NATIONAL ACADEMIES Sciences Engineering Medicine

Incorporating Climate into Macroeconomic Modeling

Workshop | June 14–15, 2023

JUNE 2023

Session 4:
Projecting Economic and Financial Impacts of the Energy Transition

NATIONAL ACADEMIES Sciences Engineering Medicine

The role of transition-related expectations

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Incorporating Climate into Macroeconomic Modeling

National Academies of Sciences, Engineering, and Medicine

Washington/Hybrid, 14-15 June 2023

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Transition-related expectations

- Expectations key in defining transition pathways
  - Expectations of future policy implementation, tech development, physical/financial stranding, climate impacts..
  - Transition expectations affect investment decisions today
  - Misalignment of expectations can lead to disruptions

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  - Misalignment of expectations can lead to disruptions
- Very complex to capture them in full
  - Behavioural econ $\rightarrow$ expectations are heterogeneous, volatile, biased, forward-looking with finite horizon..
  - Neoclassical vs complexity macro modelling approaches
  - Still untapped in transition modelling: diagnostic expectations (e.g. Gennaioli and Schleifer 2018); heterogeneous expectations (e.g. Hommes 2021)...
  - An application to policy uncertainty and low-carbon transition (Campiglio, Lamperti and Terranova, 2023)

Numerous recent cases of policy reversals

Tony Abbott (2014)

"*..the repeal of the carbon tax means a $550 a year benefit for the average family*"

"*On energy, I will cancel job-killing restrictions on the production of American energy - including shale energy and clean coal - creating many millions of high-paying jobs*"

Donald Trump (2016)

Common reason for reversals: perceived transition costs

- Concerns regarding costs (unemployment, stranding, financial volatility) associated with low-carbon transition

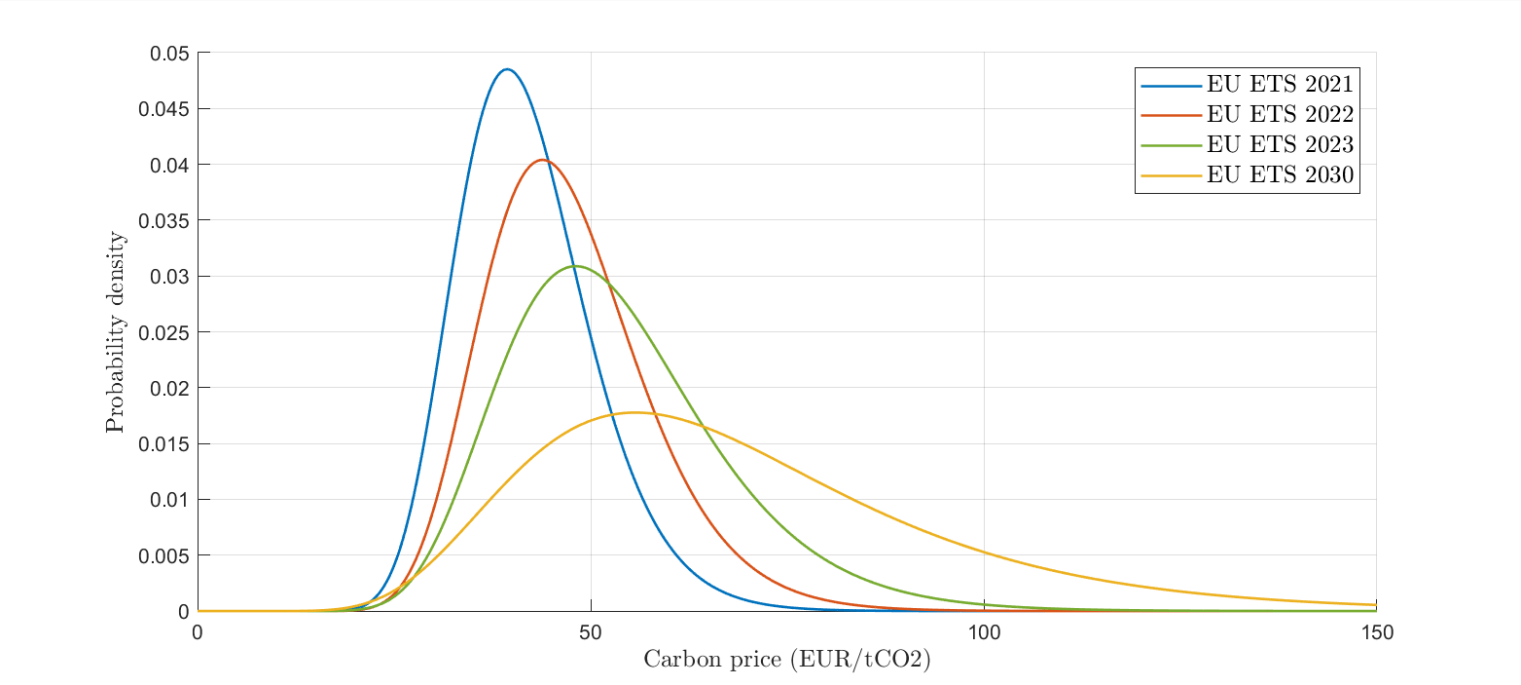
$\rightarrow$ Revision/withdrawal of announced plans

Gilets Jaunes movement in France (2018)

Kazakhstan protests after LPG price cap lift (2022)

Heterogeneous climate policy sentiments

- Uncertainty + behavioural factors → Heterogeneous beliefs on policy credibility → Heterogeneous carbon price expectations



Distribution of expected carbon price in the EU Emission Trading Scheme for different time horizons. Source: Cahen-Fourot et al. (2022). Data from Refinitiv (2021)

Model overview

- Dynamic model focusing on investment allocation choices
  - Two technologies: low-carbon (l) vs high-carbon (h)
  - Investment function of heterogeneous expected tech costs

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  - Firms observe policy-maker climate policy announcements ($\bar{g}_\tau$)
  - They evaluate its credibility: believers (b) vs sceptics (s)
  - Policy-maker can default on goals with high transition risks (function of policy ambition and carbon intensity of economy)
  - Actual tax depends on government's commitment (c)

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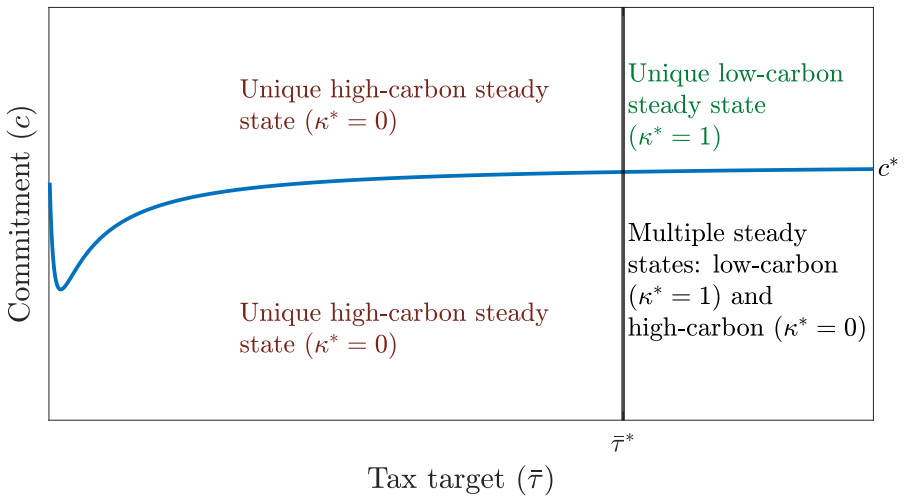
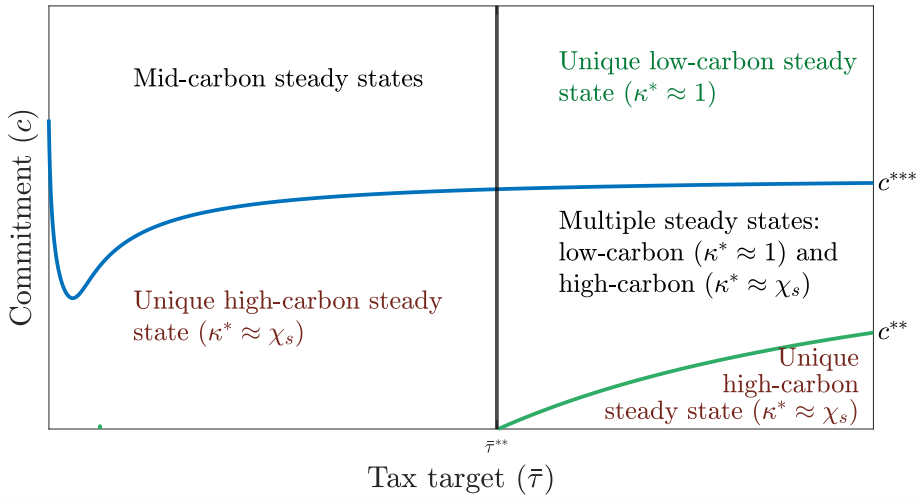
- Heterogeneous choices across firms
  - β: Belief responsiveness to policy-maker track-record
  - γ: Investment responsiveness to perceived cost differentials
  - From 'neoclassical limit' without frictions ($\beta = \gamma = \infty$) to entirely random (full hedging) investment choices ($\beta = \gamma = 0$)

Analytical results

- Ambitious announcements + weak commitment $\rightarrow$ multiple equilibria (a 'high-carbon trap')
- Heterogeneity $\rightarrow$ 'behavioural premiums' on tax announcement and commitment minimum levels

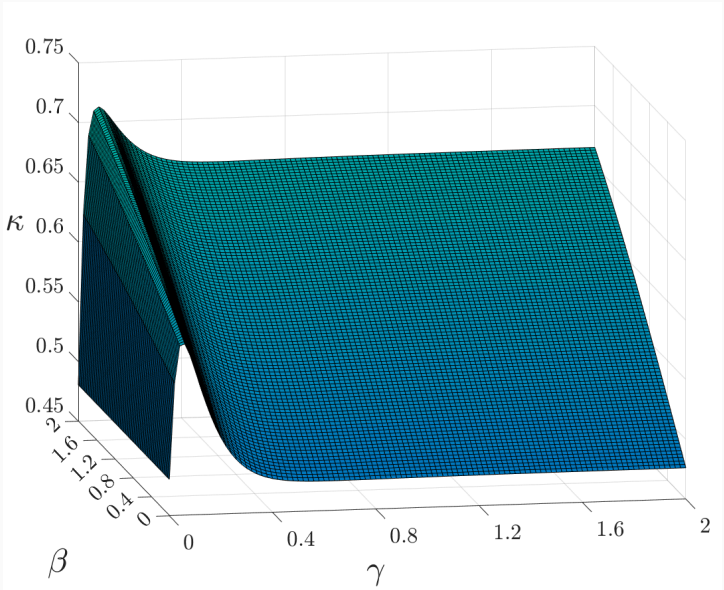




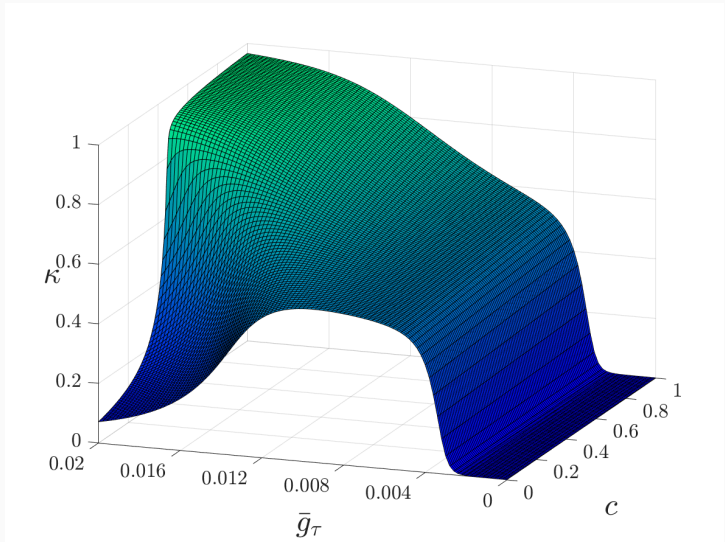
Steady state analysis (above: homogeneity; below heterogeneity).

Numerical results (calibrated to EU economy)

- Full commitment: full decarbonisation but heterogeneity affects transition speed
- Weak commitment: credibility loss $\rightarrow$ higher-carbon investments $\rightarrow$ weaker policies $\rightarrow$ transition failure



Mid-term low-carbon capital share κ as a function of belief/investment responsiveness (β and γ



Long-term low-carbon capital share κ as a function of policy ambition $\bar{g}_\tau$ and commitment c

What next?

- Capture transition-related expectations
  - Apply econometric methods to financial market data
  - Elicit opinions via surveys
  - Study communications via NLP
  - Run experiments online, in lab, in field

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  - E.g. role of electoral cycles; financial dynamics

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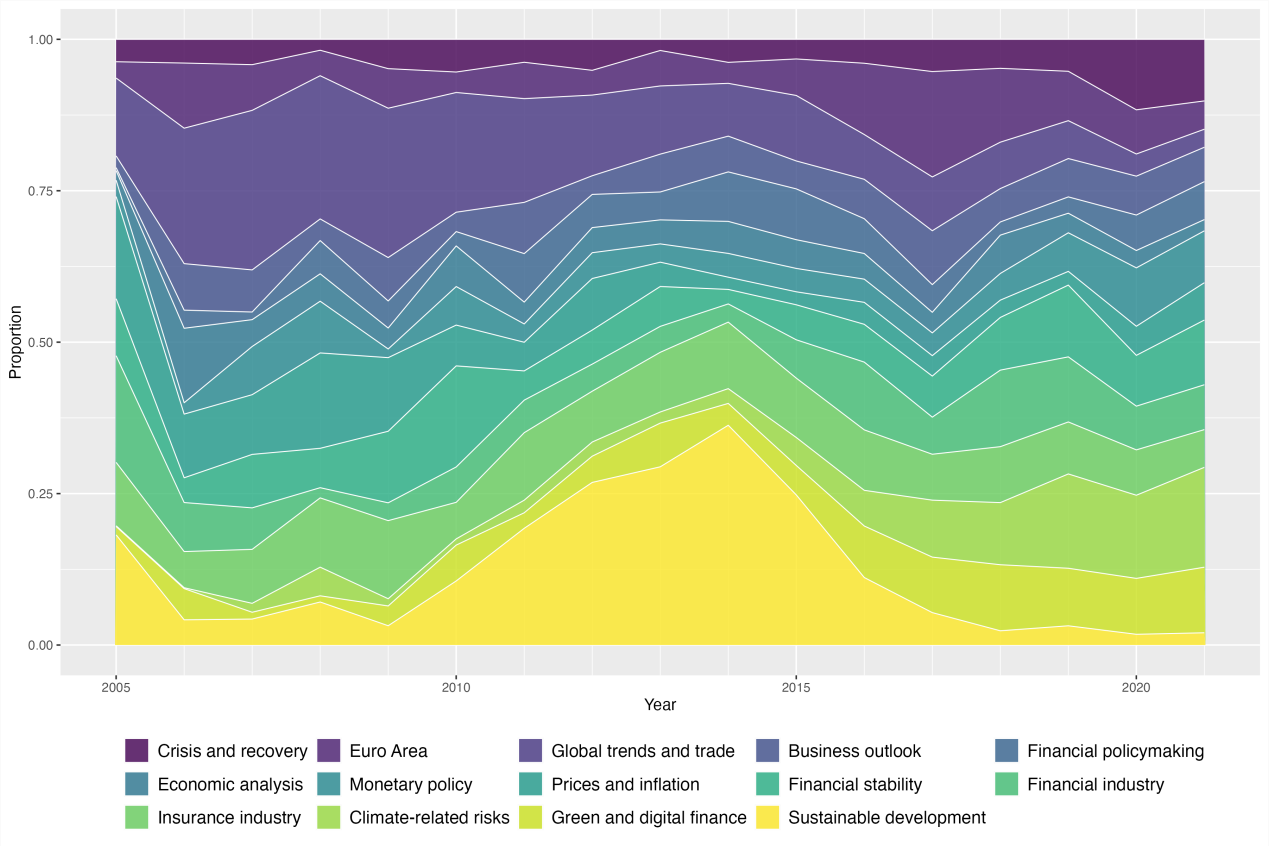
- Understand how to manage expectations
  - What is most appropriate policy/institutional framework?
  - Transition-related expectations alignment (e.g. via communication)

Central bank communication on climate change

- Central bank speech dataset $\approx$ 30,000 speeches from 118 countries
- Several key climate-related topics emerging and evolving



Evolution of climate-related topics. Source: Campiglio, Deyris, Romelli (2023)

Thank you!

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Rhodium Group

Macroeconomic pathways and US GHG emissions

Projecting economic and financial impacts of a transition to a low-GHG economy

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John Larsen
Partner
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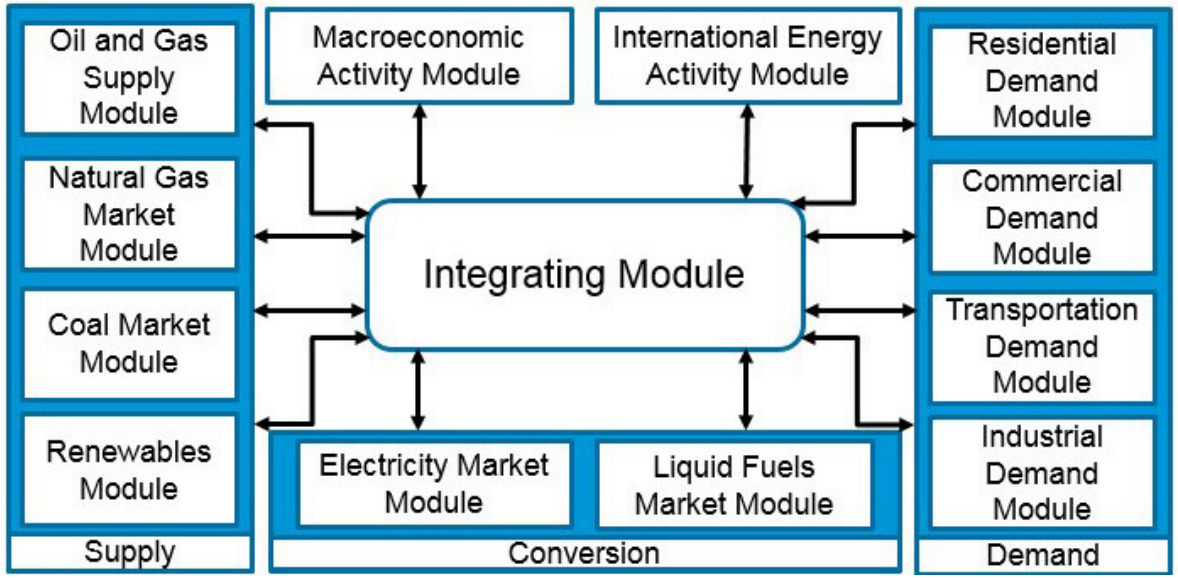
RHG-NEMS: the primary energy system model we use for US analysis

RHG-NEMS



Created by the Energy Information Administration, modified, operated and maintained by Rhodium Group

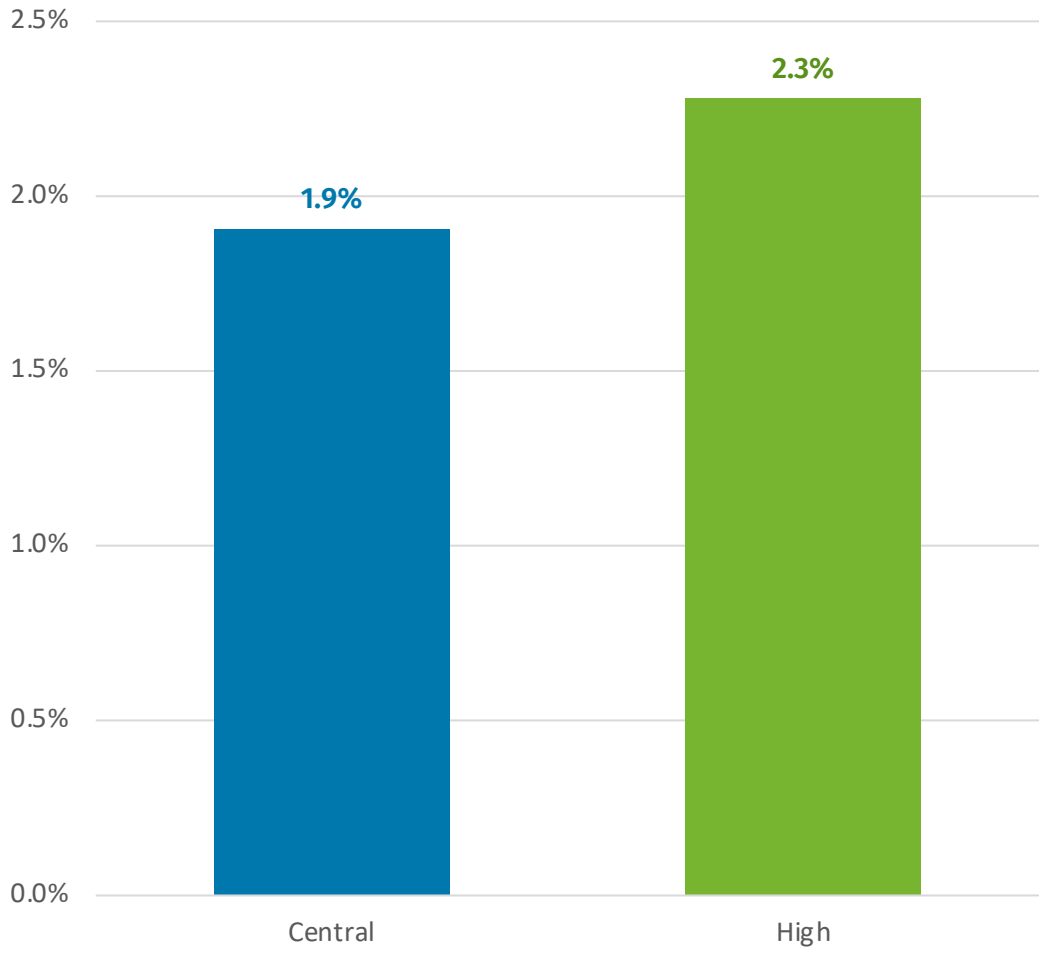
Rhodium modifications and expansions to NEMS

- Update for recent federal and state policy
- Update for recent market and economic conditions
- Update cost and performance assumptions for clean energy technologies
- Expand clean energy technology options in the industrial and electric power sector (carbon capture, direct air capture, etc.)
- Project all 6 major greenhouse gases
- Downscale select results to all 50 states

Macroeconomic growth is the primary driver of GHG emissions

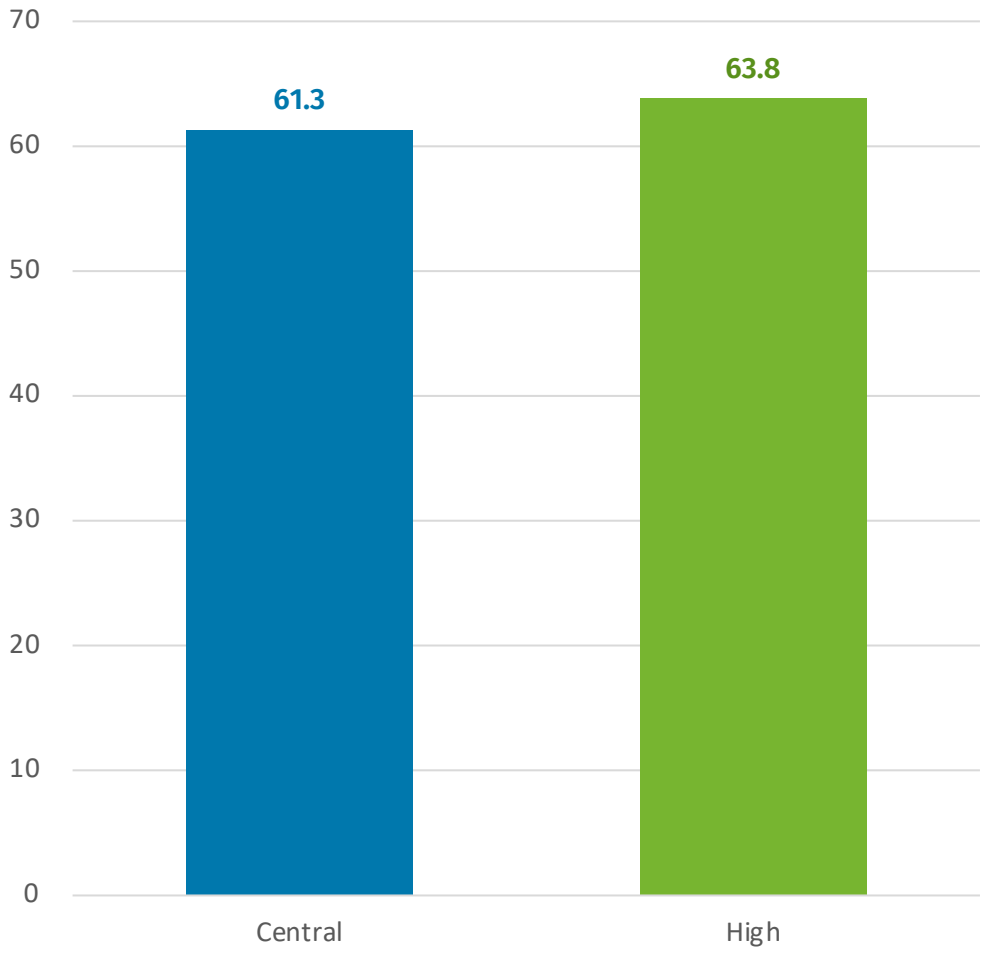
Macroeconomic growth rate, 2023-2035

Average annual % change



US cumulative net-GHG emissions, 2023-2035

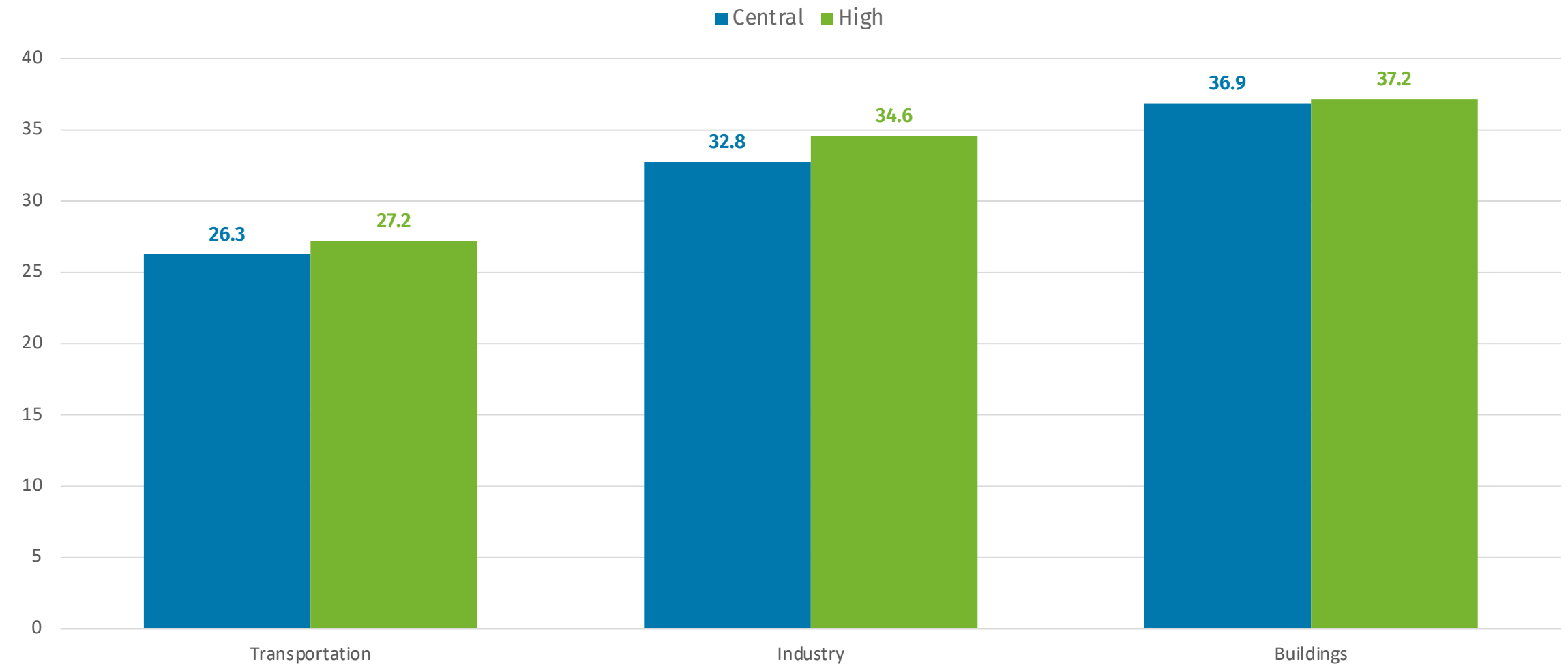
Billion metric tons CO_2e



Source: Rhodium Group. Note: All scenarios shown do not include the Inflation Reduction Act.

Macroeconomic growth drives primary energy demand

QUADs



Source: Rhodium Group. Note: Electric power energy is assigned to end-use sectors. All scenarios shown do not include the Inflation Reduction Act.

Inflation Reduction Act (IRA) analysis scenario design

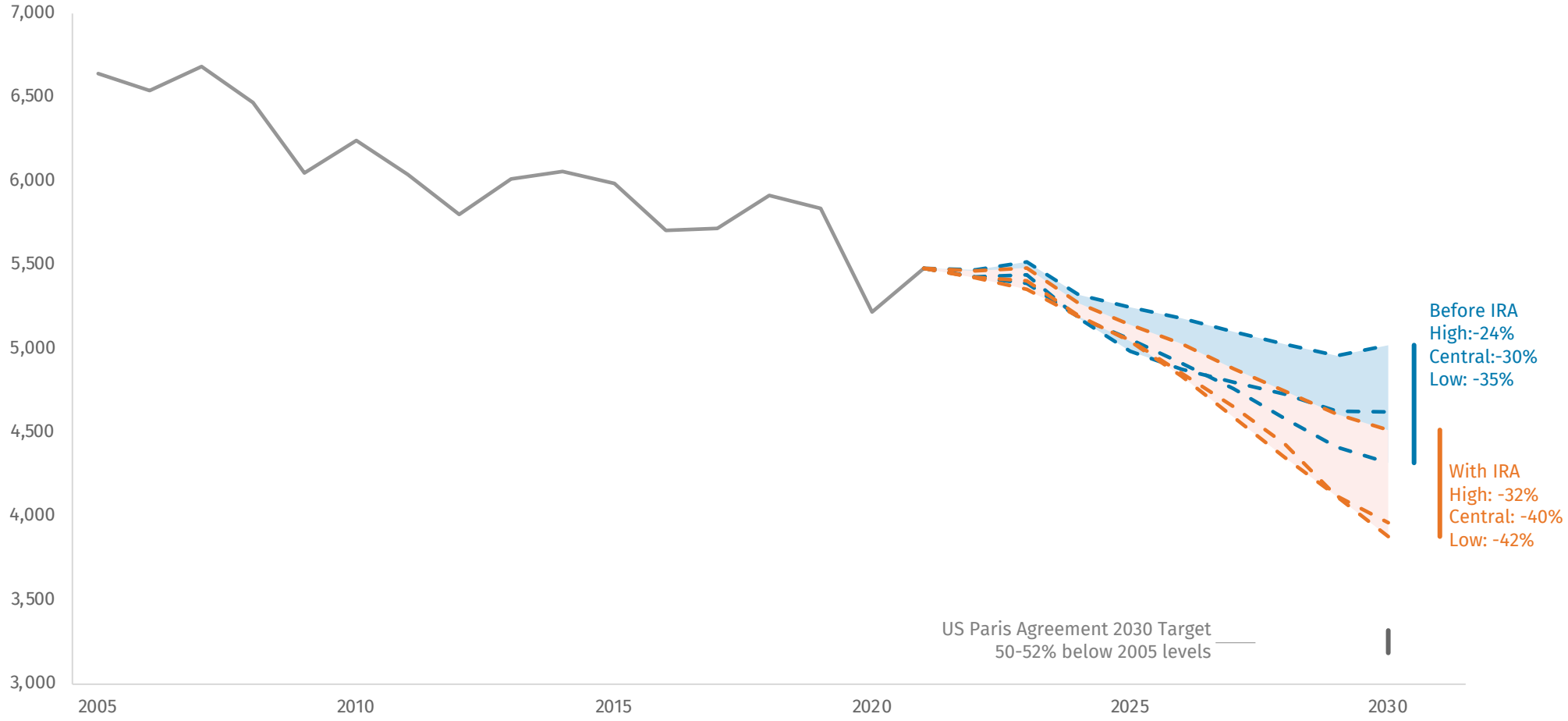
- We assess the impacts of the IRA by comparing emissions under our three core Taking Stock 2022 emissions scenarios, which reflect all policy on the books as of June 2022, with emissions under those same scenarios plus the IRA.
- To conduct this analysis, we used RHG-NEMS, a version of the Energy Information Administration's (EIA) National Energy Modeling System modified by Rhodium Group.

TS 2022 Main Scenarios	Low Emissions	Central	High Emissions
Natural gas & oil prices	High	Mid	Low
Clean technology costs	Low	Mid	High
Economic growth	Central	Central	High

Congress passed the IRA with an array of spending and tax credits for clean energy deployment the drives US emissions downward

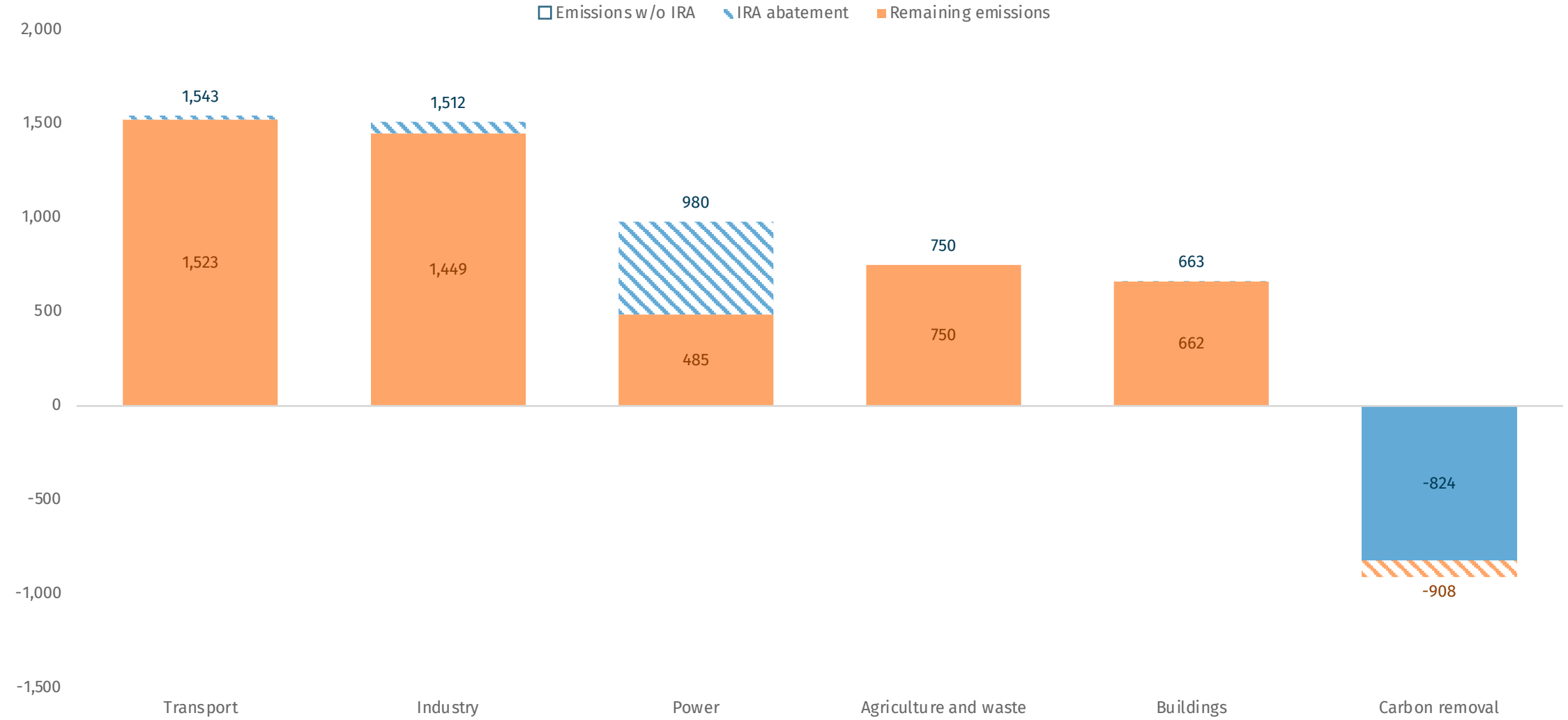
US net greenhouse gas emissions

Net million metric tons (mmt) of CO_2e



Where does the IRA drive down emissions? Primarily electric power

2030 GHG emissions (MMT CO_2e) with and without the IRA, central emissions scenario

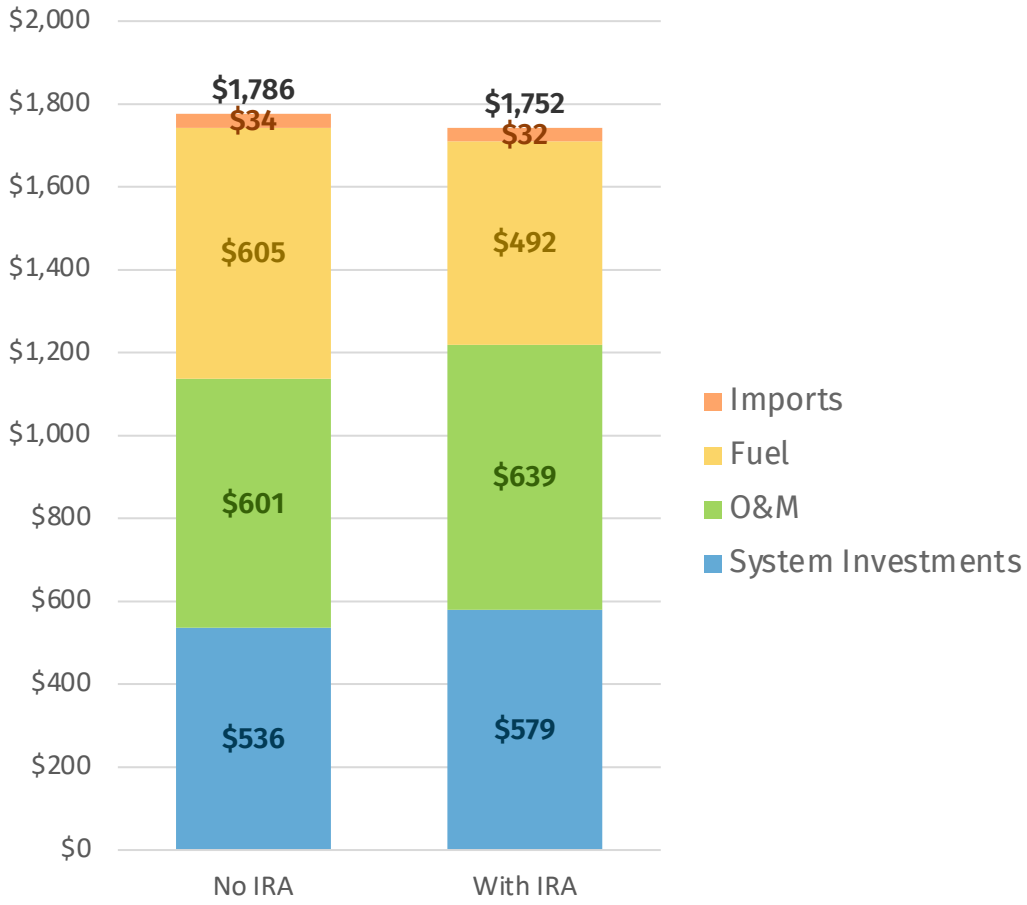


Source: Rhodium Group

The IRA shifts electric power investment and drives decarbonization

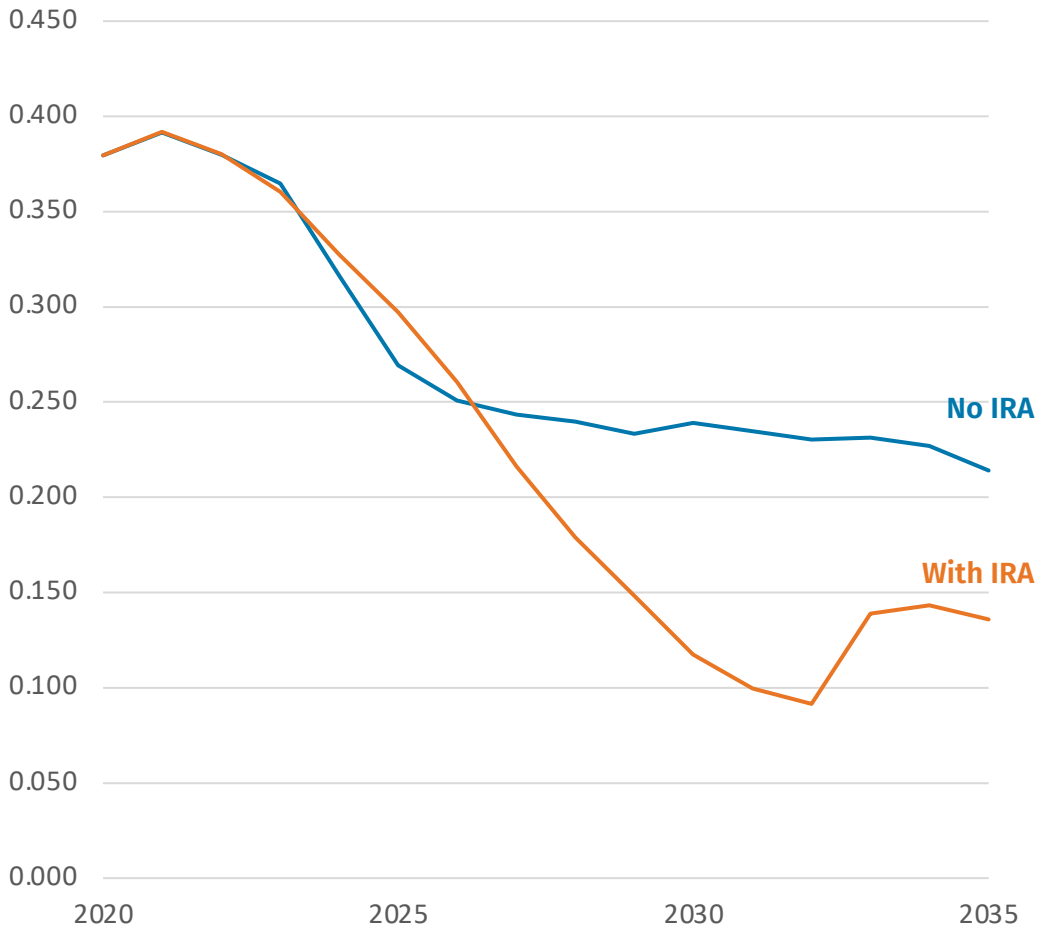
Cumulative electric power resource costs, 2023-2035

$2022 USD Billions



Electric Power CO_2 intensity, 2020-2035

Metric tons per Megawatt hour



Source: Rhodium Group.

Key takeaways

- Macroeconomic conditions and assumptions around future growth are the primary drive of GHG emissions trends.
- When policies are enacted to tackle climate change they primarily shift the carbon intensity of energy production and consumption all else being equal
- The scale of clean energy investment, while large on its own is small relative to the overall size of the US economy
- Clean energy investment may shift economic activity within the energy system but won't have a large aggregate impact on the macroeconomic trajectory of the US
- Plenty of room and a real need for more decarbonization over the coming decades

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Inflation Reduction Act and the Climate Transition

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The views expressed here are the views of the author and do not necessarily represent the views of the Federal Reserve Bank of Minneapolis or the Federal Reserve System

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Inflation Reduction Act subsidizes clean energy investment

- Clean electric power generation:
  - Investment tax credit and production tax credit
  - Uncapped, expiring only after emissions targets are reached
- Electric vehicles and residential appliances
- Carbon capture and clean fuels:
  - Larger financial incentives allowing for CO_2 capture
  - Tax credit for clean hydrogen

KEY QUESTIONS

1. What are the implications of IRA for energy markets?

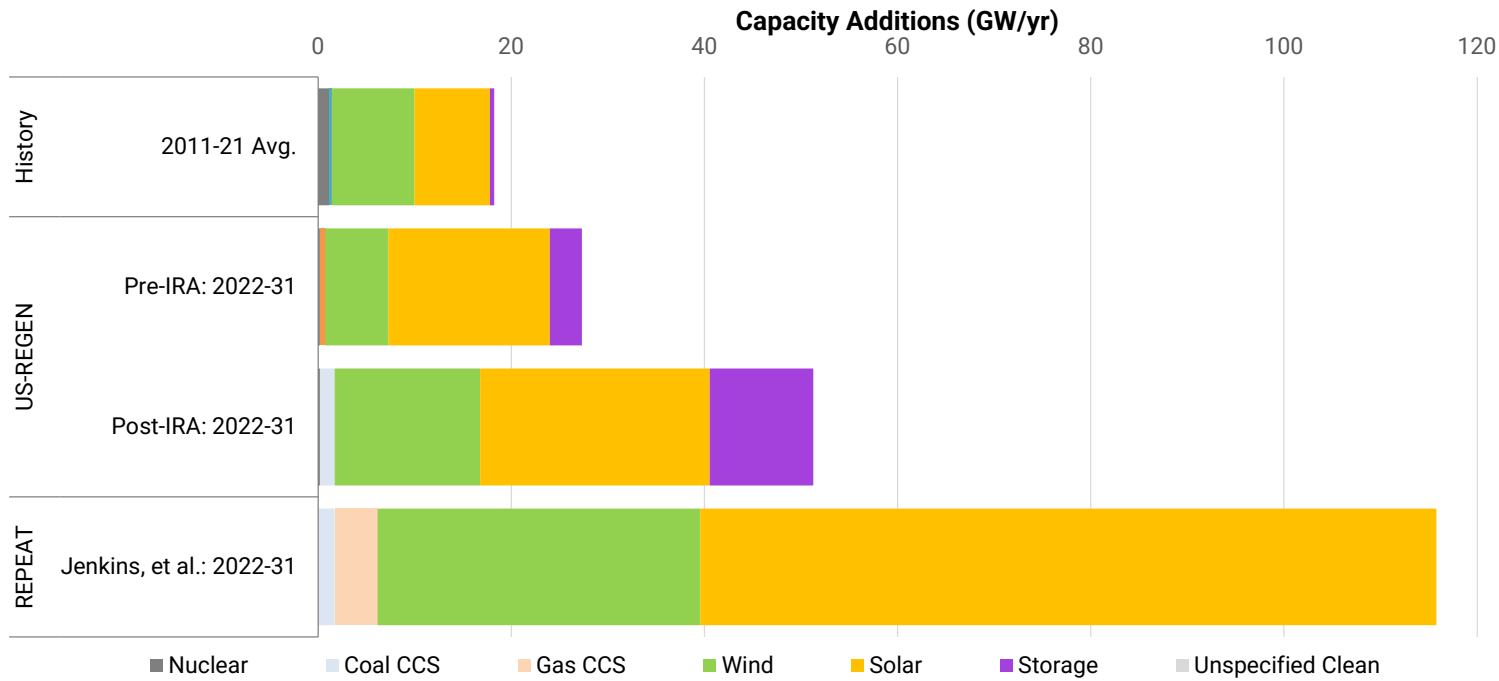
2. What are the macroeconomic implications of the climate provisions of IRA?

Energy market impacts

1. What are the implications of IRA for energy markets?
   - 50% increase in renewable power investment and sizable reduction in CO_2 emissions
   - Increased power generation capacity raises possibility of negative wholesale electricity prices
   - Significantly higher fiscal cost: $900 bn over 10 years
2. What are the macroeconomic implications of the climate provisions of IRA?

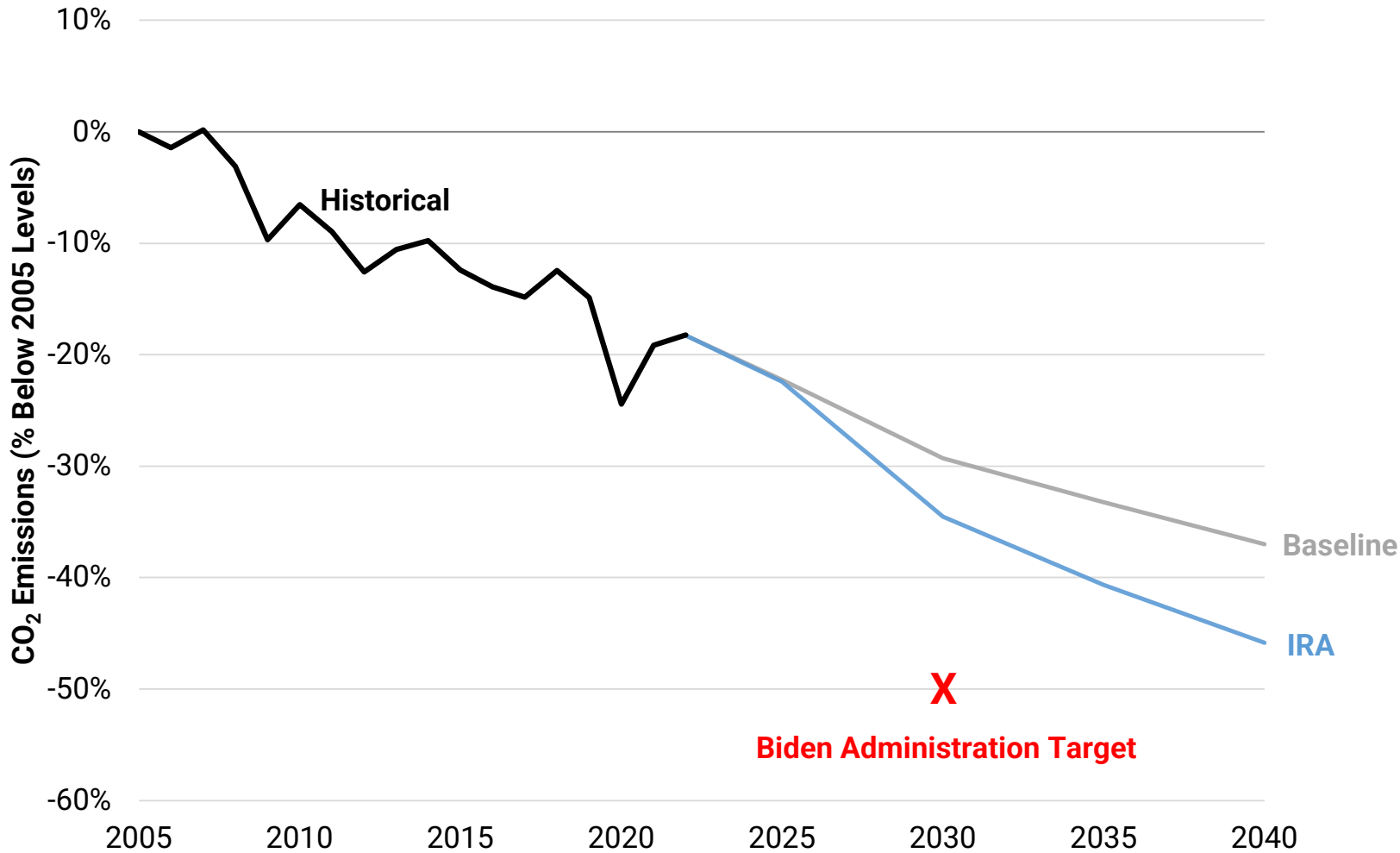
50% INCREASE IN CLEAN ENERGY INVESTMENT DUE TO IRA

- Large increases in new solar and wind projects over the next decade
- REGEN projection conservative relative to other modeling

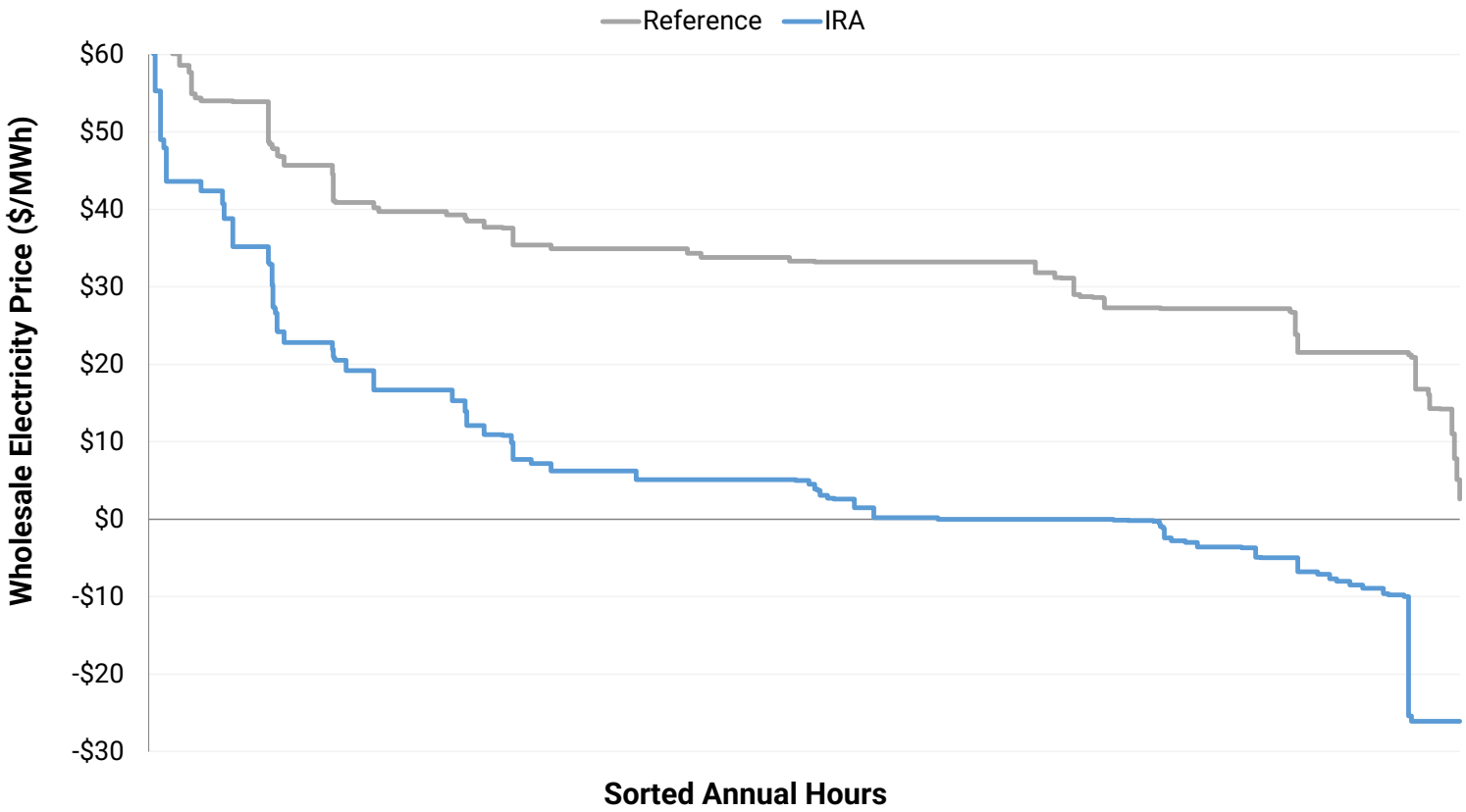


IRA LOWERS CARBON EMISSIONS BY 7 PP

EMISSIONS RELATIVE TO 2005 LEVELS



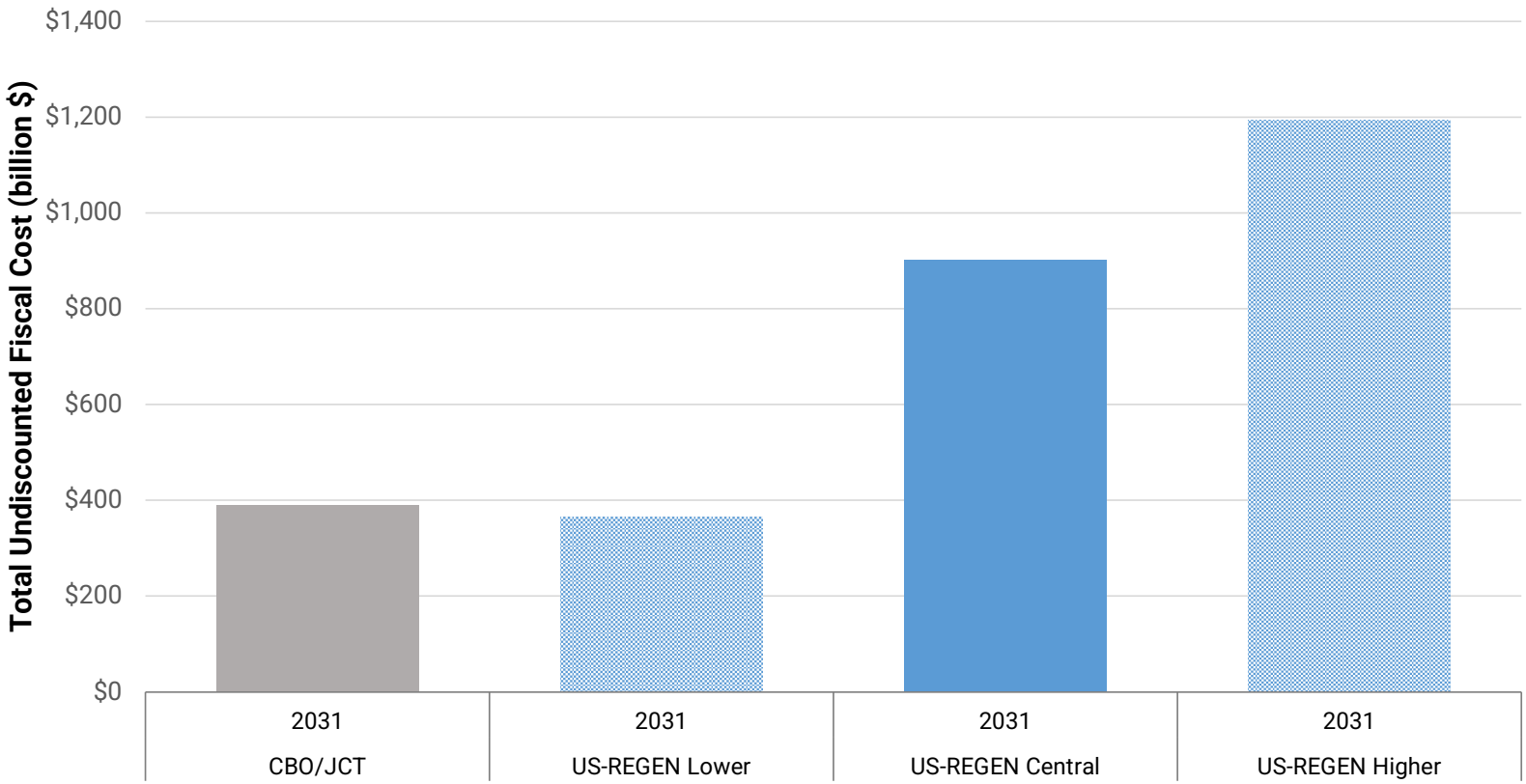
IRA RAISES POSSIBILITY OF NEGATIVE ELECTRICITY PRICES



- Wholesale price could turn negative up to 20% of hours
- More modest projected declines in retail prices of 2.2% by 2030

Projections of higher fiscal cost

Comparison of REGEN and JCT/CBO score



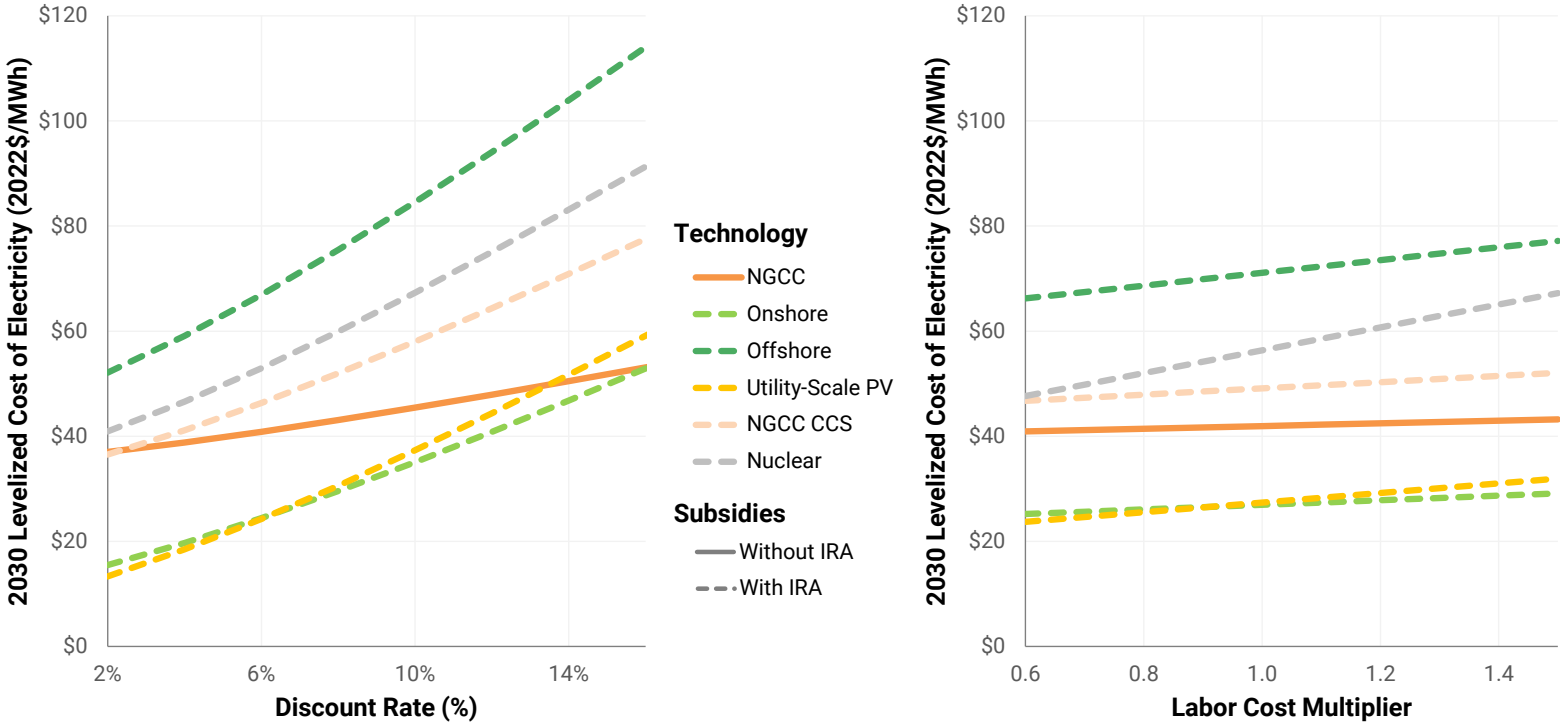
Macroeconomic impacts

1. What are the implications of IRA for energy markets?

2. What are the macroeconomic implications of the climate provisions of IRA?

   - Long-run supply-side benefits through lower electricity prices
   - Short-run increases in nonresidential investment that boost demand/raise rates
   - Macroeconomic environment post-pandemic may be less favorable to climate investment

Higher rates negatively impact clean energy generation



- LCOE for clean energy more sensitive to changes in interest rates
- Large construction cost increases over pandemic: structures up 20%, power plant equipment up 13% and transmission up 27%

TRANSITION IMPACTS ARE LIKELY MODEST

	Nominal, 2018-2022 averages		REGEN IRA impact, 10-year avg
	$ billions	% of GDP	$ bn (2022)
Electric power structures	79	0.4	21
Electrical transmission and distribution	52	0.2	7

- Substantial structures investment but modest in aggregate
- FRB/US finds demand effects result in small increases in output, employment, core inflation initially
- Important limitations to FRB/US modeling:
  - Does not include upstream investment effects (i.e. investments in clean energy supply chain)
  - Combined effects of IIJA, IRA, and CHIPs Act

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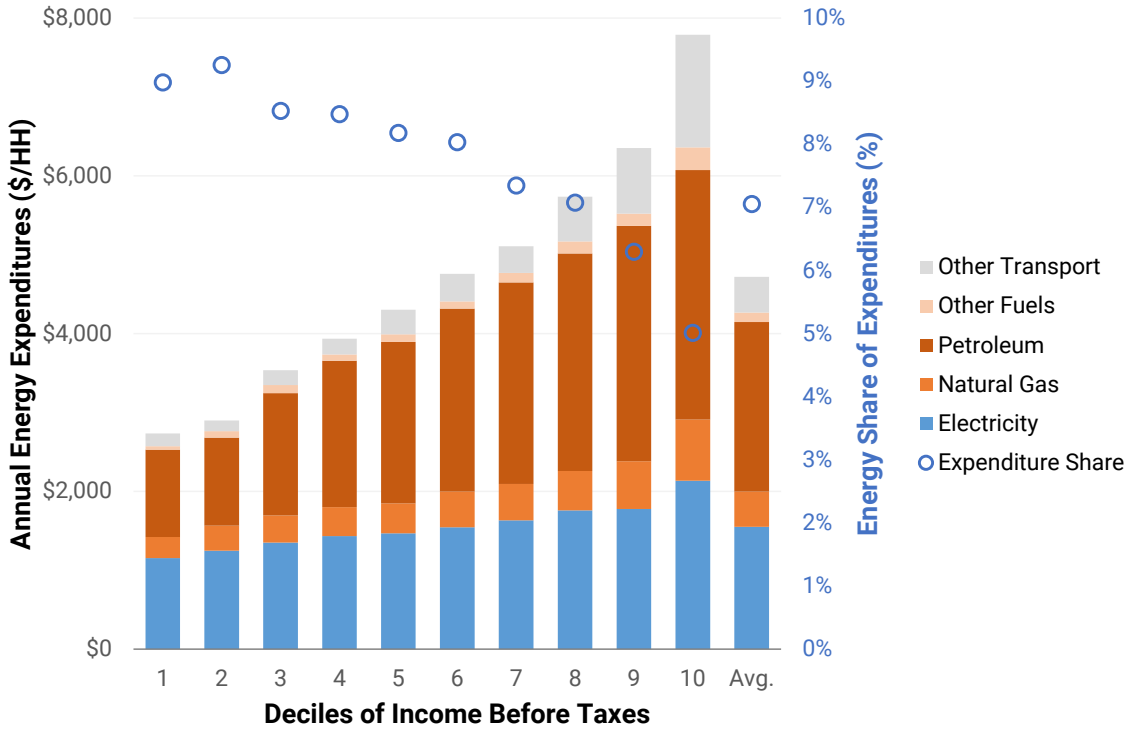
KEY TAKEAWAYS

1. What are the implications of IRA for energy markets?
   - 50% increase in renewable power generation and 6-11 pp decline in carbon emissions
   - Fiscal costs estimated around $1 trillion over 10 years
   - Possibility of very low or negative wholesale electricity prices
2. What are the macroeconomic implications of the climate provisions of IRA?
   - Increases in investment demand may rates interest rates or inflation
   - Macroeconomic environment post-pandemic may be less favorable to climate investment

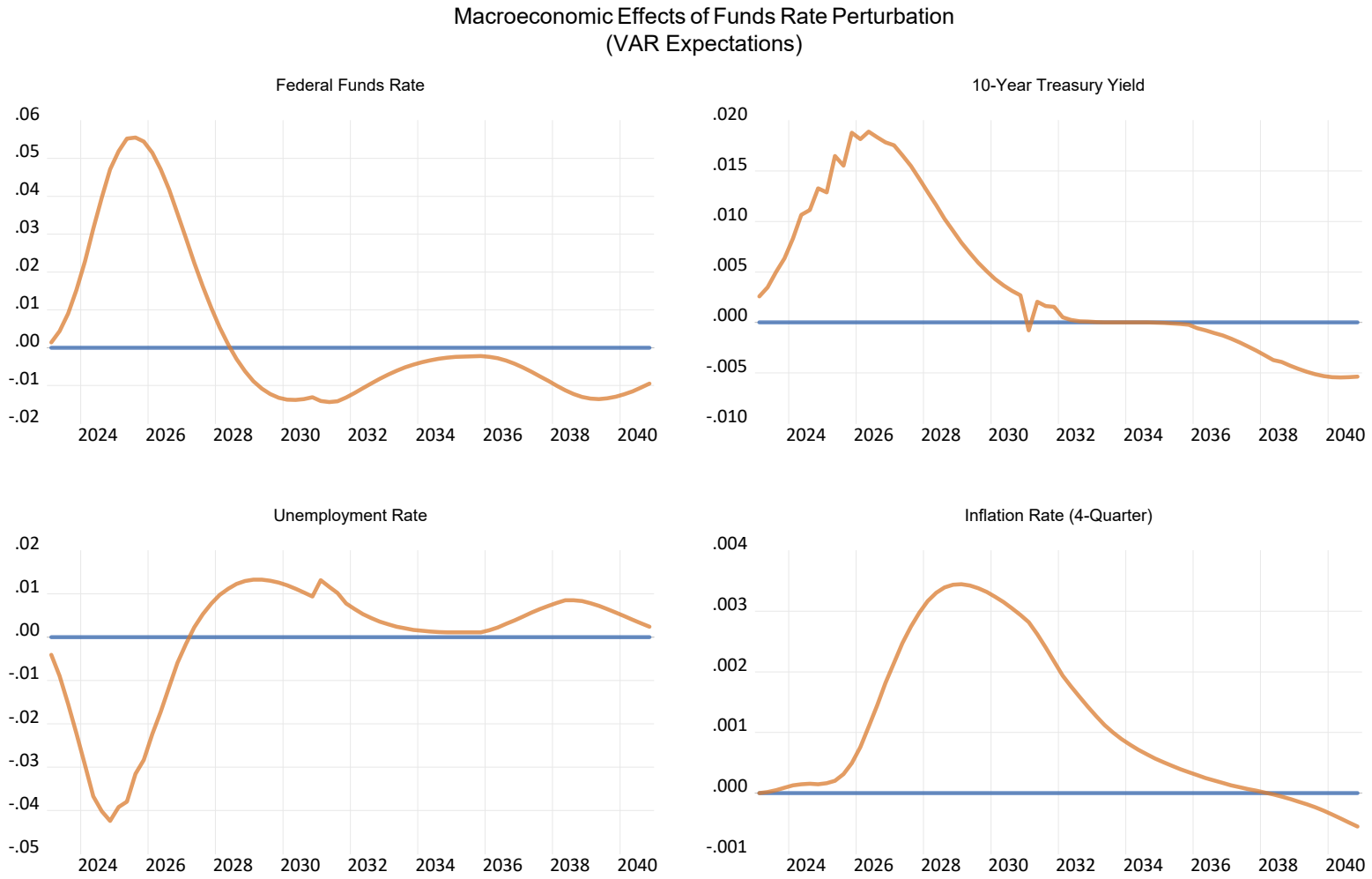
Additional Slides

TAX V. SUBSIDY DISTRIBUTIONAL CONSIDERATIONS



- Concerns that carbon tax disproportionately impacts poorer households
- A carbon tax/dividend welfare improving for bottom half if energy consumption increasing in absolute terms

SMALL MACROECONOMIC IMPACTS IN FRB/US



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Carbon tax delivers lower abatement costs

Metric (units)	2021	IRA Scenario 2030	IRA Scenario 2035	CO_2 Equivalent 2030	CO_2 Equivalent 2035	Difference (p.p.) 2030	Difference (p.p.) 2035
Generation Share (%)							
Coal	22%	11%	8%	7%	4%	-4%	-5%
Coal CCS	0%	3%	3%	0%	0%	-3%	-3%
Gas	39%	20%	18%	35%	34%	15%	17%
Gas CCS	0%	0%	0%	0%	0%	0%	0%
Other	2%	9%	11%	7%	8%	-2%	-3%
Nuclear	19%	17%	14%	17%	16%	0%	2%
Hydro	6%	6%	6%	6%	6%	0%	0%
Wind and Solar	13%	33%	41%	28%	32%	-6%	-9%
CO_2 Emissions (% Reduction from 2005)	35%	64%	68%	64%	68%	0%	0%
Generation Price ($/MWh)	N/A	$56	$52	$65	$62	16%	20%
Abatement Cost ($/t-$CO_2$)	N/A	N/A	N/A	$12	$15	N/A	N/A

Back