REPEAT Rapid Energy Policy Evaluation and Analysis Toolkit

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Zero-carbon Energy Systems Research and Optimization Laboratory

Climate Progress and the 117th Congress: The Impacts of the Inflation Reduction Act and Infrastructure Investment and Jobs Act

July 2023

Climate Progress and the 117th Congress: The Impacts of the Inflation Reduction Act and Infrastructure Investment and Jobs Act

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Forward

With the close of the 117th Congress in January 2023, REPEAT Project has completed a revised analysis of the climate and energy system impacts of legislation passed during this landmark session. This includes detailed analysis of the combined impacts of H.R. 5376, the **Inflation Reduction Act of 2022** (IRA) and H.R. 3684, the **Infrastructure Investment and Jobs Act of 2021** (IIJA). This report presents REPEAT Project's revised findings on the impact of these laws on the energy system and greenhouse gas emissions trajectory of the United States.

In this revised analysis, we have updated all assumptions to reflect the latest data available at year-end 2022[1] and improved the quality of source data and analysis on oil and gas sector methane emissions and abatement opportunities in agriculture and forestry sectors relative to our Preliminary Report on the Inflation Reduction Act released in August, 2022. This revised analysis now includes a range of three **Current Policies**[2] scenarios ('Conservative', 'Mid-range', and 'Optimistic') to better reflect uncertainty about the effectiveness of IRA and IIJA provisions and the potential impacts of constraints on supply chains and other rate-limiting factors.[3] This report also presents two benchmark scenarios: a **Frozen Policies (Jan. '21)** scenario which only reflects policies enacted as of the start of the 117th Congress in January 2021; and a **Net-Zero Pathway** scenario, which reflects a cost-effective pathway to reduce U.S. greenhouse gas emissions to 50-52% below 2005 levels by 2030 and net-zero by 2050, consistent with the United States' mid- and long-term climate mitigation goals.

In this report, you will find results for greenhouse gas emissions, clean energy and electric vehicle deployment, fossil energy production and use, and more, along with estimated impacts on energy expenditures, capital investment, energy supply-related employment, air pollution, and public health.

Given the significant uncertainty about future outcomes, **all results in this report should be considered approximate**. REPEAT Project updates our analysis regularly as new data and inputs become available and new policies are proposed and enacted.

Note that this work has not been subject to formal peer review.

1 – This includes an increase in near-term fossil fuel prices due to Russia's invasion of Ukraine and revised assumptions on electric vehicle uptake reflecting current market trends.

2 – Note that this report does *not* include the impact of light duty vehicle tailpipe emissions standards through MY2026 or heavy-duty vehicle soot rule for MY2027+ finalized in late 2022. However, modeled results are very close to compliant with these rules in all cases. Both will be explicitly treated in subsequent REPEAT Project analysis later this year.

3 – See http://bit.ly/REPEAT-Policies for a complete list of policies in IRA and IIJA and assumptions and treatment of each policy under the three Current Policies scenarios.

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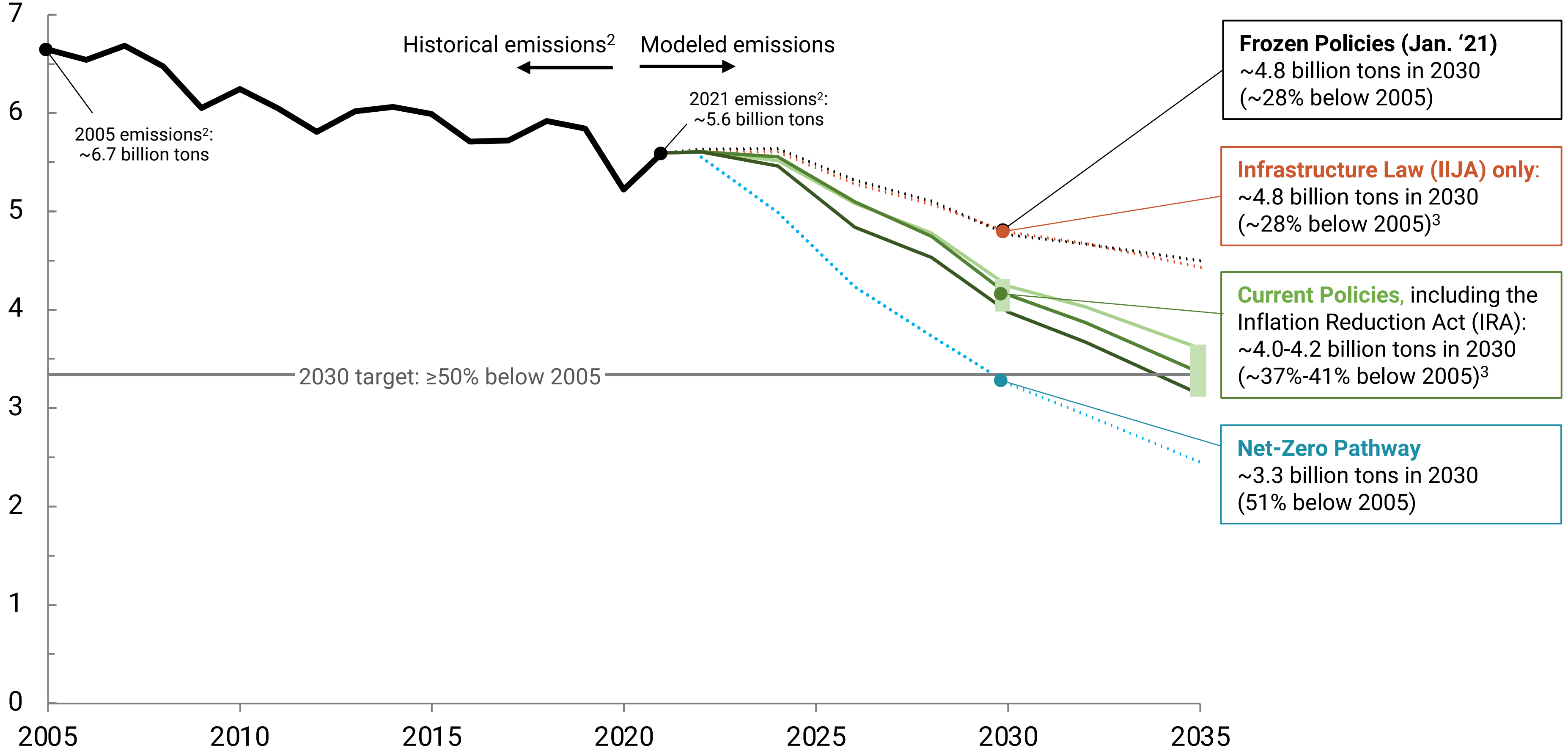
Executive Summary

Historical and Modeled Net U.S. Greenhouse Gas Emissions (Including Land Carbon Sinks)

billion metric tons CO_2-equivalent (Gt CO_2-e)[1]



Legislation enacted by the 117th Congress could:

- **roughly double the pace of annual U.S. decarbonization** to ~4%/year.
- cut annual emissions in 2030 by **520-780 million metric tons** relative to the Frozen Policies scenario.
- **get the U.S. to ~37-41% below 2005 historical GHG emissions** (vs national target of 50-52%)
- **reduce cumulative GHG emissions by about 3.4-5.6 billion tons over the next decade** (2023-2032).

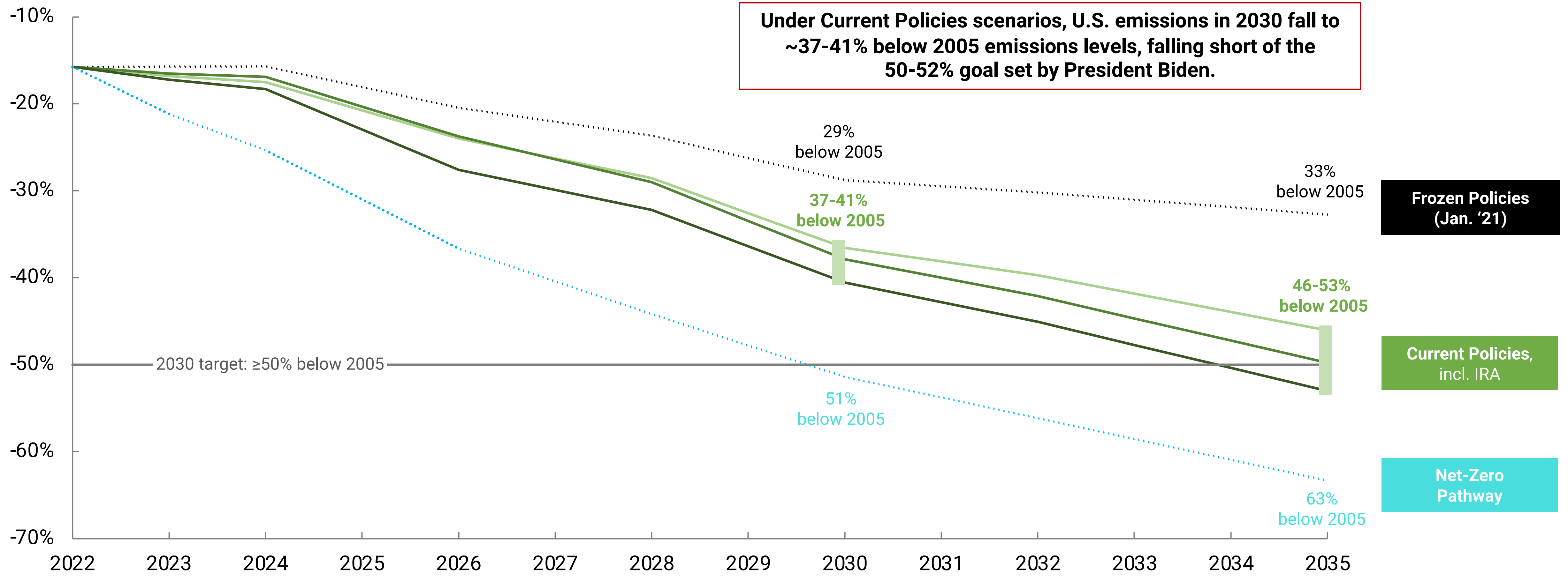
1 - CO_2-equivalent emissions calculations use IPCC AR4 100 year global warming potential as per EPA Inventory of Greenhouse Gas Emissions and Sinks. **All values should be regarded as approximate given uncertainty in future outcomes.**

2 - Historical data from U.S. EPA Inventory for 2005-2020; 2021 estimate from February 2023 draft EPA Inventory.

3 - Modeled emissions exclude any changes in passenger and freight miles traveled due to surface transportation, rail, and transit investments in IIJA. According to the Georgetown Climate Center, emissions impact of these changes depend heavily on state implementation of funding from IIJA, which could result in anywhere from -14 Mt/yr to +25 Mt/yr change in CO_2 emissions from transportation in 2030.

Modeled Net U.S. Greenhouse Gas Emissions (Including Land Carbon Sinks)

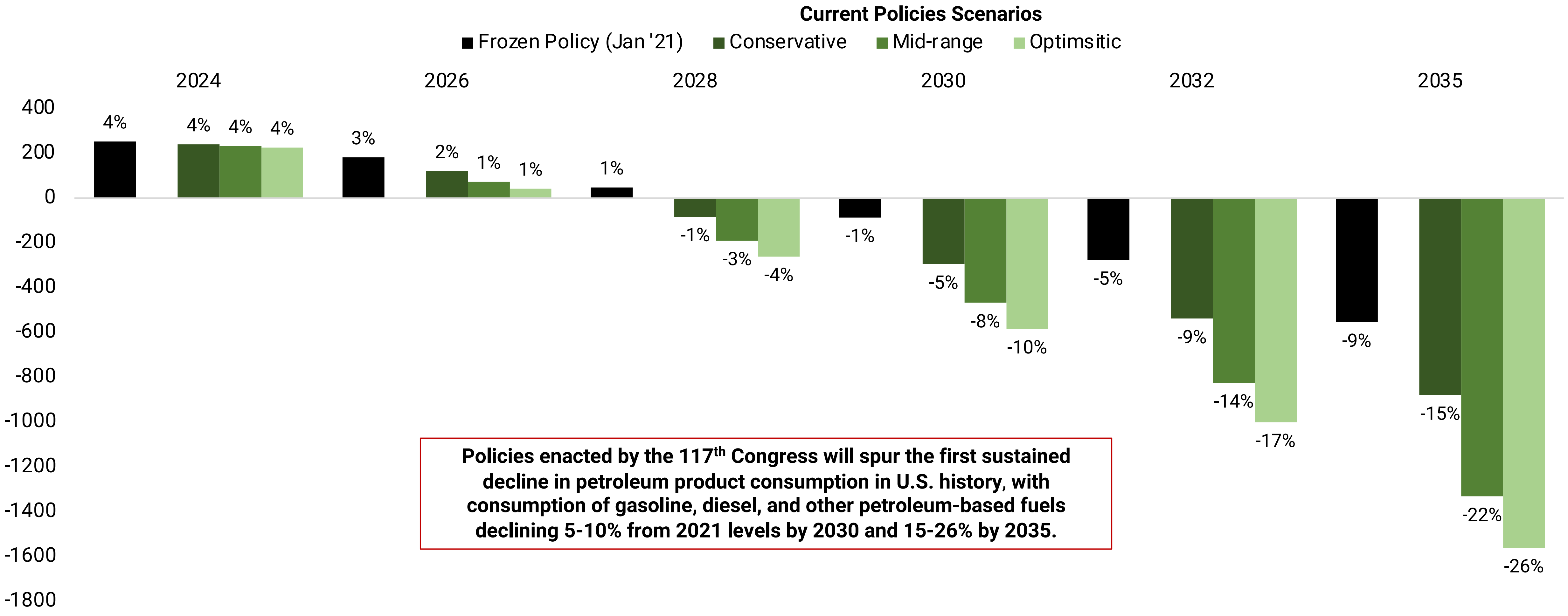
percent below 2005 historical emissions[1]



1 - 2005 historical net U.S. greenhouse gas emissions were 6,686 million metric tons of CO_2-equivalent (EPA Inventory of Greenhouse Gas Emissions and Sinks). CO_2-equivalent emissions calculations use IPCC AR4 100 year global warming potential as per EPA Inventory of Greenhouse Gas Emissions and Sinks.

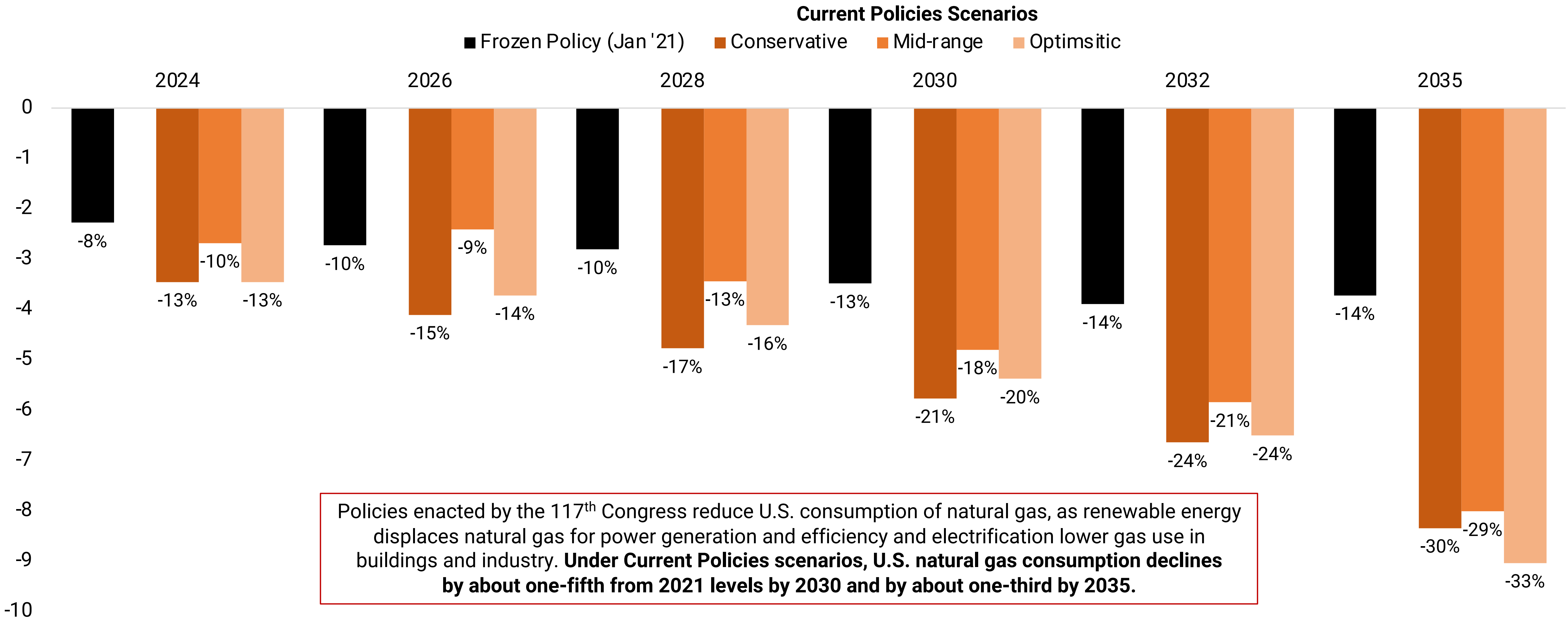
Changes in Annual U.S. Petroleum Product Consumption vs 2021

million barrels per year (mmbbl/y)



Policies enacted by the 117th Congress will spur the first sustained decline in petroleum product consumption in U.S. history, with consumption of gasoline, diesel, and other petroleum-based fuels declining 5-10% from 2021 levels by 2030 and 15-26% by 2035.

Changes in Annual U.S. Natural Gas Consumption vs 2021
trillion cubic feet per year (Tcf/year)

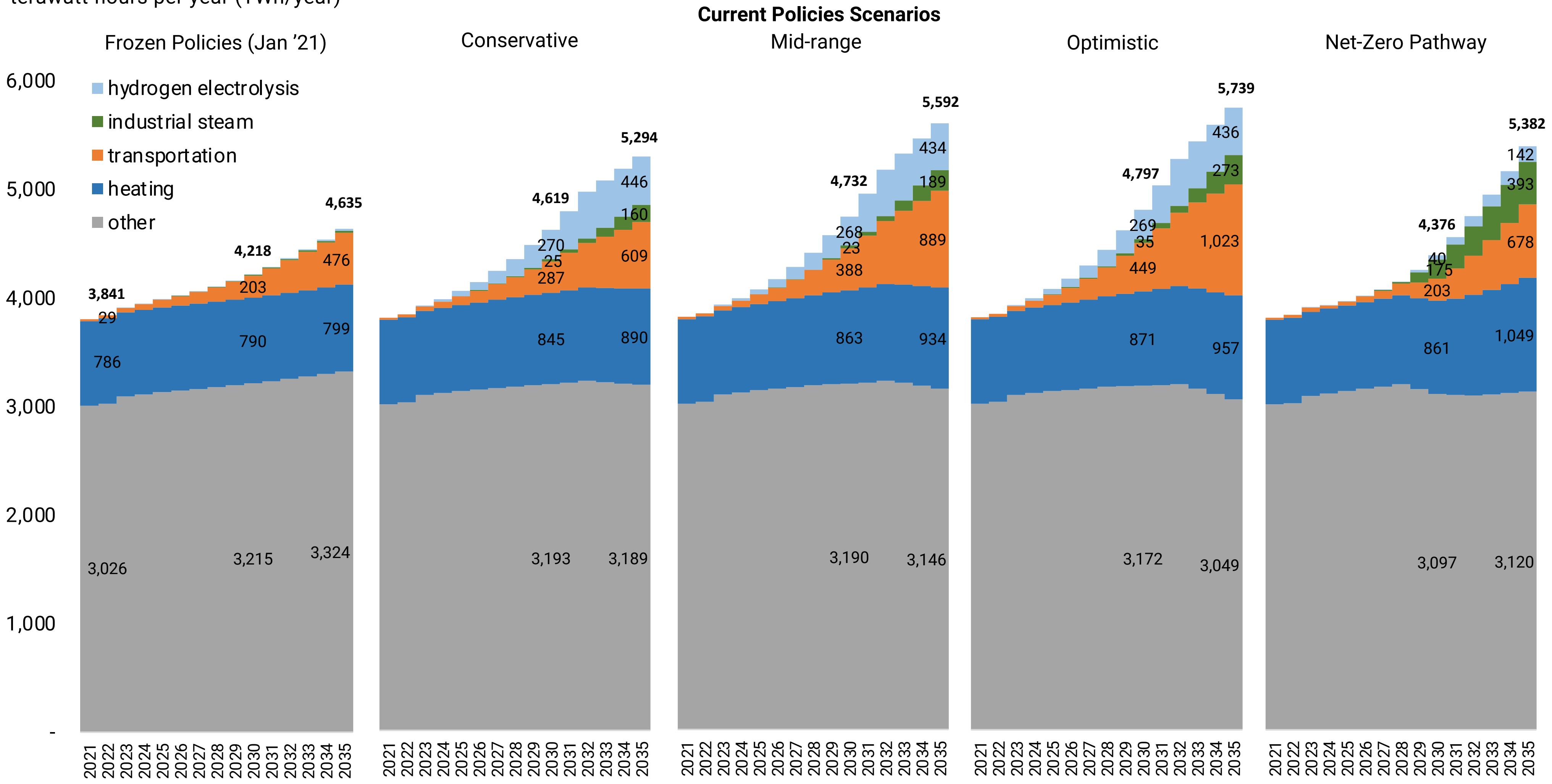


Policies enacted by the 117th Congress reduce U.S. consumption of natural gas, as renewable energy displaces natural gas for power generation and efficiency and electrification lower gas use in buildings and industry. **Under Current Policies scenarios, U.S. natural gas consumption declines by about one-fifth from 2021 levels by 2030 and by about one-third by 2035.**

Note – The magnitude of reductions in natural gas demand is affected by the balance of wind and solar power deployment rates (which offset gas consumption for power generation, all else equal) and the pace of electrification (which increases electricity demand and thus natural gas consumption for power generation, all else equal). As a result, the Conservative scenario with slower electrification results in lower gas demand in many years than the Middle or Optimistic Current Policies scenarios, as these scenarios have both faster wind and solar deployment *and* higher electricity demand from more rapid EV adoption and other electrification.

Electricity Demand by Sector

terawatt-hours per year (TWh/year)

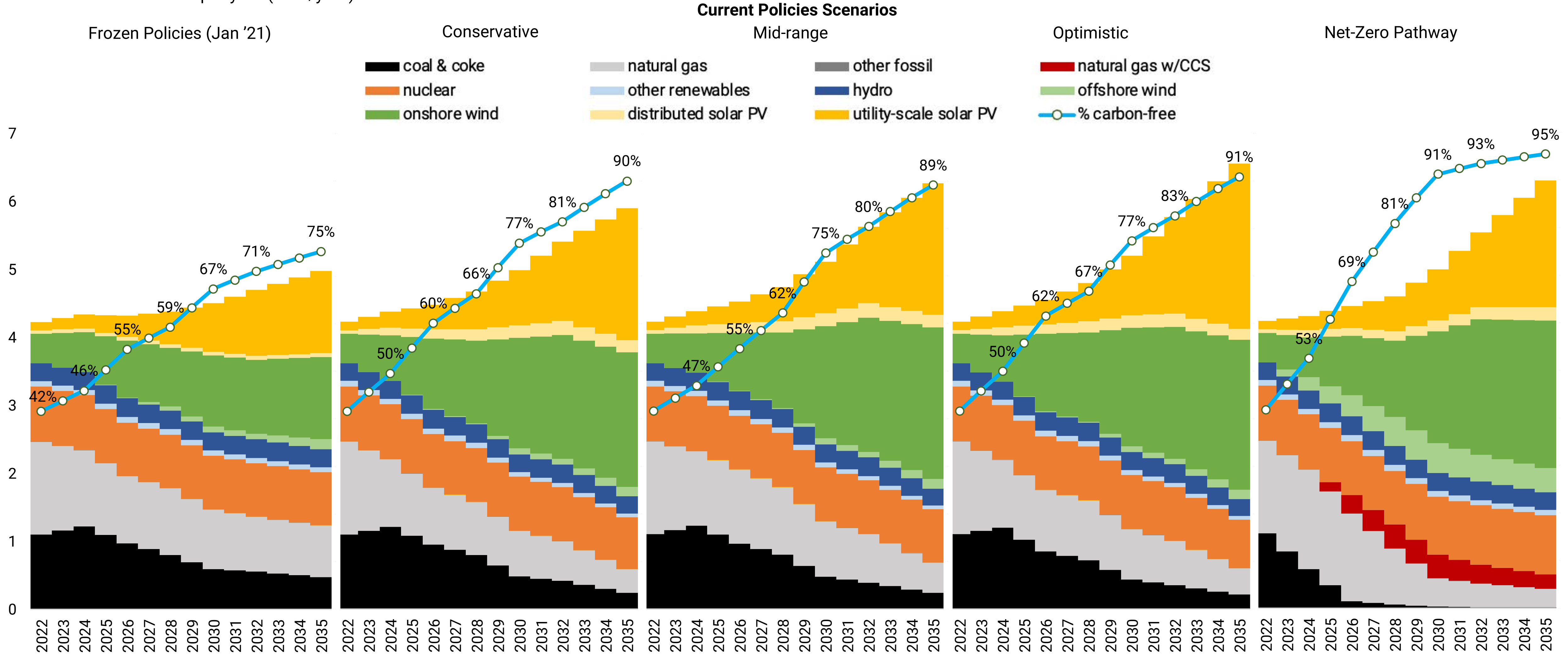


Growing adoption of electric vehicles, heat pumps, industrial electric boilers, and hydrogen electrolysis will drive **a sustained increase in U.S. electricity consumption** for the first time since the mid-2000s.

Under Current Policies scenarios, **U.S. electricity demand grows 20-25% from 2022 to 2030** and reaches 38-49% higher than 2022 demand by 2035.

Electricity Generation by Resource

thousand terawatt-hours per year (TWh/year)



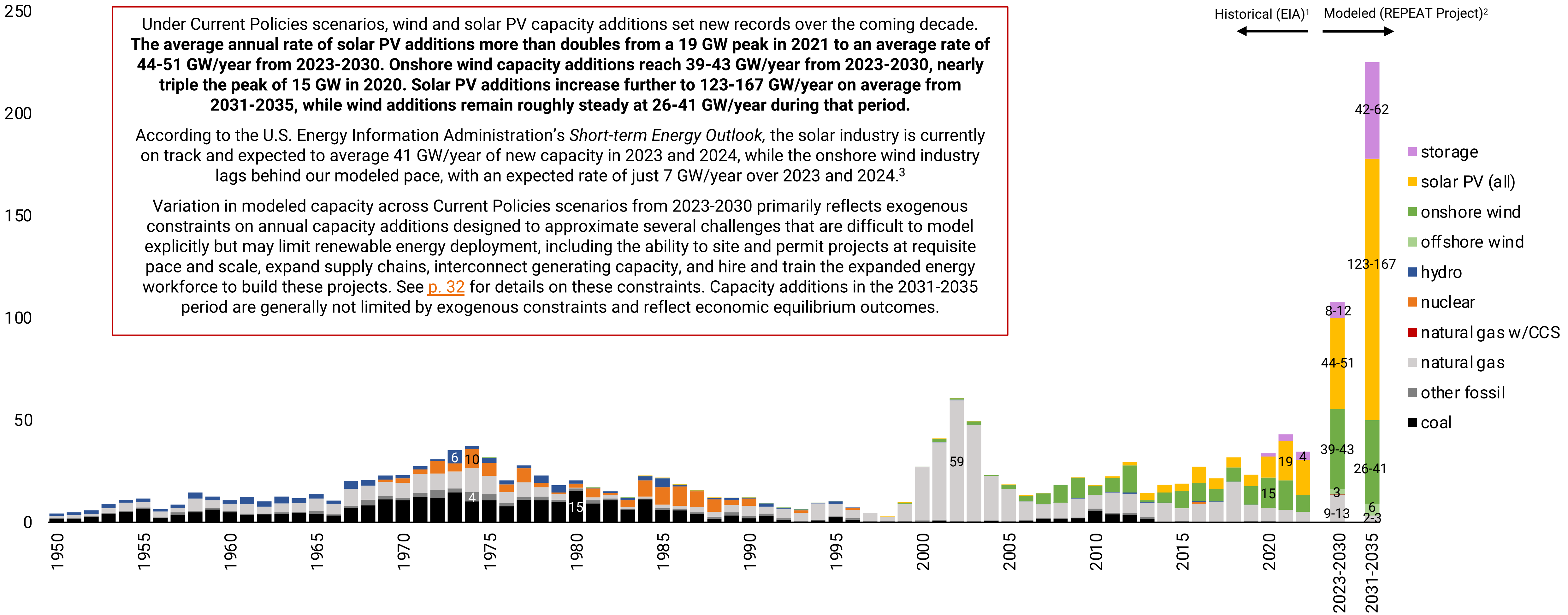
Historical Annual Electricity Capacity Additions vs. Modeled Annual Average Capacity Additions Under Current Policies Scenarios

average gigawatts/year (GW/year)

Under Current Policies scenarios, wind and solar PV capacity additions set new records over the coming decade. **The average annual rate of solar PV additions more than doubles from a 19 GW peak in 2021 to an average rate of 44-51 GW/year from 2023-2030. Onshore wind capacity additions reach 39-43 GW/year from 2023-2030, nearly triple the peak of 15 GW in 2020. Solar PV additions increase further to 123-167 GW/year on average from 2031-2035, while wind additions remain roughly steady at 26-41 GW/year during that period.**

According to the U.S. Energy Information Administration's *Short-term Energy Outlook*, the solar industry is currently on track and expected to average 41 GW/year of new capacity in 2023 and 2024, while the onshore wind industry lags behind our modeled pace, with an expected rate of just 7 GW/year over 2023 and 2024.[3]

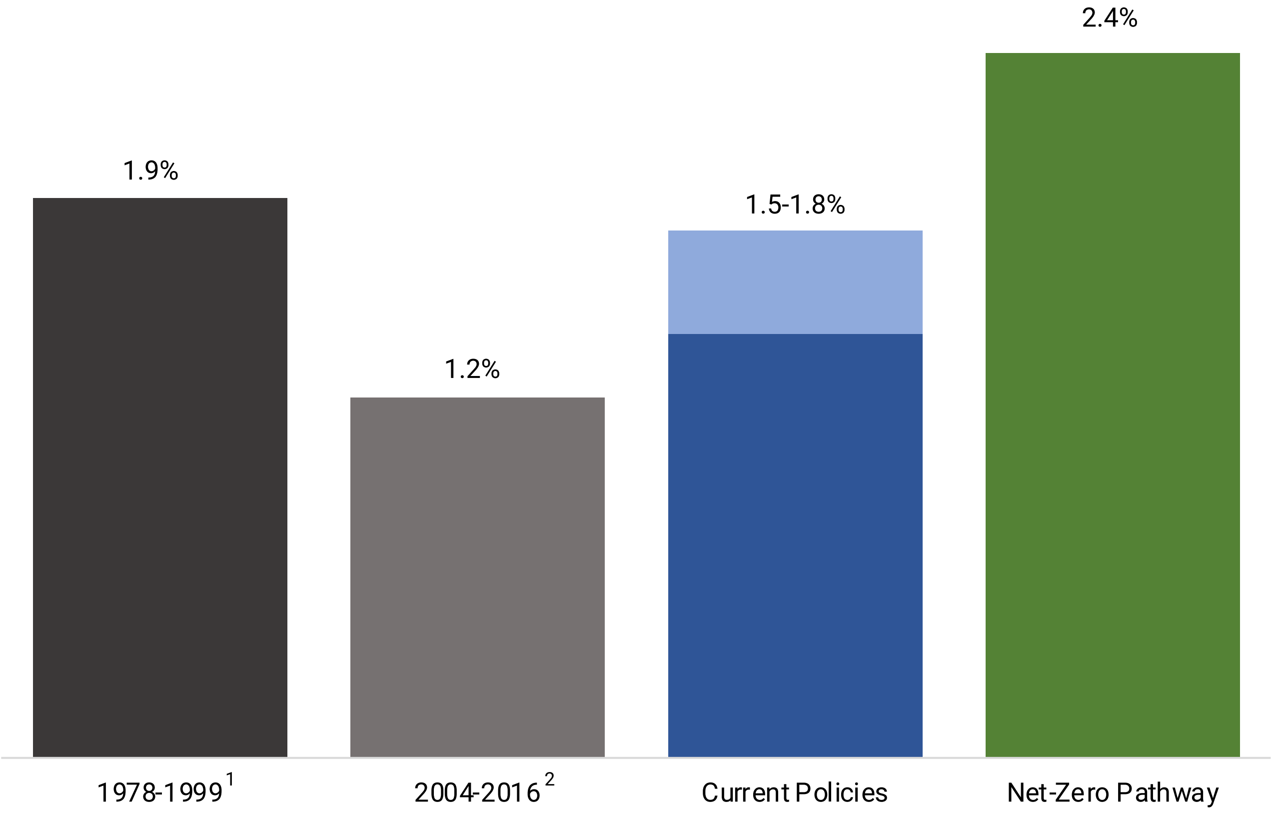
Variation in modeled capacity across Current Policies scenarios from 2023-2030 primarily reflects exogenous constraints on annual capacity additions designed to approximate several challenges that are difficult to model explicitly but may limit renewable energy deployment, including the ability to site and permit projects at requisite pace and scale, expand supply chains, interconnect generating capacity, and hire and train the expanded energy workforce to build these projects. See p. 32 for details on these constraints. Capacity additions in the 2031-2035 period are generally not limited by exogenous constraints and reflect economic equilibrium outcomes.



1 - Historical data labels represent peak historical annual additions (source, 1950-2020: EIA Form 860; 2021-2022: EIA Short-term Energy Outlook, June 6, 2023)
2 - Modeled data labels reflect range across Current Policies scenarios (Conservative, Mid-range and Optimistic). Depicted bars represent results for the Mid-range scenario.
3 - EIA *Short-term Energy Outlook*, June 6, 2023 edition

Compound Annual Growth in Electricity Transmission Capacity, 2020-2035 vs. Historical Periods

percent annual growth in gigawatt-miles



To achieve the maximum emissions reduction under Current Policies, U.S. transmission capacity must expand roughly 50% faster through 2035 than the recent historical rate.[2]

While our modeling finds this outcome makes economic sense given incentives under IRA, current U.S. transmission planning, siting, permitting and cost allocation practices can all potentially impede the real-world pace of transmission expansion. We explore the impacts of more constrained transmission expansion on the following page.

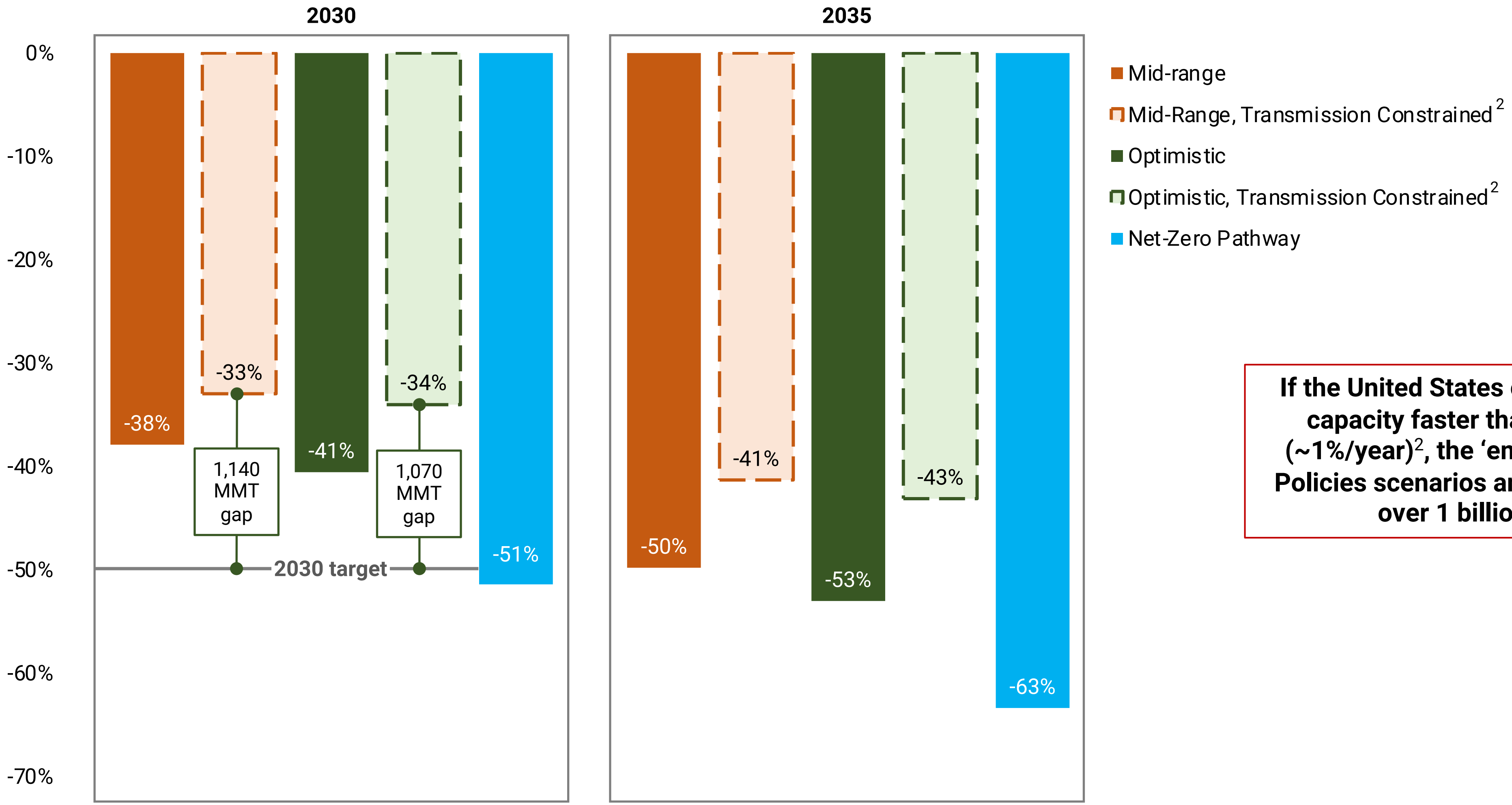
Note that U.S. electricity demand has been roughly flat since the mid-2000s, and **modeled transmission expansion rates under Current Policies are roughly equal to the historical pace achieved from the 1970s to the 1990s**[1], the last period during which U.S. electricity demand steadily increased.

The pace of transmission expansion under the Net-Zero Pathway exceeds the historical 1978-1999 rate and is twice as fast as the more recent 2004-2016 period.

1 - Reported by U.S. Department of Energy and cited in Cembalest (2022), "Eye on the Market 12th Edition: 2022 Annual Energy Paper" p.12.
2 - Reported by UT Austin and cited in Cembalest (2022), p.12.

Impact of Transmission Expansion Constraints on Modeled Net U.S. Greenhouse Gas Emissions (Including Land Carbon Sinks)

percent change vs. 2005 emissions[1]



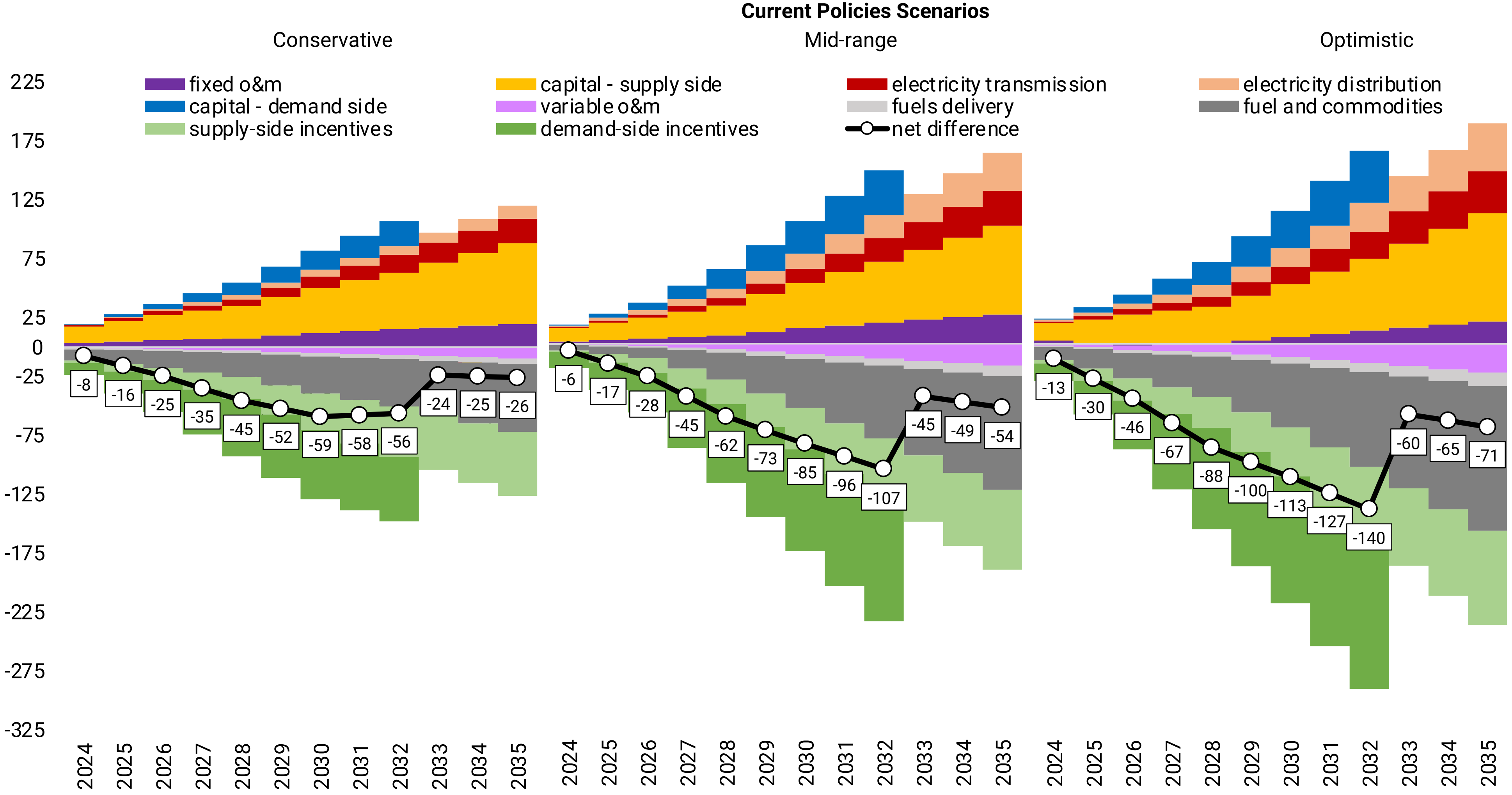
If the United States cannot build new transmission capacity faster than the recent historical pace (~1%/year)[2], the 'emissions gap' between Current Policies scenarios and U.S. climate goals widens to over 1 billion metric tons in 2030.

1 - CO_2-equivalent emissions calculations use IPCC AR4 100 year global warming potential as per EPA Inventory of Greenhouse Gas Emissions and Sinks.

2 - Transmission constrained cases limit total transmission capacity expansion to a compound annual growth rate of 1%/year, roughly equivalent to the 2004-2016 average historical pace. The maximum total increase in GW-miles for each model year is allocated as constraints on expansion of inter-regional transmission, interconnection lines for wind and interconnection lines for solar PV respectively in proportion to the total expansion for each category of lines under unconstrained Current Policies cases.

Change in Annual Energy Expenditures vs Frozen Policies as of January 2021

billions of 2023 US dollars[1]



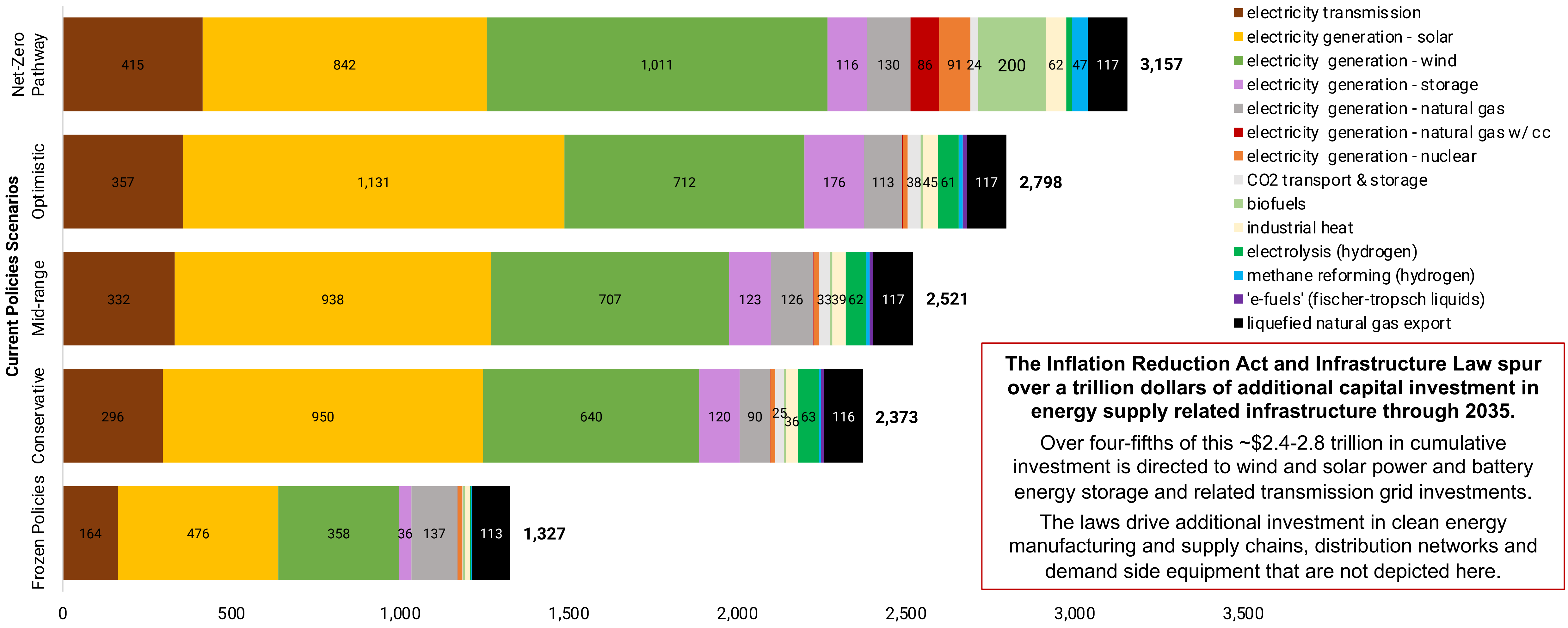
The Inflation Reduction Act and Infrastructure Law lower annual U.S. energy expenditures ~3-7% in 2030, a savings of $59-$113 billion for U.S. households, businesses, and industry.

Annual energy cost savings peak in 2032 prior to the scheduled expiration of several IRA incentives (i.e., tax credits for EV adoption, efficiency etc.) but remain about 1-3% lower than the Frozen Policies scenario through 2035.

1 - Dollar values modeled internally as 2018 USD, and converted for display to 2023 USD using Bureau of Labor Statistics CPI Inflation Calculator: 1 2018 UDS = 1.207 2023 USD.

Cumulative Capital Investment in Energy Supply Related Infrastructure, 2023-2035

billions of 2023 US dollars[1]



The Inflation Reduction Act and Infrastructure Law spur over a trillion dollars of additional capital investment in energy supply related infrastructure through 2035.

Over four-fifths of this ~$2.4-2.8 trillion in cumulative investment is directed to wind and solar power and battery energy storage and related transmission grid investments.

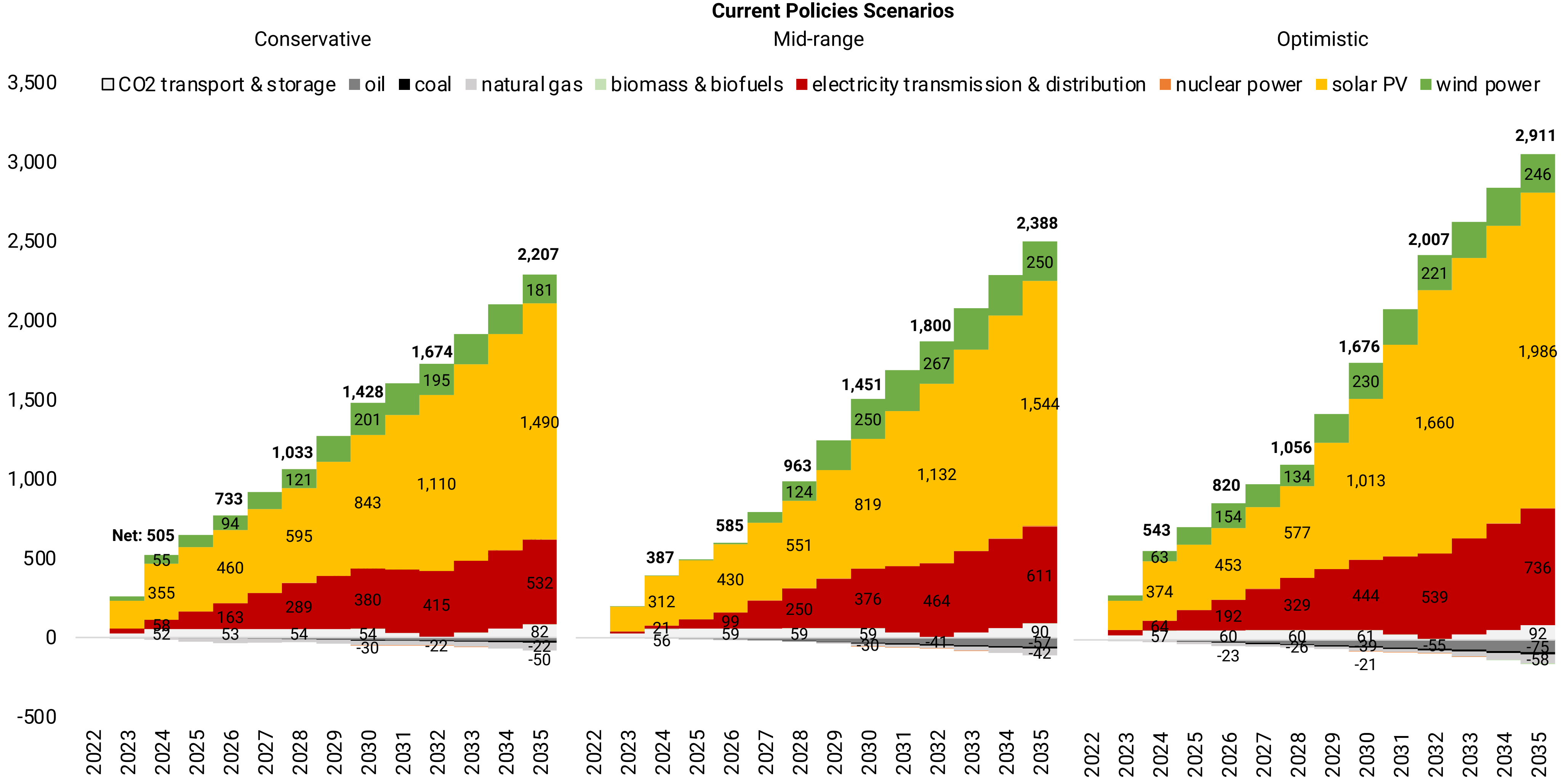
The laws drive additional investment in clean energy manufacturing and supply chains, distribution networks and demand side equipment that are not depicted here.

1 - Dollar values modeled internally as 2018 USD, and converted for display to 2023 USD using Bureau of Labor Statistics CPI Inflation Calculator: 1 2018 UDS = 1.207 2023 USD. Values less than $20 billion not displayed in data labels. Capital investment in fuel and electricity distribution are not included.

2 - Includes associated transmission investments.

Change in Energy Supply Related Employment by Resource vs Frozen Policies as of January 2021

thousands of jobs[1]



The Inflation Reduction Act and Infrastructure Law could increase energy supply related employment[1] by **about 1.4-1.7 million additional jobs in 2030 and 2.2-2.9 million by 2035.**

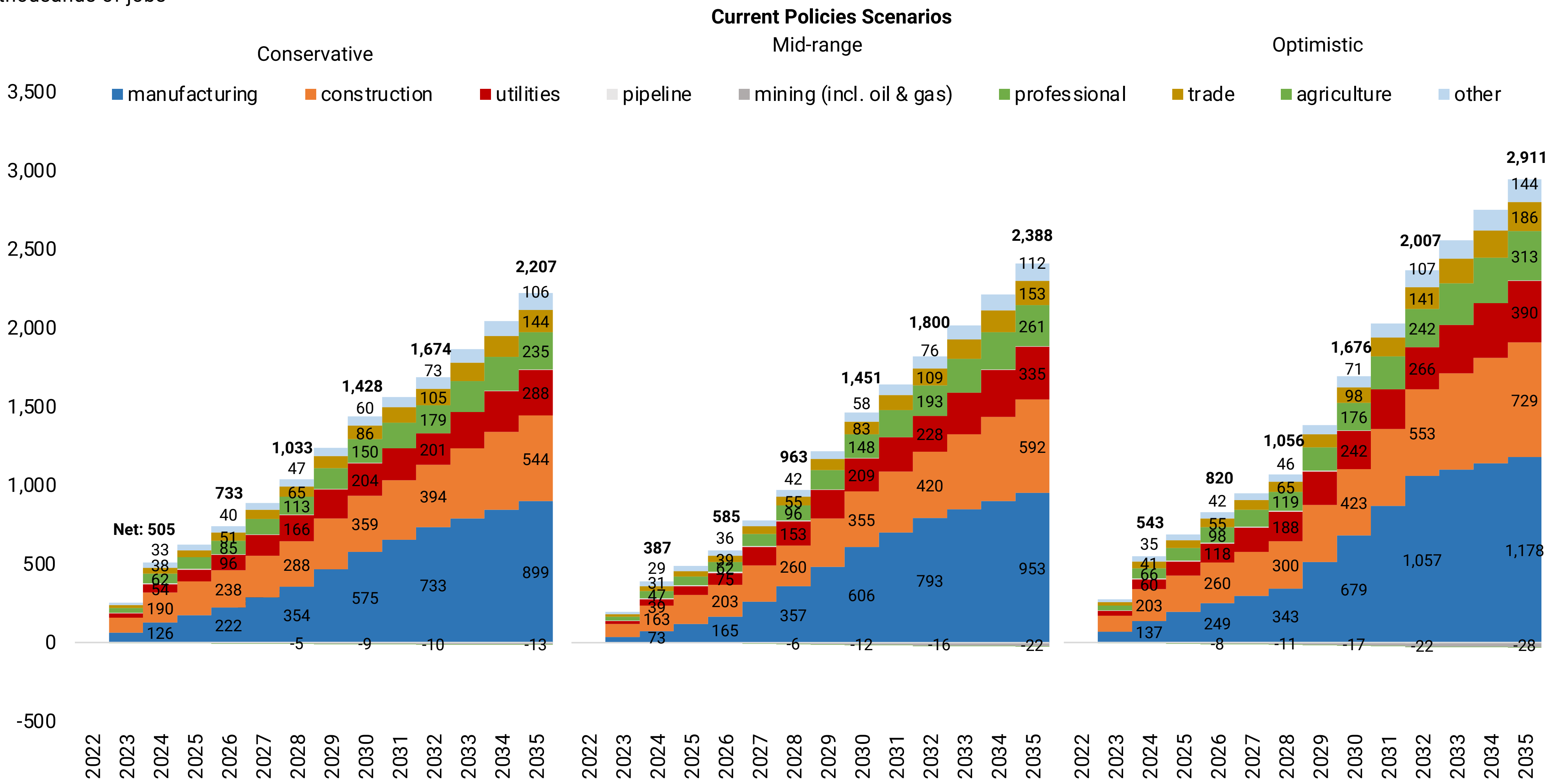
Solar, wind, and grid related jobs expand rapidly under Current Policies scenarios accounting for the vast majority of additional employment.

Oil, natural gas, and coal related employment declines by ~50,000-70,000 jobs in 2030, roughly equal to the additional jobs created in CO_2 transport & storage.

1 - Employment in petroleum fuel refining, distribution, and retailing; hydrogen production, distribution and retailing; energy storage manufacturing, installation and operations; automotive supply chains and assembly; and energy efficiency are excluded from this analysis. Values less than 20 thousand jobs not displayed in labels

Change in Energy Supply Related Employment by Sector vs Frozen Policies as of January 2021

thousands of jobs[1]



The Inflation Reduction Act and Infrastructure Law could increase energy supply related employment[1] by **about 1.4-1.7 million additional jobs in 2030 and 2.2-2.9 million by 2035.**

That includes **about 600,000 additional manufacturing jobs in 2030 and roughly one million more manufacturing jobs in 2035,** primarily in solar PV and wind turbine component manufacturing.

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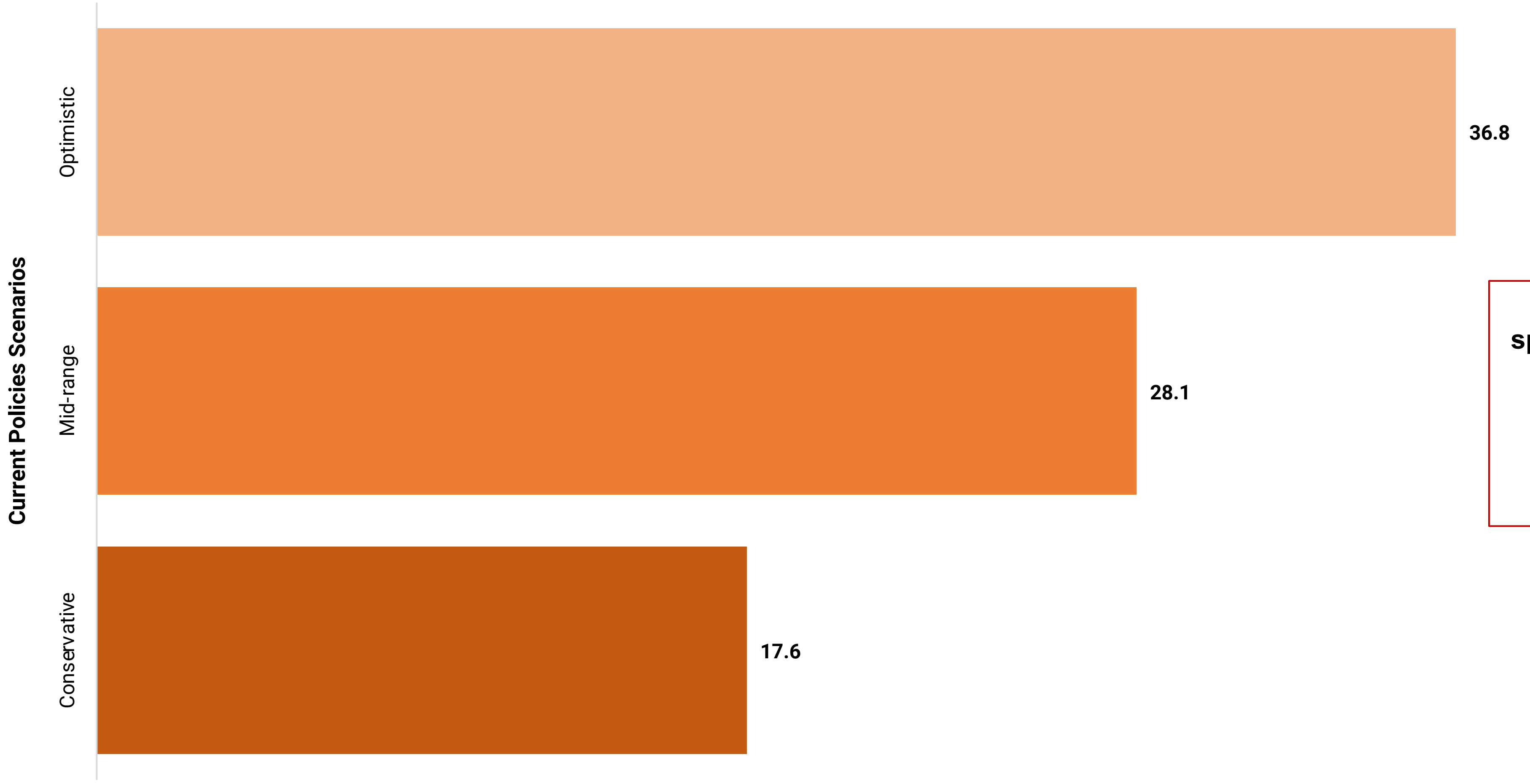
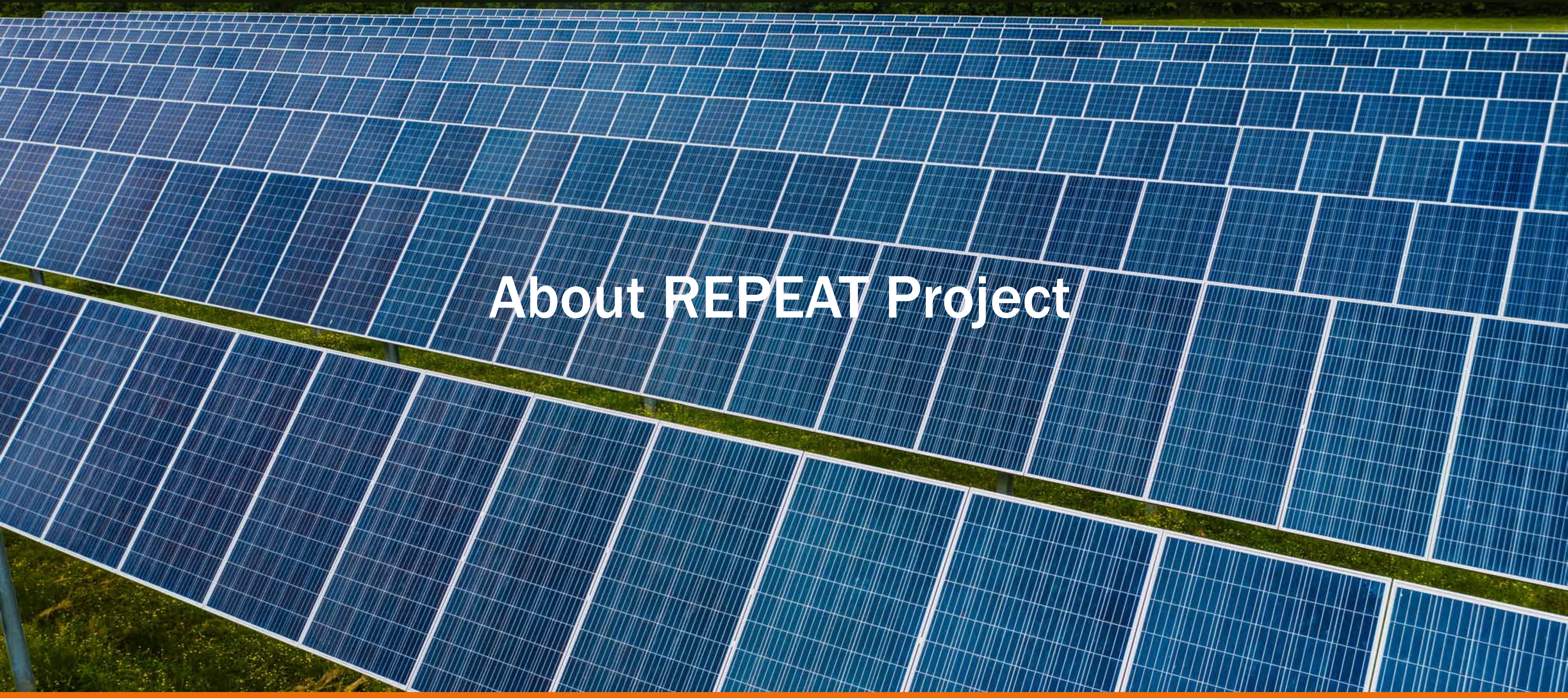
1 - Employment in petroleum fuel refining, distribution, and retailing; hydrogen production, distribution and retailing; energy storage manufacturing, installation and operations; automotive supply chains and assembly; and energy efficiency are excluded from this analysis. Values less than 5 thousand jobs not displayed in labels

Cumulative Avoided Premature Deaths From Exposure to Fine Particulate Matter From Energy Activities vs Frozen Policies, 2023-2035

thousands



Reductions in fine particulate pollution spurred by the Inflation Reduction Act and Infrastructure Law could avoid roughly 17,000-37,000 premature deaths from 2023-2035, saving ~$150-325 billion in economic damages from avoided mortalities alone.



About REPEAT Project

About REPEAT Project

REPEAT Project provides regular, timely and independent environmental and economic evaluation of federal energy and climate policies as they're proposed and enacted, offering a detailed look at the United States' evolving energy and climate policy environment and the country's progress on the path to net-zero greenhouse gas emissions.

Approach: we employ geospatial planning and analysis tools coupled with detailed macro-energy system optimization models to **rapidly evaluate federal policy and regulatory proposals at politically-relevant spatial resolutions** (e.g., state, county, and finer resolutions). This is a refinement of methods used in the Princeton *Net-Zero America* study.

Goal: provide independent, timely, and credible information and analysis for broad educational purposes, including as a resource available publicly for stakeholders, decision-makers, and the media.

Funding: funding for the REPEAT Project was provided by a grant from the Hewlett Foundation.

Impact: throughout the 117th Congress, REPEAT Project played a central role in informing debate, media coverage, and public understanding of the impacts of proposed and enacted legislation. The project continues to provide regular analysis of pending and finalized federal regulations, updates on progress towards climate goals, and other analysis at **repeatproject.org**

The REPEAT Project Team

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Binghamton University: Prof. Neha Patankar;

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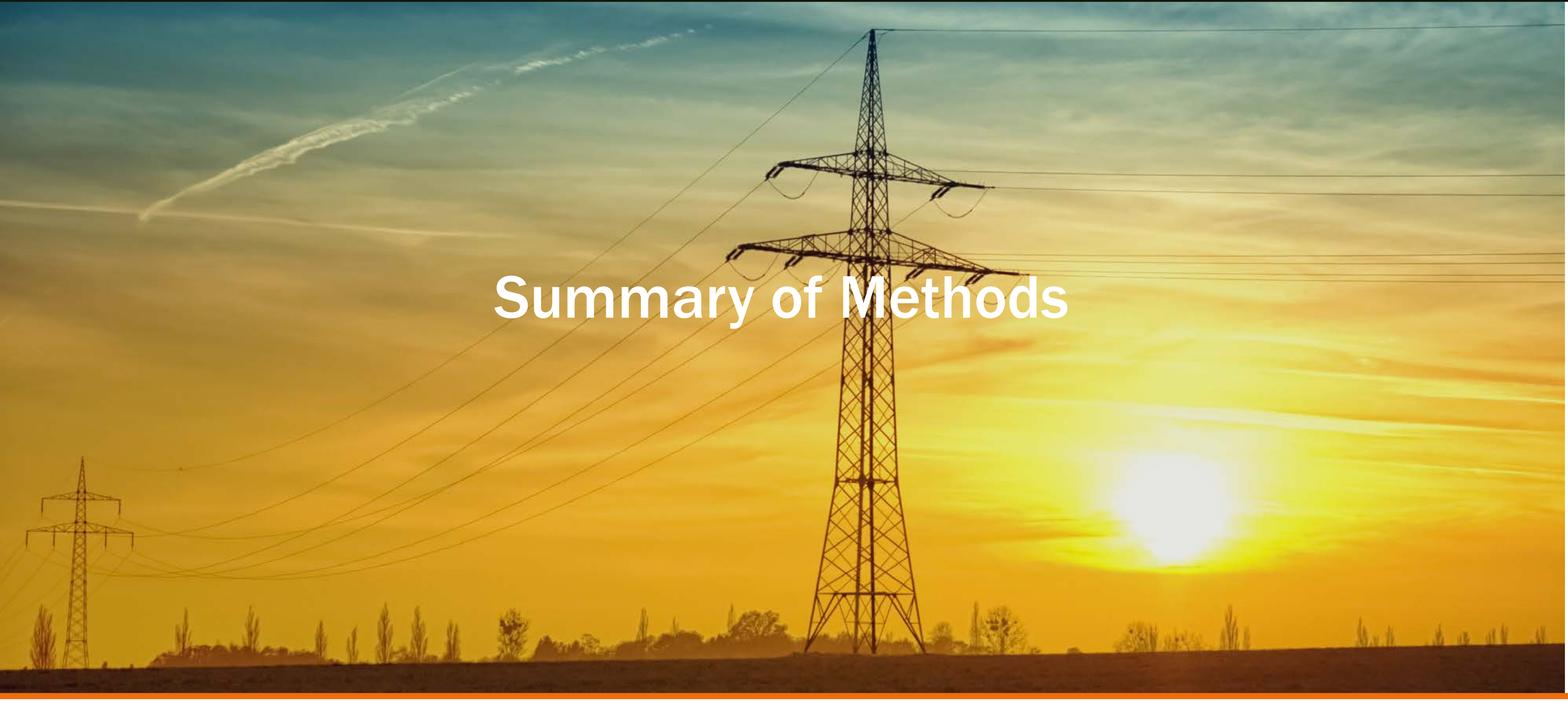
Website development by Hyperobjekt.

For more, see repeatproject.org/about

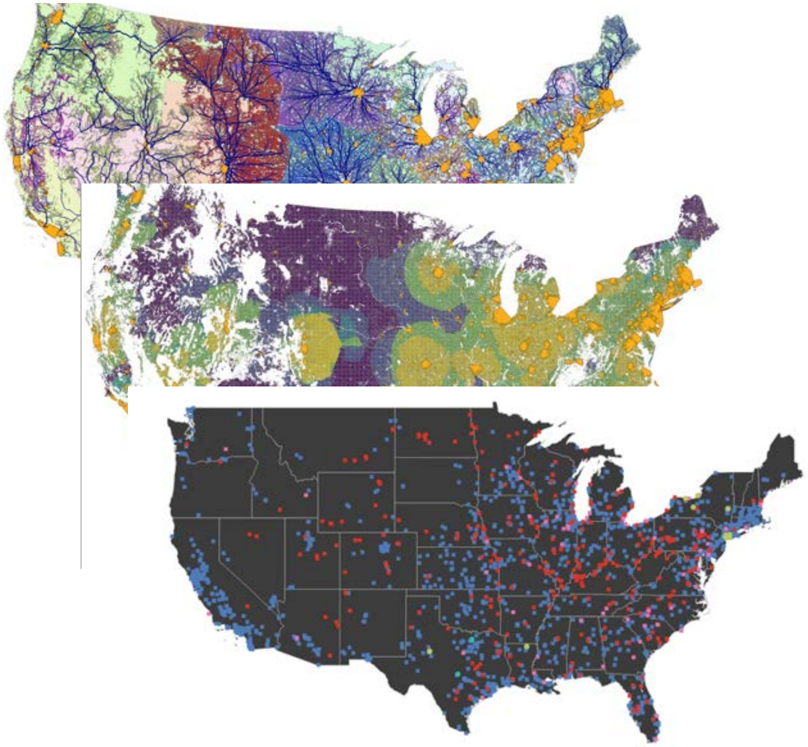
Statement of interests: Jesse D. Jenkins is part owner of DeSolve, LLC, which provides techno-economic analysis and decision support for clean energy technology ventures and investors. A list of clients can be found at https://www.linkedin.com/in/jessedjenkins. He serves on the advisory boards of Eavor Technologies Inc., a closed-loop geothermal technology company, and Rondo Energy, a provider of high-temperature thermal energy storage and industrial decarbonization solutions, and he has an equity interest in both companies. He also provides policy advisory services to Clean Air Task Force, a non-profit environmental advocacy group, and serves as a technical advisor to MUUS Climate Partners and Energy Impact Partners, both investors in early-stage climate technology companies.



Summary of Methods

Analysis Framework

1. Geospatially-resolved inputs



2. Macro-energy systems modeling

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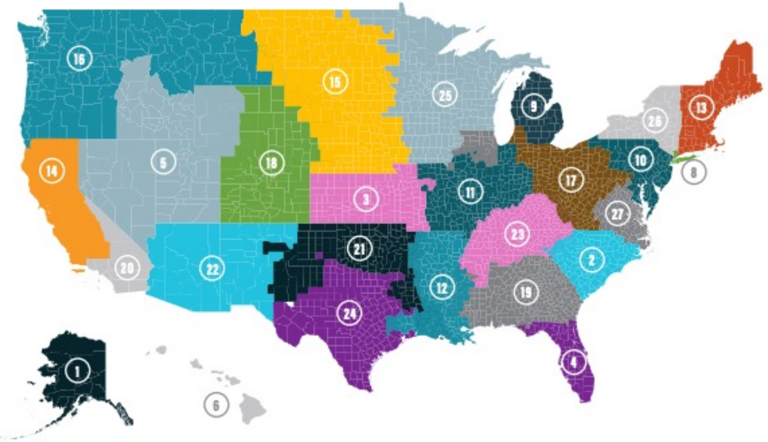
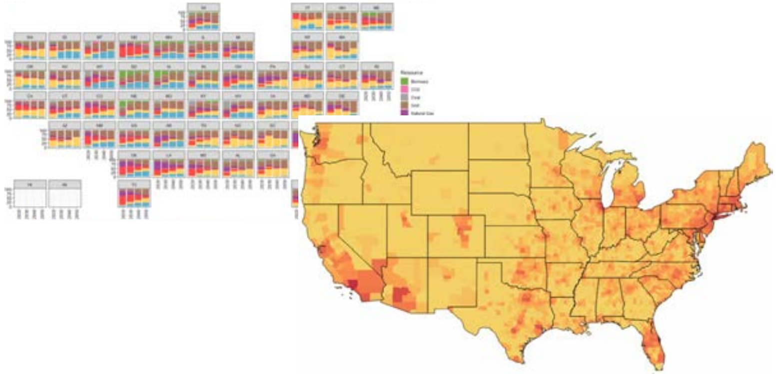
EnergyPATHWAYS
scenario tool
+
RIO
optimization tool



Note that with this revised analysis, we have updated the RIO U.S. model to 27 zones for finer spatial resolution and accuracy

3. Geospatially-resolved downscaling & mapping

4. Impact modeling (employment & air pollution)



Scenarios and policies modeled in this report

Frozen Policies (Jan. '21) Benchmark – no new policies or regulations after January 2021.

Net-Zero Pathway Benchmark – cost-effective pathway to reduce GHG emissions 50-52% below 2005 levels by 2030 and net-zero by 2050, consistent with President Biden's climate mitigation goals.

Current Policies – three scenarios ('Conservative', 'Mid-range', and 'Optimistic') reflecting the potential impact of Current Policies, including the Inflation Reduction Act and Infrastructure Investment and Jobs Act enacted by the 117th Congress.[1] The three scenarios are intended to reflect uncertainty about the effectiveness of IRA and IIJA provisions and the potential impacts of constraints on supply chains and other rate-limiting factors. Note that these scenarios do *not* reflect broader macro-economic uncertainties such as the pace of economic growth, variation in global commodity prices, and other factors that may impact outcomes.

Infrastructure Law Only – reflects the impact of the Infrastructure Investment and Jobs Act alone. This scenario removes all Inflation Reduction Act policies from the Current Policies scenario above to isolate the impact of IIJA.

See https://bit.ly/REPEAT-Policies for detailed section-by-section descriptions of climate and clean energy related policies in each legislation and explanation of treatment in REPEAT Project modeling.

1 – Note that this report does *not* include the impact of light duty vehicle tailpipe emissions standards through MY2026 or heavy-duty vehicle soot rule for MY2027+ finalized in late 2022. However, modeled results are very close to compliant with these rules in all cases. Both will be explicitly treated in subsequent REPEAT Project analysis later this year.

Net-Zero Pathway: Non-CO_2 and land sink assumptions drive modeled CO_2 limits

Mt CO_2-equivalent[1]				
Year[2]	CO_2	Non-CO_2	Total Land sink	Total GHGs
1990	*5,121*	*1,424*	*-939*	*5,606*
2005	*6,132*	*1,418*	*-854*	*6,696*
2010	*5,680*	*1,435*	*-807*	*6,307*
2015	*5,376*	*1,441*	*-752*	*6,065*
2019	*5,262*	*1,420*	*-768*	*5,914*
2022	**4,980**	1,350	-777	5,553
2024	**4,529**	1,257	-795	4,991
2026	**3,862**	1,187	-812	4,237
2028	**3,444**	1,119	-830	3,733
2030	**3,026**	1,071	-848	3,249
2032	**2,713**	1,072	-851	2,933
2035	**2,239**	1,067	-855	2,451
2040	**1,446**	842	-863	1,425
2050	**-43**	802	-877	-118

- The Net-Zero Pathway achieves an overall GHG emissions trajectory that reaches 51% below 2005 emissions levels by 2030 and net-zero anthropogenic GHG emissions by 2050, consistent with the United States' mid- and long-term climate mitigation goals.
- A limit on total CO_2 emissions from energy and industrial activities is explicitly modeled as a constraint in RIO. The emissions limit is based on the total GHG limit less exogenous assumptions about non-CO_2 GHG mitigation opportunities and improvements in land carbon sinks described below:
  - The non-CO_2 trajectory is based on EPA's 2019 non-CO2 GHG Marginal Abatement Cost Curve and assumes all mitigation opportunities available at <$100/t CO2-e plus the impacts of the American Innovation and Manufacturing Act of 2020, which requires phase down of HFCs and will result in an additional ~120 MMt CO_2e reduction in 2030 and 158 MMt by 2050 as per EPA analysis.
  - The land carbon sink trajectory is based on the *Net-Zero America* study and increase from ~770 MMt in 2019 to ~850 MMt in 2030 and ~880 MMt in 2050.
- Methane emissions associated with changes in oil, natural gas, and coal production are also estimated. As these emissions are calculated after solving RIO under the previously determined CO_2 emissions constraint, total net emissions in 2050 are slightly negative (-118 MMt).

1 - CO_2-equivalent emissions calculations use IPCC AR4 100 year global warming potential as per EPA Inventory of Greenhouse Gas Emissions and Sinks.
2 - Historical data for 1990-2019 from U.S. EPA Inventory.

Methane abatement

Methane emissions under each scenario reflect the following analysis and assumptions:

- **All scenarios:** all scenarios include estimated mitigation from regulations enacted prior to January 2021 as well as the impact of changes in modeled oil, natural gas and coal production volumes.
- **Infrastructure Law Only**: additionally includes an estimated 0.25 MMt CO_2-e per year in methane reductions (increasing linearly from 2022-2030) from plugging abandoned oil and gas wells as funded by Section 40601 of the law ("Orphaned well site plugging, remediation, and restoration"), based on the RFF report, "Plugging Abandoned Wells: Effects of the Draft Energy Infrastructure Act" (RFF, July 2021).
- **Current Policies scenarios:** additionally include the impacts of the Inflation Reduction Act's Methane Emissions Reduction Program (Section 60113, aka the "methane fee"), based on oil & gas methane mitigation modeling performed for REPEAT Project by Clean Air Task Force and considering estimated marginal abatement opportunities for covered entities[1] available at or below the methane fee level. For documentation of CATF modeling approach, see "Reducing Methane from Oil and Gas: A Path to a 65% Reduction in Sector Emissions" (CATF, December 2020). Note that this analysis accounts for changes in modeled oil and natural gas production volumes across Conservative, Mid-range, and Optimistic scenarios, which impacts available abatement opportunities relative to the baseline.
- **Net-Zero Pathway:** assumes all mitigation opportunities available at <$100/t CO_2-e.

1 - We assume covered entities capture all abatement <$50/$tCO_2$e (methane fee is $60/$tCO_2$e at AR4 GWP100) beginning with the EPA 2019 MAC curve, which is then scaled down to reflect the ratio of CH_4 emissions reported by GHG Reporting Program (GHGRP) covered entities subject to the IRA methane fee to total EPA inventory for CH_4 from Oil & Gas Systems (39%). We then further scaled down estimated abatement opportunities to reflect the ratio between modeled GHGI Baseline and EPA MAC baseline (which is larger and reflects an older edition of the GHGI report).

Agricultural non-CO_2 abatement and land carbon sinks

Reductions in agriculture related non-CO_2 greenhouse gases (CH_4 and N_2O) and improvements in land carbon sinks are based on marginal abatement cost estimates from a meta-study conducted by ICF for the Environmental Defense Fund report "Ambitious Climate Mitigation Pathways for U.S. Agriculture and Forestry: Vision for 2030" (EDF and ICF, September 2022). Reductions under each scenario reflect the following analysis and assumptions:

- **Frozen Policies (Jan. '21) and Infrastructure Law Only:** no additional mitigation relative to baseline from "Global Non-CO2 Greenhouse Gas Emission Projections & Mitigation Potential: 2015-2050" (EPA 2019).
- **Current Policies:** assume additional reductions from the following Inflation Reduction Act programs:
  - Section 21001 - Additional Agricultural Conservation Investments
  - Section 21002 - Conservation Technical Assistance
  - Section 23001 - National Forest System Restoration and Fuels Reduction Projects
  - Section 23002 - Competitive Grants for Non-Federal Land Owners
  - Section 23003 - State and Private Forestry Conservation Programs

  For all scenarios, we assume 10% of program budgets for overhead and the remaining 90% allocated across relevant categories of estimated marginal abatement costs from the EDF/ICF (2022) study. Across the Conservative / Mid-range / Optimistic cases, we assume 10% / 20% / 25% of the total technical abatement potential at each price point is available/responsive to incentives, creating variation in the effectiveness of the programs.
- **Net-Zero Pathway:** assumes all mitigation opportunities in the EDF/ICF (2022) study available at <\$100/t CO_2-e.

Treatment of policy incentives for demand-side adoption (other than vehicles)

For demand-side choices other than vehicles (e.g. heating, cooling, building efficiency), sales trajectories are scenario based in all cases.

- **Frozen Policies (Jan '21):** demand-side technology adoption is based on the EIA's Annual Energy Outlook 2022.
- **Net-Zero Pathway:** assumes an S-curve change in sales patterns that see lower carbon alternatives saturate markets in 2035, consistent with a comprehensive and sustained effort to achieve economy-wide net-zero GHG at low cost (similar to scenarios from Evolved Energy Research's Annual Decarbonization Perspectives 2022).
- **Infrastructure Law Only and Current Policies**: we allocate funds from demand-side incentives to specific end-use subsectors and assume these funds "buy our way up the S-curve" of adoption for each technology relative to the Net-Zero Pathway as follows:
  - We calculate incremental up-front (capital) cost of all demand-side subsectors in the Net-Zero Pathway vs Frozen Policies (Jan. '21) scenario (i.e., commercial ventilation, residential building shells, residential heating, etc.).
  - We total all available budgets for incentives for each demand-side subsector (with some judgement applied as to allocation of budgets that apply to multiple sub-sectors; see Policy Worksheet for details).
  - We reduce effective budgets for all demand-side measures (incl. vehicles) by varying amounts depending on scenario to reflect administration, implementation costs, programmatic inefficiencies, and funding for inframarginal purchases that would have occurred otherwise (a simplifying assumption reflecting that programs are not perfectly efficient in allocating available funds). The program effectiveness 'haircut' for each scenario is as follows: Current Policies (Conservative): 40%; Current Policies (Mid-range) and Infrastructure Law Only: 20%; Current Policies (Optimistic): 10%.
  - Then we follow the sales curve for the Net-Zero Pathway scenario, using the policy funds to cover any incremental costs of the subsector in the Net-Zero Pathway relative to the Frozen Policies (Jan. '21) scenario until the available funds are exhausted.
  - After funds are exhausted, sales shares stay fixed at the highest level achieved at that time.

Light duty vehicle transition assumptions

For **all scenarios**, we assume 2022-2024 sales shares follow the forecast from the BloombergNEF "Electric Vehicle Outlook 2022" (BNEF EVO22), published prior to IRA, assuming that EV supply chains constrain demand during this period and sales volumes are thus unaffected by vehicle purchase incentives. This corresponds to the following EV sales shares[1]: 4.7% in 2021; 6% in 2022; and 8% in 2023; 11% in 2024.

After 2024, sales trajectories vary across scenarios as follows:

- **Frozen Policies:** sales shares in the U.S. lag behind BNEF EVO22 by two years, assuming that IIJA's impact accelerates changes in sales shares. This corresponds to the following ZEV sales shares: 14% in 2026; 20% in 2028; 31% in 2030; 42% in 2032; 49% in 2035.
- **Infrastructure Law Only, and Current Policies (Conservative):** U.S. sales shares follow shares projected in BNEF EVO22. That is, these scenarios assume *no* incremental increase in sales from IIJA or IRA incentives. This corresponds to the following EV sales shares: 20% in 2026; 31% in 2028; 42% in 2030; 49% in 2032; 59% in 2035. Note additional 2% of light vehicle sales are hydrogen FCVs in 2030 and 4% in 2035.
- **Current Policies (Mid-range):** California and 17 states + DC that historically follow the California Zero Emissions Vehicle (ZEV) program[2] are assumed to meet California's Advanced Clean Cars 2 standard, which requires zero emissions vehicle sales to reach 100% by 2035, while all other states are assumed to follow the Conservative scenario sales shares above. We linearly interpolate the sales shares from 2024-2035, resulting in the following national EV sales shares: 22% in 2026; 36% in 2028; 52% in 2030; 66% in 2032; and 82% in 2035. Note an additional 2% of light sales are hydrogen FCVs in 2030 and 4% in 2035.
- **Current Policies (Optimistic):** sales shares across the entire country are assumed to meet California's Advanced Clean Cars 2 standard, which requires zero emissions vehicle sales to reach 100% by 2035, resulting in the following national EV sales shares: 27% in 2026; 46% in 2028; 65% in 2030; 81% in 2032; and 94% in 2035. Note an additional 2% of light sales are hydrogen FCVs in 2030 and 5% in 2035.

For purposes of calculating the cost of adoption and consumer energy expenditures, we phase in the value of the light duty vehicle tax credits over the 2025-2032 period, assuming the automotive sector progressively reorients supply chains to meet the battery and materials sourcing requirements of the IRA EV personal income tax credit. We assume 70% of vehicle sales receive either the personal or business tax credit (including leases and fleet purchases) and assume the following average credit values: $5,000 in 2024-2026 period; $6,000 in 2027-2028 period; and $7,500 in 2029-2032 period.

1 - Overall EV sales shares between light autos and light trucks reflect EIA *Annual Outlook 2022* sales projections between the two categories, skewing toward light trucks at roughly two-to-one.

2 - 18 states + DC follow CARB low-emissions tailpipe standards now: CA, NY, MA, VT, ME, PA, CT, RI, WA, OR, NJ, MD, DE, CO, MN, NV, VA, NM plus DC (~40% of the U.S. vehicle market).

Medium and heavy duty vehicle transition assumptions

For **all scenarios**, we assume 2022-2024 sales shares follow the forecast from the BloombergNEF "Electric Vehicle Outlook 2022" (BNEF EVO22), published prior to IRA, assuming that supply chains constrain demand during this period and sales volumes are thus unaffected by vehicle purchase incentives. This corresponds to the following ZEV sales shares: 0.2% in 2021; 0.4% in 2022; 0.9% in 2023; 1.8% in 2024.

After 2024, sales trajectories vary across scenarios as follows:

- **Frozen Policies:** sales shares in the U.S. lag behind BNEF EVO22 by two years, assuming that IIJA's impact accelerates changes in sales shares. This corresponds to the following ZEV sales shares: 1.8% in 2026; 4.9% in 2028; 9.3% in 2030; 16% in 2032; 25% in 2035.
- **Infrastructure Law Only, and Current Policies (Conservative):** U.S. sales shares follow shares projected in BNEF EVO22, assuming *no* incremental increase in sales from IRA incentives. This corresponds to the following ZEV sales shares: 4.9% in 2026; 9.3% in 2028; 16% in 2030; 25% in 2032; 31% in 2035.
- **Current Policies (Mid-range):** IRA incentives drive rapid growth in this scenario across all states, driving sales share increases for zero-emission MDV and HDV on a trajectory roughly inline with California's Advanced Clean Trucks standard. Once incentives roll off, sales shares decline slightly, and CA along with 17 states + DC accelerate again by 2036 on a pace to reach 100% ZEV in 2045. All other states follow the same increases in sales share by year as the Conservative scenario sales shares above. US-wide ZEV sales shares are: 16% in 2026; 38% in 2028; 58% in 2030; 67% in 2032; and 53% in 2035.
- **Current Policies (Optimistic):** sales shares across the entire country are assumed to roughly follow the California's Advanced Clean Trucks standard. After 2032 all states follow the same trajectory as states on the CA ZEV trajectory in the Mid-range scenario above achieving 100% ZEV by 2045. Through 2035 sales shares are identical to the Mid-range scenario, they begin to diverge in subsequent years.

Note: For purposes of calculating the cost of adoption, we assume commercial vehicles capture the lesser of $40,000 or 30% of the capital cost of the ZEV from 2023-2032, assuming the incentives will be a critical factor in vehicle purchases, and vehicle prices will decline over time. Based on assumed vehicle cost inputs across MDV and HDV fleets, this results in average incentives of: $35,000 in 2024-2026 period; $33,000 in 2027-2028 period; and $30,500 in 2029-2032 period.

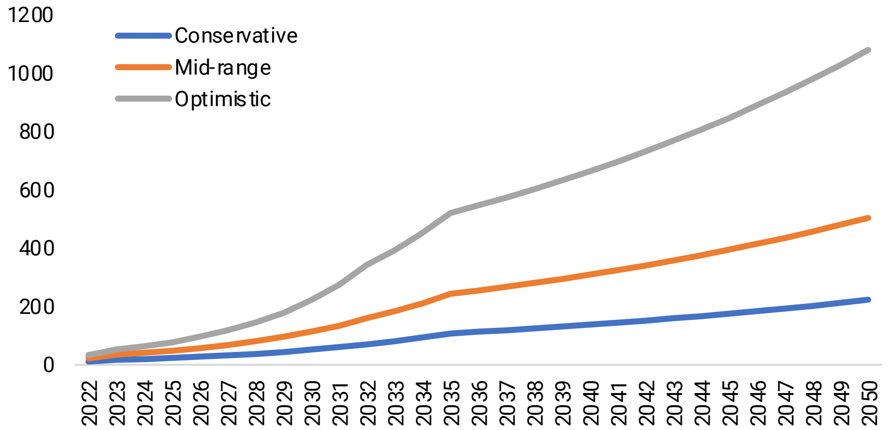
Constraints on technology growth rates

Onshore wind and solar annual build constraints:

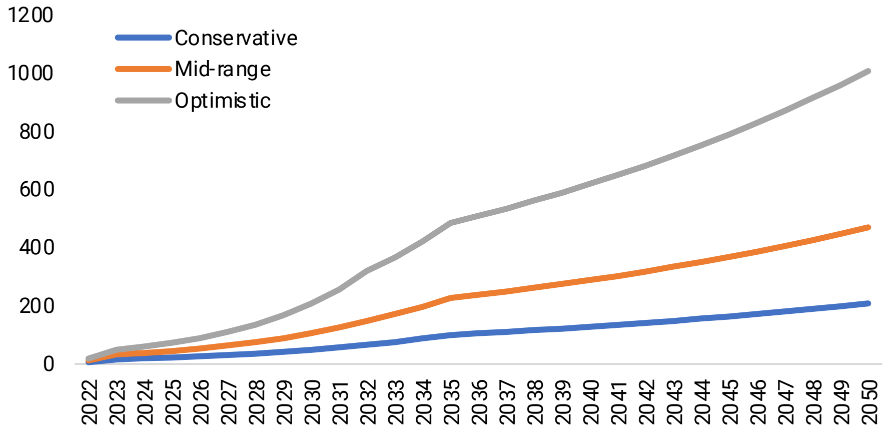
For **all Current Policies scenarios**, we assume onshore wind and utility-scale solar additions are fixed at 11 GW of wind and 6 GW of solar in 2022 and 17 GW of wind and 16 GW of solar in 2023.[1] All other scenarios have the same 2022 annual build and no minimum annual build in 2023. Beyond 2023, annual build constraints increase at different rates by scenario. These constraints are intended to approximate several challenges that are difficult to model explicitly but may limit renewable energy deployment, including the ability to site and permit projects at requisite pace and scale, expand supply chains, interconnect generating capacity, and hire and train the expanded energy workforce to build these projects.

- **Current Policies (Conservative):** maximum annual additions for both onshore wind and utility-scale solar grow at a compound annual growth rate (CAGR) of 17% from 2023-2032. From 2033-2035 this drops to 10%, and for 2036 and after is limited to 5% as incentives sunset and the markets for these technologies reach maturity at large scale.
- **Frozen Policies, Infrastructure Law Only, and Current Policies (Mid-range):** maximum annual additions for both renewable technologies grow at a CAGR of 20% from 2023-2032. The same assumptions as the Conservative scenario are applied after 2032 (2033-2035 at 10% CAGR, after 2035 at 5%).
- **Current Policies (Optimistic):** from 2023-2032 maximum annual additions for onshore wind and utility-scale solar grow at a CAGR of 30%. The same post-2032 assumptions as the Conservative scenario apply.

Maximum annual onshore wind capacity additions
gigawatts/year (GW/year)



Maximum annual utility-scale solar PV capacity additions
gigawatts/year (GW/year)



1 - Maximum wind capacity additions reflect projected additions for 2022 and reported historical maximum additions for 2023 as reported by DOE "Wind Technologies Market Report, 2022 Edition." Maximum solar capacity additions in 2022 and 2023 reflect Solar Energy Industrial Association "Solar Market Insights Report, Q3 2022 edition."

Constraints on technology growth rates

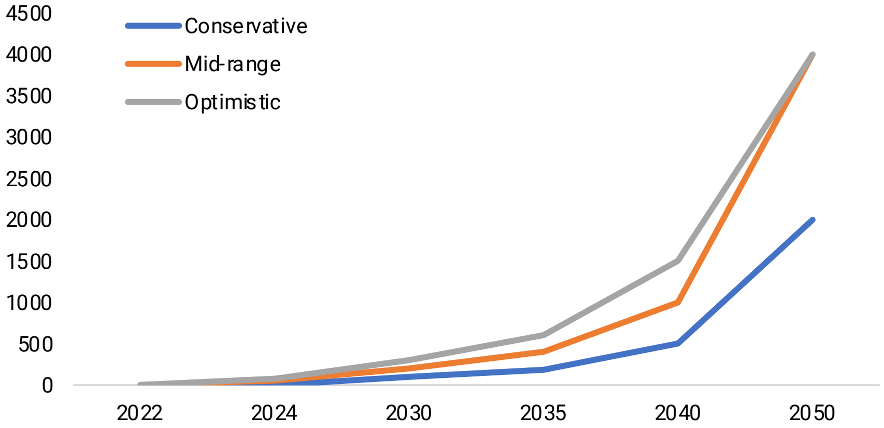
Ramp-up of CO_2 injection and Electrolysis constraints:

Each scenario incorporates different assumptions about the maximum annual growth rate in infrastructure to enable CO_2 injection into geological formations. Development of network infrastructure for CO_2 transport as well as CO_2 storage basins and injections wells are likely to be binding constraints on the growth of carbon capture and storage, at least in initial years. These constraints are intended to proxy for variations in the potential scale-up of this enabling infrastructure for CO_2 capture, transport, and storage and vary by scenario as follows:

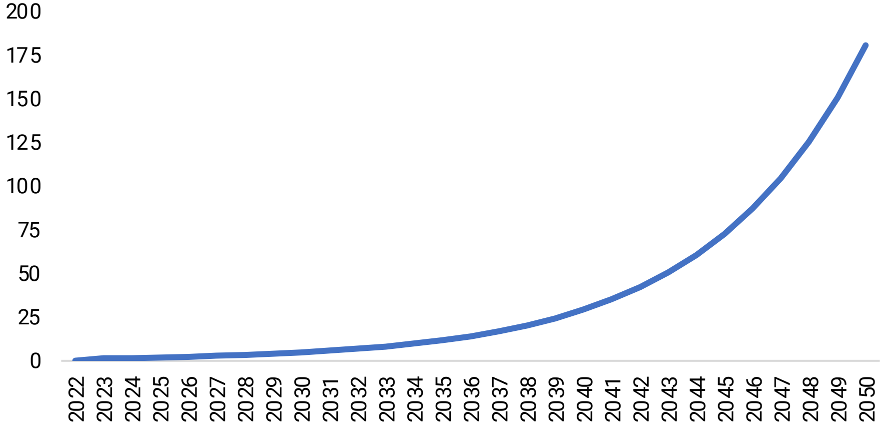
- **Current Policies (Conservative):** the injection constraint is 5 MMt/yr in 2024, rising to 100 MMt/yr in 2030, 180 MMt/yr in 2035, 500 MMt/yr in 2040 and 2,000 MMt/yr in 2050. Much of this constraint is taken up by the exogenous assumptions about industrial carbon capture such as gas processing, cement, and iron and steel.[1]
- **Frozen Policies, Infrastructure Law Only, and Current Policies (Mid-range):** the injection constraint is 50 MMt/yr in 2024, 200 MMt/yr in 2030, 400 MMt/yr in 2035, 1,000 MMt/yr in 2040 and 4,000 MMt/yr in 2050.
- **Current Policies (Optimistic):** starting in 2022, the injection constraint rises from 0 to 75 MMt/yr in 2024, 300 MMt/yr in 2030, 600 MMt/yr in 2035, 1,500 MMt/yr in 2040 and 4,000 MMt/yr in 2050.

All scenarios share the same assumption on maximum annual deployment of electrolyzer capacity, starting at 1.3 MMt /yr of hydrogen production capacity in 2023, and growing at 20% compound annual growth in subsequent years.

Maximum annual CO_2 storage injection rate
million metric tons per year (MMt/year)



Maximum annual electrolyzer capacity additions
million metric tons of H_2 output per year (MMt/year)



1 - The CO_2 injection constraint only turns out to be binding in the Conservative scenario (through 2035).

Treatment of tax credit ‘bonuses’ and ‘adders’

Several tax credits in the Inflation Reduction Act, notably incentives for clean electricity, energy storage, carbon capture, storage & use, and existing nuclear power plants in Title I, Subtitle D, require qualified projects to meet certain prevailing wage and minimum apprenticeship requirements to claim the full value of the tax credit, referred to in the law as the ‘bonus’ value (see bit.ly/REPEAT-Policies for details). Failure to meet these requirements reduces the credit value to a ‘base’ value worth 20% of the ‘bonus’ value. **Throughout our modeling, we assume all eligible projects meet the requirements for the ‘bonus’ credit value**, as projects that fail to do so will be significantly disadvantaged economically relative to projects that do meet these requirements and are thus unlikely to be competitive.

The production and investment tax credits available to new clean electricity generation and energy storage projects also offer ‘adders’ that increase the value of the production tax credit by 10% and the investment tax credit by 10 percentage points if (a) projects meet certain domestic content requirements and/or (b) projects are built in certain ‘energy communities’ defined in the law (both adders can be claimed if a project meets both requirements). **In this analysis, neither the domestic content adder or energy communities adder are considered to apply to the marginal projects represented in our modeling, with the exception of new nuclear power plants.** We assume demand for domestic content will exceed supply through 2035 and thus projects receiving the domestic content adder are likely to be inframarginal and do not effect modeled equilibrium outcomes. For nuclear power plants, we assume the most competitive projects would be built at repowered coal power plant sites and thus receive the bonus 10% energy communities adder (for a 40% ITC value), although limited nuclear capacity is built in practice in any Current Policies cases. For other technologies, the implicit assumption is that marginal projects in each model zone are not located in an energy community, so the energy community bonus credit is disregarded. This is a notably conservative assumption given the breadth of energy communities as defined by the law. In forthcoming revisions of our work, we will incorporate recent guidance on energy communities into our geospatial data sets and adjust our clean electricity resource supply (cost) curves accordingly.

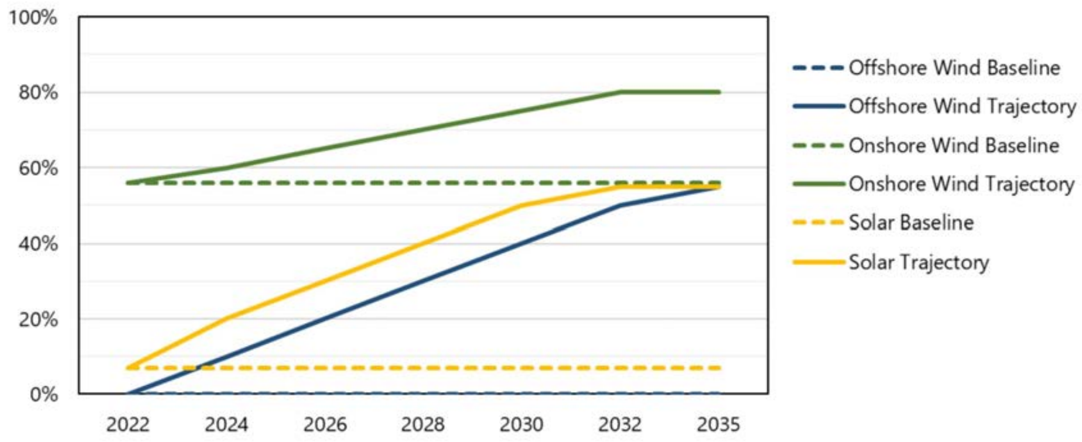
Treatment of the Section 45X Advanced Manufacturing Production Tax Credit

The Section 45X Advanced Manufacturing Production Tax Credit provides qualifying manufacturers located in the United States with income tax credits for the manufacture of: solar PV modules and components; inverters; wind turbines and components; offshore wind foundations and service vessels; battery cells, packs/modules, and electroactive materials; and the production and processing of critical minerals. These tax credits have the potential to substantially reduce the cost of domestic manufacturing and enable U.S. manufacturers to price at or below the cost of competing imports.[1]

In this modeling, we assume the 45X tax credits help increase domestic content shares and help expand supply chains to meet modeled deployment rates. However, **we assume no passthrough of the 45X tax credit to modeled project prices**, which is consistent with the assumption that demand for domestic content will exceed supply through 2035 and thus domestic manufacturers will price final products competitively against available imports without affect marginal project prices.

We assume the 45X manufacturing tax credit and the domestic content 'adder' available to clean electricity projects will drive strong demand for U.S. manufactured solar PV and wind turbine components that exceeds available supply, inducing investment to steadily increase U.S. manufacturing capacity. **For the purposes of modeled employment in energy supply related sectors, we assume gradual increases in domestic content shares for solar and wind projects** as depicted in the figure at right.[1]

Domestic Content Shares for Wind & Solar PV[1]
percent



1 - See Min et al. (2023), "Effects of Renewable Energy Provisions of the Inflation Reduction Act on Technology Costs, Materials Demand, and Labor," Dartmouth College Sustainable Transition Lab and Princeton ZERO Lab, June 2023, available at https://zenodo.org/record/8027939

A note on interpretation of modeled results

Optimization modeling used in this work assumes rational economic behavior from all actors. The modeling also has limited ‘frictions’ on deployment of infrastructure (e.g., power generation or transmission capacity), scale-up of industry supply chains (e.g., wind and solar), or consumer adoption of alternative products (e.g., EVs, heat pumps).

Modeling results should thus be interpreted primarily as indications of the relative alignment of economic incentives as a result of policy changes. In other words, these results indicate what decisions make good economic sense for consumers and businesses to make. This is likely a necessary condition, but whether or not actors make such decisions in the real world depends on many factors we are unable to explicitly model.

Real world outcomes will also contend with various non-cost related challenges that may slow the pace of change relative to modeled results, including the ability to site and permit projects at requisite pace and scale, expand electricity transmission and CO_2 transport and storage to accommodate new generating capacity, and hire and train the expanded energy workforce to build these projects.

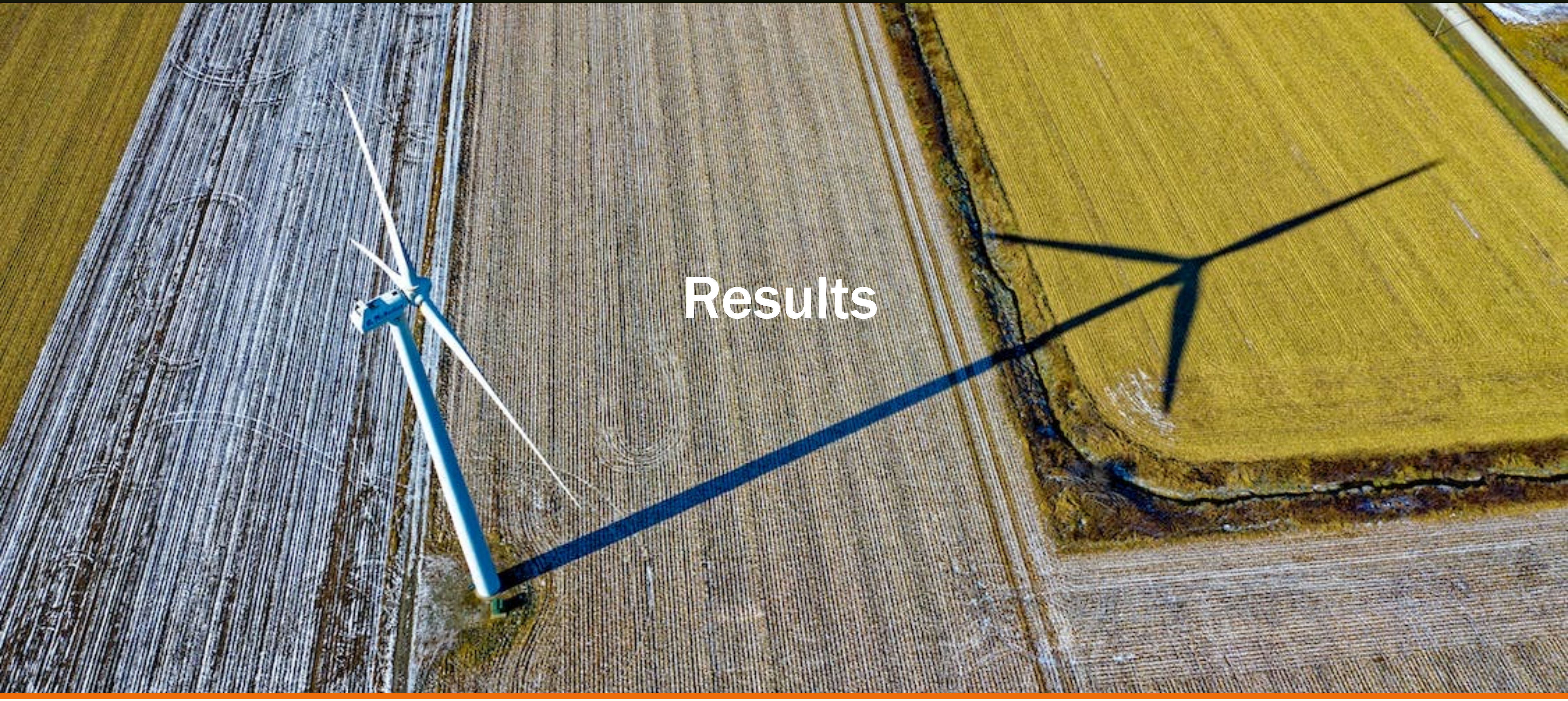
These **non-cost related challenges are roughly approximated in our modeling via exogenous assumptions constraining the scale-up of various technologies and modulating the assumed effectiveness of various policy programs,** which vary across Conservative, Mid-range and Optimistic variants of the Current Policies scenarios.[1]

Additionally, modeled outcomes reflect a least-cost optimization. There are likely many alternative outcomes with similar costs within a few percent of these outcomes that may offer advantages in terms of other important outcomes related to the distribution of costs and benefits associated with energy systems. Various stakeholders may prefer one or more of these alternative portfolios to the outcomes presented here.

Readers should interpret modeled results accordingly.

1 – These assumptions include variation in the portion of program budgets or tax credit incentives effectively incentivizing deployment or adoption vs administrative overhead, transaction costs, or funding for inframarginal purchases. See other methods slides and section-by-section explanation of uncertainty treatment for each policy at https://bit.ly/REPEAT-Policies

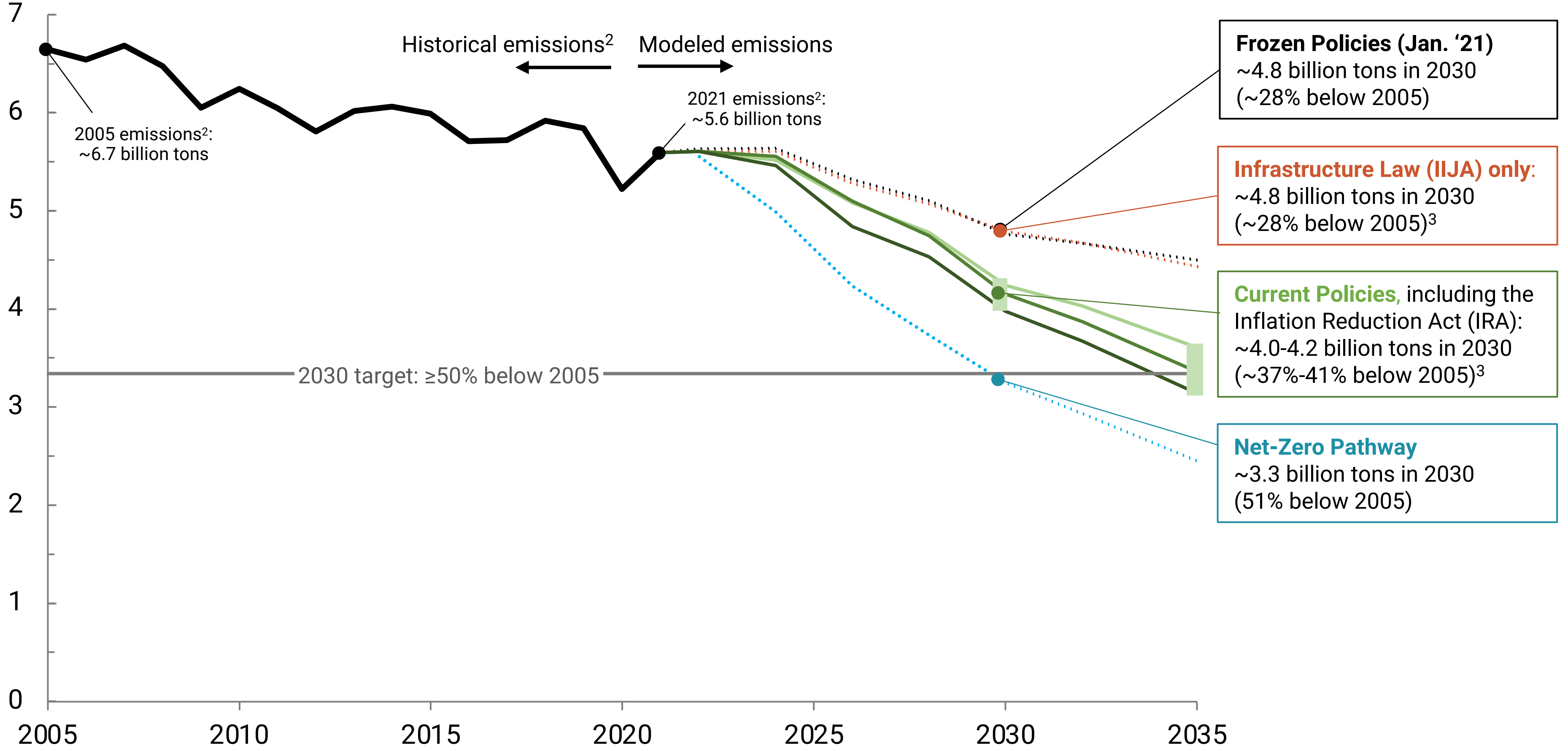
Results



Greenhouse Gas Emissions

Historical and Modeled Net U.S. Greenhouse Gas Emissions (Including Land Carbon Sinks)

billion metric tons CO_2-equivalent (Gt CO_2-e)[1]



Legislation enacted by the 117th Congress could:

- **roughly double the pace of annual U.S. decarbonization** to ~4%/year.
- cut annual emissions in 2030 by **520-780 million metric tons** relative to the Frozen Policies scenario.
- **get the U.S. to ~37-41% below 2005 historical GHG emissions** (vs national target of 50-52%)
- **reduce cumulative GHG emissions by about 3.4-5.6 billion tons over the next decade** (2023-2032).

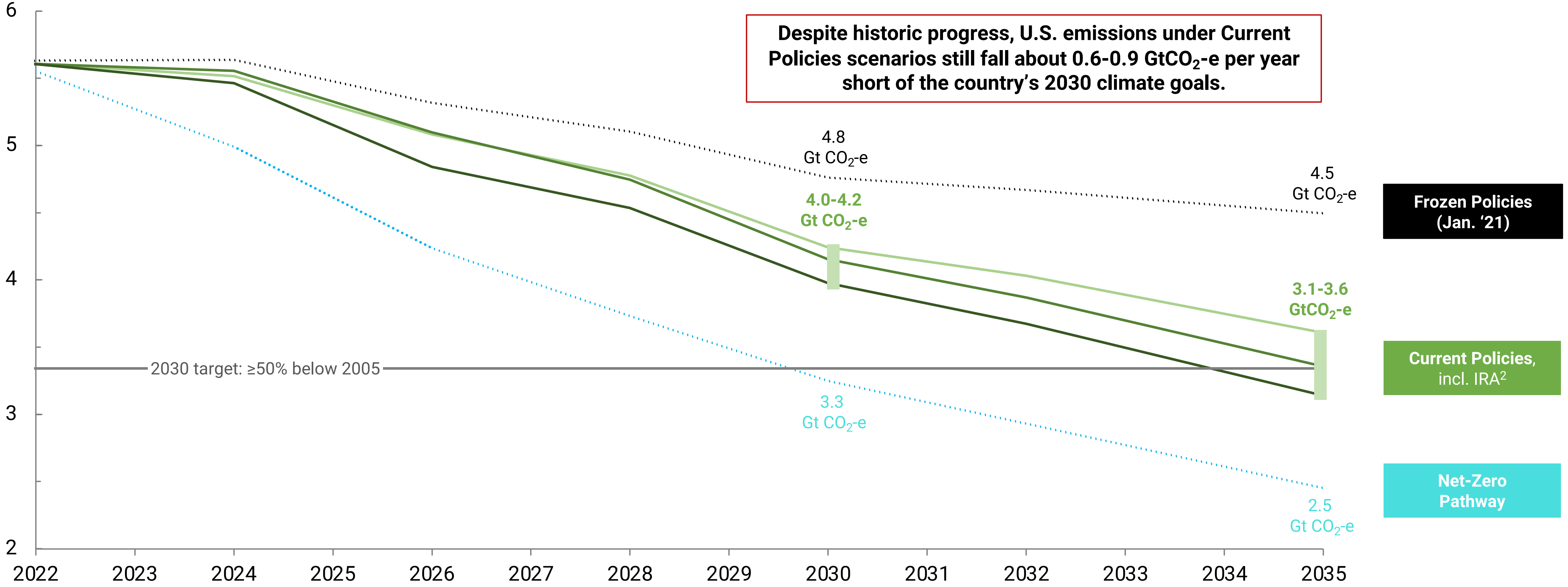
1 - CO_2-equivalent emissions calculations use IPCC AR4 100 year global warming potential as per EPA Inventory of Greenhouse Gas Emissions and Sinks. **All values should be regarded as approximate given uncertainty in future outcomes.**

2 - Historical data from U.S. EPA Inventory for 2005-2020; 2021 estimate from February 2023 draft EPA Inventory.

3 - Modeled emissions exclude any changes in passenger and freight miles traveled due to surface transportation, rail, and transit investments in IIJA. According to the Georgetown Climate Center, emissions impact of these changes depend heavily on state implementation of funding from IIJA, which could result in anywhere from -14 Mt/yr to +25 Mt/yr change in CO_2 emissions from transportation in 2030.

Modeled Net U.S. Greenhouse Gas Emissions (Including Land Carbon Sinks)

billion metric tons CO_2-equivalent (Gt CO_2-e)[1]

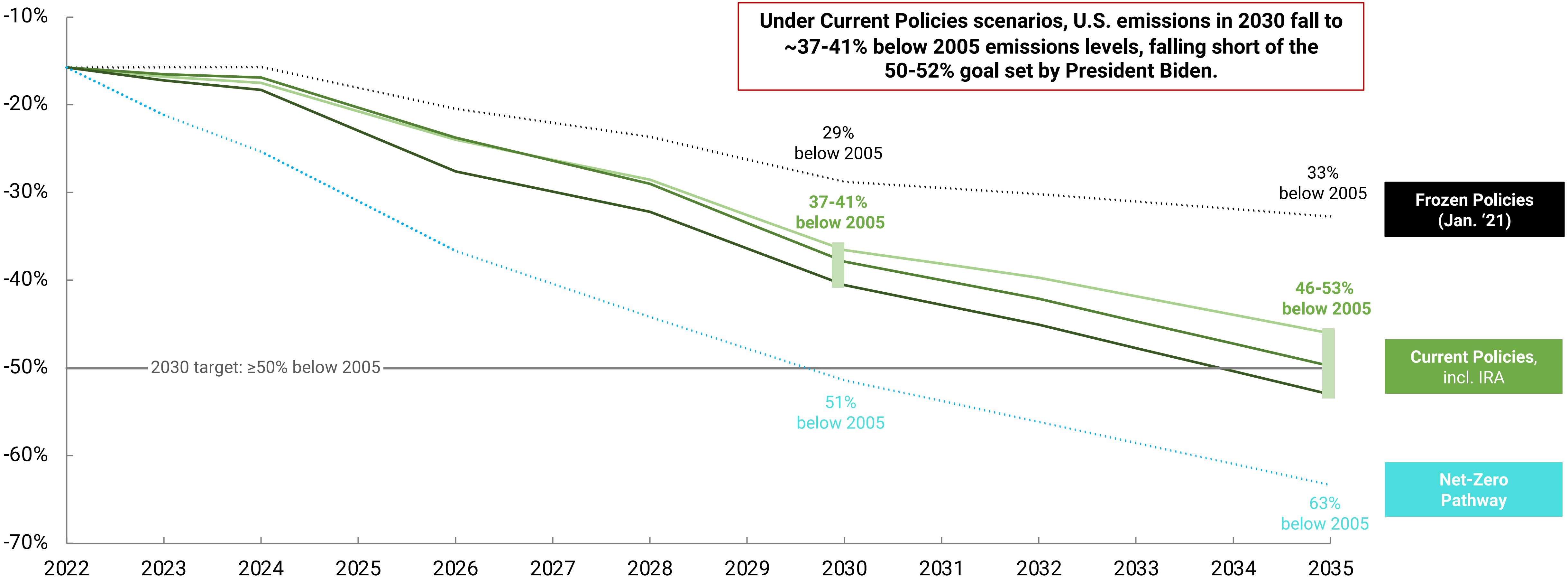


1 - CO_2-equivalent emissions calculations use IPCC AR4 100 year global warming potential as per EPA Inventory of Greenhouse Gas Emissions and Sinks. **All values should be regarded as approximate given uncertainty in future outcomes.**

2 - Modeled emissions exclude any changes in passenger and freight miles traveled due to surface transportation, rail, and transit investments in IIJA. According to the Georgetown Climate Center, emissions impact of these changes depend heavily on state implementation of funding from IIJA, which could result in anywhere from -14 Mt/yr to +25 Mt/yr change in CO_2 emissions from transportation in 2030.

Modeled Net U.S. Greenhouse Gas Emissions (Including Land Carbon Sinks)

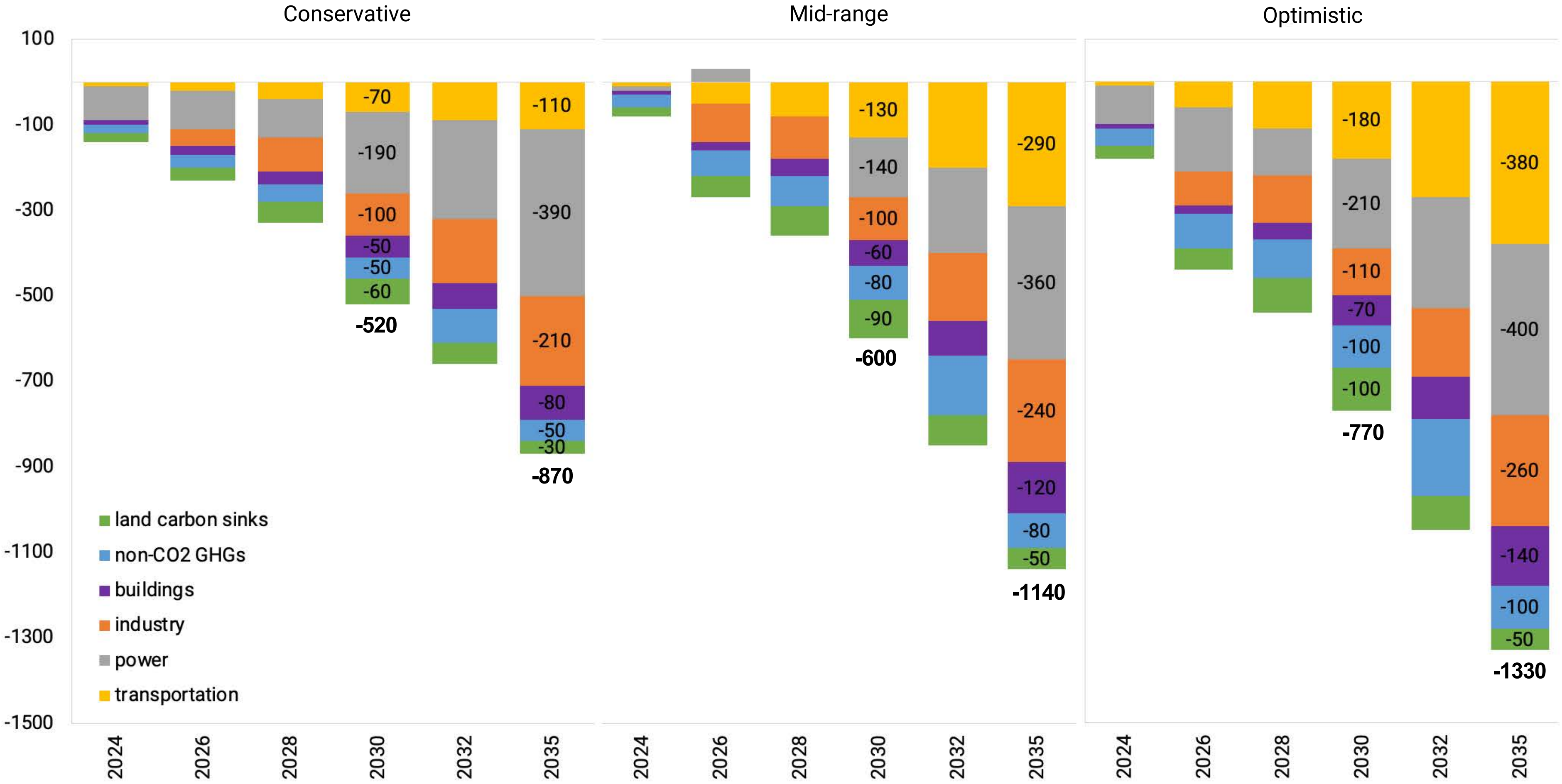
percent below 2005 historical emissions[1]



1 - 2005 historical net U.S. greenhouse gas emissions were 6,686 million metric tons of CO_2-equivalent (EPA Inventory of Greenhouse Gas Emissions and Sinks). CO_2-equivalent emissions calculations use IPCC AR4 100 year global warming potential as per EPA Inventory of Greenhouse Gas Emissions and Sinks.

Difference in Sectoral Emissions Under Current Policies vs Frozen Policies as of January 2021

million metric tons CO_2-equivalent (Mt CO_2-e)[1,2]



- Changes in **the transportation sector** (e.g. electrification) **and power sector** (e.g. renewable energy deployment) **are responsible for roughly half of all emissions reductions** across all Current Policies scenarios.
- Yet **IRA delivers emissions reductions across all major emitting sectors** of the economy including industry, buildings, and agricultural and forestry lands.

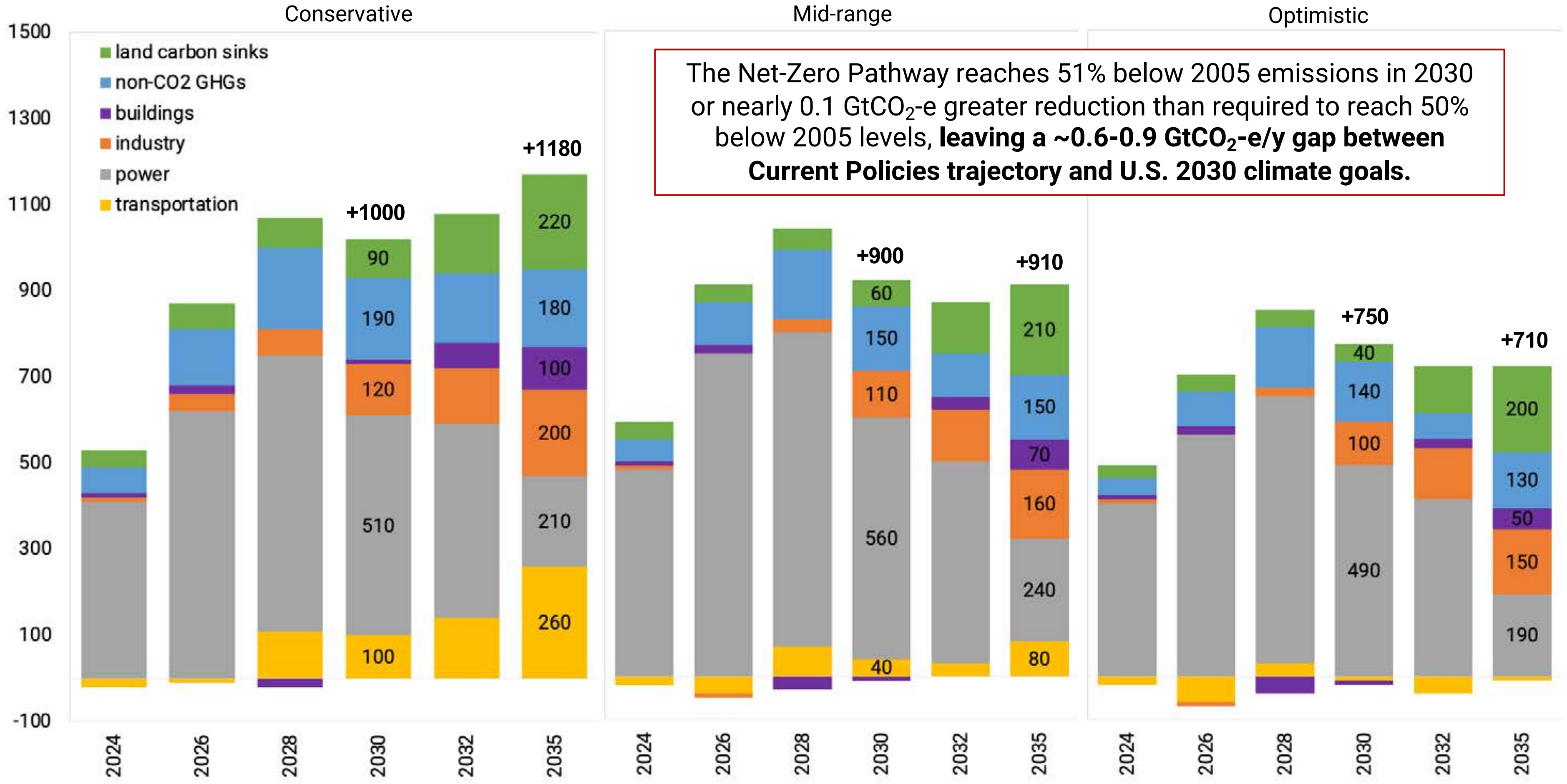
Notes:

1 - CO_2-equivalent emissions calculations use IPCC AR4 100 year global warming potential as per EPA Inventory of Greenhouse Gas Emissions and Sinks. All values rounded to nearest 10 M/yr. **All values should be regarded as approximate given uncertainty in future outcomes.**

2 - Modeled emissions exclude any changes in passenger and freight miles traveled due to surface transportation, rail, and transit investments in IIJA. According to the Georgetown Climate Center, emissions impact of these changes depend heavily on state implementation of funding from IIJA, which could result in anywhere from -14 Mt/yr to +25 Mt/yr change in CO_2 emissions from transportation in 2030.

Difference in Sectoral Emissions Under Current Policies vs Net-Zero Pathway

million metric tons CO_2-equivalent (Mt CO_2-e)[1,2]



The Net-Zero Pathway reaches 51% below 2005 emissions in 2030 or nearly 0.1 $GtCO_2$-e greater reduction than required to reach 50% below 2005 levels, **leaving a ~0.6-0.9 $GtCO_2$-e/y gap between Current Policies trajectory and U.S. 2030 climate goals.**

Further reductions are needed to close the gap with the Net-Zero Pathway and reach 2030 targets.

Major opportunities[3] include:

- ~0.2 Gt in the power sector by accelerating **coal plant retirements.**[4]
- ~0.1 Gt via improved **industrial process efficiency**.
- ~0.2-0.3 Gt via additional **abatement of non-CO_2 GHGs** and **improved agricultural and forestry practices**.

Notes:

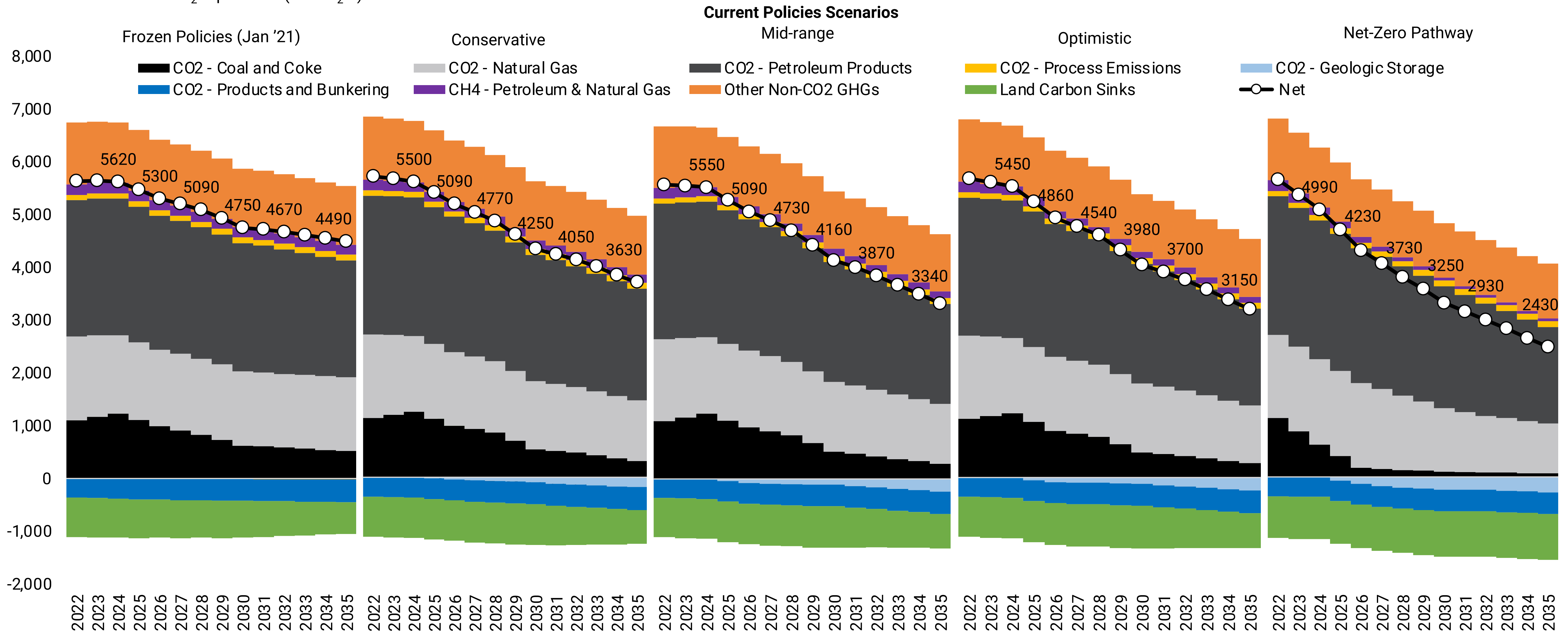
See additional Notes 1-2 on prior page

3 - While transportation electrification under IRA scenarios largely aligns with the Net-Zero Pathway, accelerated **improvements in internal combustion vehicle fuel efficiency** could further reduce transport sector emissions by ~10 Mt/yr in 2030 and ~10-30 Mt/yr in 2035.

4 – In Current Policies scenarios, solar capacity additions are already constrained through 2035 and wind capacity additions are close to constraints. Additional **reductions in coal-fired generation** would therefore likely be compensated primarily by increases in gas-fired generation. Displacing ~400-450 TWh of remaining coal generation in 2030 with gas CCGTs would result in a net reduction of ~0.2 GtCO2-e/year. Deeper reductions could potentially be achieved via deployment of carbon capture in the power sector, which is minimal in these revised REPEAT Project results.

Annual Greenhouse Gas Sources and Sinks

million metric tons CO_2-equivalent (Mt CO_2-e)[1,2]

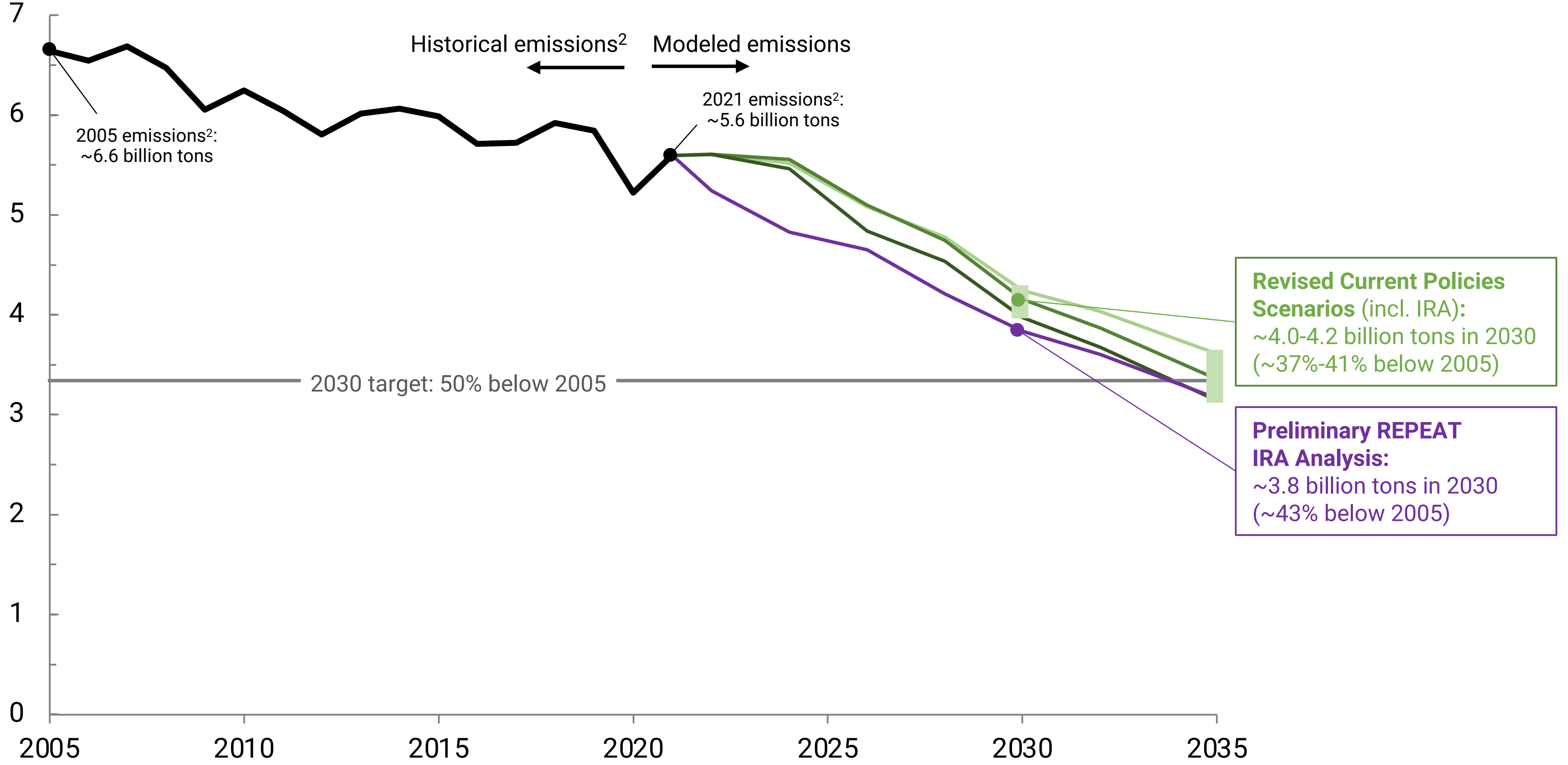


1 - CO_2-equivalent emissions calculations use IPCC AR4 100 year global warming potential as per EPA Inventory of Greenhouse Gas Emissions and Sinks. All values rounded to nearest 10 M/yr. **All values should be regarded as approximate given uncertainty in future outcomes.**

2 - Modeled emissions exclude any changes in passenger and freight miles traveled due to surface transportation, rail, and transit investments in IIJA.

Revised and Preliminary REPEAT Analysis of the Inflation Reduction Act

billion metric tons CO_2-equivalent (Gt CO_2-e) net U.S. greenhouse gas emissions (including land carbon sinks)[1]



Reflecting constraints on supply chains and other rate-limiting factors, this analysis estimates a slower start to the energy systems transformation under Current Policies (including IRA) than preliminary results reported in August, 2022[4]:

- This revised analysis now includes a range of three Current Policies scenarios (‘Conservative’, ‘Mid-range’, and ‘Optimistic’), better reflecting uncertainty about the impacts of IRA.
- ‘Preliminary’ results generally estimated more rapid increases in EV sales share and more rapid solar PV and wind deployment rates than revised results.
- The ‘Optimistic’ Current Policies scenario & ‘Preliminary’ scenario converge by 2032.
- See p. 46 for sector-by-sector comparison of Revised & Preliminary results

4 – Jenkins et al. (2022), “Preliminary Report: The Climate and Energy Impacts of the Inflation Reduction Act of 2022, REPEAT Project,, updated September 21, 2022, https://doi.org/10.5281/zenodo.7106218

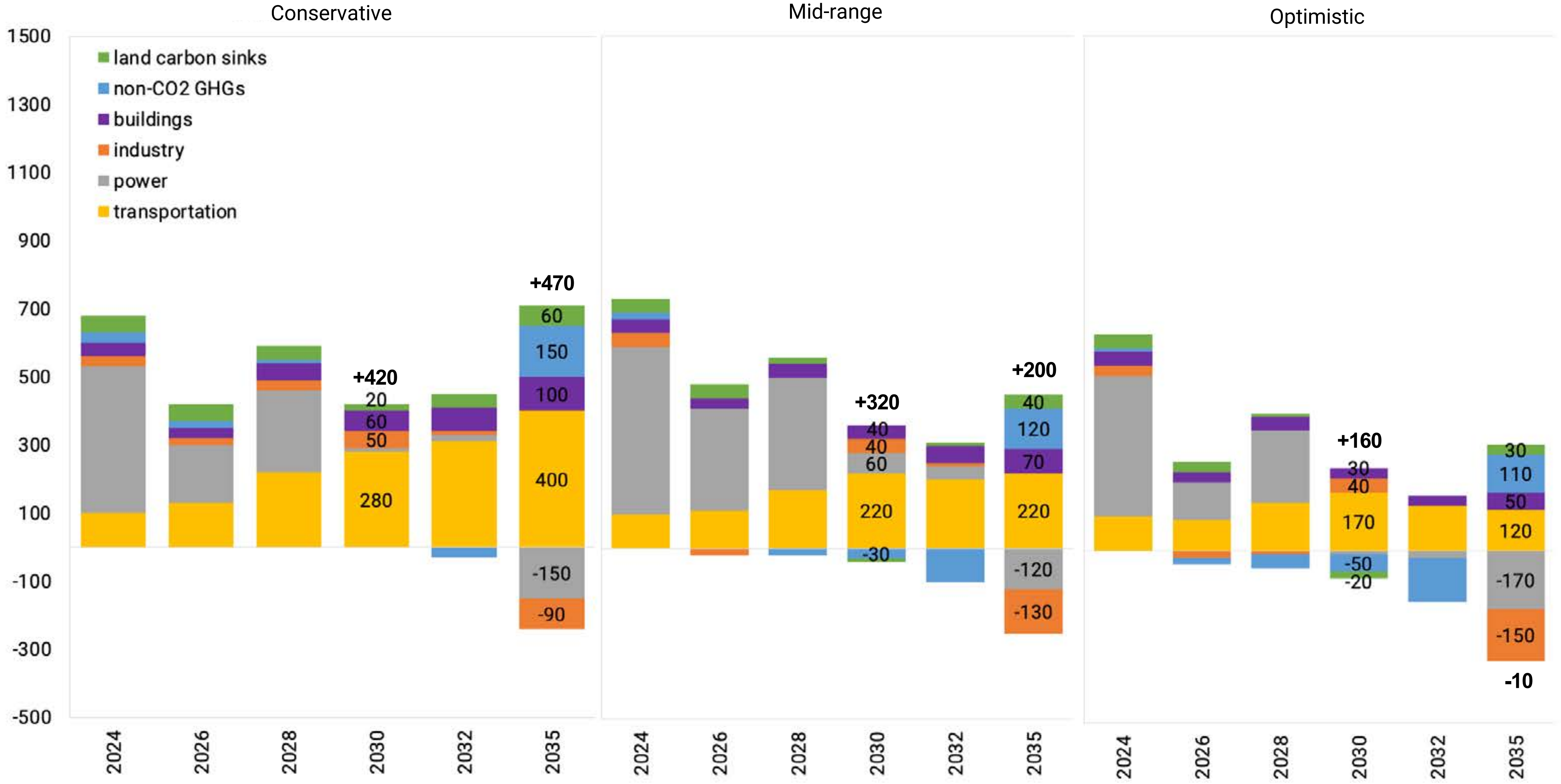
1 - CO_2-equivalent emissions calculations use IPCC AR4 100 year global warming potential as per EPA Inventory of Greenhouse Gas Emissions and Sinks. **All values should be regarded as approximate given uncertainty in future outcomes.**

2 - Historical data from U.S. EPA Inventory for 2005-2030; 2021 estimate from February 2023 draft EPA Inventory.

3 - Modeled emissions exclude any changes in passenger and freight miles traveled due to surface transportation, rail, and transit investments in IIJA. According to the Georgetown Climate Center, emissions impact of these changes depend heavily on state implementation of funding from IIJA, which could result in anywhere from -14 Mt to +25 Mt change in CO_2 emissions from transportation in 2030.

Differences Between Revised Current Policies Scenarios and Preliminary REPEAT Analysis of the Inflation Reduction Act

million metric tons CO_2-equivalent (Mt CO_2-e)[1,2,3]



Notes:

1 - CO_2-equivalent emissions calculations use IPCC AR4 100 year global warming potential as per EPA Inventory of Greenhouse Gas Emissions and Sinks. All values rounded to nearest 10 Mt and all values <10 Mt omitted from labels. **All values should be regarded as approximate given uncertainty in future outcomes.**

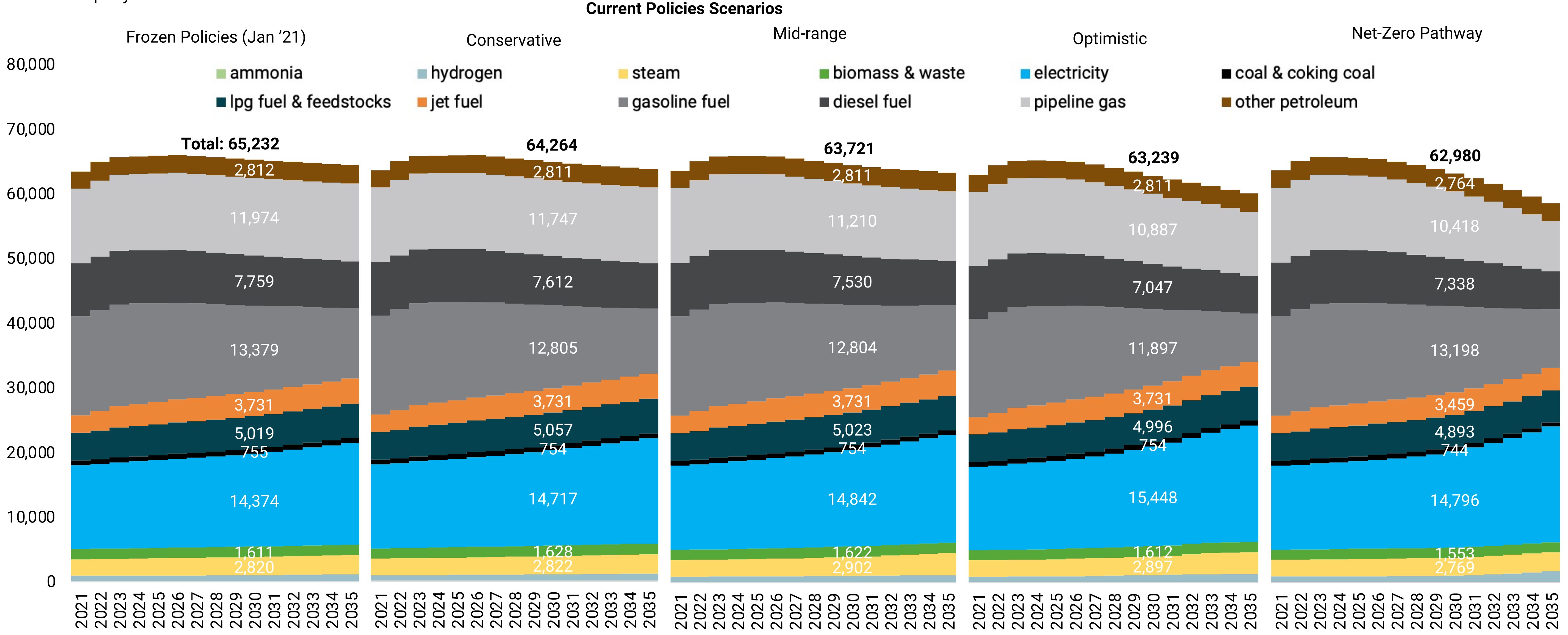
2 - Modeled emissions exclude any changes in passenger and freight miles traveled due to surface transportation, rail, and transit investments in IIJA. According to the Georgetown Climate Center, emissions impact of these changes depend heavily on state implementation of funding from IIJA, which could result in anywhere from -14 Mt/yr to +25 Mt/yr change in CO_2 emissions from transportation in 2030.

3 – Differences vs values reported in Jenkins et al. (2022), "Preliminary Report: The Climate and Energy Impacts of the Inflation Reduction Act of 2022, REPEAT Project,, updated September 21, 2022, https://doi.org/10.5281/zenodo.7106218

Energy Demand

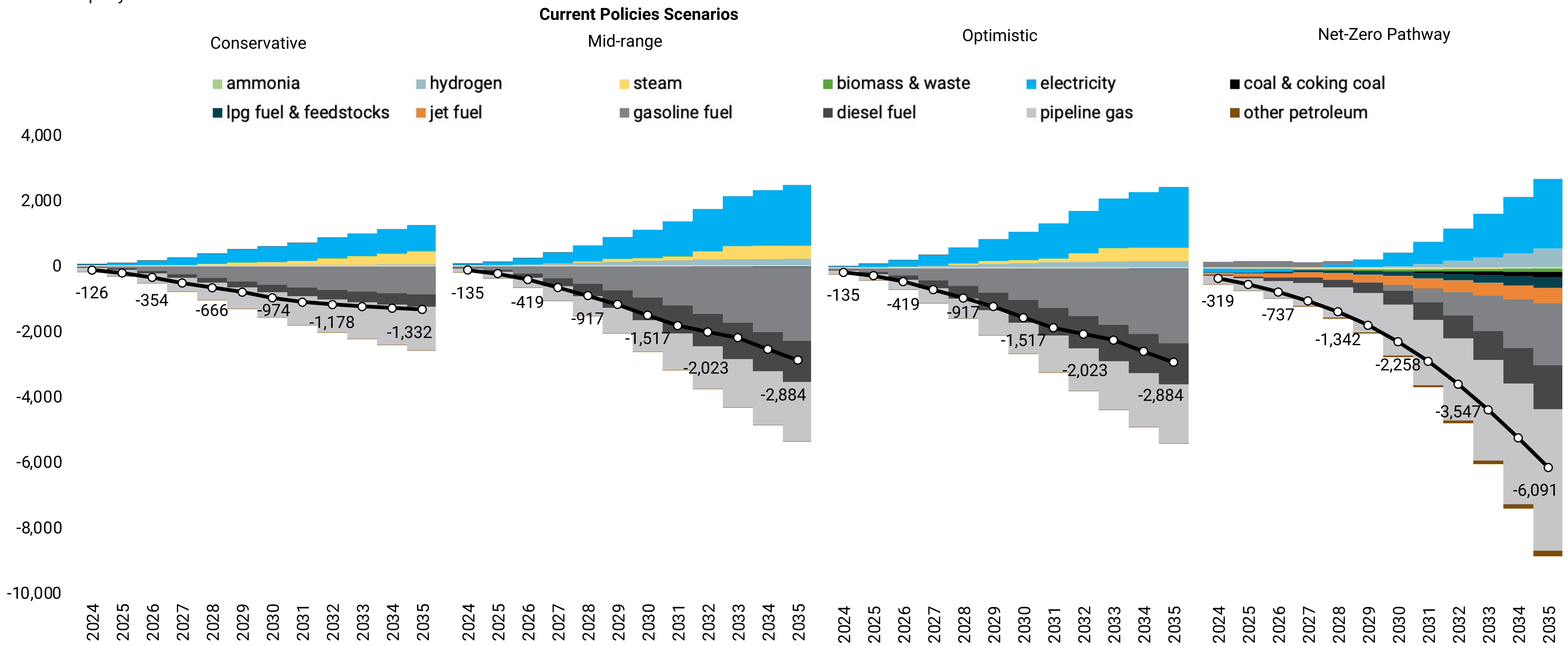
Final Energy Demand by Energy Carrier/Fuel

trillion Btu per year



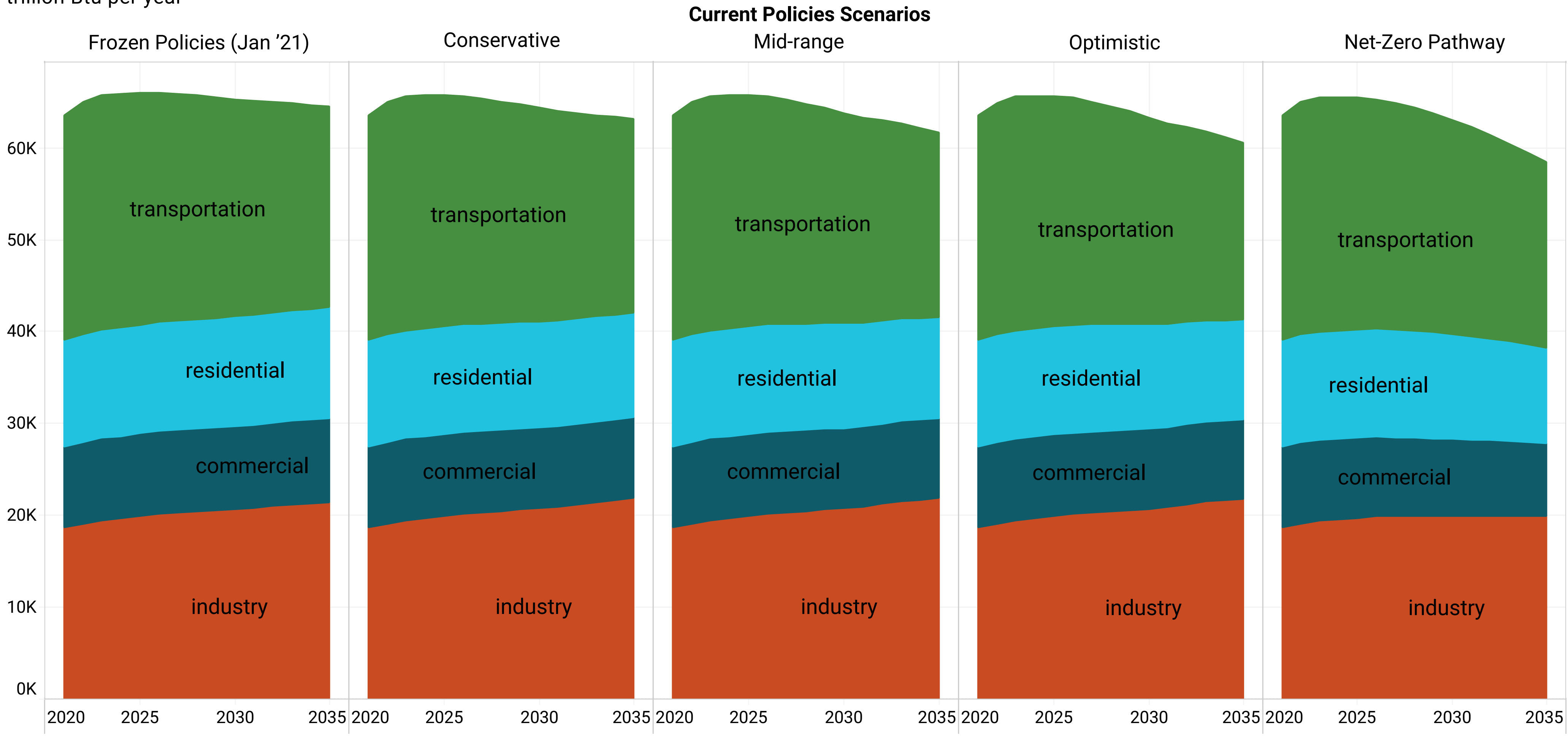
Change in Final Energy Demand by Energy Carrier/Fuel vs Frozen Policies as of January 2021

trillion Btu per year



Final Energy Demand by Sector

trillion Btu per year

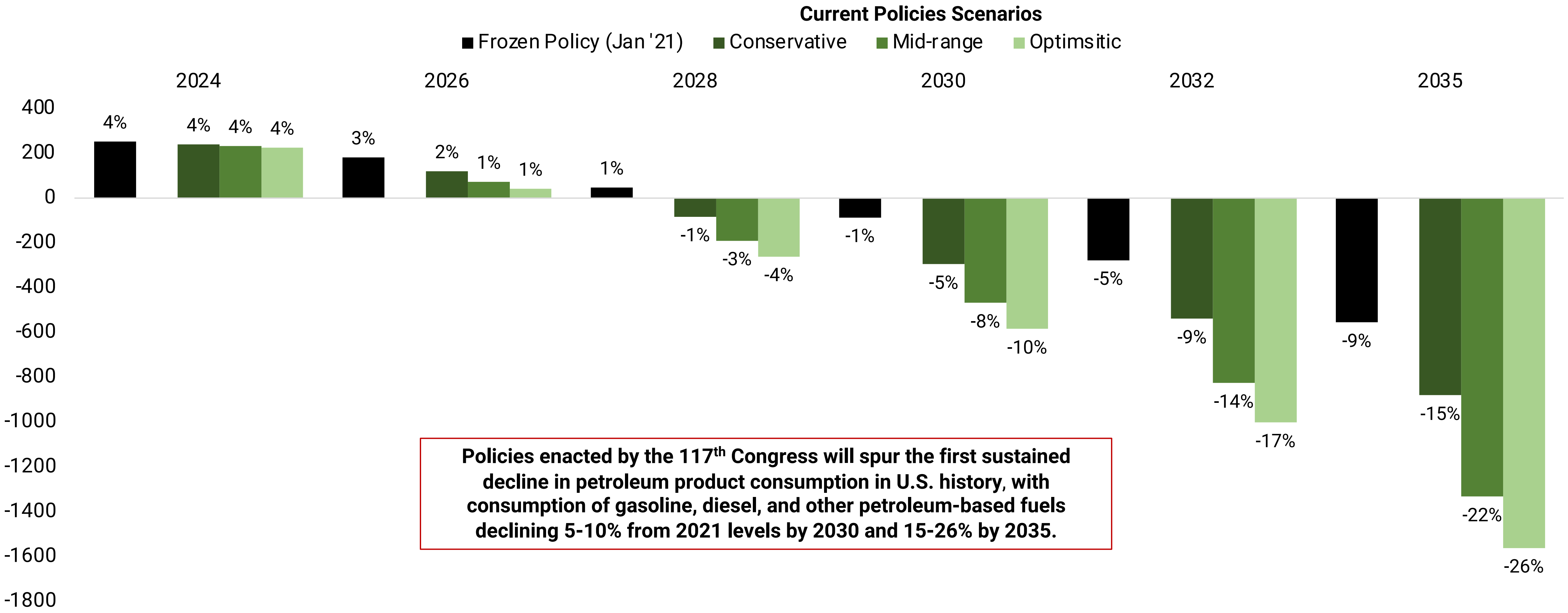


Electrification and end-use efficiency lower final energy consumption in Current Policies and Net-Zero Pathway scenarios, even as total demand for energy services increases.

Electric vehicles and heat pumps are much more efficient at converting final energy carriers to energy services (vehicle miles traveled, square footage conditioned) than internal combustion engines and fossil boilers.

Changes in Annual U.S. Petroleum Product Consumption vs 2021

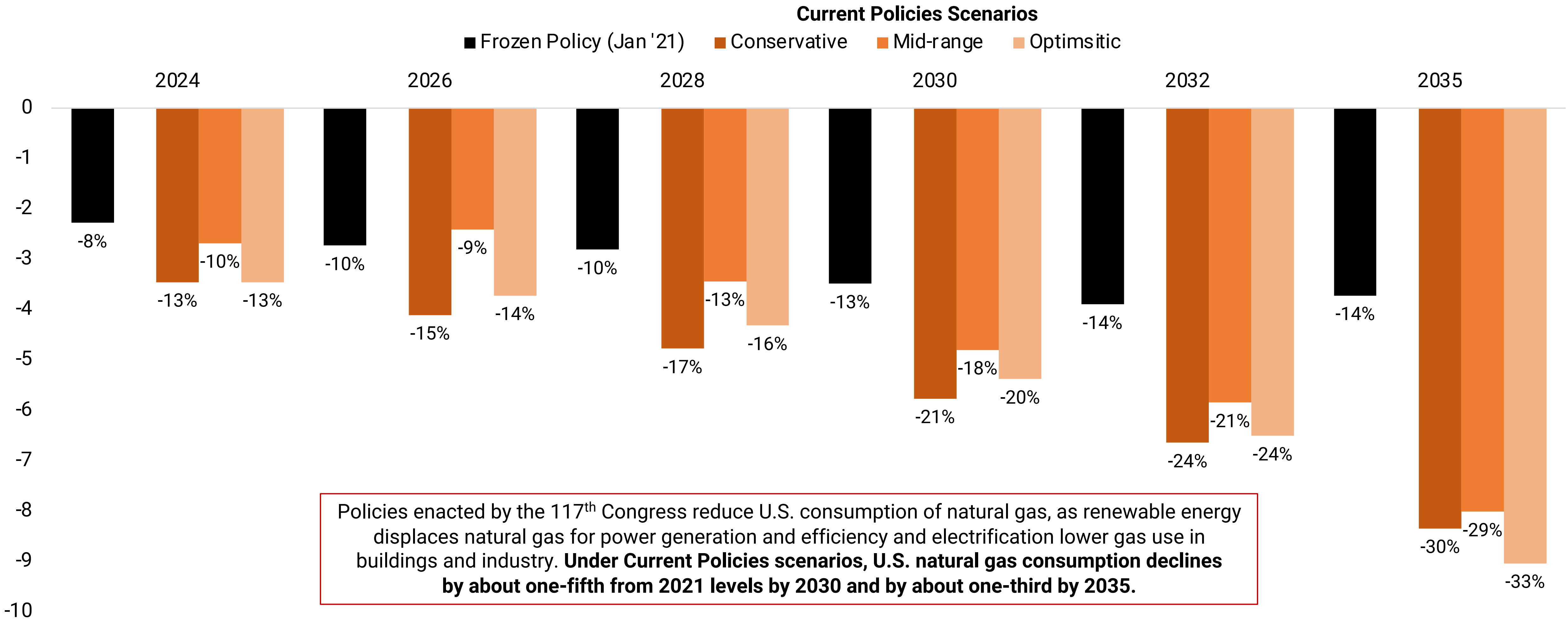
million barrels per year (mmbbl/y)



Policies enacted by the 117th Congress will spur the first sustained decline in petroleum product consumption in U.S. history, with consumption of gasoline, diesel, and other petroleum-based fuels declining 5-10% from 2021 levels by 2030 and 15-26% by 2035.

Changes in Annual U.S. Natural Gas Consumption vs 2021

trillion cubic feet per year (Tcf/year)

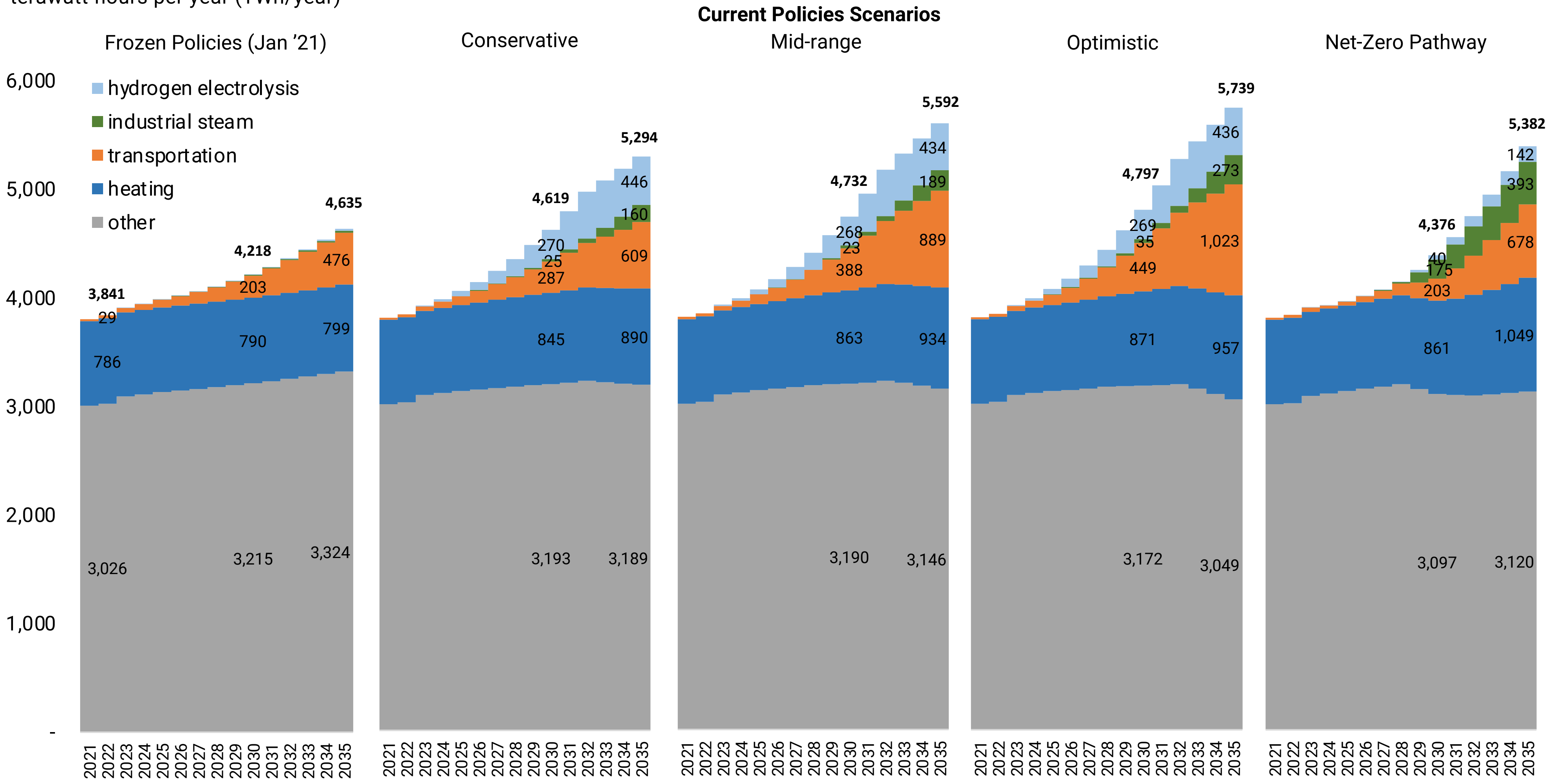


Policies enacted by the 117th Congress reduce U.S. consumption of natural gas, as renewable energy displaces natural gas for power generation and efficiency and electrification lower gas use in buildings and industry. **Under Current Policies scenarios, U.S. natural gas consumption declines by about one-fifth from 2021 levels by 2030 and by about one-third by 2035.**

Note – The magnitude of reductions in natural gas demand is affected by the balance of wind and solar power deployment rates (which offset gas consumption for power generation, all else equal) and the pace of electrification (which increases electricity demand and thus natural gas consumption for power generation, all else equal). As a result, the Conservative scenario with slower electrification results in lower gas demand in many years than the Middle or Optimistic Current Policies scenarios, as these scenarios have both faster wind and solar deployment *and* higher electricity demand from more rapid EV adoption and other electrification.

Electricity Demand by Sector

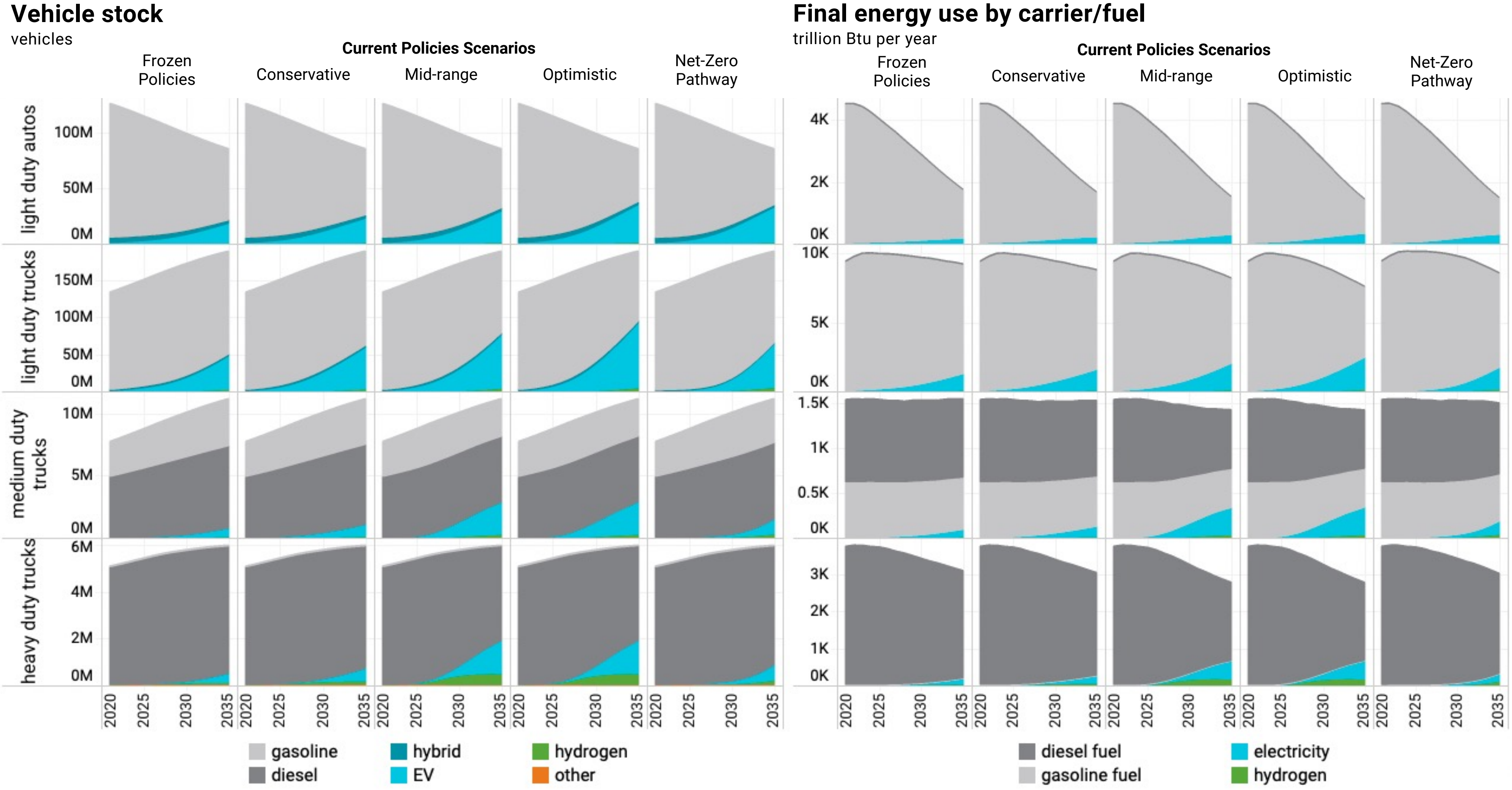
terawatt-hours per year (TWh/year)



Growing adoption of electric vehicles, heat pumps, industrial electric boilers, and hydrogen electrolysis will drive **a sustained increase in U.S. electricity consumption** for the first time since the mid-2000s.

Under Current Policies scenarios, **U.S. electricity demand grows 20-25% from 2022 to 2030** and reaches 38-49% higher than 2022 demand by 2035.

Transportation Sector Changes



Penetration and impact of EVs under Current Policies scenarios

Light duty vehicle sales share: 42-65% by 2030, 59-94% by 2035.

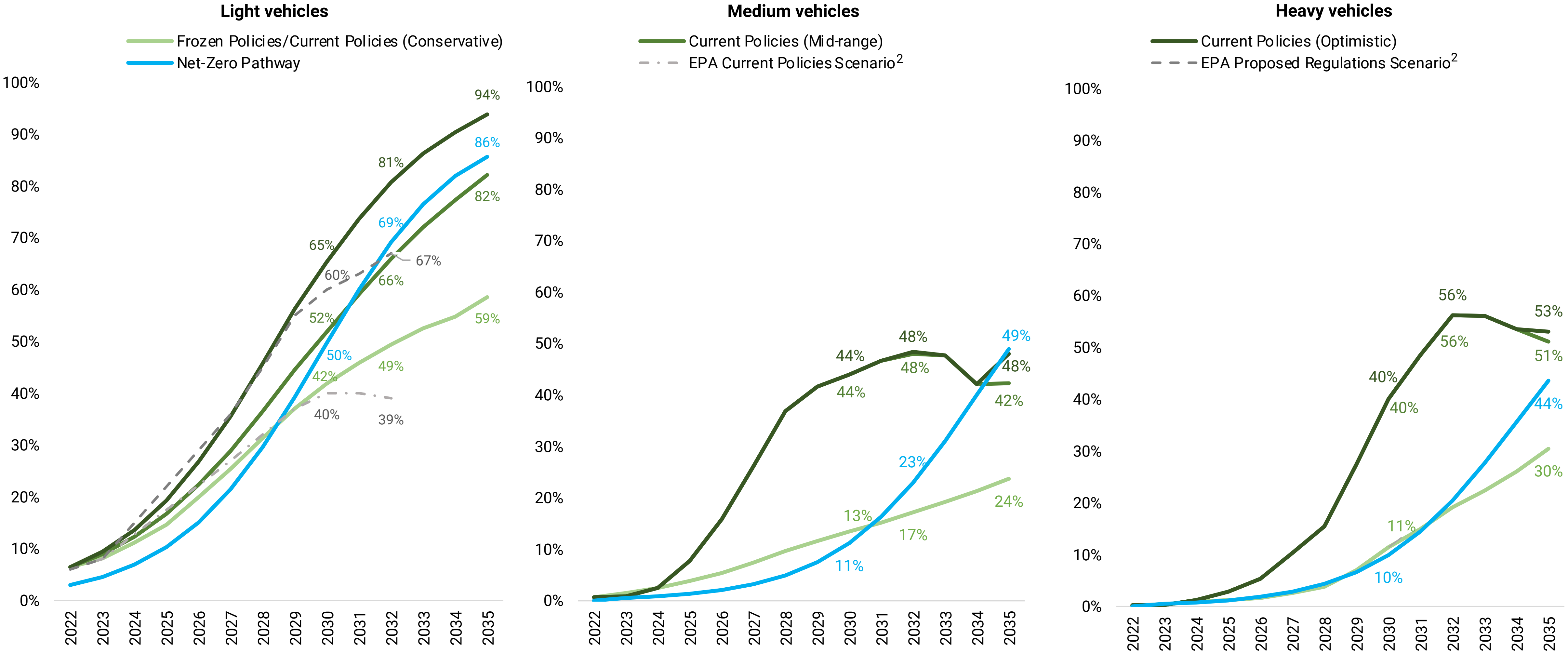
Light duty vehicle fleet share: 13-19% by 2030, 29-44% by 2035. 36-51 million EVs on U.S. roads in 2030.

Medium/heavy truck sales share: ~12-42% by 2030, 27-51% by 2035.

Medium/heavy truck fleet share: ~3-10% by 2030, 9-24% by 2035. 0.5-1.6 million EV medium/heavy trucks on U.S. roads in 2030.

Electric Vehicle Sales Shares

percent of new vehicle sales per year[1]

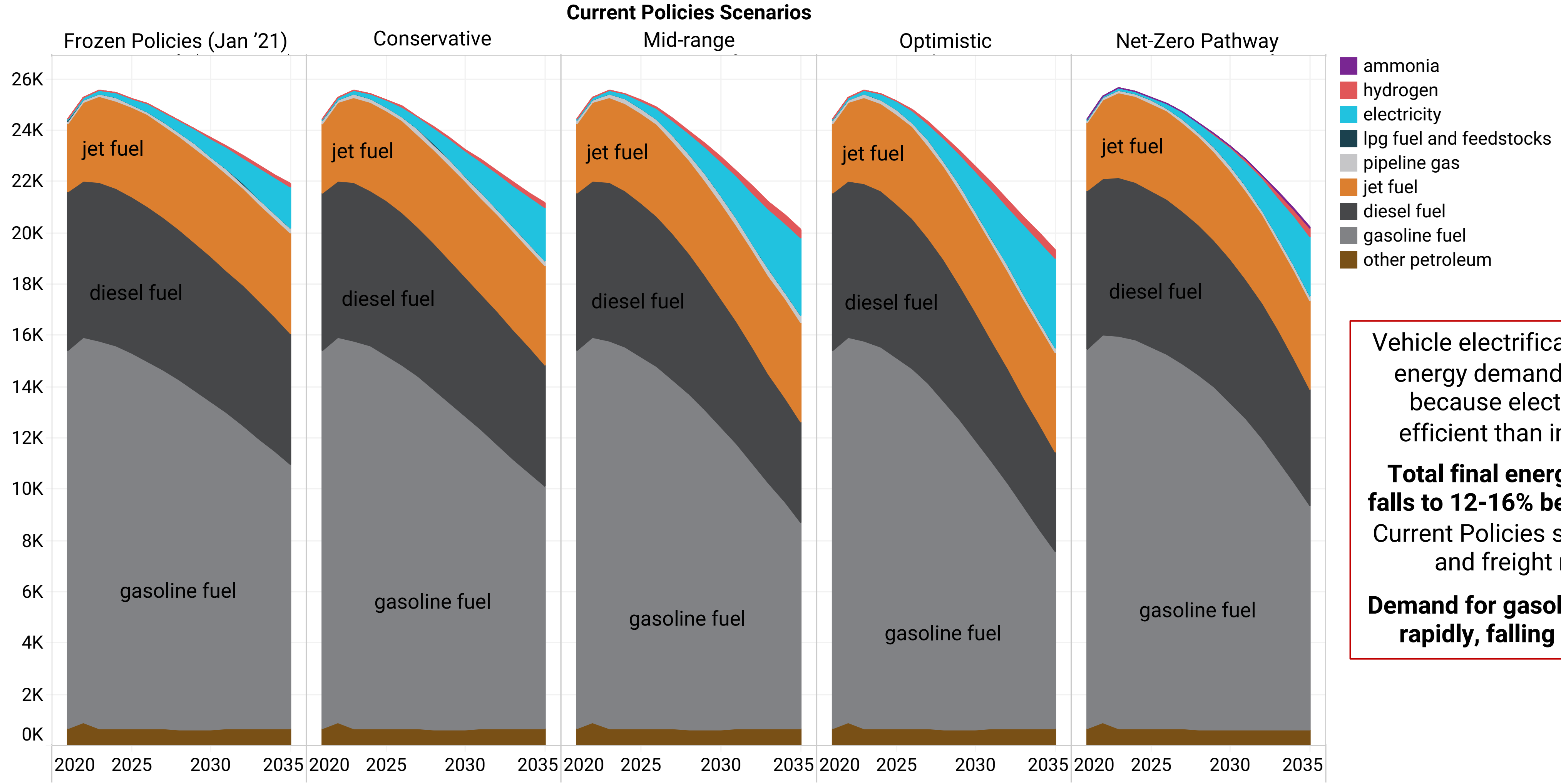


1 - See p. 30-31 for details on REPEAT Project treatment of electric and zero emissions vehicle adoption.

2 - EPA scenarios provided for comparison purposes from "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles: Draft Regulatory Impact Analysis" U.S. EPA (April 2023), at p. 13-35 & 13-37. "Proposed Regulations" scenario includes modeled compliance with proposed MY2027+ multi-pollution emissions standard, which is not included in REPEAT Project Current Policies scenarios.

Transportation Final Energy Demand by Energy Carrier/Fuel

trillion Btu per year



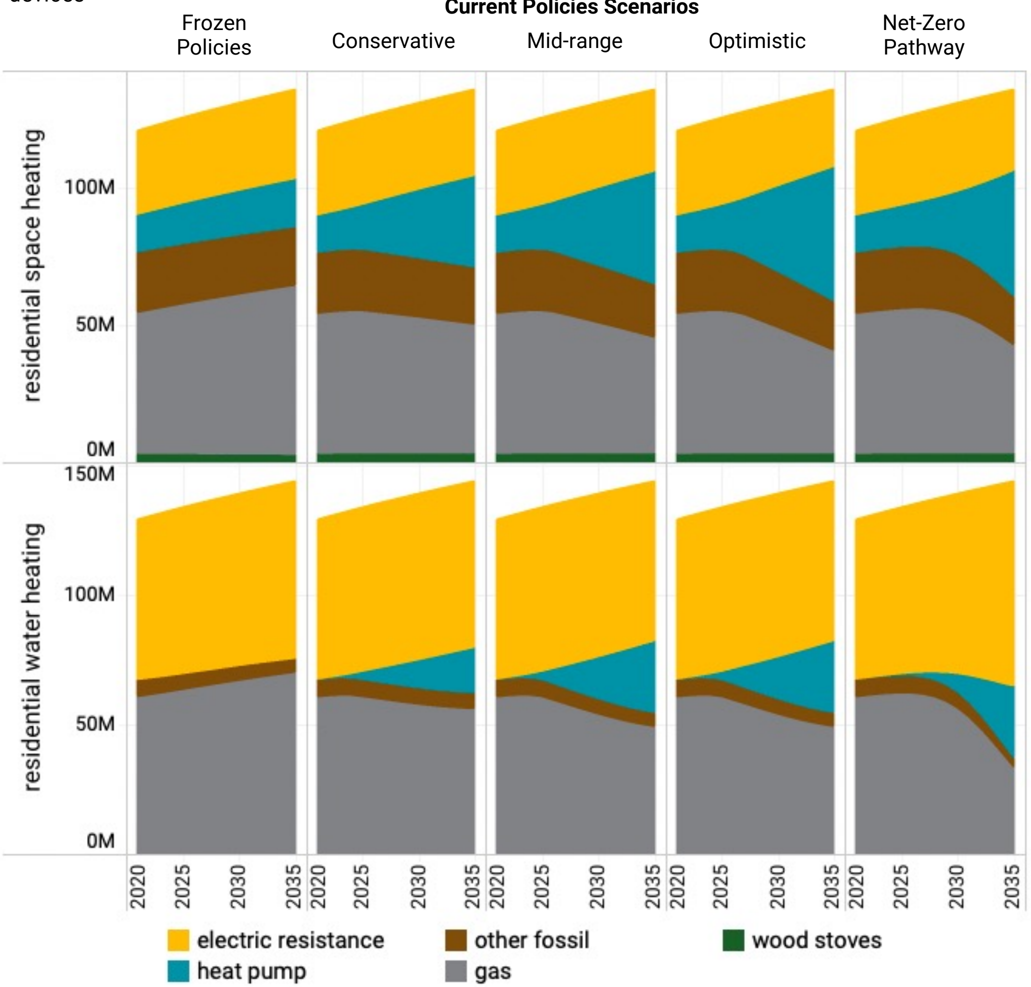
Vehicle electrification significantly reduces final energy demand in the transportation sector, because electric vehicles are much more efficient than internal combustion engines.

Total final energy demand for transportation falls to 12-16% below 2022 levels in 2030 under Current Policies scenarios, even as total vehicle and freight miles traveled increases.

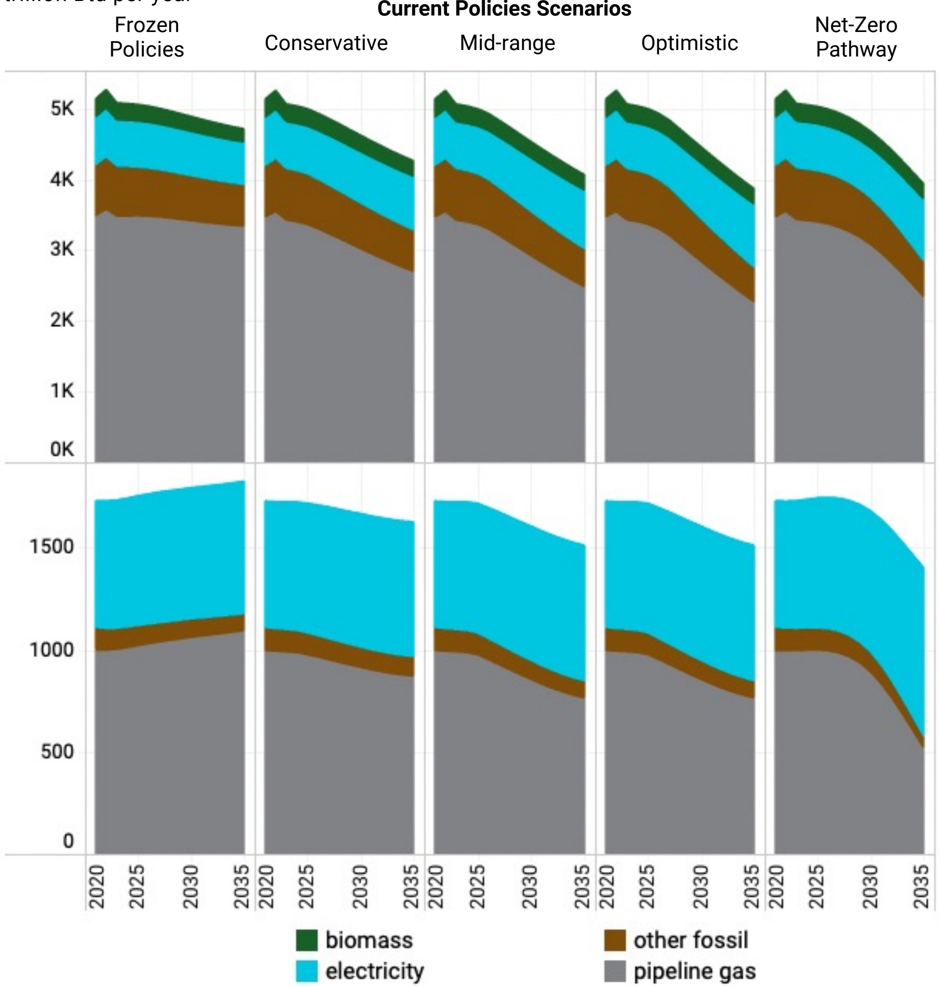
Demand for gasoline and diesel fuel drops more rapidly, falling 17-24% from 2022 to 2030.

Residential Building Sector Changes

Device stock



Final energy use by carrier/fuel



Penetration and impact of residential heat pumps under Current Policies scenarios

Space heating sales share:
34-59% by 2030 and after (up from ~15% in Frozen Policies).

Space heating stock:
19-24% by 2030, 24-36% by 2035. 25-31 million heat pumps in U.S. homes in 2030.

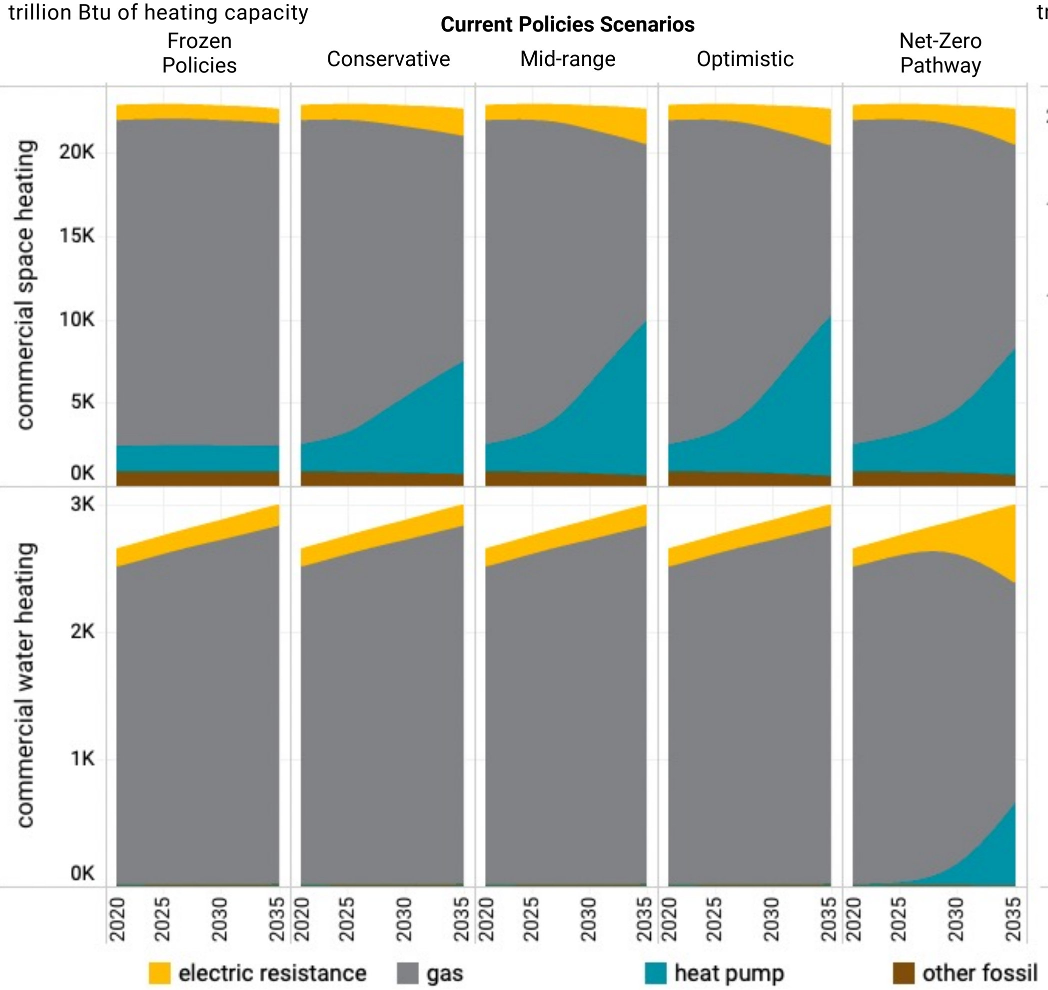
Water heating sales share:
12-21% by 2030 and after (up from ~0% in Frozen Policies).

Water heating stock:
8-12% by 2030, 12-19% by 2035. 11-16 million heat pump water heaters in U.S. homes in 2030.

Commercial Building Sector Changes

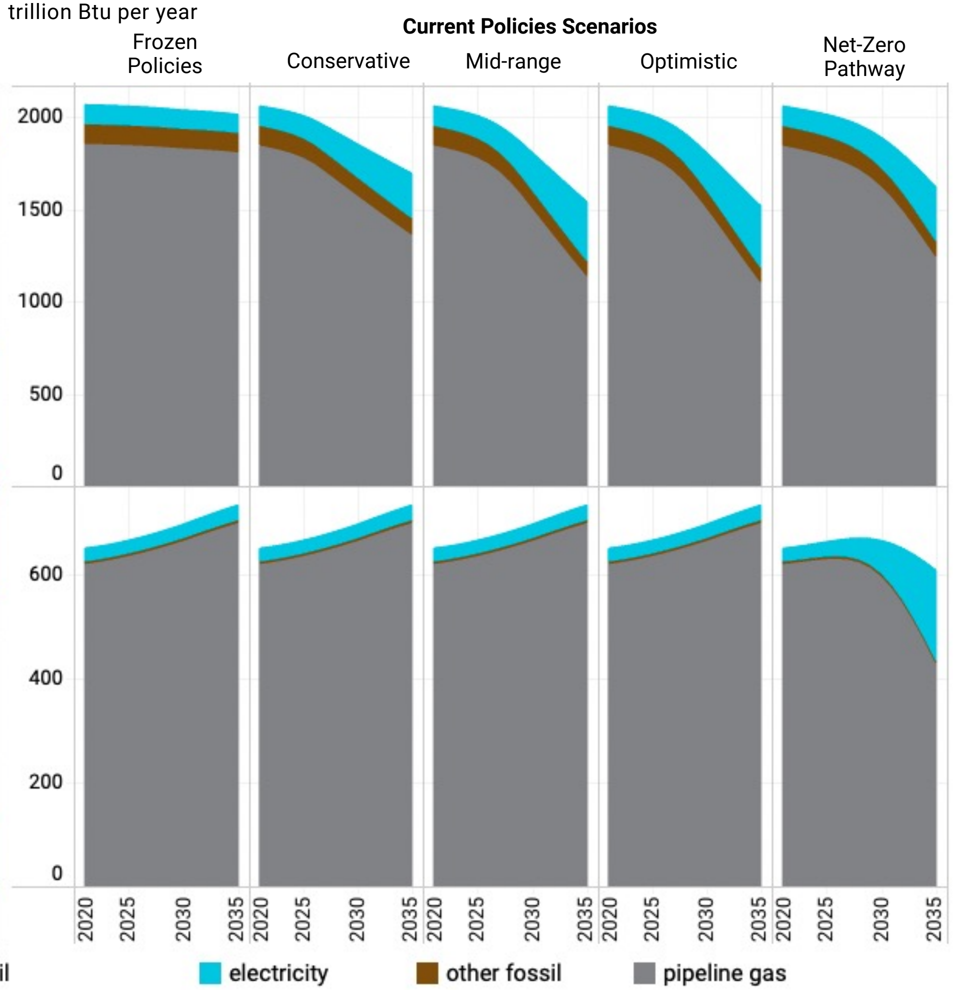
Device stock

trillion Btu of heating capacity



Final energy use by carrier/fuel

trillion Btu per year



Penetration and impact of commercial heat pumps under Current Policies scenarios

Space heating sales share:
43-70% by 2030 and after (up from 7% in Frozen Policies).

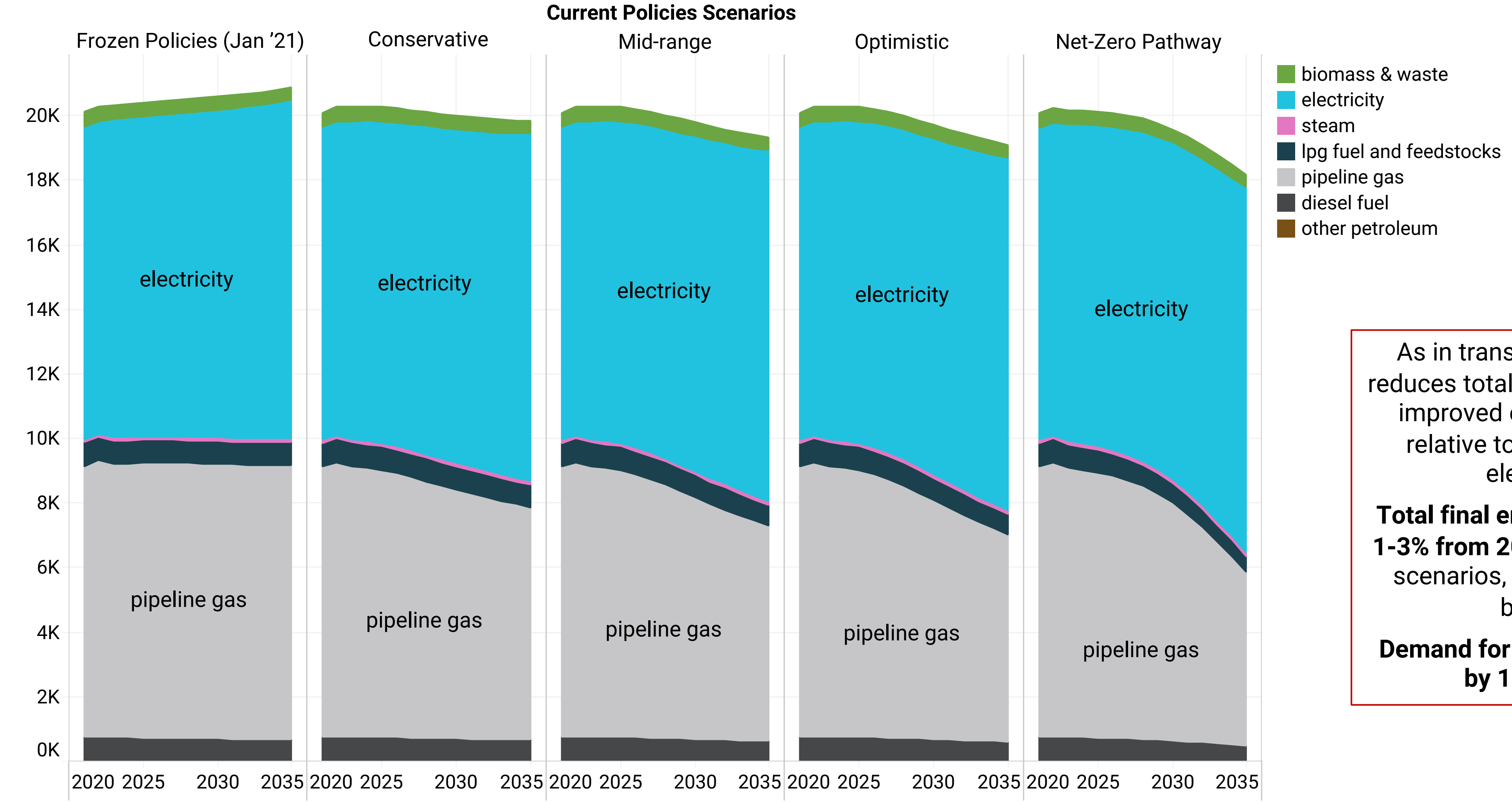
Space heating stock:
20-23% by 2030, 30-42% by 2035.

Water heating sales share:
~2% and unaffected by policy scenarios (vs. 24% in 2030 in Net-Zero Pathway).

Water heating stock:
~0.2% (vs 6% in 2030 in Net-Zero Pathway)

Building Final Energy Demand by Energy Carrier/Fuel

trillion Btu per year



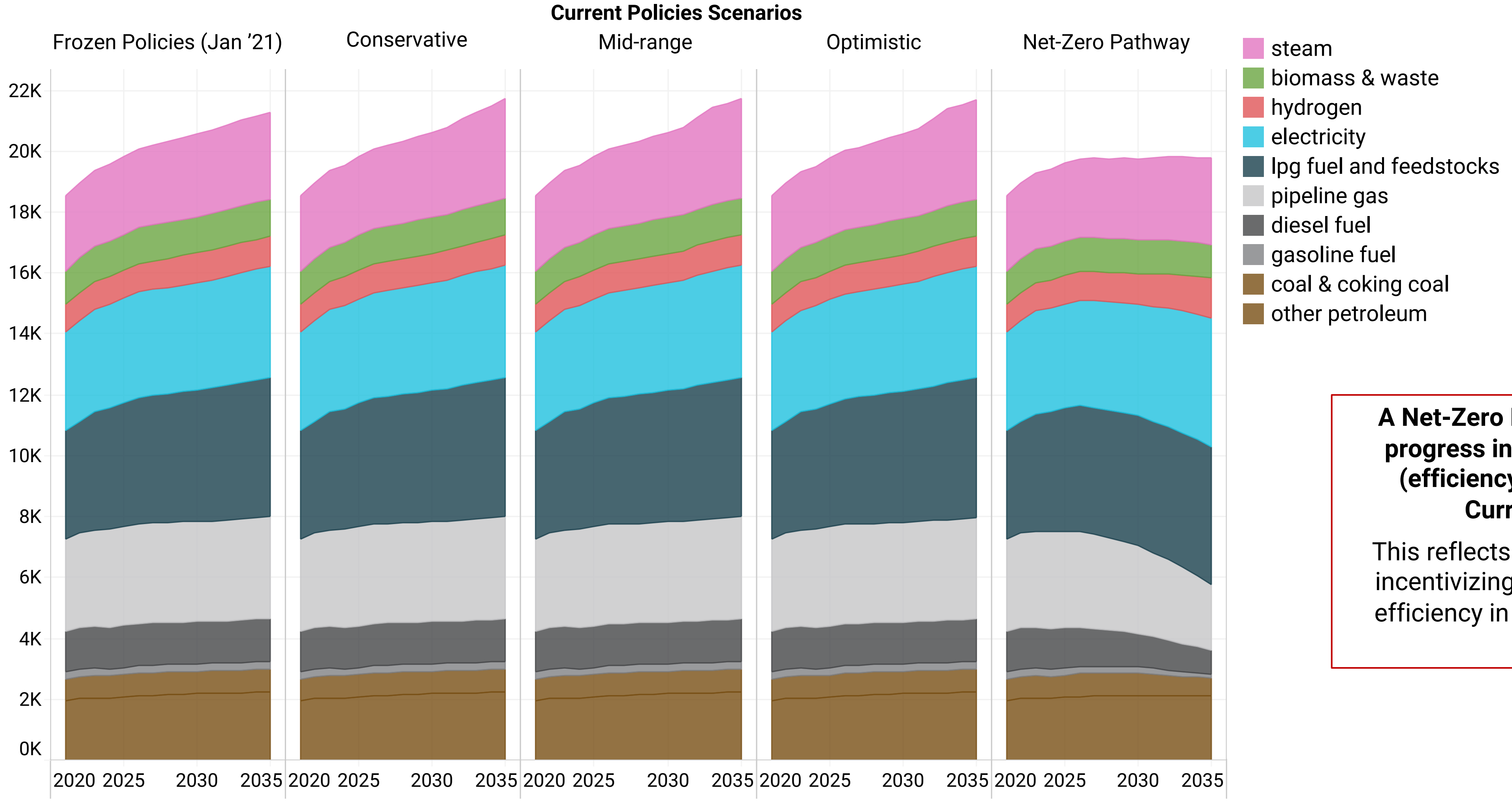
As in transportation, building electrification reduces total final energy demand, thanks to the improved efficiency of electric heat pumps relative to fossil boilers and furnaces and electric resistance heating.

Total final energy demand in buildings falls by 1-3% from 2022 to 2030 under Current Policies scenarios, despite growth in population and building square footage.

Demand for natural gas in buildings contracts by 10-13% from 2022 to 2030.

Industrial Final Energy Demand by Energy Carrier/Fuel

trillion Btu per year

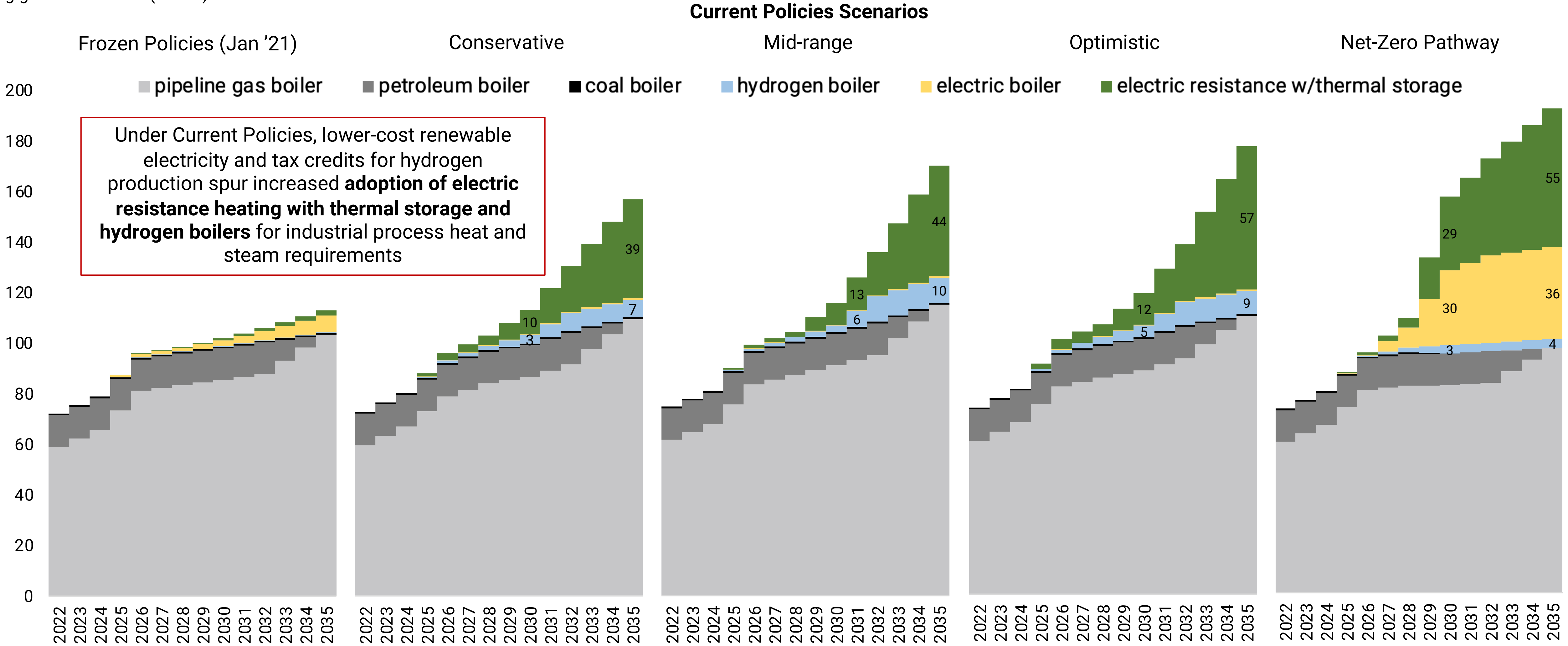


A Net-Zero Pathway would see more rapid progress in industrial energy productivity (efficiency) gains than observed under Current Policies scenarios.

This reflects a lack of comprehensive policy incentivizing industrial decarbonization and efficiency in the Inflation Reduction Act and Infrastructure Law.

Industrial Steam Production Capacity Stock

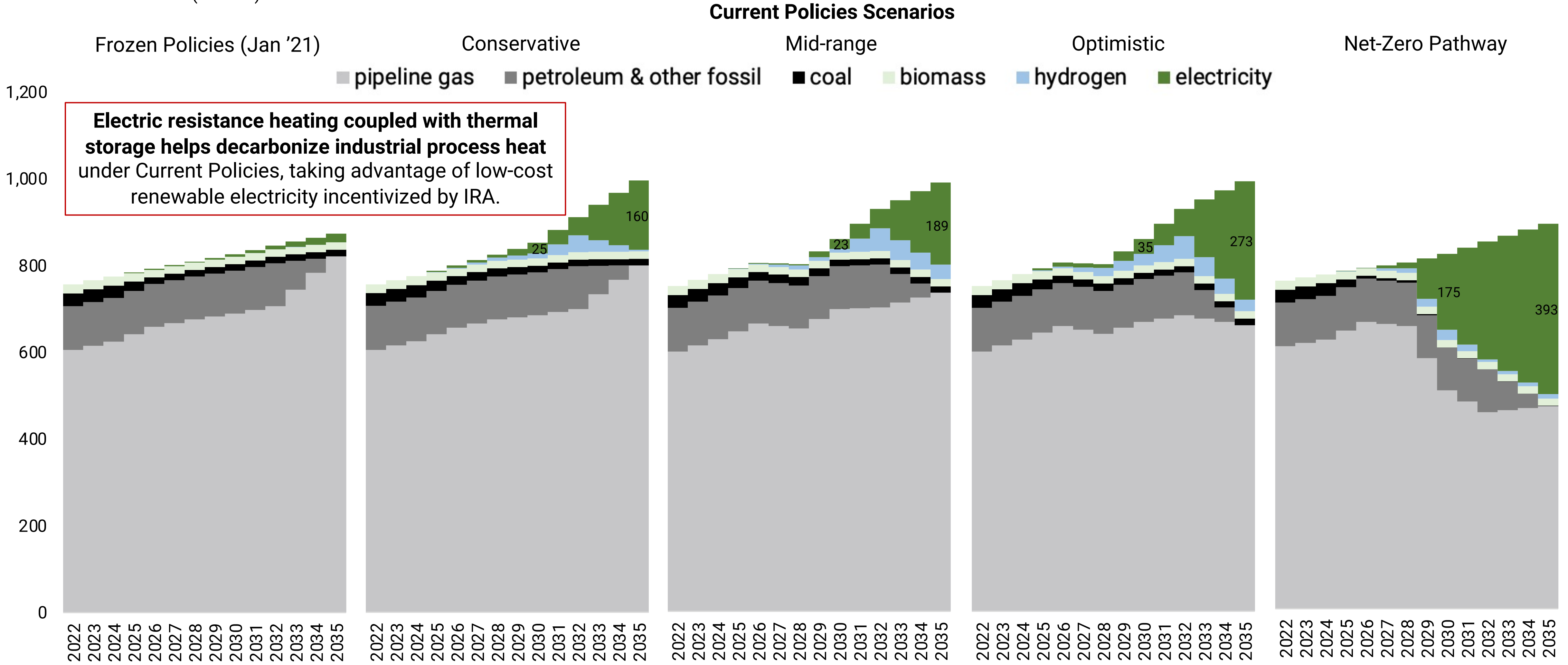
gigawatts thermal (GW-th)



Industrial Steam Production

terawatt-hours thermal (TWh-th)

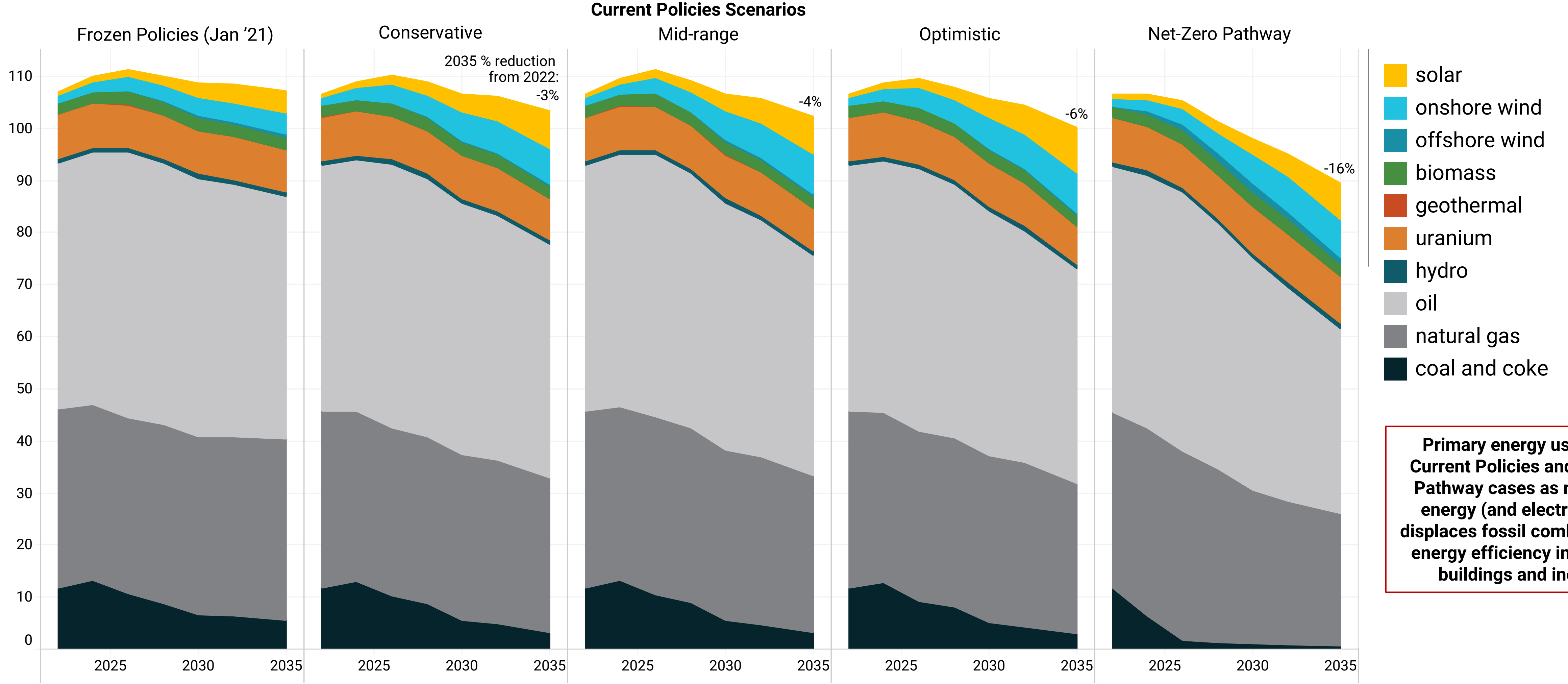
Electric resistance heating coupled with thermal storage helps decarbonize industrial process heat under Current Policies, taking advantage of low-cost renewable electricity incentivized by IRA.



Energy Supply

Primary Energy Supply

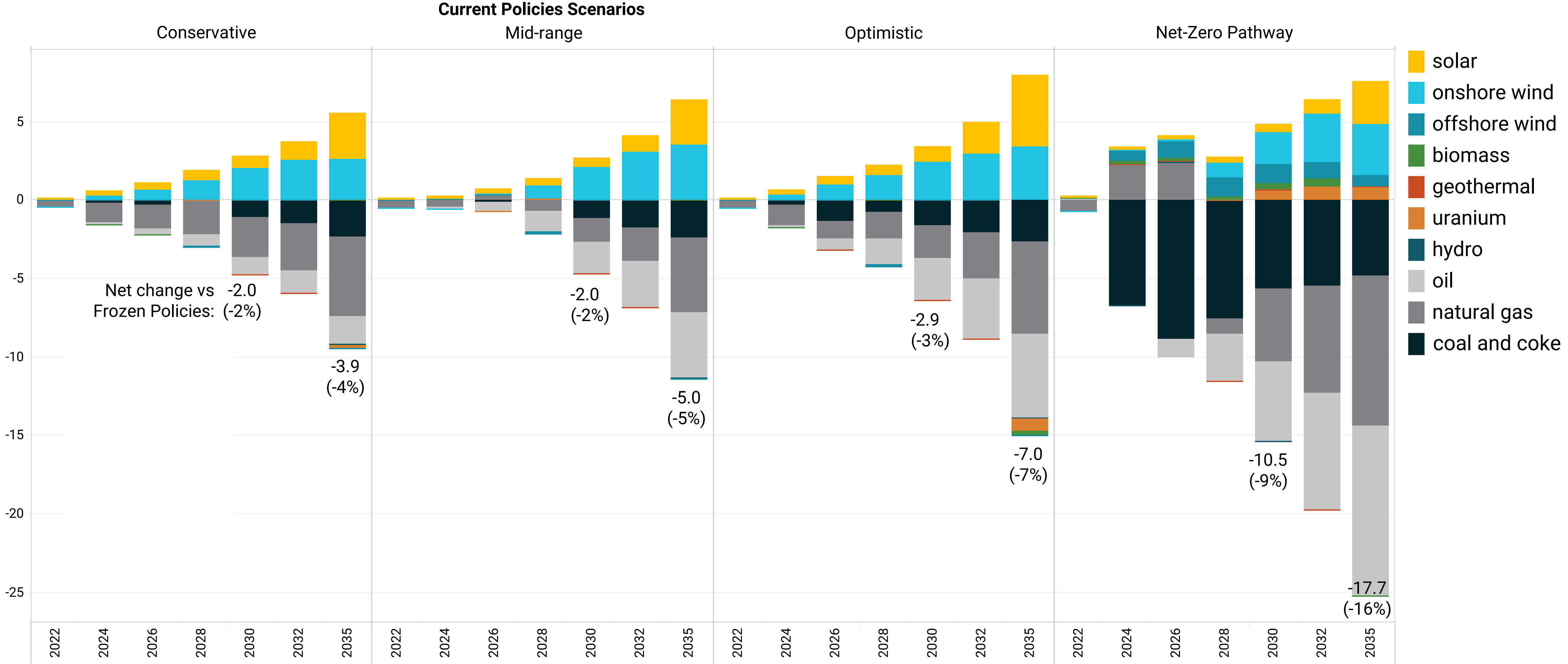
quadrillion Btu per year (Quads/year)



Primary energy use falls in Current Policies and Net-Zero Pathway cases as renewable energy (and electrification) displaces fossil combustion and energy efficiency improves in buildings and industry.

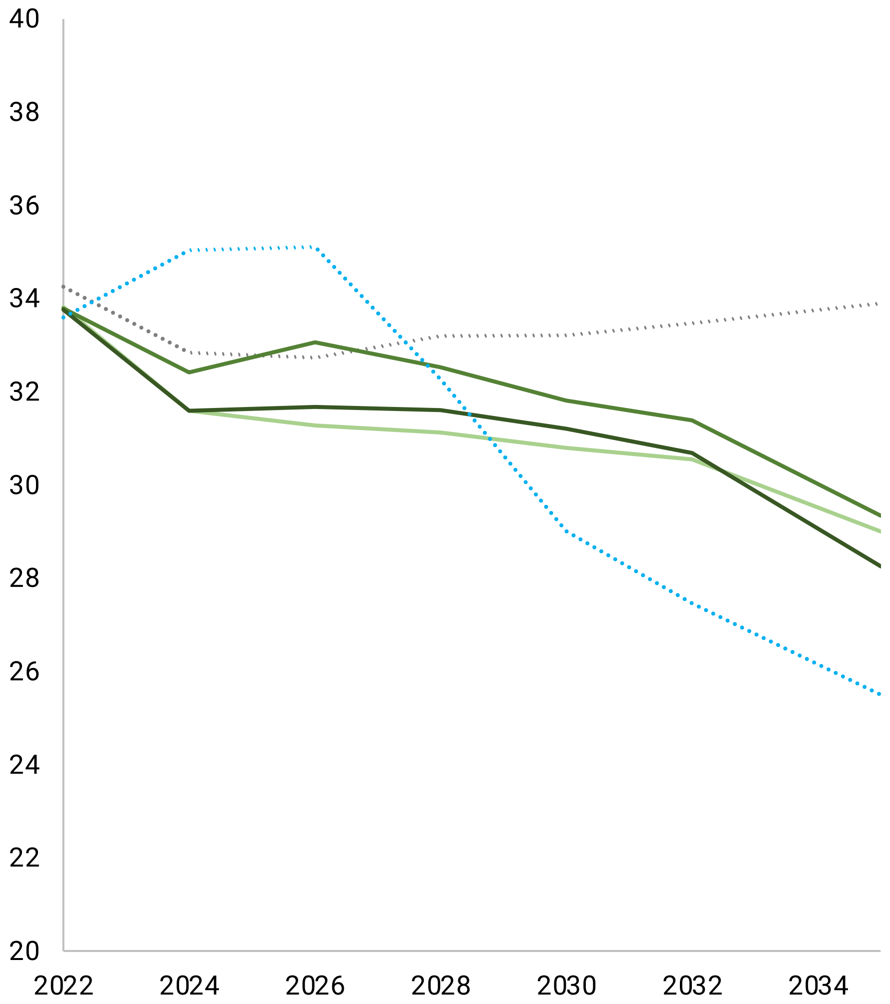
Change in Primary Energy Supply vs Frozen Policies as of January 2021

quadrillion Btu per year (Quads/year)



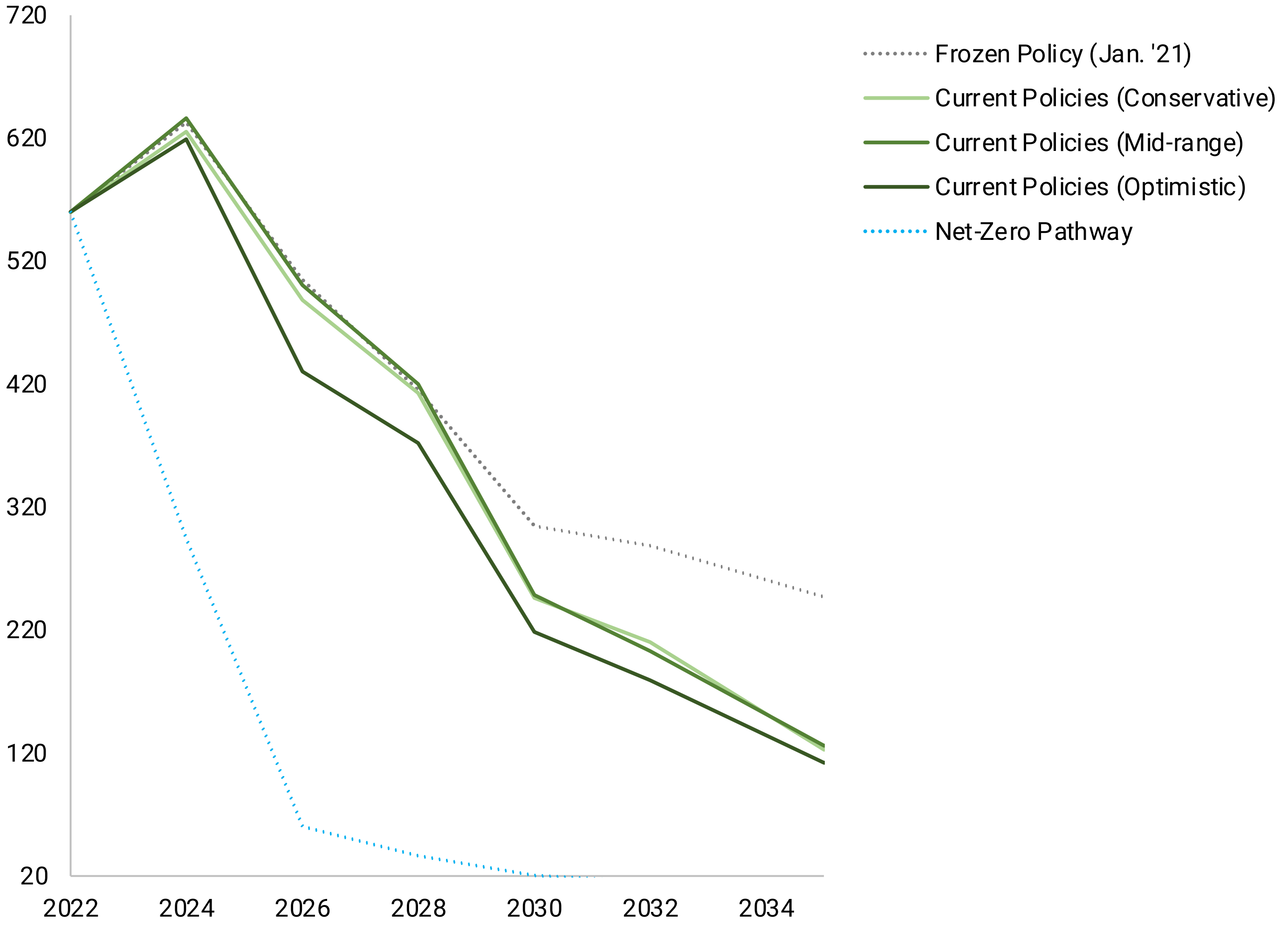
Modeled U.S. Dry Natural Gas Production

trillion cubic feet per year (Tcf/year)[1]



Modeled U.S. Coal Production

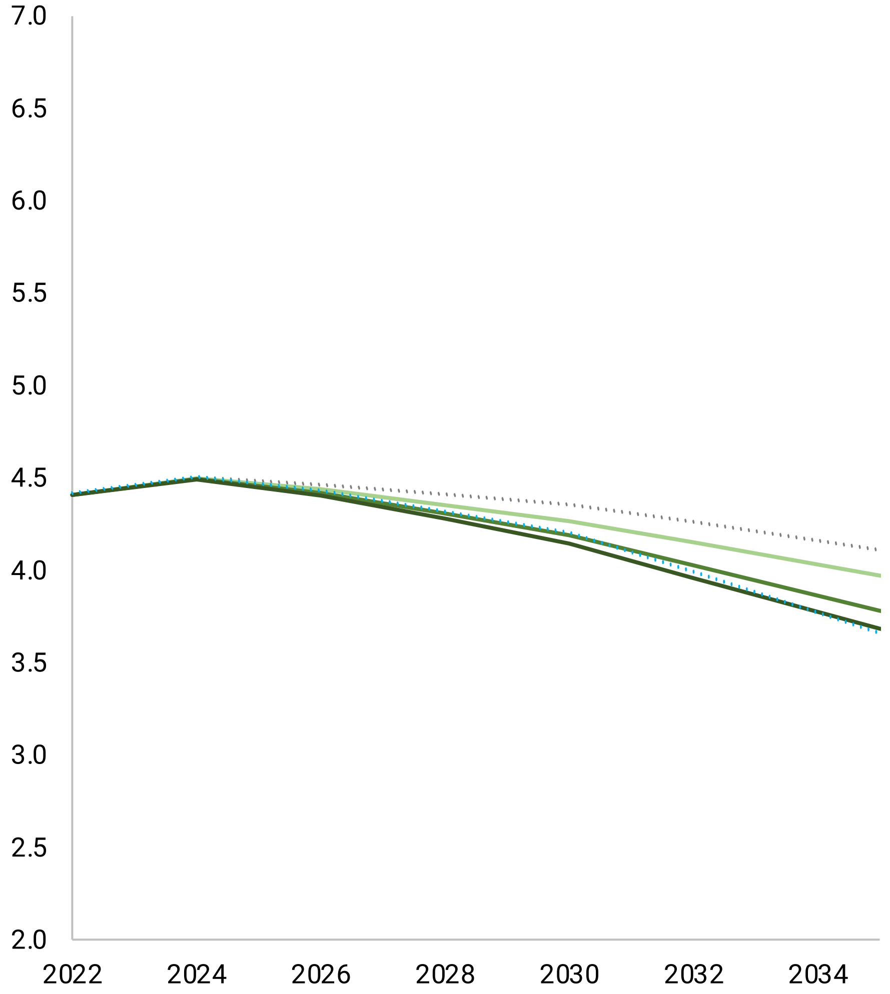
million short tons per year (million t/year)[1]



1 – Modeled U.S. fossil fuel production volumes assume export volumes remain constant at levels from the EIA Annual Energy Outlook 2022 (AEO2022) Reference scenario and reductions in domestic fuel consumption reduce both domestic production and imports in proportion to the historical share of domestic and imported supply in U.S. consumption. If domestic consumption increases above AEO2022 levels, all incremental demand is assumed to be satisfied by domestic production.

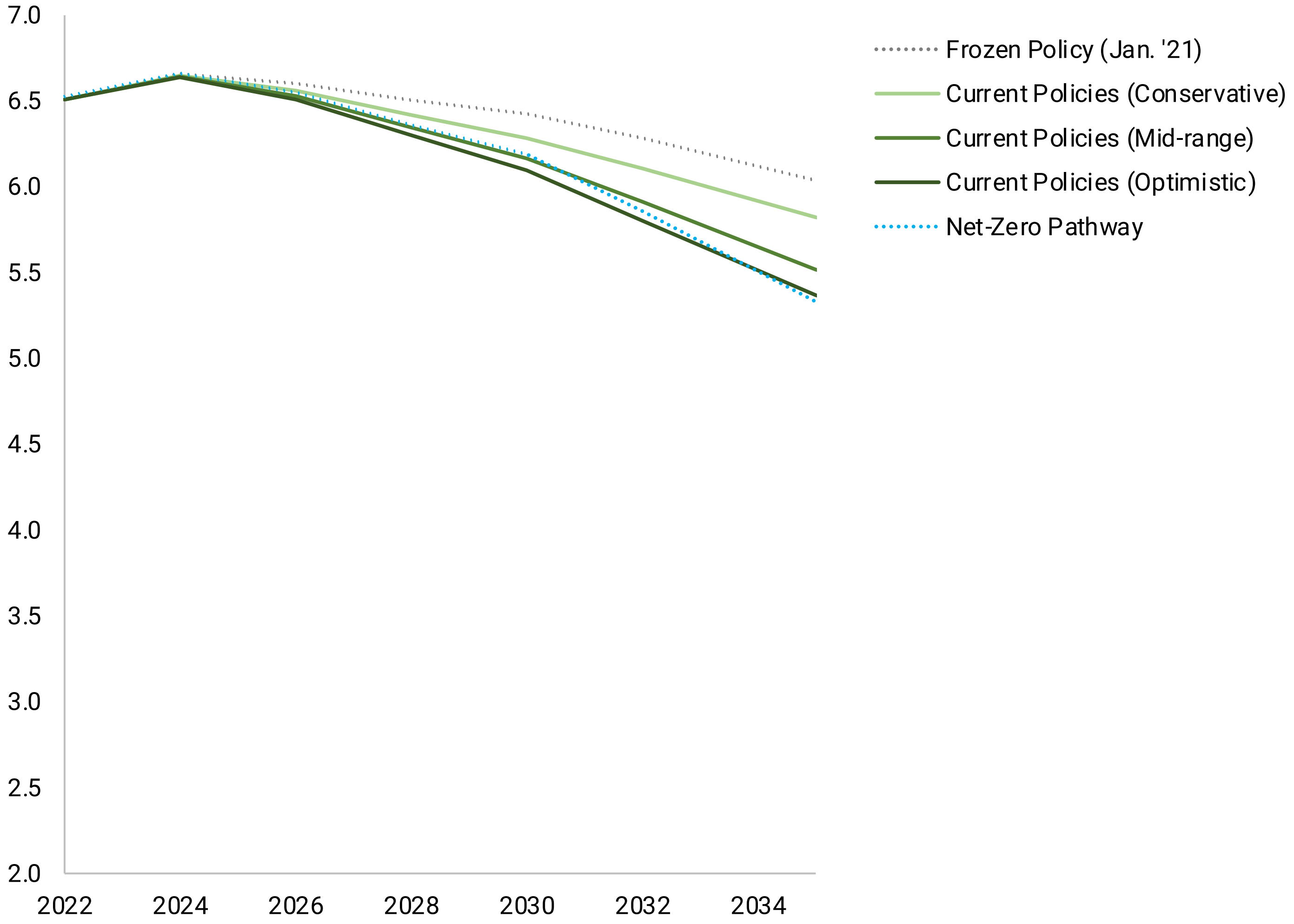
Modeled U.S. Crude Oil Production

billion barrels per year (billion bbl/year)[1]



Modeled U.S. Crude Oil and Natural Gas Liquids Production

billion barrels of oil equivalent per year (billion boe/year)[1]

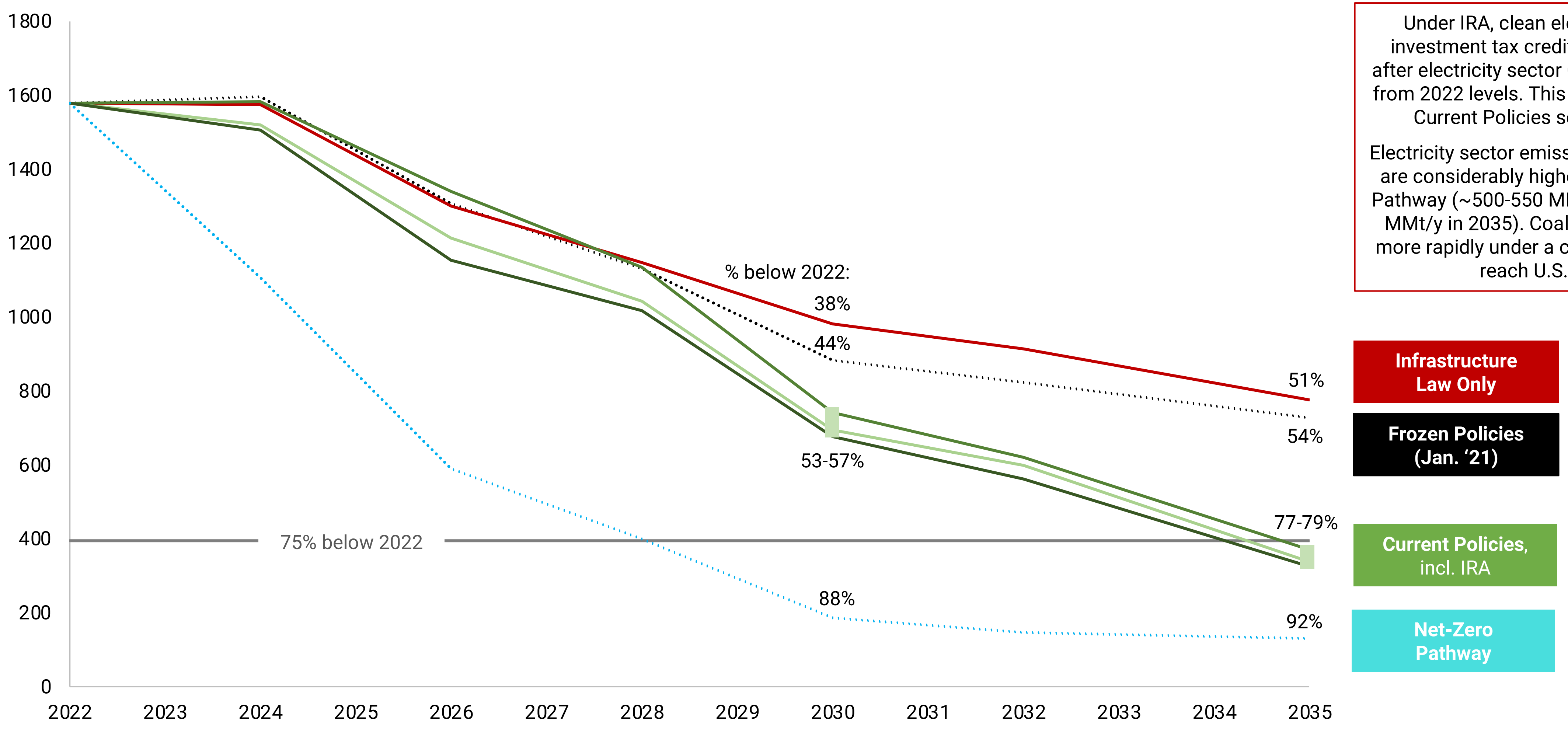


1 – Modeled U.S. fossil fuel production volumes assume export volumes remain constant at levels from the EIA Annual Energy Outlook 2022 (AEO2022) Reference scenario and reductions in domestic fuel consumption reduce both domestic production and imports in proportion to the historical share of domestic and imported supply in U.S. consumption. If domestic consumption increases above AEO2022 levels, all incremental demand is assumed to be satisfied by domestic production.

Electricity

CO_2 Emissions from Electricity Generation

million metric tons per year (MMt/year)

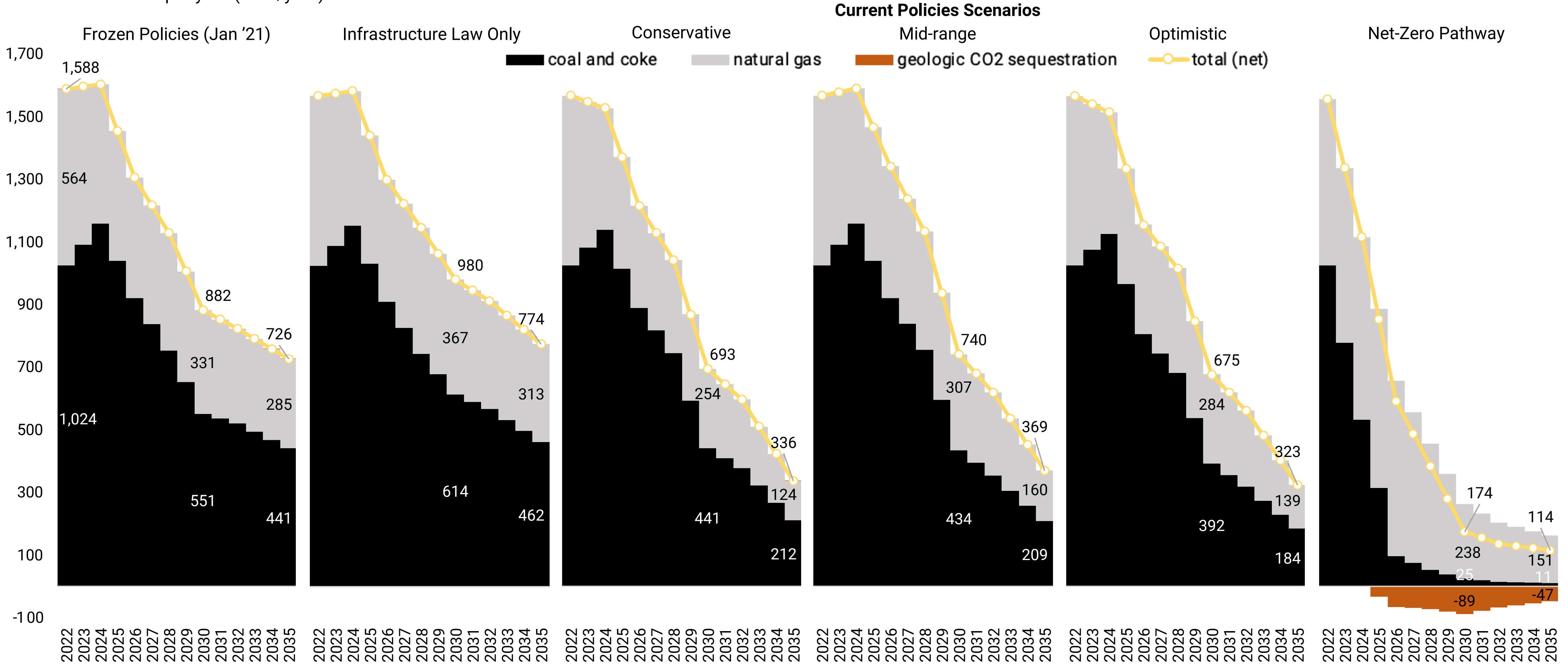


Under IRA, clean electricity production and investment tax credits begin phasing out only after electricity sector CO_2 emissions decline 75% from 2022 levels. This threshold is reached under Current Policies scenarios around 2035.

Electricity sector emissions under Current Policies are considerably higher than under the Net-Zero Pathway (~500-550 MMt/y in 2030 and ~200-240 MMt/y in 2035). Coal power plants retire much more rapidly under a cost-optimized trajectory to reach U.S. climate goals.

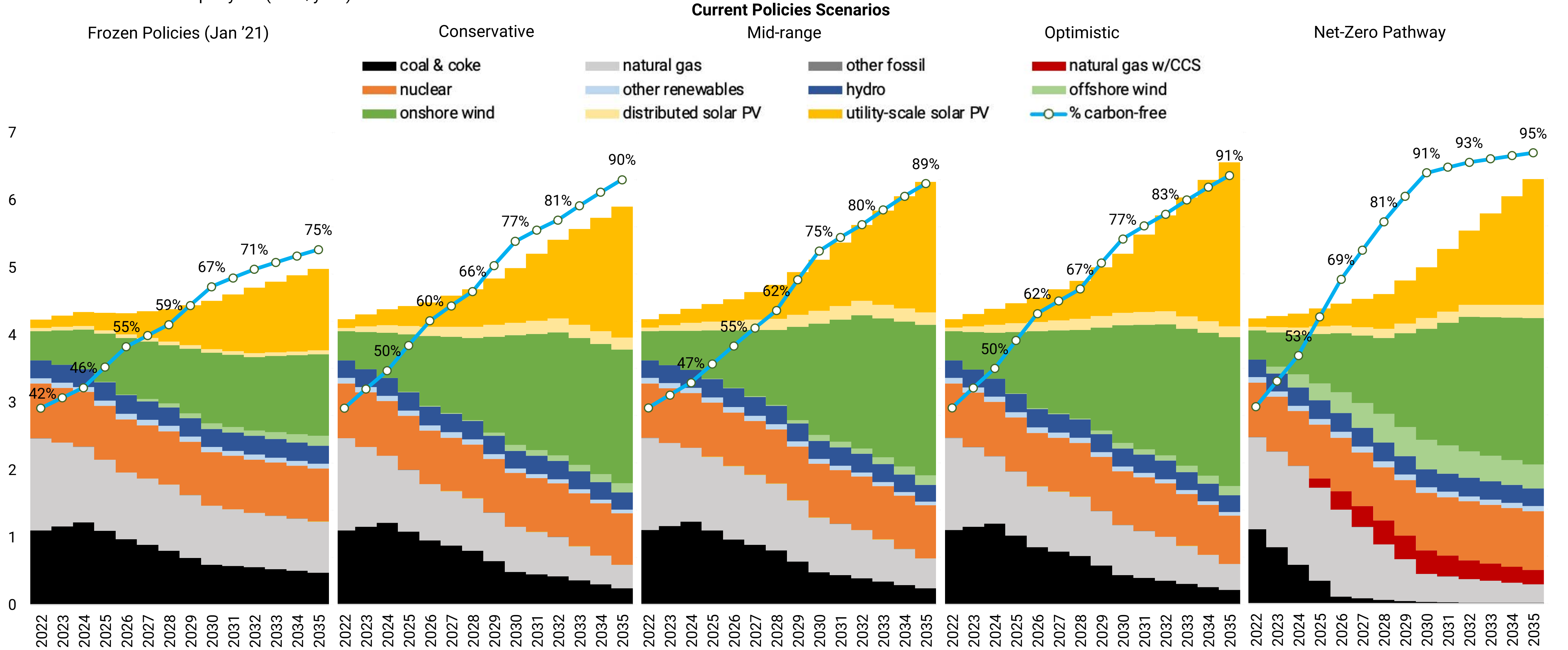
CO_2 Emissions from Electricity Generation by Source/Sink

million metric tons per year (MMt/year)



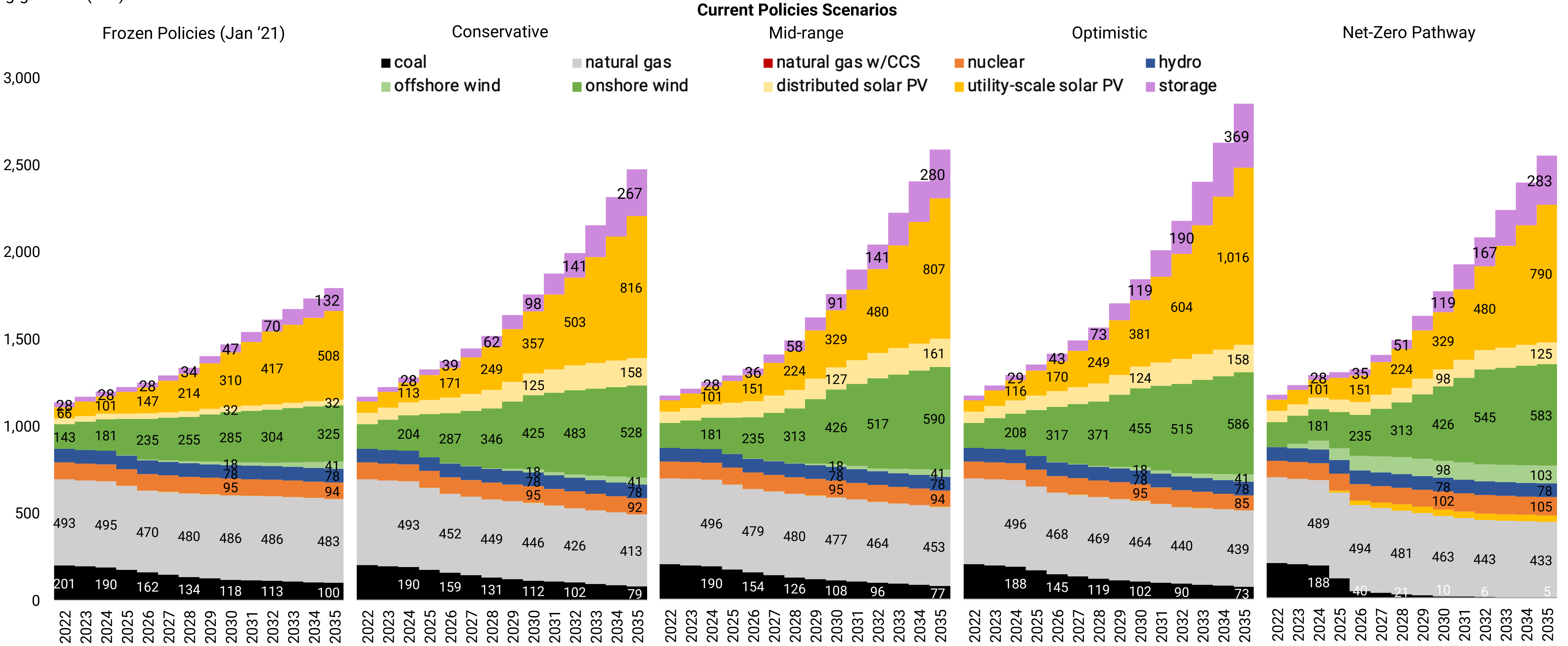
Electricity Generation by Resource

thousand terawatt-hours per year (TWh/year)



Electricity Capacity by Resource

gigawatts (GW)[1]



1 - Plot excludes small quantities of capacity of other renewables (biomass, geothermal, landfill gas, municipal waste and solar thermal), other fossil (petroleum, fossil waste) and fuel cells.

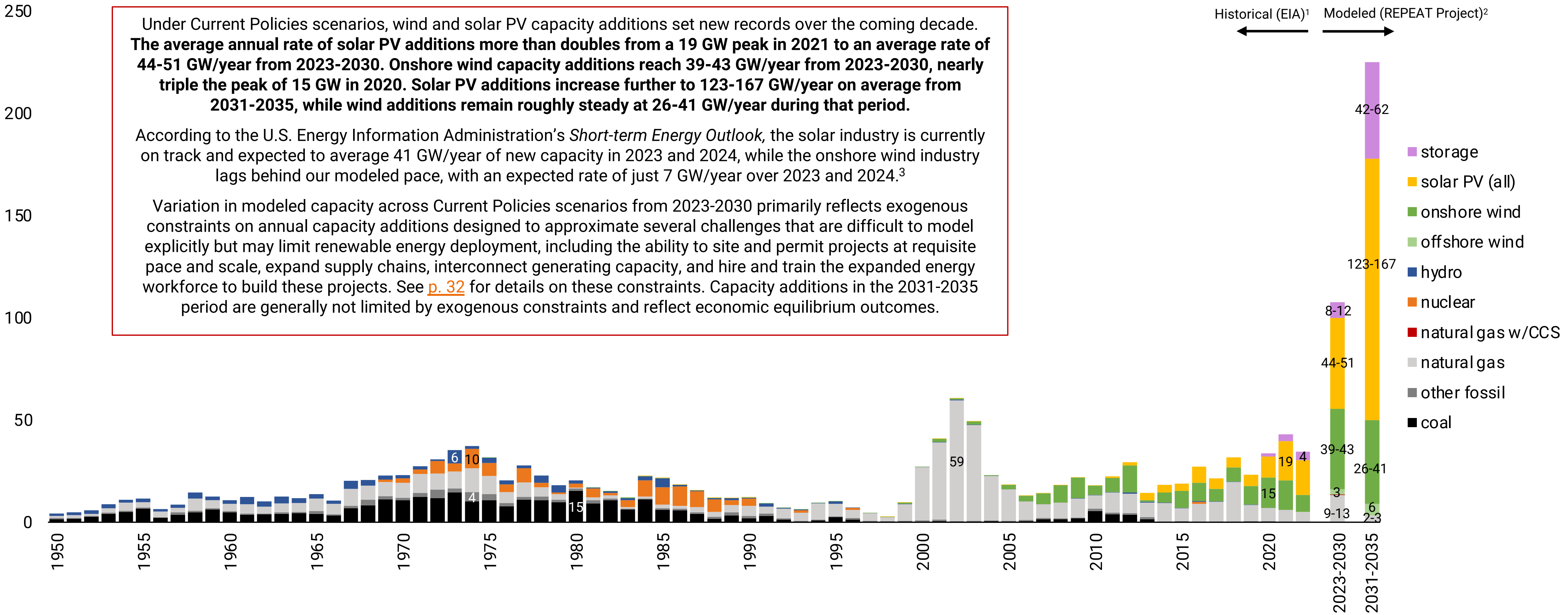
Historical Annual Electricity Capacity Additions vs. Modeled Annual Average Capacity Additions Under Current Policies Scenarios

average gigawatts/year (GW/year)

Under Current Policies scenarios, wind and solar PV capacity additions set new records over the coming decade. **The average annual rate of solar PV additions more than doubles from a 19 GW peak in 2021 to an average rate of 44-51 GW/year from 2023-2030. Onshore wind capacity additions reach 39-43 GW/year from 2023-2030, nearly triple the peak of 15 GW in 2020. Solar PV additions increase further to 123-167 GW/year on average from 2031-2035, while wind additions remain roughly steady at 26-41 GW/year during that period.**

According to the U.S. Energy Information Administration's *Short-term Energy Outlook*, the solar industry is currently on track and expected to average 41 GW/year of new capacity in 2023 and 2024, while the onshore wind industry lags behind our modeled pace, with an expected rate of just 7 GW/year over 2023 and 2024.[3]

Variation in modeled capacity across Current Policies scenarios from 2023-2030 primarily reflects exogenous constraints on annual capacity additions designed to approximate several challenges that are difficult to model explicitly but may limit renewable energy deployment, including the ability to site and permit projects at requisite pace and scale, expand supply chains, interconnect generating capacity, and hire and train the expanded energy workforce to build these projects. See p. 32 for details on these constraints. Capacity additions in the 2031-2035 period are generally not limited by exogenous constraints and reflect economic equilibrium outcomes.



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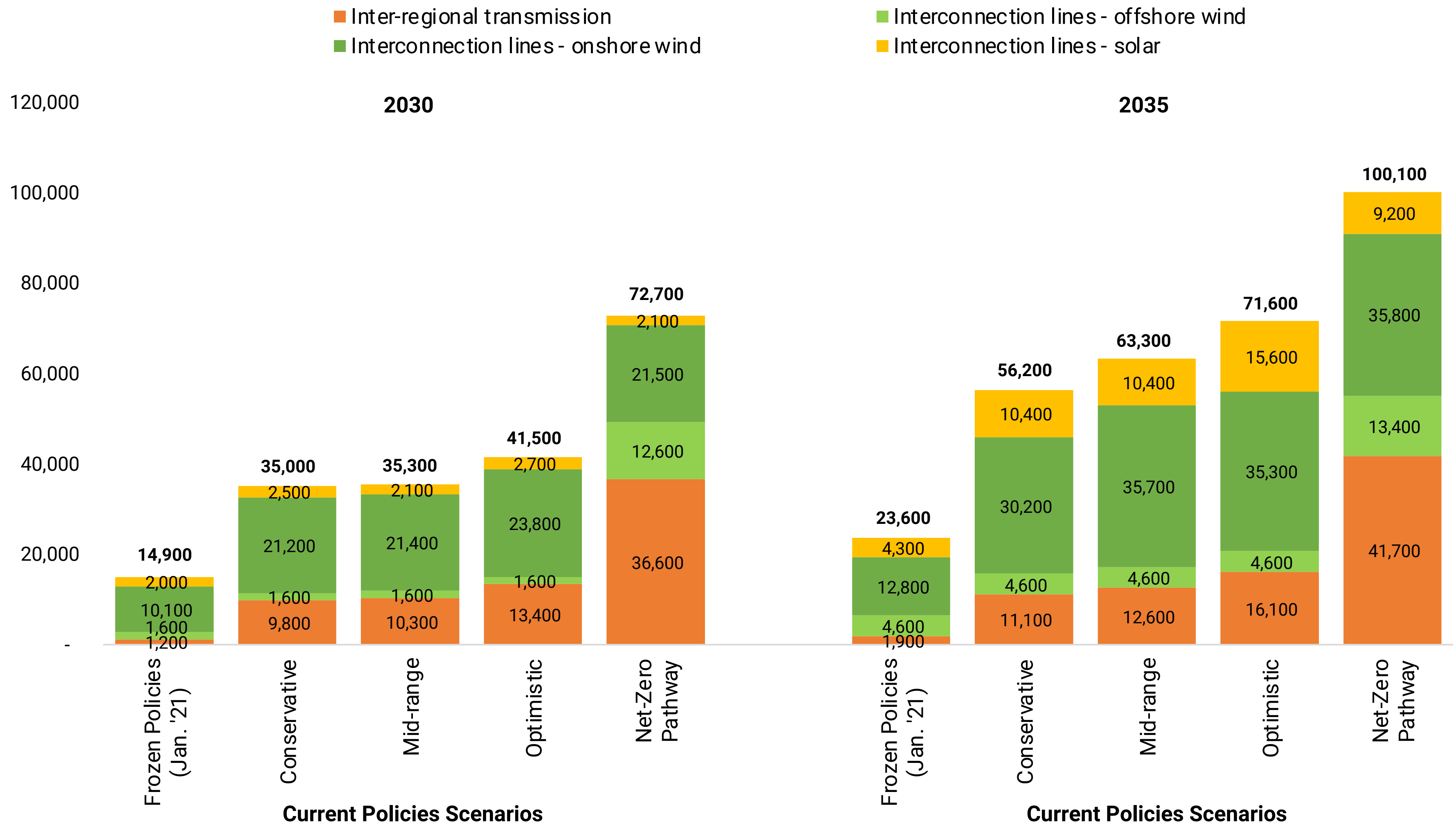
1 - Historical data labels represent peak historical annual additions (source, 1950-2020: EIA Form 860; 2021-2022: EIA Short-term Energy Outlook, June 6, 2023)

2 - Modeled data labels reflect range across Current Policies scenarios (Conservative, Mid-range and Optimistic). Depicted bars represent results for the Mid-range scenario.

3 - EIA *Short-term Energy Outlook*, June 6, 2023 edition

Cumulative Electricity Transmission Expansion vs. 2020

gigawatt-miles (GW-miles)



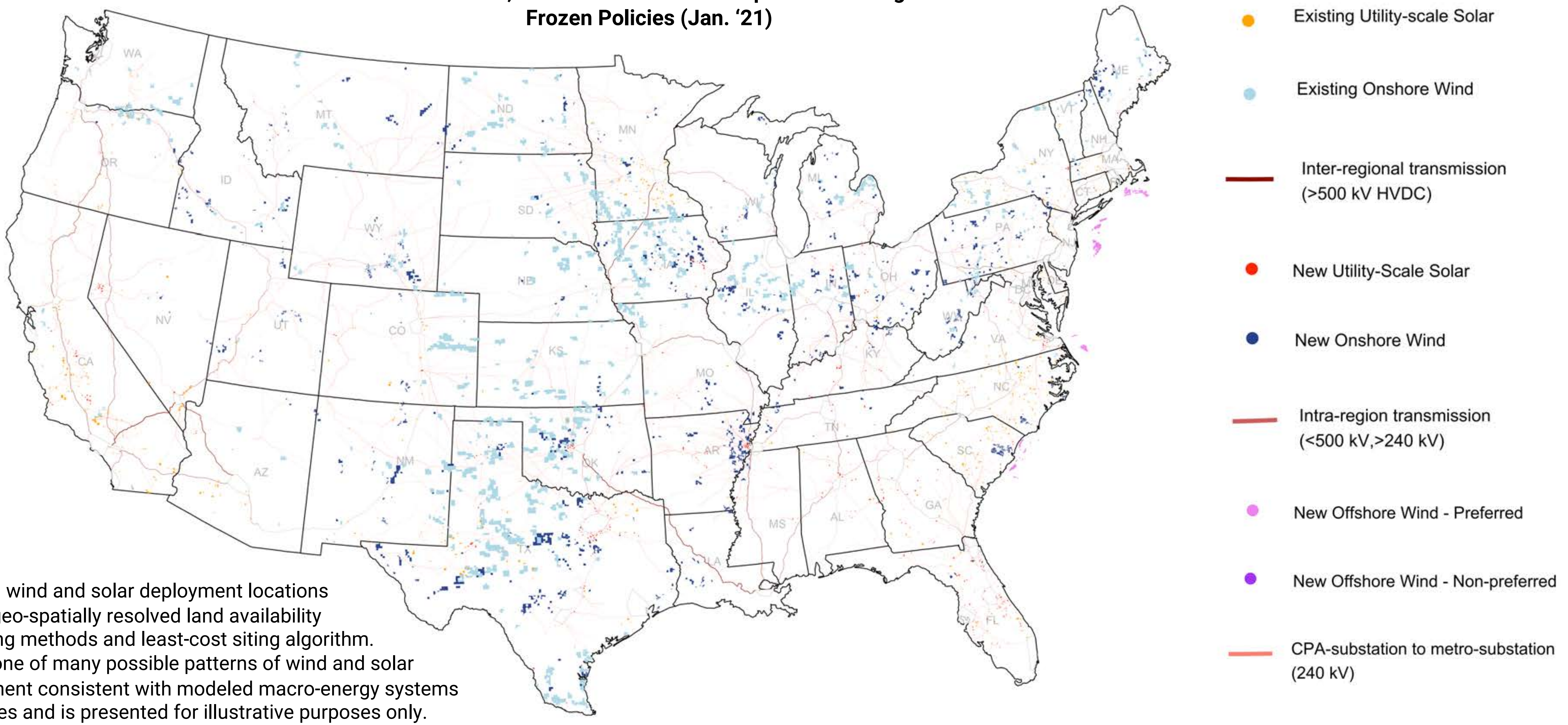
To keep up with growing electricity demand and connect to the best wind and solar resources across the country, **the pace of electricity transmission capacity more than doubles under Current Policies** scenarios relative to the Frozen Policies scenario (and increases more than four-fold under the Net-Zero Pathway).

High voltage transmission capacity expands roughly 15-18% from 2020 to 2030 under Current Policies and about 24-31% by 2035.[1] Transmission capacity expands 32% by 2030 and 43% by 2035 under the Net-Zero Pathway.

The majority of new transmission capacity is driven by the need to interconnect wind farms. Wind power quality varies much more across sites than it does for solar PV, and populated areas tend to be farther from the best wind resources. That means solar PV projects have greater siting flexibility and generally require less long-distance transmission per gigawatt.

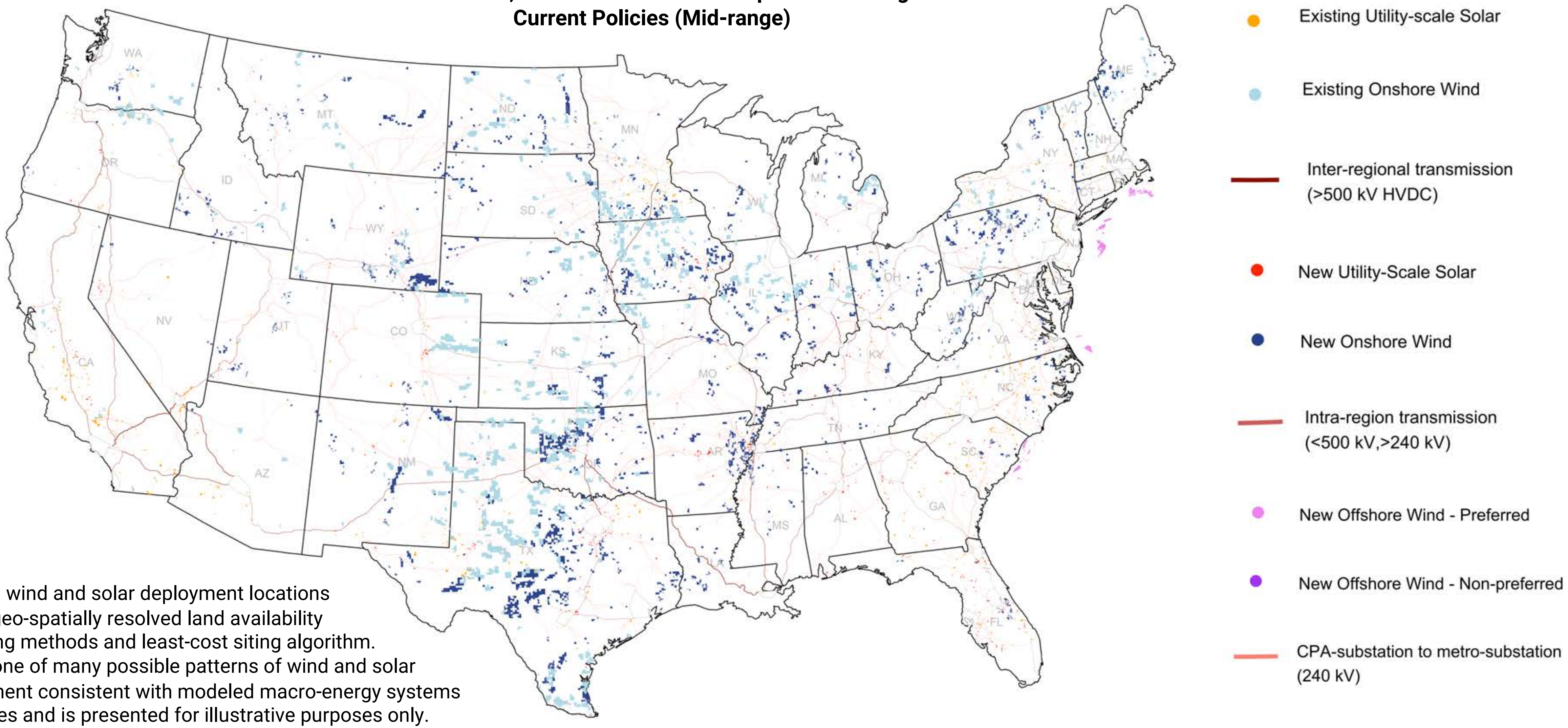
1 - Estimated total U.S. transmission capacity stood at roughly 232,000 GW-miles in 2020. This is based on ~200,000 GW-miles circa 2008 as reported by Homeland Infrastructure Foundation Layer Database (2008) and cited in NREL "Renewable Electricity Futures Study" (2012) p. 26 and assuming 1.2% annual average growth in transmission capacity, consistent with the historical average from 2004-2016 reported by UT Austin and cited in Cembalest (2022), "Eye on the Market 12th Edition: 2022 Annual Energy Paper" p.12.

‘Downscaled’ Wind, Solar & Transmission Expansion Through 2030
Frozen Policies (Jan. ‘21)



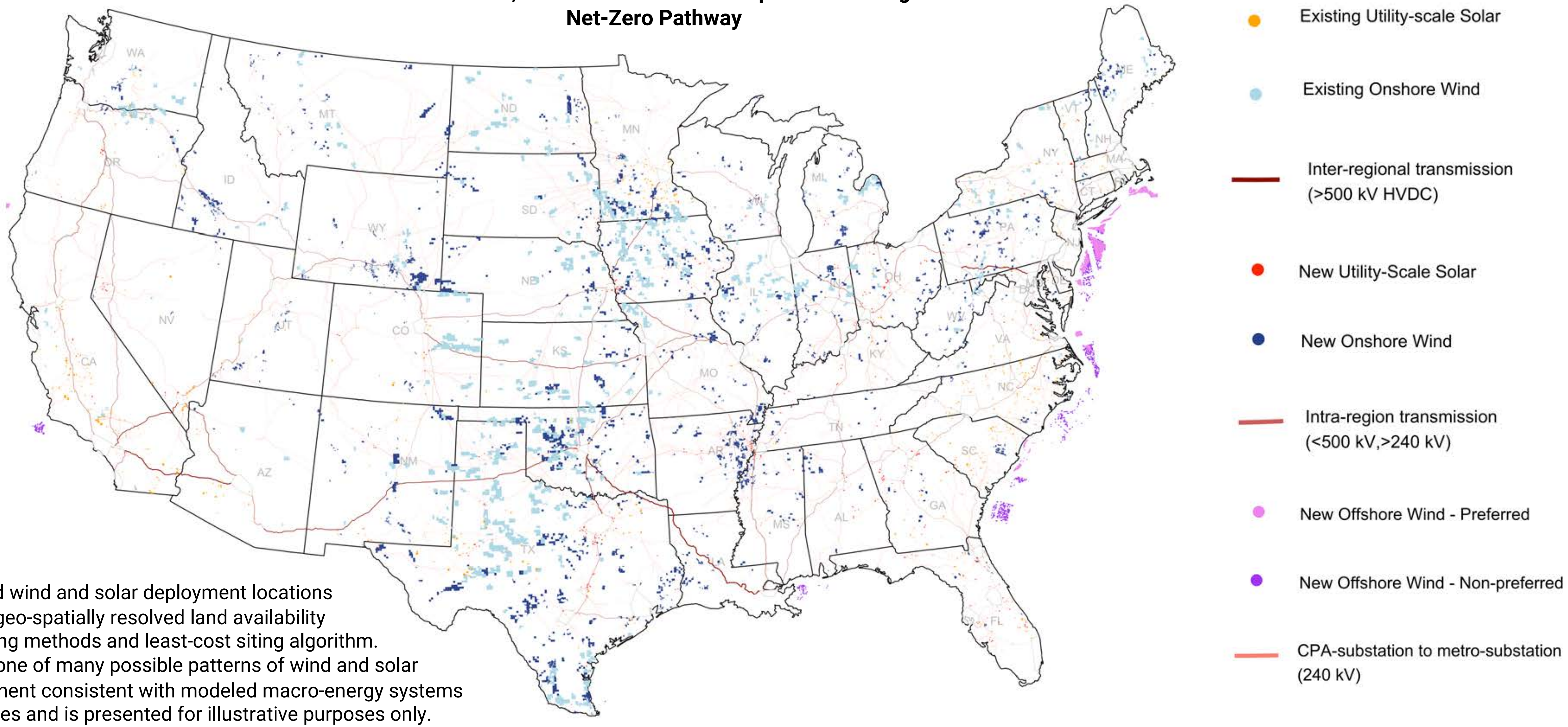
Mapped wind and solar deployment locations reflect geo-spatially resolved land availability screening methods and least-cost siting algorithm. This is one of many possible patterns of wind and solar deployment consistent with modeled macro-energy systems outcomes and is presented for illustrative purposes only.

'Downscaled' Wind, Solar & Transmission Expansion Through 2030
Current Policies (Mid-range)



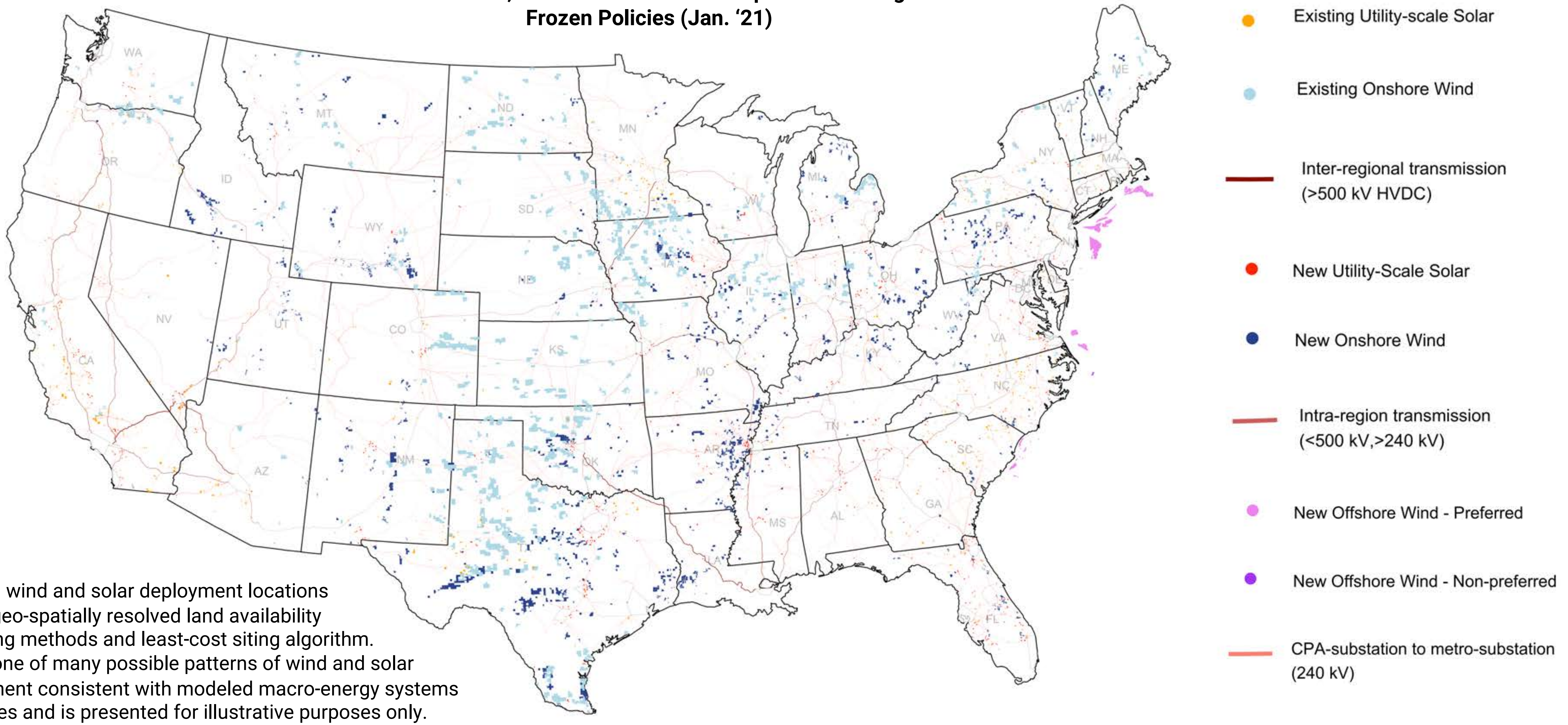
Mapped wind and solar deployment locations reflect geo-spatially resolved land availability screening methods and least-cost siting algorithm. This is one of many possible patterns of wind and solar deployment consistent with modeled macro-energy systems outcomes and is presented for illustrative purposes only.

'Downscaled' Wind, Solar & Transmission Expansion Through 2030
Net-Zero Pathway



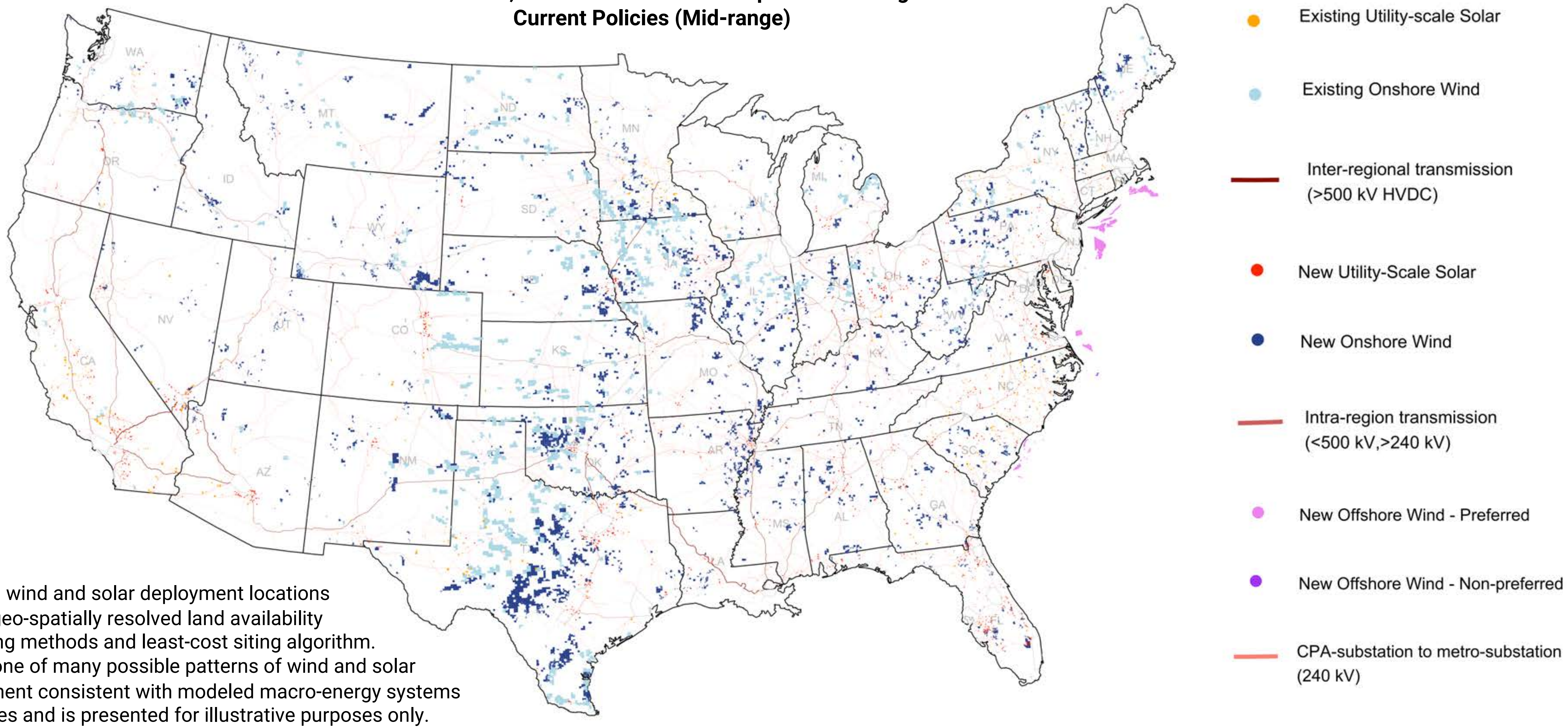
Mapped wind and solar deployment locations reflect geo-spatially resolved land availability screening methods and least-cost siting algorithm. This is one of many possible patterns of wind and solar deployment consistent with modeled macro-energy systems outcomes and is presented for illustrative purposes only.

'Downscaled' Wind, Solar & Transmission Expansion Through 2035
Frozen Policies (Jan. '21)



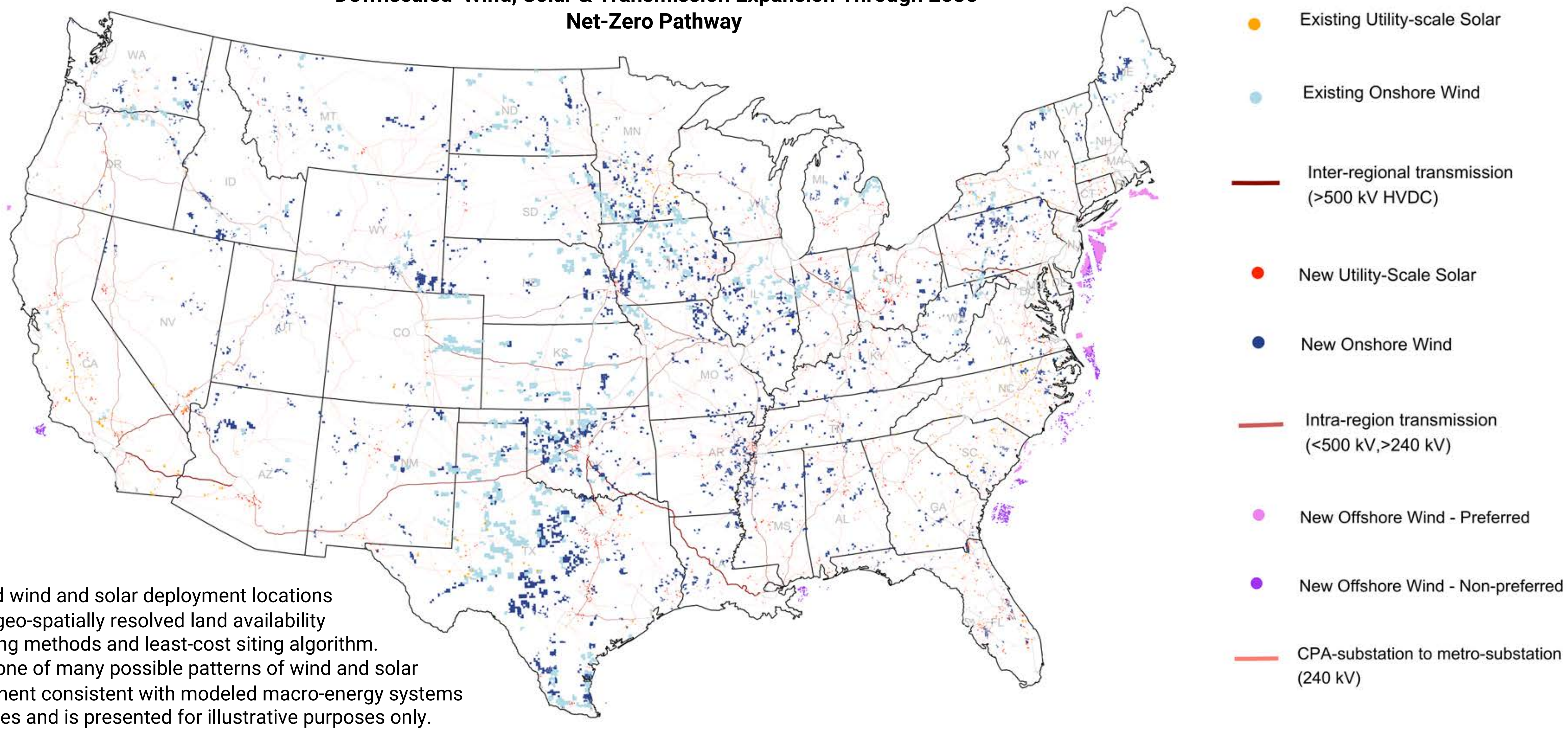
Mapped wind and solar deployment locations reflect geo-spatially resolved land availability screening methods and least-cost siting algorithm. This is one of many possible patterns of wind and solar deployment consistent with modeled macro-energy systems outcomes and is presented for illustrative purposes only.

‘Downscaled’ Wind, Solar & Transmission Expansion Through 2035
Current Policies (Mid-range)



Mapped wind and solar deployment locations reflect geo-spatially resolved land availability screening methods and least-cost siting algorithm. This is one of many possible patterns of wind and solar deployment consistent with modeled macro-energy systems outcomes and is presented for illustrative purposes only.

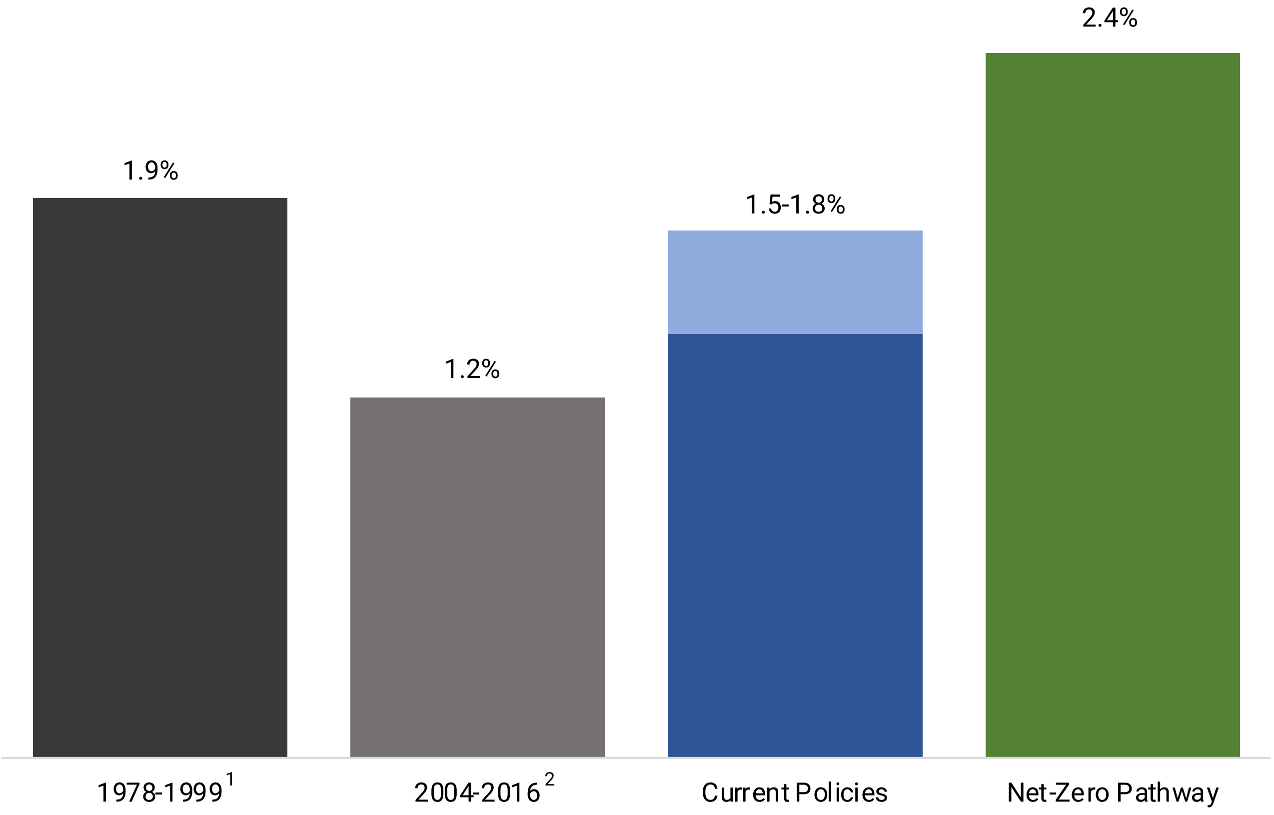
‘Downscaled’ Wind, Solar & Transmission Expansion Through 2035
Net-Zero Pathway



Mapped wind and solar deployment locations reflect geo-spatially resolved land availability screening methods and least-cost siting algorithm. This is one of many possible patterns of wind and solar deployment consistent with modeled macro-energy systems outcomes and is presented for illustrative purposes only.

Compound Annual Growth in Electricity Transmission Capacity, 2020-2035 vs. Historical Periods

percent annual growth in gigawatt-miles



To achieve the maximum emissions reduction under Current Policies, U.S. transmission capacity must expand roughly 50% faster through 2035 than the recent historical rate.[2]

While our modeling finds this outcome makes economic sense given incentives under IRA, current U.S. transmission planning, siting, permitting and cost allocation practices can all potentially impede the real-world pace of transmission expansion. We explore the impacts of more constrained transmission expansion on the following page.

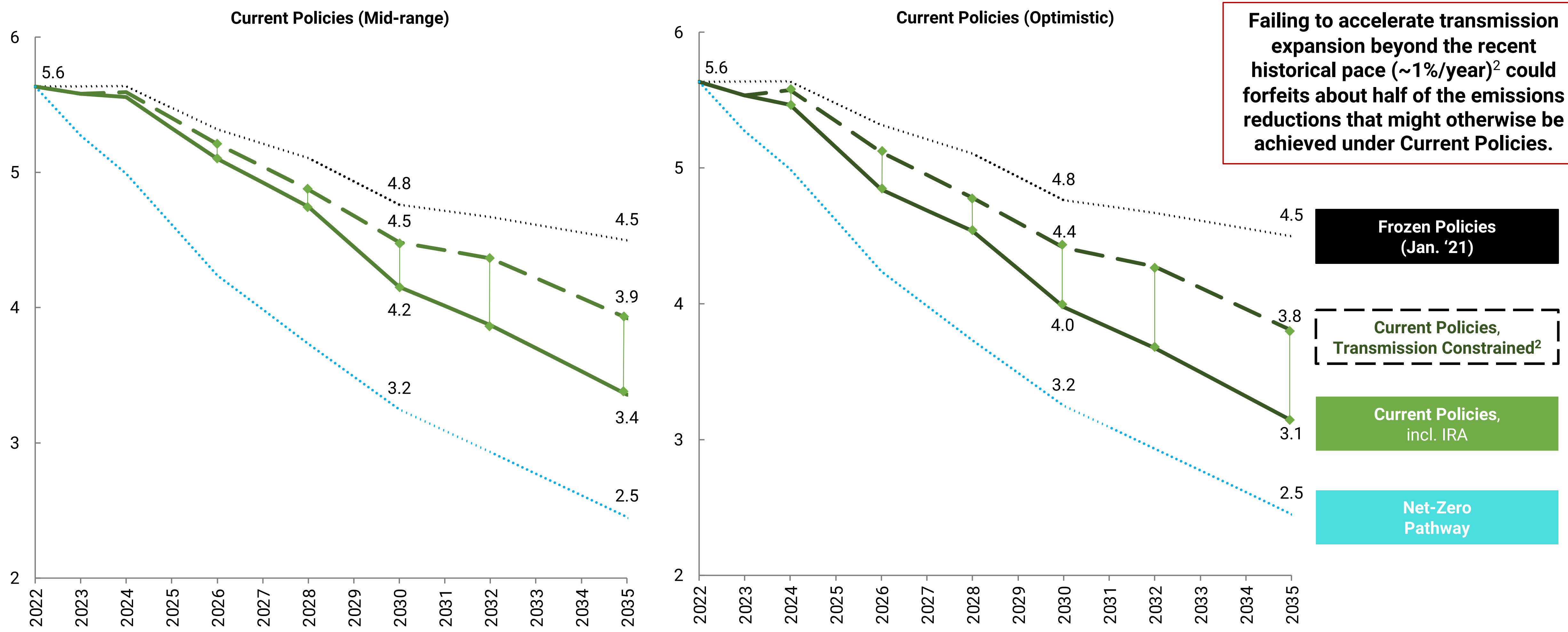
Note that U.S. electricity demand has been roughly flat since the mid-2000s, and **modeled transmission expansion rates under Current Policies are roughly equal to the historical pace achieved from the 1970s to the 1990s**[1], the last period during which U.S. electricity demand steadily increased.

The pace of transmission expansion under the Net-Zero Pathway exceeds the historical 1978-1999 rate and is twice as fast as the more recent 2004-2016 period.

1 - Reported by U.S. Department of Energy and cited in Cembalest (2022), "Eye on the Market 12th Edition: 2022 Annual Energy Paper" p.12.
2 - Reported by UT Austin and cited in Cembalest (2022), p.12.

Impact of Transmission Expansion Constraints on Modeled Net U.S. Greenhouse Gas Emissions (Including Land Carbon Sinks)

billion metric tons CO_2-equivalent (Gt CO_2-e)[1]



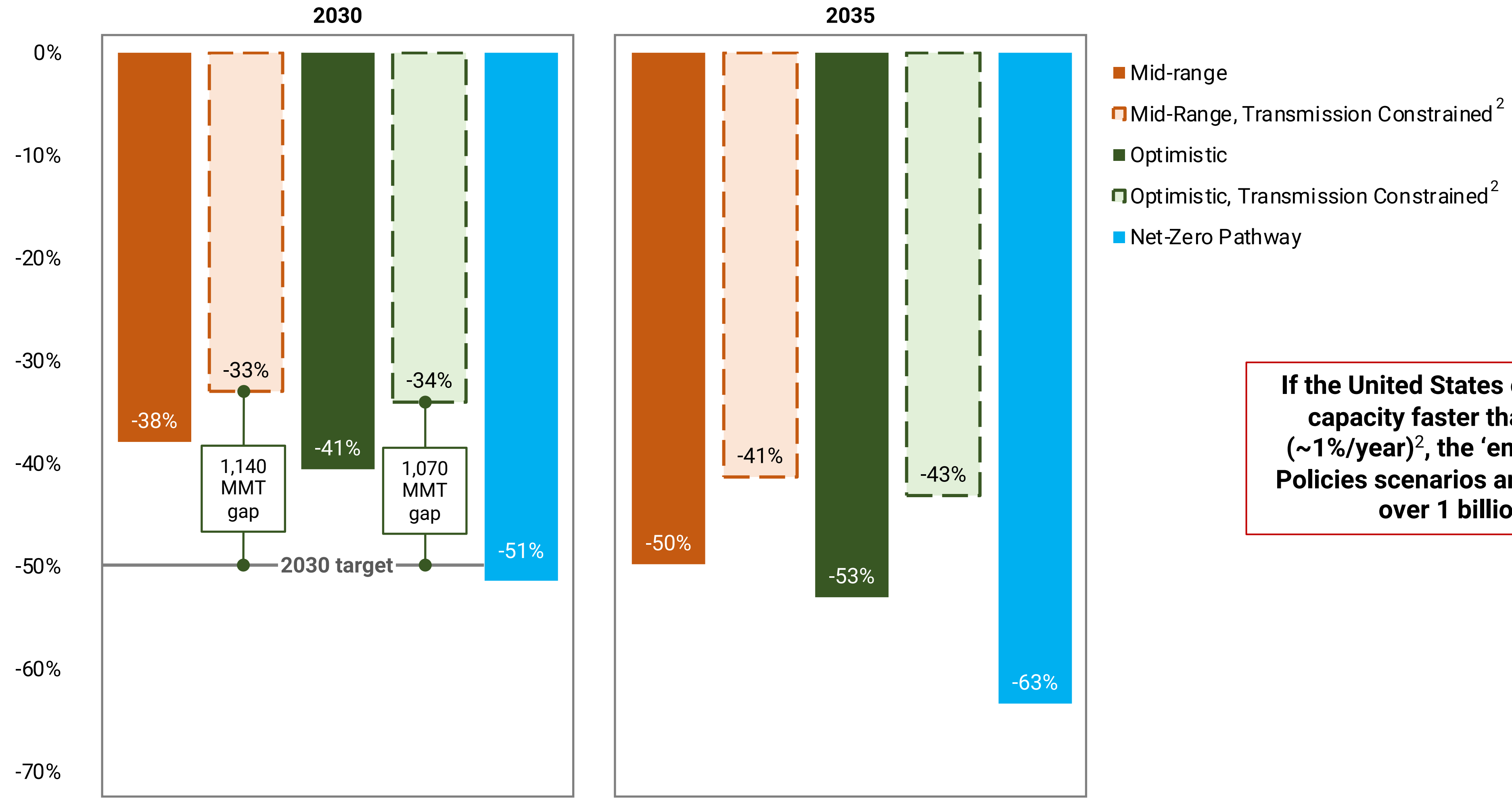
Failing to accelerate transmission expansion beyond the recent historical pace (~1%/year)[2] could forfeits about half of the emissions reductions that might otherwise be achieved under Current Policies.

1 - CO_2-equivalent emissions calculations use IPCC AR4 100 year global warming potential as per EPA Inventory of Greenhouse Gas Emissions and Sinks.

2 - Transmission constrained cases limit total transmission capacity expansion to a compound annual growth rate of 1%/year, roughly equivalent to the 2004-2016 average historical pace. The maximum total increase in GW-miles for each model year is allocated as constraints on expansion of inter-regional transmission, interconnection lines for wind and interconnection lines for solar PV respectively in proportion to the total expansion for each category of lines under unconstrained Current Policies cases.

Impact of Transmission Expansion Constraints on Modeled Net U.S. Greenhouse Gas Emissions (Including Land Carbon Sinks)

percent change vs. 2005 emissions[1]



If the United States cannot build new transmission capacity faster than the recent historical pace (~1%/year)[2], the 'emissions gap' between Current Policies scenarios and U.S. climate goals widens to over 1 billion metric tons in 2030.

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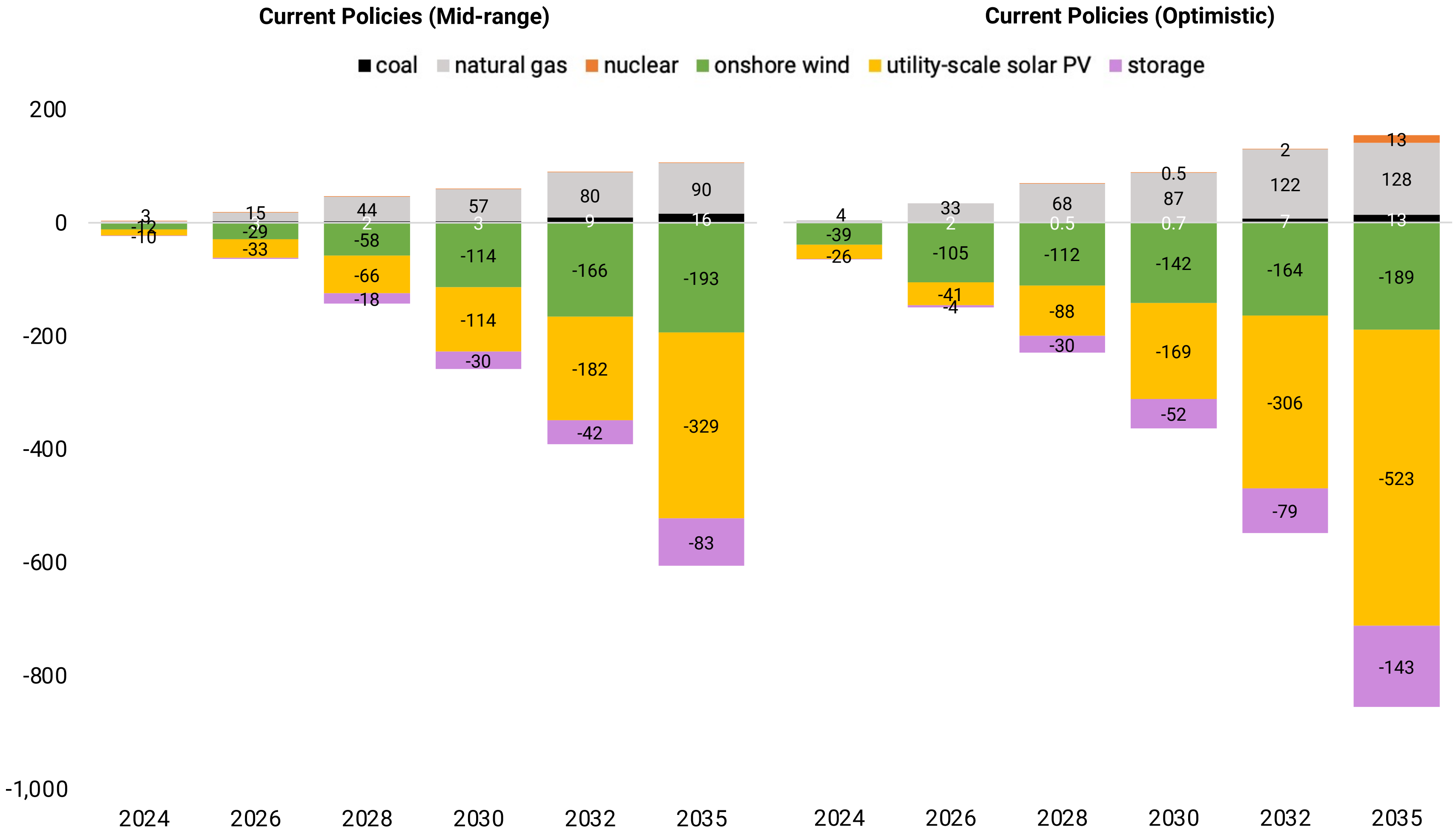
1 - CO_2-equivalent emissions calculations use IPCC AR4 100 year global warming potential as per EPA Inventory of Greenhouse Gas Emissions and Sinks.

2 - Transmission constrained cases limit total transmission capacity expansion to a compound annual growth rate of 1%/year, roughly equivalent to the 2004-2016 average historical pace. The maximum total increase in GW-miles for each model year is allocated as constraints on expansion of inter-regional transmission, interconnection lines for wind and interconnection lines for solar PV respectively in proportion to the total expansion for each category of lines under unconstrained Current Policies cases.

Impact of Transmission Expansion Constraints on Electricity Capacity by Resource

gigawatts (GW)[1]



To achieve the full emissions reduction potential of Current Policies, new clean electricity must be rapidly added to simultaneously meet growing demand from electric vehicles, heat pumps, and other electrification *and* reduce fossil fuel use in the power sector.

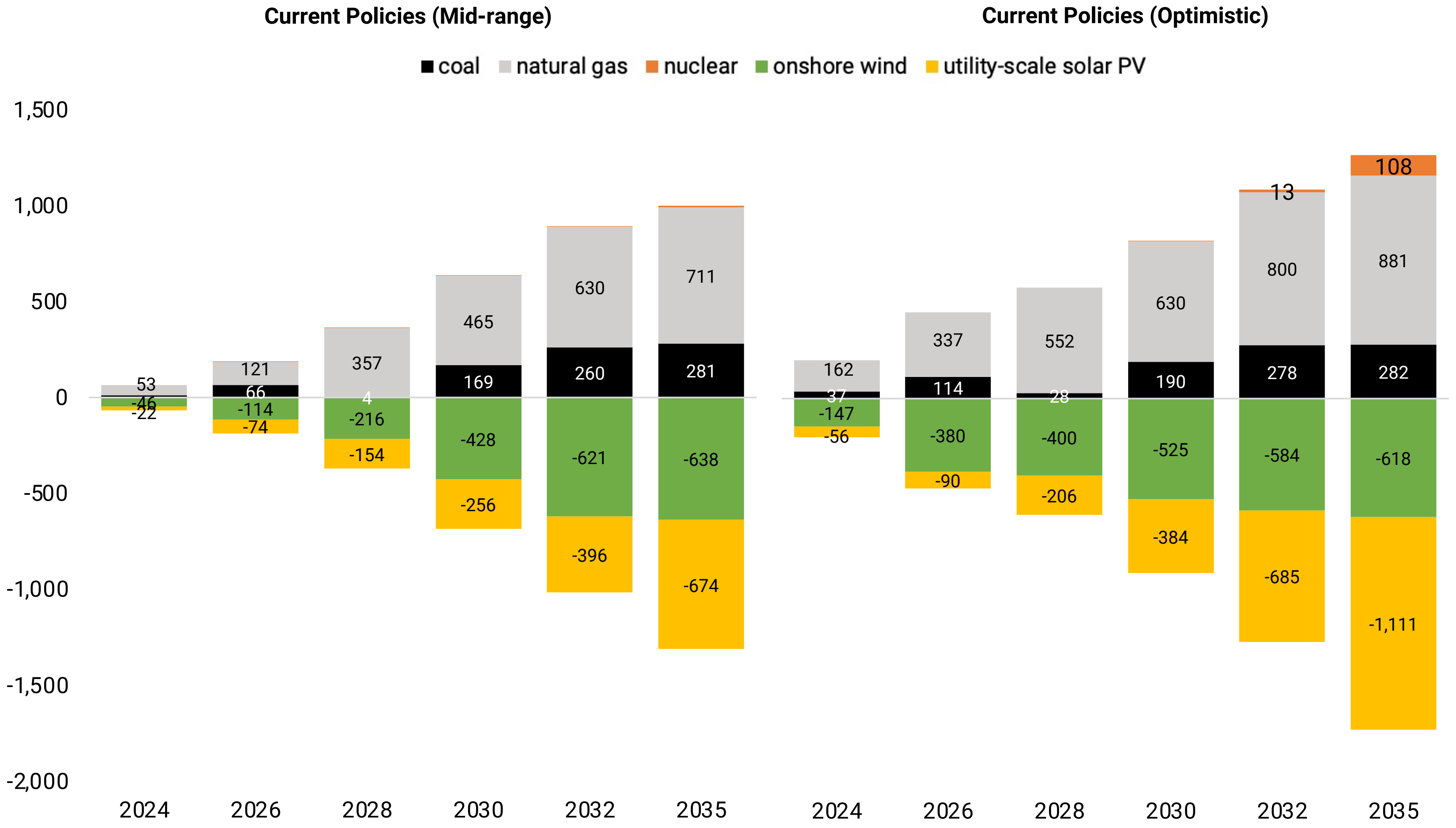
Constraining transmission growth[1] **severely limits the expansion of wind and solar power** (and indirectly reduces the economic deployment of energy storage).

As a result, **the lifespan of dozens of coal-fired power plants are extended and hundreds of new natural gas power plants are constructed to meet growing demand in transmission constrained scenarios.**

1 - Transmission constrained cases limit total transmission capacity expansion to a compound annual growth rate of 1%/year, roughly equivalent to the 2004-2016 average historical pace. The maximum total increase in GW-miles for each model year is allocated as constraints on expansion of inter-regional transmission and interconnection lines for onshore wind, offshore wind, solar PV respectively in proportion to the total expansion for each category of lines under unconstrained Current Policies cases.

Impact of Transmission Expansion Constraints on Electricity Generation by Resource

terawatt-hours per year (TWh/year)[1]



If new transmission capacity cannot be added at a faster pace[1], growth of wind and solar power will be substantially constrained. The United States would thus be more reliant on coal and natural gas power plants to meet growing demand from electric vehicles and other electrification.

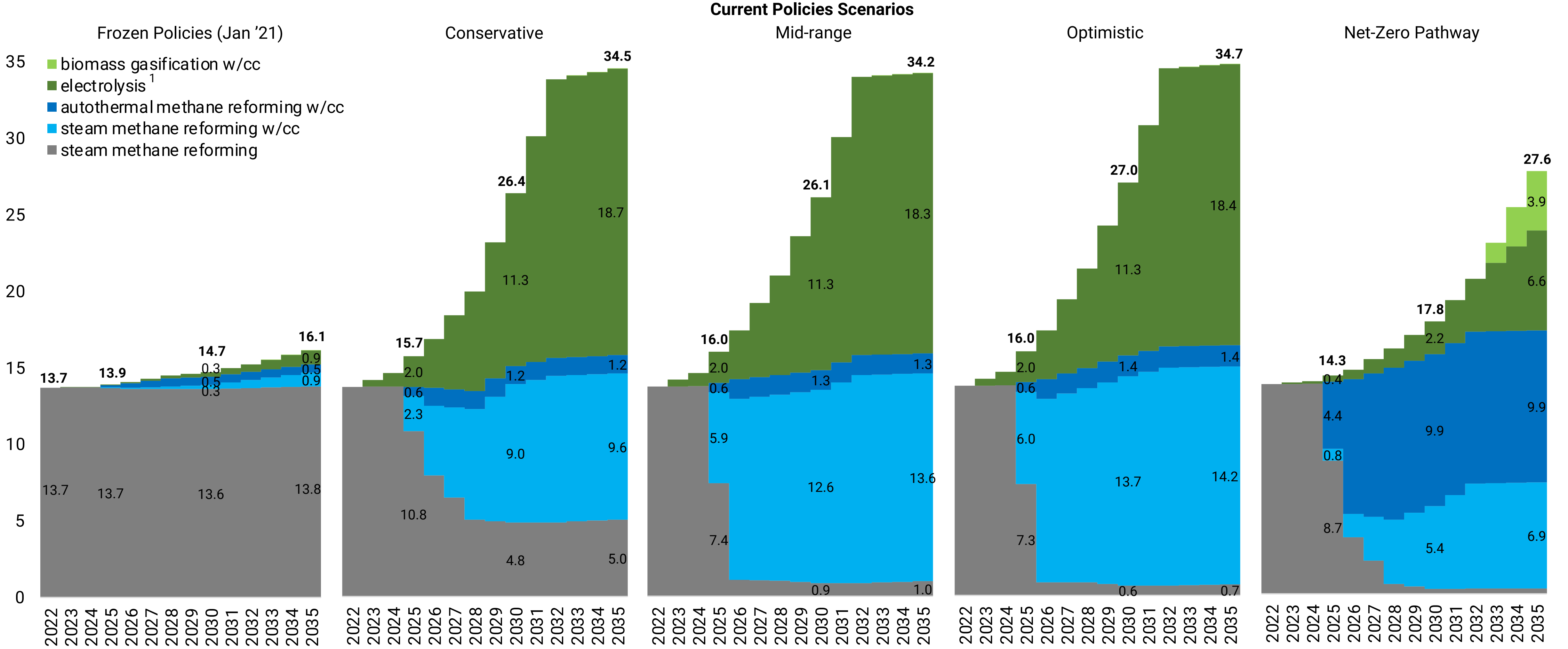
While ~75-77% of generation is supplied by low-carbon sources in 2030 and 89-91% in 2035 under Current Policies scenarios, this share falls to 61-62% in 2030 and 71-72%, in 2035, if transmission expansion is constrained.

1 - Transmission constrained cases limit total transmission capacity expansion to a compound annual growth rate of 1%/year, roughly equivalent to the 2004-2016 average historical pace. The maximum total increase in GW-miles for each model year is allocated as constraints on expansion of inter-regional transmission and interconnection lines for onshore wind, offshore wind, solar PV respectively in proportion to the total expansion for each category of lines under unconstrained Current Policies cases.

Hydrogen

Hydrogen Production Capacity

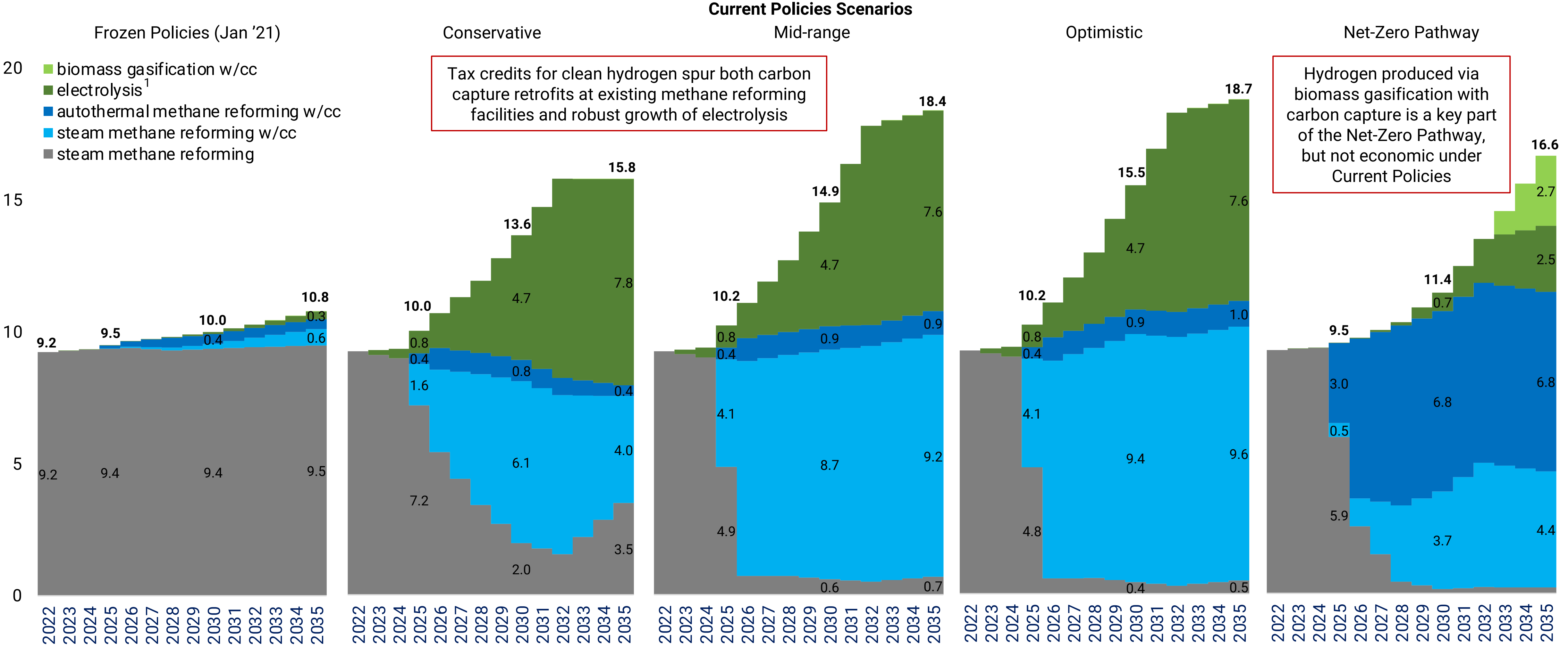
million metric tons of hydrogen per year (MMt H_2/year)



1 - Note that in Current Policies scenarios in this analysis, we model hydrogen electrolysis facilities to be eligible for the 45V clean hydrogen production tax credit if they use only new, carbon-free electricity from within the same model region on an annual matching basis. This is less stringent than the hourly matching requirements likely required to ensure indirect CO_2 emissions from hydrogen production do not exceed statutory requirements under IRA. See Ricks, Xu & Jenkins (2022), "Minimizing emissions from grid-based hydrogen production in the United States," *Environmental Research Letters* and "45V Tax Credit: Three-Pillars Impact Analysis," (Evolved Energy Research, June 23, 2023) for more.

Hydrogen Supply

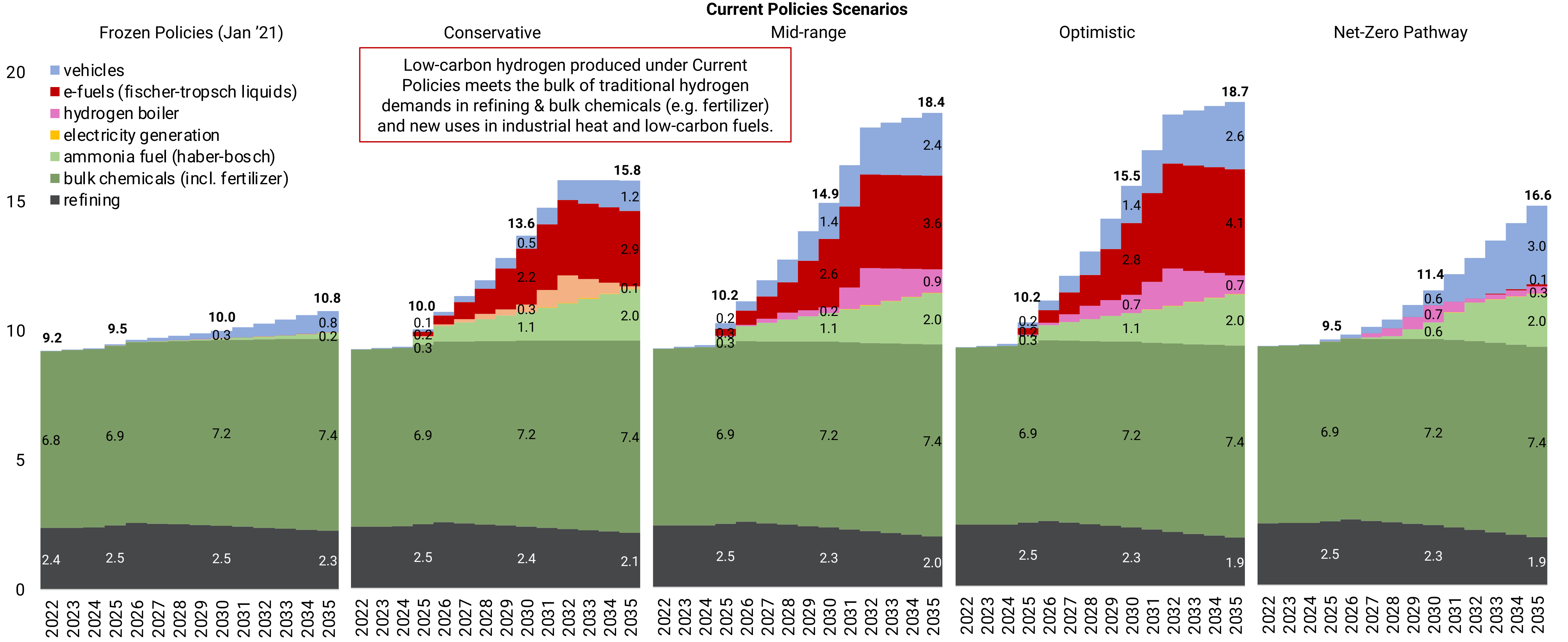
million metric tons of hydrogen per year (MMt H_2/year)



1 - Note that in Current Policies scenarios in this analysis, we model hydrogen electrolysis facilities to be eligible for the 45V clean hydrogen production tax credit if they use only new, carbon-free electricity from within the same model region on an annual matching basis. This is less stringent than the hourly matching requirements likely required to ensure indirect CO_2 emissions from hydrogen production do not exceed statutory requirements under IRA. See Ricks, Xu & Jenkins (2022), "Minimizing emissions from grid-based hydrogen production in the United States," *Environmental Research Letters* and "45V Tax Credit: Three-Pillars Impact Analysis," (Evolved Energy Research, June 23, 2023) for more.

Hydrogen Demand

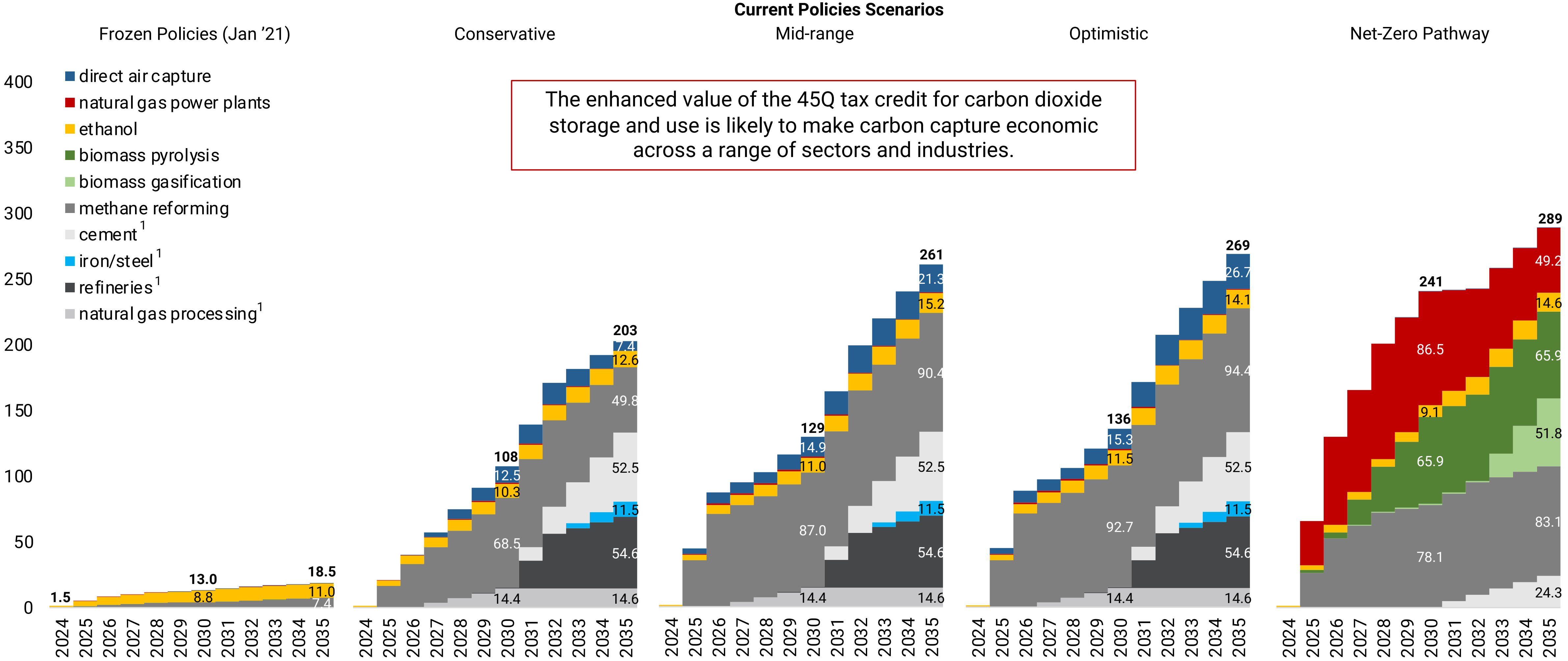
million metric tons of hydrogen per year (MMt H_2/year)



Carbon Capture, Use, and Storage

Carbon Dioxide Capture by Source

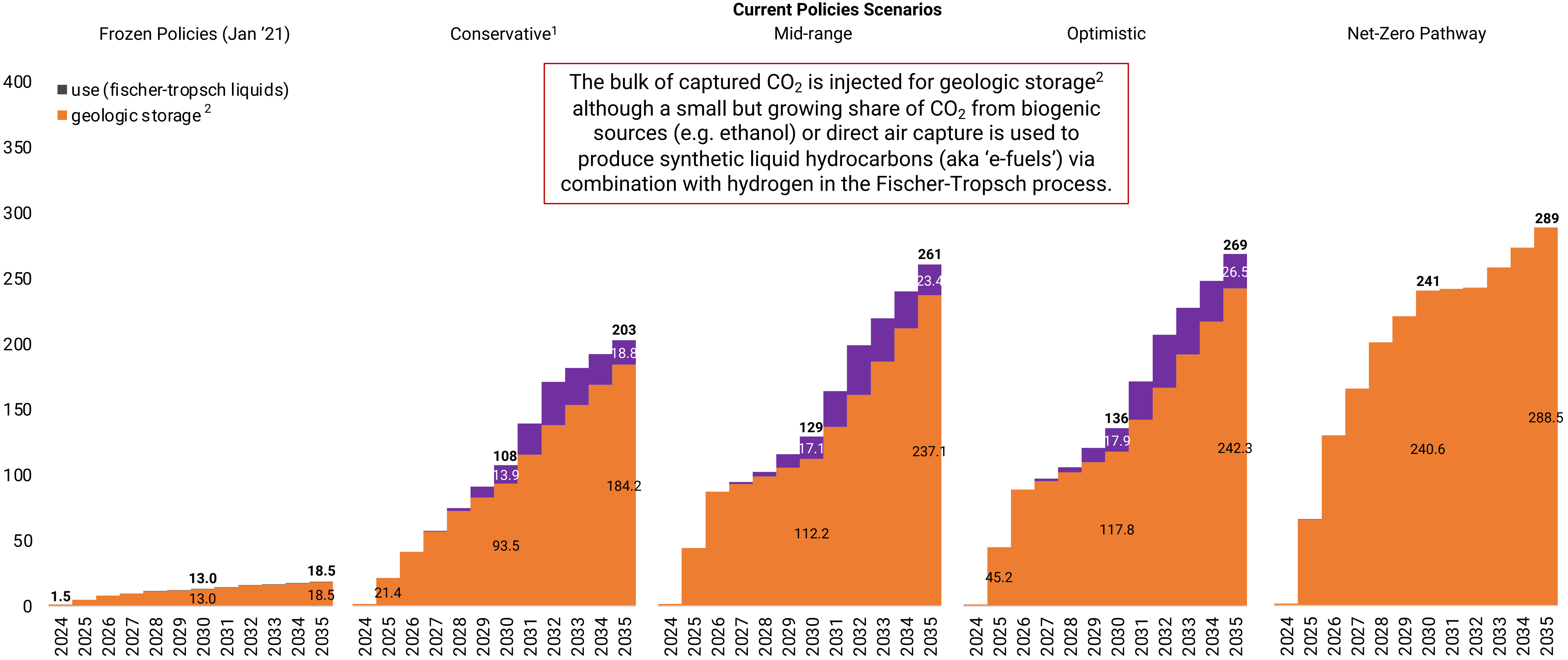
million metric tons of CO_2 per year (MMt CO_2/year)[1]



1 - Excludes currently operating CCS projects with up to 18.6 MMT/y of capacity that exclusively supply CO_2 for enhanced oil recovery (see https://www.catf.us/ccsmapus/). Capture volumes in the cement, iron/steel, refineries and natural gas processing sectors are exogenous inputs based on Larson et al. "A Turning Point for US Climate Progress: Assessing the Climate and Clean Energy Provisions in the Inflation Reduction Act," (Rhodium Group: August 12, 2022) in Current Policies scenarios and on "Annual Decarbonizaton Perspective" (Evolved Energy Research, August 19, 2022) for Net-Zero Pathway. All other capture volumes are endogenously optimized in RIO model.

Carbon Dioxide Use and Sequestration

million metric tons of CO_2 per year (MMt CO_2/year)



The bulk of captured CO_2 is injected for geologic storage[2] although a small but growing share of CO_2 from biogenic sources (e.g. ethanol) or direct air capture is used to produce synthetic liquid hydrocarbons (aka 'e-fuels') via combination with hydrogen in the Fischer-Tropsch process.

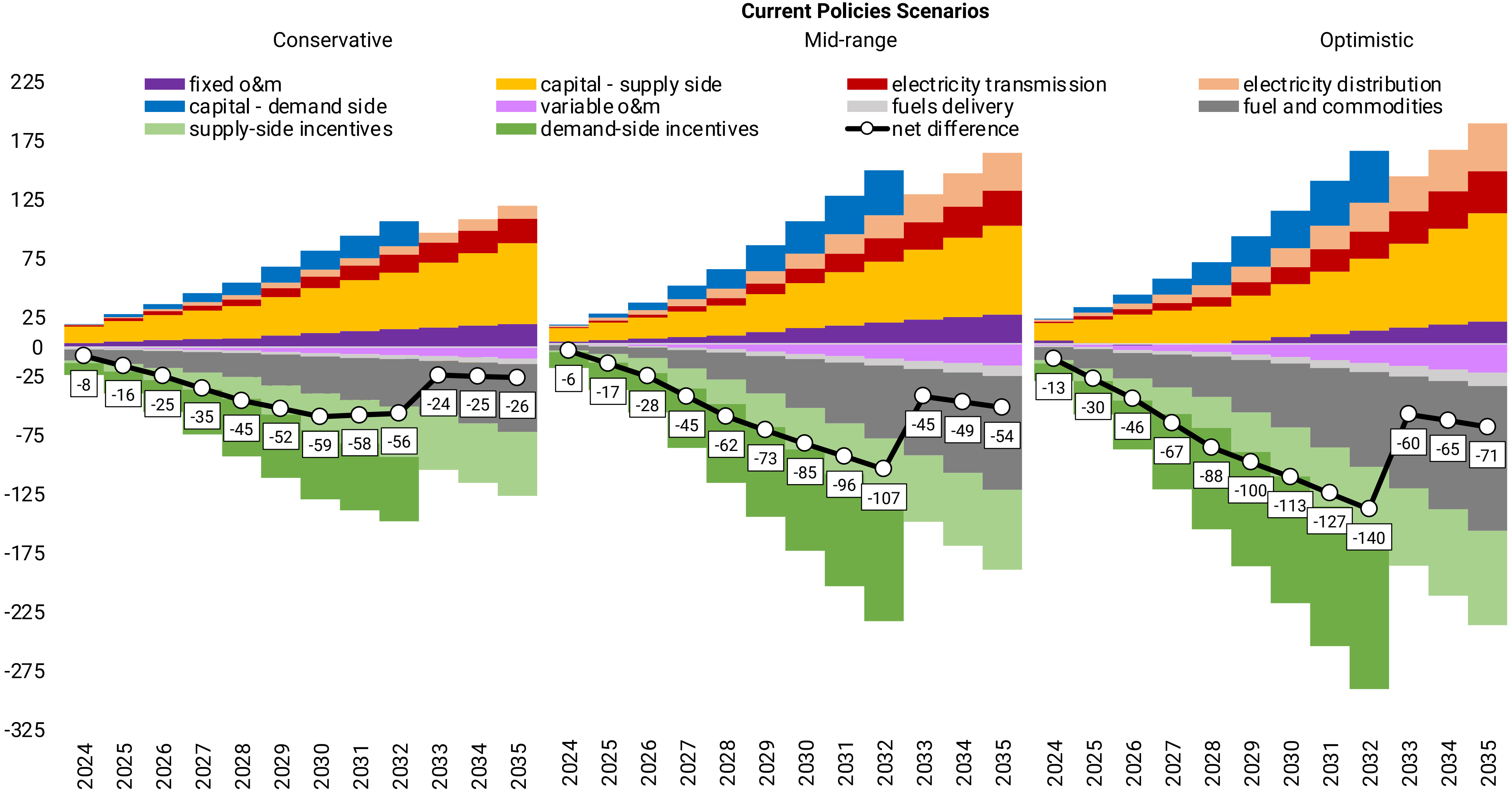
1 - Note that geologic storage in the Conservative scenarios is subject to a binding exogenous constraint on the increase in annual CO_2 injection through 2035. See p. 33.

2 - We model geologic storage as dedicated CO_2 sequestration (earning \$85/t CO_2 45Q credit value). In practice, some projects may make use of CO_2 in oil fields for enhanced oil recovery (EOR), claiming the lower \$60/t CO_2 credit value for use of captured CO_2. However, as amended by IRA, 45Q now provides greater economic incentive for dedicated storage relative to EOR and only 1 out of 171 projects announced since January 2021 has stated it plans to inject CO_2 for EOR (see https://www.catf.us/ccsmapus/).

Annual Energy Expenditures

Change in Annual Energy Expenditures vs Frozen Policies as of January 2021

billions of 2023 US dollars[1]



The Inflation Reduction Act and Infrastructure Law lower annual U.S. energy expenditures ~3-7% in 2030, a savings of $59-$113 billion for U.S. households, businesses, and industry.

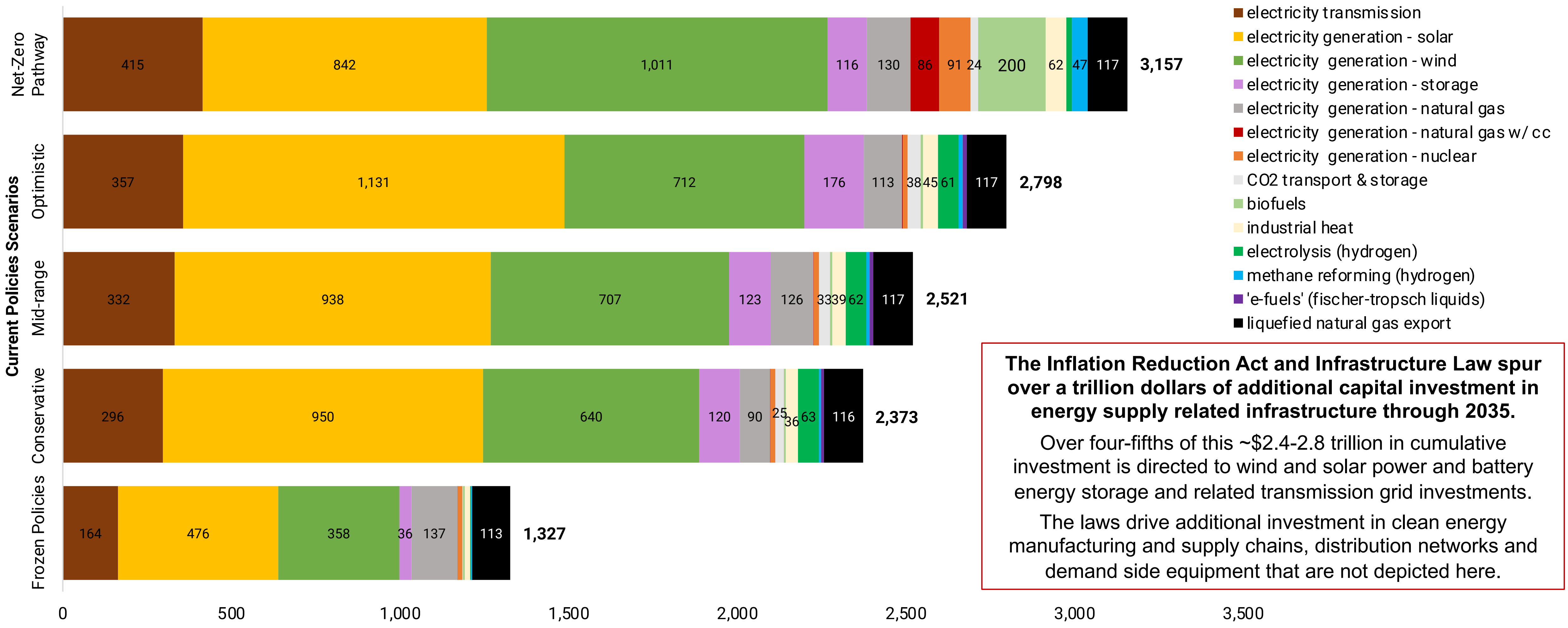
Annual energy cost savings peak in 2032 prior to the scheduled expiration of several IRA incentives (i.e., tax credits for EV adoption, efficiency etc.) but remain about 1-4% lower than the Frozen Policies scenario through 2035.

1 - Dollar values modeled internally as 2018 USD, and converted for display to 2023 USD using Bureau of Labor Statistics CPI Inflation Calculator: 1 2018 UDS = 1.207 2023 USD.

Capital Investment in Energy Supply Infrastructure

Cumulative Capital Investment in Energy Supply Related Infrastructure, 2023-2035

billions of 2023 US dollars[1]



The Inflation Reduction Act and Infrastructure Law spur over a trillion dollars of additional capital investment in energy supply related infrastructure through 2035.

Over four-fifths of this ~$2.4-2.8 trillion in cumulative investment is directed to wind and solar power and battery energy storage and related transmission grid investments.

The laws drive additional investment in clean energy manufacturing and supply chains, distribution networks and demand side equipment that are not depicted here.

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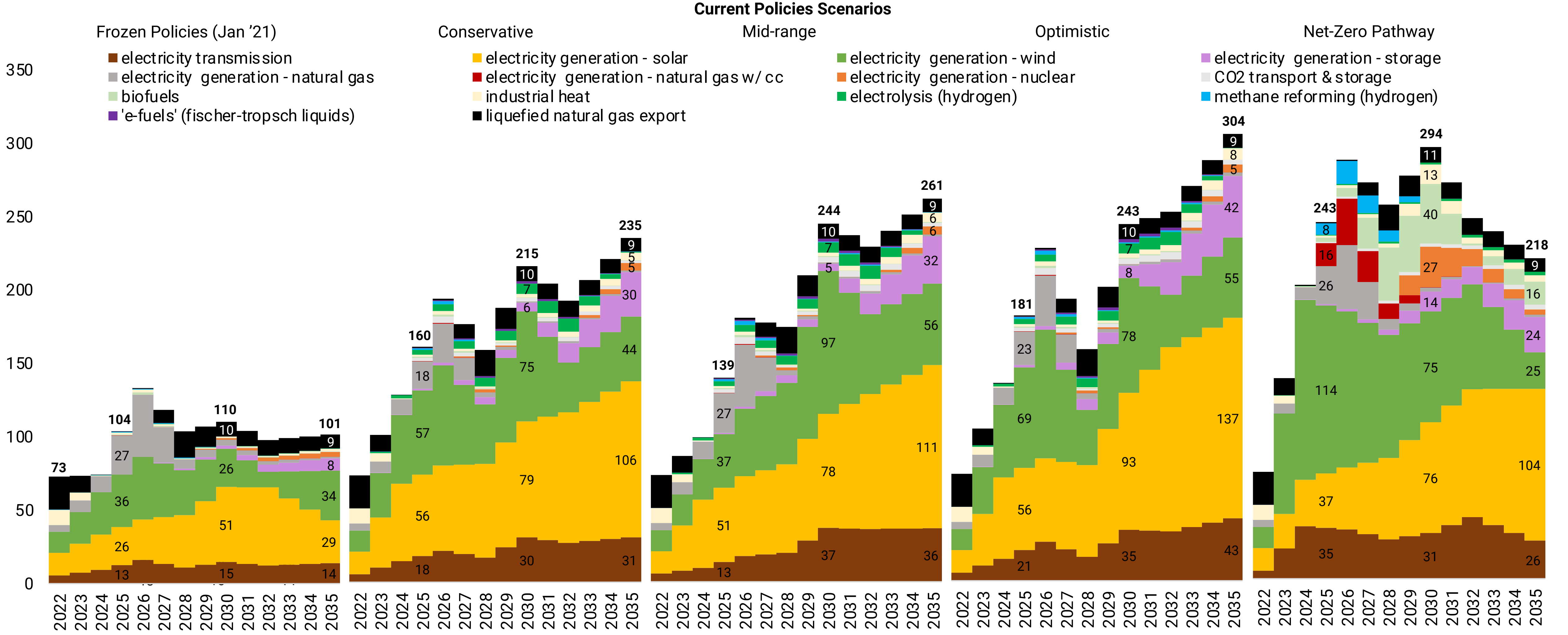
1 - Dollar values modeled internally as 2018 USD, and converted for display to 2023 USD using Bureau of Labor Statistics CPI Inflation Calculator: 1 2018 UDS = 1.207 2023 USD. Values less than $20 billion not displayed in data labels. Capital investment in fuel and electricity distribution are not included.

2 - Includes associated transmission investments.

Annual Capital Investment in Energy Supply Related Infrastructure

billions of 2023 US dollars[1]

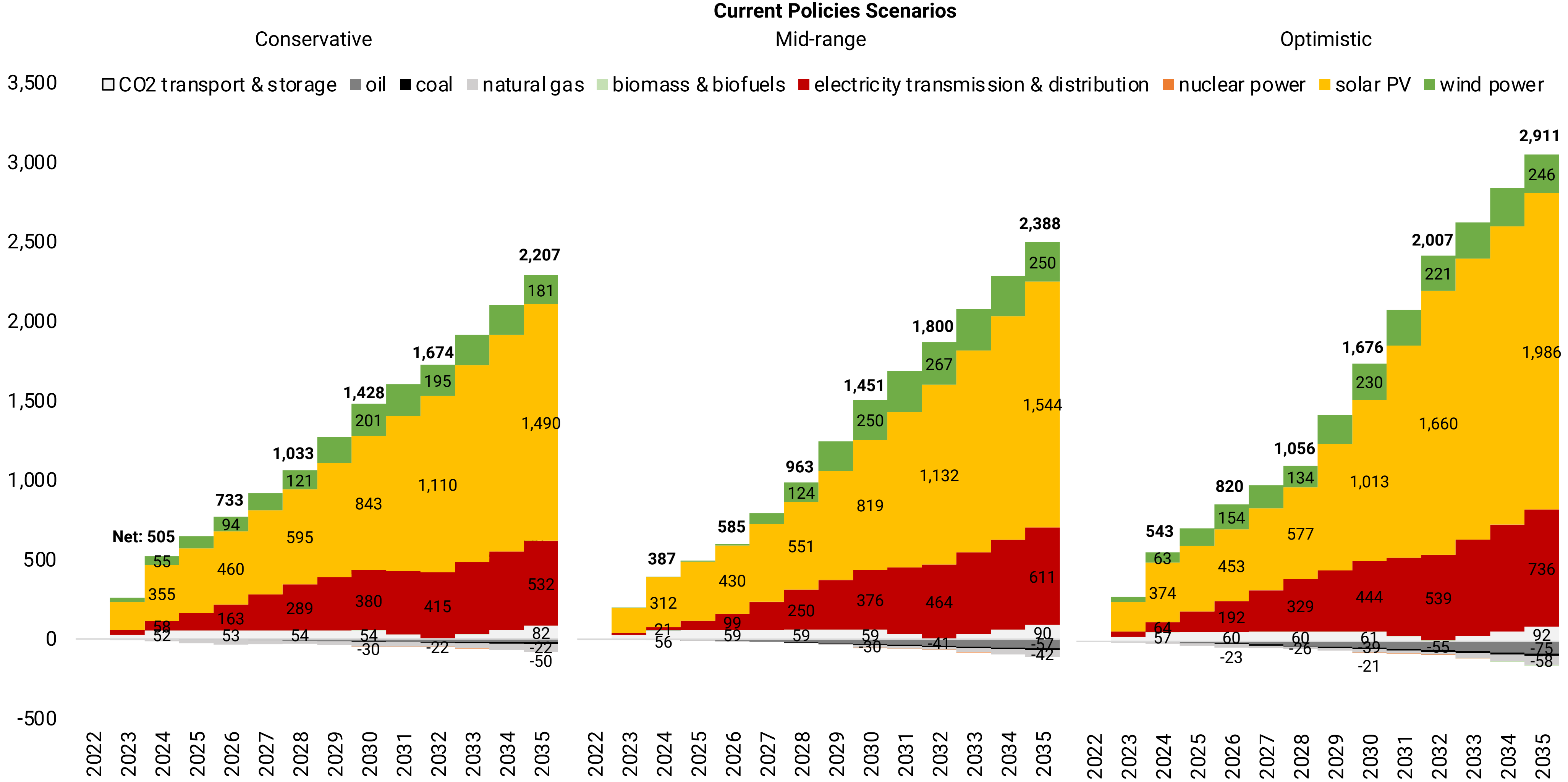


1 - Dollar values modeled internally as 2018 USD, and converted for display to 2023 USD using Bureau of Labor Statistics CPI Inflation Calculator: 1 2018 UDS = 1.207 2023 USD. Values less than $5 billion not displayed in data labels. Capital investment in fuel and electricity distribution are not included.

Employment Impacts

Change in Energy Supply Related Employment by Resource vs Frozen Policies as of January 2021

thousands of jobs[1]



The Inflation Reduction Act and Infrastructure Law could increase energy supply related employment[1] by **about 1.4-1.7 million additional jobs in 2030 and 2.2-2.9 million by 2035.**

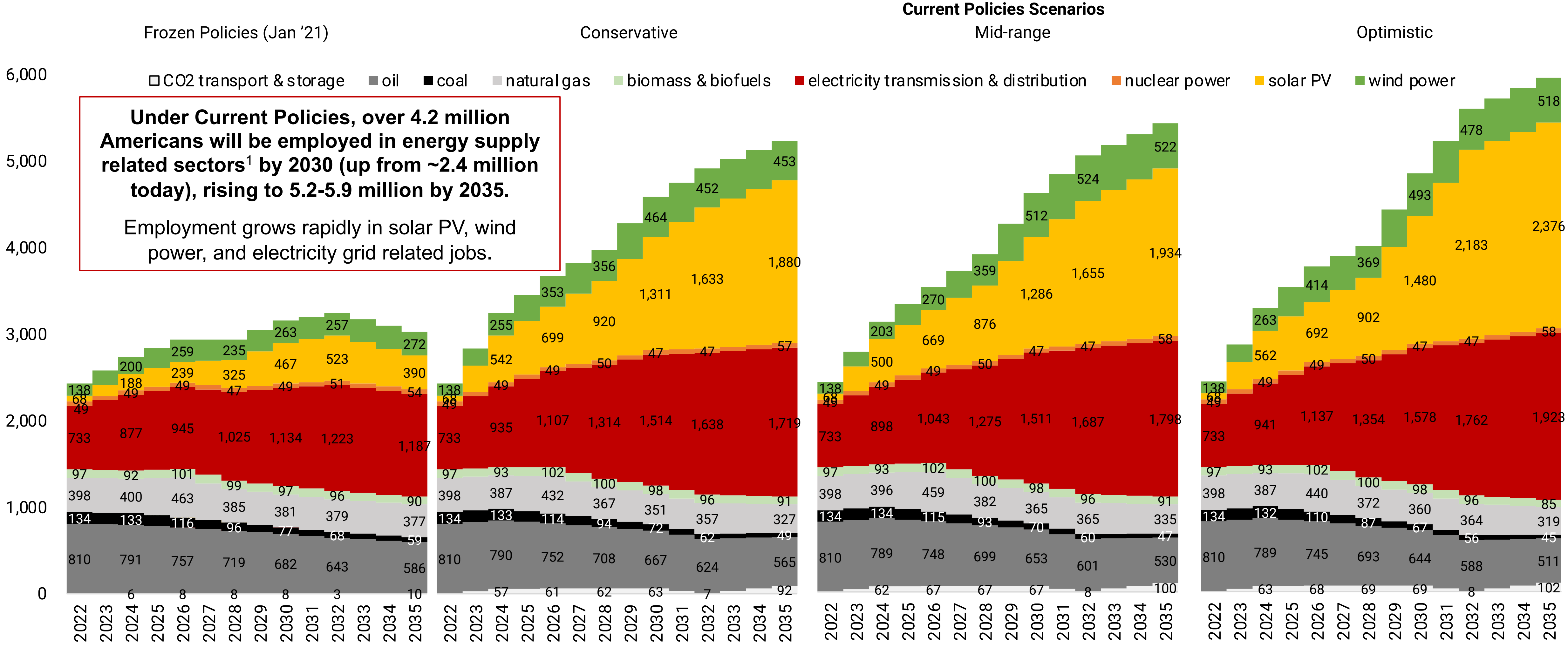
Solar, wind, and grid related jobs expand rapidly under Current Policies scenarios accounting for the vast majority of additional employment.

Oil, natural gas, and coal related employment declines by ~50,000-70,000 jobs in 2030, roughly equal to the additional jobs created in CO_2 transport & storage.

1 - Employment in petroleum fuel refining, distribution, and retailing; hydrogen production, distribution and retailing; energy storage manufacturing, installation and operations; automotive supply chains and assembly; and energy efficiency are excluded from this analysis. Values less than 20 thousand jobs not displayed in labels

Total Energy Supply Related Employment by Resource

thousands of jobs[1]



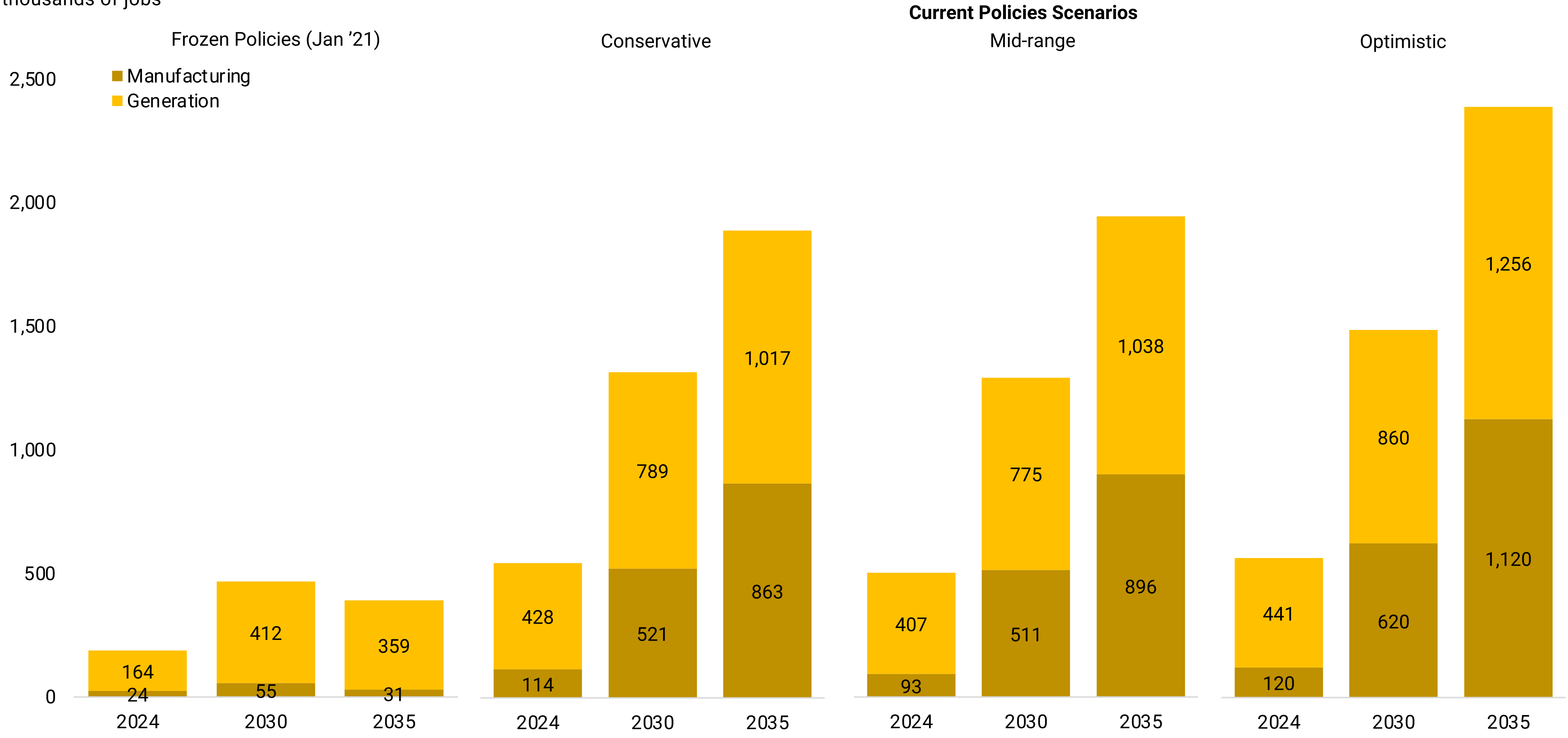
Under Current Policies, over 4.2 million Americans will be employed in energy supply related sectors[1] by 2030 (up from ~2.4 million today), rising to 5.2-5.9 million by 2035.

Employment grows rapidly in solar PV, wind power, and electricity grid related jobs.

1 - Employment in petroleum fuel refining, distribution, and retailing; hydrogen production, distribution and retailing; energy storage manufacturing, installation and operations; automotive supply chains and assembly; and energy efficiency are excluded from this analysis. Values less than 5 thousand jobs not displayed in labels

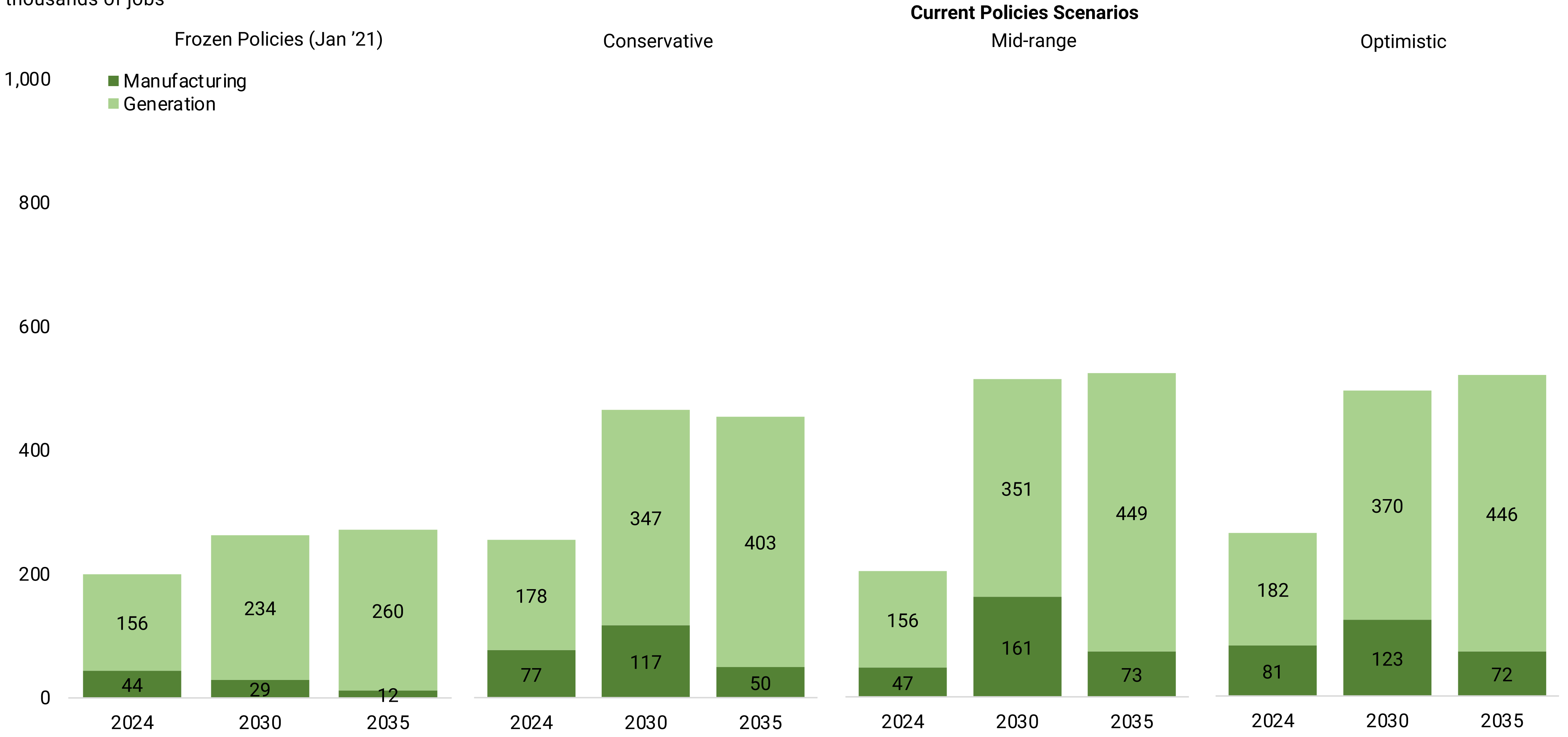
Total Employment in U.S. Solar PV Industry

thousands of jobs



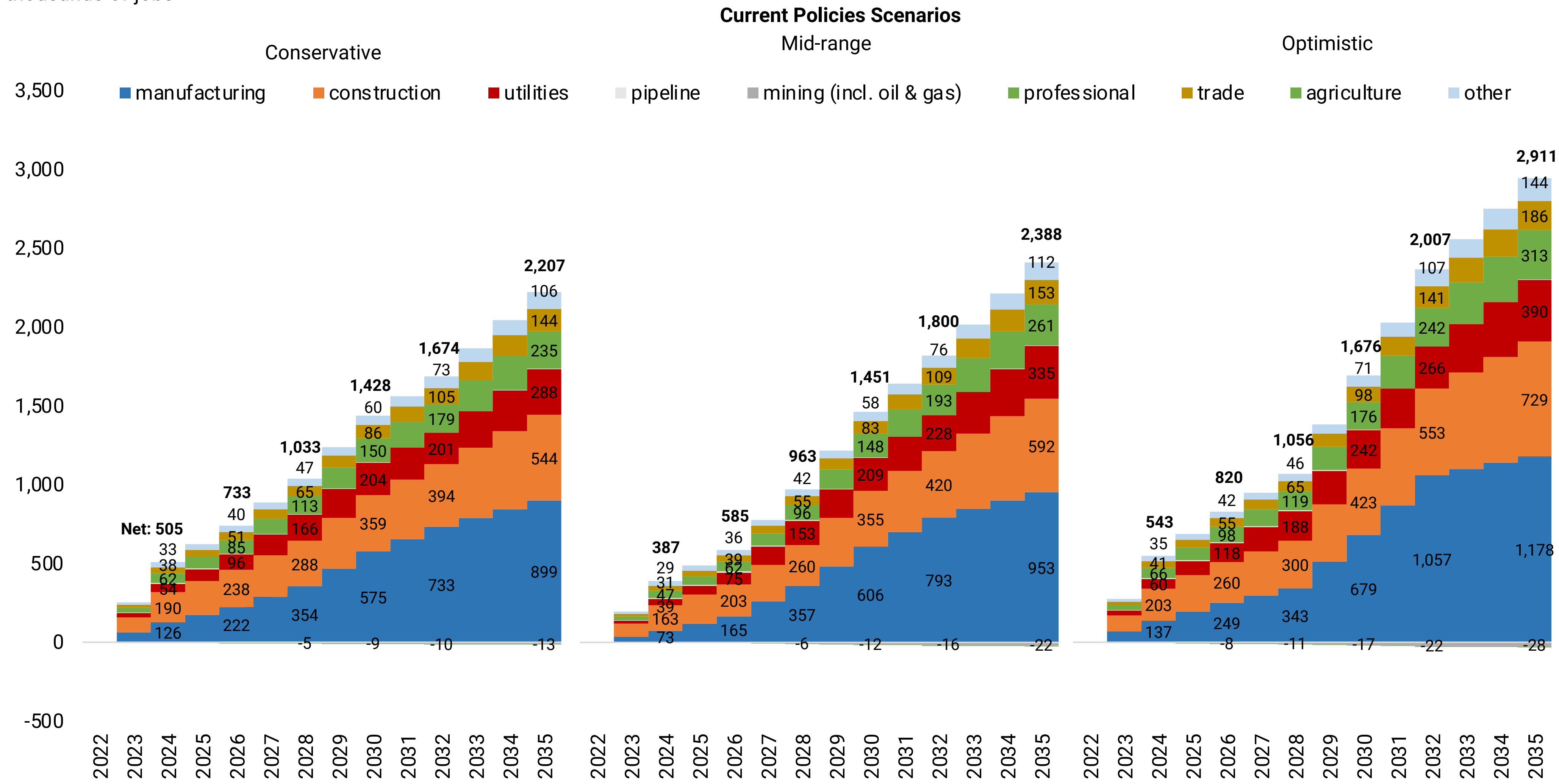
Total Employment in U.S. Wind Power Industry

thousands of jobs



Change in Energy Supply Related Employment by Sector vs Frozen Policies as of January 2021

thousands of jobs[1]



The Inflation Reduction Act and Infrastructure Law could increase energy supply related employment[1] by **about 1.4-1.7 million additional jobs in 2030 and 2.2-2.9 million by 2035.**

That includes **about 600,000 additional manufacturing jobs in 2030 and roughly one million more manufacturing jobs in 2035,** primarily in solar PV and wind turbine component manufacturing.

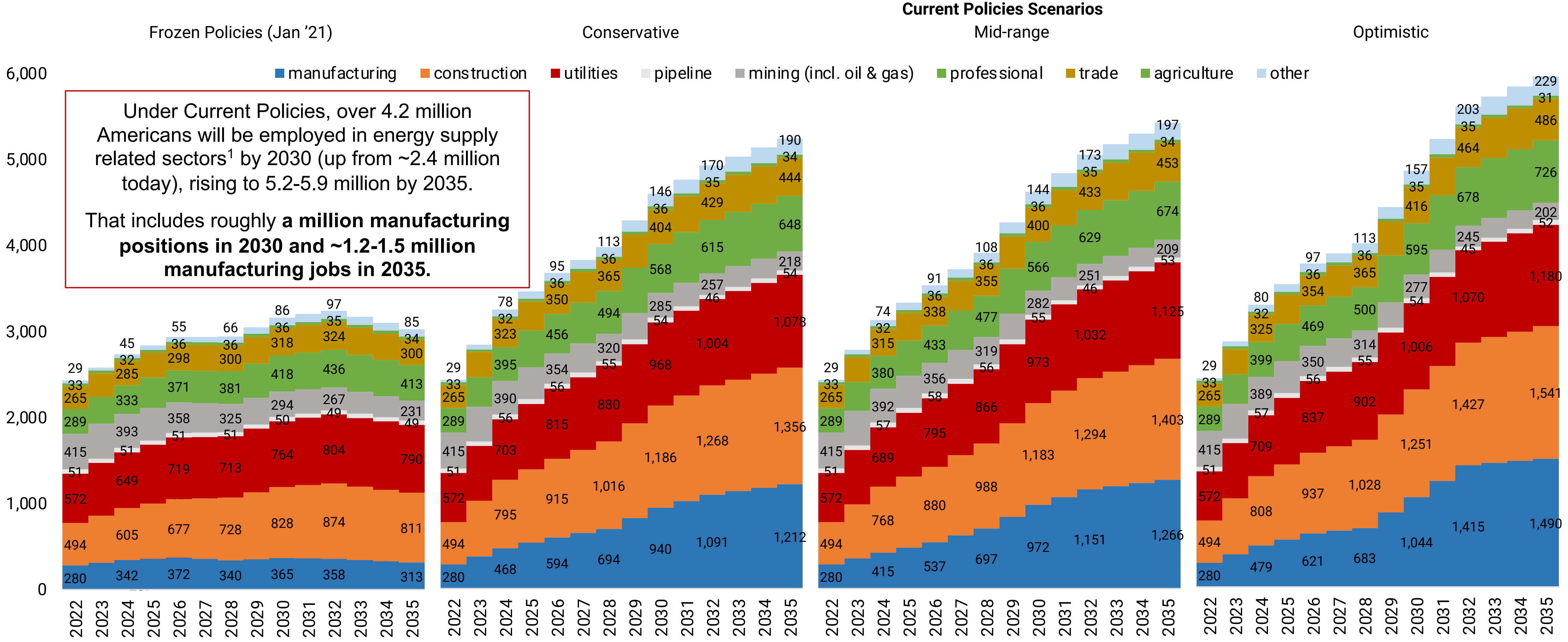
1 - Employment in petroleum fuel refining, distribution, and retailing; hydrogen production, distribution and retailing; energy storage manufacturing, installation and operations; automotive supply chains and assembly; and energy efficiency are excluded from this analysis. Values less than 5 thousand jobs not displayed in labels

Total Energy Supply Related Employment by Sector

thousands of jobs[1]

Under Current Policies, over 4.2 million Americans will be employed in energy supply related sectors[1] by 2030 (up from ~2.4 million today), rising to 5.2-5.9 million by 2035.

That includes roughly **a million manufacturing positions in 2030 and ~1.2-1.5 million manufacturing jobs in 2035.**

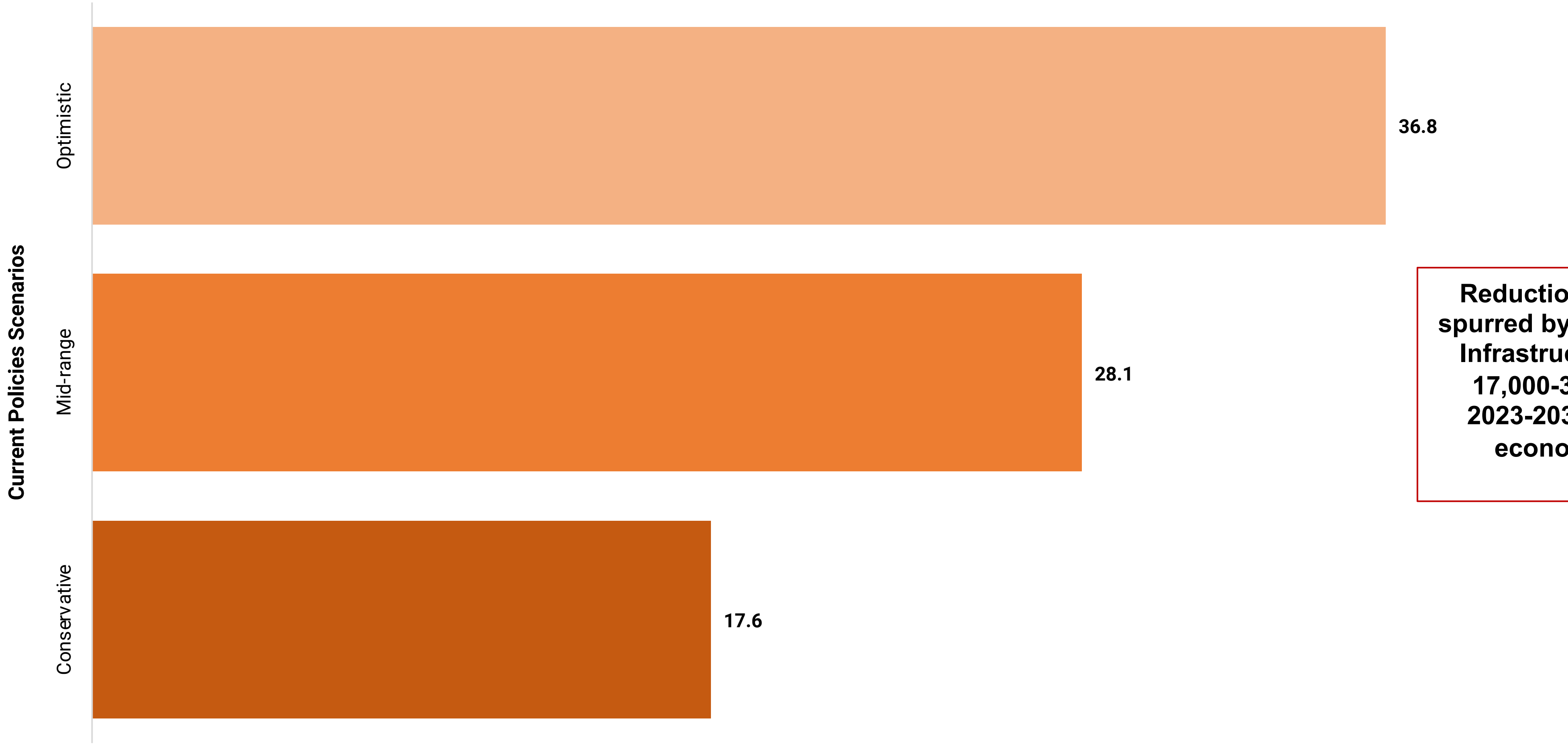


1 - Employment in petroleum fuel refining, distribution, and retailing; hydrogen production, distribution and retailing; energy storage manufacturing, installation and operations; automotive supply chains and assembly; and energy efficiency are excluded from this analysis. Values less than 5 thousand jobs not displayed in labels

Air Pollution and Public Health Impacts

Cumulative Avoided Premature Deaths From Exposure to Fine Particulate Matter From Energy Activities vs Frozen Policies, 2023-2035

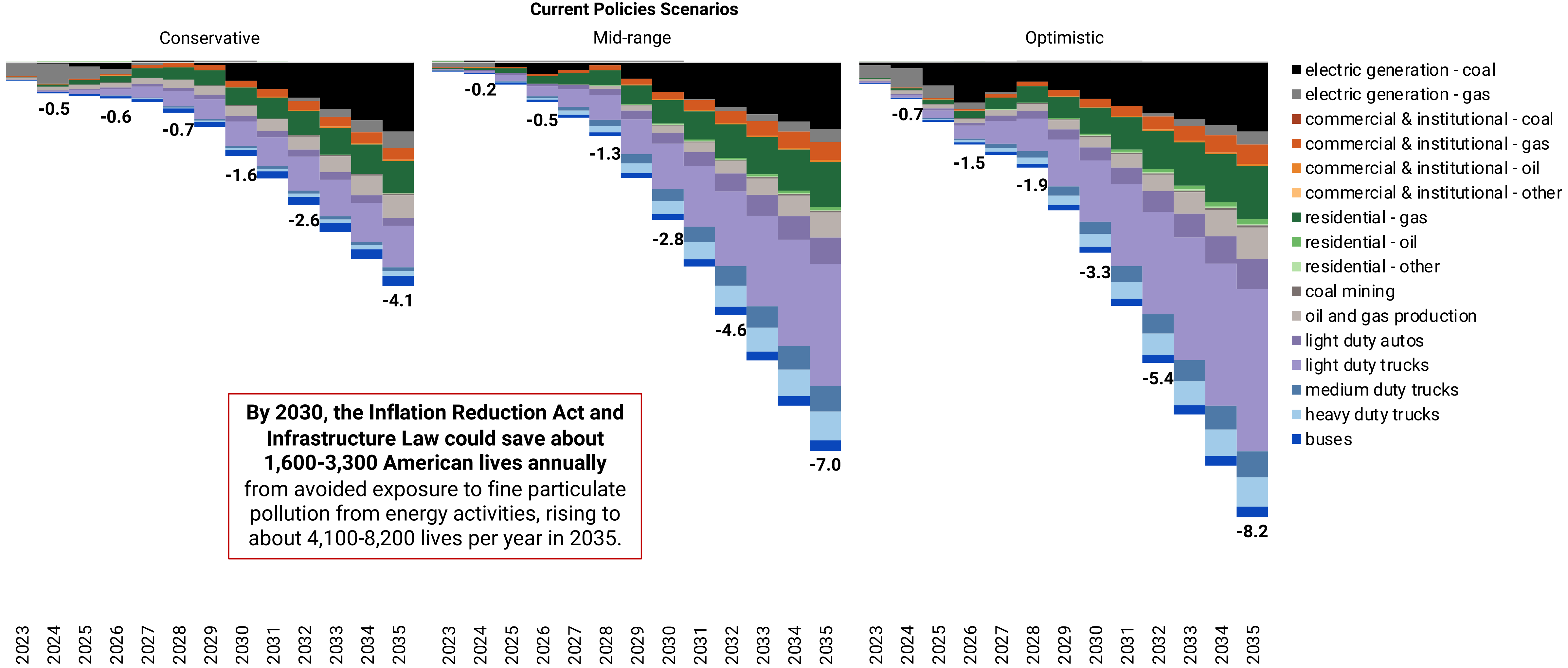
thousands



Reductions in fine particulate pollution spurred by the Inflation Reduction Act and Infrastructure Law could avoid roughly 17,000-37,000 premature deaths from 2023-2035, saving ~$150-325 billion in economic damages from avoided mortalities alone.

Annual Avoided Premature Deaths From Exposure to Fine Particulate Matter From Energy Activities vs Frozen Policies as of January 2021

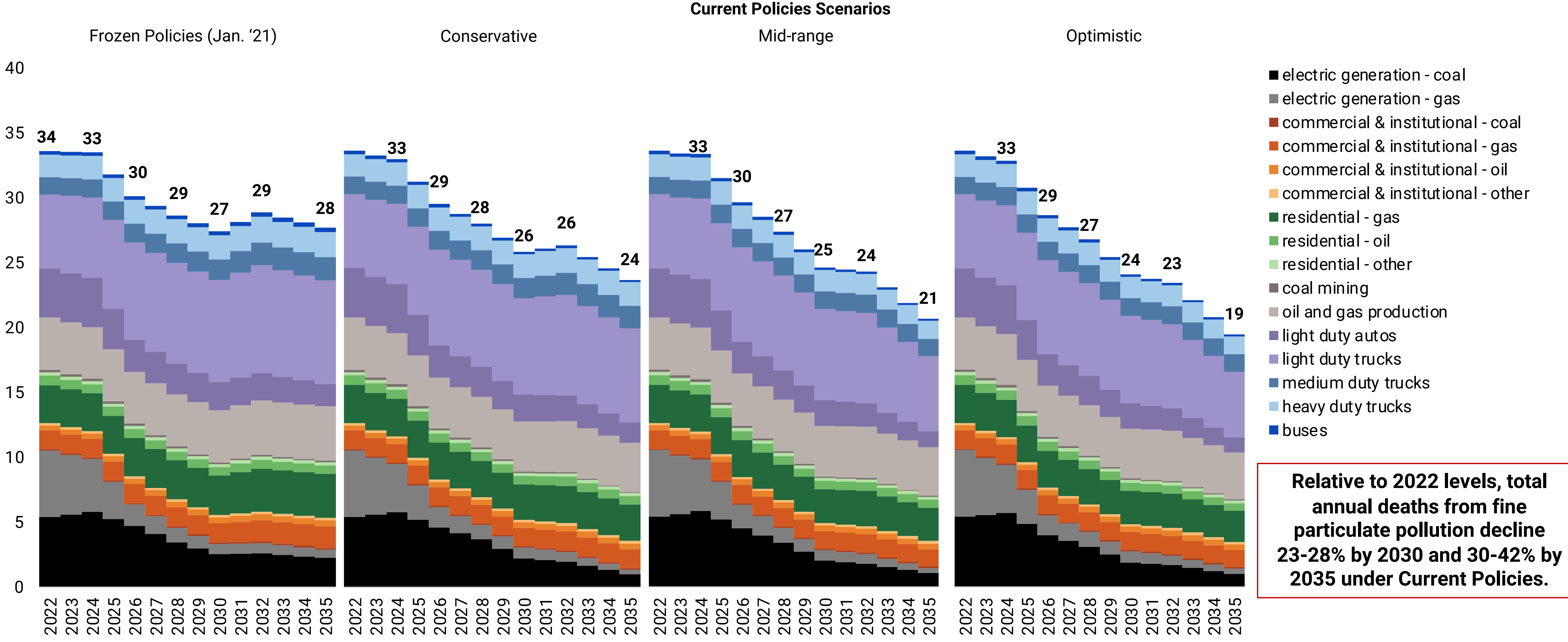
thousands



By 2030, the Inflation Reduction Act and Infrastructure Law could save about 1,600-3,300 American lives annually from avoided exposure to fine particulate pollution from energy activities, rising to about 4,100-8,200 lives per year in 2035.

Annual Premature Deaths From Exposure to Fine Particulate Matter From Energy Activities

thousands



Relative to 2022 levels, total annual deaths from fine particulate pollution decline 23-28% by 2030 and 30-42% by 2035 under Current Policies.

Additional Impacts

Additional impacts of Inflation Reduction Act policies

Beyond the direct emissions reduction impacts of the policies modeled in this report, the Inflation Reduction Act contains important policy measures and programs that will spur innovation and maturation of nascent advanced energy industries, build U.S. clean energy manufacturing and supply chains, improve public health and environmental justice, and drive investment and economic opportunities in communities across the United States.

IRA builds on the demonstration and hubs funding in the Infrastructure Law by **providing early market deployment opportunities over the next decade that will drive innovation and maturation of important nascent clean technologies** that need to be ready for wide-scale deployment in the 2030s and 2040s, including clean hydrogen, carbon capture, zero-carbon liquid fuels, direct air capture, advanced nuclear and geothermal energy, and more. These technologies all have access to robust deployment subsidies (many for the first time)[1] that are likely to have a similar catalytic impact as the tax credits that cultivated wind and solar energy industries and drove costs down by ~90% for solar and ~70% for wind from 2010 to 2021.

IRA also contains **robust support for the development of American manufacturing of solar, wind, battery and electric vehicle components and assembly as well as critical minerals processing**. The bill ties bonus tax incentives for clean electricity and credits for consumer clean vehicles purchases to domestic content sourcing standards, providing strong demand for U.S. materials and manufacturing.[2] It also provides $2 billion in grants and $40 billion in loans to retool American auto manufacturing to produce clean vehicles and $37 billion in new tax credits to spur investment in America's capacity to produce and assemble wind and solar PV components, batteries and clean vehicles, and process critical minerals.[3] An additional $0.5 billion is also appropriated for the President to use the Defense Production Act to build American supply chains for heat pump and battery manufacturing, critical minerals, and other strategic priorities.[4] Those policies are important to expand supply chains and enable rapid scale-up of these technologies, and they will also create **hundreds of thousands of manufacturing jobs across the country**, giving countless communities a direct, tangible, near-term stake in the clean energy transition.

1 – These include the clean hydrogen PTC (Sec. 13204), 45q tax credit for CCS (Section 13104), and new technology-neutral production and investment tax credits for all carbon-free electricity generation (Sec. 13701 and 13702) and a clean fuel production tax credit (Sec. 13704). The bill also provides $40 billion in expanded loan authority for the DOE Loan Programs Office (LPO) to support investment in nascent clean energy sectors.

2 – A bonus 10% increase in the value of the production tax credit (Sec. 13101 and 13701) and 10 percentage point increase in the investment tax credit (Sec. 13102 and 13702) are available for clean electricity projects that meet domestic content requirements for materials and manufactured components. The consumer clean vehicles tax credit (Section 13401) is also tied to increasing requirements for sourcing of batteries and critical minerals from North America or our trade partners.

3 – See the Domestic Manufacturing Conversion Grants (Sec. 50143), Advanced Vehicle Technology Manufacturing loan program at DOE (Sec. 50142), and the 48C Advanced Energy Project Credit (Sec. 13501) and Advanced Manufacturing Production Credit (Sec. 13502).

4 – Enhanced Use of Defense Production Act of 1950 (Sec. 30001).

Additional impacts of Inflation Reduction Act policies (continued)

A package of environmental justice provisions in IRA provide at least $60 billion to reduce harmful pollution in environmentally overburdened communities, ensure more equitable access to renewable energy and energy efficiency and building electrification opportunities, and improve public health and climate resiliency.

A variety of programs will direct funding to **cut pollution in low-income communities and areas burdened by the worst air pollution in the country**. This includes $3 billion for block grants for community-led environmental and climate justice projects and more than $4 billion in funds to reduce air pollution at America's ports, replace dirty heavy duty vehicles like garbage trucks and city buses with zero-emissions vehicles, and improve interior air quality in schools in low-income communities.[1] The law funds 'fenceline' air pollution monitoring to empower EPA and local air quality agencies to track and reduce pollution burdens on the most vulnerable communities, and it appropriates needed funding for the White House to map and identify environmental justice communities on the frontlines of pollution.[2] IRA reinstates (and adjusts for inflation) the 'polluter pays' Superfund Tax to cover the cost of remediating the worst environmentally contaminated industrial sites, and it invests $1 billion to improve energy and water efficiency, indoor air quality, and climate resiliency of affordable housing and over $3 billion to improve neighborhood walkability, safety, and affordable transportation access.[3]

The IRA also dedicates tens of billions of dollars to **expand equitable access to clean and efficient technologies**. The $27 billion Greenhouse Gas Reduction Fund devotes more than half of this funding to deploy clean energy and pollution-reducing technologies in low-income and disadvantaged communities and to establish 'green banks' to provide financial assistance for clean energy projects benefiting disadvantaged communities.[4] Hundreds of millions in grants and $20 billion in loan authority will help Tribal and Native Hawaiian communities improve climate resilience, access clean electricity, and electrify buildings.[5] Finally, two rebate programs also provide $8.8 billion to ensure access to energy efficiency and building electrification funds for low- and middle-income households that lack tax liability to take advantage of other tax credits.[6]

1 – See the $3 billion Environmental and Climate Justice Block Grants program (Sec. 60201), $3 billion for Grants to Reduce Air Pollution at Ports (Sec. 60102), $1 billion for Clean Heavy-Duty Vehicles (Sec. 60101), $60 million for Diesel Emissions Reductions (Sec. 60104), and $50 million for Funding to Address Air Pollution at Schools (Sec. 60106).

2 – See the $281 million Funding to Address Air Pollution (Sec. 60105) and $32.5 million Environmental and Climate Data Collection program for the White House Council on Environmental Quality (Sec. 60401).

3 – See the Reinstatement of Superfund (Sec. 13601), Improving Energy Efficiency or Water Efficiency or Climate Resilience of Affordable Housing (Sec. 30002), and Neighborhood Access and Equity Grant Program (Sec. 60501).

4 – The Greenhouse Gas Reduction Fund (Sec. 60103) dedicates at least $15 billion out of $27 billion in total funding to low-income and disadvantaged communities.

5 – See Tribal Energy Loan Guarantee Program (Sec. 50145), $260m for Tribal Climate Resilience and Native Hawaiian Climate Resilience (Sec. 80001 and 80002), $150m Tribal Electrification Program (Sec, 80003) and $13m Emergency Drought Relief for Tribes (Sec. 80004).

6 – See the $4.3 billion Home Energy Performance-Based Whole-House Rebates Program (Sec. 50121) and $4.5 billion High-Efficiency Electric Home Rebate Program (Sec. 50122).

Additional impacts of Inflation Reduction Act policies (continued)

The IRA provides grants, loans, and tax incentives that will drive hundreds of billions of dollars in cumulative investment in American energy communities between now and 2030. Bonus tax credits are available for investments in clean electricity generation sited in traditional 'energy communities' across America, defined as areas with significant historical employment in energy resource, extraction, processing or transportation or where coal plants or mines have closed in recent decades, providing a strong financial incentive to retool and repower existing power plant sites and reinvest in energy producing communities.[1] These tax incentives complement $9.7 billion in financial assistance for rural electric cooperatives to install zero-emissions generation, carbon capture, or grid upgrades and $5 billion in appropriations to create a new energy community reinvestment financing program that will support up to $250 billion in loan guarantees to retool, repower, repurpose, or replace aging energy infrastructure and install carbon capture and other low emissions retrofits at electricity generation and fuels production and refining facilities.[2] The Act also sets aside $4 billion in tax incentives that will spur at least $13 billion in clean energy manufacturing investments in these energy communities.[3]

The full impacts of most of these provisions are beyond the scope of this project to model, but they will nevertheless deliver real, salient benefits for diverse communities across the country.

1 – A bonus 10% increase in the value of the production tax credit (Section 13101 and 13701) and 10 percentage point increase in the investment tax credit (Section 13102 and 13702) are available for clean electricity projects installed in 'energy communities.'

2 – See the USDA Assistance for Rural Electric Cooperatives program (Sec. 22004) and new DOE Section 1703 Energy Infrastructure Reinvestment Financing program (Sec. 50144).

3 – The 48C Advanced Energy Project Credit (Sec. 13501) specifically sets aside $4 billion (out of $10 billion in total incentives) for energy communities; the 30% investment tax credit will spur at least $13.3 billion in investment.

REPEAT Rapid Energy Policy Evaluation and Analysis Toolkit

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