Deep Decarbonization and Rapid Electrification in Duke Energy Indiana’s Service Territory

The Company’s Integral Role in All-Sector Decarbonization

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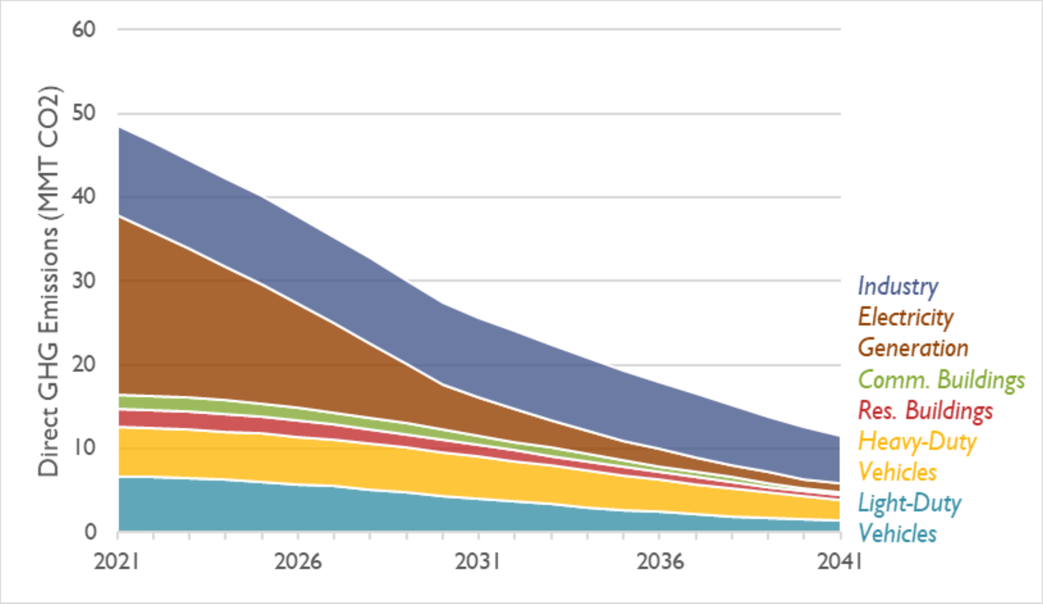
CONTENTS

EXECUTIVE SUMMARY

The threat of climate change requires urgent action to reduce greenhouse gas (GHG) emissions across the economy. Duke Energy Indiana (DEI) is a major contributor to GHG emissions in the Ohio River Valley and has an important role to play in decarbonizing the Indiana economy. As the electric utility for the region it serves, DEI can also facilitate the transition to clean energy in other sectors of the economy through the electrification of transportation, buildings, and industry.

In this report, we analyze a Deep Decarbonization and Rapid Electrification scenario that includes two key components. First, DEI reduces the GHG emissions from its generation resources 75 percent by 2030 and 95 percent by 2040 relative to 2020 levels to lead the way to net zero emissions by 2050. Second, the transportation, buildings, and industrial sectors decarbonize significantly through electrification, leading to an increase in demand for electricity in DEI's service territory. DEI can help its service territory decarbonize across all sectors to achieve the emissions reductions shown in Figure ES-1.

Figure ES-1. DEI service territory all-sector GHG emissions



Further, we find that achieving this clean energy future can bring large benefits to residents and businesses associated with reduced expenditures on fossil fuels and mitigated climate damages.

Deep decarbonization and rapid electrification are achievable and essential to avert the worst impacts of climate change. DEI's Integrated Resource Plan (IRP) development process should identify how DEI can facilitate and accelerate the region's transition to a sustainable energy future by planning for both deep decarbonization and rapid electrification.

1. THE NECESSITY OF PLANNING FOR DEEP DECARBONIZATION

Climate change driven by greenhouse gas (GHG) emissions poses an existential threat to life on Earth. To avert the worst impacts of climate change, nations around the world have called for limiting warming to 1.5 degrees Celsius by the end of the century. To achieve that goal, GHG emissions must decline dramatically, with wealthy nations like the United States leading the way. In particular, the Paris Climate Accords are premised on such global emissions declining to "net zero" by 2050.

1.1. Greenhouse Gas Emissions in Duke Energy Indiana's Service Territory

Duke Energy Indiana (DEI) has one of the most carbon intensive power generation fleets in the country. In 2020, DEI's carbon intensity was 0.88 metric tons of carbon dioxide (CO_2) per MWh.[1] By comparison, the national average carbon intensity was 0.39 metric tons CO_2 per MWh.[2] DEI's well above-average carbon intensity is driven by DEI's reliance on coal to fuel most of its generation.

The southern and central Indiana region that DEI's electricity business serves produces GHG emissions across several additional sectors of its economy. In this analysis, we focus on sectors where electrification is a key strategy for decarbonization, because these are the sectors that most impact DEI's future planning and IRP process. Specifically, we model the energy-related GHG emissions from the transportation, buildings, and industrial sectors, in addition to those from the electric power sector.

Emissions from other sectors where electrification is less applicable—such as non-energy-related industrial processes, airplanes, and agriculture—were not accounted for here because they have less impact on DEI's IRP in the near term. However, these sectors will also need to be decarbonized in the longer term to meet global climate goals and avoid the worst effects of climate change.

1.2. Incorporating Deep Decarbonization into Utility Resource Planning

The DEI IRP analyzes ways for DEI to serve its customers' load over a 20-year period, which for the 2021 IRP was 2022–2041. Given the urgency of reducing carbon emissions, the IRP process must consider futures in which DEI's power supply is largely decarbonized in that timeframe. In the context of IRP modeling, this can be achieved by specifying a limit on how much carbon can be emitted by DEI's generation fleet each year. Then, a capacity expansion model can help develop the most cost-effective resource plans that meet the decarbonization goal.

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[1] RMI. 2022. Utility Transition Hub. Available at https://utilitytransitionhub.rmi.org/emissions/.

[2] U.S. Energy Information Administration (EIA). 2021. "How much carbon dioxide is produced per kilowatthour of U.S. electricity generation?" *Frequently Asked Questions*. Available at https://www.eia.gov/tools/faqs/faq.php?id=74.

Decarbonization of the electric power sector on its own, however, is insufficient. Other sectors of the economy that directly consume fossil fuels such as transportation, buildings, and industry must also decarbonize rapidly. In these sectors, the clearest technological pathway for decarbonization is electrification: replacing the direct consumption of fossil fuels like gasoline, diesel, and natural gas with electricity derived from renewable resources that do not produce GHG emissions. DEI has a critical role in providing clean electricity to power these other sectors and modeling a deep decarbonization future in DEI's service territory requires accounting for the increased electricity demand from these sectors.

DEI's own preferred IRP scenario forecasts some small growth in electricity demand from electrification in the transportation sector but at a rate far too slow to meet transportation sector emissions goals. DEI's preferred scenario does not forecast any growth in electricity demand from building or industrial electrification.

2. MODELING METHODOLOGY

We modeled least-cost pathways for achieving deep decarbonization in DEI's service territory. In this analysis, we examined how the transportation, buildings, and industrial sectors can decarbonize through electrification and the reduction of direct fossil fuel consumption. We then modeled how DEI can simultaneously decarbonize its electric generation fleet while providing additional clean energy to meet projected load growth from the electrification of other sectors.

2.1. Modeling Tools

Transportation, Buildings, and Industry

We modeled the transportation and buildings sectors using two Synapse models.

Synapse's **EV-REDI** (Electric Vehicle Regional Emissions and Demand Impacts) is a tool for modeling multiple impacts of transportation electrification for specific states and provinces. EV-REDI relies on high-resolution data from publicly available sources to assemble state-specific information on the historical adoption of EVs and to develop trajectories of future EV deployment. It is a stock turnover model that considers how EVs grow as a share of on-road vehicles over time as older vehicles reach the end of their useful lives and are retired. EV-REDI can quantify both gas-powered vehicle and EV sales and stock. It combines data on vehicle sales, efficiencies, miles traveled, and lifetimes to calculate the resulting impacts on electricity sales, tailpipe emissions, gasoline consumption, and other metrics through 2050. EV-REDI separately models and accounts for the unique characteristics of two categories of light-duty vehicles (cars and light trucks) and four categories of medium- and heavy-duty vehicles (medium-duty trucks, single unit heavy-duty trucks, combination heavy-duty trucks, and buses).

The **BDC** (Building Decarbonization Calculator) is a tool for modeling the energy consumption of space and water heating systems, cooking, and clothes drying in residential and commercial buildings across the country. (These end uses account for the vast majority of direct fossil fuel consumption in residential and commercial buildings.) The model uses a stock turnover framework to evaluate how installations of various heating system technologies and other appliances impact building energy consumption over time, including changes in electricity consumption resulting from the adoption of electric heating, water heating, cooking, and drying technologies. It also calculates emissions impacts from changes in the market share of electrified technologies and evaluates how various trajectories of heat pump installations and electric cooking and drying appliances can help meet GHG reduction goals. The BDC uses state-specific data on existing buildings from the U.S. Census Bureau's *American Community Survey* along with the U.S. Energy Information Administration's *Residential and Commercial Buildings Energy Consumption Surveys* (RECS and CBECS) to develop estimates for the characteristics of current building heating system and appliance stock.

To model the industrial sector, we relied on the *U.S. Mid-Century Strategy for Deep Decarbonization* (MCS) report.[3] The MCS envisions declining energy use in the industrial sector over time due to increased efficiency and increasing use of low-carbon electricity. Industrial sector innovation opportunities include: energy efficiency; fuel-switching and alternative feedstocks; process intensification and optimization; process heating technologies; material efficiencies and advanced materials; and industrial carbon capture, use, and storage (CCUS). Industrial sector energy-related fossil fuel consumption is responsible for 23 percent of Indiana's energy-related GHG emissions.[4] This sector includes a diverse set of fossil fuel consumption, some of which may be more challenging to electrify or otherwise decarbonize relative to other sectors. The MCS forecasts how industrial energy consumption in Indiana would change through 2050 to meet emissions reduction requirements. We based our analysis on the report's No Carbon Capture, Utilization, and Storage (No CCUS) scenario. To determine how much electricity will be required by the industrial sector in a decarbonized future, we focused on the growth in industrial electricity consumption the MCS forecasts relative to the amount of industrial fossil fuel consumption that must be displaced.

Electric Power

To model the electric power sector, we used the EnCompass model. EnCompass is an industry-standard production-cost and capacity-expansion model that DEI also uses. It incorporates detailed data on each power plant in the United States and uses a least-cost dispatch algorithm to evaluate metrics like marginal wholesale costs, emissions, and capacity additions and retirements under a set of user-specified constraints (e.g., load projections, carbon caps, renewable portfolio standards). For this analysis, we used EnCompass at both the utility service territory scale (Duke Energy Indiana) and the balancing authority scale (to model MISO prices). Modeling outputs from EnCompass include metrics

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[3] The White House. 2016. *United States Mid-Century Strategy for Deep Decarbonization*. Available at https://unfccc.int/files/focus/long-term_strategies/application/pdf/mid_century_strategy_report-final_red.pdf.

[4] U.S. EIA. 2022. Energy-Related CO_2 Emissions Tables. Available at https://www.eia.gov/environment/emissions/state/.

such as emissions and wholesale power prices, as well as generation, capacity additions, and retirements by resource type and area.

2.2. Scenario Inputs and Assumptions

Transportation and Building Sector Decarbonization Trajectories

To achieve necessary global climate targets, the transportation and buildings sectors must decarbonize rapidly. In the transportation sector, we focused our analysis on motor vehicles that produce emissions through the consumption of gasoline and diesel. Vehicles can have long lifetimes, often between 15 and 20 years, which means it can take decades for the fleet to turn over completely. This means that new vehicle sales must be shifted to zero emissions EVs quickly. In this scenario, we modeled 93 percent EV market share among new light-duty vehicle sales by 2030 so that light-duty vehicles are essentially all electrified by 2050. Medium- and heavy-duty EV adoption proceeds at a less aggressive pace, with EVs making up 35 percent of new sales by 2030. The light-duty and medium- and heavy-duty EV market share trajectories are shown in Figure 1 and the resulting motor vehicle tailpipe GHG emissions are shown in Figure 2.

Figure 1. EV adoption

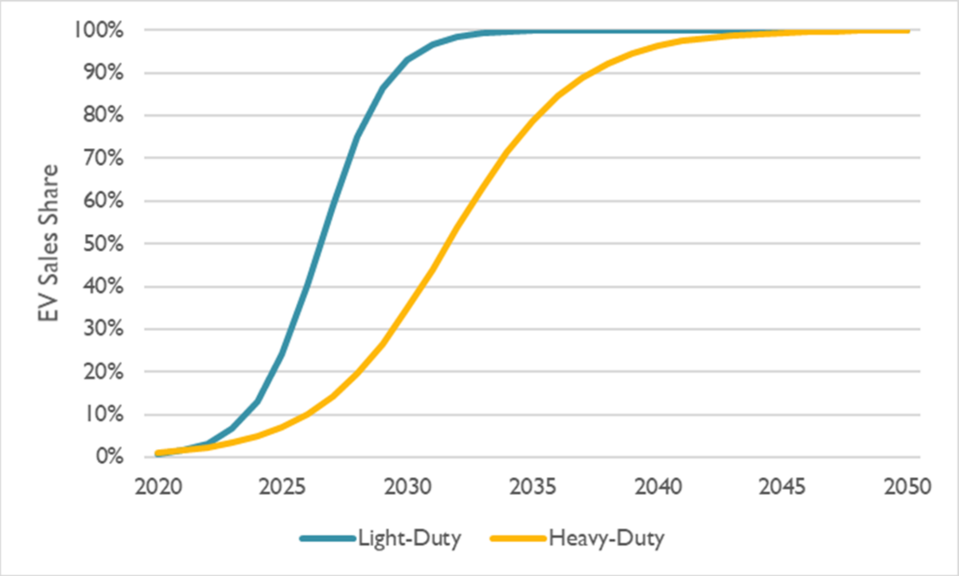
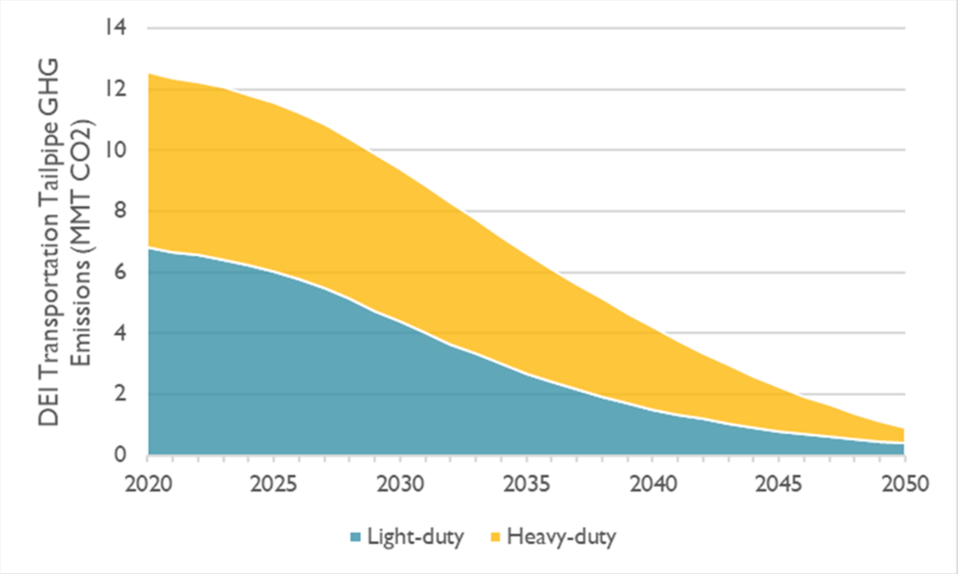
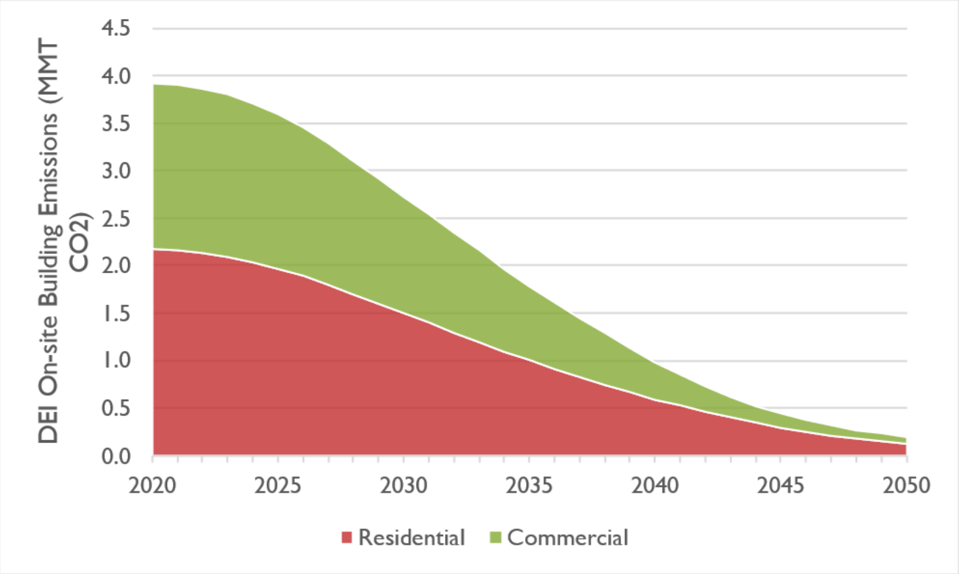


Figure 2. Transportation sector tailpipe GHG emissions from motor vehicles



In the buildings sector, emissions reductions proceed at a similarly rapid pace, as efficient electric heat pumps displace natural gas, oil, and propane consumption in residential and commercial buildings for space and water heating. Emissions decline from 3.9 million metric tons (MMT) of CO_2 in 2021 to 0.2 MMT CO_2 in 2050, as shown in Figure 3.

Figure 3. Building sector on-site GHG emissions



Electric Power Sector Decarbonization

We modeled a Deep Decarbonization and Rapid Electrification (DDRE) scenario that constrains the model to reflect the urgency of decreasing GHG emissions and shifting away from the consumption of fossil fuels. Figure 4 shows the emissions cap we selected for the electric power sector based on previous analyses of how quickly the U.S. power sector must decarbonize to limit warming to 1.5 degrees Celsius. Based on an RMI study evaluating futures that stayed within the U.S. carbon budget for a 1.5 degree Celsius future, we modeled a 75 percent reduction in power sector GHG emissions between 2020 and 2030.[5]

Figure 4. DEI electric power sector GHG emissions cap

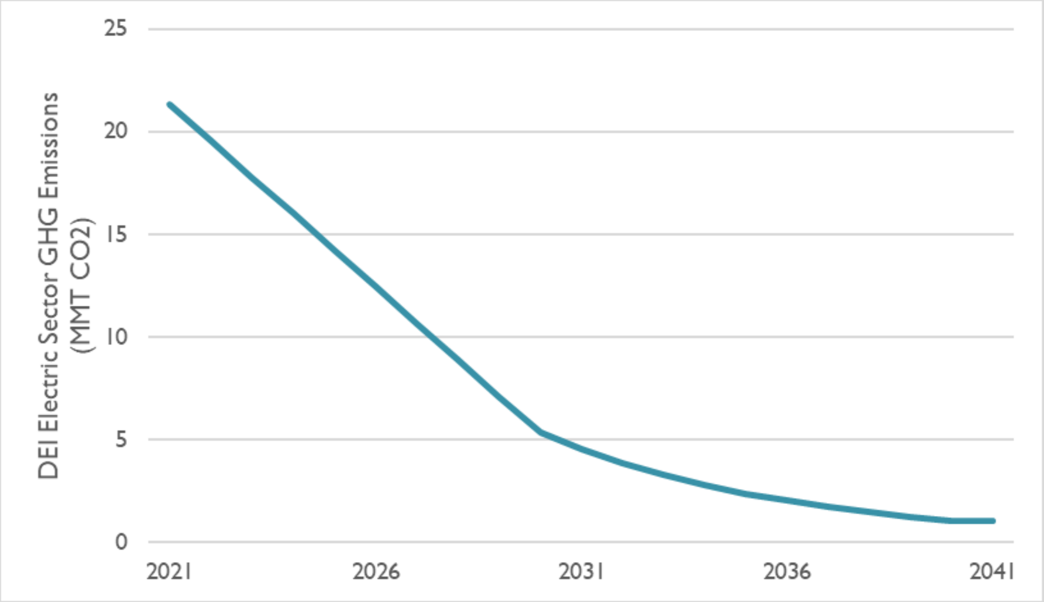


Figure 5 shows the emissions reductions across all modeled sectors in DEI’s service territory. Due to the aggressive decarbonization we model in other sectors, in addition to the electric power sector, total emissions in DEI’s service territory decrease by 44 percent by 2030 and 74 percent by 2040 relative to 2020. After 2040, most remaining emissions are from industrial energy consumption, where additional innovation is important for achieving full decarbonization. This figure does not include other emitting sectors outside the scope of this analysis, such as air travel, non-energy-related industrial processes, and agriculture.

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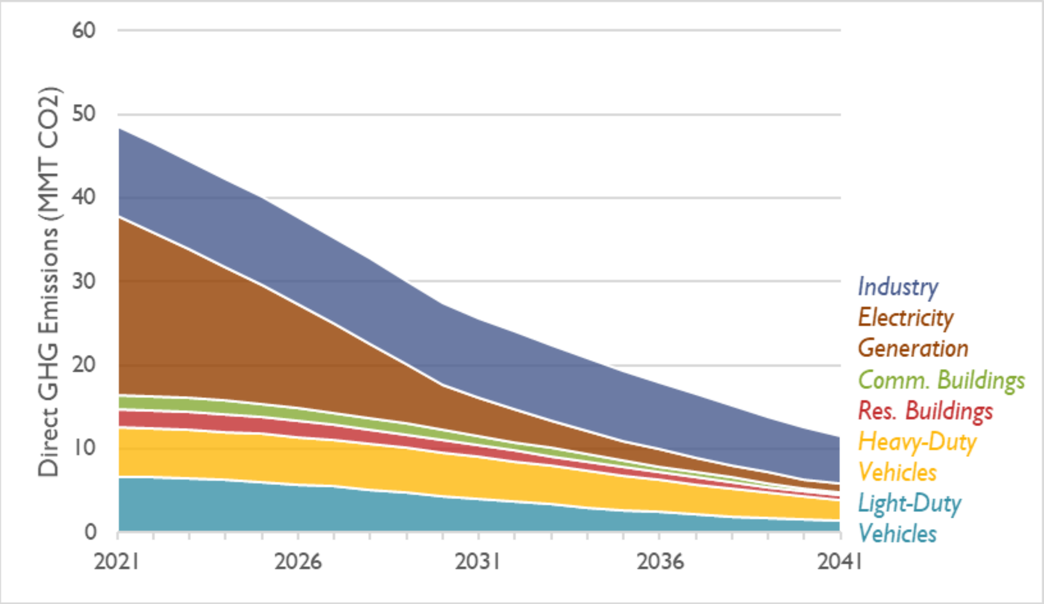
[5] Teplin, C., et al. 2021. *The United States’ Role in Limiting Warming to 1.5°C*. RMI. Available at https://rmi.org/insight/scaling-us-climate-ambitions/.

Figure 5. DEI service territory all-sector GHG emissions



While DEI has a critical role in facilitating and accelerating decarbonization within its service territory, it will not have a monopoly on decarbonization. Clean distributed energy resources (DER) sited at customer facilities will play an important role in supplying clean power and reducing pressure on the transmission and distribution system. In our analysis, we relied on a Lawrence Berkeley National Laboratory study of the integration of DERs into Indiana's energy mix.[6] Figure 6 shows the DER adoption trajectories we assumed for distributed solar and battery storage resources in the DDRE scenario.

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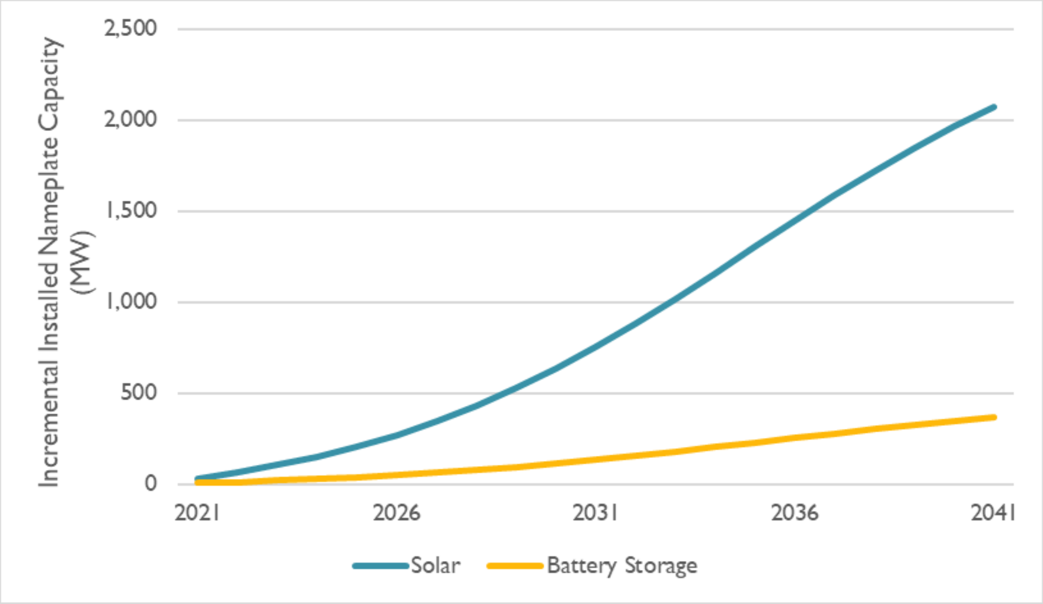
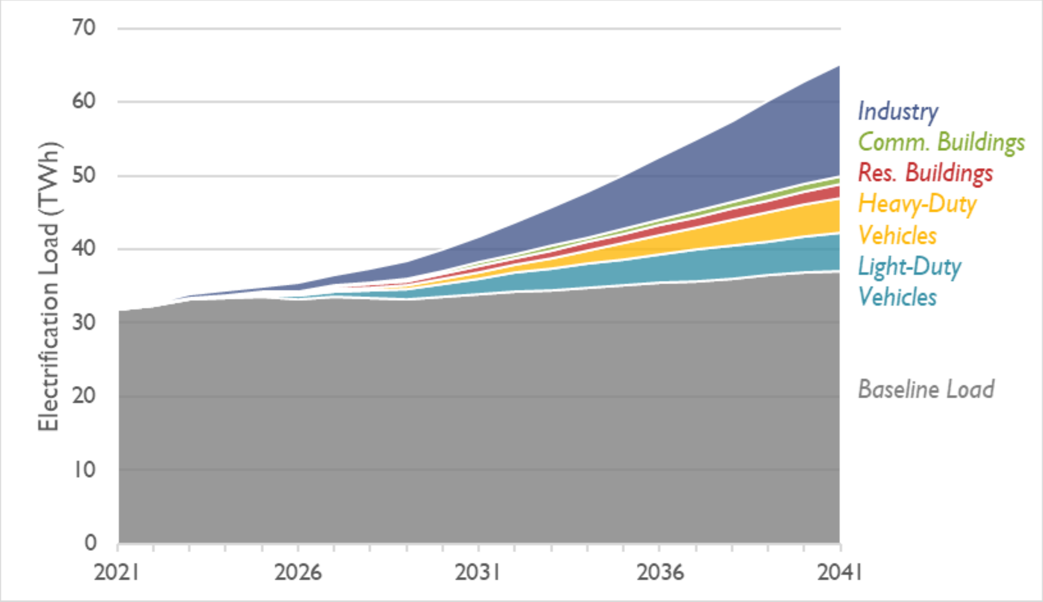
[6] Carvallo, J.P., et al. 2020. *Indiana 21st Century Energy Policy: Emerging Technologies on the Electricity Distribution System*. Lawrence Berkeley National Laboratory. Available at https://eta-publications.lbl.gov/sites/default/files/iurc_comprehensive_study_-_definitive_-_06-30-2020.pdf.

Figure 6. Distributed energy resource adoption



The decarbonization of the non-electric sectors involves electrification, and total electric load in DEI's service territory increases substantially as a result. Figure 7 shows the change in total load over the study period. While loads grow rapidly, most of the growth occurs after 2030, which gives DEI time to plan ahead now. The industrial sector accounts for a large portion of electric load growth due to the disproportionately large amount of industrial activity and energy consumption in Indiana and in DEI's service territory. The rapid growth in electric demand due to electrification highlights the need for aggressive energy efficiency measures to limit impacts on the transmission and distribution systems as well as on the total amount of clean energy supply required.

Figure 7. Load growth due to electrification



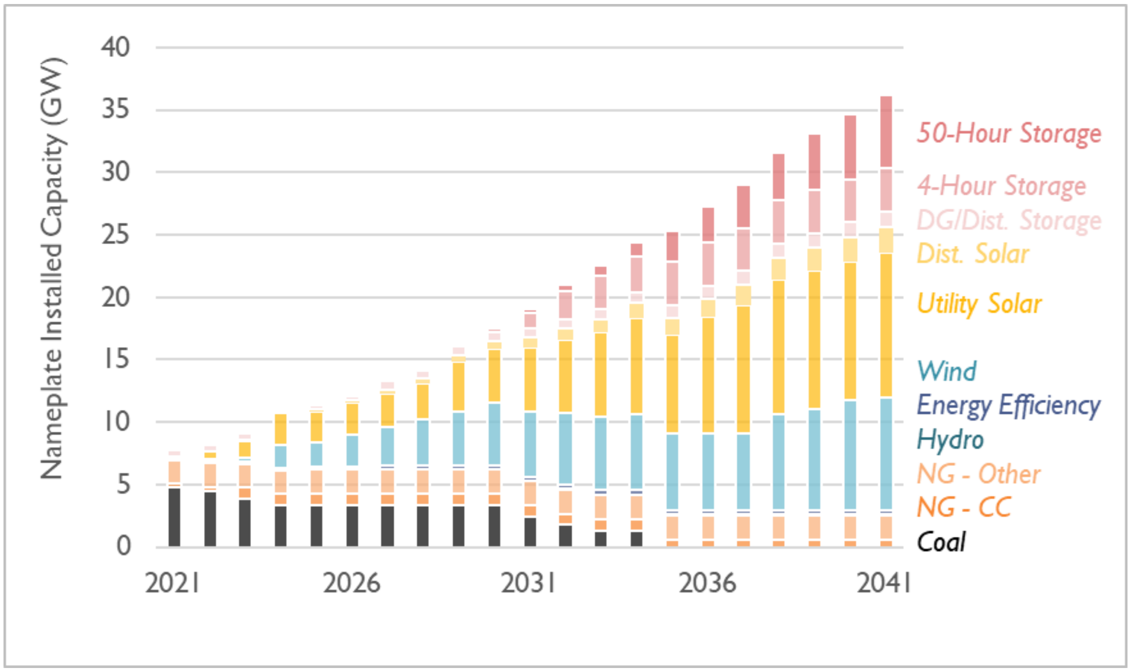
3. ELECTRIC POWER SECTOR MODELING RESULTS

3.1. Capacity and Generation

To meet the emissions and electrification load constraints described in the previous section, we used the EnCompass model to build out an optimized set of new generation resources (in addition to retirements of existing fossil resources). The model can choose in which years existing resources get retired; and it can add new solar, wind, battery storage, and other generation resources. Starting in 2030, it can also add long-duration storage. This resource has a 50-hour duration and has roundtrip efficiency and cost parameters based on a McKinsey & Company report on long-duration storage technologies.[7]

Figure 8 shows DEI's generation capacity by resource type. In 2021, DEI has nearly 5 GW of coal resources, which are all retired by 2035. By 2041, the system adds more than 20 GW of solar and wind generation to displace fossil generation and to meet growing loads resulting from electrification.

Figure 8. DEI generation capacity



Between 2021 and 2041, generation transitions from mostly coal and natural gas to nearly all solar and wind, supported by energy storage resources. DEI largely phases out coal generation, which accounts for

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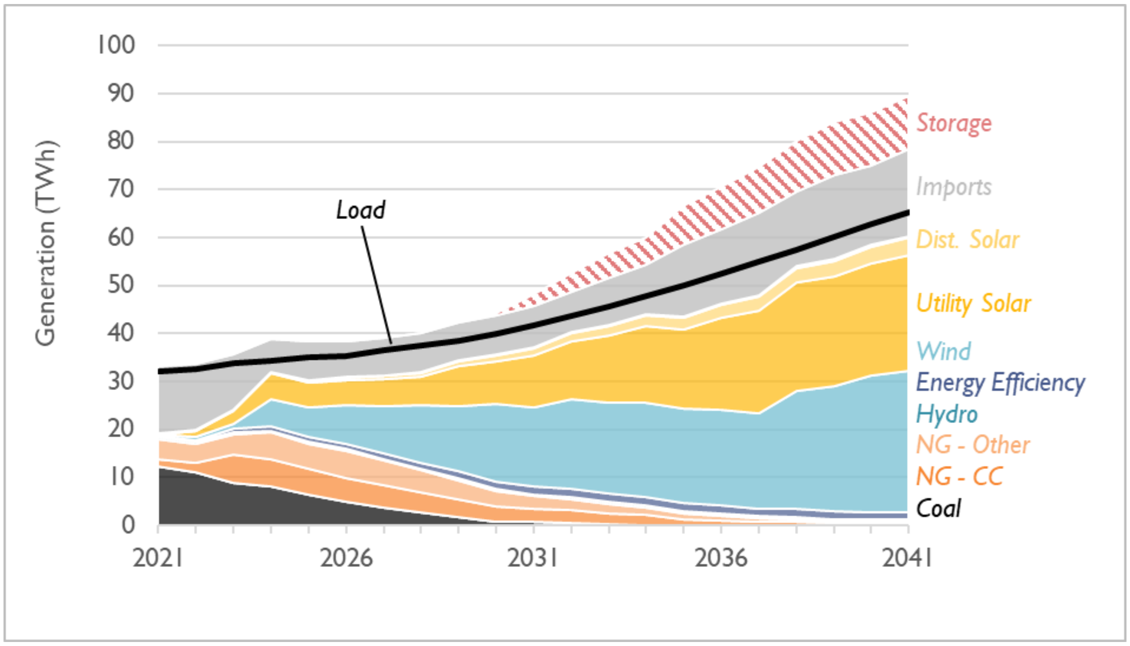
[7] *Net-zero Power.* 2021. McKinsey & Company for Long Duration Energy Storage Council. Available at https://www.ldescouncil.com/static/4f36253ddb28832cb88c55e7f3e3b121/LDES-brochure-F3-HighRes.pdf.

most of its generation in 2021, by 2030. Solar and wind see large initial investments in 2024, and these resources continue to grow in capacity throughout the study period.

Figure 9. DEI generation



3.2. Revenue Requirements and Avoided Costs

Decarbonization of electricity production and electrification of transportation, buildings, and industry rely on proven, scalable, and cost-effective technologies. The challenge is to deploy these technologies at the fastest, orderly rate possible. At every opportunity, the fossil fuel burning resources need to be retired and clean energy resources need to be scaled up. Soon, each new vehicle purchased needs to be electric; each new or replacement HVAC system needs to be based on heat pumps; and each industrial optimization needs to reduce fossil fuel use. Fortunately, the transition to a decarbonized economy will create vast consumer savings on fossil fuels like gasoline, diesel, and natural gas, while redirecting energy spending toward clean, locally generated electricity. The significant savings and redirection of spending will spur new industries and job growth.

To evaluate the economic costs and benefits of the DDRE scenario, we examined the electric sector investment in the form of revenue requirements for DEI's ratepayers. The revenue requirements represent the costs associated with generating electricity and building new generation resources. Using similar generation resource costs and fuel prices as in DEI's IRP, we calculated the revenue requirement for DEI over each of the next 20 years. We also calculated savings due to avoided consumption of fossil fuels in key sectors of the economy and mitigated climate damages generally (i.e., the social and environmental costs of carbon).

Table 1 shows the revenue requirements and avoided costs associated with the DDRE scenario. We show the present values of the revenue requirements and avoided costs calculated using real discount rates of zero percent and two percent. A zero percent real discount rate accounts only for inflation by converting future costs and savings to constant dollar years. A two percent real discount rate further discounts future monetized values to account for societal preferences between the present and the future.[8] These are different discount rates than DEI uses in its IRP because we have expanded the scope of our calculation to broader societal costs and savings that are unrelated to DEI's private Weighted Average Cost of Capital (WACC).

Table 1. DDRE Scenario Cost Impacts, 2022–2041 (billion 2020$)

	0% Real Discount Rate	2% Real Discount Rate
Electric Sector Revenue Requirement	25.8	21.1
Avoided Fossil Fuel Expenditures	32.3	25.1
Mitigated Climate Damages	22.5	17.3

The avoided fossil fuel expenditures and mitigated climate damages combined exceed the electric generation revenue requirements by a present value of $21.3 to $29 billion, depending on the discount rate used. Importantly, some factors are beyond the scope of our DDRE modeling and consequently Table 1 does not quantify all the cost impacts associated with the DDRE scenario. For example, we did not quantify any transmission and distribution system upgrades that would be needed to serve growing loads. Energy efficiency and smart utilization of DERs should be a key part of DEI's planning process to mitigate the need to invest in new transmission and distribution projects, but there will with virtual certainty be remaining needs for new transmission and distribution as well.

The revenue requirements presented here are not directly comparable to those presented in the DEI IRP for two additional reasons. First, the DDRE scenario includes large amounts of new electricity load associated with the decarbonization and electrification of the transportation, buildings, and industrial sectors. All else equal, increasing the amount of electricity that needs to be generated by DEI will increase DEI's revenue requirements. As a result, we anticipate greater electric sector revenue requirements in the DDRE scenario, which will be offset from the customer and societal perspective by decreased spending directly on fossil fuels in the transportation, buildings, and industrial sectors and mitigation of climate damages.

In addition to the difference in load between the DEI IRP modeling and the DDRE scenario, the DDRE scenario includes substantially different market prices. Critical to the DDRE scenario assumptions is that the global economy moves decisively toward mitigating the increase in global average temperatures to no more than 1.5 degrees Celsius. Thus, in the DDRE scenario modeling, we assumed that the rest of

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[8] Drupp, M.A., M.C. Freeman, B. Groom, F. Nesje. 2018. "Discounting Disentangled." *American Economic Journal: Economic Policy*, November, page 33.

MISO outside DEI's service territory will decarbonize at a comparably aggressive rate. This impacts the MISO electricity prices at which DEI can buy and sell power over the modeling period. The electricity prices impact the revenue requirements for DEI, sometimes significantly when either electricity is expensive on the MISO market in hours during which DEI needs to import power or DEI has available generation to export back to the rest of MISO.

Figure 10 and Figure 11 show the avoided non-electric fuel expenditures and mitigated climate damages respectively. Transportation fuels, which are relatively more expensive per unit of energy compared with other fuels, account for most of the avoided fuel expenditures. However, our estimate of the avoided natural gas expenditures is conservative because it only accounts for savings from purchasing less gas and does not account for savings that could result from retiring significant portions of the gas distribution system. The retail price that customers pay for natural gas includes both the commodity price for the gas itself and a charge associated with the cost of operating the gas distribution system. The climate damages shown in Figure 11 are based on the federal Interagency Working Group's (IWG) analysis.[9] For this study, we used an updated social cost of carbon that combines the IWG's findings with a two percent discount rate instead of a three percent discount rate, to better reflect the most recent research on long term discount rates in the context of climate change.[10]

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[9] Interagency Working Group on Social Cost of Greenhouse Gases, Unites States Government. 2021. *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990*. Available at https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf.

[10] Knight, P. 2021. *AESC 2021 Supplemental Study: Update to Social Cost of Carbon Recommendation*. Synapse Energy Economics for AESC Supplemental Study Group. Available at https://www.synapse-energy.com/sites/default/files/AESC_2021_Supplemental_Study-Update_to_Social%20Cost_of_Carbon_Recommendation.pdf.

Figure 10. DDRE scenario avoided non-electric fuel expenditures

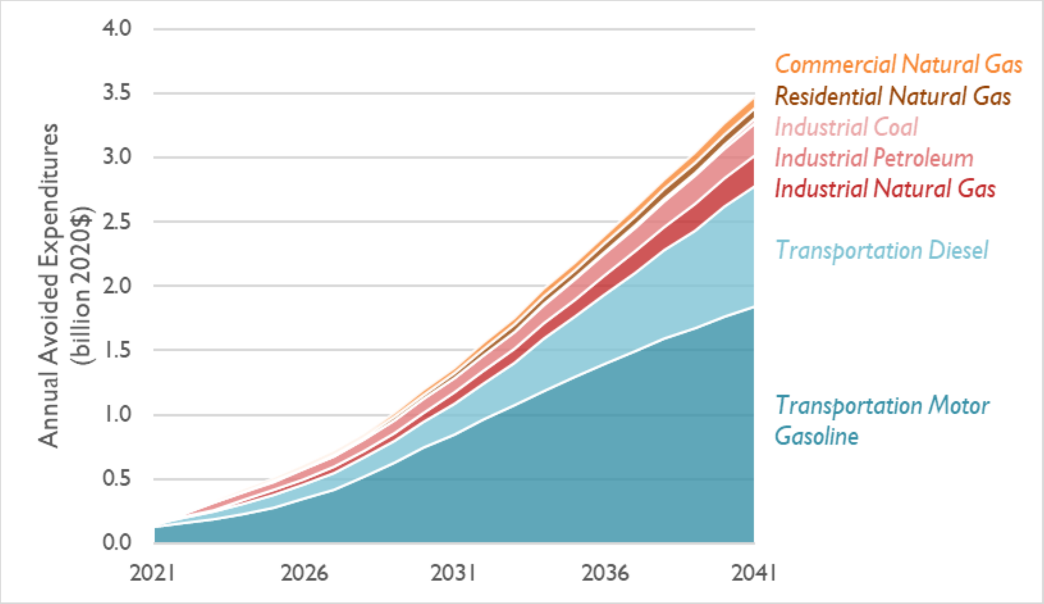
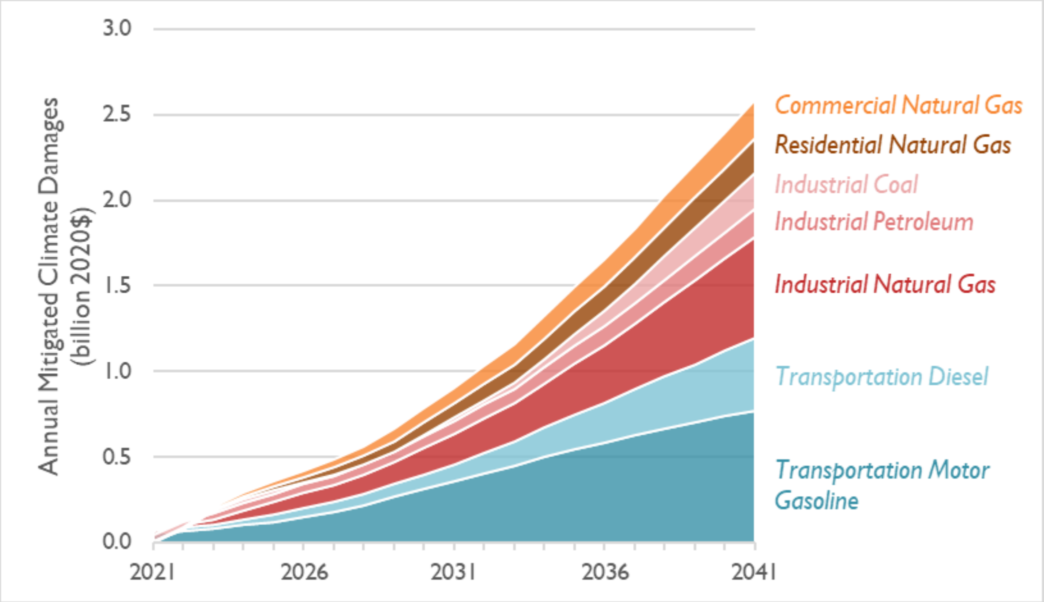


Figure 11. DDRE mitigated non-electric climate damages



4. KEY TAKEAWAYS AND CONCLUSIONS

Deep decarbonization of the electric power sector and rapid electrification of the transportation, buildings, and industrial sectors are essential for averting the worst impacts of climate change. In Indiana, DEI can and should play a critical role by increasing the supply of clean energy within its service territory. Our modeling demonstrates that even with rapid load growth due to electrification, DEI can retire its existing fossil-fuel-fired power generation resources and reduce its overall emissions 75 percent by 2030 and 95 percent by 2040, relative to 2020 levels. At the same time, electrified technologies such as EVs and heat pumps can rapidly decarbonize other sectors of the economy and expand the use of renewable electricity.

This transition will have widespread impacts on the ways residents and businesses consume (as well as produce) energy in Indiana. While some changes will involve investments in the electric sector to serve new loads, there are large benefits to be gained in the form of avoided customer expenditures on fossil fuels and reduced climate-change-related damages around the globe. These reduced costs are large enough to offset increased investment in clean energy generation, though additional transmission and distribution investments of indeterminate cost will be needed.

Deep decarbonization and rapid electrification, the key components of the DDRE scenario, are achievable and widely recognized as essential to avoiding the worst impacts of climate change. DEI's IRP process should be planning for a future that achieves these objectives for the wellbeing of the residents and businesses in the DEI service territory as well as the larger world.