Revisiting the Inflation Reduction Act: Cost Increases and the EPA GHG Proposal

Nicholas Institute

January 25, 2024

Duke NICHOLAS INSTITUTE *for* ENERGY, ENVIRONMENT & SUSTAINABILITY

Overview

- Important Questions and Factors to Consider
- DIEM Modeling Assumptions
  - Structure
  - Renewables costs
  - Fuel prices
- IRA – Findings and Sensitivities across Renewables Prices and Other Assumptions
  - Emissions
  - Annual capacity changes
  - Regional investment patterns
  - Effects of potential limits on renewables siting
- EPA GHG Proposal – Findings and Sensitivities
  - Emissions
  - Investments
  - Hydrogen and CCS
  - Behavior of gas units
- Any Additional Discussion of Other Topics or Questions

Important Questions and Factors to Consider

- Does the Inflation Reduction Act (IRA) still lead to increases in renewables and lower emissions in the face of recent cost increases?
- How many renewables sites can be developed in the future?
- How do emissions respond to the draft EPA GHG proposal?
- What are the impacts of different assumptions about the relative costs of natural gas versus hydrogen?
- How much hydrogen is needed and how is it produced (electrolysis or other)?
- How do gas units alter behavior because of GHG proposal?

Nicholas Institute DIEM Model – Electricity Component

- DIEM is a long-term capacity planning and dispatch model of U.S. wholesale electricity markets
- Basic structure is a linear programming model with foresight (similar to IPM and NREL ReEDS models)
  - Minimize present-value costs of generation subject to meeting demand across seasons/time-of-day and policy goals

- Standard assumptions:
  - Existing units from EPA IPM NEEDS data (with updates on construction from EIA)
  - Existing policies added (e.g., RGGI and California, State RPS, SIP Call, MATS, ACE, Virginia Clean Economy Act)
  - Operating reserves (spinning, regulation, flexibility) from NREL (2018) "Operating Reserves in Long-term Planning Models"
  - AEO 2023 forecasts of new unit costs, electricity demand, and wholesale fuel prices (fuel transport costs from EPA IPM)
  - NREL Annual Technology Baseline (ATB) 2023 forecasts of renewables and storage costs
  - CCS retrofit costs for existing units, carbon transport costs, and gas-pipeline costs for coal plants from EPA IPM modeling
  - Policies
    - IRA tax credits get 5x labor market bonuses (i.e., 30% ITC or $25/MWh), credits for nuclear generation
    - EPA GHG Proposal – applies to existing coal, new combined cycle, existing combined cycle over 300 MW and 50% utilization rates, new simple cycle over 20%

- Alternative assumptions in some scenarios:
  - "*ATB 2022*" previous NREL forecasts of renewables and storage costs
  - "*Cheap Gas*" from EPA IPM modeling (~$2/MMBtu delivered)
  - "*Reduced Renewables*" from NREL 2022 Standard Scenarios Reduced Case (limits on available renewables sites)
  - "*H2 Retrofit Cost of 20%*" from NREL ReEDS model (units burning hydrogen face capital costs equal to 20% of a new unit)
  - Hydrogen fuel prices ($1.0/kg versus $0.5/kg)

Duke NICHOLAS INSTITUTE *for* ENERGY, ENVIRONMENT & SUSTAINABILITY

DIEM Model Assumptions – Renewables

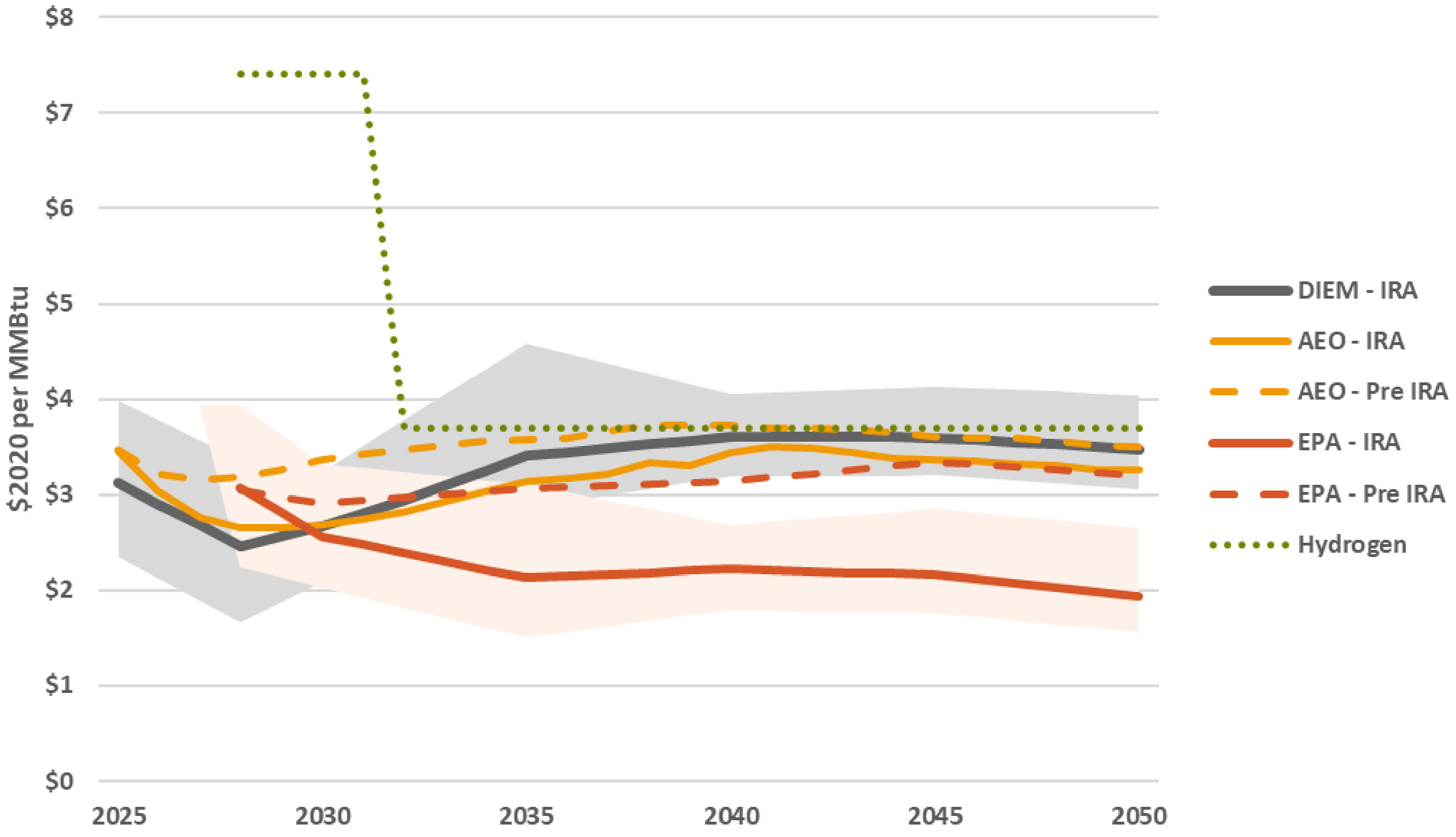
- Overnight Capital Costs ($/kW) – NREL Annual Technology Baseline (ATB) Moderate Case
  - ATB 2023 versus ATB 2022
  - *Some scenarios look at renewables costs from the NREL Advanced Case (labeled as "Low Cost" renewables)*
- Availability of Renewables – NREL Standard Scenario 2022 versus NREL "Reduced" Scenario
  - Additional setbacks and land exclusions
  - Potential technical (rather than economic) supply of wind and solar is reduced by 50% to 70%

Technology		2023	2030	2032	2040	2050
Onshore wind	ATB 2023	$1,305	$1,037	$1,016	$935	$833
	ATB 2022	$1,258	$913	$895	$822	$730
	% Increase	4%	14%	14%	14%	14%
Solar PV*	ATB 2023	$1,230	$959	$882	$705	$584
	ATB 2022	$1,049	$734	$721	$669	$603
	% Increase	17%	31%	22%	5%	-3%
Solar PV + battery**	ATB 2023	$2,044	$1,523	$1,432	$1,190	$980
	ATB 2022	$1,690	$1,042	$1,021	$939	$836
	% Increase	21%	46%	40%	27%	17%
Battery (4 hour)	ATB 2023	$1,642	$1,152	$1,117	$974	$797
	ATB 2022	$1,256	$895	$873	$783	$671
	% Increase	31%	29%	28%	24%	19%

Duke

DIEM Model Assumptions – Fuel Markets

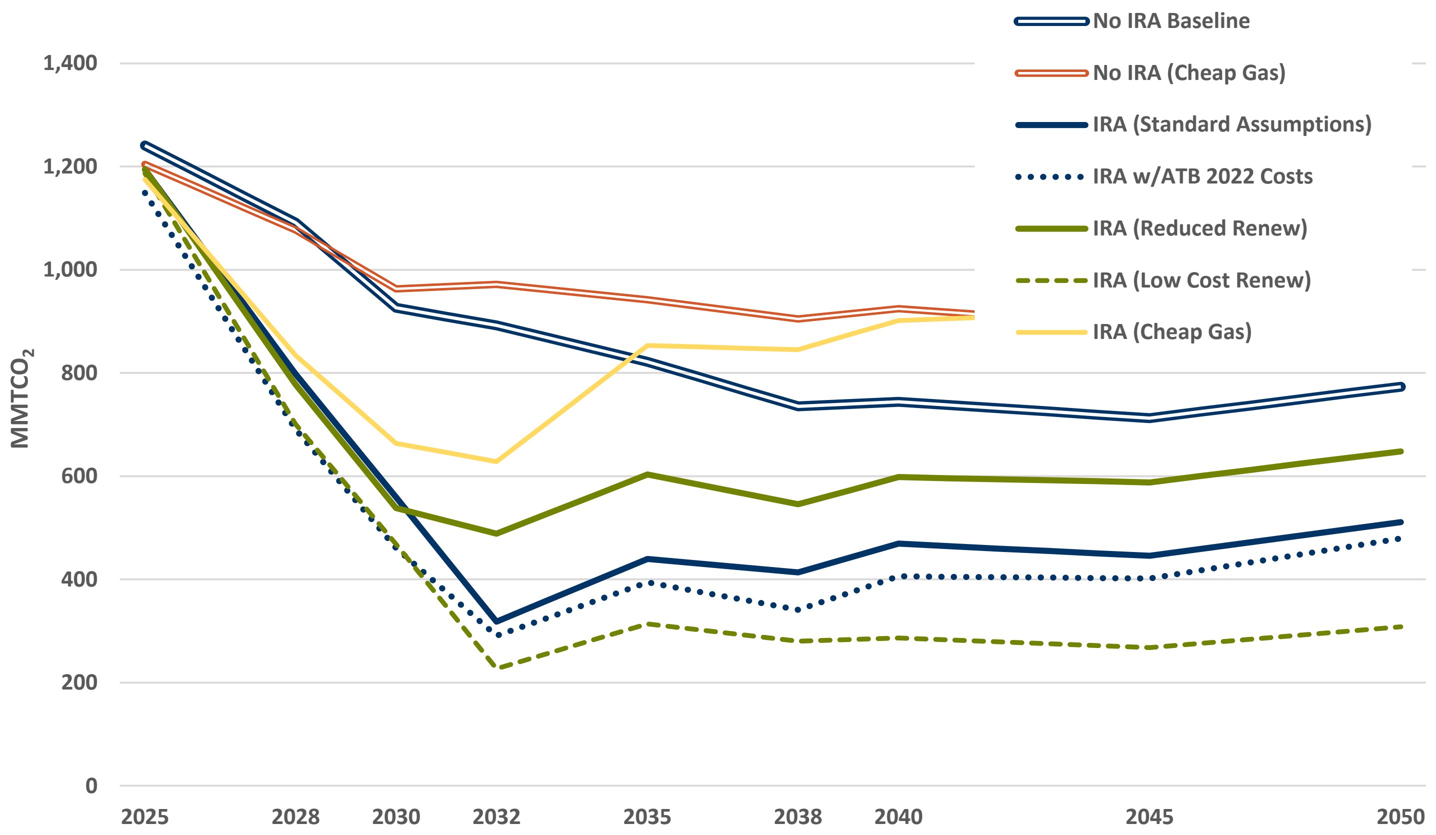
- Natural gas prices – Annual Energy Outlook 2023 vs EPA IPM data from the Post-IRA analysis
- Hydrogen prices – $0.5/kg from EPA RIA of GHG Proposal ($3.7/MMBtu) versus $1.0/kg (other EPA analyses)
- Other hydrogen issues
  - Does hydrogen come from outside the electricity sector or is it produced through electrolysis?
  - Are there additional costs of retrofitting gas units to burn hydrogen?



Emissions under IRA – Highlights

- In the absence of the IRA, emissions would trend downwards over time, but at a gradual pace and the improvements would have been quite dependent on fossil fuel prices.
- The IRA substantially accelerates the decline in emissions through 2032, even in the face of recent renewables cost increases. After 2032, continued reductions would require additional policies.
- Emissions under IRA are ~13% higher on average as the result of the recent renewables cost increases
- The extent of emissions reductions under IRA remains highly dependent on natural gas prices and the ability to site and permit new renewables generation.
- Reductions in the scope of renewables sites can lead to emissions that are 50% higher in 2032 than otherwise expected in under the IRA, and emissions remain around 30% higher through 2050.
- The EPA GHG Proposal can potentially cut remaining emissions in half but won't reach net-zero by 2050

CO_2 Emissions – No IRA vs IRA (national)



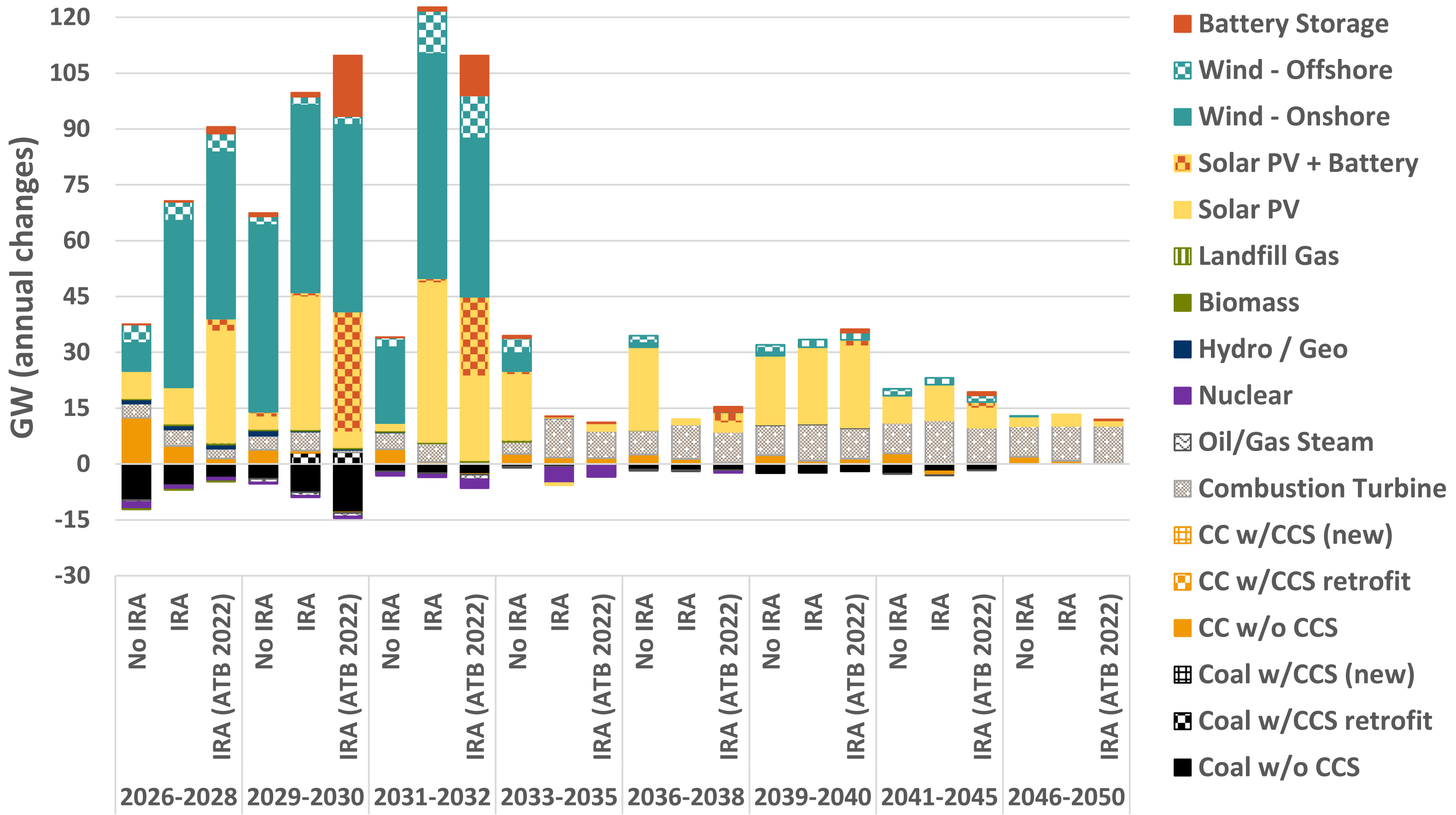
- Baseline Emissions without IRA
  - Emissions in DIEM already decline in the "No IRA" case, depending on gas prices
  - Baseline emissions in NREL 2022 and the AEO 2023 are relatively flat without IRA
  - EPA's version of IPM (2023) shows modest decline in emissions
- Emissions with IRA Tax Credits
  - Under the IRA, DIEM finds emissions trend down significantly more than in its baseline No-IRA forecast ("Standard")
  - Using lower renewables costs from older NREL ATB 2022 gives additional reductions
  - Limits on renewables siting can raise emissions by 50% in 2032
  - Cheap renewables ("NREL Advanced") could drop emissions below IRA cut-offs
  - Cheap gas ($2/MMBtu) has a large impact on emissions, even with IRA

Duke NICHOLAS INSTITUTE *for* ENERGY, ENVIRONMENT & SUSTAINABILITY

National Capacity under IRA – Highlights

- Recent increases in financing and equipment costs, which have disproportionately large effects on renewables, have dampened the speed of the renewables transition but not altered basic trends.
- Higher estimates of construction costs shift new capacity installations toward wind and away from solar, and especially away from battery storage.
- Only one-third as many (or fewer) new combined cycle units are needed because of IRA, and around one-half of the anticipated nuclear retirements are delayed until after IRA expires.
- Higher battery costs in the ATB 2023 lead to installation of additional combustion turbines for reliability, compared to the ATB 2022 data that had lower battery cost estimates and thus higher battery use.
- Once the IRA ends, some new renewables continue to appear as future construction costs decline, but most renewables build during 2030–2040 are timed to take advantage of the IRA credits. Eventually, continuing cost declines over the decade lead to more solar installations. The mix of new units is likely to emphasize turbines as a source of reliability rather than batteries.

US Annual Capacity Changes – "No IRA" vs IRA vs IRA with Cheap Renewables



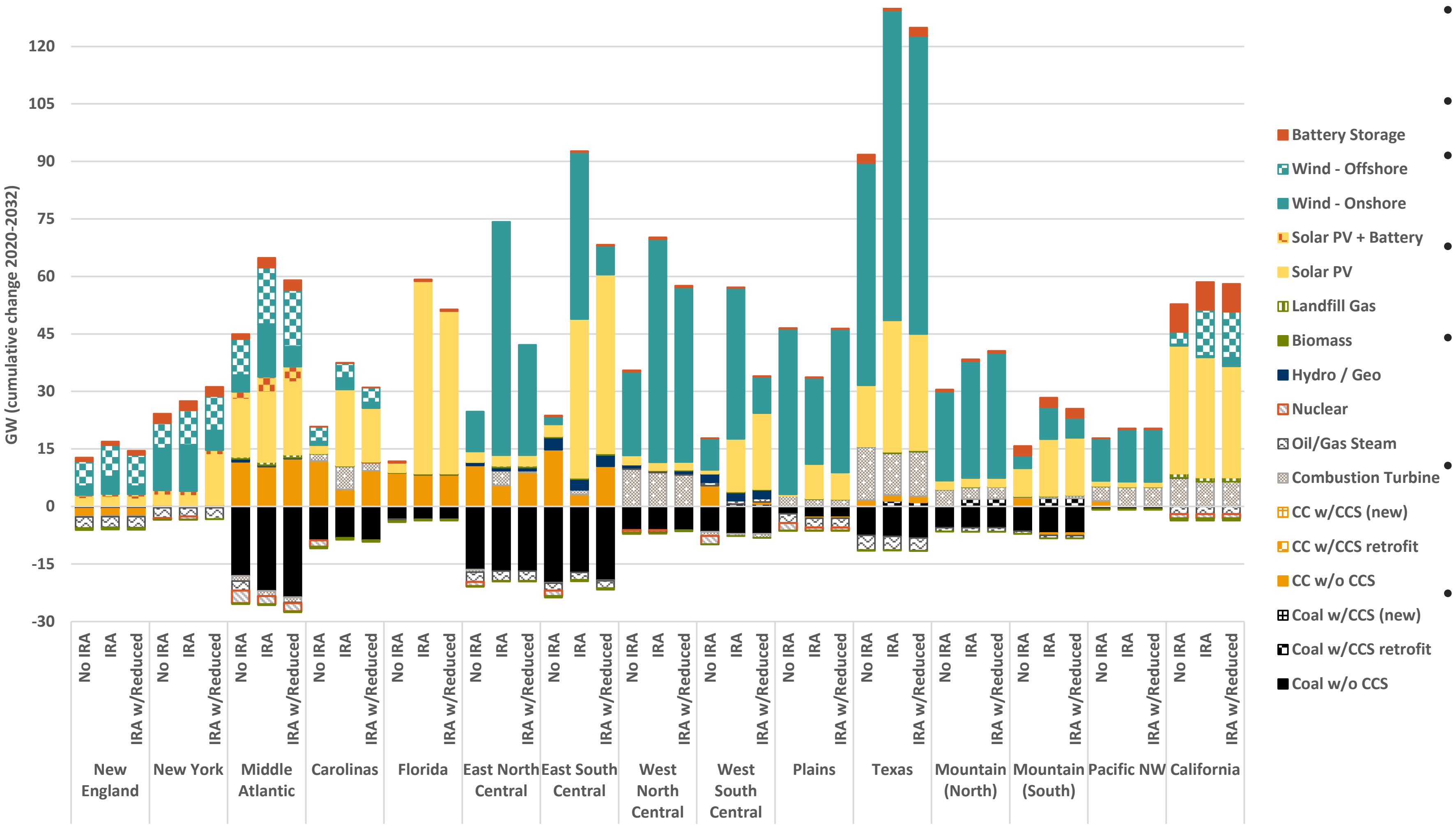
- 2026-2028
  - IRA accelerates renewables, regardless of costs
  - IRA shifts mix away from combined cycle
  - Higher costs in "IRA" versus "IRA (ATB 2022)" shift away from solar in early years compared with previous NREL solar cost estimates
- 2029-2030
  - Wind sites become cost competitive across assumptions about capital costs and credits
  - Higher battery costs in the standard assumptions ("IRA") lead to more turbines and fewer batteries than under ATB 2022 costs
- 2031-2032
  - Without IRA credits, solar is less attractive based on the 30% increase in capital costs
  - With IRA the renewable installations continue, regardless of cost assumptions
- 2033-2038
  - Installations shift towards turbines after IRA credits expire
  - Nuclear retirements that were delayed by IRA credits happen now

Duke NICHOLAS INSTITUTE *for* ENERGY, ENVIRONMENT & SUSTAINABILITY

Regional Capacity and Renewables under IRA – Highlights

- The IRA can dramatically change the desired investments in renewables in some regions of the country, while other regions might adopt similar strategies irrespective of the IRA.
- Variations in gas prices have large effects in some regions, but limited impacts in other areas.
- Demand for renewable generation increases under IRA, regardless of any limits on the number of sites available. Regional differences from potential restrictions on renewable resources can be significant.
- In some regions, a significant number of miles of new spur transmission lines will be needed to connect new renewables to the grid. However, interregional expansion of long-distance transmission may be limited, based on current costs.
- In most policy modeling (including this analysis), non-generating fossil units tends to remain available in the future to help provide reliability when there are high levels of renewables in the system. On average under the IRA in 2032, more than 70% of the capacity used to meet reserve margins is from fossil units (not including nuclear).

Regional Cumulative Capacity Changes to 2032 – "No IRA" vs IRA vs IRA with Reduced Renewables

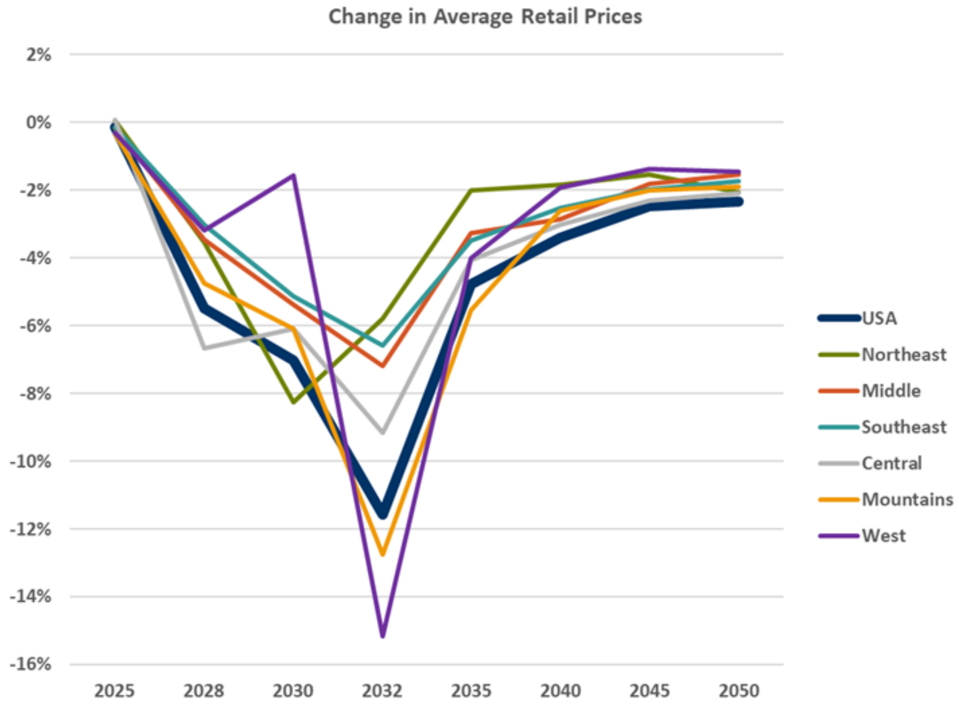


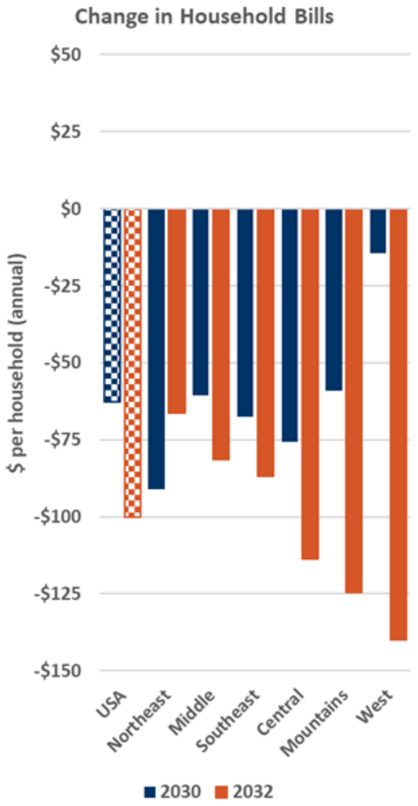
- Minor changes on the Coasts where there are preexisting climate regulations
- Wind in Middle Atlantic helped by IRA
- A continued shift into solar in the Carolinas and Florida from IRA credits
- Fewer nuclear retirements in all regions, particularly in Carolinas and Central
- The East Central regions expand renewables because of IRA, but wind development depends on site availability
- Wind would have been built in the West Central, Plains and Texas regions, but increases because of IRA (if sites are avail)
- Some coal CCS (around 6 GW) is built in the Gulf and Mountain regions where the captured CO_2 can be used for EOR

Duke NICHOLAS INSTITUTE *for* ENERGY, ENVIRONMENT & SUSTAINABILITY

Policy Costs under IRA – Highlights

- A regional summary of changes in retail prices shows declines that peak in 2032 with full IRA implementation
- Subsidizing specific types of generation such as renewables can lower the marginal costs of generation if electricity from new renewables is the price-setter in the markets during at least some seasons of the year and times of day.
- Also, lower gas prices used in the IRA scenarios will lower costs for gas units that can be the price-setter on the margins.
- Retail prices don't capture the broader costs of providing the IRA subsidies (see the report for other cost measures)





EPA GHG Proposal Criteria

New Gas Combined Cycle

Utilization Rate	H_2 Cofiring	CCS
<50%	30% in 2032	90% CCS in 2035
>50%	30% in 2032 96% in 2038	90% CCS in 2035

New Simple Cycle Turbines

Utilization Rate	H_2 Cofiring
<20%	Not Required
20% - 50%	30% H_2 in 2032

Existing Gas Combined Cycle

Utilization Rate	Size < 300 MW	Size > 300 MW
<50%	Nothing	Nothing
>50%	Nothing	30% H_2 in 2032 / 96% H_2 in 2038 90% CCS in 2035

Existing Simple Cycle Turbine

Utilization Rate	All Units
<20%	Nothing
20% - 50%	Nothing

Existing Coal

Size Criteria (>25 MW)

Retirement Date	Utilization <20%	Utilization >20%
Before 2032	No Increase in Emissions Rate	No Increase in Emissions Rate
Before 2035	No Increase in Emissions Rate	Not allowed
Before 2040	40% gas cofiring In 2030	40% gas cofiring In 2030
After 2040	90% CCS in 2030	90% CCS in 2030
Coal-to-Gas Conversion	No Additional Action	

Notes

Phase #1 is efficient turbines. The criteria in this figure focus on phases #2 and #3.

Base load are units running greater than 50% utilization rate, intermediate load are 20%-50%, and peaking are below 20%.

New Units – Defined as starting construction after 2023.

Existing NGCC – The RIA assumed 300 MW, but the size criteria may receive comments.

Simple Cycle – The utilization rate criteria of 20% may receive comments.

Existing Coal – Requirements are by retirement date for any coal units above 25 MW. In the IRA, the “Proposal” and “More Stringent” assumed 500 MW. The “Less Stringent” assumed 700 MW and smaller units avoided CCS with 40% H_2 cofiring.

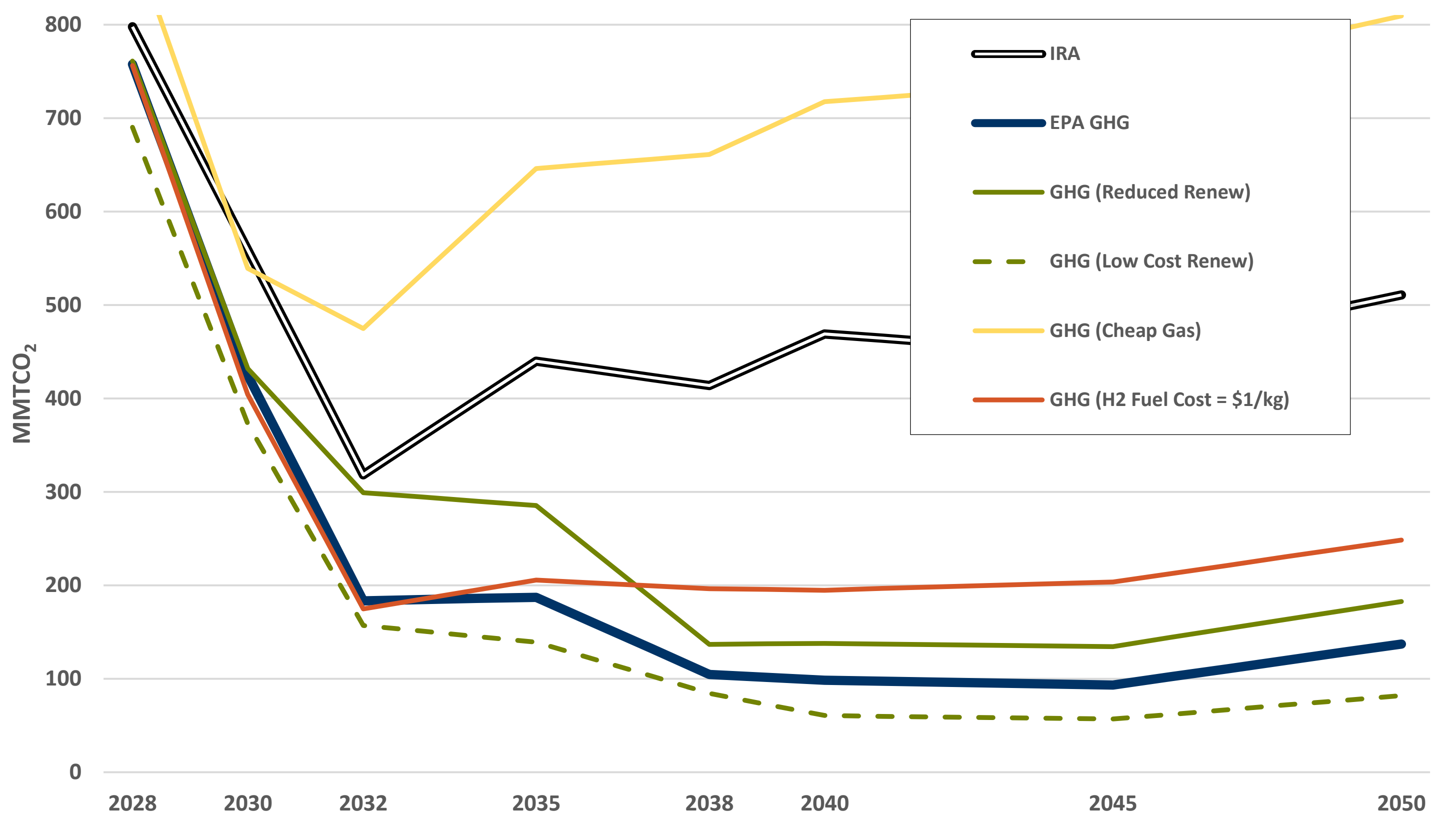
EPA GHG Proposal – Highlights

- The EPA GHG proposal can potentially cut emissions in half after the conclusion of the IRA. However, the proposal does not reach net-zero emissions from generation by 2050.
- Emissions under the EPA GHG proposal still depend on natural gas prices and renewables availability, along with sources of clean hydrogen.
- Coal plants retrofitting with CCS increase to around 30 GW by 2030, compared with 6 GW for the IRA.
- The majority of emissions reductions prior to 2038 come from coal CCS. After 2038, hydrogen markets contribute additional reductions, and renewable generation also increases from the GHG proposal.
- Annual storage needs expand from around 25 $MMTCO_2$ under the IRA to more than 200 $MMTCO_2$ under EPA GHG proposal (most of which is still used for EOR – assumes no competition for EOR from other sectors).
- Overall renewable installations are higher by 2030 as the result of the GHG proposal. Onshore wind installations, in particular, are up to 30 GW higher than with the IRA alone.
- Scenario assumptions about the availability and cost of renewable generation have larger impacts on emissions and the costs per ton reduced than do the modeled range of criteria for gas turbines.
- Changes in US average retail electricity prices average less than 2% in most scenarios.

EPA GHG Proposal – Emissions Impacts

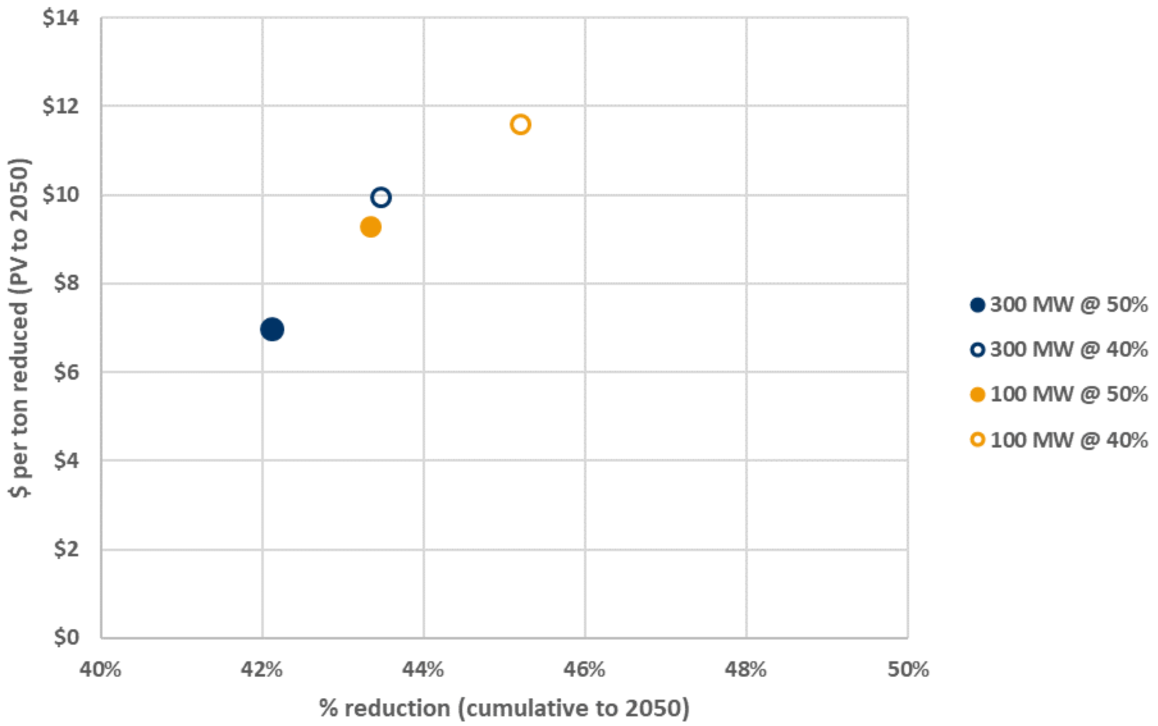
Table 1. Relative impacts of variables in the EPA GHG proposal

Variable	Relative Influence on Emissions: Minimal	Moderate	Significant
Size of combined cycle unit (300 MW or 100 MW)	●		
Utilization rate of combined cycle (50% or 40%)	●		
Costs of renewables		●	
Availability of renewables		●	
Relative price of natural gas versus hydrogen			●
Potential costs of retrofitting combined cycle for hydrogen cofiring			●
Clean hydrogen produced through electrolysis			●



Duke NICHOLAS INSTITUTE *for* ENERGY, ENVIRONMENT & SUSTAINABILITY

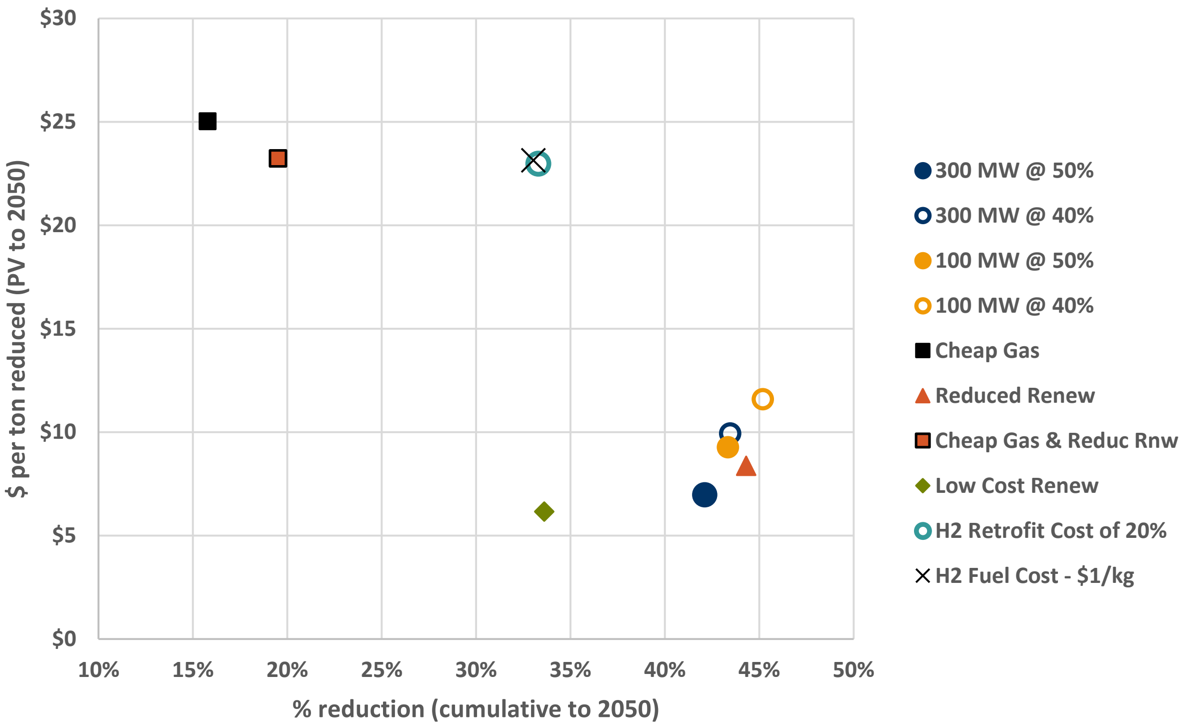
EPA GHG Proposal – Cost of CO_2 Reduction ($/ton) vs % reduction



- Criteria regarding the size of existing gas units and their utilization rates are varied from >300 MW and >50% utilization rate to lower levels in order to evaluate the sensitivity of overall emissions.
- Costs per ton range between $7 and $12 across the range of criteria, in all cases significantly less than estimates of the social cost of carbon (SCC) even before any accounting of other benefits of pollution reductions from generation.
- In absolute terms, there is not too much variation across either the costs per ton or the cumulative emissions reductions. In relative terms, more restrictive criteria regarding the existing combined-cycle units (meaning lower capacity and utilization rate thresholds) can increase costs per ton by 33% to 66% without much impact on overall emissions.

Duke NICHOLAS INSTITUTE *for* ENERGY, ENVIRONMENT & SUSTAINABILITY

EPA GHG Proposal – Cost of CO_2 Reduction ($/ton) vs % reduction



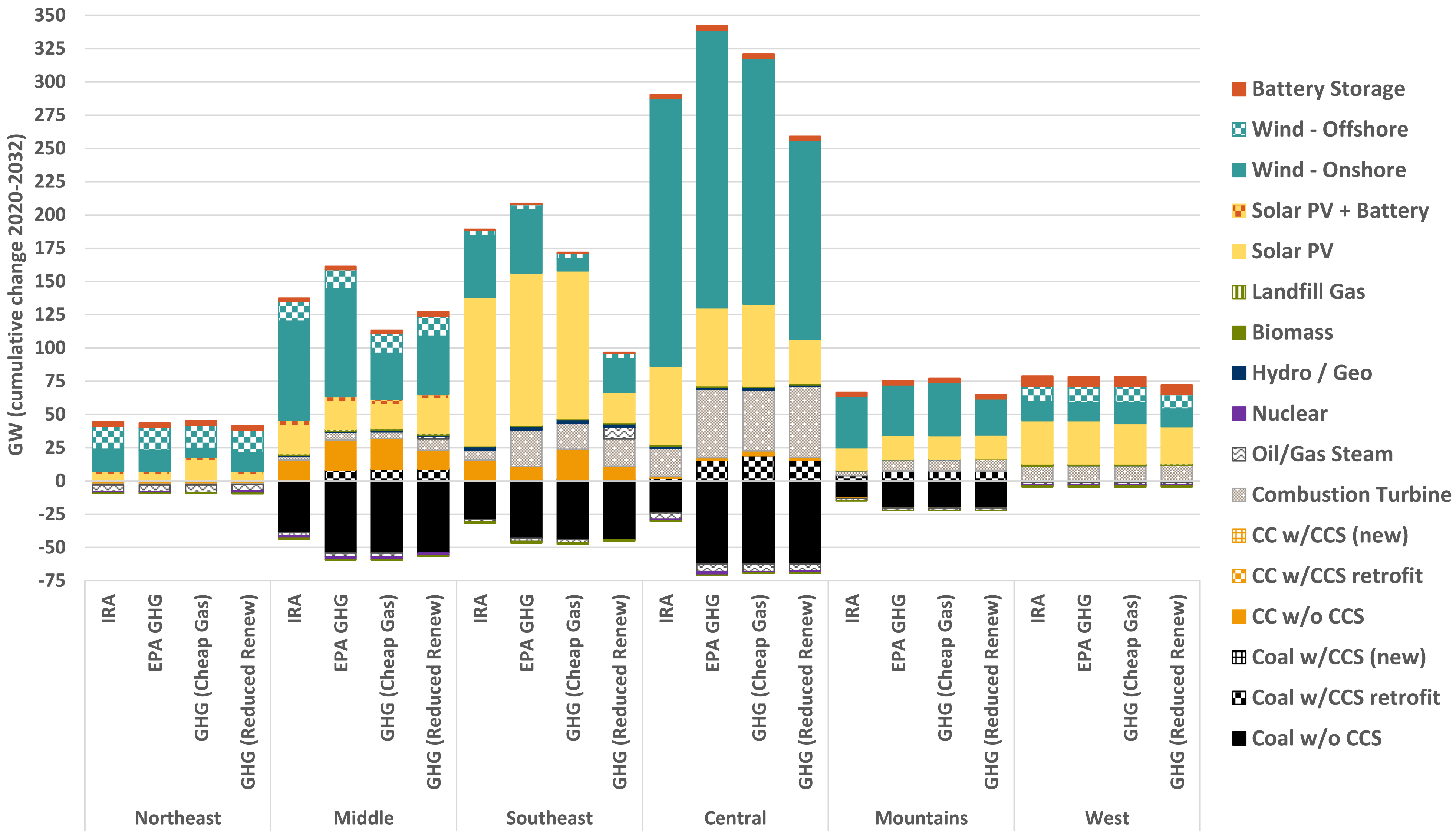
- A "Cheap Gas" future (delivered gas prices around $2/MMBtu) lowers potential emissions reductions to around 15% cumulatively through 2050. The cost per ton reduced also rises to around $25/ton.
- "Reduced" renewable development has less of an impact in relative terms (i.e., emissions reductions and costs per ton are similar to the main GHG scenario), but in absolute terms the total annual emissions are significantly higher than if more renewables sites are developed.
- Availability of "Low Cost" renewables implies more development under IRA and hence a smaller subsequent impact of the GHG Proposal.
- Higher costs associated with hydrogen use ("Retrofit Cost" or "$1/kg") will lower emissions reductions from the Proposal and raise cost per ton.

Duke NICHOLAS INSTITUTE *for* ENERGY, ENVIRONMENT & SUSTAINABILITY

Capacity Changes under EPA GHG Proposal

- Coal plants retrofitting with CCS increase to around 30 GW by 2030, compared with 6 GW for the IRA over the same time period (for most cases, no gas with CCS is forecasted).
- Overall renewable installations are higher by 2030 as the result of the GHG proposal. Onshore wind installations, in particular, are up to 30 GW higher than with the IRA alone.
- Similar to other scenarios, the EPA GHG proposal tends to concentrate the additional renewables in the middle sections of the country, rather than the coasts.
- The Southeast and Central regions add more new combustion turbines because of the GHG proposal than other areas, partly to provide reliability services in a system with more renewables and fewer combined-cycle units than under the IRA.
- All regions install additional capacity if hydrogen is produced through electrolysis, with the largest increases coming through new onshore wind capacity in the middle of the country.

Regional Capacity Changes to 2032: IRA versus EPA GHG Proposal

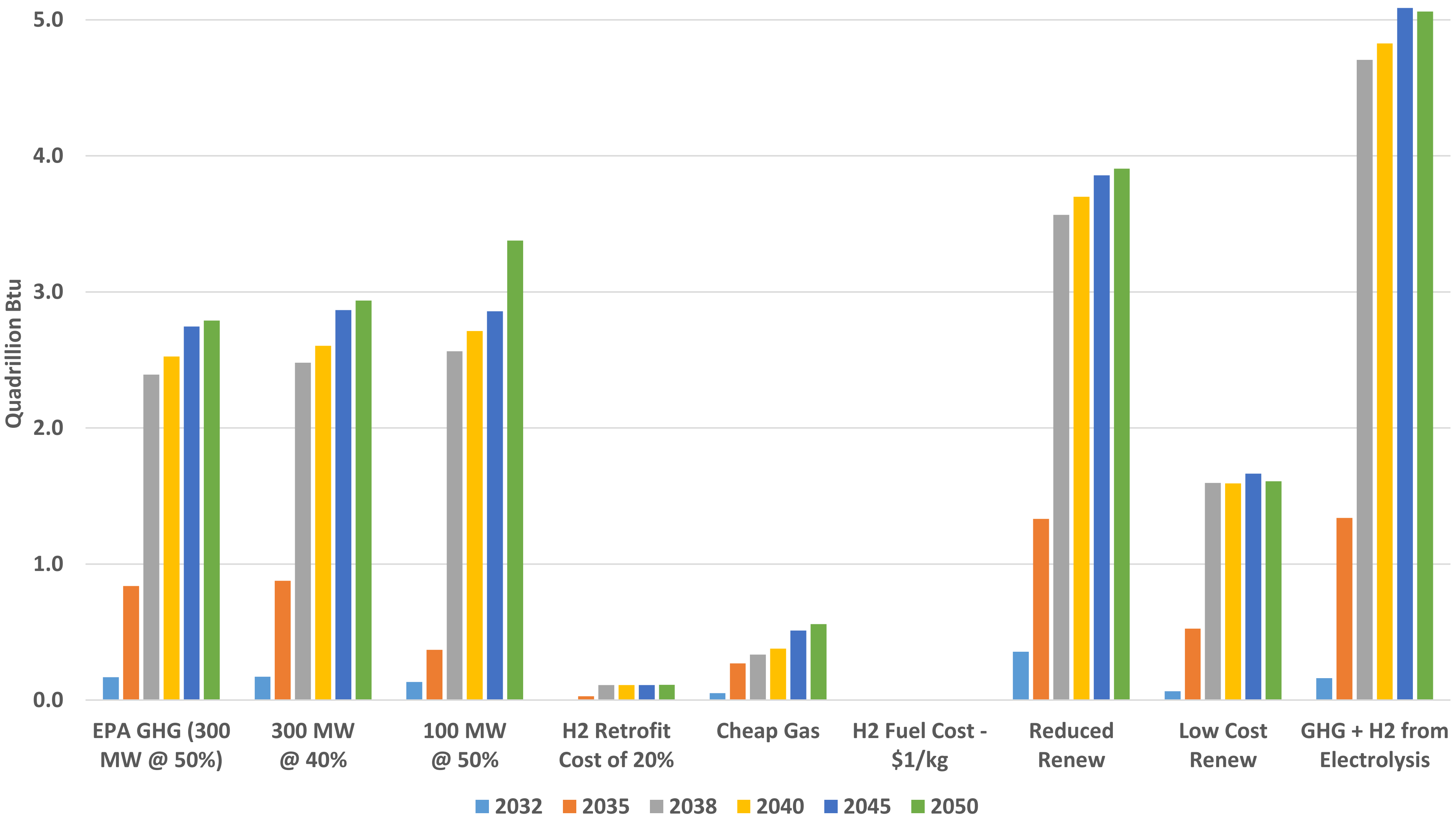


Duke NICHOLAS INSTITUTE *for* ENERGY, ENVIRONMENT & SUSTAINABILITY

Hydrogen Demand under EPA GHG Proposal

- The relative prices of natural gas and hydrogen have dramatic impacts on potential outcomes of EPA GHG Proposal
- Several scenarios suggest the possibility of using comparatively large quantities of hydrogen in gas units, depending on relative costs (hydrogen consumption can reach 2.5 quadrillion Btu or more in 2038).
- Lowering the criteria for either the size of the gas units or their utilization rates leads to only small increases in hydrogen demand as more gas units are covered by the GHG proposal.
- If delivered hydrogen costs $1.0/kg (instead of the $0.5/kg assumed in the EPA RIA), hydrogen demand can drop to zero. Similarly, if gas costs around $2/MMBtu, hydrogen demand drops even if priced at $0.5/kg (or $3.7/MMBtu)
- Very few existing or new gas units are willing to pay retrofitting costs associated with burning hydrogen. In this case, existing gas units are more likely to operate below any Proposal utilization-rate thresholds
- Reducing the availability of renewables through siting restrictions (setbacks, land exclusions, or local opposition) increases the need for hydrogen as additional gas generation is used to offset lower generation by renewables.
- If the electricity used for hydrogen production comes from renewables otherwise available to generate for the grid, the system will need to add to add additional resources—whether renewable or fossil—to meet the original demands from customers. If additional gas generation is used to provide for this demand, these gas units will also be subject to GHG proposal requirements for hydrogen cofiring (or CCS), which potentially leads to even more demand for hydrogen.

Hydrogen Demand by Gas Turbines under EPA GHG Proposal

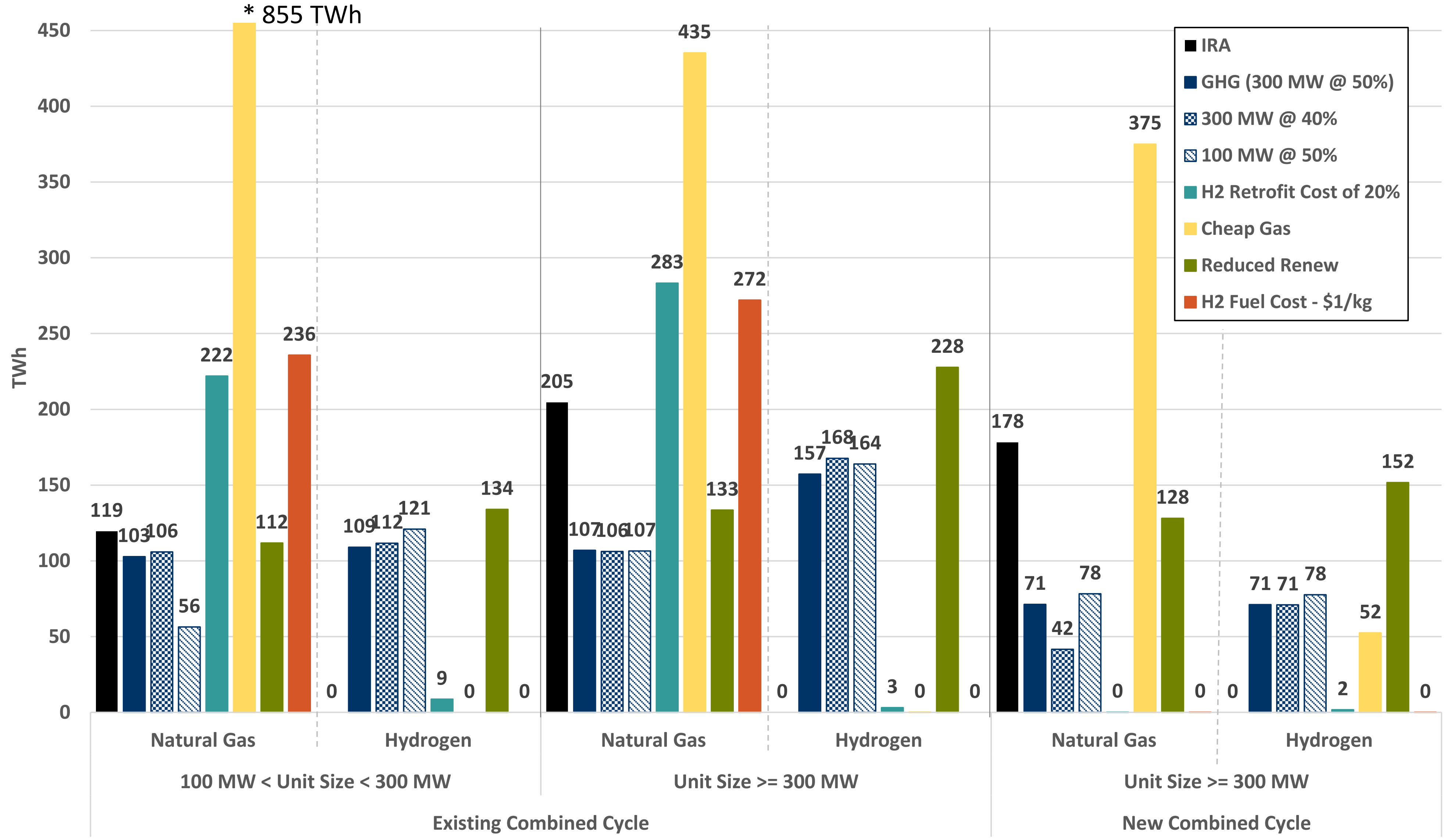


Duke NICHOLAS INSTITUTE *for* ENERGY, ENVIRONMENT & SUSTAINABILITY

Natural Gas and Hydrogen Generation

- Compared to generation levels under IRA, existing turbine units in the main GHG 300 MW @ 50% scenario drop their gas generation but add even more hydrogen generation, leading to a total increase from existing combined-cycle units.
- There are few impacts on generation from adjusting the proposal's utilization-rate criteria from 50% to 40%. Lowering the size criteria from 300 MW to 100 MW cuts gas generation by small units in half, with a slight increase in hydrogen co-firing at these smaller units.
- The assumption that units would need capital investments in order to cofire hydrogen eliminates all hydrogen consumption at existing units, even if the hydrogen price (at $0.5/kg) is roughly comparable to natural gas prices.
- Cheap gas causes large increases in gas generation as might be expected, however, the size of units involved is altered from what is seen under the IRA. While all units generate more, the biggest impact is on units below 300 MW since they do not face the 50% utilization rate criteria.
- With cheap gas, existing units above 300 MW double their generation relative to IRA levels but are more constrained by the utilization constraints (i.e., none of the existing gas units burn any hydrogen when gas is cheap so they have to run less than 50% of the time).
- Reduced availability of renewables increases gas generation across all categories, but has the largest effects on installations of and generation from new combined-cycle units.

Shifts in Gas Generation by Unit Size under EPA GHG Proposal



Duke NICHOLAS INSTITUTE *for* ENERGY, ENVIRONMENT & SUSTAINABILITY

Additional Discussion and Questions