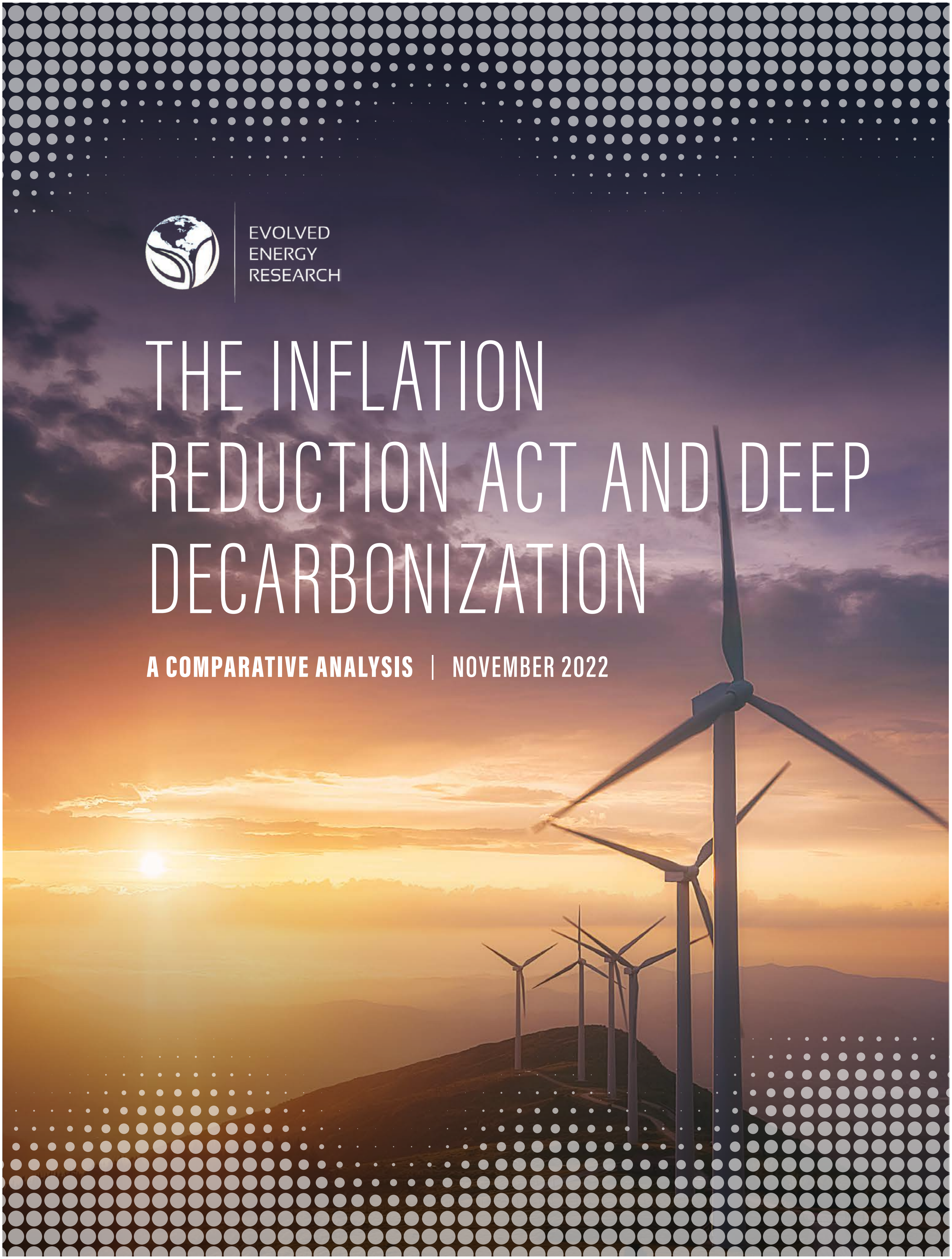

EVOLVED ENERGY RESEARCH

THE INFLATION REDUCTION ACT AND DEEP DECARBONIZATION

A COMPARATIVE ANALYSIS | NOVEMBER 2022

ABOUT THIS STUDY

Breakthrough Energy Foundation supported the 2022 U.S. Annual Decarbonization Perspective and this accompanying white paper

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EVOLVED ENERGY RESEARCH

ABOUT EVOLVED ENERGY RESEARCH

Evolved Energy Research (EER) is a research and consulting firm focused on questions posed by transformation of the energy economy. Their consulting work and insight, supported by sophisticated technical analyses of energy systems, are designed to support strategic decision-making for policymakers, stakeholders, utilities, investors, and technology companies. They have developed models to simulate and optimize economy-wide energy systems, bulk power systems operations, and utility distribution systems.

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I INTRODUCTION

Evolved Energy Research (EER) released its 2022 U.S. Annual Decarbonization Perspective (ADP) August 17, the day after President Biden signed The Inflation Reduction Act (IRA). Given the timing of the bill's passage, its provisions were not included in the analysis. This study is intended to act as a supplement to the 2022 ADP and contextualize the role of the IRA—the most expansive climate legislation in U.S. history—in the country's progress along a net-zero pathway.

II STUDY DESIGN

Key Study Questions

This study is intended to answer three key questions that remained unanswered in the original analysis.

1. **Where are the gaps in deep decarbonization not adequately supported by the IRA?**
2. **What are the opportunities for regulatory policy, state policy, and technology progress to address those gaps?**
3. **Does the relative weight of policy ambition in the IRA (clean electricity, hydrogen, carbon capture, etc.) change the optimal decarbonization strategy in the long-term?**

IRA provisions modeled

Prior to the passage of the IRA, EER participated in a multi-year effort to model potential climate and clean energy policy packages. Most recently, EER did so as a member of the Rapid Energy Policy Evaluation and Analysis Toolkit (REPEAT) project at the Princeton University Zero Lab. Our work on that project focused on developing methodologies for representing the emissions reductions of the many policy provisions in the IRA. This analysis leverages that work in mapping the policy impacts from the REPEAT project for things like vehicle adoption, land sector, and methane impact all while using EER assumptions for things like technology cost and availability, fuel costs, etc. This representation of the IRA can now be considered the new Reference Case for our U.S. energy modeling.

Scenarios

To answer the key study questions, three scenarios were run to isolate the impact of the IRA in the context of a net-zero pathway. The following table names, describes and motivates each of the three scenarios.

TABLE 1. Scenarios

Scenario	Description	Purpose
IRA	This is EER's representation of IRA provisions including demand-side programs, non-energy reductions, land sink contributions, and tax credits.	Illustrate the U.S.'s emissions trajectory after passage of the IRA
Central	This is the pre-IRA least-cost pathway for achieving net-zero greenhouse gas emissions by 2050 in the U.S. It is economy-wide and includes energy and industrial CO_2, non-CO_2 GHGs, and the land CO_2 sink. It is built using a high electrification demand-side case, and on the supply-side has the fewest constraints on technologies and resources available for decarbonization.	Illustrate the trajectory necessary to achieve the 2030 NDC target and 2050 net-zero economy-wide target on a purely cost-optimized basis.
Central + IRA	This is the Central scenario that also includes a representation of the IRA, which accelerates and privileges certain technology deployments based on IRA provisions (tax credit etc.). It is the optimal pathway from the perspective of energy consumers given government programs and incentives.	Illustrate the impact that provisions in the IRA have on the optimal trajectory.

III RESULTS

As a general principle, we would note that most models are too optimistic in near-term and pessimistic in the long-term. Near-term supply chain impacts, bottlenecks, and increased technology prices may hinder deployment of key technologies before 2030. However, in the long-term, induced technological learning from the IRA may make much larger impacts than modeled here. It is difficult to assess market transformation impacts generally and even more challenging to account for more limited or indirect funding vehicles in building electrification, advanced manufacturing, and R&D activities. This analysis also doesn't capture increased state policy and corporate ambition that accompanies technology demonstration and cost declines. It is possible that near-term constraints could limit the emissions impact of the IRA in the next 5-10 years more than our modeling suggests. It would be a mistake to assume that such an outcome must be the result of insufficient policy ambition. Rather, it is more likely that accelerating decarbonization was always going to reveal these sorts of systemic implementation challenges.

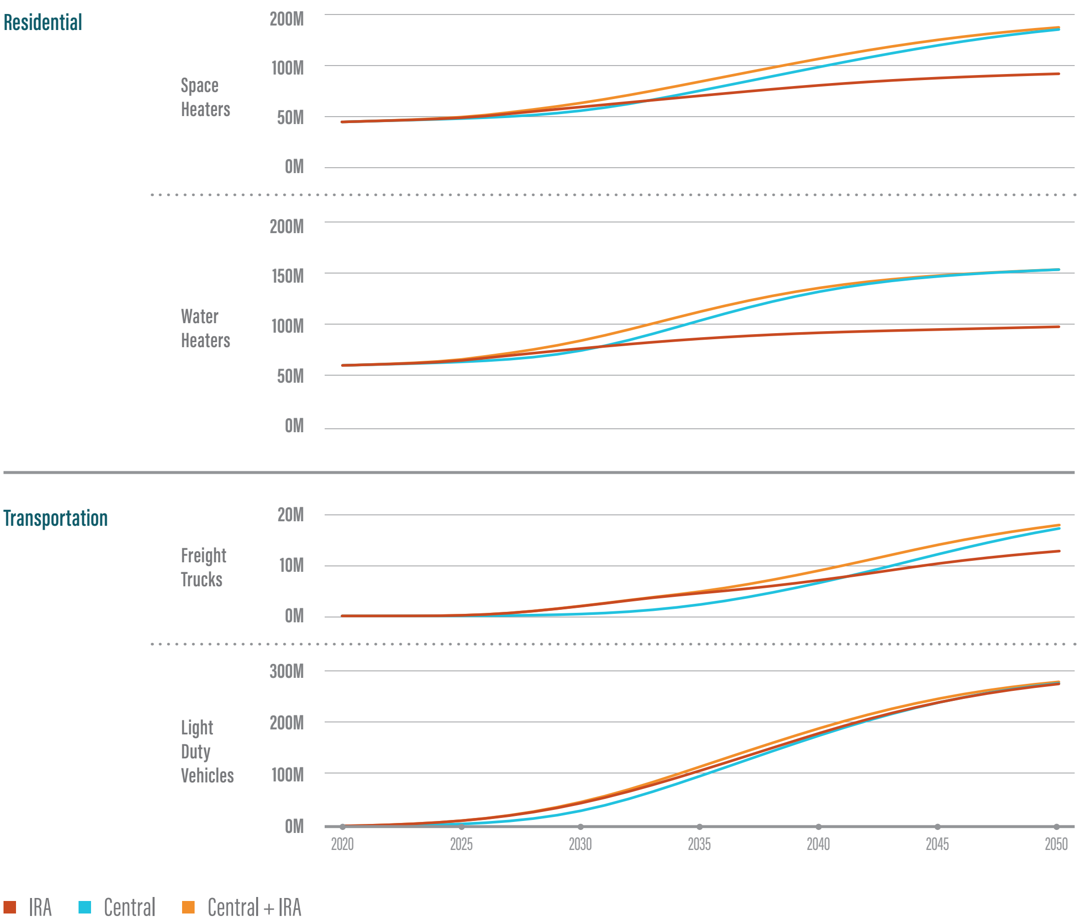
Energy Demand

Impacts to energy demand are a result of the assumed induced consumer behavior, given incentives. In the IRA, specifically in transportation, these are in the form of generous upfront tax credits. Transportation tax credits are not exhaustible and so have a significant impact in terms of overall adoption. Funding pools for building measures are more limited; while they have an impact in the near-term, they are quickly exhausted and so their impact is somewhat transient.

In the figure below, we show the number of key zero-emission (electric or fuel cell) technologies in service (representative of equipment stocks, not sales) in the three scenarios. In residential space and water heating, the IRA accelerates deployment early but flattens quickly and results in only a modest increase in overall electrification. In freight trucks, the IRA results in significant deployment not seen in the **Central** scenario. However, in the long-term, the expiration of IRA provisions means that there remain a significant number of diesel freight trucks remaining in service in the long-term. In light-duty vehicles, **IRA** scenario adoption rates are very close to those in our **Central** scenario and that the high adoption rates through 2035 result in effectively the displacement of all new ICE vehicle sales by 2035.

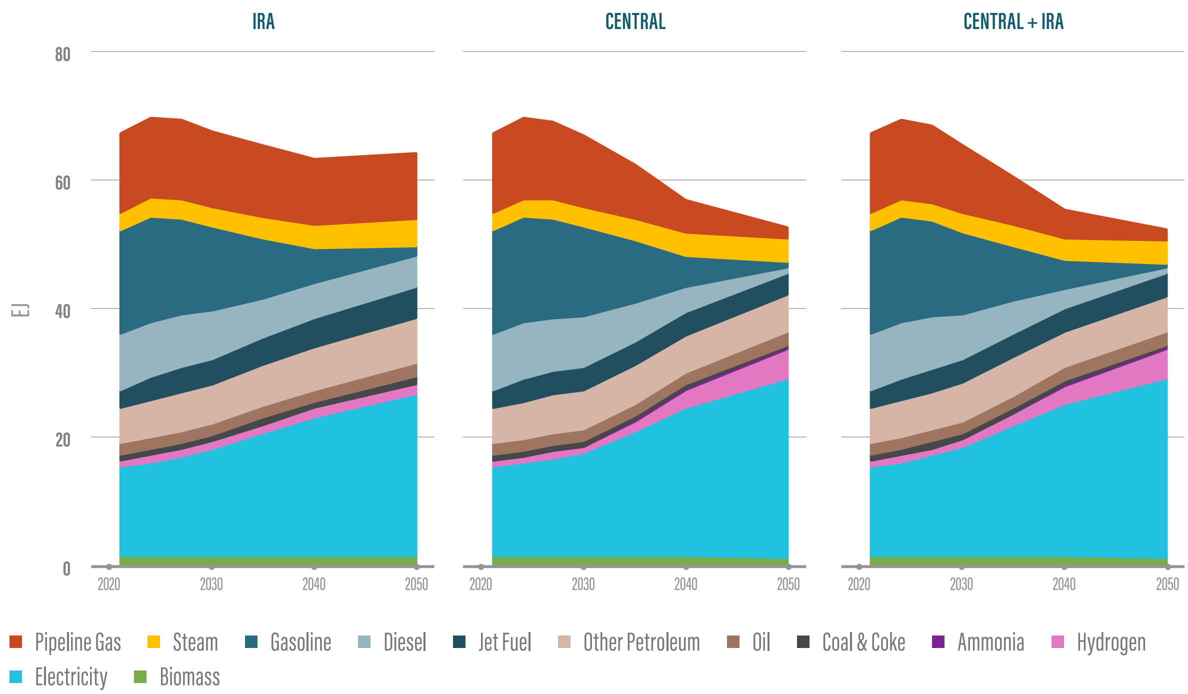
FIGURE 1.

Key zero-emission equipment stocks



The resulting energy demand across the economy is shown in Figure 2. The largest differences are in pipeline gas, where limited transformation in buildings and industry in the **IRA** scenario result in generally flat demand for pipeline gas (and reduced growth in electricity and hydrogen demand). Transformation of the transportation sector does result in significant electricity demand growth in the long-term.

FIGURE 2.
Final Energy Demand

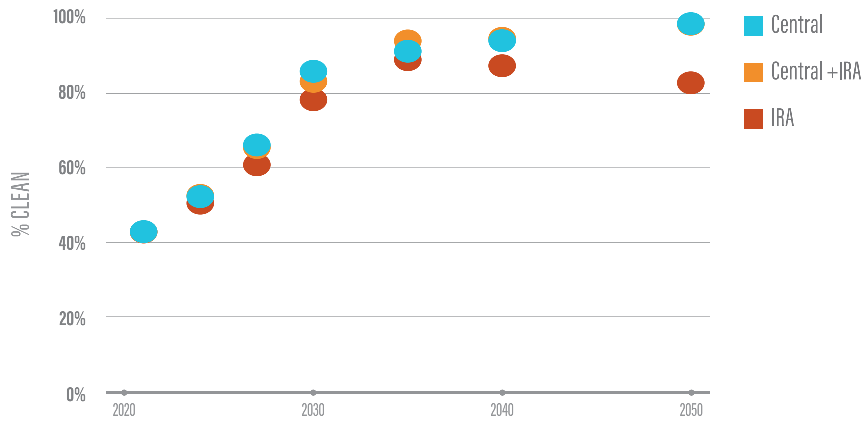


Electricity Sector

Some of the IRA's strongest provisions are in the electric sector in the form of investment and production tax credits. This subsidy increases the competitiveness of clean-electricity generation against new fossil resources and existing operations of existing fossil resources. The generation mix given these subsidies shows a rapid decarbonization, with the progress in clean electricity approaching the trajectory of the **Central** scenario.

FIGURE 3.

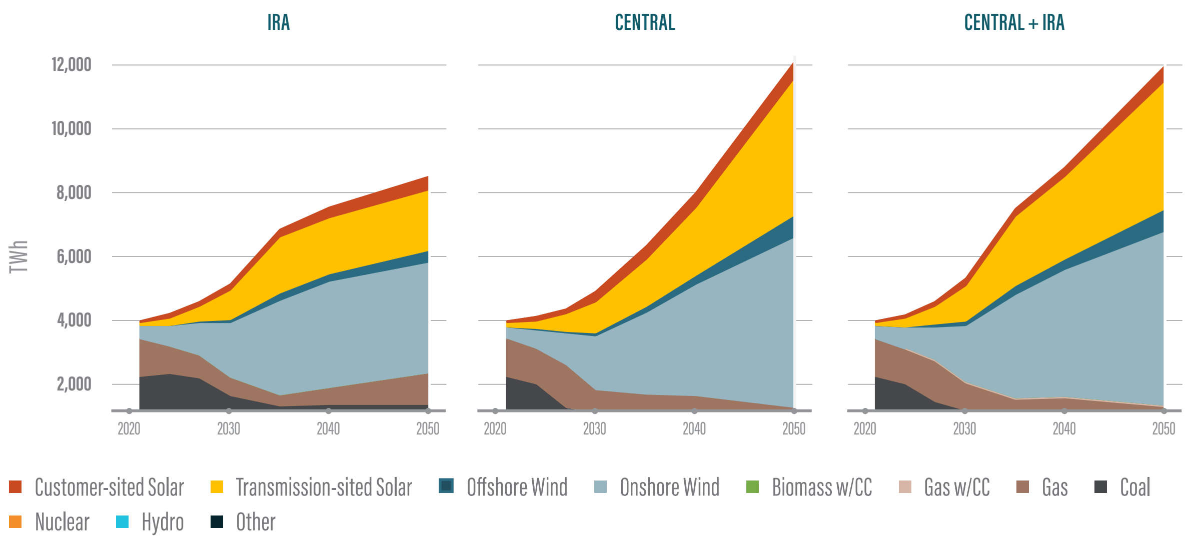
Clean Electricity Share (generation)



The generation mix in terms of clean electricity resources in the **IRA** scenario is reflective of the **Central** scenario, with the technology-agnostic tax credits serving to maintain their relative competitive positions against each other. The largest difference is in the residual fossil share. In our **Central** and **Central + IRA** scenarios, the carbon price (resulting from the emissions cap) results in the rapid retirement of coal generation. In the **IRA** scenario, both gas and coal are displaced, but we don't see the retirement of all coal generation in the 2030 timeframe[1]. This is reflective of the fact that the **IRA** doesn't directly regulate or incentivize emissions.

FIGURE 4.

Generation Mix



1 This IRA scenario does not include potential additional coal plant retirements incented by the Section 1706 loan program.

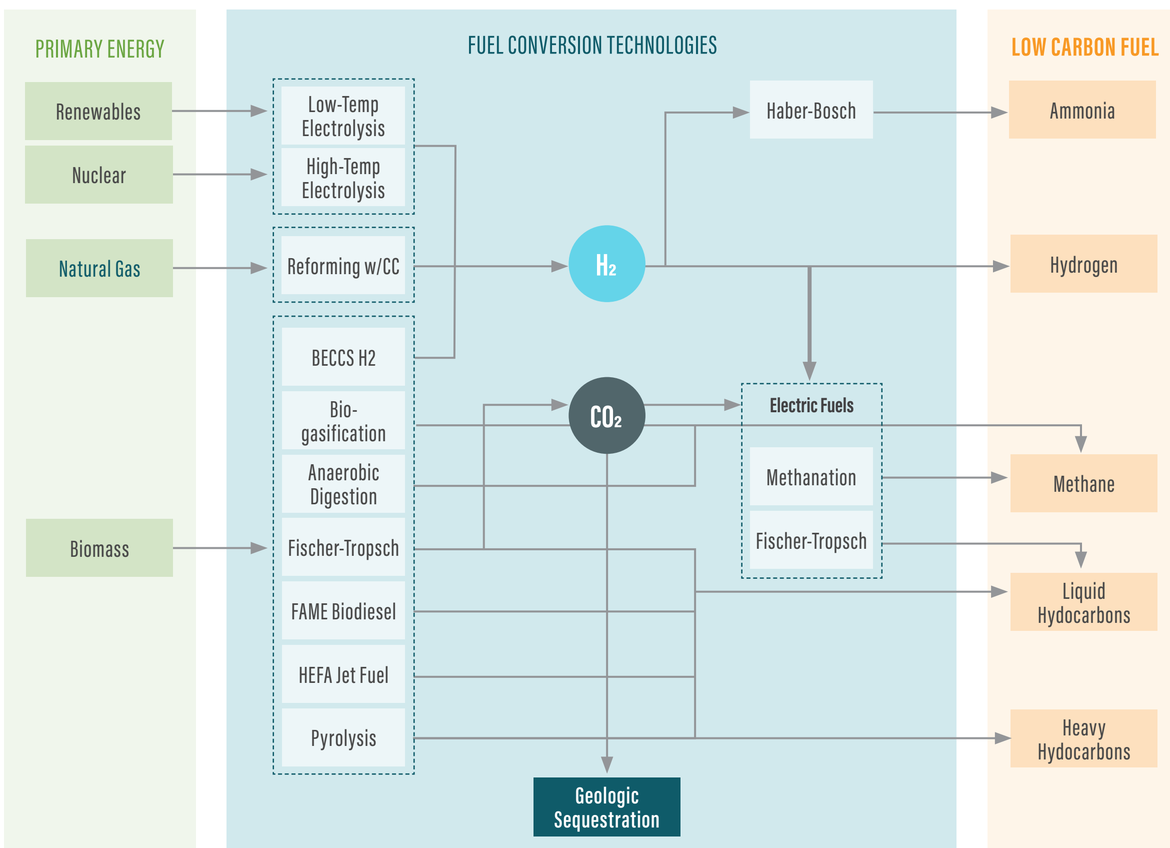
Post-2035, with the expiration of clean electricity tax credits, there is a significant slow-down of clean electricity deployment. As electrification of the transportation sector increases, much of this load is met by additional fossil generation.

Hydrogen and Clean Fuels

One of the most incented areas of the deep decarbonization transition is clean fuels, specifically, hydrogen. Hydrogen's direct customer use or use in a feedstock (synthetic hydrocarbon fuel, ammonia, etc.) benefits from subsidies that reduce the cost of energy inputs (clean electricity tax credits), receive direct production tax credits, and receive lower-cost captured carbon via additional incentives, making the production of synthetic hydrocarbons more attractive.

FIGURE 5.

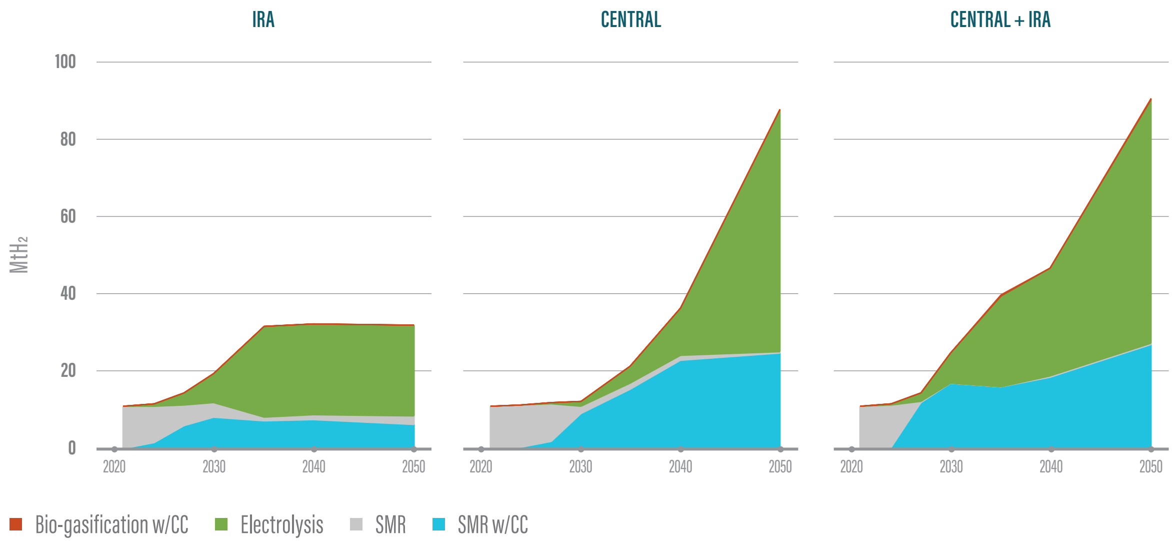
Low-Carbon Fuel Production Pathways



This combination of subsidies is enough to accelerate the deployment of clean hydrogen ahead of what is shown by the optimal pathway in the **Central** scenario.

FIGURE 6.

Hydrogen Production



This acceleration doesn't necessarily represent significant additional emissions reductions if, in a supply-chain constrained environment, deployment of clean electricity goes to produce hydrogen rather than displace fossil fuels on the grid. However, if supply-chains are unconstrained, accelerated hydrogen deployment should increase overall clean energy deployment because electrolyzer load must be met with clean electricity and will reduce emissions in this case by displacing grey hydrogen from steam methane reforming without carbon capture. The accelerated deployment does represent a need to develop low-carbon hydrogen technologies earlier than we saw in the **Central** scenario.

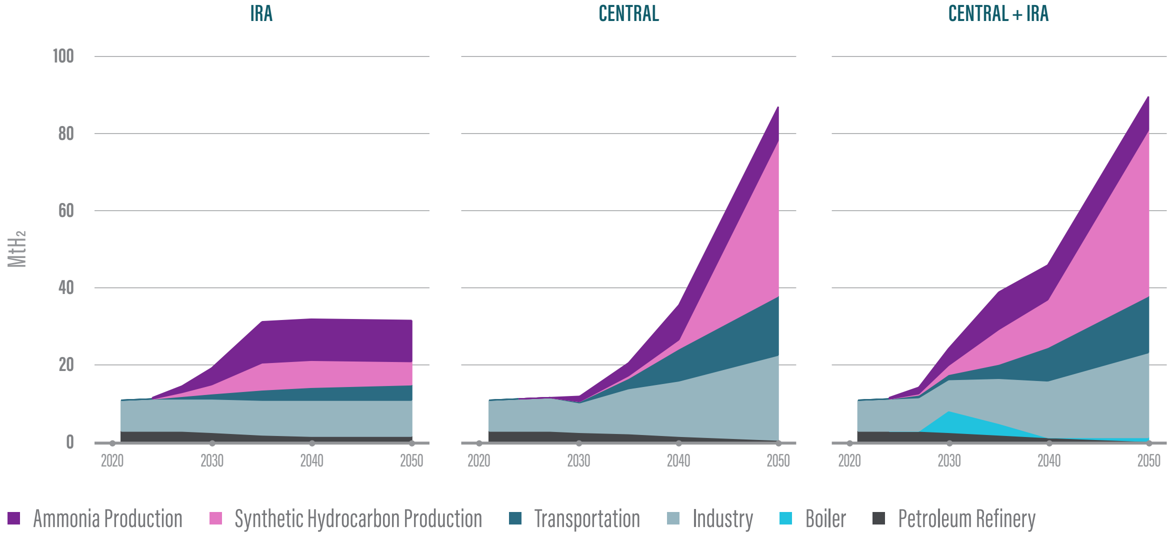
In the **IRA** scenario, this hydrogen has four principal uses:

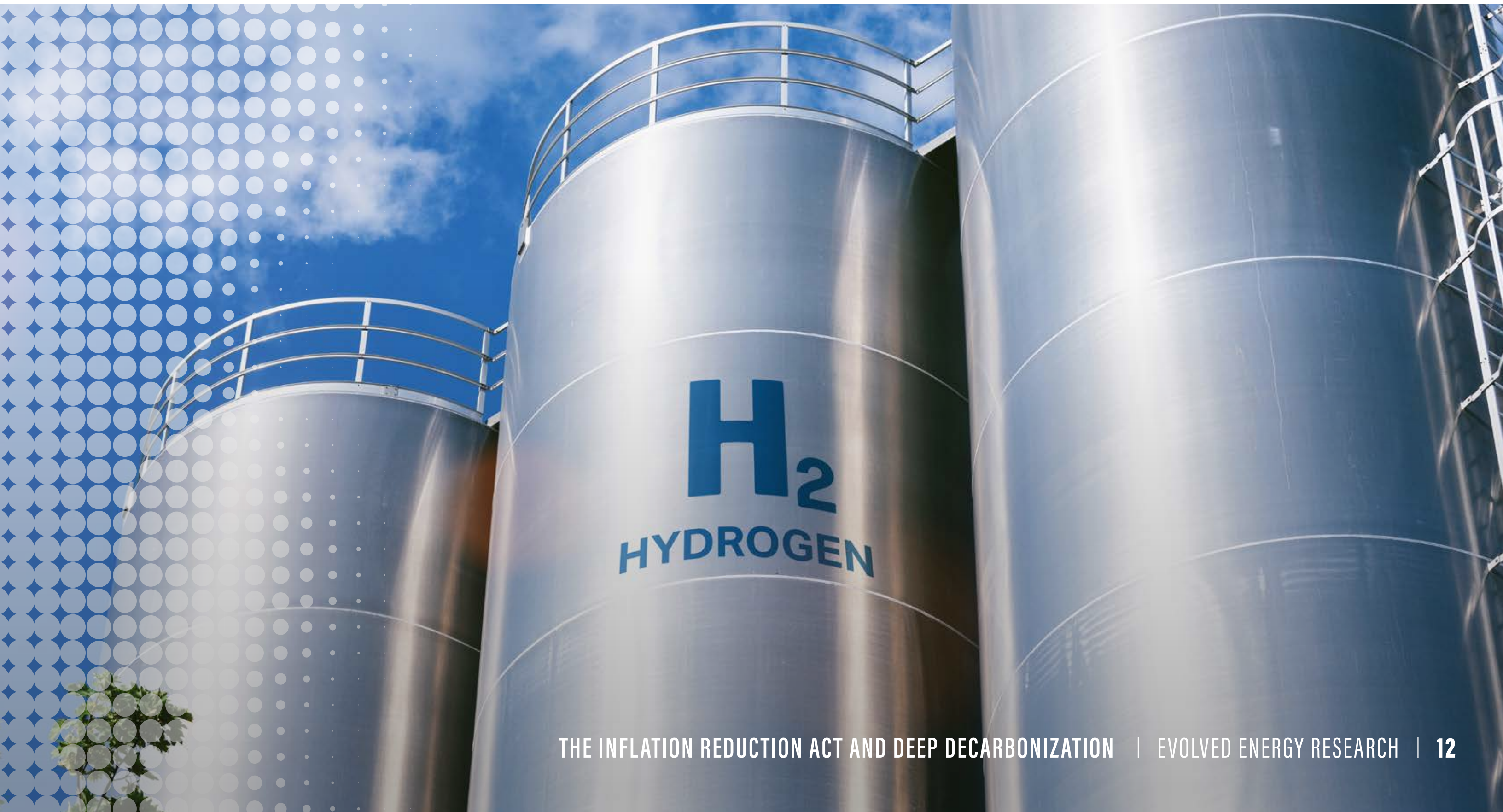
1. Fueling hydrogen fuel cell trucks that have been incented with vehicle tax credits
2. Displacing current hydrogen demand in petroleum refineries
3. Displacing current hydrogen demand in the bulk chemicals industry
4. As a feedstock for additional zero-carbon fuel production in the form of synthetic hydrocarbons and ammonia

This pattern of usage is similar to what we see in the **Central** scenario, though somewhat accelerated from the 2040 to the 2030 timeframe. In the long-term, additional demand for hydrogen is seen in industrial process heating that is insufficiently incented by the IRA. Additionally, the scale of zero-carbon fuels, specifically synthetic hydrocarbons, grows significantly past the point reached by the **IRA** scenario.

FIGURE 7.

Hydrogen Utilization



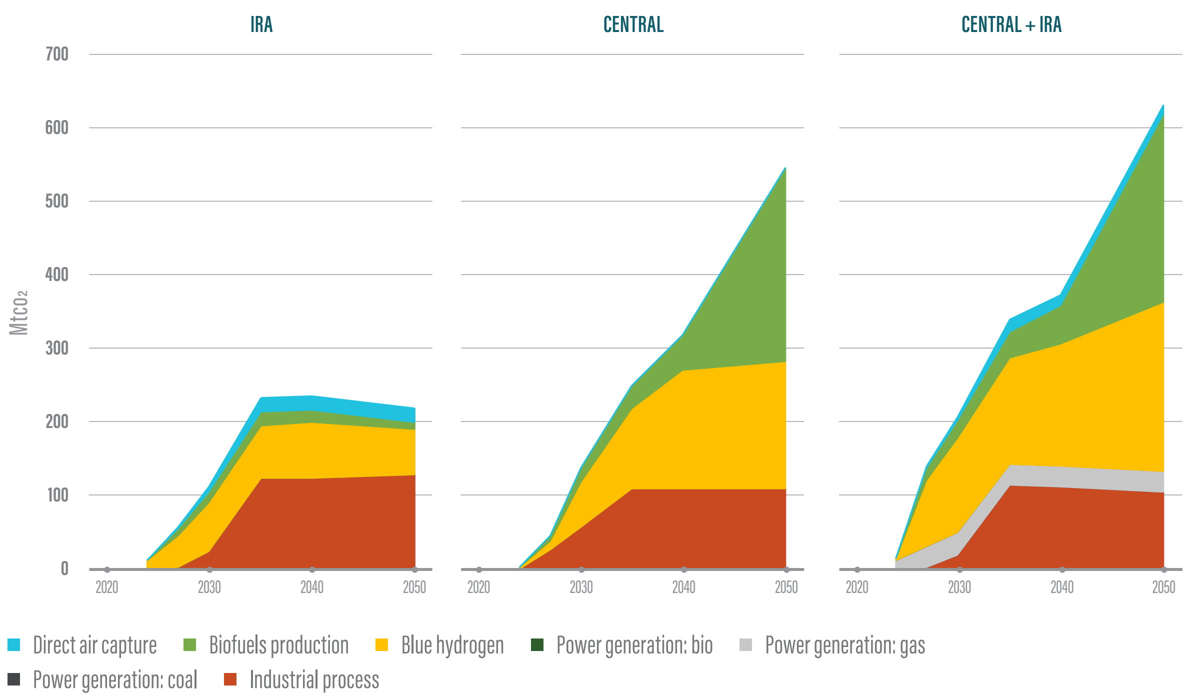


Carbon Management

45Q tax credits represent a significant opportunity to develop carbon capture in the **IRA** scenario across a variety of sources including cement, iron and steel, blue hydrogen, and direct air capture. This generally reflects the pattern we see in the **Central** scenario, with the exception of direct air capture, which we see in many scenarios in ADP 2022, but not in the **Central** scenario. In the **Central** scenario, we do see a large amount of carbon capture from biofuels. The **IRA** scenario, however, has relatively limited support for biofuels and thus sees limited deployment outside of retrofitting existing corn ethanol plants. In the **Central + IRA** scenario, we see deployment of gas with carbon capture that we don't see in the other scenarios, with the value of 45Q in conjunction with an emissions cap being enough to incent deployment.

FIGURE 8.

Captured carbon by source

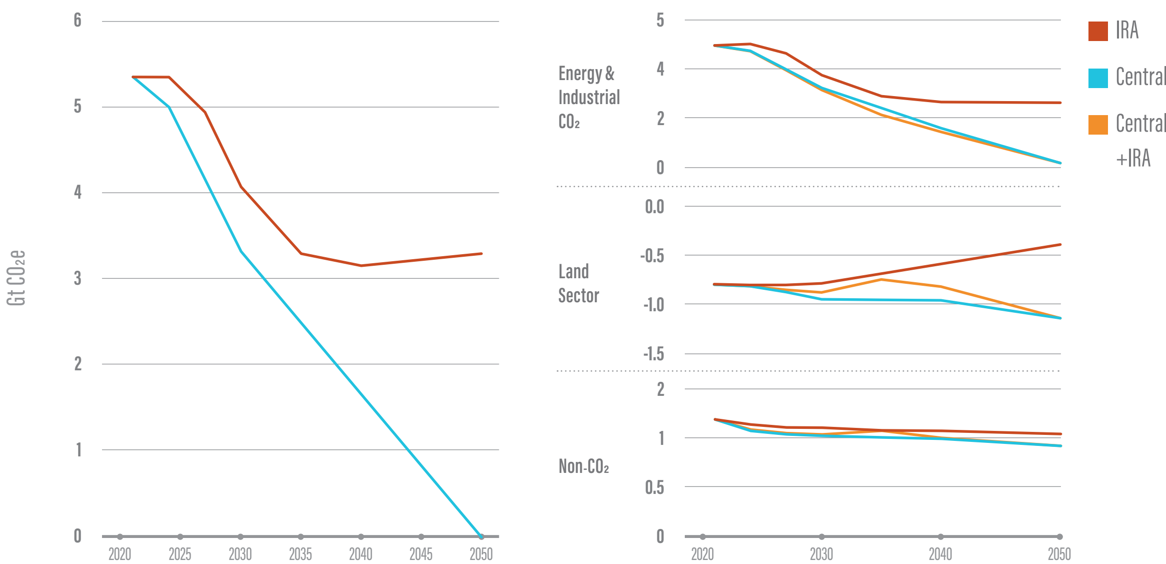


Emissions

The combination of activities incented by the **IRA** results in significant emissions reductions across the economy. However, the **IRA** does not maintain the pace of reductions past 2035 and also falls short of 2030 targets set out in the NDC (50% reduction from 2005 levels). When the IRA provisions expire, there is a plateau in total emissions though 2050 at approximately 50% of today's emissions. The total gap in 2030 between the NDC target and the **IRA** scenario is 700 MMt CO_2e. Another interpretation of this gap is temporal, with progress through 2035 achieving the 2030 NDC target, meaning that there is a 5-year gap between the target date and the anticipated date of achievement.

FIGURE 9.

Emissions trajectories



Four Pillars of Decarbonization

Another way to gauge progress and consistency with optimal trajectories is through an assessment of the progress the **IRA** represents towards achieving the four pillars of deep decarbonization: electricity decarbonization; end-use electrification; energy efficiency; and carbon capture. We take snapshots of that progress in both 2035 (when many of the IRA provisions have the greatest impact) and 2050.

In 2035, there is strong progress made across the Four Pillars in the **IRA** scenario, though it slightly lags benchmarks set by the **Central** scenario. By 2050, as the emissions gap widens, there is a clear need to supplement the IRA with additional support, as electricity emissions go up, the efficiency gap widens, carbon capture actually declines to 2050, and electrification, while it continues to transform the transportation sector, fails to reach buildings and industry.

FIGURE 10.

2035 Four Pillars comparison

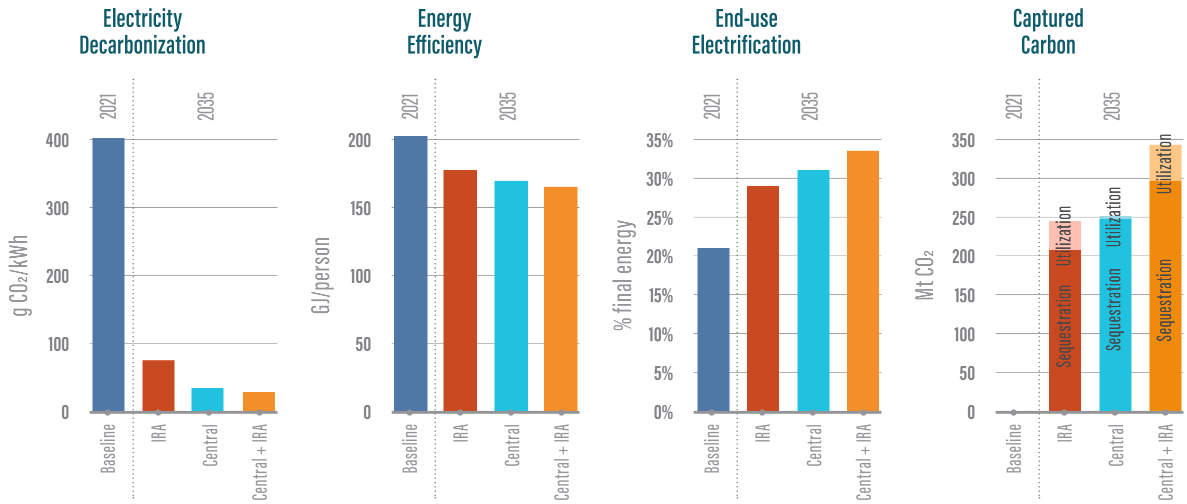
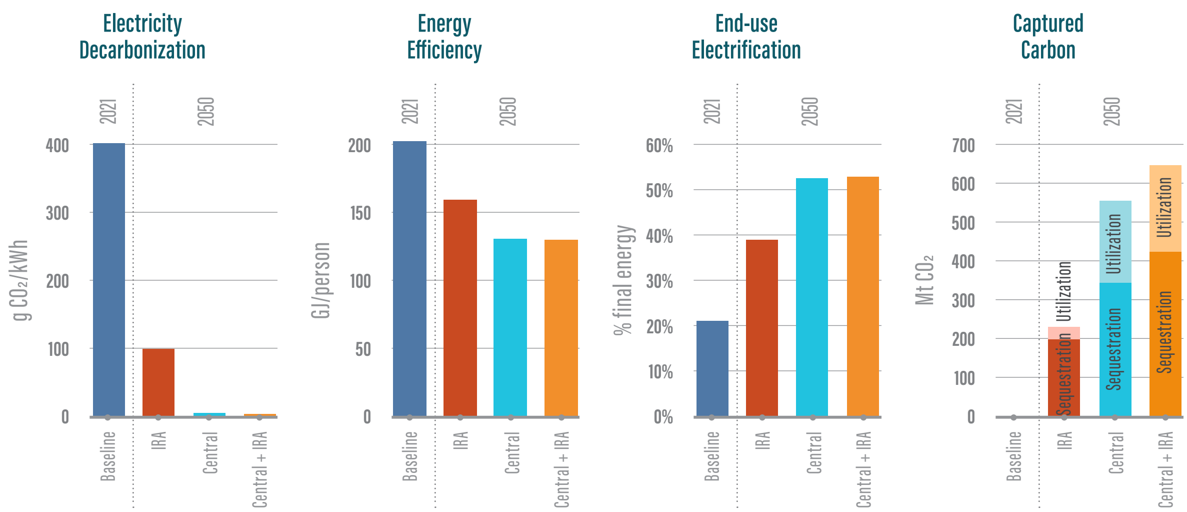


FIGURE 11.

2050 Four Pillars comparison



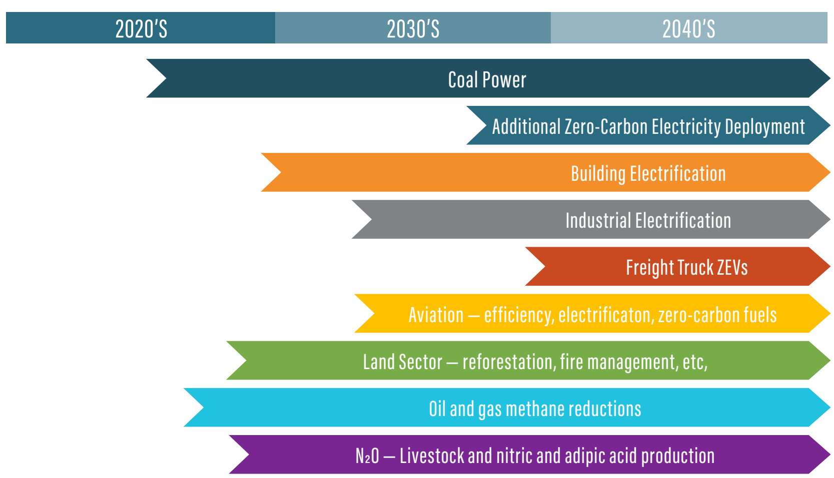
IV DISCUSSION

Where are the gaps in the IRA?

The figure below shows a timeline of the emissions reduction opportunities that are realized in the **Central** scenario but are not leveraged in the **IRA** scenario. The IRA is a package consisting primarily of carrots, not sticks. While this is extremely effective in deploying clean energy technologies, there are still significant gaps in areas with large amounts of emissions needing to be reduced.

FIGURE 12.

Emissions gaps



What are the opportunities to address those gaps?

Maintaining progress towards a net-zero future means supplementing the IRA in the near-term with additional emissions reductions and maintaining ambition in the long-term after the expiration of the IRA.

The table below presents opportunities for doing that outside of additional federal legislation. This is not an exhaustive list, but merely highlights some key activities that would enhance emissions reduction progress in sectors of the economy that may not be adequately supported by the IRA.

TABLE 1. EXAMPLE OPPORTUNITIES FOR CLOSING THE EMISSIONS GAP TO NET-ZERO

Emissions Gap	Federal Regulatory Policy	State Policy	Private Sector: Corporate Goals and Technology Development
Coal Power	Clean Air Act – Section 111; Section 1706 loan guarantees	Clean energy standards	Nuclear SMR and Gas w/CC development for retrofitting of existing sites; Corporate net-zero pledges;
Additional Zero-Carbon Electricity Deployment	Clean Air Act – Section 111; additionality requirements for clean hydrogen deployment; interstate transmission permitting reform	Clean energy standards; rate design to encourage non-storage integration solutions; permitting reform	Thermal energy storage; lower-cost electricity storage; nuclear, geothermal, offshore wind and gas w/cc technology development for areas with limited onshore wind and solar
Building Electrification		New gas hookup moratoriums; targeted electrification programs	Low-temperature heat pumps; broader heat pump technology offerings; smart controls
Industrial Electrification		Rate design to encourage flexible clean heating technologies (thermal energy storage, dual fuel boilers, etc.)	
Freight-Truck ZEVs	Clean truck rules	Clean truck rules	Lower-cost battery and HFCV vehicle options
Aviation			Hydrogen-powered airframes; Increased SAF blending percentages; lower-cost SAF as e-fuels or advanced biofuels; electrification technologies
Land Sector		Natural and working lands implementation plans and inventories	
Oil and Gas Methane Reductions	Methane leak regulations; abandoned oil and gas well capping	Methane leak regulations	Monitoring technologies
N_2O		Manure management	

Does the IRA change long-term net-zero strategies?

The **Central + IRA** scenario reflects an optimal pathway to deep decarbonization concurrent with the implementation of IRA. It reflects the relative weighting of the IRA in different sectors and towards different technologies. In general, the IRA maintains technology neutrality within the energy system – the optimal solution set in the long-term remains unaltered with the exception of:

1. Deployment of direct air capture, which we don't see in the **Central** scenario

2. Deployment of gas with carbon capture in the power sector, which is not in the **Central** scenario

3. Higher medium-term emphasis on electricity-derived fuels rather than biofuels, due to the robust tax credits for hydrogen.

In terms of allocation of emissions reductions, the relative ambition of the IRA in the energy sector means that we see additional reductions out of this sector in the 2030s compared to the **Central** scenario which sees larger contributions from the non-CO_2 and land sectors.

Next Steps

The IRA does a very good job at incenting deep decarbonization energy system activities in the near to medium-term. Post-2035, continued emissions reductions would need to be supported by the continuation of federal policy or state policy and continued technology development. Anticipation of secondary effects (domestically and globally) is difficult, but IRA does appear to position the U.S. well in key sectors (electricity and transportation) and with the deployment of technologies that may be necessary in the longer-term (hydrogen, direct air capture, etc.). Even after taking the IRA into account, there are still many significant opportunities for continuing to reduce emissions in the next decade and maintaining the pathway to net-zero.

V APPENDIX

CHANGES FROM 2022 ADP

In order to preserve a comparison to our August Annual Decarbonization Perspective (ADP), we made as few changes to input assumptions as possible. This section summarizes some of the changes that were material to the results presented here.

Firstly, the relevant years for faithfully modeling the IRA meant that we changed the combination of optimized years that represent the pathway to 2050.

TABLE 1. MODELED YEARS

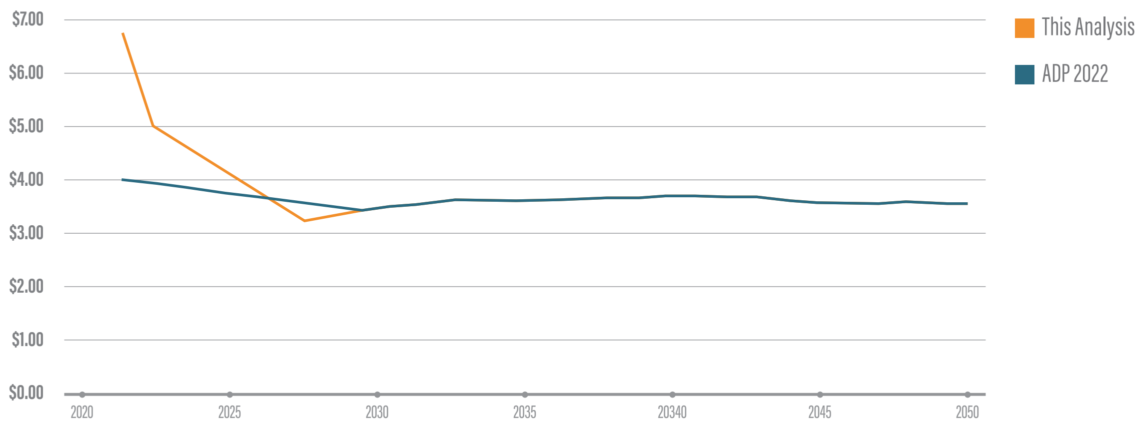
August 2022 Annual Decarbonization Perspective	This Analysis
2021	2021
2025	2024
2030	2027
2035	2030
2040	2035
2045	2040
2050	2050

Second, the IRA, with its generous early tax credits for renewable and clean hydrogen technologies, also challenges the deployment rates of these technologies in the near-term. In other words, the inclusion of the hydrogen tax credits in the modeling yields a least-cost solution that deploys hydrogen infrastructure at a rate so swift as to be implausible in the near-term. Because of this, we need to impose constraints on the rate of build of key technologies. This imposition of annual build rates changes the least-cost solution (primarily in the near-medium term) while leaving the long-term trajectories relatively unimpacted.

Third, we changed the near-term trajectory of natural gas prices. Using the 2022 Annual Energy Outlook as our base we were missing the early-year spike in natural gas prices that has a potentially material effect on the economics of near-term renewable deployment. By 2030, we return to consistency with the AEO 2022 gas price forecast.

FIGURE 13.

Comparison of assumed Henry Hub gas prices ($/MMBtu)



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