Economic Impacts of Relicensing the Dresden Clean Energy Center (DCEC)

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Overview

Economy-Wide Impacts of Retiring DCEC in 2029 & 2031

Retiring DCEC early (compared to relicensing until 2049 & 2051) would result in:

$21 Billion Cumulative Net Loss in State GDP

Concentrated almost entirely in the six counties surrounding DCEC
Net state GDP impact is negative in all years

1,100 Lost Jobs in Illinois

700 direct jobs at the plant are lost
Plus an additional loss of 400 jobs (on average) in Illinois

$4.7 Billion Cumulative Loss in Tax Revenue

$1.1 billion less in state tax revenue
$3.6 billion less in federal tax revenue

Notes: Dollar values are undiscounted nominal dollars.

Power Sector Impacts of Retiring DCEC in 2029 & 2031

Retiring DCEC early would also:

Increase Emissions by over 76 Million Metric Tons (MMT) Over 20 Years

DCEC reduces annual emissions by 3.8 MMT on average, offsetting around 75% of Chicago's annual on-road vehicle emissions (or ~900,000 light duty vehicles)[1]

Limit Flexibility and Impede Progress in Meeting Clean Energy and Emissions Goals

DCEC accounts for 11% of Illinois' annual electricity demand
Its annual generation is equivalent to ~60% of in-state renewable generation[2]

Reduce Around-the-Clock Supply, Increasing the Challenge of Meeting Growing Electricity Demand Reliably

DCEC license renewal will provide enough energy to offset 28% of the output of the existing gas and coal plants that are mandated to retire by state policy[3]

Notes:

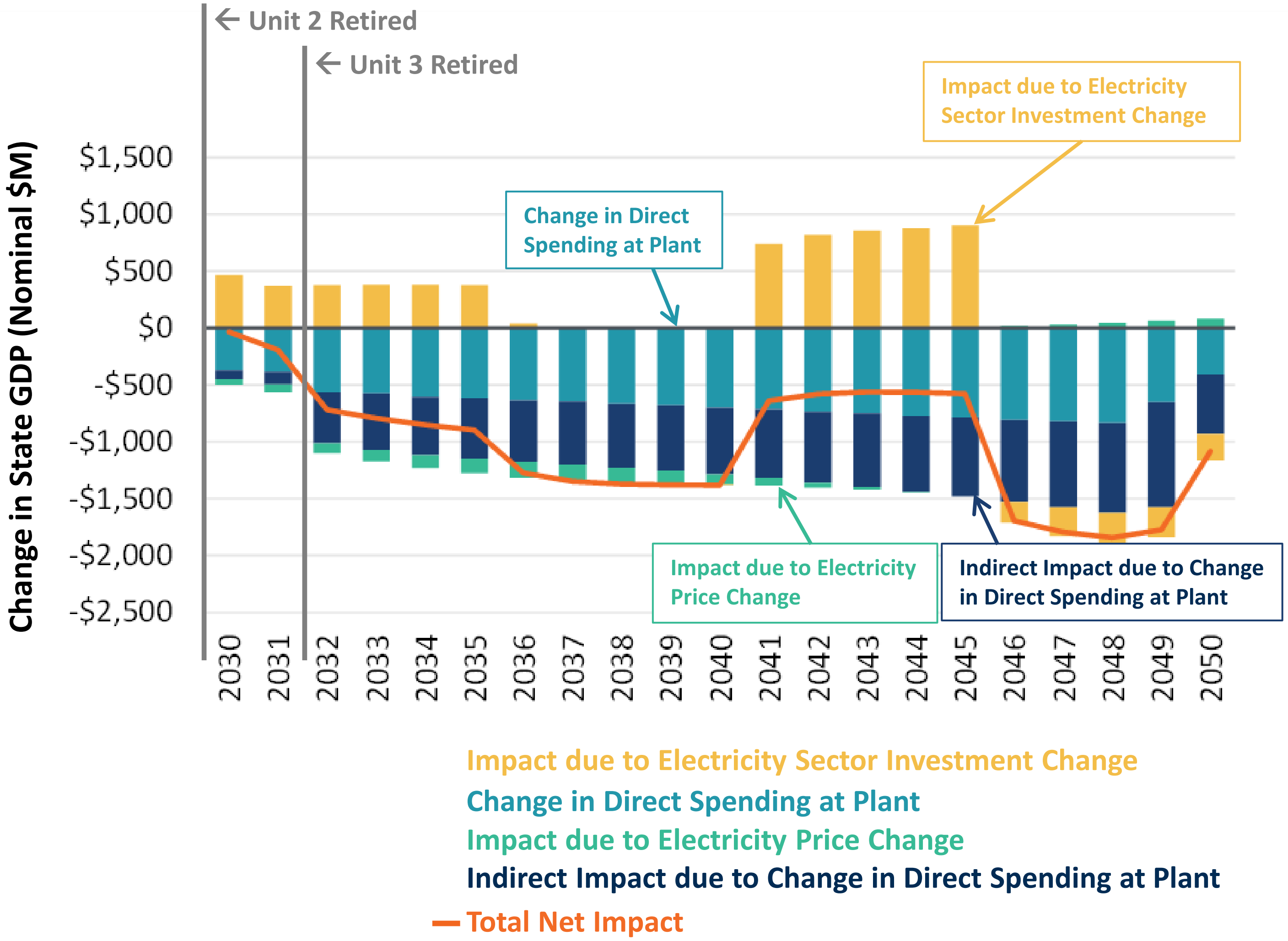
[1] On-road vehicles produced 5.11 MMT of GHG emissions in Chicago in 2022 (Regional GHG Emissions Inventory); emissions offset is equivalent to ~900,000 light-duty vehicles (LDVs) (EPA GHG Emissions)

[2] DCEC produces about 15 TWh/year; 2023 retail electricity sales were 131 TWh; 2023 utility-scale renewable generation was 24 TWh (EIA Electricity Data Browser)

[3] Scheduled plant closures will result in 23 TWh of annual gas generation losses and 31 TWh of annual coal generation losses (IL Department of Labor)

DCEC Retirement Impact on Illinois GDP

State GDP Impact

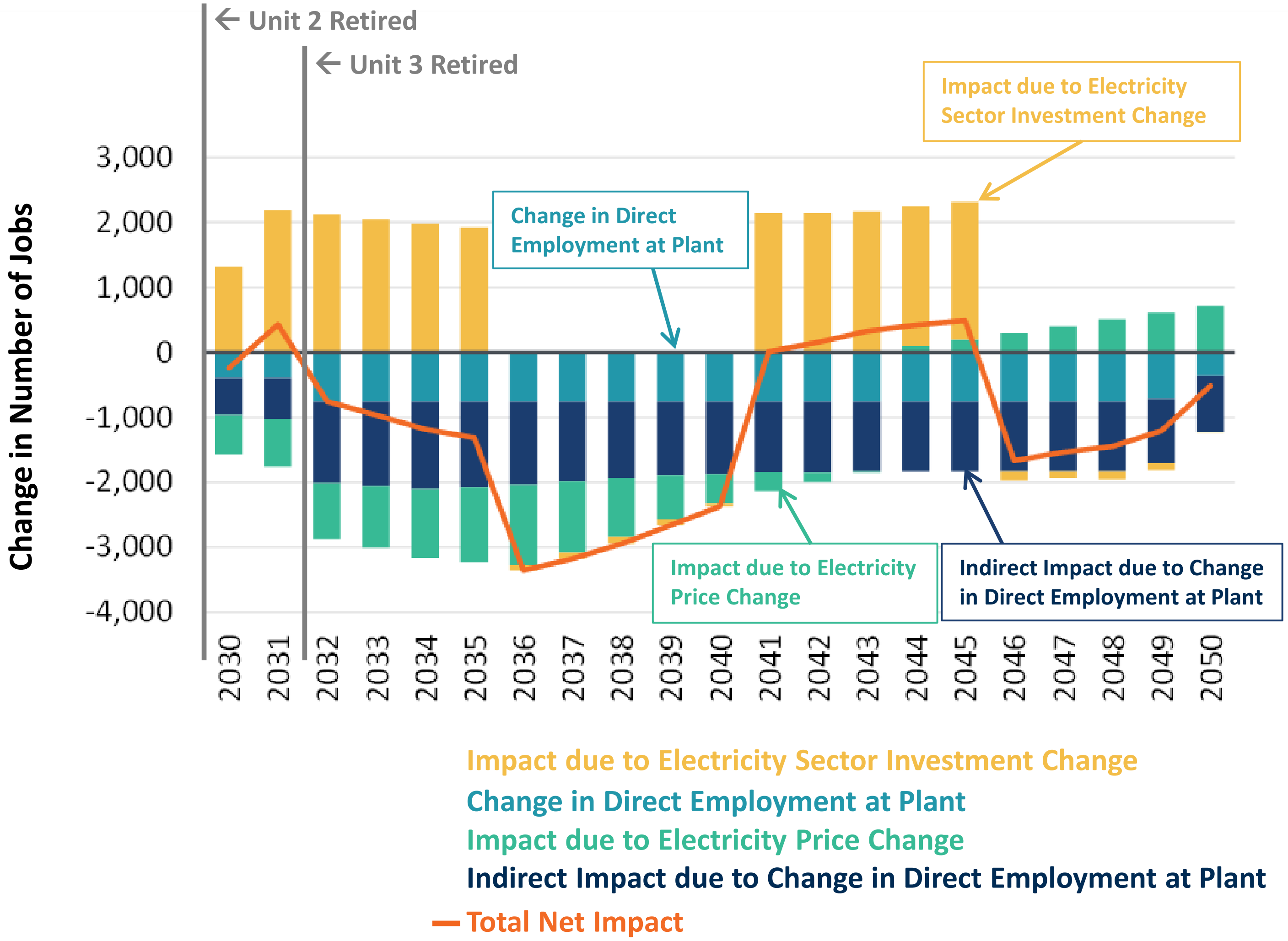


Key Observations

- Negative GDP impacts are driven primarily by the loss in plant expenditures and employment that occur with retiring the Dresden plant.
- GDP impacts are moderated by investment in additional in-state generation resources needed after Dresden's closure.
  - Positive GDP impact of these partially offsets the GDP losses driven by plant closure and higher power prices.
  - This analysis conservatively models the large majority of new resources needed to replace DCEC (to meet resource adequacy and RPS requirements) as being sited in-state. If a greater share of these resources are sited out-of-state, the positive offset would be smaller.
- Dresden Units 2 and 3 alternate each year in refueling (each on a 24-month fuel cycle). No refueling occurs in 2049 (reflected in lower direct plant spending).

DCEC Retirement Impact on Employment in Illinois

State Employment Impact



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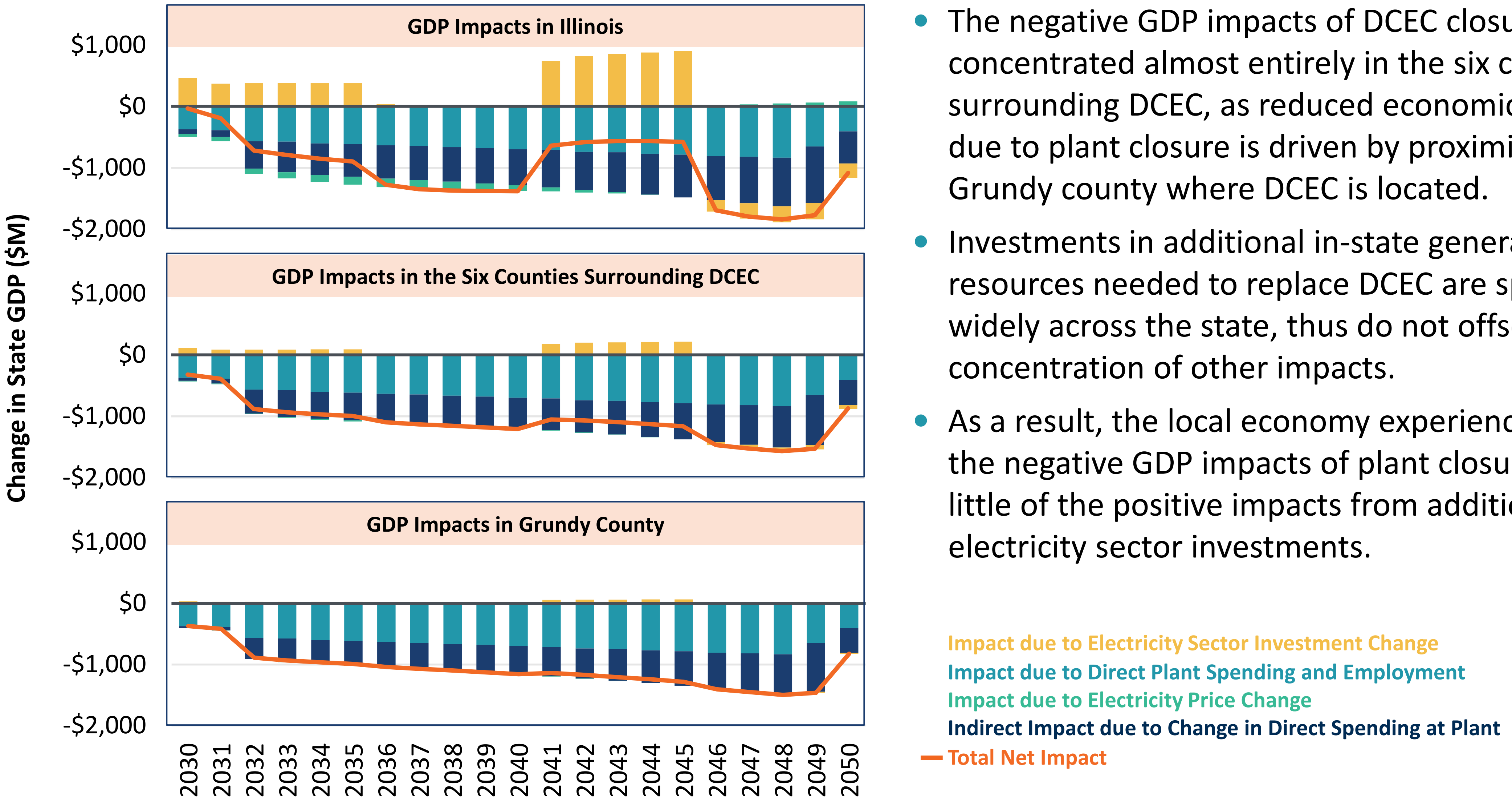
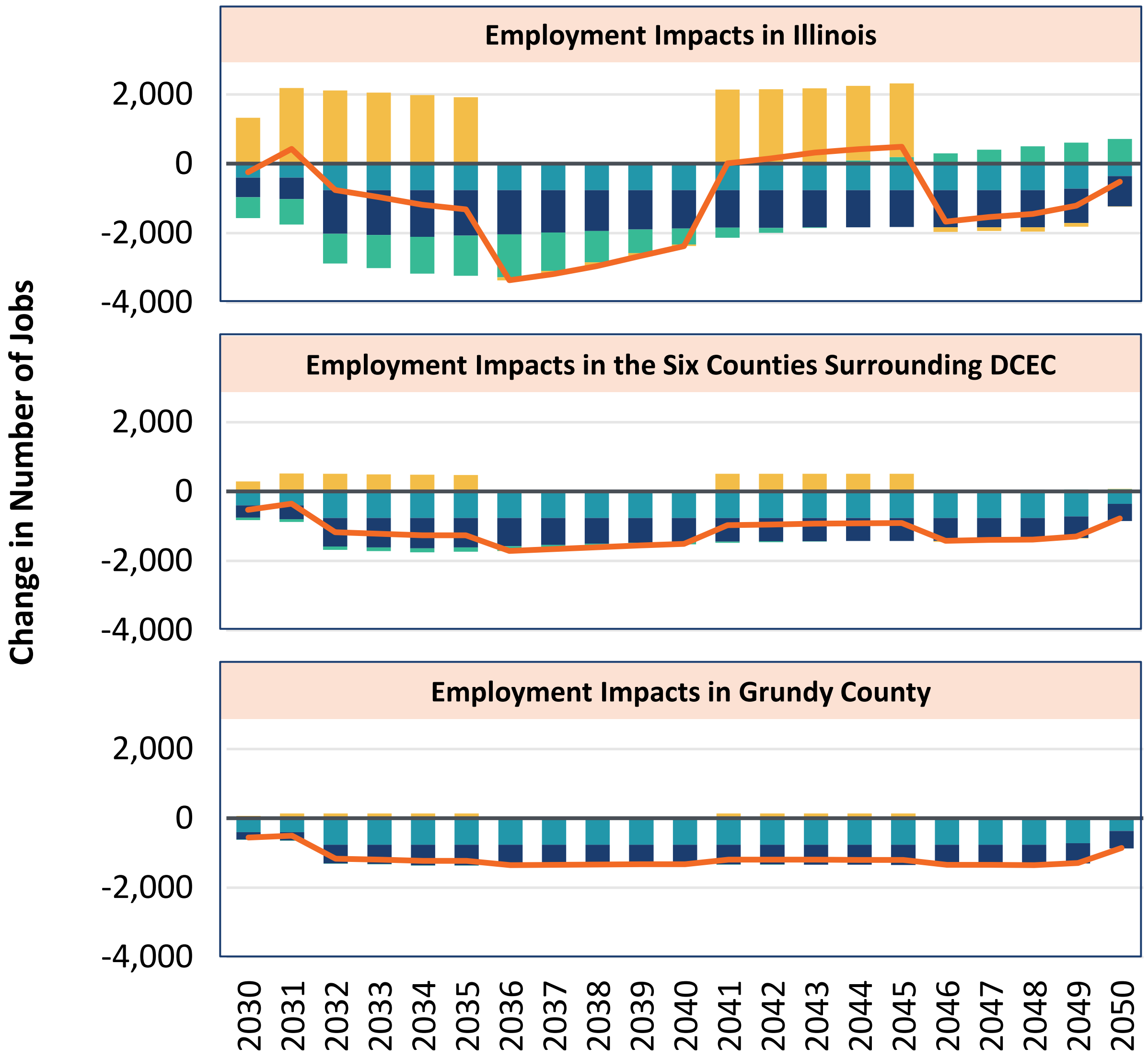
- Negative overall employment impacts are driven primarily by the direct employment effects, and loss in plant expenditures that occur with retiring the Dresden plant.
- Employment can be more sensitive to indirect effects (indirect impacts are relatively larger).
  - Electricity price effect in particular – employers facing higher electricity prices have less to spend on labor.
- Employment impacts are moderated by investment in additional in-state generation resources needed after Dresden's closure.
  - These positive employment impacts partially offset the direct and indirect employment losses resulting from plant closure and higher electricity prices.
  - This analysis conservatively models the large majority of new resources needed to replace DCEC as being sited in-state. If a greater share of these resources are sited out-of-state, this positive GDP contribution would be smaller, and overall impacts more negative.

GDP Impacts are Highly Localized



- The negative GDP impacts of DCEC closure are concentrated almost entirely in the six counties surrounding DCEC, as reduced economic activity due to plant closure is driven by proximity to Grundy county where DCEC is located.
- Investments in additional in-state generation resources needed to replace DCEC are spread widely across the state, thus do not offset the local concentration of other impacts.
- As a result, the local economy experiences most of the negative GDP impacts of plant closure, but very little of the positive impacts from additional electricity sector investments.

Employment Impacts are also Highly Localized



- The negative employment impacts of DCEC closure are heavily concentrated in the six counties surrounding DCEC.
  - Virtually all the direct employment impact is local, and so is much of the indirect impact – the negative GDP impacts that influence employment are also localized.
- Investments in additional in-state generation resources are spread widely across the state, and thus do not offset the local concentration of other impacts.
- As a result, the local economy experiences most of the negative employment impacts, but very little of the positive impacts from additional electricity sector investments.

Impact due to Electricity Sector Investment Change
Impact due to Direct Plant Spending and Employment
Impact due to Electricity Price Change
Indirect Impact due to Change in Direct Spending at Plant
Total Net Impact

DCEC Retirement Impact on Tax Revenue

The cumulative reduction in state tax revenue through 2050 is estimated as $1,078 million, and $3,618 million for federal tax revenue. The negative tax revenue impacts are heavily concentrated in the six counties surrounding DCEC.

Effect on Tax Revenue ($ Million)

Region	State Tax Impact	Federal Tax Impact	Total Tax Impact
State Level	-$1,078	-$3,618	-$4,696
Six Counties Surrounding DCEC	-$1,148	-$3,852	-$4,999
Grundy County	-$1,150	-$3,859	-$5,008

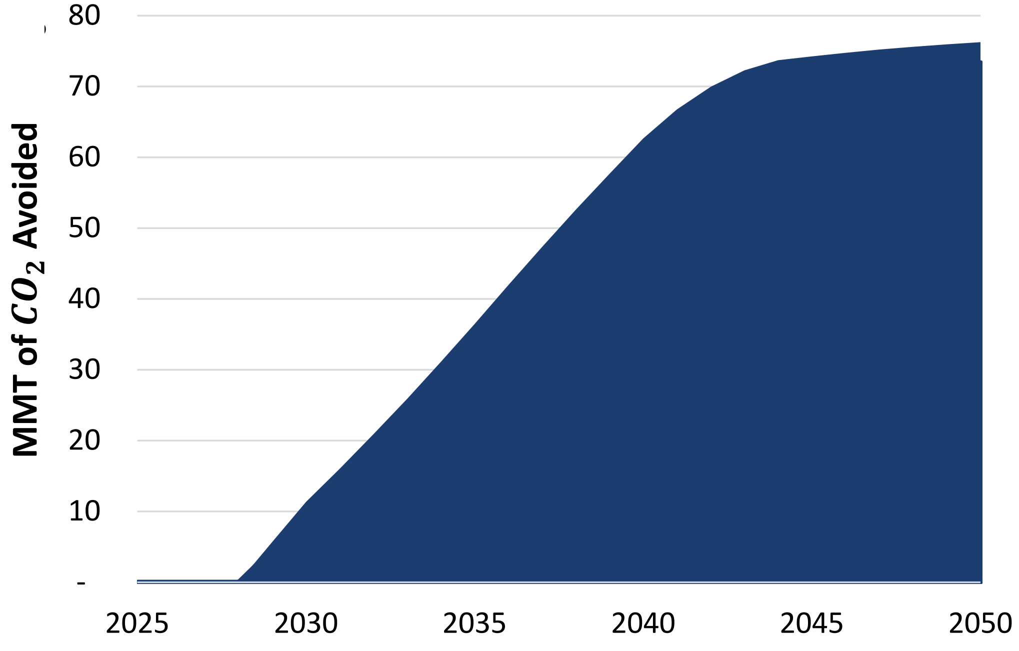
Sources and Notes:
Tax revenue is approximated as a fixed portion of GDP based on their historical relationship.
1. State tax revenue estimated using average over 2014-2023 of IL tax revenue as percent of IL GDP (5%)
2. Federal tax revenue estimated using average over 2014-2023 of federal tax revenue as percent of federal GDP (17%)

DCEC Retirement Impact on Emissions

Dresden's clean energy generation will reduce total CO_2 emissions by over 76 million metric tons (MMT) during its operations until 2050. Dresden produces the same amount of energy annually as three-fifths of renewable resources in the state and accounts for approximately 11% of Illinois' annual electricity demand (as of 2023).[1]

Carbon Emission Reductions:

Cumulative MMT of CO_2 Avoided



- Extending Dresden avoids substantial CO_2, particularly in the early years
- Impact diminishes somewhat in later years as the grid becomes cleaner overall and there is less CO_2 to avoid

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Overview of Modeled Policies

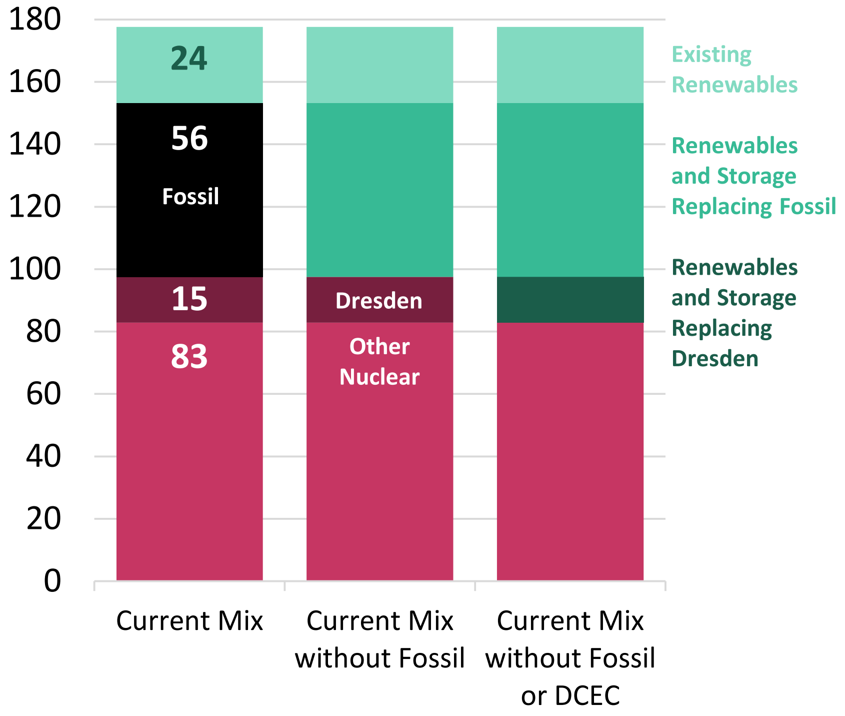
- **Renewable and Clean Energy Goals:**
  - Clean energy targets are modeled at the state level, including technology-specific procurement targets.
- **Emissions Reduction Goals:**
  - For PJM, carbon emissions limits are modeled based on state decarbonization goals.
  - For MISO, carbon emissions limits are modeled based on a combination of state and utility decarbonization goals.
- **Inflation Reduction Act:**
  - Production tax credits (PTC) are modeled for solar, onshore wind, and nuclear generation. Hydrogen PTCs are incorporated into the fuel costs for H2 resources.
  - Investment tax credits (ITC) are modeled for offshore wind and battery storage.
- **Section 45Q Credit for Carbon Oxide Sequestration**
  - Tax credit for carbon capture and storage (CCS) is modeled for all new and retrofitted CCS units.
- **Climate and Equitable Jobs Act:**
  - Currently, we model a 2045 zero-emissions deadline for IL as outlined in CEJA. The emissions limit slopes linearly from present-day levels down to zero in 2045.
  - CEJA does not explicitly call for the retirement of fossil units. However, plants that don't comply with emissions targets by the deadline (e.g., through CCS) will be forced to retire. Our model implements a phased retirement or retrofit of fossil units according to the timeline identified by the IL Dept. of Labor.

Note: Further details on modeled policies are available in gridSIM Model Assumptions appendix

Climate and Equitable Jobs Act (CEJA) Requirements

- **CEJA is modeled at the statewide and individual unit level.**
  - We model a 2045 decarbonization goal for Illinois' electric sector as well as a phased retirement of fossil plants.[1]
- **To meet CEJA requirements, Illinois will need to replace fossil generation with clean energy. Without DCEC, additional clean energy will be needed.**
  - 5.5 GW of renewables and storage are needed to replace the 1.8 GW loss from DCEC. This represents an increase of more than 50% from today's renewable and storage capacity.[3]
- **If CEJA standards are not achieved, economic benefits (GDP, tax revenue and employment) driven by clean energy investments would be lower.**
  - Failing to meet Illinois' carbon-free targets would result in less investments in clean energy resources, which partially offset the negative economic impacts of DCEC's closure.

Comparing Generation Mix[2] *(TWh)*



[1] *Climate and Equitable Jobs Act Economic and Workforce Effects Preliminary Analysis*, (IL Department of Labor)
[2] Figure illustrates impact of DCEC and CEJA retirements on today's resource mix; values reflect Illinois' 2023 generation mix based on EIA data (EIA Electricity Data Browser)
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Note: Further details on modeled policies and resource buildout in Illinois are available in gridSIM Model Assumptions appendix

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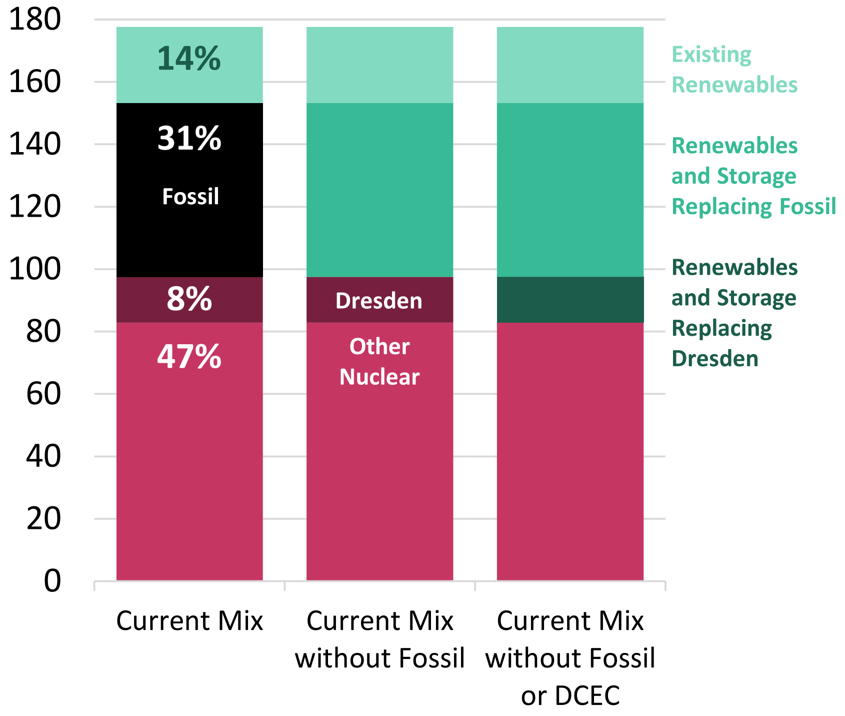

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Economic Impacts of Relicensing the Dresden Clean Energy Center (DCEC)

Project Overview

We examine the macroeconomic and power sector impacts of relicensing the **Dresden Clean Energy Center (DCEC)** in Illinois. To capture the interdependencies between the electricity sector and regional economic growth, our analysis integrates two modeling tools, characterizing first the electricity system, and also the broader economy:

- **gridSIM**, Brattle's power sector capacity expansion model, is used to simulate the power sector impacts of relicensing the DCEC. Energy demand, resource adequacy, market regulations and clean energy policies in MISO and PJM as well as those in neighboring markets were accounted for in the analysis. To model the impact of relicensing on the interchange between MISO and PJM, the two electricity markets that supply electricity in Illinois, gridSIM optimizes capacity expansion in both markets.
- **REMI Policy Insight Model**, a dynamic economic impact assessment tool, is used to simulate regional economic impacts. The model evaluates key macroeconomic indicators in Illinois including state GDP, employment and industrial production. Economic impacts consider two channels: the direct loss in employment and spending in Grundy county due to closure of DCEC; and the power sector impacts driven by changes in the generation resource mix (i.e., changes in customer electricity costs and resource investment in Illinois).

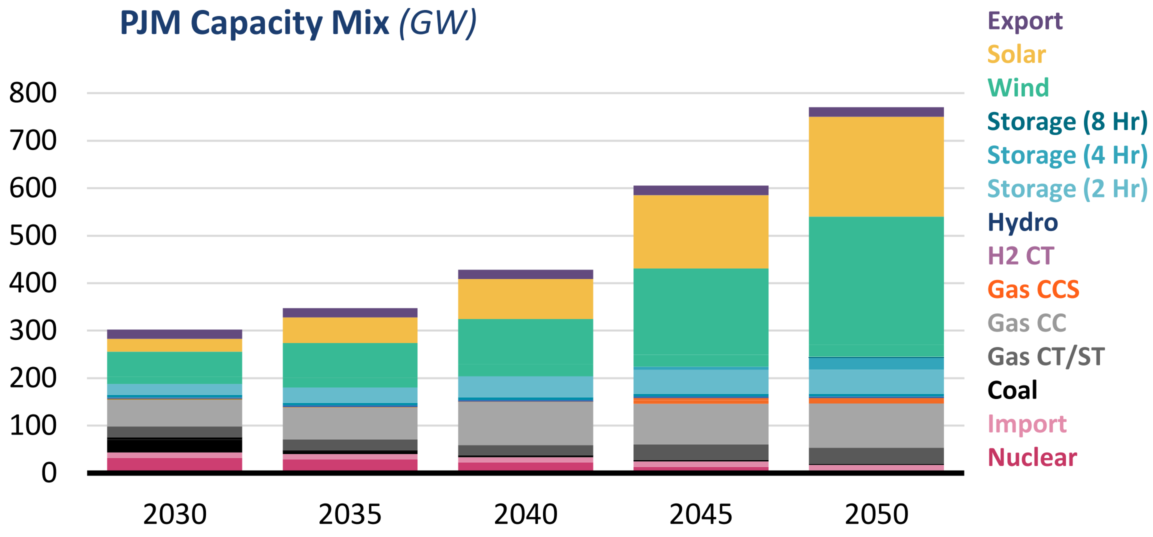
We assess the value of extending the plant's license by comparing two scenarios:

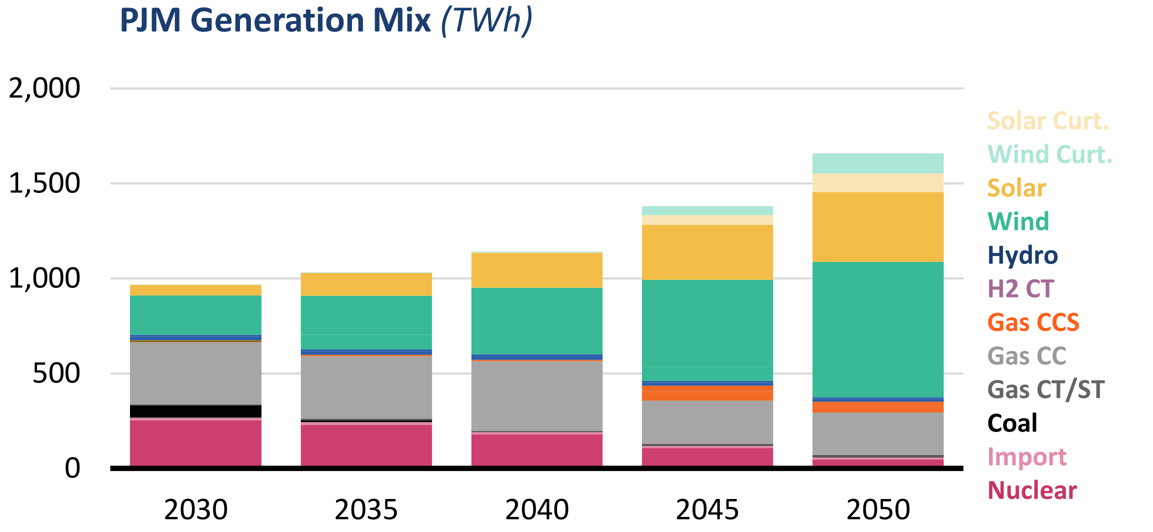
- Reference scenario: DCEC operates until the end of the renewed license (2049 for Unit 2 and 2051 for Unit 3).
- Alternate scenario: DCEC retires at end of current license (2029 for Unit 2 and 2031 for Unit 3).

Power Sector Modeling

REFERENCE SCENARIO RESULTS

Capacity and Generation Mix in PJM



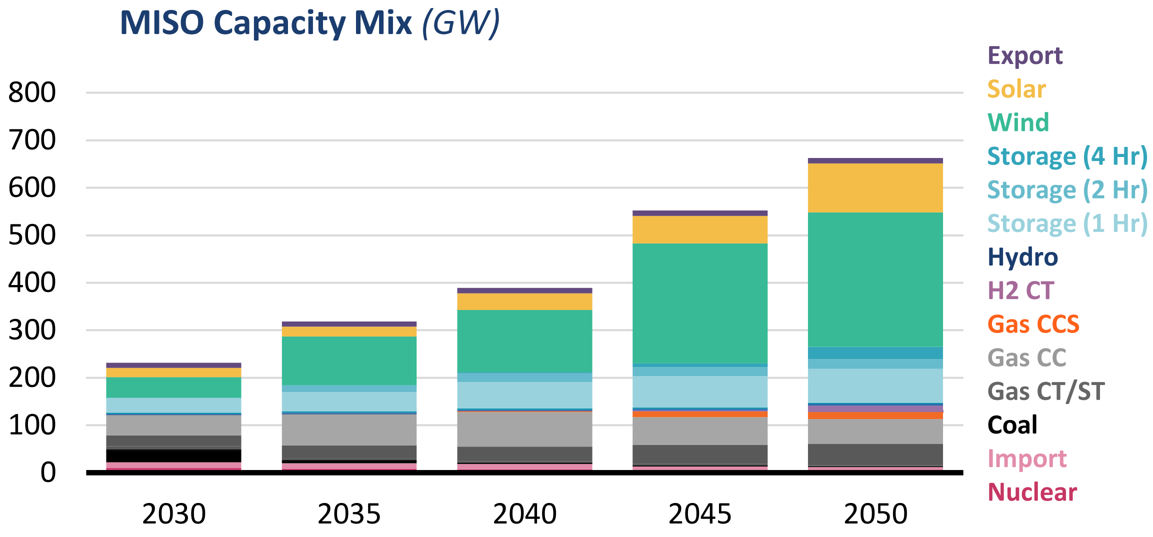


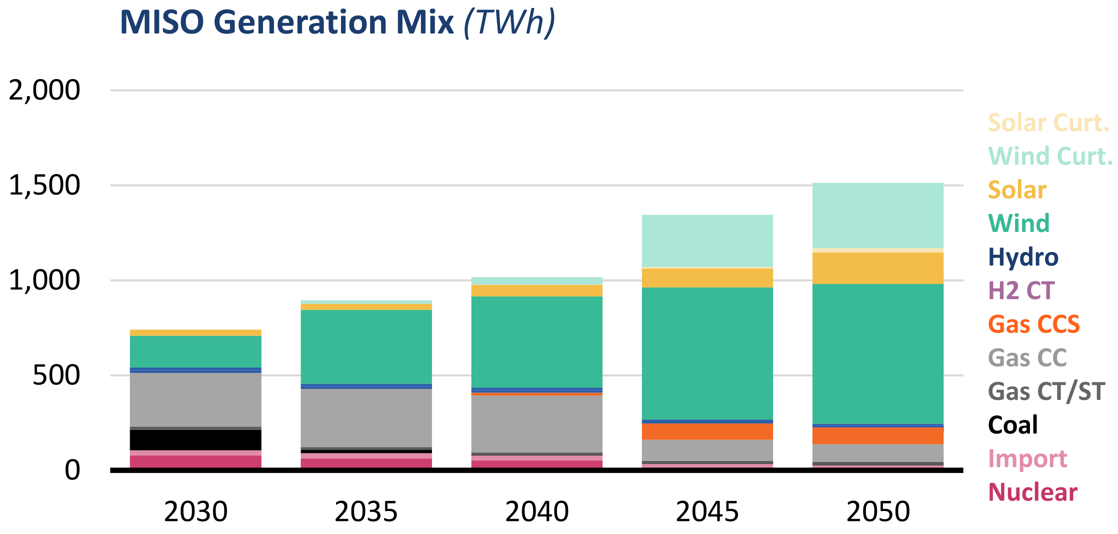
Comparison to National Renewable Energy Laboratory (NREL) Cambium 2023 Data*:

- Buildout of ELCC resources as a whole (at resource portfolio level) is aligned in 2040.
  - Total wind and solar capacity in 2040 is 204 GW in SIM and 217 GW reported by NREL.
  - Penetration of ELCC resource type (wind vs. solar) differs due to differences in modeled capacity accreditation. (gridSIM explicitly models how intermittent and correlated renewables affect system capacity; Cambium makes simplifying assumptions).
- gridSIM's remaining gas capacity of 118 GW + 12 GW CCS in 2045 is consistent with NREL Cambium's high electrification scenario, which shows 125 GW.
- Up-to-date project pipeline and retirement data are _not_ fully accounted for in Cambium Report. Retirement schedule of nuclear plants also differs.

* High Electrification scenario, https://scenarioviewer.nrel.gov/

Capacity and Generation Mix in MISO





Comparison to MISO Futures Report*:

- Total wind capacity is between the Futures 2A and 3A scenarios. Solar capacity is lower due to differences in resource accreditation and generation profiles. Battery penetration is aligned with combined Battery & DER capacity in the Futures scenarios.
- Penetration of gas plants, *particularly peakers***, is higher in gridSIM (107 GW in 2040 vs. ~80 GW in report). This is explained by:
  - More aggressive carbon reduction and renewable penetration constraints that result in 83% to 99% carbon reduction by 2042 across the three futures. Based on state and utility-level data, our model finds the 2042 MISO carbon reduction target in gridSIM to be 72%.
  - How renewable resources are assumed to contribute to meeting peak load. Futures report assumes exogenous capacity credit for ELCC resources (e.g., solar starts with 50% capacity credit and decreases by 3% starting in year 2028 and does not go below 20%).

* https://cdn.misoenergy.org/Series1A_Futures_Report630735.pdf

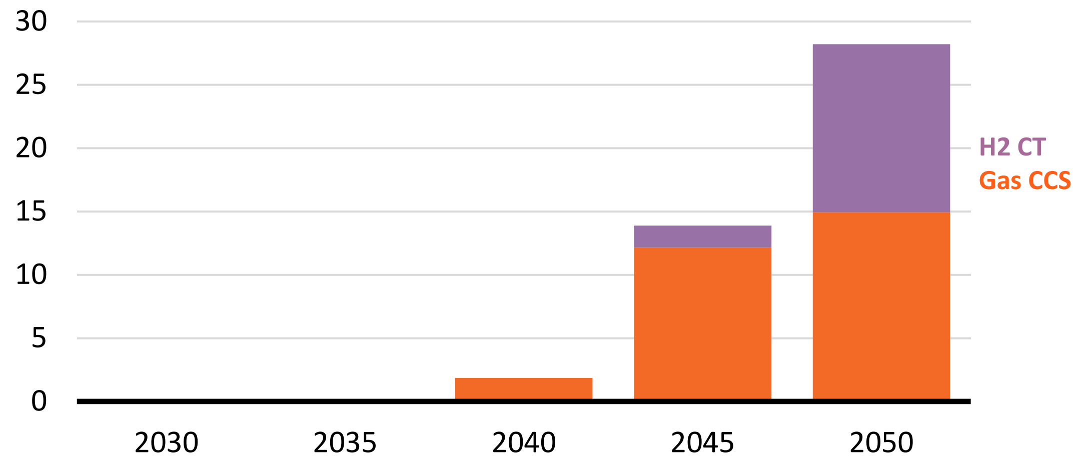
** MISO *Futures Report also states that natural gas resource builds represent peaker plants that operate during ramping hours when wind and solar generation is sparse.*

Dispatchable Emerging Technology Capacity

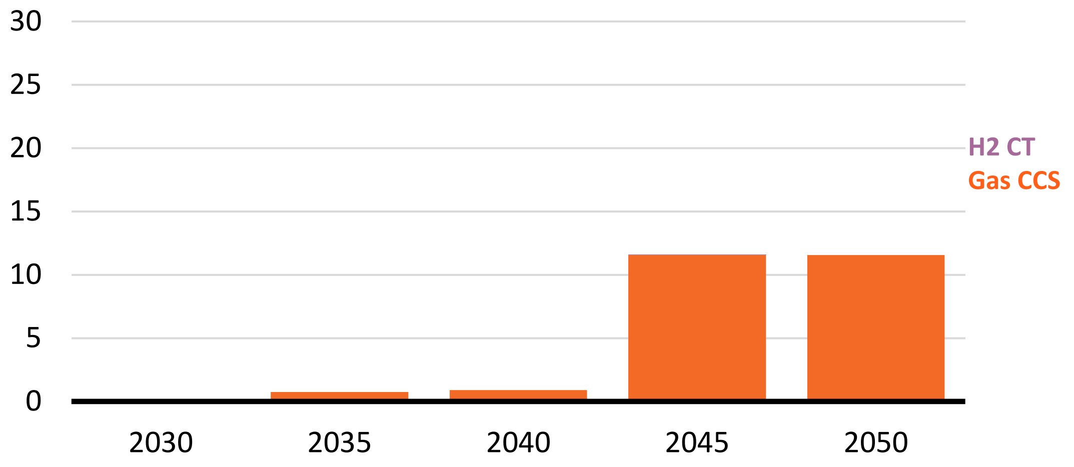
Model Results and Comparison to Public Reports:

- gridSIM allows Carbon Capture and Storage (CCS) resources to be used at scale starting in 2030.
- Hydrogen to be used for generation starting 2036.
- The model can build CCS resources as soon as 2030, but only economically chooses to do so in 2036 onwards.
- Dispatchable emerging technology resources make up 4% of the 2050 MISO capacity mix and 1.6% of the 2050 PJM capacity mix.
- While MISO has more dispatchable emerging technology capacity than PJM, generation from these resources are similar in magnitude.
- MISO Futures Report, *MISO Future 2* shows 29 GW of dispatchable emerging technology capacity in 2042.
- The PJM Cambium Report shows 5 GW of CCS capacity in 2040.

MISO Capacity Mix *(GW)*



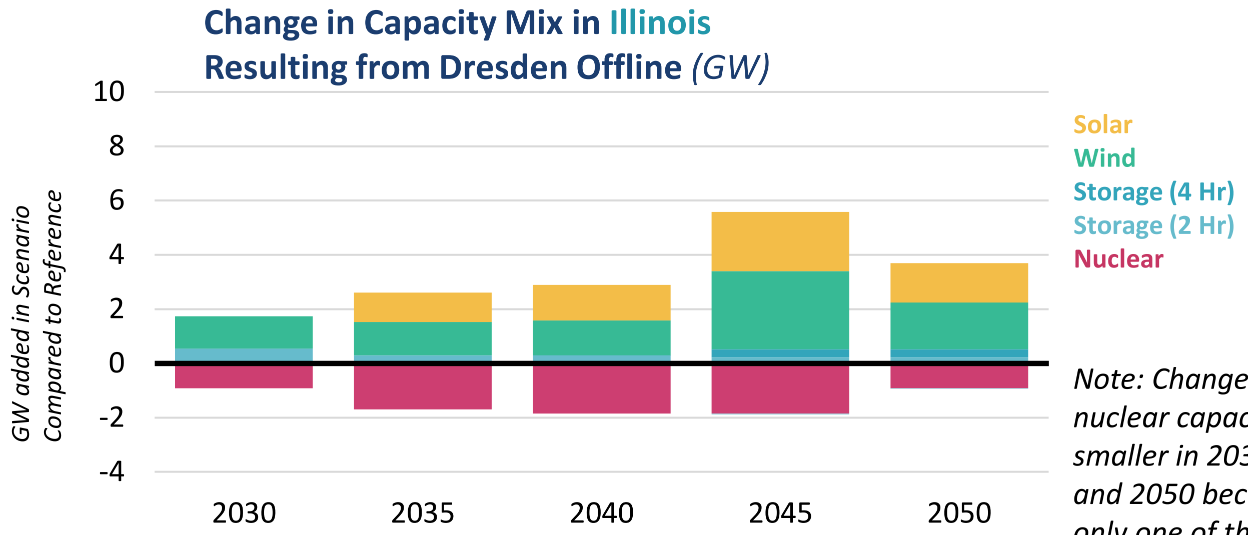
PJM Capacity Mix *(GW)*



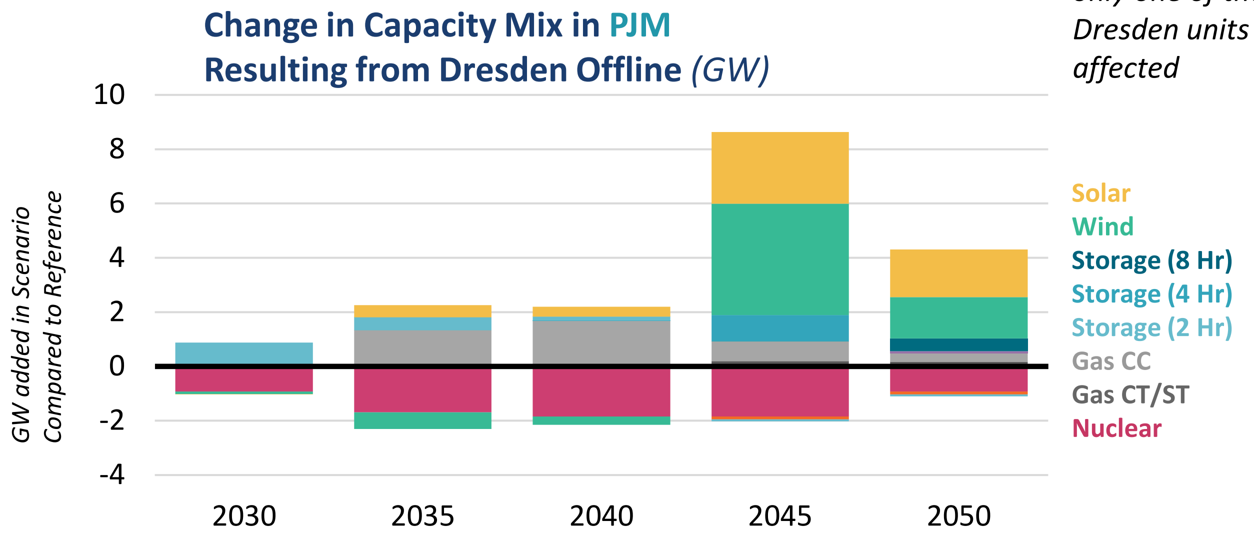
DCEC Retires in 2029 (Unit 2) and 2031 (Unit 3)

POWER SECTOR IMPACTS

Capacity Impacts in Illinois and PJM

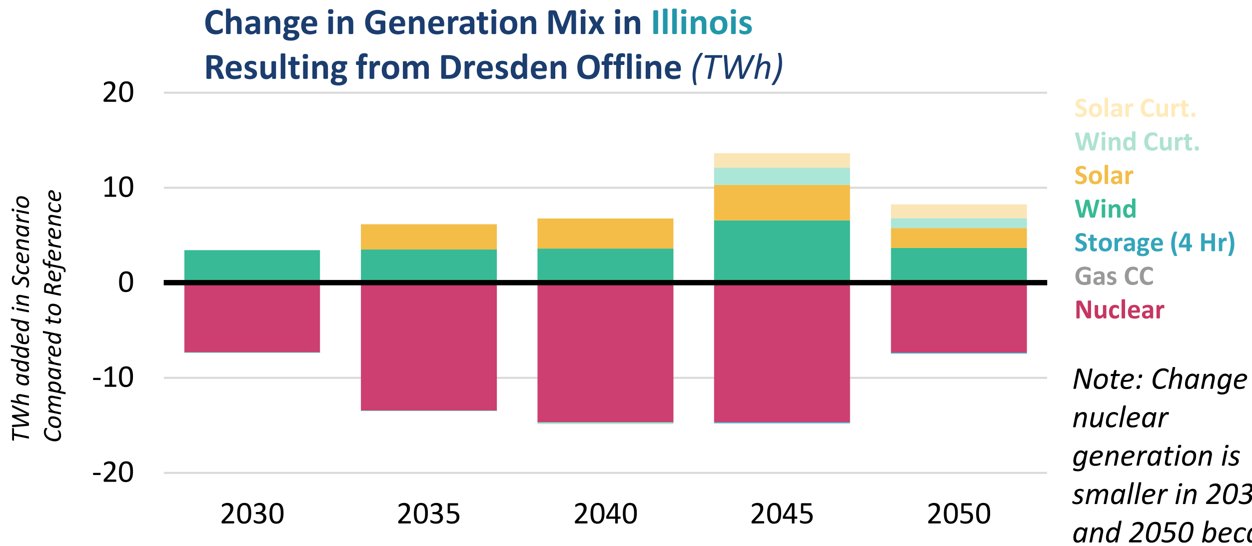


Note: Change in nuclear capacity is smaller in 2030 and 2050 because only one of the Dresden units is affected



- **Retiring Dresden leads to:**
  - In PJM, a combination of more fossil resource builds (Gas CT and CC) for reliability, and more renewables and storage (especially post-2045) to meet emissions goals.
  - Minor impact on MISO's capacity mix.
  - As a result of CEJA, none of the change in natural gas capacity occurs in Illinois.
  - Renewable and storage capacity in Illinois determined based on state RPS targets and Illinois' historical portion of capacity within the PJM-ComEd region.
  - A large portion of the capacity deficit created by the retirement of Dresden is filled internally within PJM-ComEd. This is driven by the zone's high internal resource requirement for reliability.

Generation Impacts in Illinois and PJM



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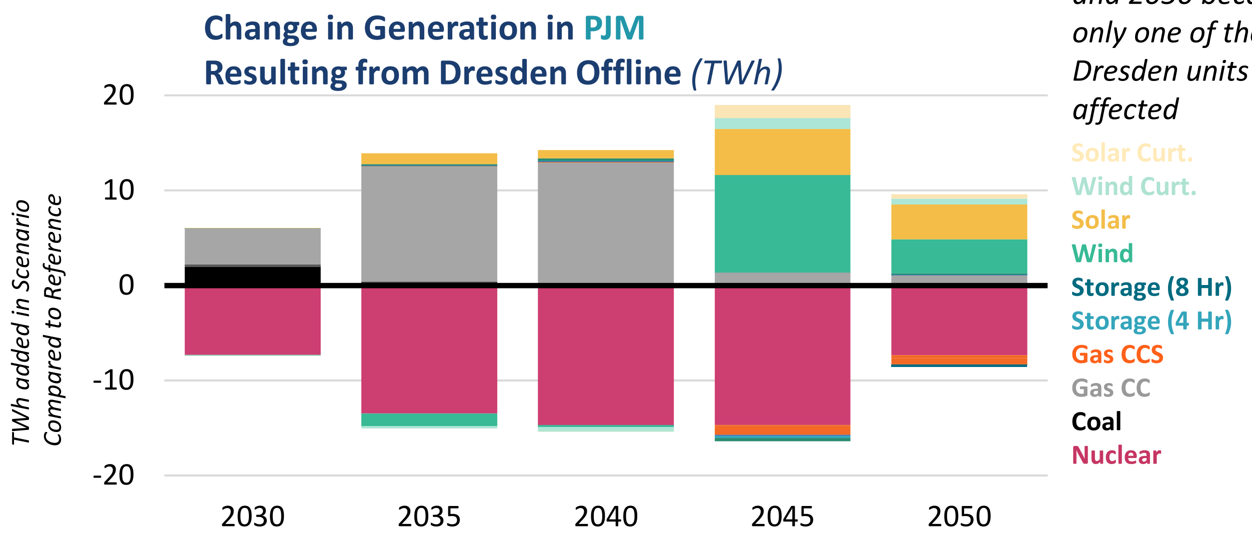
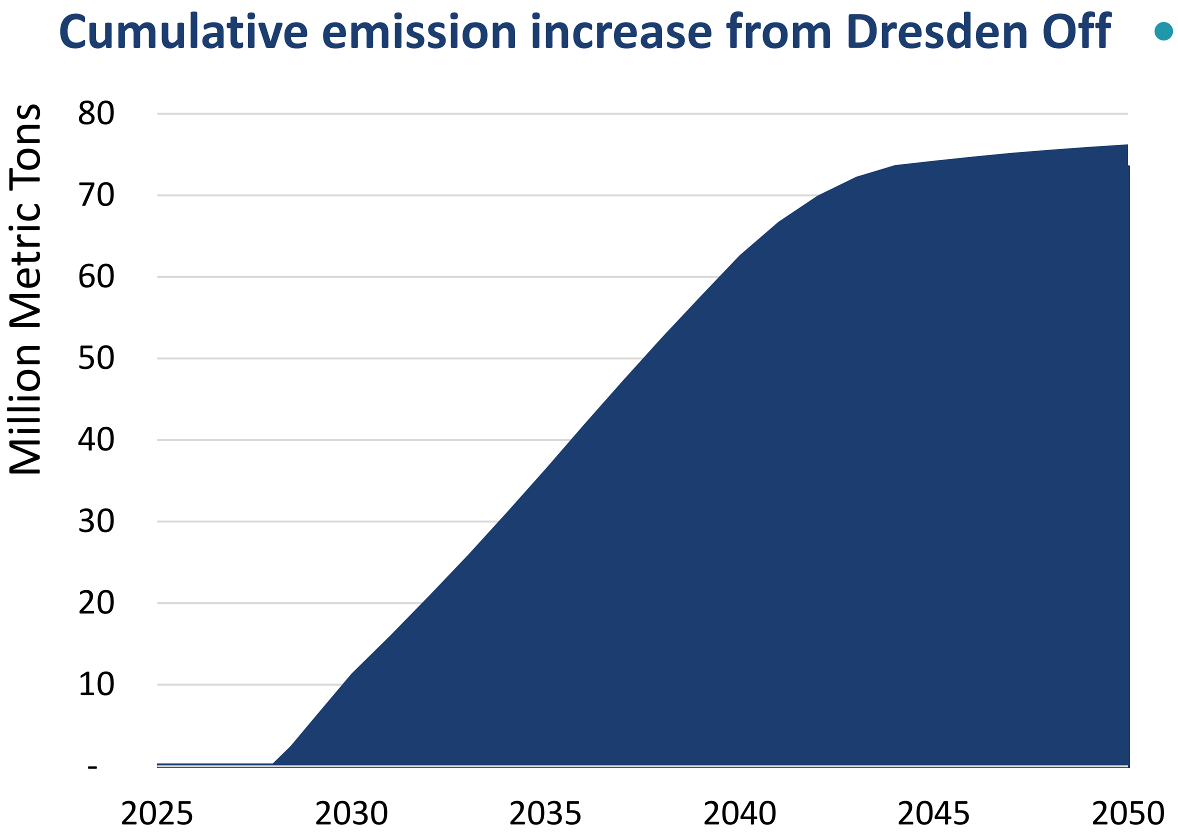


- **Retiring Dresden leads to:**
  - Increased fossil generation and more air pollution in PJM, particularly before 2045.
    - Generation from Dresden is almost entirely replaced by generation from gas combined cycle plants in the near-term; by renewables in the longer term.
  - Large portion of the change in generation occurs within PJM-ComEd, as the region is largely self-reliant due to its high internal resource requirement for reliability purposes.
  - As a result of CEJA, none of the change in fossil resource generation occurs in Illinois.
  - For the MISO portion of Illinois, renewable and storage generation in Illinois determined based on state RPS targets and Illinois' historical portion of capacity within the MISO-Central* region.

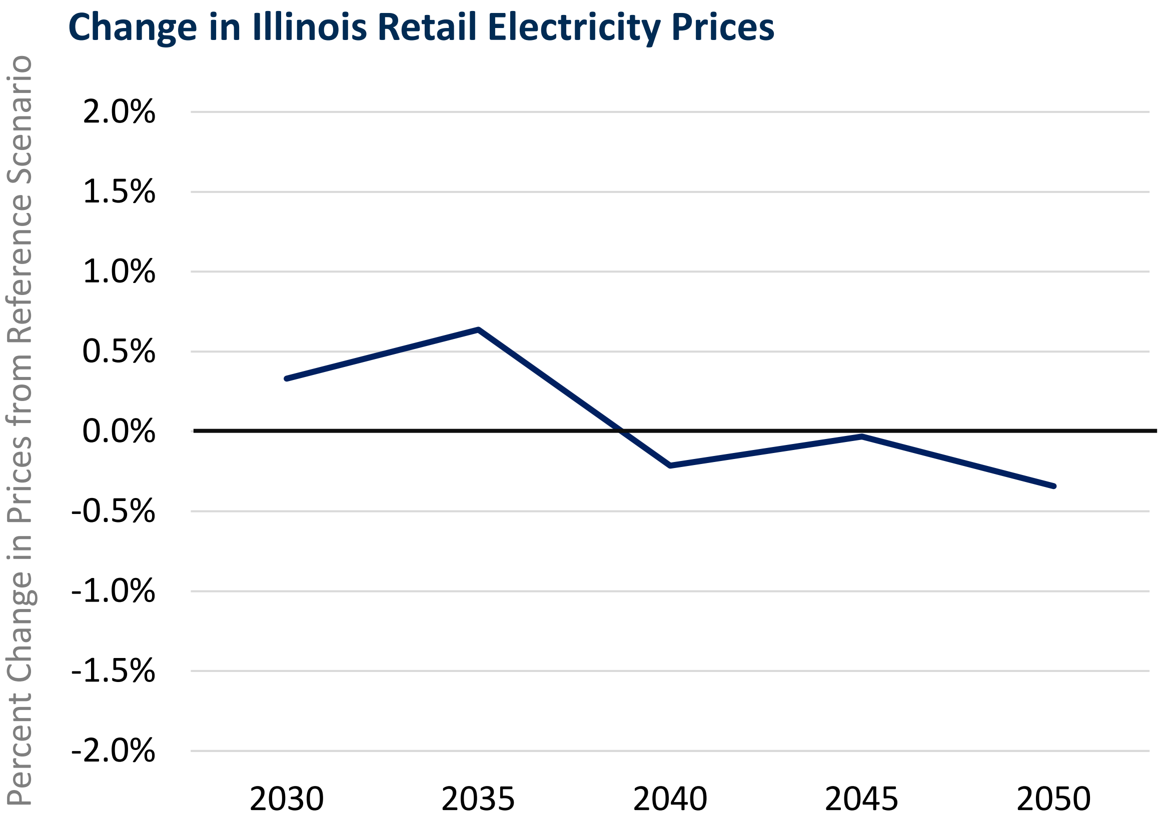
*MISO-Central is modeled as a single region composed of Local Resource Zones (LRZs) 4, 5, and 6. Within MISO-Central, IL specific capacity is determined based on historical capacity share by state. Resulting capacity in IL is consistent with CEJA, the state's RPS targets and resource adequacy requirements in MISO and PJM.

DCEC Retirement Impact on Emissions



- **Retiring Dresden leads to:**
  - Large emissions increase as more fossil resources are built and used for generation in PJM (outside of Illinois) when Dresden is retired.
  - More than 76 million metric tons of additional CO_2 emissions by 2050.
  - Emissions steadily increase until 2045; emissions increase at a declining rate after 2045 due to Illinois' zero carbon standard.

Retail Electricity Price Impact



The retail electricity price impact shown above is calculated as one-third of the wholesale electricity price impact. Wholesale prices ($/MWh) are the sum of energy, capacity, and ZEC prices. IL prices are calculated as the load-weighted average of MISO-Central and PJM-ComEd regions. Further details are available in gridSIM Model Assumptions appendix

- **Retiring Dresden leads to:**
  - Increased wholesale energy prices are due to a high portion of Dresden's generation being replaced by dispatchable generation in neighboring states (largely gas generation before 2045).
    - Change in retail electricity rates in Illinois is due to higher wholesale energy prices largely balancing lower wholesale capacity prices.
  - A shift in renewable energy builds to earlier years due to closure of DCEC decreases the cost of meeting Renewable Portfolio Standards (RPS) in later years, contributing to lower retail electricity rates.
  - Further penetration of renewables due to IL's zero carbon standard imposed in 2045 results in both lower wholesale energy and capacity market prices, contributing to lower retail electricity rates.
    - Wholesale capacity prices decrease as higher renewable penetration increases the capacity value of storage.

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ECONOMY-WIDE IMPACTS

DCEC Retirement Impact on Illinois GDP

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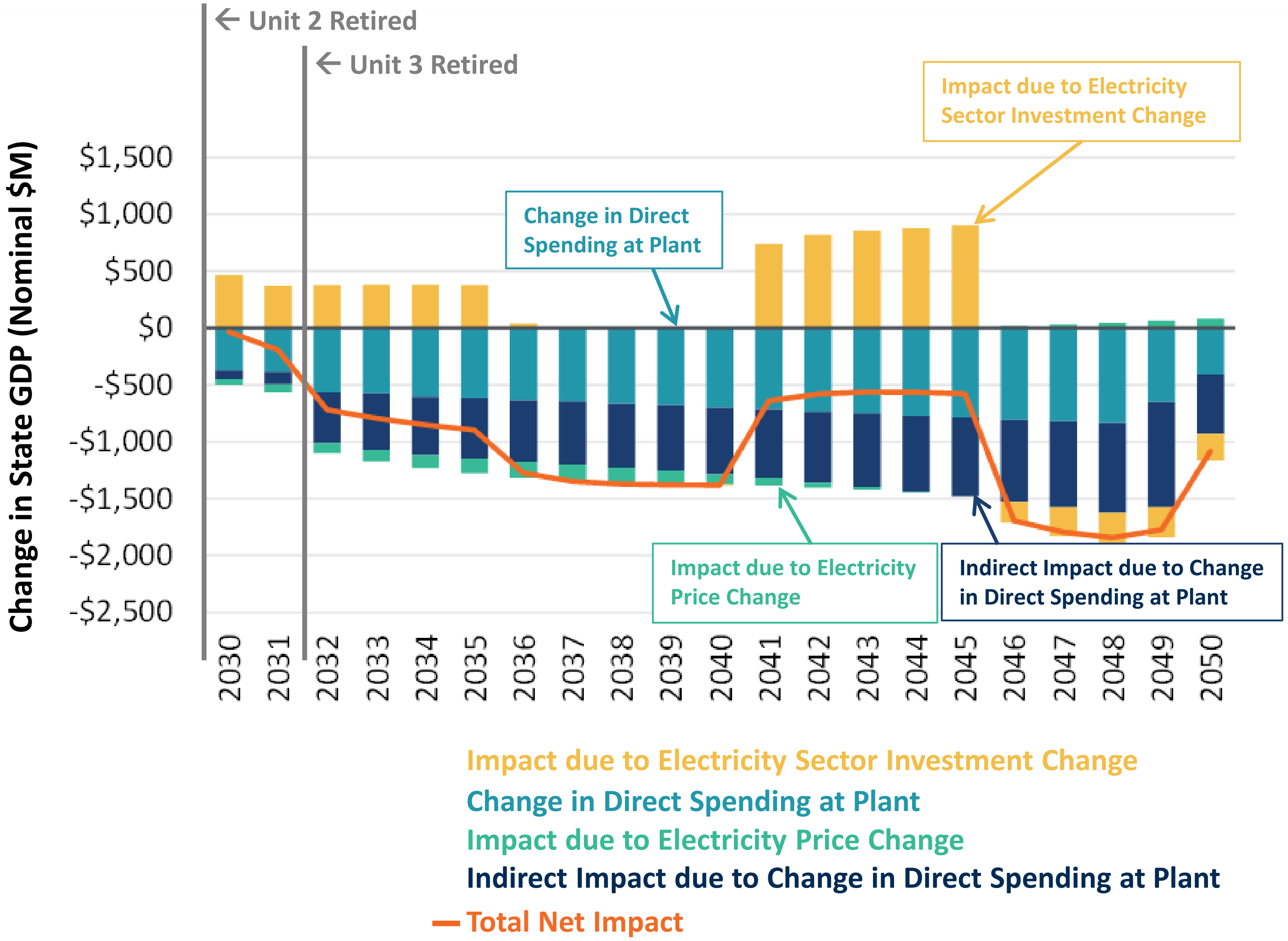

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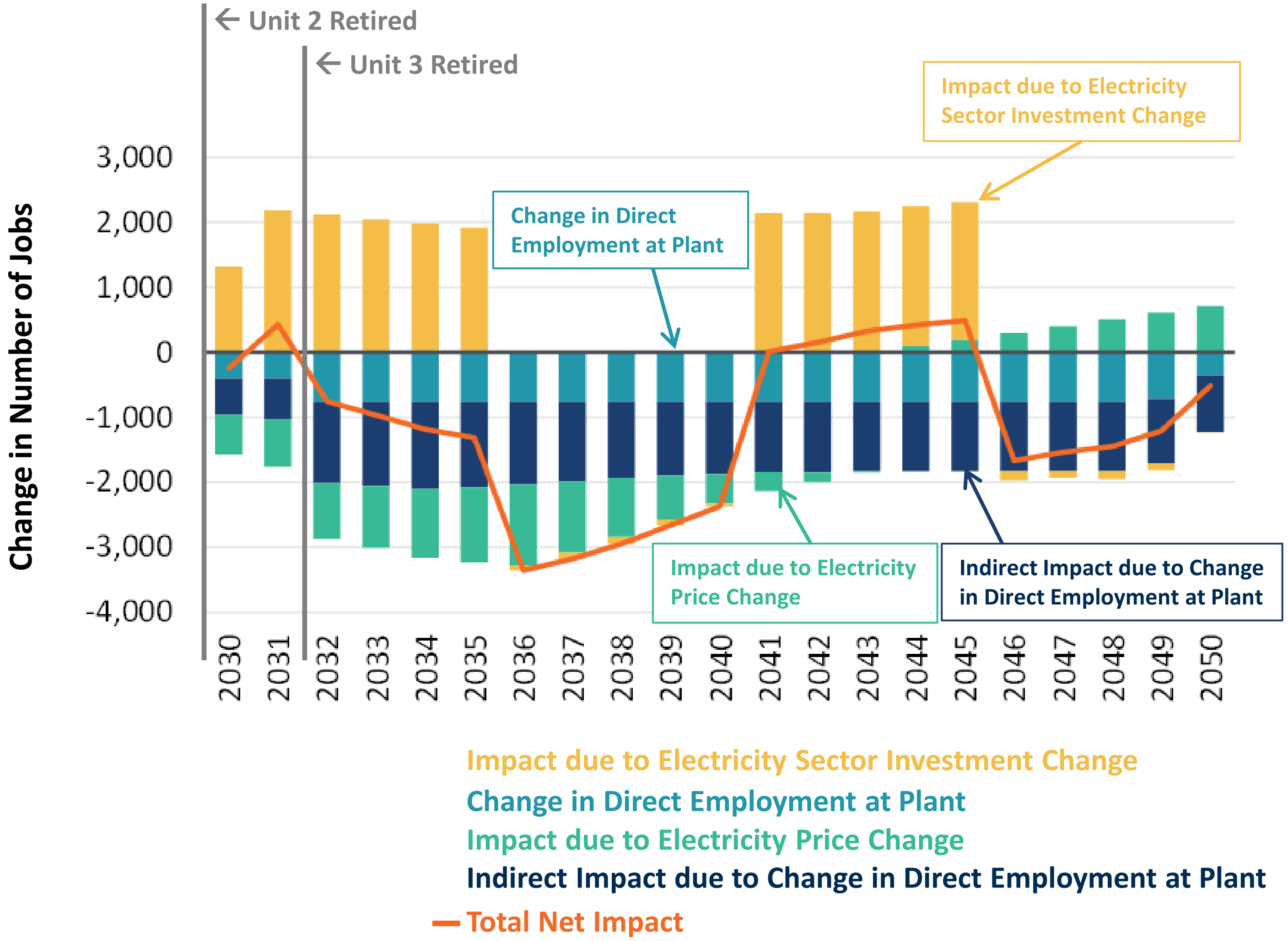

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Distribution of Impacts Across Neighboring Counties

The distribution of impacts across neighboring counties are driven by inter-county relationships that include:

- **Industry-level trade flows**, which dictate where Grundy businesses spend on their supply chain and Grundy consumers spend their disposable personal income.
- **Commuting patterns**, which dictate how much income earned in Grundy stays locally or is spent in the surrounding counties from which workers commute.
- **Population migration**, specifically in response to changing economic conditions.

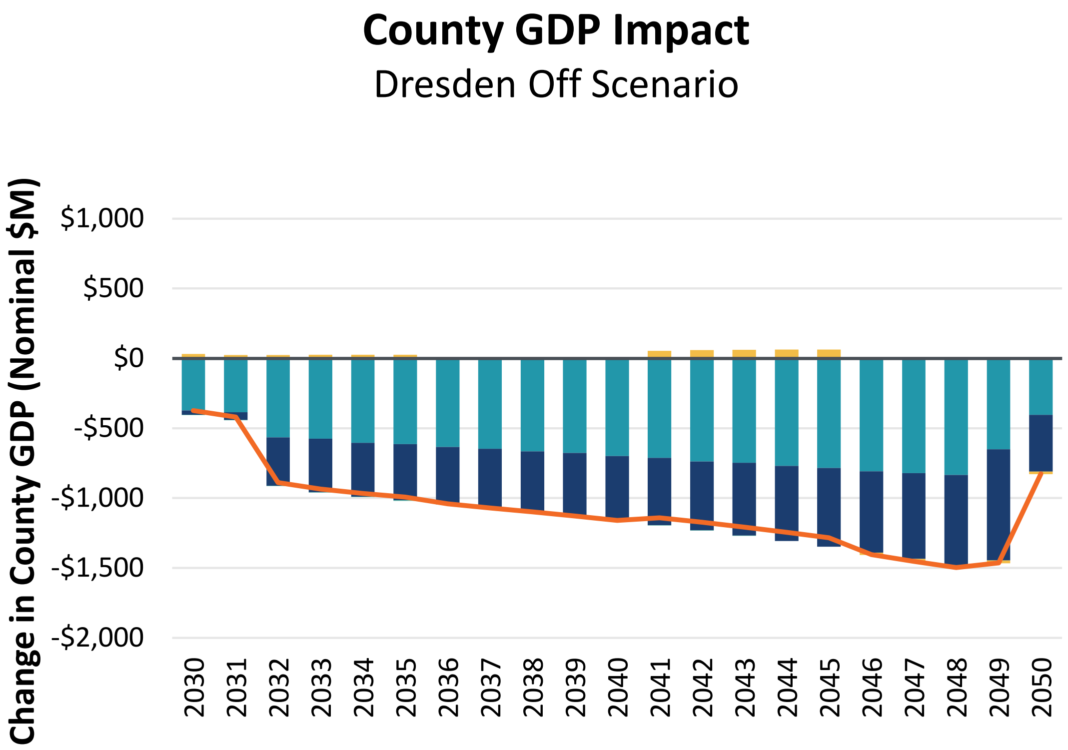
The model assumes people stay or relocate into a region over time based on relative employment opportunities and earnings.

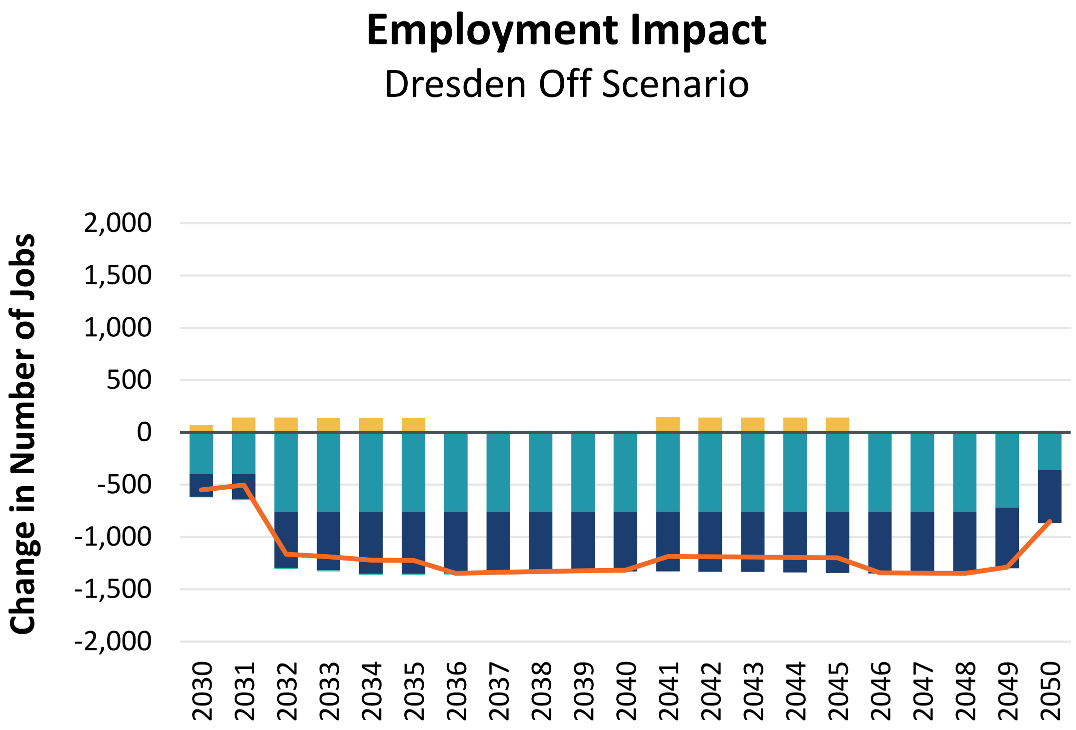
Will County, a relatively large neighboring county to Grundy, experiences negative employment gains for the duration of the forecast period, however at a declining rate after year four. Dresden's workers are employed over time by Will County's relatively large Transportation and Utilities sectors. Indirect and induced employment related to employee earnings will also shift from Grundy County towards Will County over time.

Both Will County and LaSalle County have large utility industries that together account for around 15% of the state's utility industry. As the investment in additional in-state generation resources needed after DCEC's closure is distributed regionally based on the size of the regions' utility industry, Will and LaSalle counties show relatively large electricity sector investments that can offset the losses resulting from plant closure and higher electricity prices.

DCEC RETIRES IN 2029 & 2031: ECONOMY-WIDE IMPACTS

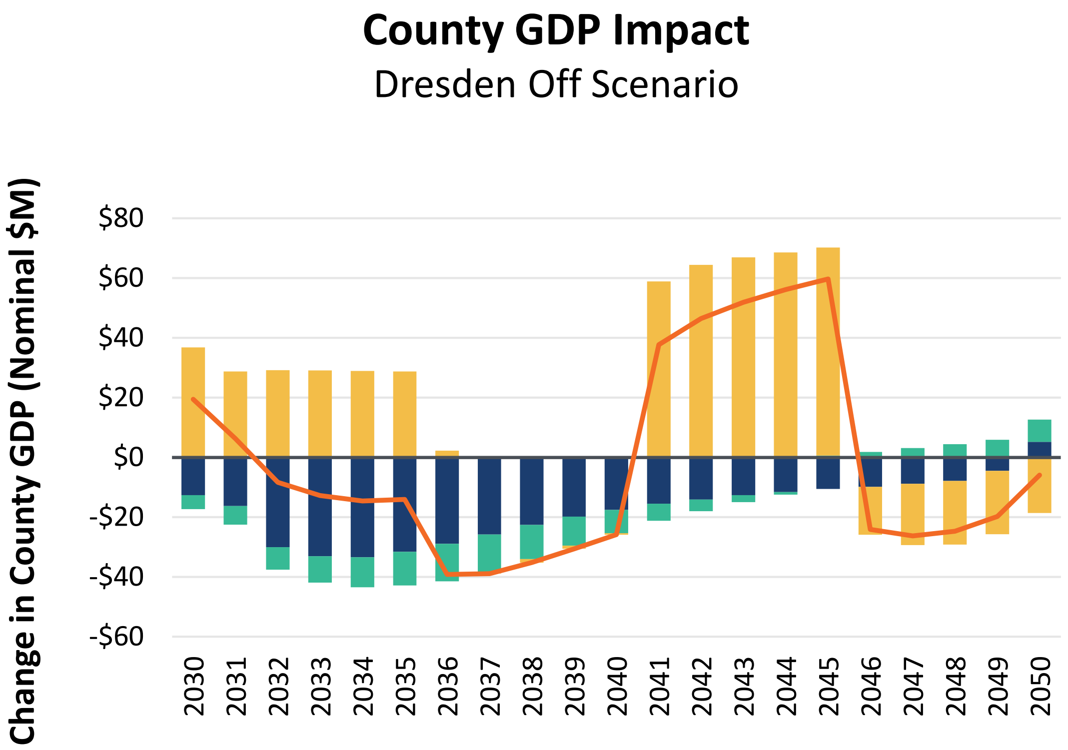
Grundy County Impact

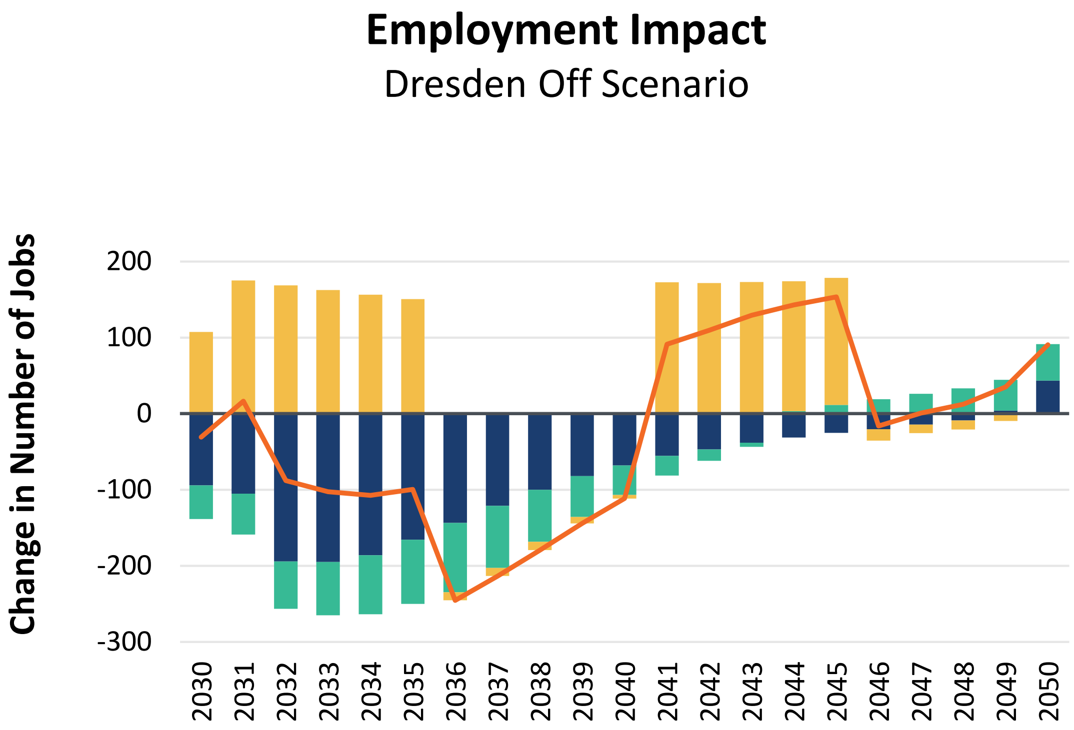




Impact due to Electricity Sector Investment Change
Impact due to Direct Plant Spending and Employment
Impact due to Electricity Price Change
Indirect Impact due to Change in Direct Spending at Plant
Total Net Impact

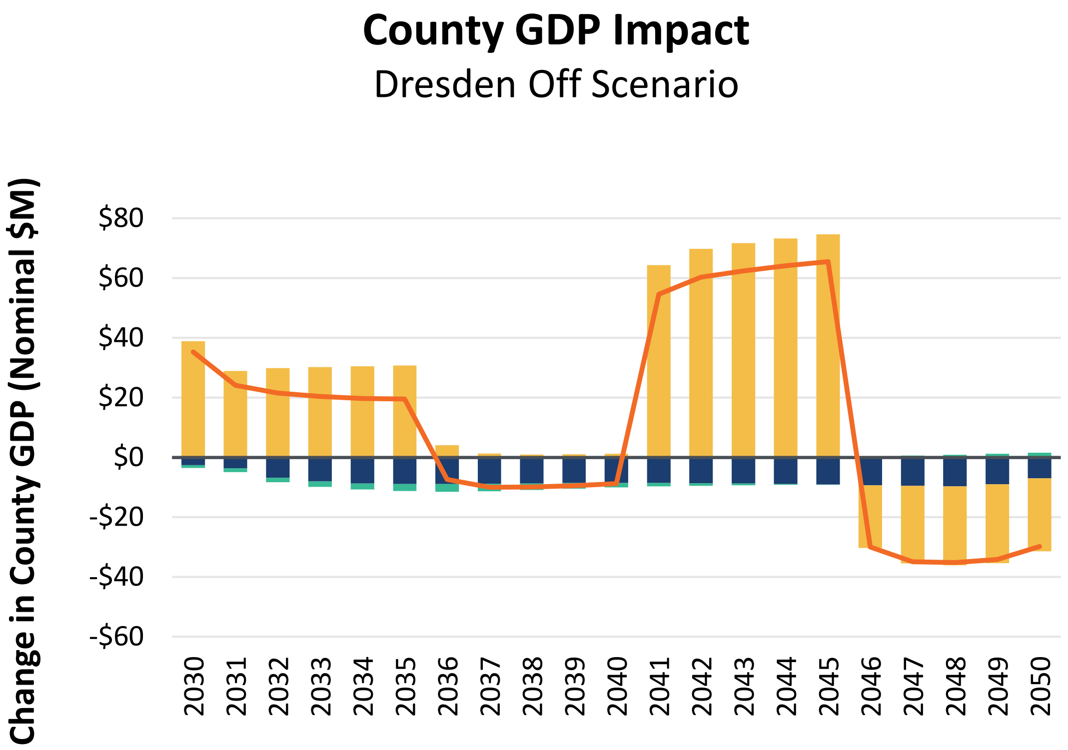
Will County Impact

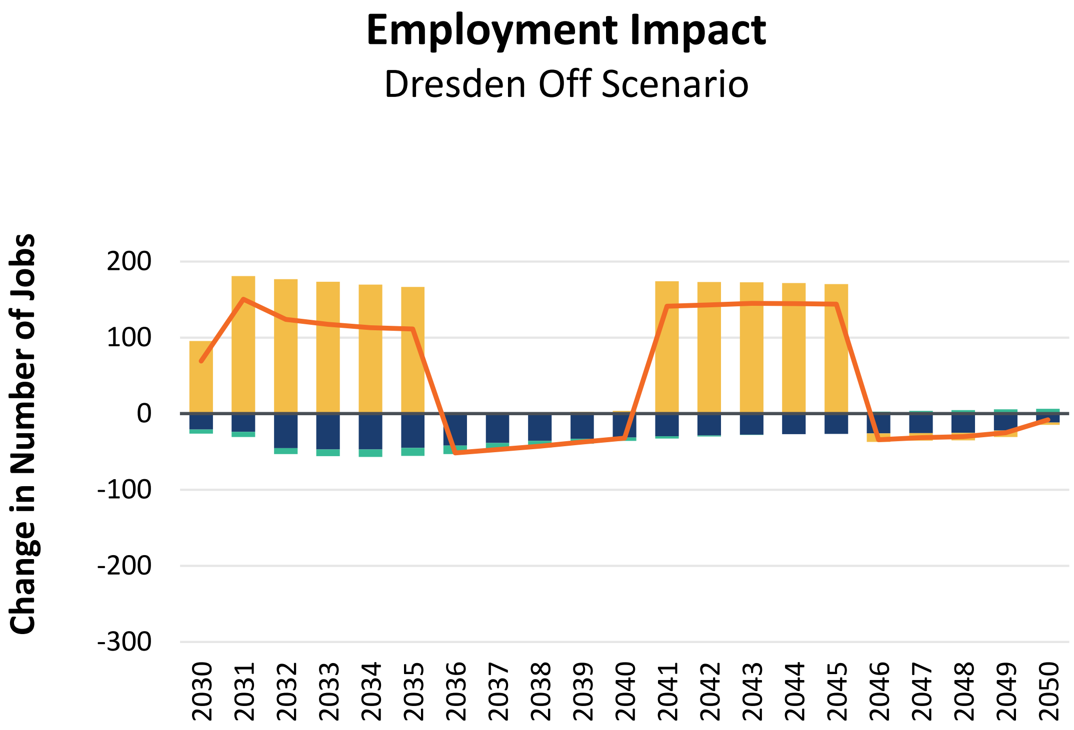




Impact due to Electricity Sector Investment Change
Impact due to Direct Plant Spending and Employment
Impact due to Electricity Price Change
Indirect Impact due to Change in Direct Spending at Plant
Total Net Impact

LaSalle County Impact

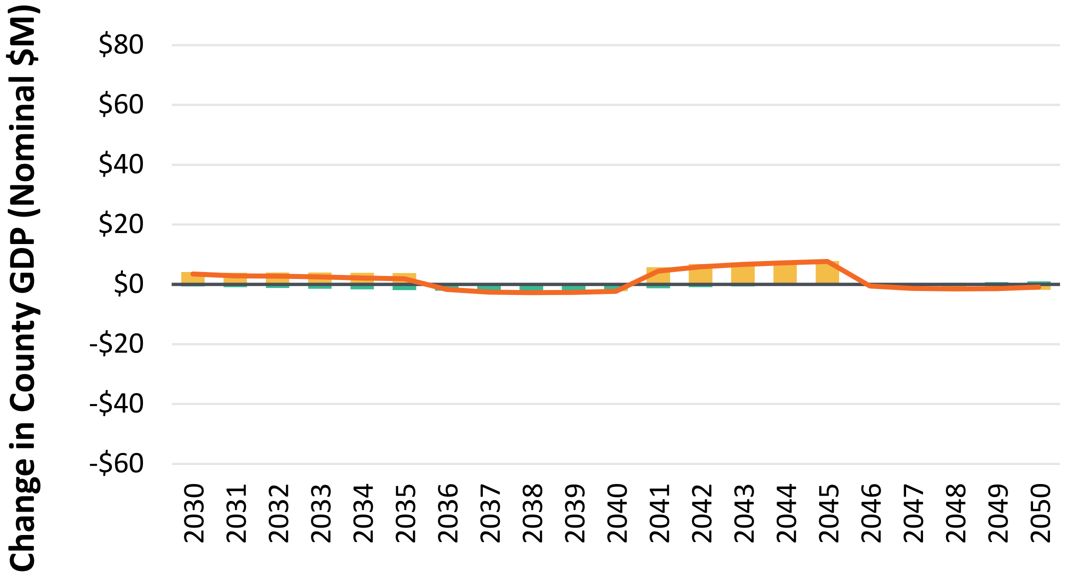




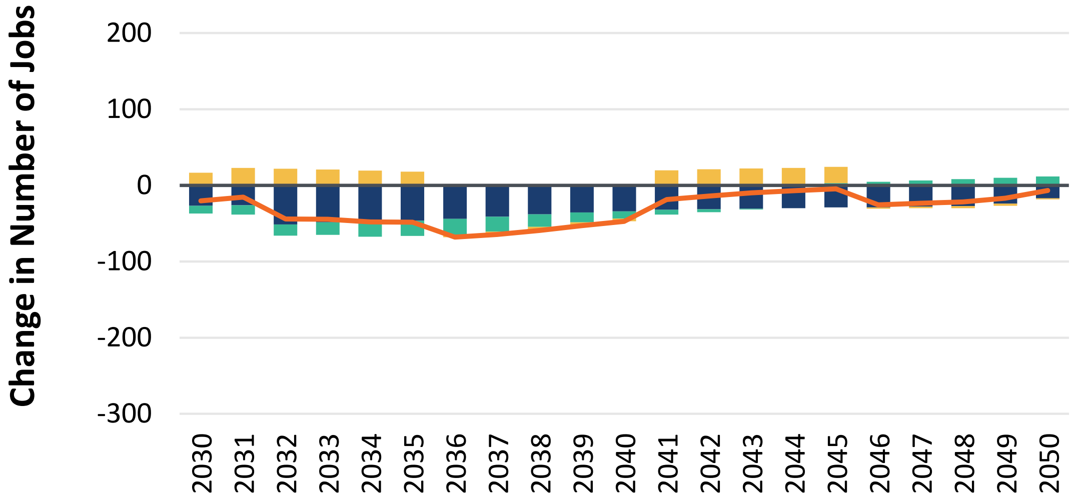
Impact due to Electricity Sector Investment Change
Impact due to Direct Plant Spending and Employment
Impact due to Electricity Price Change
Indirect Impact due to Change in Direct Spending at Plant
Total Net Impact

Kendall, Kankakee, and Livingston Counties Impact

County GDP Impact
Dresden Off Scenario

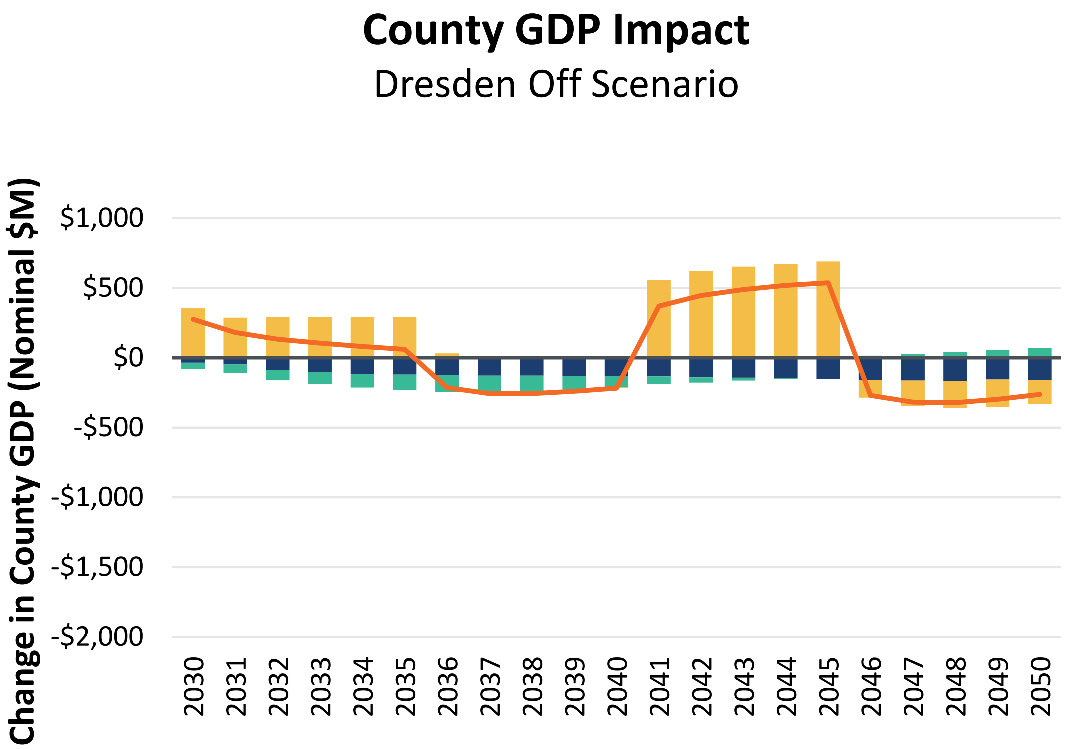


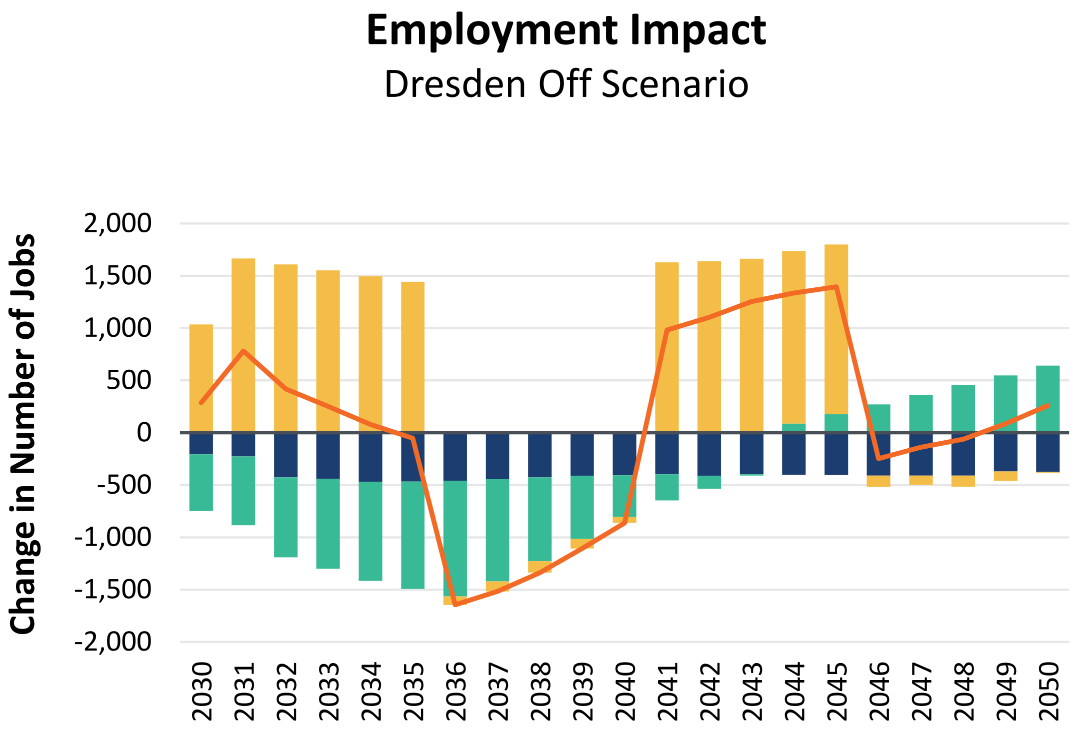
Employment Impact
Dresden Off Scenario



Impact due to Electricity Sector Investment Change
Impact due to Direct Plant Spending and Employment
Impact due to Electricity Price Change
Indirect Impact due to Change in Direct Spending at Plant
Total Net Impact

All Other IL Counties Impact





Impact due to Electricity Sector Investment Change
Impact due to Direct Plant Spending and Employment
Impact due to Electricity Price Change
Indirect Impact due to Change in Direct Spending at Plant
Total Net Impact

Technical Appendix

Model framework and assumptions

REMI Model Assumptions

Modeling Economy-Wide Impacts in REMI

The **REMI Policy Insight Model** is a dynamic forecasting and policy analysis tool. REMI integrates input-output, computable general equilibrium and econometric methodologies to simulate policy impacts. The model evaluates key macroeconomic indicators including GDP, employment and industrial production.

We modeled the following aspects of relicensing the Dresden Clean Energy Center (DCEC):

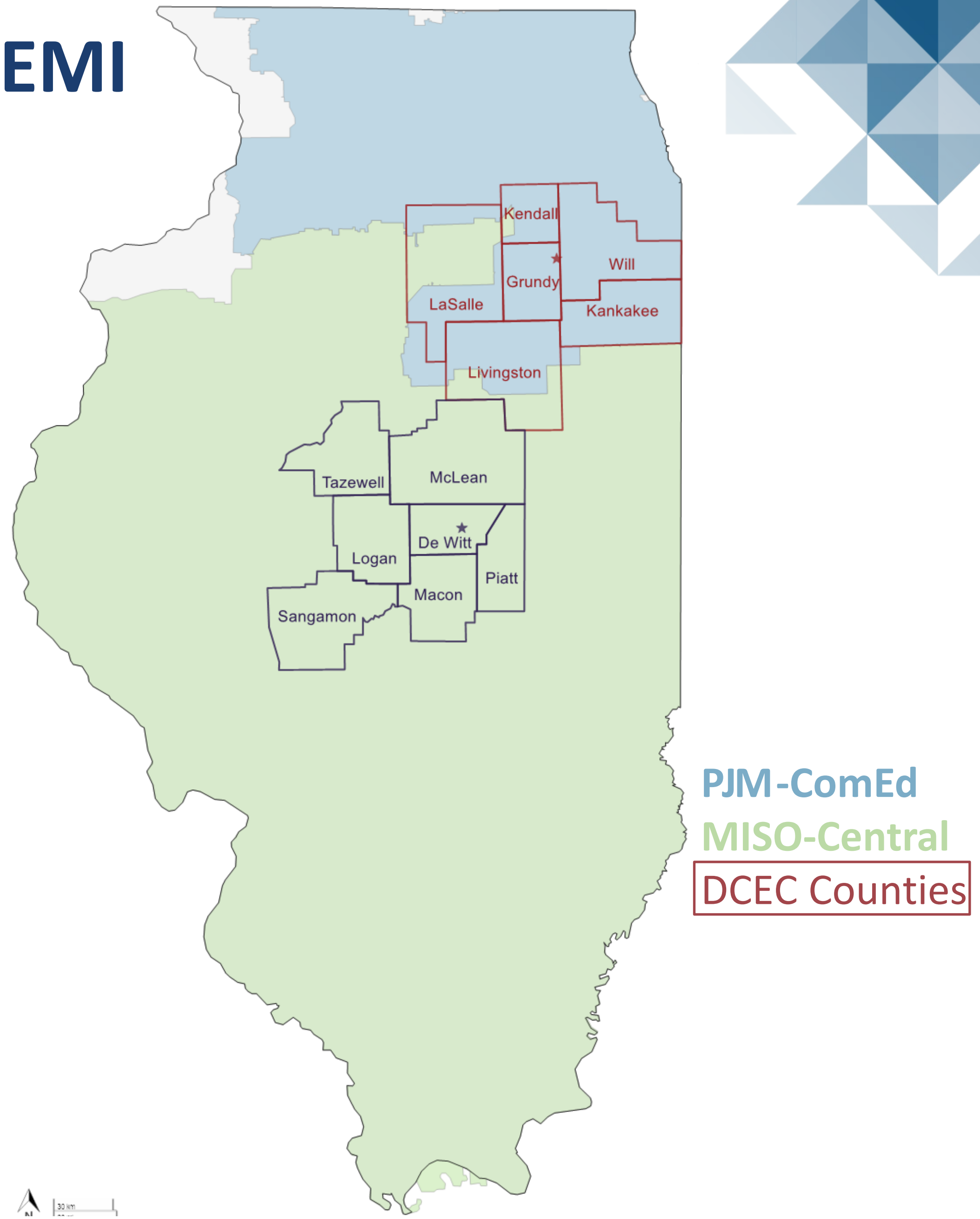
- **Direct Employment and Spending at DCEC:** All direct investments to operate Dresden were exogenously specified and are assumed to occur in Grundy County. Resulting GDP and employment impacts in IL driven by the operation of DCEC are assessed using REMI.
- **Economic Activity Driven by Net Electricity Sector Impacts:** Changes in the power sector are estimated using Brattle's proprietary capacity expansion model, gridSIM. These projected impacts, including changes to the generation resource mix and electricity rates, are modeled in REMI to assess the impact IL's GDP and employment. Changes in system costs due to DCEC retiring are distributed across counties based on county population.

Two scenarios were analyzed:

- A reference scenario in which DCEC's license is extended
- An alternate scenario in which DCEC stops operations at currently scheduled retirement year

Modeling Electricity Price Impacts in REMI

- The retirement of DCEC results in change in electricity prices in IL. Change in electricity prices impacts consumption of both electricity and non-electricity goods and services for firms and households in the regional economy. Increase in prices often results in lower overall consumption for households and lower output for producers.
- REMI models the percent change in electricity prices at the commercial, industrial and consumer level, using price changes specific to PJM or MISO (determined by gridSIM).
    - For Grundy county (the county in which DCEC is located) and its five neighboring counties, price changes are assigned based on the electricity market in which each county is predominantly located.
    - For the rest of Illinois, price changes are weighted proportionally to the population in the PJM and MISO regions.



gridSIM Model Assumptions

Modeling Electricity Sector Impacts in gridSIM

gridSIM, Brattle's power sector capacity expansion model, was used to simulate the power sector impacts of relicensing the Dresden Clean Energy Center (DCEC). Energy demand, resource adequacy, market regulations and clean energy policies in Dresden's regional electricity market as well as those in neighboring markets were accounted for in the analysis.

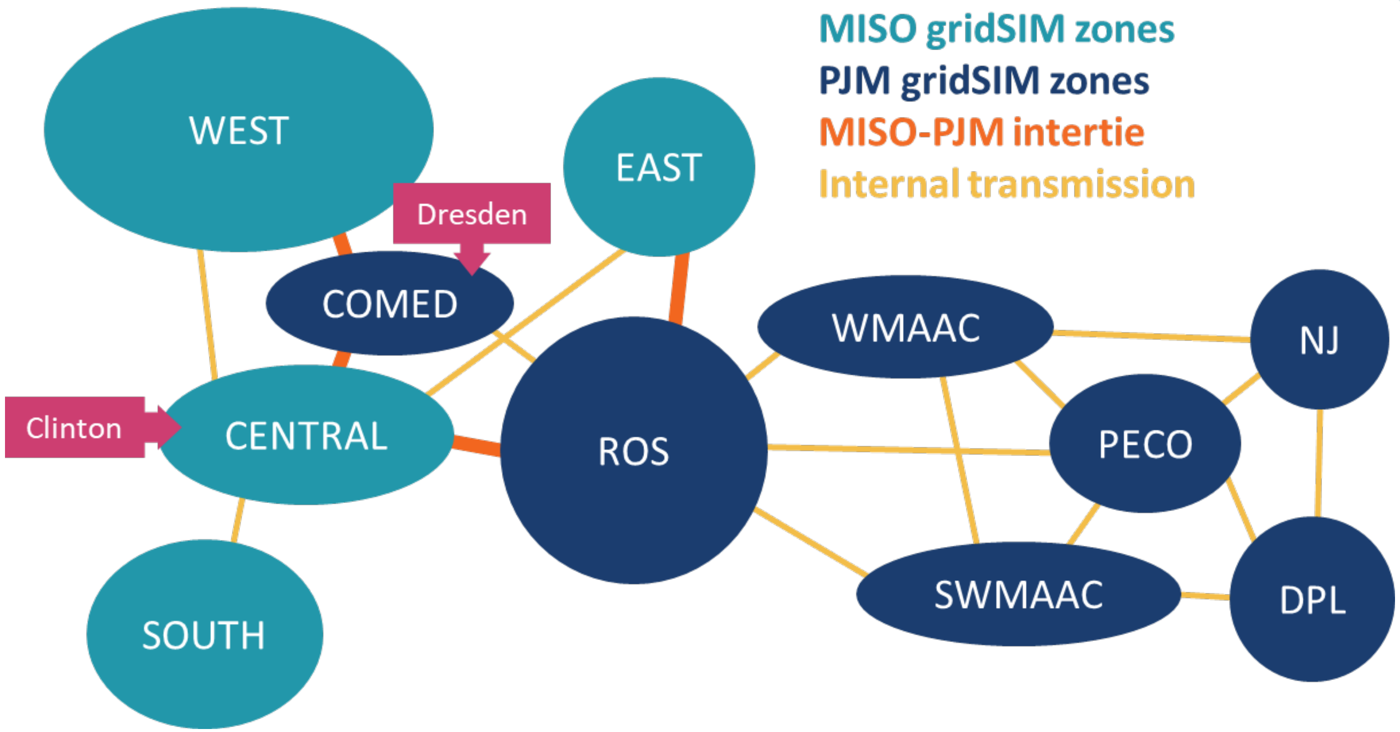
While DCEC is located within the PJM electricity market, other parts of Illinois fall within the MISO electricity market. MISO and PJM are connected, and power constantly flows between them depending on the conditions in each grid—retiring DCEC would therefore have material impacts on both markets. As such, MISO and PJM were modeled as a joint power system, allowing us to better capture these impacts. Power flows to other neighboring markets were also accounted for using historical data.

Two modeling scenarios were analyzed:

- A reference scenario in which DCEC's license is extended
- An alternate scenario in which DCEC stops operations at currently scheduled retirement year

gridSIM Model Topology

- gridSIM optimizes capacity expansion and generation across both MISO and PJM. Model topology is based on a pipe and bubble framework representing 11 MISO and PJM zones.
- Interchange limits between two connected zones are calibrated based on the physical transmission limits specified in the EPA's Integrated Planning Model (IPM).[1]
- Net power flow between MISO and PJM at the system level is calibrated to maximum historical net transfer based on EIA Interchange Data.[2]

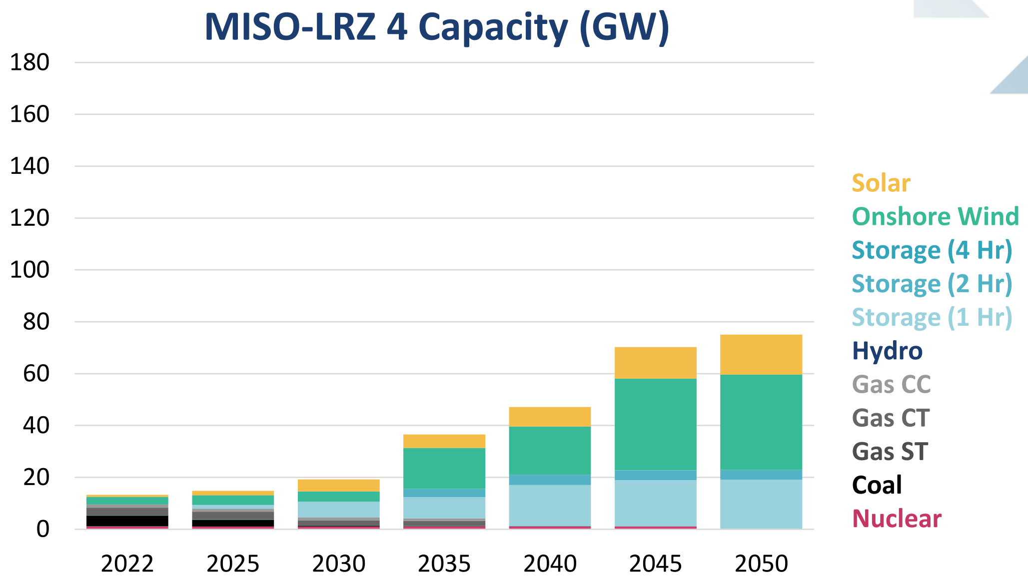


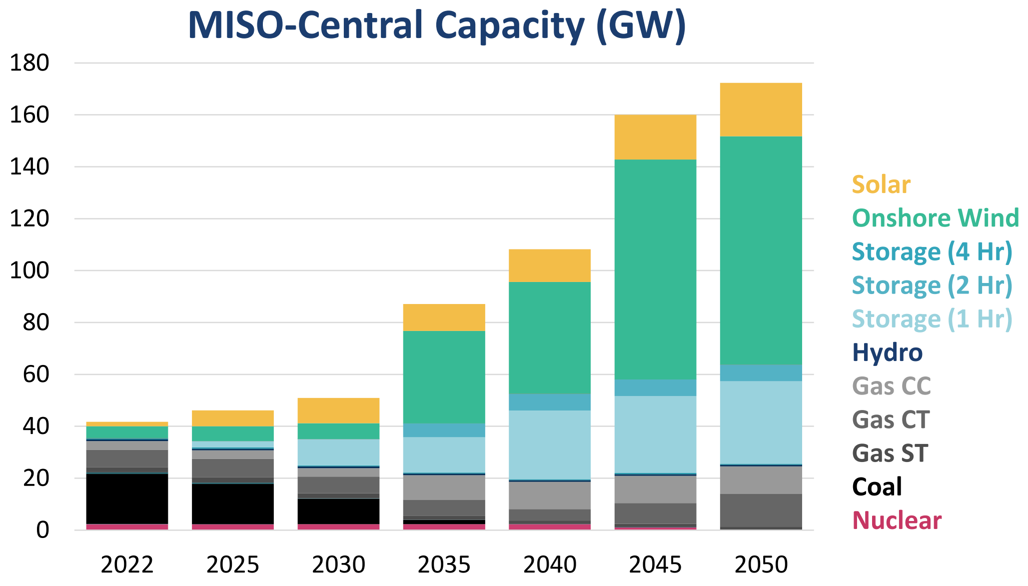
[1] EPA's Integrated Planning Model (v6 2021 Reference Case). Transmission limits from Table 3-20 "Annual Transmission Capabilities of U.S. Model Regions."
[2] https://www.eia.gov/opendata/browser/electricity/rto/interchange-data.

Illinois Capacity Calculations in MISO-Central

MISO-Central is modeled as a single zone composed of Local Resource Zones (LRZs) 4, 5, and 6. LRZ 4 corresponds to the Illinois portion of MISO-Central. Illinois specific capacity is determined based on:

- Historical capacity by state.
- Planned additions and retirements in each state.
- State policies, including CEJA and RPS targets (most new renewable builds in the MISO-Central region takes place in Illinois due to CEJA).
- Resource adequacy requirements in MISO and PJM.





Load Growth Modeling

PJM inputs:

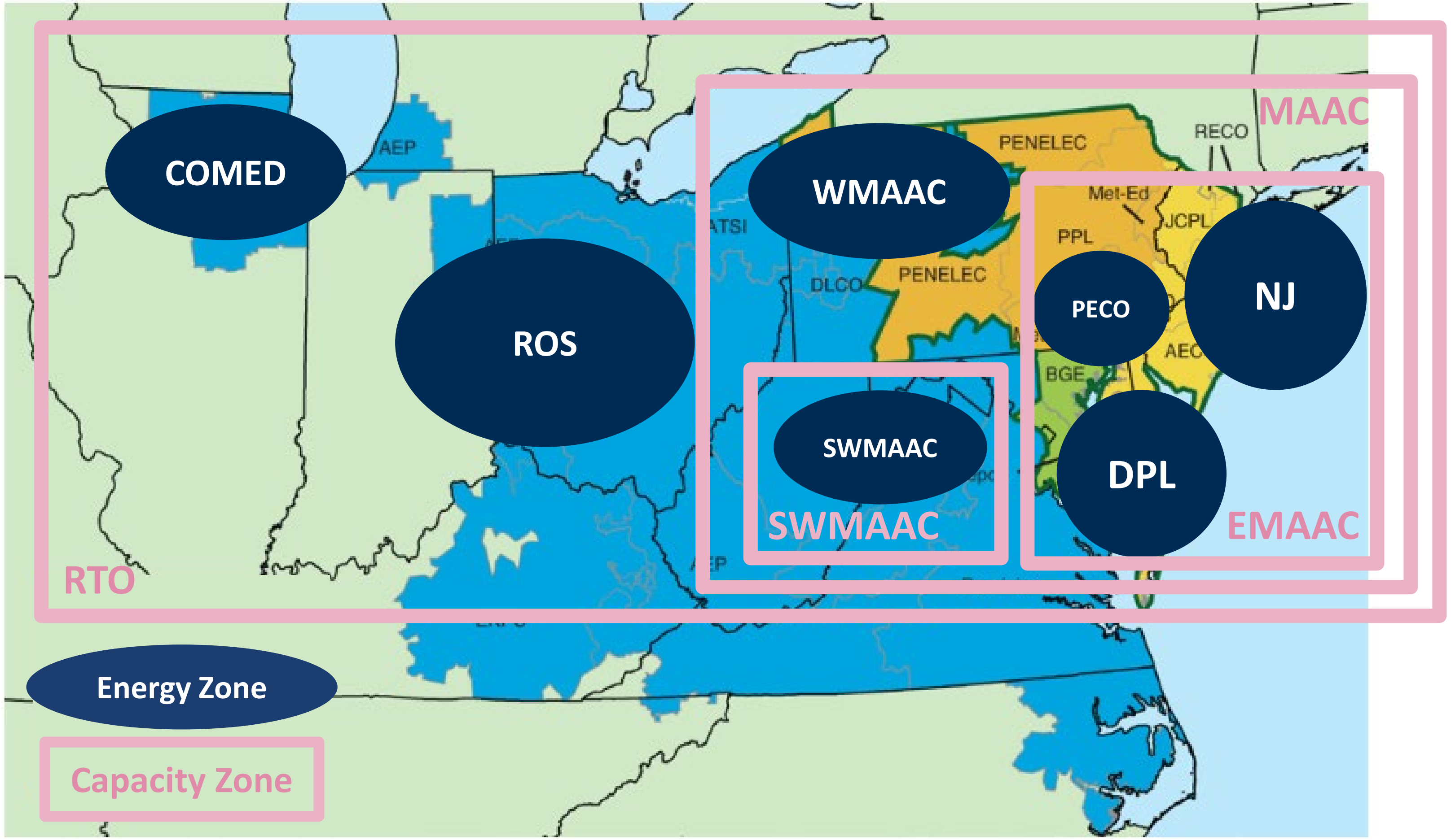
- PJM 2024 Load Forecast Report: includes projections of electric vehicle, heating load and behind-the-meter generation.
  - Heating load shapes were derived using heating degree day data from NOAA.

MISO inputs:

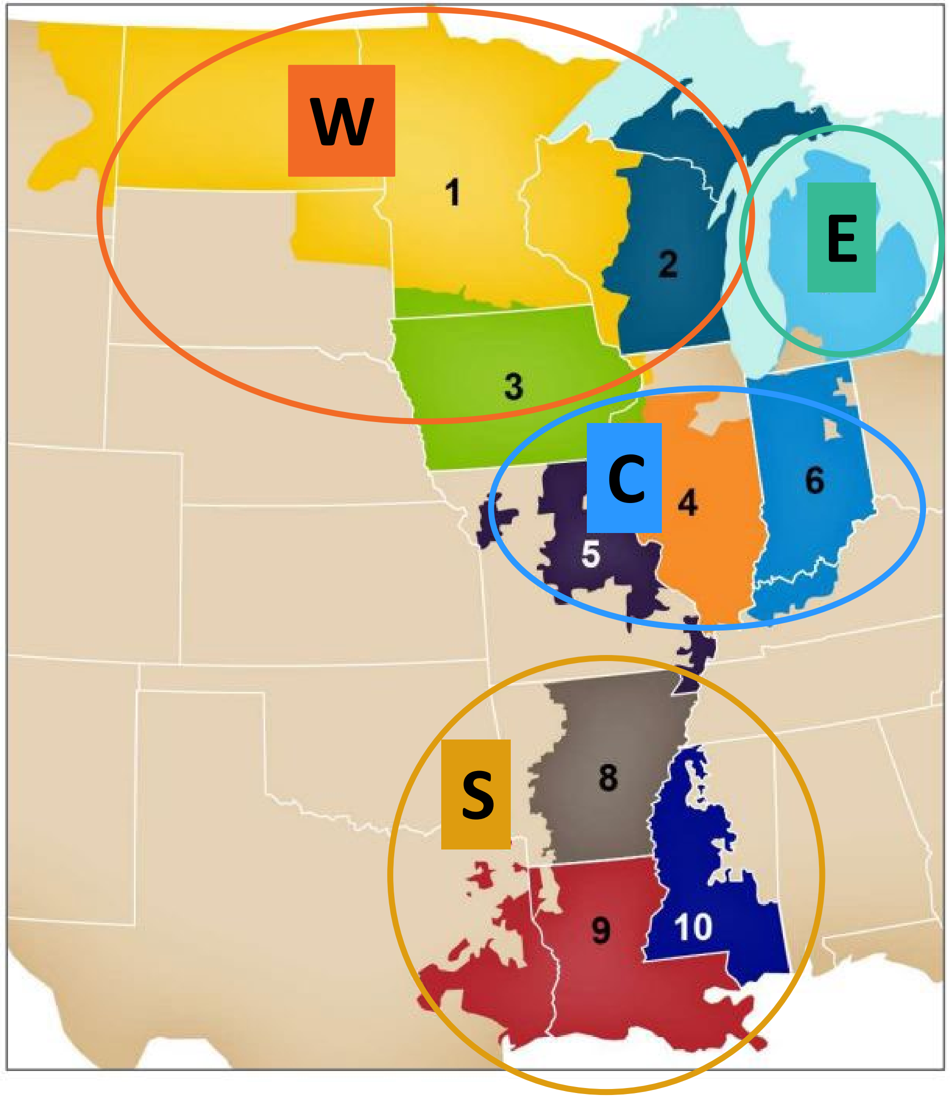
- Base load growth forecasts to 2050 from 2023 MISO Independent Energy and Peak Demand Forecast by Purdue University.
  - Transport & heating electrification not considered in base.
- Anticipated EV uptake based on Future 2 of MISO's Futures Report.
  - EV load shapes taken from US DOE EVI-Pro Lite tool.
- Anticipated electrified heating uptake based on Future 2 of MISO's Futures Report.

Nested Capacity Zones in PJM

PJM’s Nested Capacity Zones



Modeled MISO Zones



SIM Zone	Local Resource Zones
WEST	1, 2, 3
CENTRAL	4, 5, 6
EAST	7
SOUTH	8, 9, 10

Sub-regional Planning

- These zones are used in the MTEP process to review transmission solutions on a more local basis
- Solutions submitted, reviewed, and analyzed by stakeholders

Source: Use of “Zones” and “Regions” at MISO (misostates.org)

Overview of Modeled Policies

- **Renewable and Clean Energy Goals:**
  - Clean energy targets are modeled at the state level, including technology-specific procurement targets.
- **Emissions Reduction Goals:**
  - For PJM, carbon emissions limits are modeled based on state decarbonization goals.
  - For MISO, carbon emissions limits are modeled based on a combination of state and utility decarbonization goals.
- **Inflation Reduction Act:**
  - Production tax credits (PTC) are modeled for solar, onshore wind, and nuclear generation. Hydrogen PTCs are incorporated into the fuel costs for H2 resources.
  - Investment tax credits (ITC) are modeled for offshore wind and battery storage.
- **Section 45Q Credit for Carbon Oxide Sequestration**
  - Tax credit for carbon capture and storage (CCS) is modeled for all new and retrofitted CCS units.
- **Climate and Equitable Jobs Act:**
  - Currently, we model a 2045 zero-emissions deadline for IL as outlined in CEJA. The emissions limit slopes linearly from present-day levels down to zero in 2045.
  - CEJA does not explicitly call for the retirement of fossil units. However, plants that don’t comply with emissions targets by the deadline (e.g., through CCS) will be forced to retire. Our model implements a phased retirement or retrofit of fossil units according to the timeline identified by the IL Dept. of Labor.

Modeled Policies in PJM

State	Renewable and Clean Energy Goals	Emissions Reduction Goals (2005 Baseline)
Delaware	RPS: 40% by 2035 (10% from solar)	50% reduction by 2030, 100% by 2050 (de.gov)
DC	RPS: 100% by 2032 (5.5% Solar)	Carbon free by 2032 (dccouncil.gov)
Illinois[1]	RPS: 40% by 2030, 50% by 2040 (55% solar and 45% wind) CES: 100% by 2045	Carbon free by 2045 (ilga.gov)
Maryland	RPS: 52.5% by 2030 (50% Tier I, 2.5% Tier II)	60% reduction by 2031, net zero by 2045 (md.gov)
New Jersey	RPS: 52.5% by 2032 (50% Class I, 2.5% Class II) CES: 100% by 2050	Carbon free by 2050 (nj.gov)
North Carolina	RPS: 12.5% (completed)	Carbon free by 2050
Ohio	RPS: 8.5% by 2026	n/a
Pennsylvania	RPS: 18% (completed)	80% reduction by 2050 (pa.gov)
Virginia	RPS: 100% by 2050 (APCo), 100% by 2045 (DOM) CES: 100% by 2050 (APCo), 100% by 2045 (DOM)	Carbon free by 2045 (va.gov)

[1] RPS and CES obligations are split proportionally based on the amount of IL load located in MISO vs PJM.

Modeled Policies in MISO

State	Renewable and Clean Energy Goals	Emissions Reduction Goals (2005 Baseline)
Illinois[1]	RPS: 40% by 2030, 50% by 2040 (55% solar and 45% wind) CES: 100% by 2045	Carbon free by 2045 (ilga.gov)
Indiana	RPS: 10% by 2025	n/a
Iowa	RPS: 105 MW (completed 2007)	n/a
Louisiana	RPS: 80% by 2050	Net zero GHG by 2050 (MISO)
Minnesota	RPS: 10% solar by 2030, 55% by 2035 CES: 90% by 2035, 100% by 2040	Carbon free by 2040 (MISO)
Michigan	RPS: 50% by 2030, 60% by 2035, 100% by 2040	Carbon neutral by 2050 (MISO)
Missouri	RPS: 15% by 2021 (2% from solar)	n/a
Wisconsin	RPS: 10% by 2015	Carbon free by 2050 (MISO)

[1] RPS and CES obligations are split proportionally based on the amount of IL load located in MISO vs PJM.

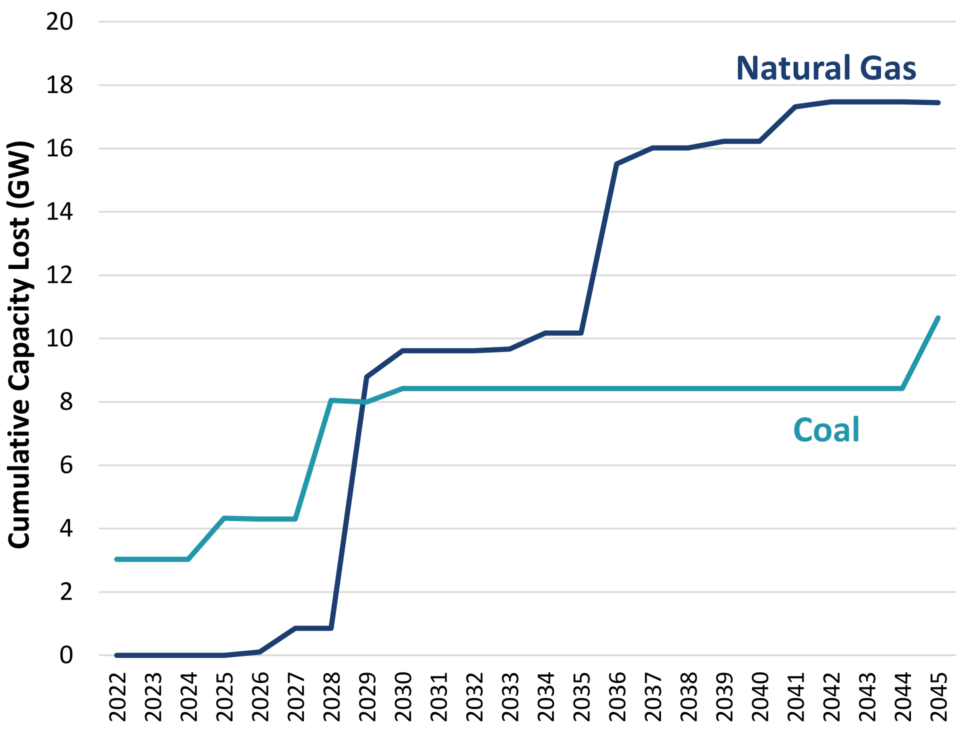
Modeled Utility Emissions Goals in MISO

Utility	State(s)	Baseline Year	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Alliant Energy	IA, MN, WI	2005	50%																				100%
Ameren Illinois	IL	2005																					100%
Ameren Missouri	MO	2005	60%										85%					100%					
Cedar Falls Utilities	IA	2010	45%																				100%
CLECO	LA, TX	2011	38%																				100%
Consumers Energy	MI	2005											100%										
Dairyland Power	WI	2005	50%																				
DTE Energy	IL, MI, WI	2005											80%										
Duke Energy	IN	2005	50%																				100%
Entergy	AR, LA, MS, TX	2000	50%																				100%
Great River Energy	MN, ND	2005																					80%
Madison Gas & Electric	WI	2005	80%																				100%
Michigan Upper Peninsula	MI	2005																					100%
MidAmerican Energy	IA	2005																					100%
Minnesota Power	MN	2005																					100%
Montana Dakota Utilities Co.	MT, ND	2005	45%																				
NIPSCO	IN	2005	90%																				
Otter Tail Power Company	MN, ND, SD	2005													80%								
SMMPA	MN	2005	90%																				
Southern Illinois Power Cooperative	IL	2005																					100%
Southern Indiana Gas & Electric	IN	2005						100%															
Springfield Illinois – City Water Light & Power	IL	2005																					100%
Upper Peninsula Power	MI	2005																					100%
Wabash Valley Power Association	IN	2005		50%									70%										100%
WEC Energy Group	WI	2005																					100%
Xcel Energy	MN, SD, WI	2005	80%																				100%

Climate and Equitable Jobs Act (CEJA)

- **Statewide Emissions:**
  - We model a *2045 decarbonization goal* for IL's electric sector, which slopes linearly from present-day levels down to zero carbon emissions in 2045.
- **Unit Level Emissions:**
  - CEJA mandates zero emissions deadlines for GHG-emitting units according to their NOx and SO2 emissions and the unit's proximity to an environmental justice (EJ) community or equity investment eligible community (EIEC).
    - Plants that don't comply with emissions targets by the deadline (e.g., through CCS) will be forced to retire.
  - We model a *phased retirement* of fossil plants based on analysis by the IL Dept. of Labor, which identifies retirement dates for each coal and gas plant in the state.

Coal and Gas Retirements in Illinois



Source: Climate and Equitable Jobs Act Economic and Workforce Effects Preliminary Analysis, Illinois Department of Labor.

Nuclear Assumptions

- **Generation:** Nuclear generation is modeled using a monthly average capacity factor for each ISO. This average capacity factor is based on 5 years of historical data (2018-2023).
- **Retirements:** Retirements of all nuclear units in PJM and MISO (except Clinton/Dresden) are consistent with license information from the Nuclear Energy Institute.
  - In the Reference scenario, Dresden is assumed to operate to the extended retirement years of its two units (2049 for Unit 2; 2051 for Unit 3). In the Retirement scenario, Dresden is assumed to retire in 2029 and 2031.
  - In both scenarios, Clinton is assumed to operate to its extended retirement year (2046).

Summary of Dresden Assumptions

Assumption	Unit 2	Unit 3
Net Summer Capacity (MW)	922.5	922.5
Currently scheduled retirement year	2029	2031
Extended retirement year	2049	2051

Carbon Capture and Sequestration (CCS) Costs and Operations

- Model can choose to retrofit existing NG CC or Coal units or build new NG CCs with CCS beginning in 2030.
- Increased costs and reduced efficiency due to parasitic load.
- 45Q Credit of $60/ton applied based on credit for geologically. sequestered CO_2 with EOR, meeting certain wage requirements.
  - Only CCS resources constructed prior to 2033 are eligible, but we assume the credit will be extended through all model years.

Parameters for Gas and Coal with Carbon Capture

Parameter	Assumption	Source
First Allowed Build Year	2030	NREL, DOE
Carbon Capture Rate	95%	NREL ATB 2023
Capital Cost ($/kW)	New NG CC w/ CCS: $2,716 NG CC Retrofit: $1,325 Coal Retrofit: $2,137	NREL ATB 2023
FOM ($/kW-yr)	New NG CC w/ CCS: $65 NG CC Retrofit: $68 Coal Retrofit: $153	NREL ATB 2023
VOM ($/MWh)	New NG CC w/ CCS: $4.76 NG CC Retrofit: $4.95 Coal Retrofit: $17.17	NREL ATB 2023
Fuel Cost	No change in fuel cost assumptions	
Transport and Sequestration Cost	$15/ton-$CO_2$	Energy Futures Initiative
Tax Credits	$60/ton-$CO_2$ from 45Q Credit	congress.gov
Parasitic Losses	30% losses from parasitic load	Advanced Post-Combustion CO2 Capture (mit.edu); Global CCS Institute

Hydrogen Costs and Operations

- Model can build hydrogen turbines or retrofit existing NG CTs beginning in 2036.
- PTC credit of $3/kg is applied through 2043.

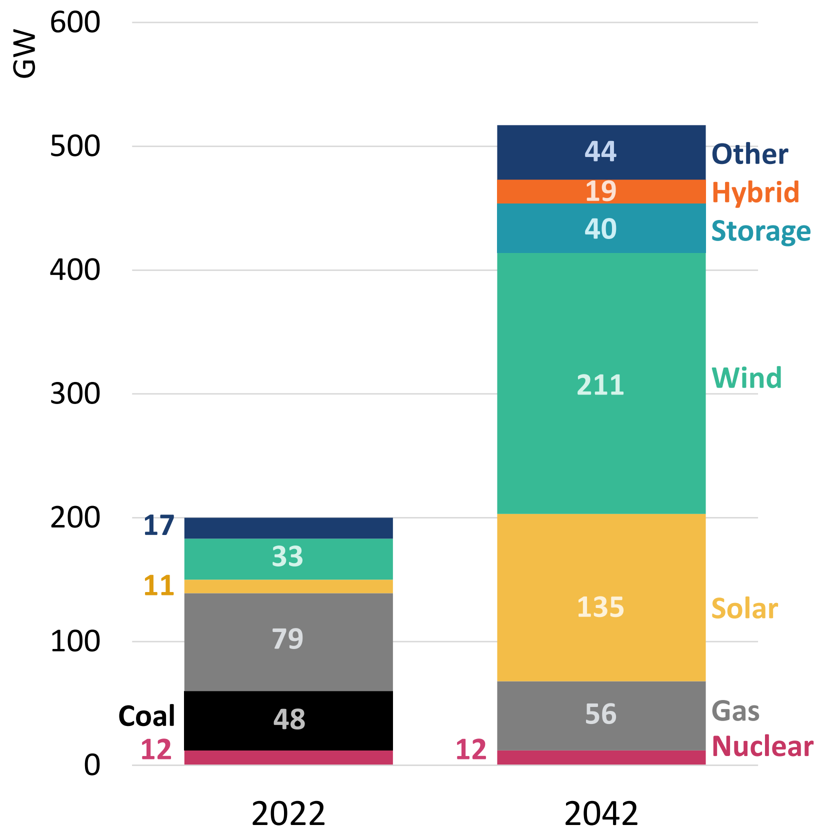
Parameters for Hydrogen Gas Turbine

Parameter	Assumption	Source
First Allowed Build Year	2036	MISO Futures report adds "Flex" resources in 2027; IL production cost modeling introduces zero emissions fuels in 2045
Operating Parameters	Operations are the same as NG CT	
Capital Cost (2020$/kW)	New build: $1,320 and follows same cost trajectory through 2050 as NG CT from NREL ATB Retrofit: 25% of NG CT capital cost	MIT 2021 (new build); ETN Global (retrofit)
FOM	Same as NG CT	NREL ATB 2023
VOM	Same as NG CT	NREL ATB 2023
Fuel Cost	Production and delivery cost: $6.25/kg or $46.64/MMBtu	Production cost of hydrogen produced through polymer electrolyte membrane (PEM) electrolysis from DOE H2A Production Analysis, Baseline scenario. Delivery costs from DOE Liftoff Report.
Tax Credits	Production Tax Credit (PTC) of $3/kg	DOE

Storage Assumptions

- Annual build limits are implemented for storage resources in MISO to align with the 2023 MISO Futures report.[1]
- Storage build limits are derived from Future 3A (the most aggressive decarbonization scenario) to set an upper bound on storage penetration.
- Between 2022-2042, Future 3A adds 40 GW of Battery, 19 GW of Hybrid, and 44 GW of Other.
  - We assume 9.5 GW of Hybrid resources are batteries.
  - The report indicates that the majority of "Other" is comprised of demand response, non-PV distributed generation, and energy efficiency. We include "Other" in our calibration of storage resources to acknowledge uncertainty in storage penetration.
- This results in around 94 GW added over 20 years. As such, we have implemented a 5 GW annual build limit for storage.

2022 and 2042 Capacity Mix for MISO Future 3A



[1] https://cdn.misoenergy.org/Series1A_Futures_Report630735.pdf

Retail Electricity Price Impact

- **Energy prices ($/MWh):**
  - Energy prices are calculated as the marginal cost of energy in each hour. The annual energy price is the load-weighted average price.
- **Capacity prices ($/MW-yr):**
  - Capacity costs are calculated based on Net Cost of New Entry (CONE). Net CONE is the sum of fixed O&M and capital costs minus revenues obtained through the energy, ancillary services, and ZEC markets.
  - Net CONE is divided by each resource's accredited capacity to obtain a $/MW-yr cost. The capacity price is set by the most expensive resource in each zone.
- **Wholesale electricity prices ($/MWh):**
  - Energy, capacity, and ZEC prices are converted to $/MWh and summed to calculate an all-in wholesale electricity price.
- **All-in retail electricity price impact (%):**
  - The retail price impact is calculated as one-third of the wholesale electricity price impact, based on the assumption that T&D costs remain fixed.

Notice and Disclaimer

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All results and any errors are the responsibility of the authors and do not represent the opinions of The Brattle Group or its clients.

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