storage |
| IRA | 50144 | - | 1706 Program (Energy Infrastructure Reinvestment Financing) | Advanced scenario: This funding is assumed to be used for industrial facilities with carbon capture in existing energy intensive industrial facilities |

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| IRA | 50261 | | Offshore Oil and Gas Royalty Rate | Both scenarios: Offshore oil and gas lease royalty rates are increased from 12.5% to 16.67-18.75% annually |
| IRA | 50262 | | Mineral Leasing Act Modernization | Both scenarios: Royalty rates for federal Mineral Leasing Act lands are increased from 12.5% to 16.67-18.75% per year for all leases beginning after 2024 |
| IRA | 60114 | | Climate Pollution Reduction Grants | Both scenarios: This provision is assumed to result in energy saving through shell improvement in the same portion as the HOMES program (IRA Section 50121) |
| IRA | 60201 | | Environmental and Climate Justice Block Grants | Both scenarios: This program provides $3 billion in grants and technical assistance to implement community-led projects in disadvantaged communities to address harms related to pollution and climate change. This analysis assumes a portion of this funding is combined with the HOMES program (IRA Section 50121) toward mitigation in residential buildings |
| IRA | 60103 | | Greenhouse Gas Reduction Fund | Both scenarios: Two thirds of the funding from this program is assumed to go toward additional residential building retrofits and commercial equipment subsidies, while one third of the funding is put toward increasing rooftop solar |

[i] U.S. Environmental Protection Agency. (2021). *Revised 2023 and Later Model Year Light-Duty Vehicle GHG Emissions Standards: Regulatory Impact Analysis* (EPA-420-R-21-028). https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1013ORN.pdf

[ii] National Highway Traffic Safety Administration (NHTSA). (2022). *Corporate Average Fuel Economy Standards for Model Years 2024–2026 Passenger Cars and Light Trucks* (49 CFR Parts 531, 533, 536, and 537). https://www.govinfo.gov/content/pkg/FR-2022-05-02/pdf/2022-07200.pdf

[iii] California Air Resources Board (CARB). (2017). *Advanced Clean Cars Midterm Review*. Advanced Clean Cars Midterm Review | California Air Resources Board

[iv] National Renewable Energy Laboratory. (2022). *2022 Electricity Annual Technology Baseline* [Dataset]. https://atb.nrel.gov/electricity/2022/index

[v] Ehsan Sabri Islam, Ram Vijayagopal, Aymeric Rousseau. "A Comprehensive Simulation Study to Evaluate Future Vehicle Energy and Cost Reduction Potential", Report to the US Department of Energy, Contract ANL/ESD-22/6, October 2022.