Economic Benefits of Decarbonization in Florida

February 2024

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Acknowledgements

Project Team

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Advisory Committee

Contributing authors to the Florida Climate Institute's Laying the Groundwork for 'Getting to Neutral' in the State of Florida, as well as representatives utilities, planning and community non-profits, business organizations, private industry, and the public sector in Florida all participated on the study's Advisory Committee and provided valuable input into this report. We thank them for their time and contributions.

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ES Executive Summary

Florida has the potential to achieve net zero by 2050 while growing the economy, creating jobs, and reducing the costs of energy and transportation for consumers.

In 2022, the Florida Climate Institute (FCI) quantified Florida's baseline greenhouse gas (GHG) emissions (1990-2018) and projected three GHG emission scenarios through 2050: business-as-usual, 100% clean electric power by 2035, and net zero emissions by 2050 using both sector-wide GHG reduction actions and carbon capture. Using the FCI study as a starting point, this study quantifies the economic impacts of achieving a Net Zero Power System by 2035 and a Net Zero Economy by 2050 relative to a baseline projection in Florida.

Florida has several characteristics that make it well-suited for decarbonization.

Year-round sunshine allowed the state to add more solar generation capacity in the first half of 2023 than any other state in the country.

Nine out of ten households already use electric power for their home heating and air conditioning.

Key findings from this study are below.

Consumer spending on energy and transportation is estimated to decline with increased solar generation and electric vehicle savings.

While natural gas is currently the primary source of power generation in Florida, the levelized cost of energy (LCOE) for solar, a measurement of the total lifetime costs of energy divided by the energy produced, is estimated to continue to decline, making utility photovoltaics (PV) increasingly attractive to build and resulting in cost savings for consumers. Electric vehicles (EV) are also expected to continue to decline in price. For passenger vehicles, consumers are expected to save money on EVs and redirect their disposable income to other goods and services with high in-state presence.

Job growth is estimated across a variety of industries, with many of the jobs offering higher wages and having lower education levels and skill requirements relative to the baseline.

In the nearer term, the growth is concentrated in certain industries supporting the shift to a net zero power grid (e.g., jobs in electrical equipment, machinery). Over the longer term, however, spending from new wages in the economy and redirected consumer spending will affect every aspect of the economy, including construction, manufacturing, consumer services, and transportation. Importantly, many of the jobs that will experience growth will be in occupations that have lower typical education attainment levels and pay higher wages. There will be an increased demand for specific skills and knowledge relative to the current economy, such as installation, mechanical skills, programming, design, and operation control and monitoring.

The estimated cost of the Net Zero Economy scenario amounts to only one-fifth of what the public and private sector spent on input purchases in 2022.

The Net Zero Power System scenario is estimated to cost nearly $130 billion by 2035 relative to the modelled baseline, while the Net Zero Economy scenario is estimated to cost just over $195 billion by 2050 relative to the modelled baseline. For context, the public and private sector spent around $1 trillion on in-state and imported input purchases in 2022, or over five times the total level of investment estimated for the Net Zero Economy scenario in just one year.

These decarbonization investments, coupled with changes in consumer spending, are estimated to result in positive impacts to gross state product (GSP) and employment.

The Net Zero Power System by 2035 scenario is estimated to result in a state economy that is 1.5% larger in 2030, around when the stimulus investment for that scenario peaks, relative to the baseline in that year (as measured by total GSP). The Net Zero Economy provides a larger stimulus and further reduces costs to businesses and households, resulting in a state economy nearly 2% larger compared to the baseline in 2050.

The transition to a decarbonized economy is already occurring.

Local governments throughout Florida have committed to GHG emission reduction targets and are actively making investments to reduce their emissions. Between 2018 and 2022, the annualized growth rate for renewable energy generation jobs in Florida was nearly 13% (the national rate was just over 1%), while non-renewable jobs had a negative rate for both the state and US. Sales of electric vehicles are rising, solar capacity is increasing, and new developments are simultaneously addressing both carbon footprints and resilience with the installation of solar microgrids.

Decarbonization in Florida is achievable and has the potential to bring widespread economic benefits. This report helps shed light on the significant efforts already underway by the public and private sector towards achieving net zero, the investment needed to meet decarbonization, and the benefits that can be gained from such investment.

01 Introduction

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This study evaluates the economic benefits associated with achieving a Net Zero Power System by 2035 and a Net Zero Economy by 2050 in Florida. The work presented here incorporates information from past efforts, in particular Florida Climate Institute's (FCI) Laying the Groundwork for 'Getting to Neutral' in the State of Florida (Ghebremichael, et al., 2022), which quantifies Florida's historical emissions and presents emission reduction scenarios (Florida Climate Institute 2022). Additional assumptions were developed to better understand the investment and changes in spending relating to sector-specific pathways towards a decarbonized economy. The study focuses on a baseline and two decarbonization scenarios, as outlined opposite.

The report begins with an overview of the economic modeling framework. This is followed by information on the two analyzed decarbonization scenarios and the baseline against which they are compared, setting out the sector-specific decarbonization pathways that have been constructed, the evidence upon which they are based, and how they compare to other published data and pathways. The resulting economic impacts are then presented and followed by a discussion on workforce considerations.

Baseline

Accounts for plans and actions already occurring within the energy sector.

Net Zero Power System scenario

Models decarbonization of electricity by 2035 with no change (relative to the baseline) in the rest of the economy.

Net Zero Economy scenario

Models decarbonization across sectors by 2050, and consists of actions for a clean electricity scenario in addition to actions that address building, transportation, industrial, and other emission sources, as well as increases in carbon capture.

Florida at a Glance

22.2 million
population in 2022

$1.4 trillion
Gross State Product in 2022

Population

- As of 2022, **Florida's population is estimated to be 22.2 million.**
- With a **1.9% increase between 2021 and 2022**, Florida was the fastest-growing state in the US. Between 2010 and 2020, as nationwide population growth slowed dipping from 0.9% to 0.5% each year, Florida's annual population growth rate ranged from 1% to 2% (Perry, Rogers, and Wilder 2022).
- As of 2020, Florida ranked **second in the nation for population aged 65 and older**, with just over one-fifth of the population in this age cohort (Florida Legislature Office of Economic and Demographic Research 2023; US Census Bureau 2020).
- Florida's **prime working age population (aged 25-54) represents less than 40% of the total population** (Florida Legislature Office of Economic and Demographic Research 2023).
- According to the American Community Survey from 2022, Florida **ranked sixth in the country for percentage of population over five years of age who speak a language other than English at home.**
- While personal consumption expenditures (PCE) on goods and services largely follow national spending patterns, **Floridians spend a larger share on housing and utilities relative to the national average** (19% vs 17% of total PCE) (US Census Bureau 2022; Bureau of Economic Analysis 2023a).

Economy

- **Florida's GSP was $1.4 trillion in 2022**, the fourth largest in the country. The top five industries by GSP were Finance and Insurance (11%), Public Administration (10%), Professional, Scientific, and Technical Services (9%), Health Care and Social Assistance (9%), and Retail Trade (8%) (Bureau of Economic Analysis 2023b; Lightcast 2023).
- Of the **state's over ten million jobs**, 12% were within Health Care and Social Assistance, followed by 11% in Public Administration, 11% in Retail Trade, 10% in Accommodation and Food Services, and 8% in Administrative and Support and Waste Management and Remediation Services. Jobs in oil and gas extraction and petroleum and coal products make up less than 1% of jobs in the state (Lightcast 2023).
- In 2022, there were **$1 trillion in input purchases by the public and private sector** in Florida's economy, over 70% of which was in-state (Lightcast 2023).
- Tourism is a large contributor to the state economy, with **nearly 138 million people visiting in 2022** (Visit Florida 2022).

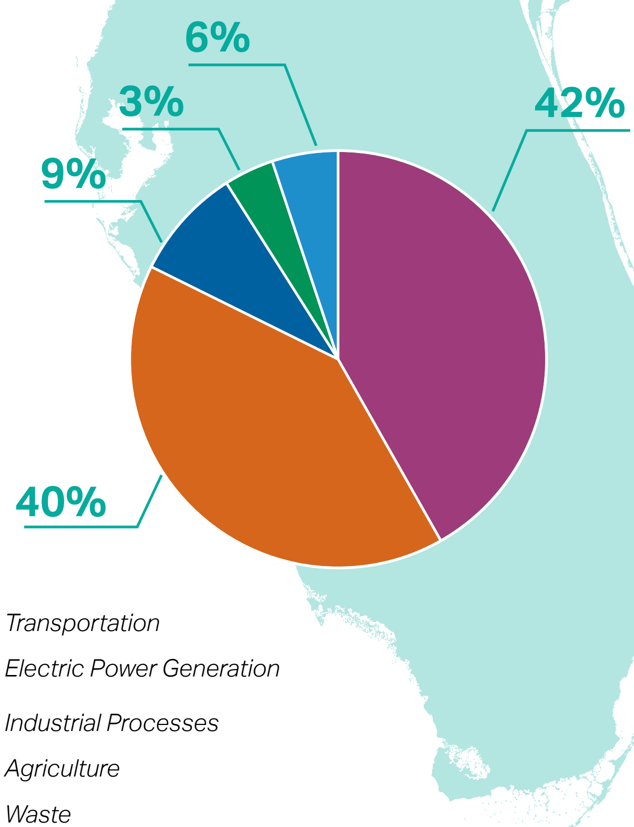
[1] Industrial processes include non-combustion process emissions from an array of industries. The FCI study considers the following source activities under industrial processes: clinker production in cement making, lime production, limestone and dolomite consumption, soda ash consumption, iron and steel production, ammonia production, urea consumption, nitric acid and adipic acid production, electric power transmission and distribution systems, consumption of ozone-depleting substances (ODS), semiconductor manufacturing, and phosphoric acid production.

14% reduction
per capita in GHG emissions 1990-2018

Emissions

- The FCI study evaluated greenhouse gas (GHG) emissions from 1990-2018. Between this time period, **gross emissions increased by 40% but decreased by 14% on a per capita basis**. Figure 1.1 shows the emissions profile with the following sectors: transportation, electric power generation, industrial processes[1], agriculture, and waste. Together, **transportation and electric power generation accounted for nearly 83% of the state's gross GHG emissions in 2018** (Florida Climate Institute 2022).
- While significant decarbonization is necessary to achieve Net Zero Power, **major changes to the grid in short time have already occurred** – natural gas represented 23% of total electric power generation in 2001 and now makes up over 75% of the state's mix, surpassing electricity generated from coal in 2004. Solar production is also on the rise, comprising around 5% of electric generation in 2022 (Energy Information Administration 2022).
- **Nine out of ten of Florida's households already use electric power for their home heating and air conditioning**, substantially decreasing the need for a residential electrification overhaul that many states face (Energy Information Administration January 19, 2023b).
- Florida's **gasoline highway vehicle emissions, which constituted the largest portion of transportation GHG emissions in 2018, fell 82% since 1997** (Florida Climate Institute 2022).
- Electric vehicles, though only a small portion of the vehicles on the road today, are increasing in prevalence as **Florida had the second-highest number of registrations of electric vehicles in 2022** in the country (Department of Energy 2023).

Figure 1.1. Total gross emissions by sector



Source: Laying the Groundwork for 'Getting to Neutral' in the State of Florida
Notes: Land Use, Land-Use Change, and Forestry (LULUCF) was included in the FCI study but results in negative emissions and therefore is not shown in the above chart.

02 Economic Modeling Framework

Image source: Adobe Stock Images

Investments to accelerate the transition to a decarbonized economy have cascading economic effects. The investments themselves provide economic stimulus in the short term, such as through the creation of construction jobs. Changing energy prices impact both consumers and suppliers of energy, and influence where expenditures are directed. Consumers spending less on energy overall can divert that consumption towards other parts of the economy. The resulting impacts on economic output, employment, and consumer spending can be estimated through the use of economic models.

A suite of models has been developed which specialize in capturing the relationship between energy systems, the economy, and the environment. Sometimes referred to as E3 models, these "all-in-one" tools simultaneously model economic and environmental impacts of various emissions reduction policies and spending by dynamically modeling how energy systems change in response to them. Typical outputs to these models include gross domestic product (GDP), economic output and employment by sector, or net consumer savings on energy prices relative to the baseline. For this study, Cambridge Econometrics' E3-US model was used to assess energy-economy linkages at US-state level. E3-US is flexible in allowing users to start from different sets of inputs. More information on the E3-US model can be found in Appendix A.

While the details differ between the various models and methods, in general, they follow a similar process. First, it is important to establish a baseline inventory of historical emissions and future business as usual emissions. Next, scenario(s) for future decarbonization are developed. Lastly, the changes in energy supply, demand, and expenditure associated with the scenarios are modeled to estimate changes in employment and output, as well as emissions. While the transition to a net zero power system and/or economy requires substantial changes within different sectors of the economy, fundamentally there are two aspects that drive most of the impact at the macro level:

- Changes in the level of investment in the economy, which will provide an economic stimulus in the short term (e.g., through the creation of manufacturing and construction jobs to build/install capital) and will alter the productivity of sectors in the medium-to-long term.
- Changes in the prices of different energy carriers (most notably electricity, which has a 'local' market, while the prices of most fossil fuels are determined by national or international, rather than state-level, demand).

The scope of the economic modeling conducted for this study does not include identification of the policies or programs needed to achieve decarbonization, or specific funding sources required to get there. Instead, it provides an understanding of the magnitude of the investment and changes in consumer spending, and the resulting sector-level impacts, in order to help residents and businesses in Florida realize the opportunities associated with decarbonization.

Furthermore, it is important to note that the economic impacts explored in this report relate to the two scenarios associated with decarbonizing Florida's economy. Additional benefits may be realized, however, from the decarbonization efforts occurring elsewhere throughout the country. For example, while Florida itself has low wind energy generating capacity, businesses in the state are supporting wind energy manufacturing which has growing demand elsewhere in the country. These impacts are not captured here though are an important part of the economic impacts that will result from decarbonization.

Section 3 describes key aspects of the scenarios relating to the deployment of technologies in specific sectors, and the way that affects energy demand. Supplementary data on technology and energy costs are used to translate these scenarios into specific changes in investment, energy consumption and spending (on energy and other goods/services) by businesses and consumers in order to evaluate the impacts on the Florida economy.

03 Scenario Design and Assumptions

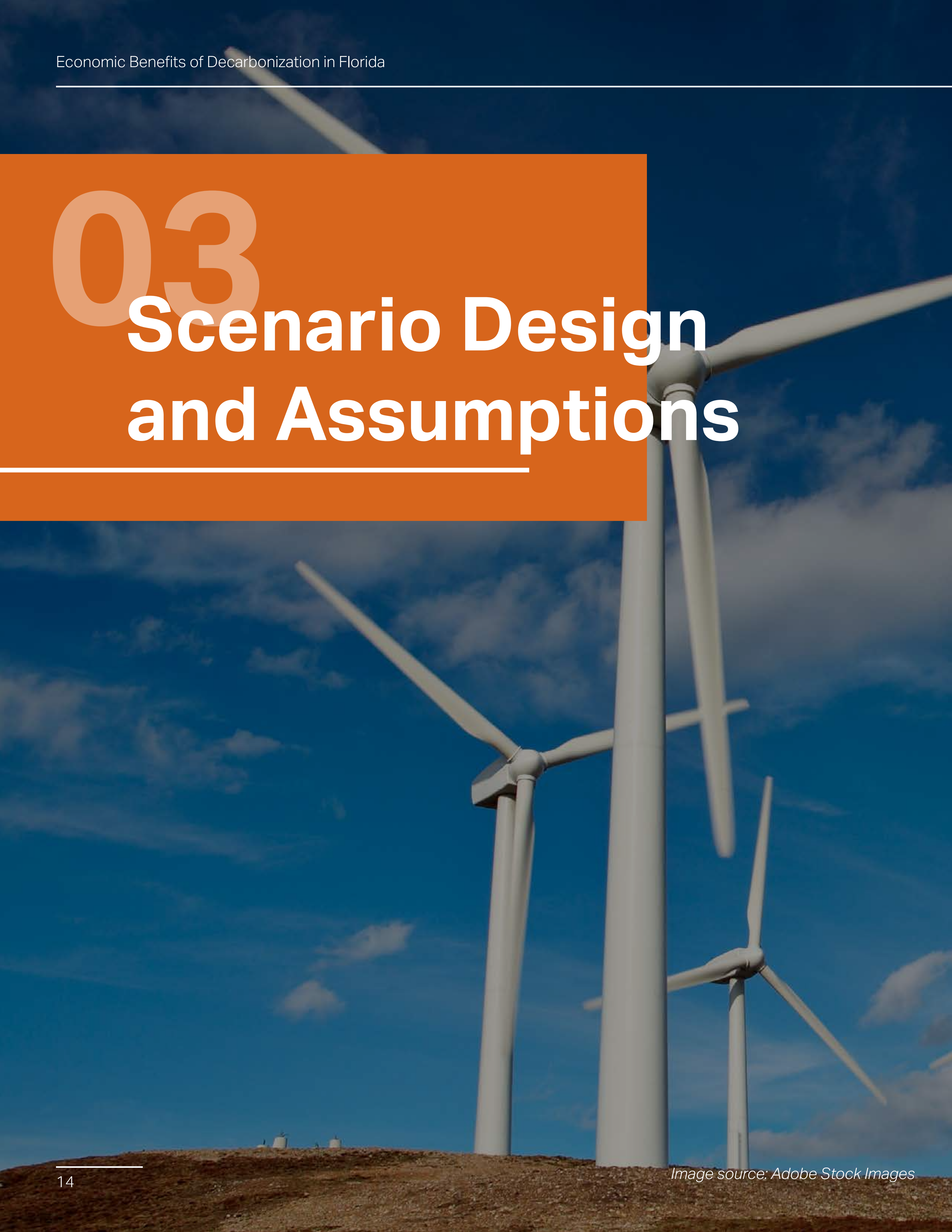


Image source: Adobe Stock Images

While Florida has not yet developed or published its own state-level emissions inventory or emissions reduction scenarios, the FCI report undertakes this task. More information on the FCI scenarios can be found in Appendix B or in Laying the Groundwork for 'Getting to Neutral' in the State of Florida. Other studies in Florida have also made projections that affect decarbonization, such as the utilities' ten-year site plans that outline existing resources and projections, and Florida Department of Transportation (FDOT) EV Infrastructure Master Plan (FDOT, 2021). These Florida studies, as well as national reports and data, were reviewed to support assumptions relating to grid mix, technology readiness and uptake rates, costs, and various other energy efficiency, land use, transportation, waste, and industrial process-related assumptions. Table 3.1 highlights some of the key Florida studies referenced for the scenario design and assumption building.

The emissions baseline for this study is consistent with the US Energy Information Administration (EIA) historical data, and in the forecast period is aligned with the reference case from the EIA Annual Energy Outlook 2023 disaggregated to the state level. This means that the E3-US baseline includes the impacts of the Infrastructure Investment and Jobs Act (IIJA) and Inflation Reduction Act (IRA) because they are part of EIA's projections (Energy Information Administration 2023b).

In the rest of this chapter, two distinct pathways for each of the analyzed sectors are laid out – a continuation of existing trends in the baseline, and a decarbonization pathway, consistent with a transition to net zero in the sector by 2035 (electricity generation sector) or 2050 (all other sectors). These pathways are based upon published data and pathways, and in instances where the finalized pathways are not consistent either with published trajectories, or with complete decarbonization by the specified date, the reasons for the discrepancy and assumed supplementary changes are explained. Electric power generation and transportation are the key drivers of the emissions profile and there are many existing studies that discuss the decarbonization of these sectors. Other main emission sources, such as industry, land use, and waste, have more limited information; as such, the analysis estimates the quantity of investment needed based on emission reduction scenarios such as those in the FCI report. The sector-specific decarbonization pathways are used to determine the baseline and decarbonization scenarios' investment and spending. The marginal changes in investment and spending in the decarbonization scenarios, relative to the baseline, are then used in the E3-US model to assess macroeconomic impacts.

Image source: Adobe Stock Images

Table 3.1. Florida decarbonization reports

Agency - Title	Description
Florida Climate Institute (FCI) – Laying the Groundwork for 'Getting to Neutral'	Quantifies Florida's GHG emissions for 1990-2018 and projects emissions through 2050 under a business-as-usual scenario, a clean electricity by 2035 scenario, and a net zero by 2050 scenario.
Florida Department of Agriculture and Cosnumer Services (FDACS) Office of Energy - Florida Energy and Climate Plan	Highlights important state-level energy and climate issues, recommends agency, legislative, and collaborative actions, and serves as a guide for the Office of Energy in the years ahead.
NextEra - Zero Carbon Blueprint	NextEra's blueprint towards being completely carbon emissions-free by no later than 2045.
Various - Ten Year Site Plan	Ten-year Site Plans submitted Spring 2023 outline existing resources and forecasted demand including from Florida Power & Light (FPL), Duke Energy, Tampa Electric (TECO), Florida Municipal Power Agency, Gainesville Regional Utilities, JEA, Lakeland Electric, Orlando Utilities Commission, City of Tallahassee Utilities, and Seminole Electric Co-op.
Florida Reliability Coordinating Council (FRCC) - Regional Load and Resource Plan	Contains the state's latest projections on power consumption by sector, fuel, and by individual plant. Plant-specific information could also be useful in evaluating upcoming projects and timelines for phase-out.
Florida Department of Transportation (FDOT) - EV Infrastructure Master Plan	Covers historical trends in EV uptake, has three scenarios going forward, and discusses the needed charging infrastructure to meet that demand.
Center for Urban Transportation Research - Autonomous Vehicle (AV) and Alternative Fuel Vehicle (AFV) Florida Market Penetration Rate and VMT Assessment Study	Analysis of AV and AFV market penetration and impact on vehicle miles traveled (VMT) in Florida, covering 2017 through 2048.

Source: Florida Climate Institute 2022; Florida Department of Agriculture and Consumer Services 2019; NextEra Energy 2022; Florida Power & Light et al. 2023; Florida Reliability Coordinating Council, Inc. 2021; Florida Department of Transportation 2021a; 2021b; Center for Urban Transportation Research 2019

3.1 Power Sector

Key Takeaways

Over the last decade, natural gas has emerged as the primary source of power generation in Florida; however growing cost competitiveness is leading to significant growth in solar generation.

Solar photovoltaics (PV) costs are anticipated to continue to decline into the future.

By 2035, solar PV accounts for 33% of power generation in the baseline. Heightened levels of investment are anticipated to increase that generation percentage in the modeled scenarios, which estimate that solar PV accounts for more than two-thirds of generation in the Net Zero Power System and Net Zero Economy scenarios by that time.

This increase in renewable generation is paired with an assumed growth in battery storage and natural gas with carbon capture for the Net Zero Power System and Net Zero Economy scenarios.

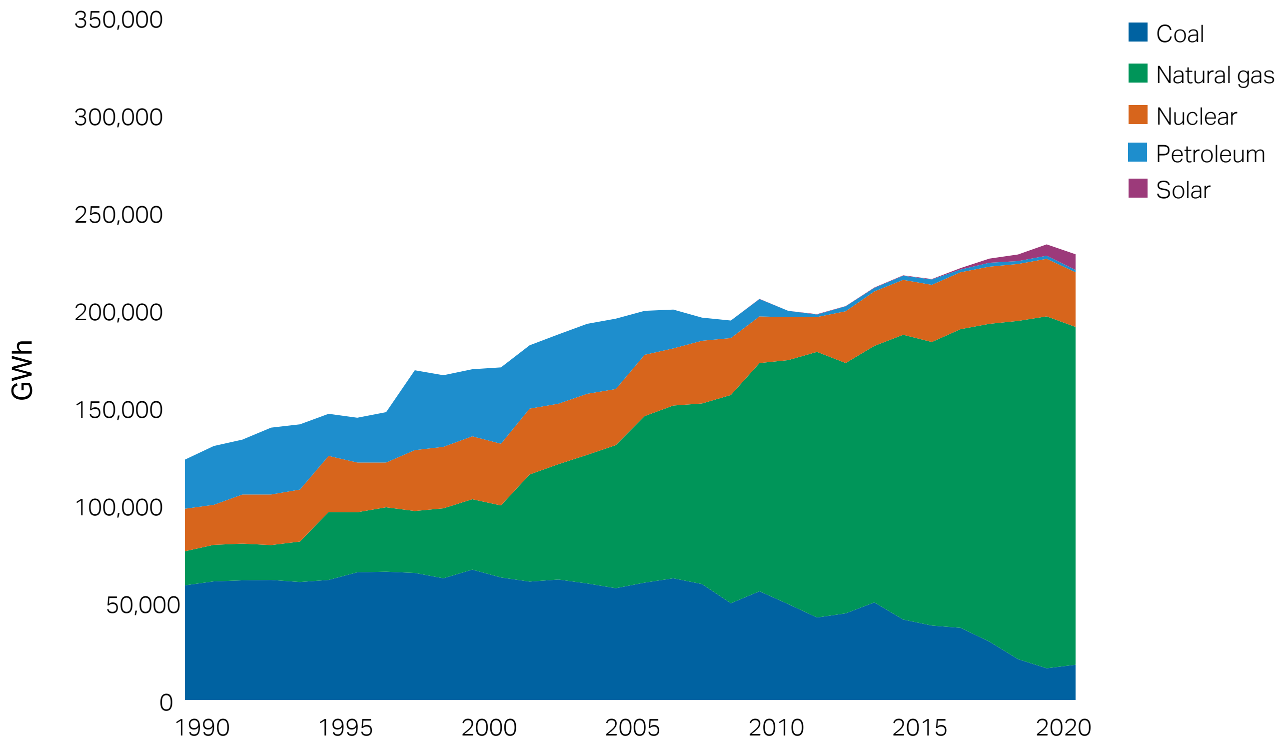
In 2021, Florida had the third-highest electric consumption in the nation (Energy Information Administration 2023). Historically, Florida has relied primarily on power plants fueled by fossil fuels to generate its electricity (see Figure 3.1). In the 1990s, more than half of electricity generation came from coal or oil-fired power plants, but both subsequently saw substantial reductions in their role in generation; oil (petroleum) mostly disappeared by 2010, while coal's share of electricity generation has been decreasing over the past 15 years. Electric generation from natural gas has expanded significantly since the early 2000s and accounted for around 75% of the state's power generation by 2021. Between 2008 and 2018, nearly one-quarter of all natural gas installations in the country were in Florida, adding nearly 16 gigwawatts (GW) of utility-scale electric generation (Energy Information Administration 2019).

However, as renewables have become more cost competitive, there has been sizeable growth in the state's renewable power capacities. Due to the abundant sunshine in Florida, this growth has mainly been from solar photovoltaics (PV). In the first half of 2023, Florida added more solar-generation capacity than any other state in the country (Hurtibise 2023). However, this growth has been from a very low base, and as a result solar only started to attain a visible market share (around 5%) in recent years.

In the baseline, deployment of renewable energy sources (mainly solar) is somewhat accelerated, reflecting the continued decrease in costs of these technologies, but fossil fuels remain a significant part of the power mix. By 2035, natural gas is estimated to comprise just over half of generation. Solar PV experiences the most rapid growth in the baseline through 2035 with its share increasing from 6% in 2022 to 33% in 2035. This reflects the continued decreases in costs of solar technology, but fossil fuels still remain a significant part of the power mix beyond 2035.

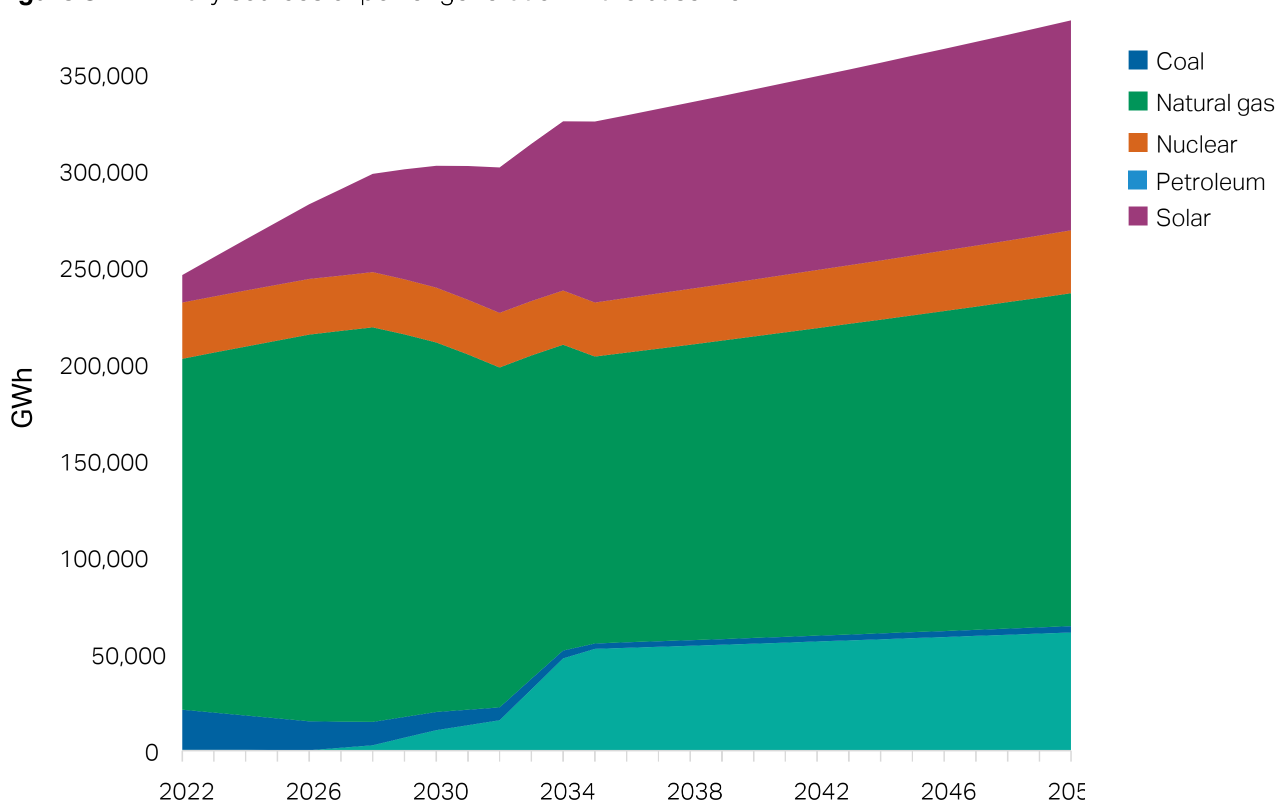
While natural gas is expected to remain an important part of the state's power mix in the baseline, it makes up a decreasing share of total power generation over time: by 2035 is estimated to comprise around 52% of generation in the baseline, compared to approximately 75% in 2021. The increase in solar PV capacity fills the gap that results from the declining role of natural gas-powered generation. From around 2030, battery storage also emerges as a major source of power generation. Although not a primary generation source, battery storage is a secondary generation source that is charged by electricity from other sources and discharges electricity when and as needed (Energy Information Administration n.d.). Battery storage provides balancing services to complement intermittent generation from renewables like solar and enhances the flexibility of renewable energy usage (Bowen, Chernyakhovskiy, and Denholm n.d.). Power from battery storage grows to be the third largest source by 2035 in the baseline (see Figure 3.2). Production continues on an upward trend through 2050 though the mix of sources stays relatively consistent (natural gas at 45%, solar at 29%, battery at 16%).

Figure 3.1. Primary sources of power generation in Florida 1990-2021



Source: Energy Information Administration.

Figure 3.2. Primary sources of power generation in the baseline



Provided by the City of Tallahassee

NEXTERA ZERO CARBON BLUEPRINT

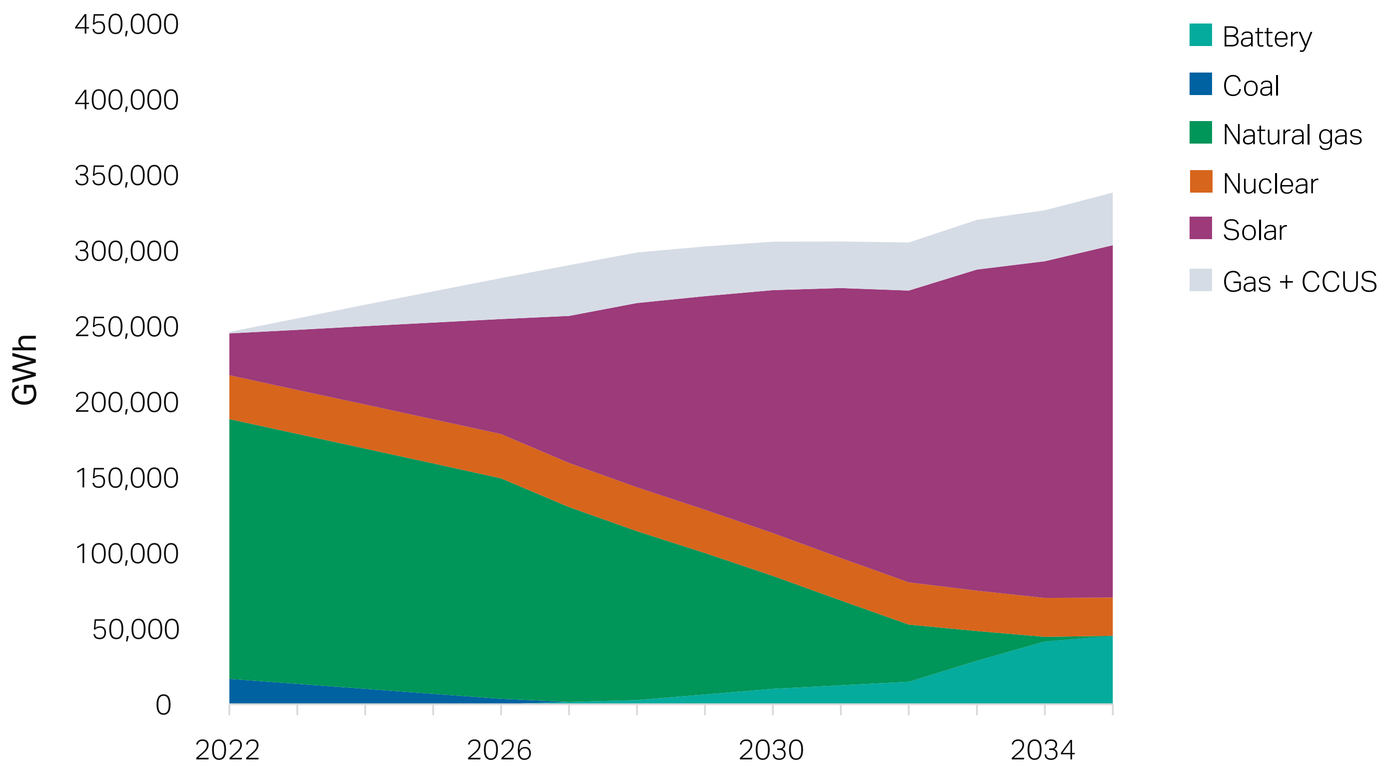
In 2022, Florida Power & Light (FPL) and its parent company, NextEra Energy, announced plans to entirely eliminate carbon emissions from its operations without relying on offsets by 2045 - a goal NextEra calls Real Zero (NextEra Energy 2022). NextEra plans to achieve this goal through significantly increasing its solar, wind, and battery storage investments, maintaining current use of clean, efficient nuclear power, displacing existing natural gas production with cleaner alternatives, and developing green hydrogen opportunities (NextEra Energy 2022). Already, FPL and NextEra have achieved significant decarbonization while increasing total generation capacity: from 2005 to 2021, NextEra's carbon emissions rate improved from 37% to 51%, better than the nationwide electric power industry average as generation capacity increased by 72% (Trabish 2022). As of 2021, NextEra had achieved a 58% carbon emission reduction compared to a 2005 adjusted baseline (Trabish 2022). With solar now the most cost-effective generation resource in most parts of FPL's service area (Florida Power & Light 2023), FPL plans to reach 11,700 MW of universal solar capacity by 2030, and is quickly operating and increasing the number of solar energy centers across the state (DeMeo and Codina 2022; Renewable Energy Magazine 2021). Each 74.5MW solar center can produce enough energy to power 15,000 homes and eliminate emissions equivalent to removing 14,000 cars from the road each year. Every solar plant is estimated to support around 200 to 250 jobs during construction. The centers also generate thousands of dollars in tax revenue for the counties where they operate and help catalyze economic development (Scott 2023).

The Net Zero Power System scenario, as its name suggests, aims to achieve a power grid with net zero emissions (i.e., any residual emissions are at least fully offset by carbon capture) by 2035. This projection is broadly in line with the National Renewable Energy Laboratory's (NREL, 2022) mid-case scenario for Florida.[2] Almost all fossil fuels are phased out of power generation by 2035; unabated coal and petroleum by 2027, followed by unabated natural gas, which disappears from the mix by 2035. However, some coal and gas plants are updated with carbon capture, use and storage (CCUS) technology; while these fossil fuels remain in the power generation mix, their emissions are minimal due to CCUS. CCUS is a process by which carbon dioxide emissions from sources like coal-fired power plants are reused as fuel on-site, compressed and transported, or stored in deep geological formations like saline aquifers (International Energy Agency n.d.). rather than released into the atmosphere. While Florida's geology poses challenges to the development of underground carbon storage sites, the modeling assumes some level of technological improvements will allow CCUS to become more viable within the analysis timeframe. Although the CCUS-supplemented plants do take over some of the market share initially held by unabated fossil technologies, solar PV technology gains the most market share. By 2035, solar PV represents 68% of power generation (see Figure 3.3).

For the Net Zero Economy scenario, the power mix holds relatively constant from 2035 to 2050 with the primary difference of the phaseout of gas plus CCUS technology (see Figure 3.4).

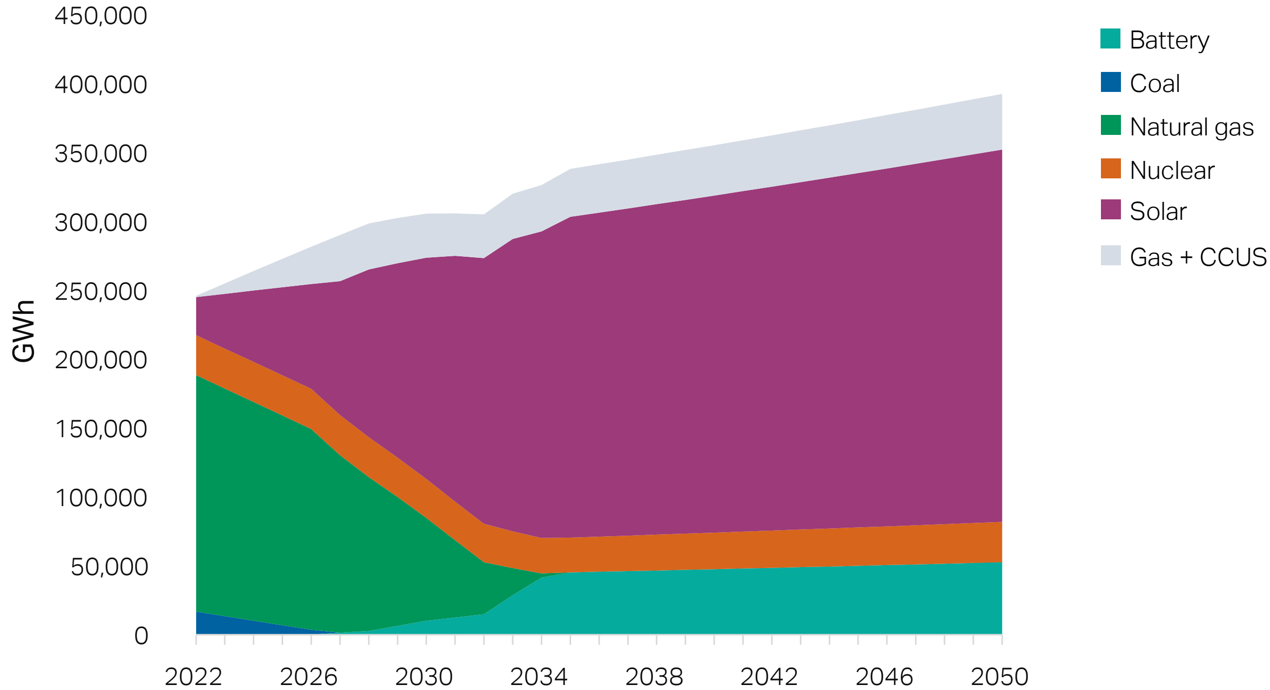
These dynamics are included in the economic impact modeling via two categories of direct inputs. First, the model evaluates the additional investment needed for this scenario to be delivered, relative to the baseline, reflecting the different supply chains for renewables and CCUS as compared to the fossil fuel-based technologies they are pushing out of the generation mix. Second, the model estimates the impact of the changing technology mix on electricity prices and the follow-on impact that this price change has on industry and consumers.

Figure 3.3. Primary sources of power generation in the Net Zero Power System scenario



[2] *One difference is that the NREL scenario still has some unabated gas, while the net zero power sector mix presented here removes all unabated fossil fuel emissions.*

Figure 3.4. Primary sources of power generation in the Net Zero Economy scenario



CITY OF TALLAHASSEE CLEAN ENERGY PLAN

In 2019, the City Commission of Tallahassee adopted the Clean Energy Resolution that committed to transitioning Tallahassee to a 100% net clean, renewable energy future by 2050. Since then, an Energy Integrated Resource Plan (EIRP) was conducted, which helped form a Clean Energy Plan. The Clean Energy Plan, composed of 87 potential actions organized into seven broad policy goals, is designed to guide the City's clean energy efforts over the near term (5-7 years). The near-term efforts focus on increasing solar energy production while partnering with local universities and research firms to promote research and development (R&D) in other emerging clean energy technologies and fuel sources. This includes the goal of enabling the installation of an additional 30-50 MW of distributed solar capacity in the community by 2030. To promote energy efficiency and conservation, the Clean Energy Plan's approach to greening municipal building operations in Tallahassee include building retrofits as well as installing maximum solar generation capacity economically feasible on municipal building roofs. For residents, the City plans to implement programs that provide financial incentives for energy efficiency retrofits (City of Tallahassee 2019).

Image provided by the City of Tallahassee

3.2 Transportation

Key Takeaways

Electric vehicle (EV) uptake rates have been on the rise and are projected to increase as vehicle purchase cost and overall cost of ownership declines relative to internal combustion engine (ICE) vehicles.

In the Net Zero Economy scenario, decarbonization in the transportation sector is reached through widescale adoption of passenger and heavy-duty EVs.

By 2050, EVs are projected to account for 90% of new passenger vehicle sales in the Net Zero Economy scenario as opposed to 30% in the baseline.

The electrification of Florida's heavy-duty vehicle fleet progresses more gradually given higher costs, with 66% expected to adopt zero-carbon technologies by 2050 in Net Zero Economy scenario compared to less than 20% in the baseline.

According to the FCI emissions analysis, transportation was the largest contributing sector of GHGs in Florida in 2018. Florida ranked fourth in the country for petroleum consumption in 2021, driven in part by the state's many tourists as well as by cargo traffic (Energy Information Administration 2023). As of 2021, Florida was 8th in the country for freight value originating from the state, and fifth in destination value (Bureau of Transportation Statistics, n.d.).

To decarbonize the transportation sector, this analysis focuses on electrifying passenger vehicles and heavy-duty trucks. Note that investments addressing emissions associated with airplanes, boats, and other mobile sources, are not captured in the economic modeling. Also note that the focus of the analysis is on the vehicle fleet in Florida, though mobile combustion emissions will also be generated by passenger and heavy-duty vehicles from other states.

As of 2022, Florida had the second-highest number of registrations of electric vehicles of any state, behind only California (Department of Energy 2023). This represented around 0.9% of total vehicles in the state, up from 0.5% in 2021. Florida ranked in the top ten states for battery electric vehicles in terms of percentage of all vehicle registrations (Department of Energy 2023).

The shift to zero-carbon vehicle technologies is essential if the state is to successfully decarbonize this sector, given that demand for passenger transport by light duty vehicle (including cars and SUVs) is expected to increase out to 2050, by around 1% per year[3] (Concas, Kolpakov, Sipiora, & Sneath, 2019), from around 240 billion vehicle miles in 2020 to 350 billion vehicles miles by 2050. This also implies at least some increase in the total number of vehicles in Florida, with implications for the amount spent on vehicles by consumers.

When looking at the future penetration of battery electric vehicles into the passenger car fleet, the primary point of comparison was the FDOT EV Infrastructure Master Plan (FDOT, 2021). This publication includes Conservative, Moderate and Aggressive deployments of electric vehicles. This study's baseline broadly follows the Conservative case from this publication, while the decarbonization pathway is based upon the Aggressive scenario. That report (FDOT, 2021) sets out trajectories to 2040, which are extended here to 2050, applying the concept of S-shaped diffusion curves for new technologies (Briscoe, Trewhitt, & Hutto, 2015). In practice, this means that simple linear increases in market share for new technologies are not assumed here, but rather transitions happen at an increasing rate until a 'tipping point' is reached, at which point such technologies are rapidly taken up at mass-market scale.

In the baseline, sales of passenger EVs increase modestly from 6% of sales in 2022, reaching almost 30% of sales by 2050.[4] Despite this, the baseline has a greater penetration of EVs in the vehicle fleet by 2040 than the Conservative scenario from FDOT, reflecting the rapid increase in the market share of EVs that has been achieved since the FDOT study was published – 17% of the fleet is electric by 2040,

[3] The average rate of growth in vehicle miles travelled (VMT) over 2018-2048 was 1.41% per year in the baseline case in the cited study (table A-1)

[4] Note that this implies smaller average year-on-year increases in sales shares than were observed between 2021 and 2022 (when the sales share increased from 3% to almost 6%), (Cross and Larsen 2021; Johnson 2022)

Figure 3.5. Millions of passenger vehicles in Florida in the baseline

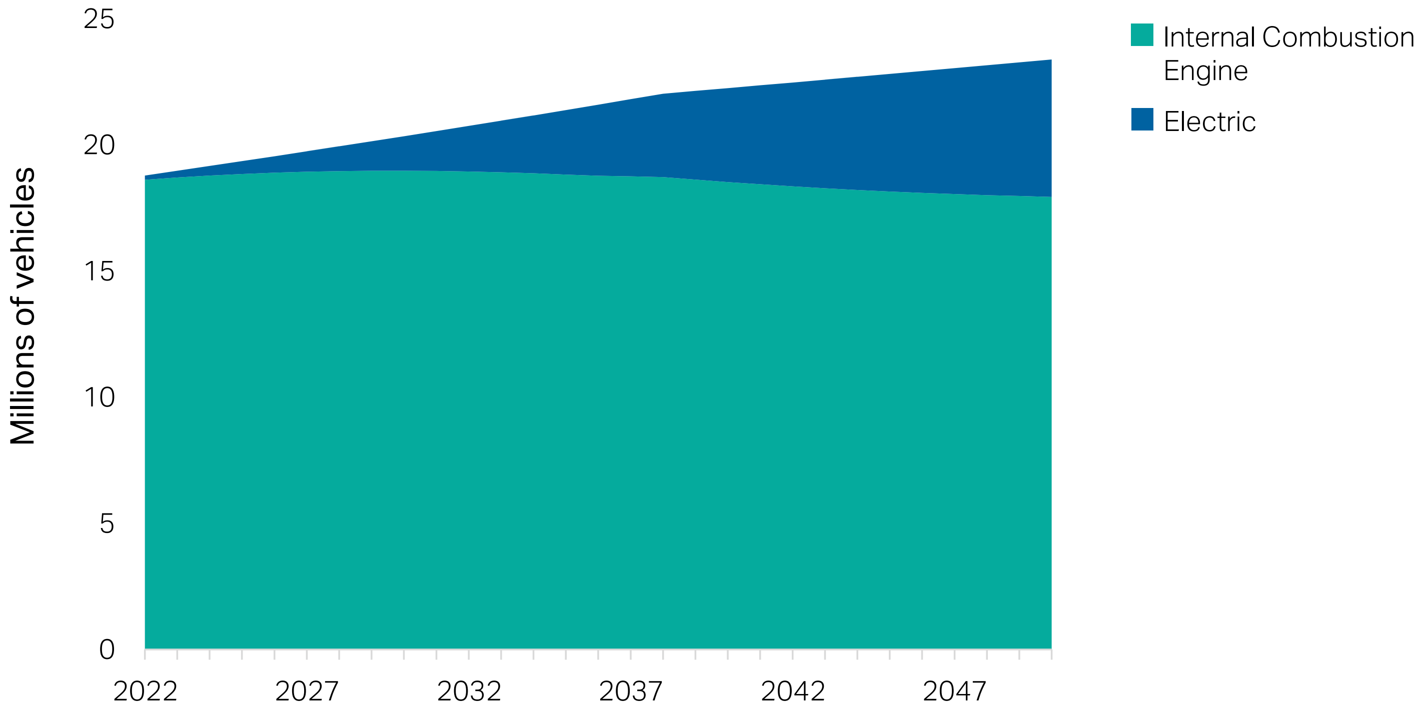
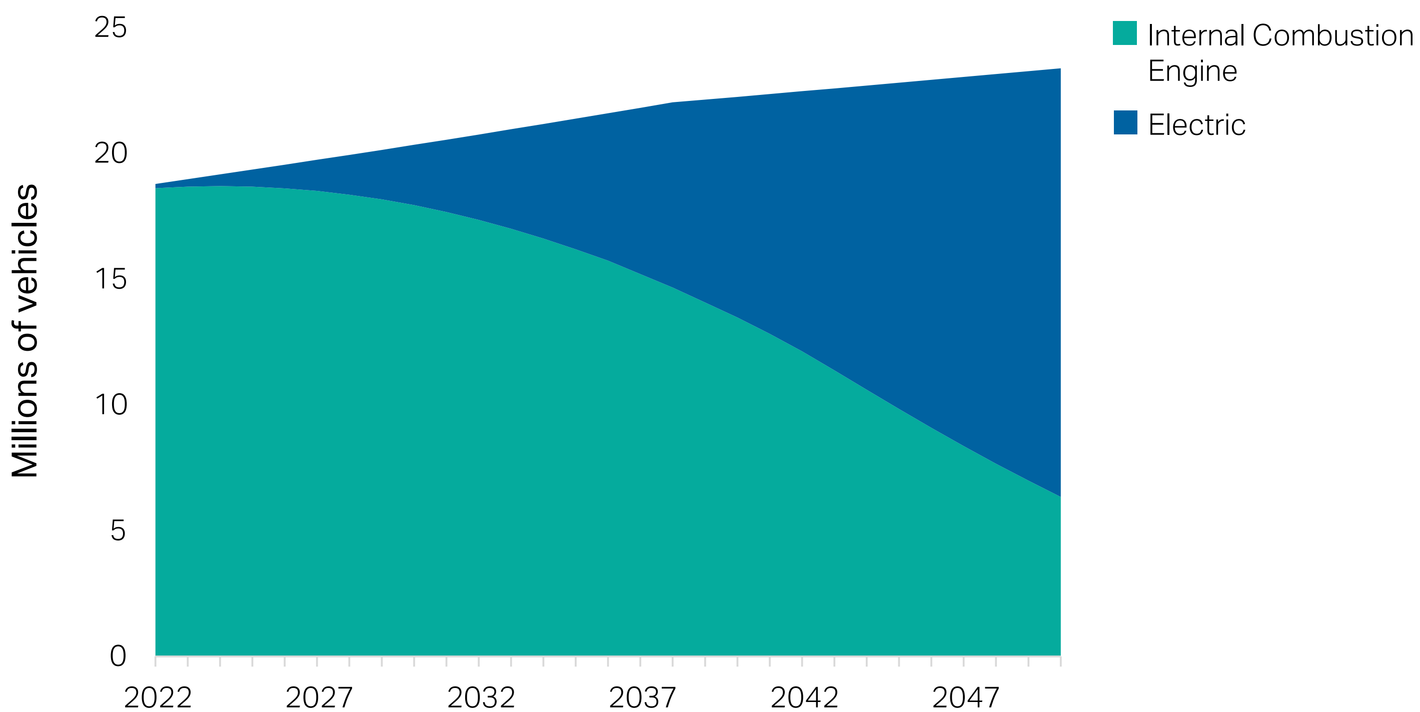


Figure 3.6. Millions of passenger vehicles in Florida in the Net Zero Economy scenario



compared to 10% in the FDOT study (see Figure 3.5).

In the Net Zero Economy scenario, the sales share of passenger electric vehicles is assumed to increase by 3 percentage points per year on average (approximately the same increase in market share as seen in 2021-22), meaning that by 2040, 60% of sales are electric, and in the same year 39% of the fleet is electric (see Figure 3.6). The modeling assumes that EV penetration rates pick up through the first half of the 2040s, meaning that by 2050 almost three quarters of the fleet (73%) is electric, and nine out of every ten vehicles sold in that year are electric. This is slightly more ambitious than FDOT's Aggressive scenario, which in 2040 foresees 35% of all vehicles as being electric – again this reflects the more rapid deployments observed since publication of the FDOT study. An ambitious deployment such as this could be realized by specifically addressing some of the barriers which currently exist to consumers' purchasing EVs, such as the cost profile (currently higher up-front costs), and the availability of models that meet consumer needs (in terms of real-world operating range and recharging speeds).

To ensure that this scenario is consistent with a Net Zero Economy, the combustion engine vehicles remaining in the fleet in 2050 are assumed to be fueled by some combination of drop-in biofuels and conventional fossil fuels with emissions abated by direct air carbon capture and storage (DACCS) technology. Note that this study does not consider it necessary for these carbon capture costs to be directly attributed to road transport (i.e., for vehicle operators to pay these costs) – simply that from a carbon accounting perspective, negative emissions elsewhere in the economy 'balance out' residual emissions from transport.

ELECTRIC VEHICLES IN FLORIDA

Florida is at the forefront of the US transition to low-carbon private transport with the second-highest number of registrations of electric vehicles of any state (Department of Energy 2023). As a percentage of total vehicle registration count, Florida's share is slightly lower than the national average, but is increasing at a rapid pace. The National Electric Vehicle Infrastructure (NEVI) program was authorized by the IIJA to help provide funding to States to strategically deploy EV charging infrastructure. In late 2022, Florida's Electric Vehicle Infrastructure Deployment Plan was approved by the Federal Highway Administration (FHWA) and over the next 5 years the state is estimated to receive $198 million through this program (Scheckner, 2023). Schools have already begun to receive awards and grants to establish training programs. For example, Indian River State College received a $2.7 million award from the National Science Foundation to establish a National Electric Vehicle Consortium to advance knowledge production and training in the sector. In addition, local governments across Florida are transitioning to electric municipal fleets. For example, Miami-Dade County has committed to 100% light fleet electrification by 2030, and is also moving towards electrifying the county's Metrobus fleet (Miami-Dade County 2023).

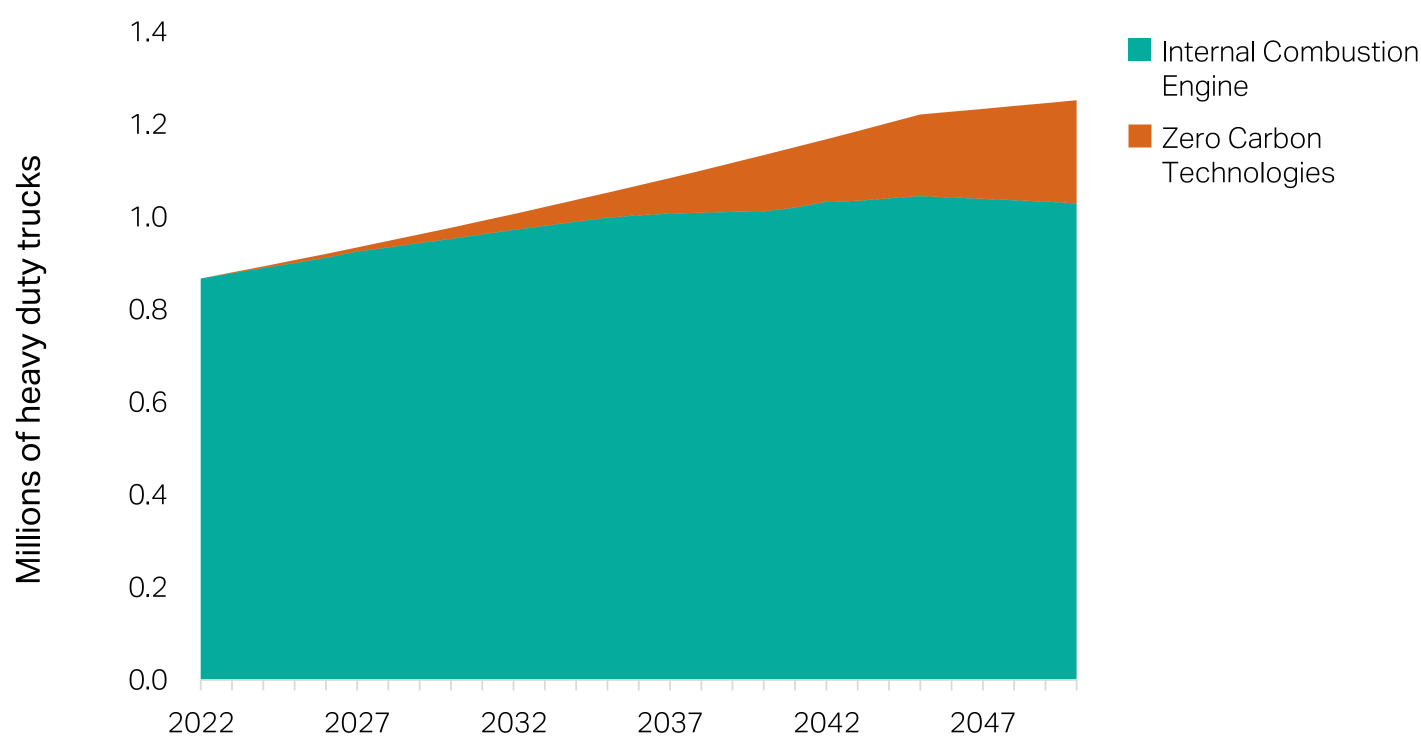
Florida's utility and private companies have also been providing incentives to encourage commercial and business customers to install EV-charging stations. FPL for example, has a program that offers to purchase, install, operate, and maintain direct fast charging EV charging stations on commercial properties at no cost to the site host. Duke Energy launched the "Park and Plug" program to assist with charging infrastructure installation. As part of this program in Florida, Duke Energy partnered with Orlando-based company NovaCHARGE to deliver 627 EV charger ports between 2018 and 2022 (PR Newswire 2022). NovaCHARGE, founded in 2008, has been responsible for the deployment of over 2,500 electric charging systems in a range of locations including multifamily apartment buildings, airports, public space, and offices (NovaCHARGE 2023). The company has also partnered with the Orlando Utilities Commission (OUC) in building out the Robinson Recharge Mobility Hub in downtown Orlando for which OUC had received a $500,000 grant from the Florida Department of Environmental Protection (PR Newswire 2022).

In contrast to passenger vehicles, the electrification of Florida's heavy-duty vehicle fleet will likely be more gradual due to several factors: the immaturity of the technology compared to passenger vehicles, the time expected before such alternative powertrains achieve mass market appeal, and the relatively slow rate of turnover compared to passenger vehicles. The heavy-duty fleet is assumed to therefore include a greater proportion of internal combustion engine vehicles through 2050, both in the baseline and the Net Zero Economy scenario.

The number of heavy-duty vehicles in Florida is estimated by applying the national share of heavy-duty trucks (relative to all trucks) to the total number of truck registrations in Florida in 2020 (Bureau of Statistics 2020). Consistent with the growth in demand for passenger vehicles – based on an analysis of growth in total vehicle miles traveled – the heavy-duty truck fleet is assumed to grow by 1.5% per year from 2020 to 2045, and by 0.5% from 2046 to 2050 (Center for Urban Transportation Research 2019).

In the baseline, sales of zero carbon heavy-duty vehicles increase from less than 1% in 2022 to 19% in 2050. While hydrogen fuel trucks make up between 15% and 25% of zero carbon truck sales over this period, these sales are dominated by electric vehicles. However, due to the slow transition to non-combustion technologies, less than 20% of the fleet is expected to utilize zero carbon technologies by 2050 (see Figure 3.7).

Figure 3.7. Millions of heavy duty vehicles in Florida in the baseline



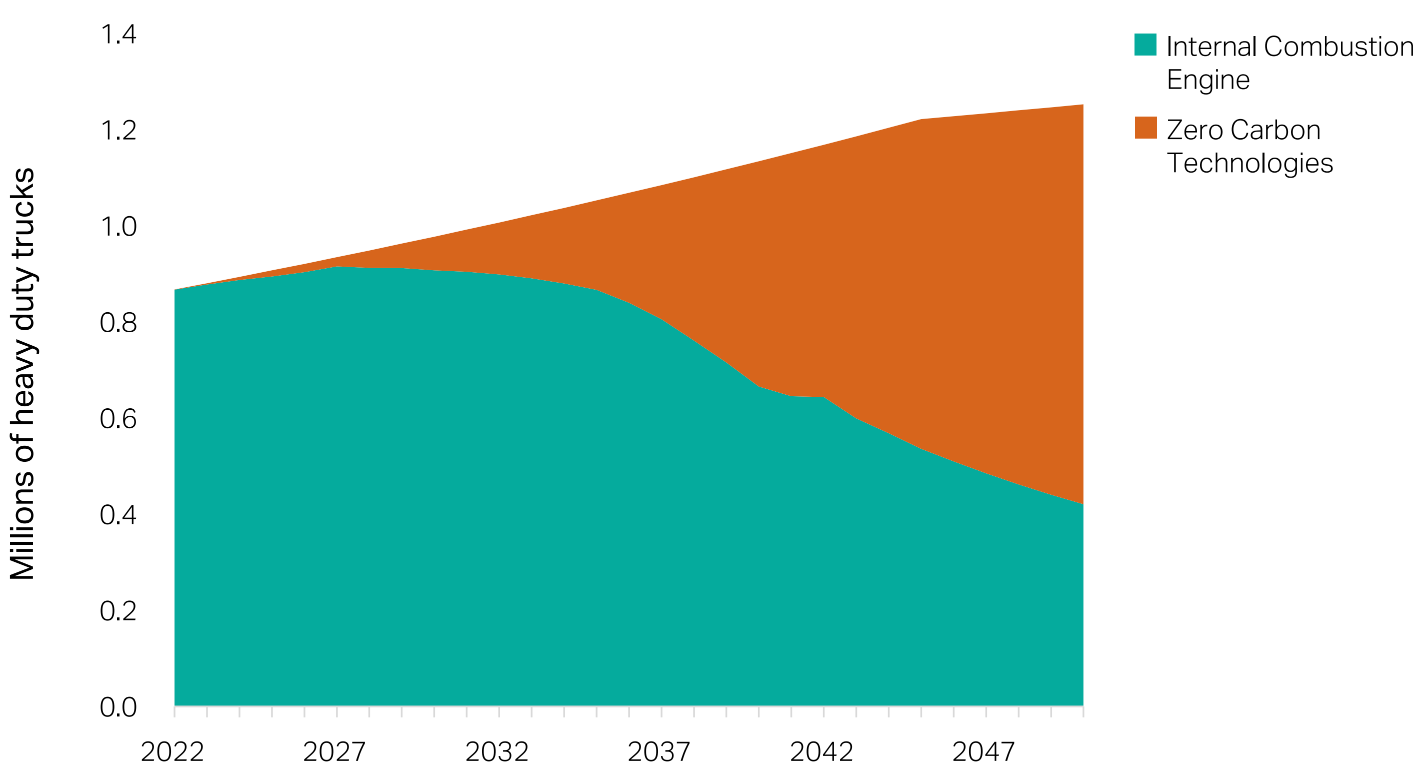
In the Net Zero Economy scenario, the market share of zero-carbon trucks is assumed to increase at a much faster rate: by 2035, approximately 18% of the heavy-duty fleet is expected to be made up of electric or hydrogen fuel trucks – this is achieved 15 years faster than in the baseline – increasing to 41% by 2040 and 66% by 2050 (see Figure 3.8). By 2050, 70% of new heavy-duty vehicle sales are electric trucks, and another 10% are hydrogen fuel cell trucks. Costs are estimated to reduce at a slightly slower pace than more ambitious forecasts currently predict, such as the International Council on Clean Transportation, which estimates between 49-56% electric heavy-duty fleet mix by 2035 (International Council on Clean Transportation, 2023).

In order for this scenario to be consistent with a Net Zero Economy, it is assumed that the internal combustion engine trucks remaining in the fleet by 2050 – approximately 34% of the total fleet – are fueled by some combination of drop-in biofuels and conventional fossil fuels with emissions abated by direct air carbon capture and storage (DACCS) technology, in order for this scenario to be consistent with a Net Zero Economy.

The economic analysis in E3-US captures a number of different impacts of this transition:

- Different consumer spending on motor vehicles, as combustion engine vehicles in the baseline are replaced with electric vehicles.
- Different consumer spending on energy, as they spend less on transport fuels and more on electricity.
- The different cost of freight trucking, with follow-on implications for costs of other industries which use freight trucking services.
- Additional investment in charging infrastructure for passenger and heavy-duty electric fleets, which creates jobs and economic activity in manufacturing and installation.

Figure 3.8. Millions of heavy duty vehicles in Florida in the Net Zero Economy scenario



3.3 Heating and Cooling Technologies

Key Takeaways

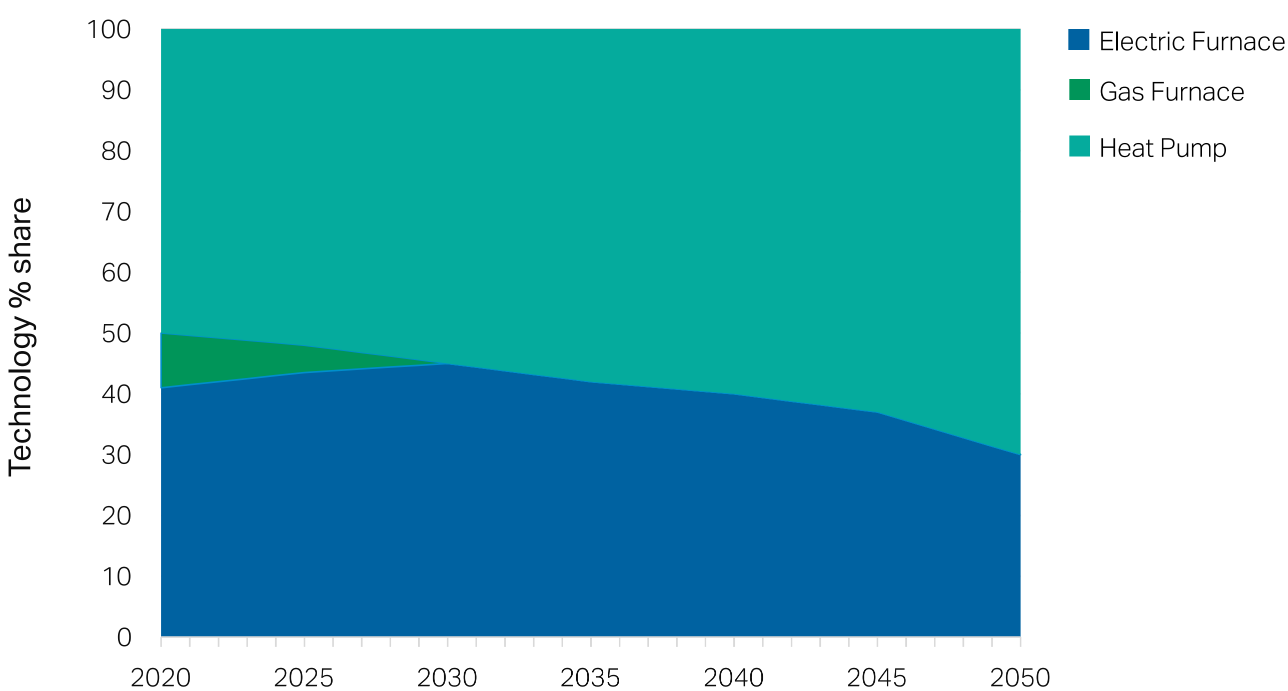
Given 90% of Florida's households already use electricity for heating and cooling, the focus in this sector in Net Zero Economy scenario revolves around minimizing energy consumption via efficiency. This is achieved through the phasing out of remaining gas furnaces and the adoption of residential heat pumps.

By 2050, heat pumps cover 70% of heating and cooling needs in the baseline, but reach 100% in the Net Zero Economy scenario, which can be reached in various ways, such as by fiscal incentives or consumers seeking higher efficiency technology.

Heating and cooling, in terms of fuel use, is well on the way to being decarbonized already. As of 2021, 90% of households already use electricity as their energy source for home heating and cooling in Florida, which is more than twice the national average of 41% (EIA, 2023). With heating less of an issue in Florida, it follows that the state has the potential to achieve the total decarbonization of its heating and cooling systems. Thus, the real challenge lies in minimizing the energy consumption of the system as a whole via energy efficiency improvements, and ensuring that the electricity used by these systems is also zero carbon (as outlined earlier in this chapter). Florida homes tend to be smaller and newer relative to the rest of the country, which can help with higher energy efficiency (Energy Information Administration 2023).[5]

To assess this, the uptake of specific heating and cooling technologies used in Florida is modeled. According to the 2020 Residential Energy Consumption Survey (RECS), the two technologies that are the most widespread are electric furnaces (~41%) and heat pumps (~50%), while central gas furnaces constitute approximately 9% of the

Figure 3.9. Heating and cooling technology shares in the baseline

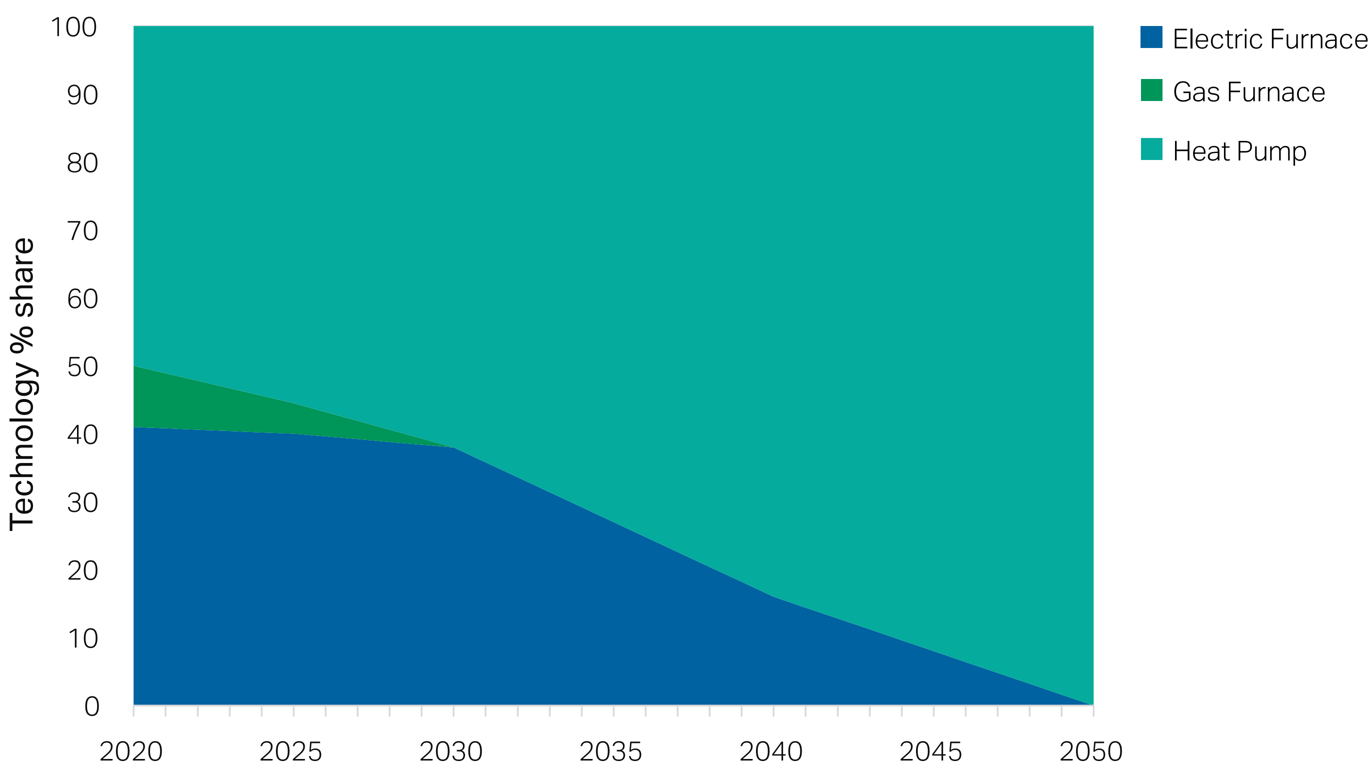


[5] Forty-five percent of homes were built in 1990 or later, relative to the national average of 36%. The total square footage per housing unit was around 1,600 in 2020 compared to the national average of 1,800 (Energy Information Administration 2020).

stock (Energy Information Administration 2020). Although electric furnaces and heat pumps are preferable to gas powered furnaces from an environmental point of view, heat pumps are the more efficient technology, and thus a more ambitious pathway should include a greater increase in the use of heat pumps.[6] By 2030, gas furnaces completely disappear from the stock in the baseline, meaning that heating and cooling needs are met entirely by electricity (see Figure 3.9). Alongside this, there is a gradual shift towards heat pumps and away from electric furnaces. By the time gas furnaces are completely phased out, electric furnaces are used to meet 55% of heating and cooling demand, while heat pumps cover the remaining 45%. The slow shift towards heat pumps continues into later years, and by 2050 heat pumps are 70% of the stock in the baseline.

In the Net Zero Economy scenario, gas furnaces follow the same path as they do in the baseline, but the dynamics of heat pumps and electric furnaces are rather different, with a much more rapid shift towards heat pumps and decline in electric furnaces (see Figure 3.10). The baseline represents an extrapolation of existing trends, which already see electrification of heating and cooling needs in the state. To provide a differential trajectory in the Net Zero Economy scenario, a greater penetration of more efficient heat pump technologies is assumed. Already by 2030 heat pumps represent 62% of the stock. The share of heat pumps increases thereafter, and by 2040 they represent 84% of the stock of heating and cooling technologies, and by 2050 all heating and cooling needs are met via heat pumps. Such a transition could be driven by fiscal incentives such as the expanded tax deduction Section 179D under the IRA for energy efficiency improvements in certain commercial building properties (Chappell, 2023). The transition can also be driven by external changes (e.g., to energy prices) which place a greater emphasis on consumer minds on running costs. This ultimately encourages a greater uptake of more efficient heat pumps which require less input energy to achieve the same heating or cooling outcome.

Figure 3.10. Heating and cooling technology shares in the decarbonization Net Zero Economy scenario

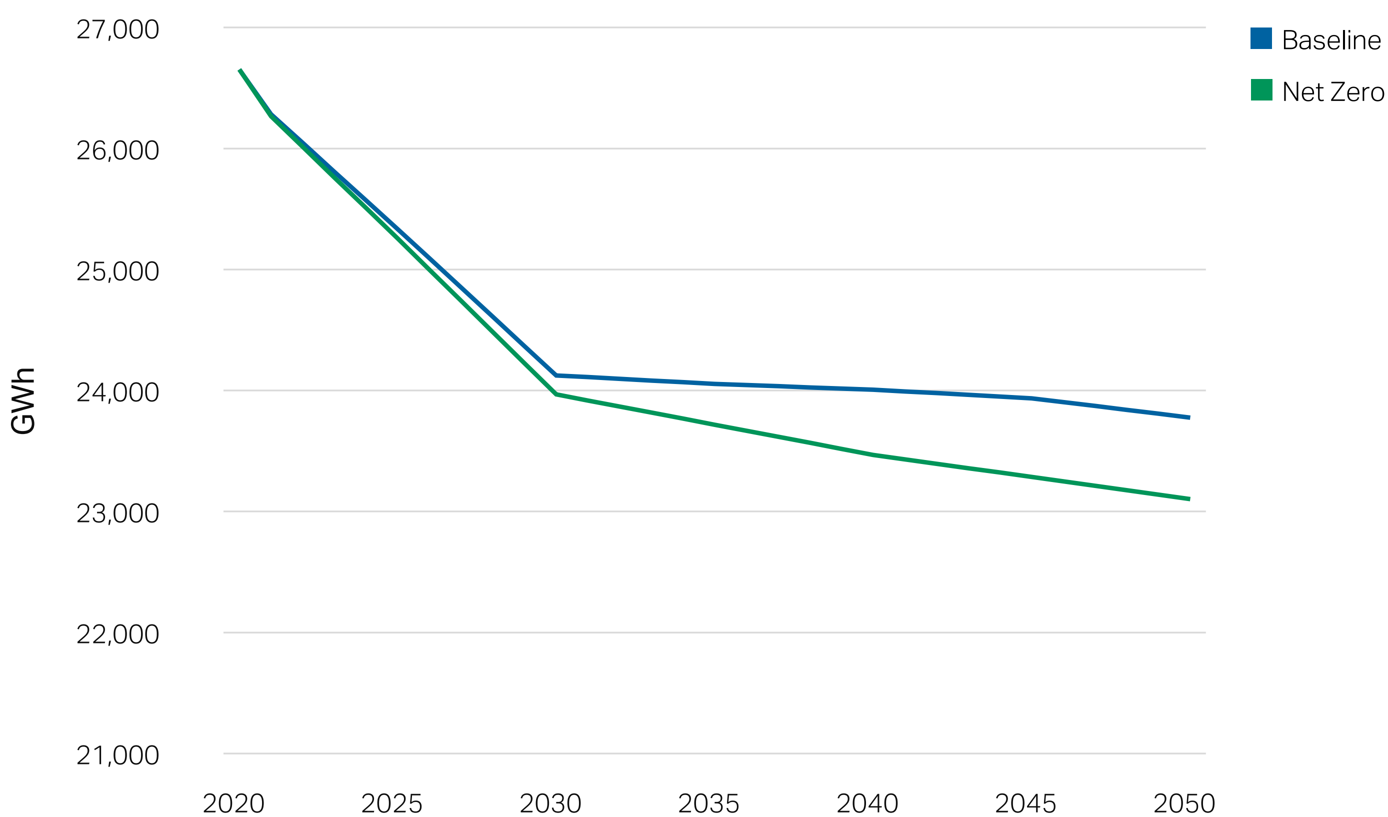


[6] *Note that although the focus is on the transition from gas furnaces to heat pumps, there are passive heating and cooling building strategies that can be implemented to improve energy efficiency, such as cool roofs, which are not included in this modeling.*

Figure 3.11 demonstrates the gains in terms of energy efficiency; by 2030, electricity demand is slightly lower in the Net Zero Economy scenario compared to baseline, but the period after 2030 highlights the greater savings that can be achieved through more aggressive adaptation of heat pumps as opposed to electric furnaces. While the absolute reduction in energy demand is not substantial, this reflects the fact that Florida is already largely using electric technologies (which are much more energy efficient that fossil fuel-based alternatives), and that there is only an incremental improvement in the uptake of heat pumps in the Net Zero Economy scenario compared to baseline.

The modeling in E3-US captures two elements of this transition: the change in consumer spending on heating technologies, as consumers shift away from gas and electric furnaces and towards heat pumps; and the change in consumer demand for energy as demand for both gas and electricity falls.

Figure 3.11. Energy consumption of the heating and cooling sector in the baseline and Net Zero Economy scenario



LOW-CARBON DEVELOPMENT

Image source: Giorgio Trovato

Across Florida, residential solar investments take advantage of the state's sunshine to decrease residents' carbon footprint and increase energy reliability and efficiency. Block Energy is a company headquartered in Tampa that is now establishing some of the first utility-focused residential microgrid systems. In partnership with Tampa Electric (TECO), Block Energy has established a four-year pilot program in the Medley subdivision of the Southshore Bay master-planned community features 40 new Lennar homes, which combine renewable energy with battery storage to create a microgrid system. Each home in the pilot program has rooftop solar panels and a BlockBox, which provides battery storage and distributed controls, all owned by Tampa Electric. The self-contained neighborhood energy system allows homes to share power with each other and increases electric reliability, as nearby power outages will not disrupt the supply. Residents pay the same rates for electricity as all other Tampa Electric customers. More recently, Block Energy entered into a contract with Lakeland Electric to build a housing subdivision of 77 homes with a solar microgrid (Walsh, 2023).

Meanwhile, just outside of Fort Myers, a planned community called Babcock Ranch is seeking to become the first fully solar powered city in the nation. While still under development by the real estate company Kitson & Partners, the finished community will accommodate nearly 20,000 homes powered by a vast solar array run by FPL. The solar-powered community is also designed to be resilient to natural disasters, with green stormwater infrastructure and other flood resilient design. In September 2022, when Category 5 Hurricane Ian hit the area, none of the residents in Babcock Ranch lost power, and the community saw minimal damage in contrast to the intense power outages experienced by neighboring areas. A community center in Babcock Ranch was able to provide shelter to those whose homes were hard-hit nearby.

3.4 Industrial Processes and Energy Use

Key Takeaways

FCI quantified emissions associated with fossil fuel combustion from the industrial sector, as well as emissions from industrial processes (e.g., iron and steel production, clinker production in cement making).

In the Net Zero Economy scenario, decarbonization for industrial processes and energy consumption focuses on deploying innovative technologies, materials, and processes to increase efficiency.

These measures are paired with other carbon capture and carbon injection technologies to help achieve net zero by 2050.

A wide range of industrial processes contribute carbon dioxide emissions (including cement and lime manufacturing, aluminum, iron, steel, and ammonia production), nitrous oxide emissions (nitric and adipic acid production), and fluoride-based emissions (including substitutes for ozone-depleting substances and electricity transmission and distribution systems). These processes combined equated to around 9% of gross emissions in 2018. Additionally, there is a smaller volume of emissions (currently about half the size, in carbon dioxide equivalent) from final energy consumption within industrial sectors.

In the baseline emissions trajectory set out in the FCI report, emissions from industrial processes are expected to increase by about 75% by 2050 compared to current levels, to more than 50 million metric tons of carbon dioxide equivalent (Florida Climate Institute 2022). Over the same period, emissions from energy consumption are expected to increase more modestly by around 30%, but equivalent to only an additional 3 million metric tons (on top of current emissions of around 12 million metric tons) (see Figure 3.12).

Emissions reductions are assumed through a number of complementary measures:

- The use of new technologies, such as electric arc furnaces or CCUS technologies, to replace the use of unabated fossil fuels for final energy consumption with low-, zero- or negative-carbon electricity.
- The use of new materials and technologies to allow production to continue but with a lower or zero emissions profile, such as the substitution of cement with pozzolan or chemically bonded phosphate ceramics (CBPCs).
- The deployment of measures and technologies to improve the efficiency (in terms of energy and emissions) of existing processes, thereby reducing emissions from production.

The combination of these measures can have a substantial impact on industrial emissions. Through their widespread application, the FCI report (Ghebremichael, et al., 2022) assumes that energy consumption emissions can be entirely removed, removing about 15 million metric tons of carbon equivalents (mmCO2e) compared to baseline by 2050. At the same time, while emissions from industrial processes are unlikely to be completely abated (because of the lack of low- and zero-carbon alternatives in some industrial sectors, and the drawbacks of alternative manufacturing approaches in others), the same study assumes that emissions from industrial processes can start to fall during the second half of the 2020s (rather than continuing to increase as in the baseline), and be brought down to around 25mmCO2e by 2050, a reduction of more than 20mmCO2e compared to baseline.

It is assumed that remaining emissions in the industrial sectors will be made consistent with a Net Zero Economy by 2050. This may be achieved directly through the use of CCUS (e.g., additional DACCS units) or indirectly through "carbon credits" earned in the power sector (i.e., net negative emissions from the power sector as a whole are allowed to balance out against residual emissions from industrial sources, as long as the economy as a whole remains at or below net zero carbon emissions). The additional costs that this may impose on industrial production is not captured in the analysis.

The economic impact modeling includes the additional investment in industrial energy efficiency measures required to achieve the emissions reductions outlined here. Consistent with a 2022 report published by the International Energy Agency (International Energy Agency, 2022), a 10% reduction in industrial energy consumption by 2030 and a 15% reduction by 2050 compared to the baseline energy demand is assumed (see Figure 3.13). (International Energy Agency 2022).

Investments in industrial energy efficiency measures in industry are estimated to cost approximately $61,000 per GWh (International Energy Agency, 2022). Modeling in E3-US captures the impact of the stream of energy efficiency investments associated with the reduction in energy demand shown in Figure 3.13 below.

CONCRETE AND CEMENT

Emissions captured in the industrial processes sector here and in the FCI report include those associated with concrete and cement production. Concrete is a ubiquitous building material. Globally, concrete is the most made material, and a key ingredient of it – cement - is one of the most energy-intensive products. In 2022, Florida was the fourth-largest cement producing state (Hatfield 2023). There are numerous strategies (Fischetti, Bockelman, and Srubar 2023). to reduce emissions associated with concrete production, including new blended cement product lines, CCUS, and more efficient use of concrete through digital tools such as building information modeling (BIM) (Hatfield 2023; Florida Climate Institute 2022).

As buildings are constructed and renovated, there is increased attention towards understanding and reducing their embodied carbon (the GHG emissions associated with all aspects of the material and construction lifecycle). The City of Miami's Greenhouse Gas Reduction Plan includes an action for the City to provide construction firms incentives to use locally sourced materials that have low embodied carbon and high-efficiency fixtures (City of Miami 2021). Miami-Dade County Climate Action Strategy includes an action to assess new construction embodied carbon and to create policies and programs that reduce it, and their Sustainable Buildings program (SBP) requires that County construction projects achieve LEED certification (Miami-Dade County 2021). LEED v4.1 addresses embodied carbon considerations, such as through the Materials and Resources (MR) credit category. Specific credits include building life-cycle impact reduction and environmental product declarations (EPDs) (Hughes 2019; US Green Building Council, n.d.). Already, nearly 3,000 buildings in Florida are LEED certified. As the public and private sectors spend over $25 billion on in-state purchases in construction annually, nearly $16 billion of which are purchases from government, public policies and market demand for embodied carbon reduction can have significant impact (Lightcast 2023).

Figure 3.12. Industrial processes and energy emissions in the baseline

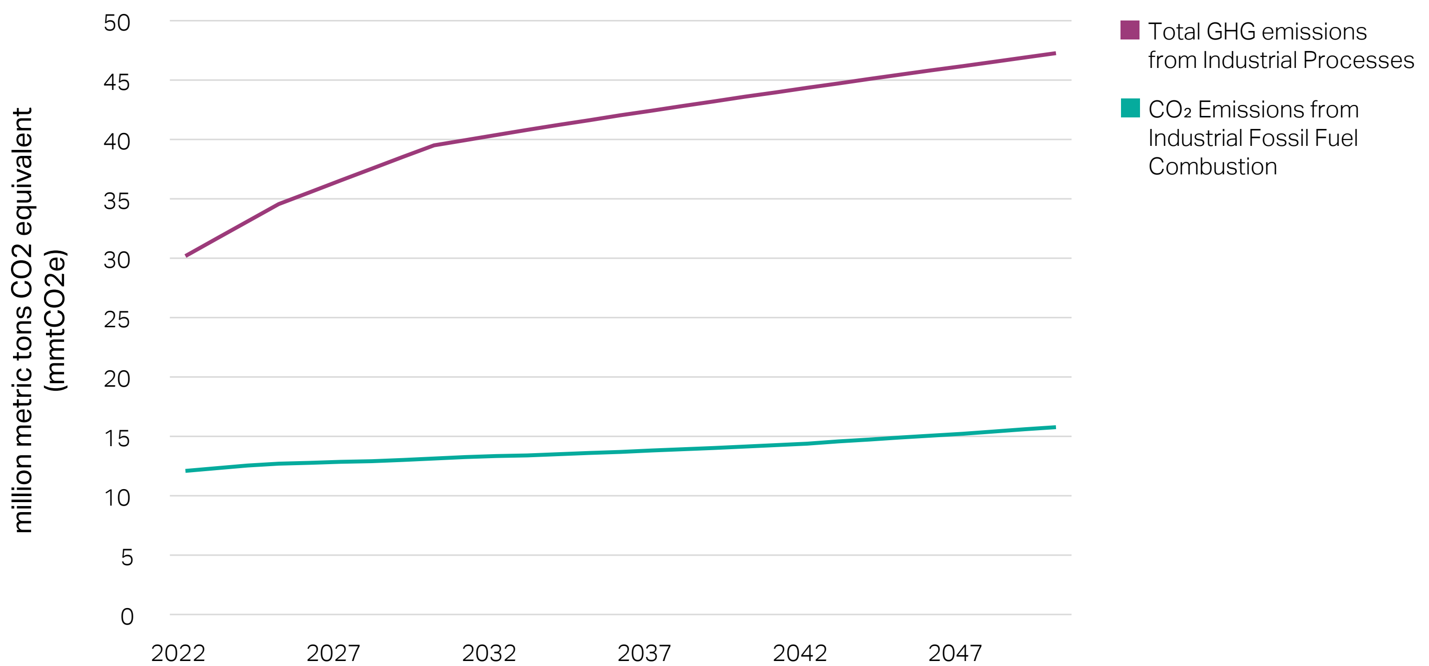
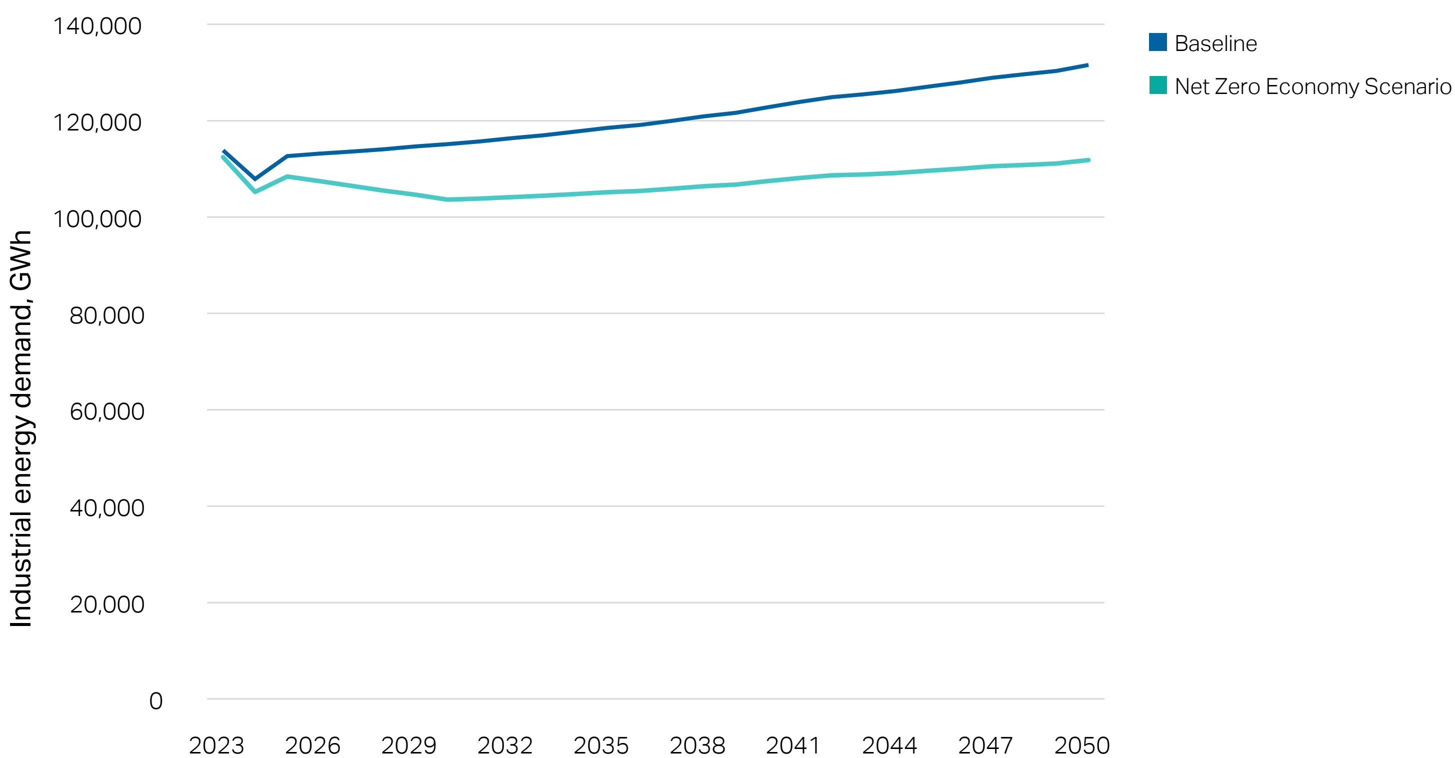


Figure 3.13. Industrial energy demand, 2023-2050, baseline and Net Zero Economy scenario



3.5 Agriculture, Forestry, and Other Land Use (AFOLU)

Key Takeaways

Agriculture emissions, 3% of the total state emissions profile, remain a challenge without mitigation. However, reforestation and afforestation present a nature-based path towards sequestration.

The Net Zero Economy scenario assumes that over 1 million hectares are reforested or afforested from 2023 through 2040.

Land use presents both a challenge and an opportunity for decarbonization in Florida. There are many ways that land use relates to decarbonization: minimizing greenfield development can avoid loss of forested land that supports carbon sequestration, increasing density near transit can reduce reliance on personal vehicles and reduce transportation emissions, and building housing near commercial and recreational amenities can reduce vehicle miles traveled (VMT). Separately, there are also many land use implications related to decarbonization, such as the conversion of agricultural land to solar fields, or the reduction of auto repair facilities as a result of increased EV adoption. This section specifically focuses on the agriculture, forestry, and other land use (AFOLU) sector, a specific sector in GHG accounting which includes emissions associated with agriculture and land management. While there are challenges to reducing emissions from existing land use (in particular agriculture), there are also significant opportunities for carbon sequestration, which can deliver net emissions reductions necessary to help abate residual emissions from other parts of the economy.

While emissions from agriculture are relatively small (at 9.4 MMTCO2e in 2018, they represented just 3% of total Florida emissions), in the baseline they are expected to remain relatively constant out to 2050, and without appropriate mitigation measures would represent an increasing share of total emissions as the rest of the economy decarbonizes.

The FCI report (Ghebremichael, et al., 2022) set out detailed emissions reduction measures for the agricultural sector in Florida, including:

- The use of anaerobic digesters, compositing, lime stabilization, aerobic digestion and heat drying to reduce emissions from livestock manure.
- Changes to animal feed to reduce enteric fermentation emissions.

Similarly, there are a number of sequestration measures that could be used to ensure that the land can act as an even greater carbon sink. FCI models the below measures and assumes annual greenhouse gas emission reductions associated with each:

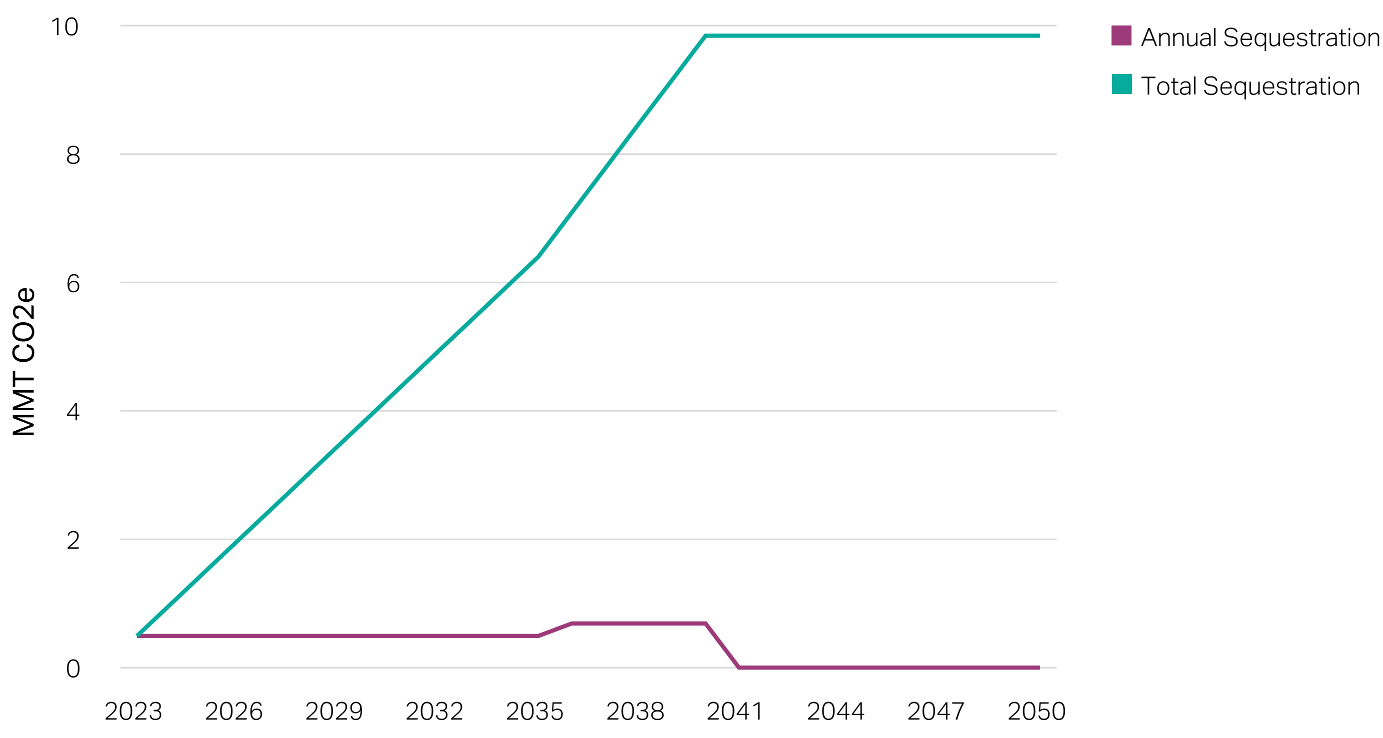
- **Revegetation and afforestation on urban lands** can contribute 0.5 MMTCO2e of negative emissions per year.
- **Flooding and cultivation on drained organic soils** can contribute an additional 0.5 MMTCO2e of negative emissions per year.
- **Seagrass restoration and creation, including water quality improvements** could lead to approximately 0.05 MMTCO2e of negative emissions per year.
- **Restoration of coastal wetland areas lost since 1990** could achieve approximately 0.005 MMTCO2e of negative emissions per year. (Florida Climate Institute 2022).

The economic impact modeling estimates the investment in reforestation and afforestation based on past studies for Florida; other activities related to agriculture and land use that are required to achieve these emissions reductions are not estimated directly in the modeling.

FCI estimates that in the Net Zero Economy scenario, 50% of the land area of low-density developed land and all open space and bare lands in Florida and 12.5% of medium intensity developed land – a total of just over 1 million hectares – is reforested or afforested; each hectare of land is estimated to sequester 9.175 tons of CO2 per year (Ghebremichael, et al., 2022). FCI estimates that reforestation/afforestation activities will be implemented at 5% from 2023 through 2035, and 7% from 2036 to 2040, resulting in total sequestration of 9.85 MMT CO2e by 2040.

Investment costs are modeled assuming reforestation and afforestation activities occur annually based on FCI's implementation assumptions – i.e., that carbon sequestration in each year has an associated investment in that year, rather than representing the accrual of an investment made in a prior year. Relying upon a survey and assessment of the costs of reforestation and afforestation activities (Fuss et al. 2018), these activities are estimated to require investments of $50 per ton of CO2e per year (the upper bound of the authors' assessment of a likely range of costs). These investments are used in the E3-US model to model the economic impacts of reforestation and afforestation activities. The economic impact of other activities related to agriculture, forestry, and land use are not explicitly evaluated. These impacts will reflect the additional economic activity that is linked to the reforestation activities, both directly and through supply chains (Fuss et al. 2018).

Figure 3.14. Annual and total sequestration from reforestation and afforestation activities



CARBON SEQUESTRATION PROGRAM

Investments to achieve increased carbon sequestration have been implemented at the state-level in Florida, and in other states. To date, Florida has focused on sequestration through forestation. For instance, the Florida Forest Service developed a $10-million Carbon Sequestration Grant Program as a means of sequestering up to 69,000 tons of CO2 per year. Since renamed the Future Forests Program, as of 2023 the program is available to non-industrial private landowners, local governments, or nonprofit institutions. Carbon sequestration programs have similarly been implemented in other states, notably restoration programs in the Chesapeake Bay of Virginia generated 459,639 tons of annual carbon removal benefits by ongoing restoration activities within the agricultural sector in Virginia in 2019 (Wiggans et al. 2021). Furthermore, the Hawaii Greenhouse Gas Sequestration Task Force began investigating ways to measure state greenhouse gas levels to propose policies that promote and incentivize increased carbon sequestration by 2023 (State of Hawaii Office of Planning and Sustainable Development 2023).

Provided by Lynetta Usher Griner

3.6 Waste

Key Takeaways

Waste currently contributes less than 6% of Florida's emissions.

Strategies to reduce emissions from the waste sector primarily involve either capturing or incinerating emissions from landfilled organic waste for energy use.

Local efforts, such as Miami-Dade County's Climate Action Strategy, pave a way towards converting 50% of non-recycled garbage into energy and reducing landfill waste

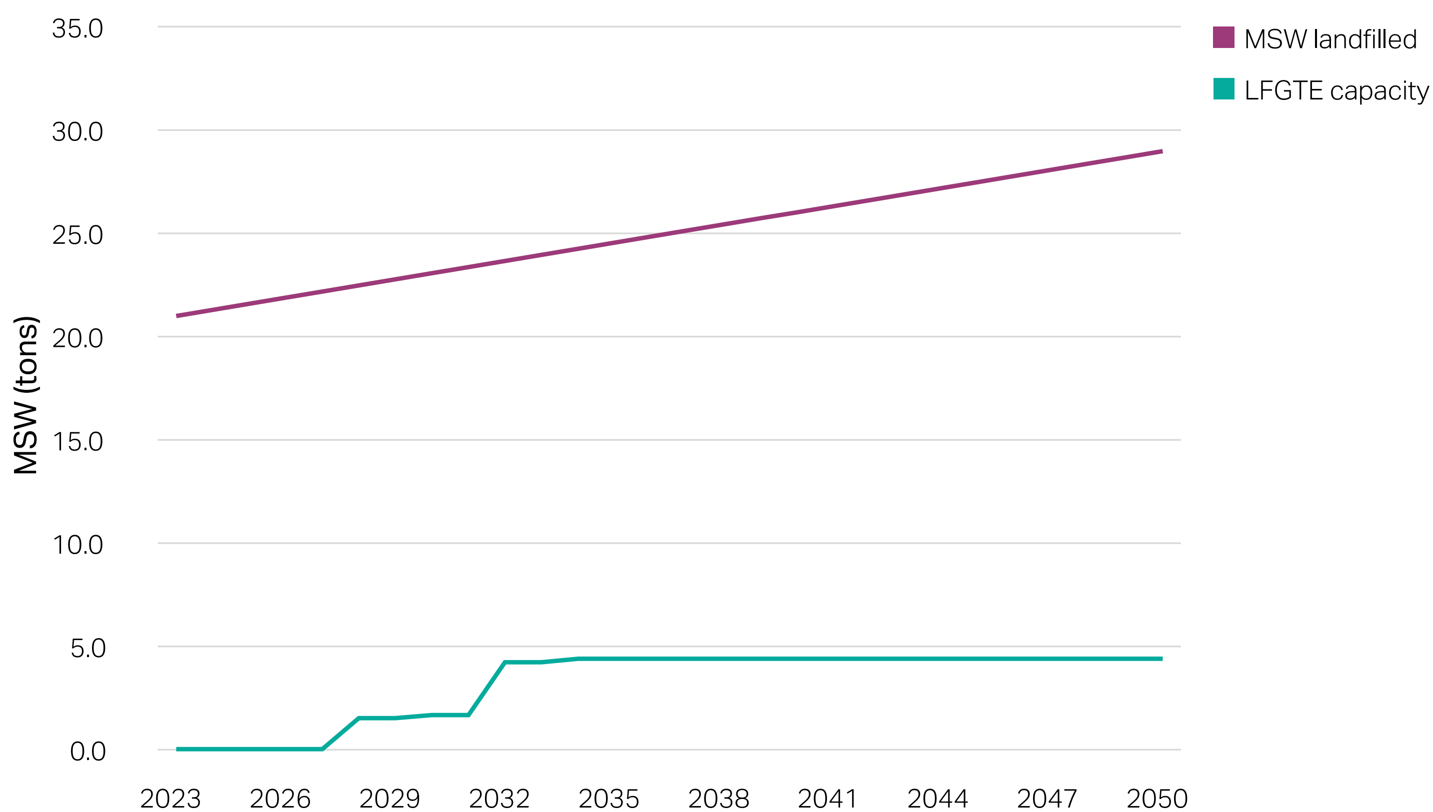
As landfilled organic waste decomposes, a mixture consisting primarily of methane and carbon dioxide known as landfill gas (LFG) or biogas is generated. The primary pathways to reduce emissions from LFG involve capturing these emissions for use as energy – either through incinerating the waste in its entirety (a process known as "waste to energy") or collecting the biogas released from the landfill for use as a fuel source. The collected biogas can be used onsite for electricity production (a process known as "landfill gas to energy," or LFGTE), or treated to remove carbon dioxide and other gases for use as a substitute for natural gas (Energy Information Administration 2020)– e.g., in heavy-duty vehicles that previously relied upon distillate fuel (Florida Climate Institute 2022). Other landfilled waste emissions reduction strategies include flaring the LFG, although this should be minimized, or through increased composting activities, or diverting organic waste from landfills.

In the Net Zero Economy scenario, it is assumed that a cumulative reduction of 12 MMT CO2e will be achieved primarily through the implementation of LFGTE projects and increased municipal composting. The economic impacts of increased composting are not estimated in this analysis, as upfront investments required are likely to be minimal. To estimate the investments needed for LFGTE projects, the modeling applies projections of municipal solid waste landfilled in Florida from 2023 to 2050 taken from the Environmental Protection Agency (EPA) State Greenhouse Gas Projection Tool, and calculates the portion of this MSW that will be treated by LFGTE projects using FCI data on the emission reductions associated with LFGTE (Ghebremichael, et al., 2022). As shown below, while the quantity of MSW landfilled is expected to increase consistently over time, Florida's total need for LFGTE (based on FCI's projections) reaches a plateau around 2032.

The capital cost of a LFGTE project is estimated at approximately $29 per ton of waste (in 2021 dollars) (Hochman et al. 2015). While capacity needs to increase at an inconsistent rate over time (see Figure 3.15), it is assumed that investments occur at a steadier rate, with annual investments smoothed based on a five-year moving average. Additionally, the modeling assumes no disinvestment – i.e., once LFGTE projects are built, they are not taken offline.

These impacts are included in the economic impact modeling via the total value of investment needed for this scenario to be delivered, relative to the baseline. This investment provides a stimulus to the Florida economy, creating direct jobs and economic activity, as well as further impacts through supply chains and the spending of additional wages across the economy.

Figure 3.15. Municipal solid waste and landfill gas to energy capacity



LOCAL AND REGIONAL CLIMATE AND RESILIENCE PLANS

Across Florida, there have been more than 20 climate and resilience action plans developed at the municipal, county, and regional levels that lay out decarbonization goals and pathways that guide the transition.[7]

At the regional-level, one of the earliest climate action plans was developed under the Southeast Florida Regional Climate Change Compact (the Compact), which was established more than a decade ago in 2010 (Perry 2023). The Compact codified its vision in 2012 under a Regional Climate Action Plan (RCAP) that outlined goals, recommendations, and supporting strategies across 11 focal areas to advance the objective of achieving net zero GHG emissions by 2050 compared to a 2005 baseline. The updated version, RCAP 3.0, serves Broward, Miami-Dade, Monroe, and Palm Beach counties, inclusive of 109 municipal governments, and a population of more than 6 million (Southeast Florida Regional Climate Change Compact 2023). Through a regional collaboration platform like the Compact, the Southeast Florida region has received millions of dollars in funding for climate resiliency and decarbonization efforts. Recently, in August 2023, the Compact region received more than $150 million dollars in FEMA's Flood Mitigation Assistance (FMA) and Building Resilient Infrastructure and Communities (BRIC) grants (Southeast Florida Regional Climate Change Compact 2023). Working within the regional umbrella, Broward, Miami-Dade, and Monroe counties have all published their own climate action plans with county-level goals and implementation plans (Miami-Dade County 2021; Broward County 2020; Monroe County 2013). For example, Miami-Dade's Climate Action Strategy, the county's most recent GHG reduction plan (released in 2022), sets the goal of achieving a 50% reduction in GHG by 2030 compared to a 2019 baseline with a focus on three key areas: Energy and Buildings, Land Use and Transportation, and Water and Waste.

Another regional effort includes the East Central Florida Regional Resilience Collaborative (ECF R2C) established by the East Central Florida Regional Planning Council in 2019 (East Central Florida Regional Planning Council 2018a). ECF R2C published a Strategic Resilience Action Plan (SRAP) in 2021 to develop better regional capacity in guiding and supporting local governments in efforts targeted at GHG reduction and improving regional climate resilience. A primary goal established through the SRAP was to help cities and counties across the region develop GHG emissions inventories to create science-based targets and high-impact actions (East Central Florida Regional Planning Council 2018b). Within the region, Orange County also has a county-level Sustainable Operations and Resilience Action Plan, published in 2021, with targets to reduce GHG emissions by 30% from 2015 baseline by 2030, and Orlando has a municipal-level Green Works Orlando Community Action Plan first released in 2013 and most recently updated in 2018 with an overall goal of reducing GHG emissions by 90% from 2007 baseline by 2040 (Green Works Orlando 2018; Orange County 2020). The ECF R2C is also preparing a Priority Climate Action Plan (PCAP) under EPA's Carbon Pollution Reduction Grant Program. Similarly, the Tampa Bay Resiliency Coalition, created in 2018, is implementing a "Clean Air Tampa Bay Climate Action Planning Initiative" to implement an EPA Carbon Pollution Reduction Grant in the region.

The most recent regional effort to be formalized is the Resilient First Coast (RFC), which is a resiliency collaborative for Northeast Florida including Baker, Clay, Duval, Flagler, Nassau, Putnam, and St. Johns counties. RFC was formalized in December 2022 to address regional challenges associated with resilience to climate change, including sea level rise, flooding, and other hazards (Scanlan 2023). The RFC is in the process of developing a Regional Resiliency Action Plan (RRAP), which will guide action over the next five years across the region, and is also working with the City of Jacksonville on a PCAP and Comprehensive Climate Action Plan (CCAP) for Northeast Florida.

[7] It is important to note that emissions reduction goals and related policies are also included in other types of planning documents aside from climate and resilience action plans, such as land use plans like Miami-Dade's Comprehensive Development Master Plan.
Note that Florida has additional regional resilience collaboratives not mentioned here that are doing equally important work: Heartland Regional Resiliency Coalition, Emerald Coast Area Resilience Collaborative and Apalachee Strong.

04 Investment and Consumer Spending Scenario Summaries

Image source: Adobe Stock Images

4.1 Net Zero Power System Scenario

Key Takeaways

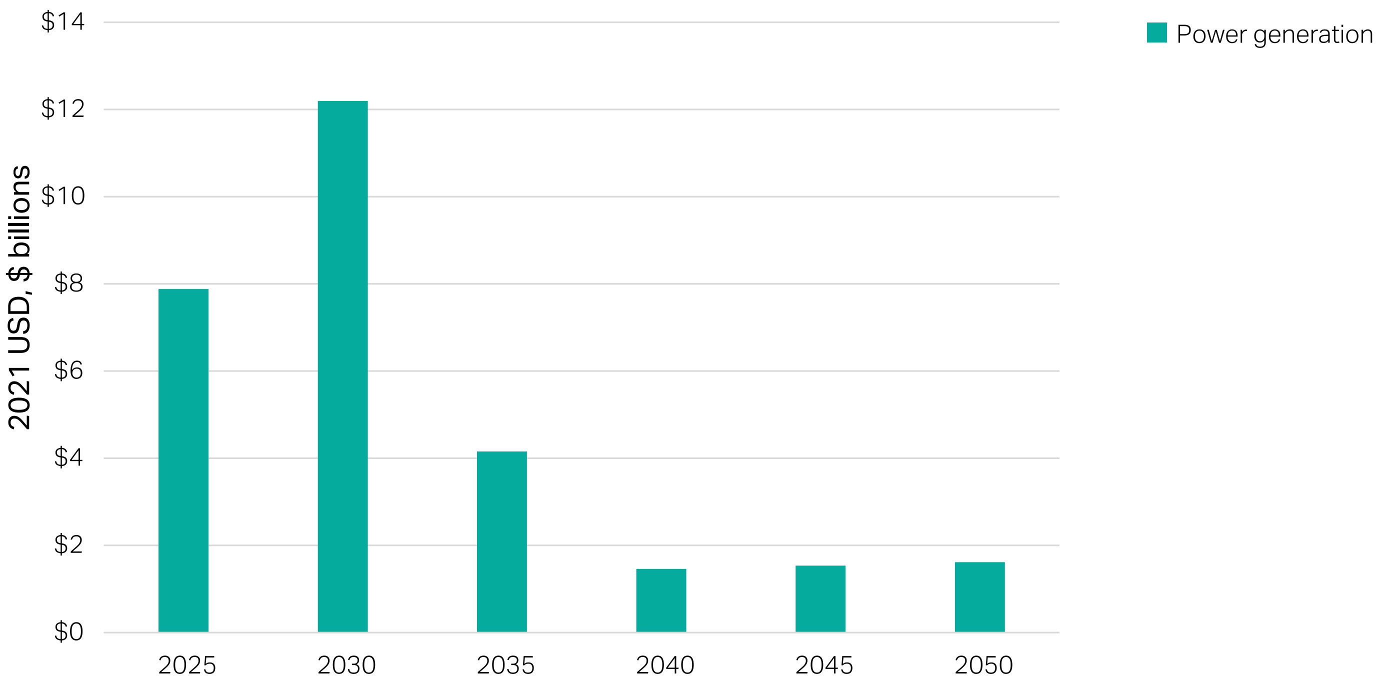
Achieving a Net Zero Power System in Florida by 2035 is estimated to require an additional cumulative investment of $129 billion from 2023 to 2035, averaging $10 billion annually but with higher investment in the earlier years.

Decreases in the levelized cost of energy (LCOE) for solar PV relative to non-renewable sources leads to lower energy prices for households and businesses, who in turn redirect their savings to other parts of the economy.

Investment

Decarbonizing Florida's power system by 2035 requires substantial additional investment over and above that expected in the baseline – in total, $129 billion cumulatively from 2023 to 2035, with an average annual additional investment of $10 billion over this period. After 2035, continued investment in low/zero-carbon generation and total investments accumulate to $152 billion through 2050. In many cases (e.g., around 2030), these investments occur earlier than they would in the baseline, as existing generation assets may need to be replaced ahead of schedule to decarbonize the power system by 2035. To put this spending in context, in 2022 the public and private sector spent over $1 trillion on in-state and imported input purchases, or the equivalent of over eight times the total level of investment estimated for the Net Zero Power System in just one year.[8]

Figure 4.1. Additional annual investments in Net Zero Power System scenario for key points in time between 2025-2050



[8] *Emsi Lightcast 2022*

Note: Figure shows investments for specific years of the analysis. Cumulative investments between 2023-2035 total $129 billion. Between 2023-2050, the total equates to $152 billion.

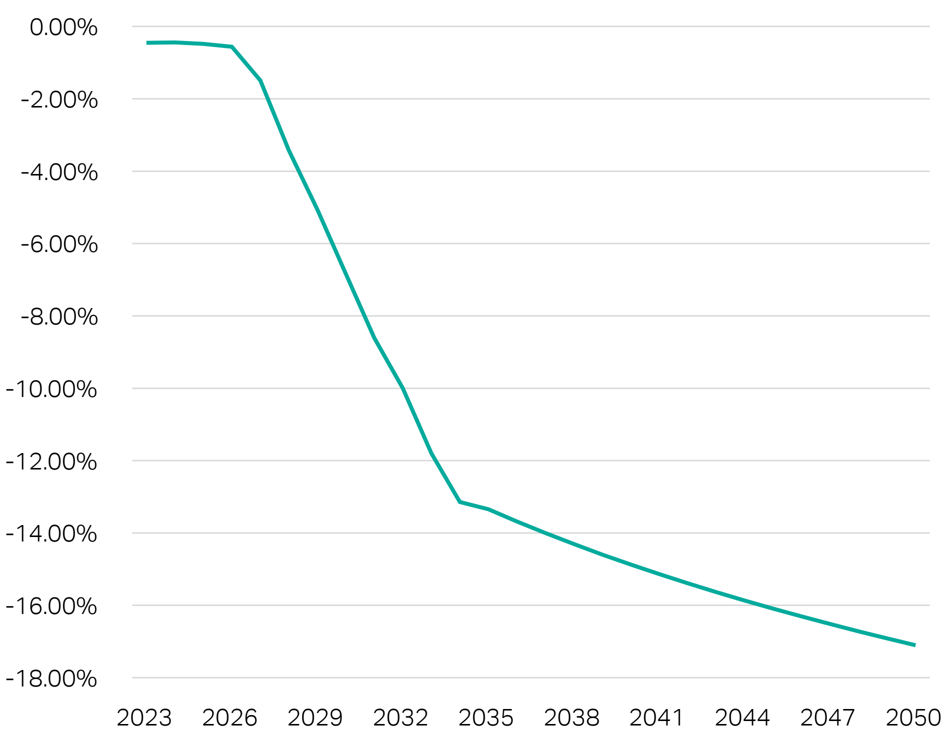
Changes in Direct Consumer Spending

Spending patterns by households and businesses will also change due to the anticipated decrease in the levelized cost of electricity (LCOE) of the renewable energy sources. According to the E3-US model, the LCOE is expected to decrease by approximately 13% by 2035, and by 17% by 2050.[9] This change is a result of the lower total cost per unit of electricity generated of the low-carbon technologies (principally solar) which are deployed in the net zero power sector and Net Zero Economy scenarios. Note that this LCOE applies to both the net zero power scenario and the Net Zero Economy scenario.[10] Also note that these changes in spending correspond to the direct spending related to achieving the decarbonization scenarios. These changes then have cascading impacts when modeled for the economic impacts, as households and businesses redirect their savings to other parts of the economy.

Levelized Cost of Energy (LCOE)

A measure of the cost of production of energy. It is calculated by dividing the total lifetime costs of energy production, including initial capital investment and operations and maintenance expenditures, divided by the total amount of energy that is expected to be generated. LCOE is often used as a summary indicator of the overall cost competitiveness of different generation technologies.

Figure 4.2. Change in LCOE relative to baseline



[9] The LCOEs used in the E3-US model are derived from International Energy Agency data, which includes country-specific LCOE estimates by generation technology (IEA, 2020).
[10] The modeling assumes that additional electricity needed in the Net Zero Economy scenario is imported to Florida, rather than increasing investment in the power sector to accommodate this. The imported electricity price is assumed to be purchased at the prevailing market price in Florida. As a result, the LCOE remains the same between the two scenarios.

4.2

Net Zero Economy Scenario

Key Takeaways

An estimated $198 billion worth of investment across the six sectors will be needed from 2023 to 2050 in for the Net Zero Economy scenario, with 77% of this investment concentrated in the power generation sector.

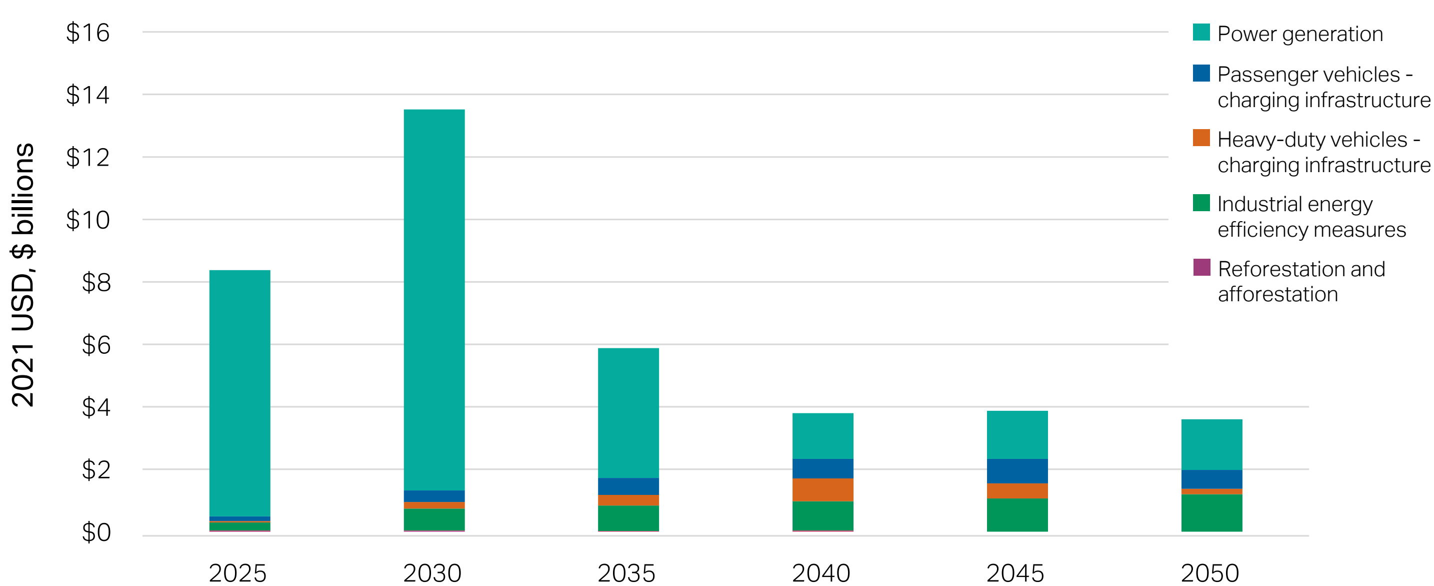
As a result of changes in spending on by consumers on passenger vehicles, $69 billion of consumer spending can be redirected to other parts of the economy.

Similar to the Net Zero Power System scenario, decreases in the levelized cost of energy (LCOE) leads to lower energy prices for households and businesses, who in turn redirect their savings to other parts of the economy.

Investment

Decarbonization activities in the six sectors discussed require substantial additional investment over and above that expected in the baseline – in total, nearly $198 billion cumulatively from 2023 to 2050, with an average annual additional investment of around $7 billion. These investments occur predominantly in the power generation sector, which accounts for just under 77% of total investments over this period. Consistent with the Net Zero Power System scenario, investments in power generation are high in the initial years – in particular, between 2027 and 2033 – but even after Florida's power system is fully decarbonized, ongoing investments in new capacity are greater in magnitude than decarbonization investments in other sectors. Charging infrastructure for electric vehicles accounts for approximately 12% of investments over this period; industrial energy efficiency measures account for 11%; and reforestation/afforestation and landfill gas-to-energy projects account for less than 1% each. As mentioned in the Net Zero Power scenario, the public and private sector spent over $1 trillion on in-state and imported input purchases, which is equivalent to over five times the total level of investment estimated for the Net Zero Economy scenario in just one year.[11]

Figure 4.3. Additional annual investments in Net Zero Economy scenario for key points in time between 2025-2050



Note: Figure shows investments for specific years of the analysis. Cumulative investments between 2023-2050 total $198 billion. Landfill gas-to-energy investments are not displayed on this graph. These investments are approximately $8m in 2025, $16m in 2030, and <$1m in 2035, 2040, 2045, and 2050.

Changes in Direct Consumer Spending

The shift to a Net Zero Economy also entails changes in spending patterns across the economy. Spending on new technologies by households and businesses across the six areas covered in this analysis are expected to result in a net consumer spending decrease of $69 billion through 2050 with an average decrease in spending of $2.4 billion per year relative to the baseline (see Table 4.1). This is mainly driven by savings associated with passenger electric vehicles. Overall, consumers are predicted to spend more on heating and cooling units over this entire period due to the higher upfront cost of heat pumps as compared to conventional air conditioning units. However, while consumer expenditure on passenger vehicles is initially greater than the baseline, EVs are assumed to be cheaper to purchase than ICE vehicles starting in the latter half of this decade and spending on passenger vehicles becomes lower than the baseline (McKerracher 2021). By 2050, consumers are expected to save more than $10 billion per year on passenger vehicles compared to the baseline due to much greater adoption of electric vehicles.

At the same time, businesses are estimated to spend more in total on zero carbon trucks – while the price premium on battery electric and hydrogen fuel cell trucks narrows, it is not expected to close completely so these options will remain more expensive in terms of up-front purchase cost than their combustion engine equivalents.[12] This additional cost to businesses will be passed on in some proportion through supply chains, and ultimately to consumers in the form of higher prices. As noted in the Net Zero Power System scenario, the lower LCOE will also impact spending, allowing for even greater savings to be spent elsewhere in the economy.

The changes in spending presented in Table 4.1 correspond to the direct spending on the technologies required to achieve the Net Zero Economy scenario. Additional savings from changes in fuel consumption, are not reported in Table 4.1 but are included in the economic impact modeling. There are also other ancillary benefits of adoption of these technologies, such as lower maintenance costs of electric vehicles, which are not explicitly reflected in the economic modeling (International Council on Clean Transportation 2022). These changes then have cascading effects in the economic impact model, as households and businesses redirect spending to other parts of the economy.

Table 4.1. Change in spending in Net Zero Economy scenario ($ millions)

Technology	2025	2030	2035	2040	2045	2050
Change in spending by consumers on passenger vehicles	$372	-$746	-$2,455	-$4,703	-$9,010	-$10,381
Change in spending by consumers on heating and cooling technologies	$65	$73	$345	$540	$438	$482
Change in spending by businesses on heavy-duty vehicles	$279	$1,181	$1,388	$2,731	$1,982	$1,070

[11] Emsi Lightcast 2022
[12] Note that for both passenger and heavy-duty vehicles, a lifespan of 15 years is assumed in the modeling.

05 Economic Benefits and Workforce Opportunity

Image source: Adobe Stock Images

5.1 Economic Impacts

Key Takeaways

In both modeled decarbonization scenarios, there is a near-term increase in the size of economy (gross state product) of approximately 1.5% by 2030 driven by significant investment in power generation to get to a net zero power grid.

In the longer term, the Net Zero Economy scenario leads to greater continued growth, with an economy nearly 2% larger by 2050 in terms of GSP relative to the baseline.

Overall, the investment drives positive job impacts. In the nearer term, these are concentrated in the industry and services sectors driven by the power sector investment.

There is increased consumer spending from greater employment and re-spending of cost savings. The re-spending creates positive feedback loops (multiplier effects), which are especially prominent in service sectors due to the greater share of consumer expenditures, labor intensity and larger in-state presence.

In the Net Zero Economy scenario, other sectors, such as electricity and transport, see experience job growth as more sectors are impacted by decarbonization investments.

This section presents the state-level economic impacts of the two decarbonization scenarios compared to the baseline. The macroeconomic impacts were modeled using Cambridge Econometrics' E3-US model which evaluates economic impacts at the individual state level. The impacts of decarbonizing the economy of the two scenarios modeled here will be felt in two stages: an initial impact in the first decade or so which is dominated by a stimulus creating new jobs principally linked to the up-front investment required to achieve the energy transition, and a long-term positive impact that results from a more efficient economy that is able to deliver electricity and private transportation at lower cost, saving consumers money and leading to positive multiplier effects mostly concentrated in consumer service sectors. Overall, the decarbonization scenarios have positive statewide economic benefits.

Provided by Lynetta Usher Griner

Gross State Product (GSP) Impacts

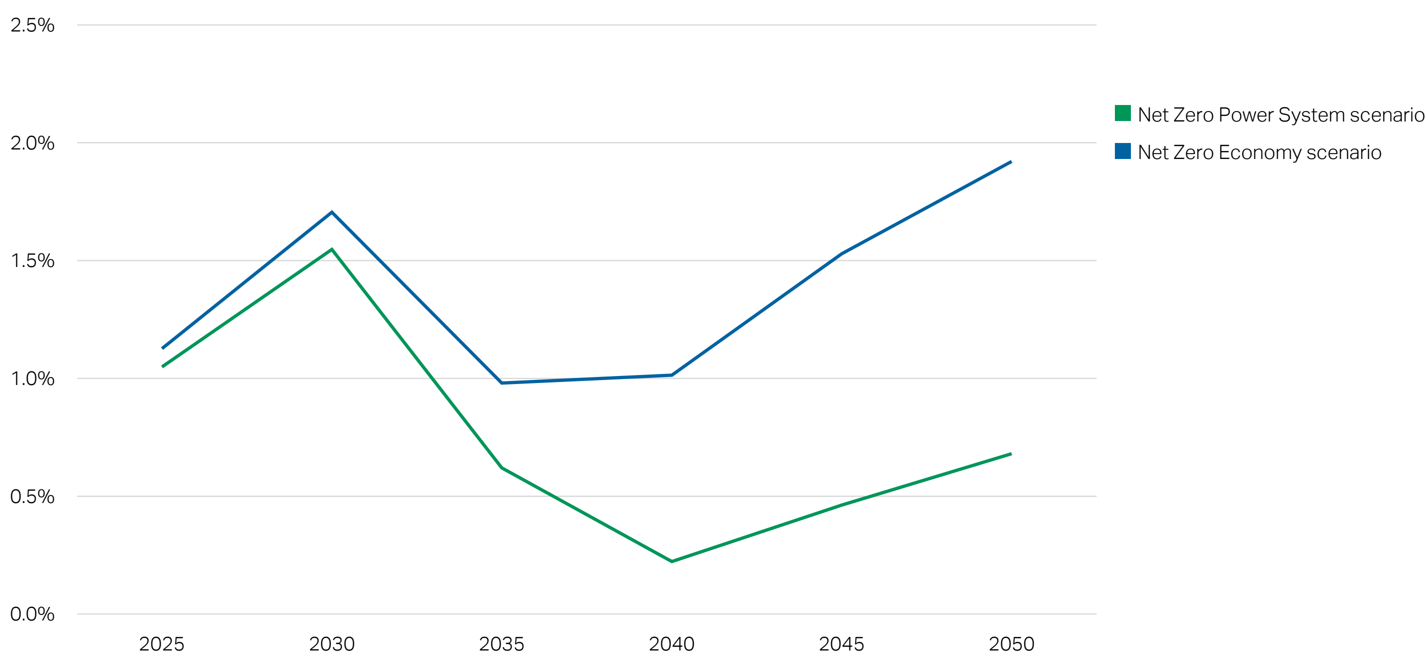
Both scenarios analyzed are projected to have positive long-run gross state product (GSP) impacts in Florida. Of the two, the economy-wide decarbonization scenario has greater positive impact on GSP (Figure 5.1). The additional investment in clean energy generation capacity required to deliver a Net Zero Power System by 2035 is projected to increase economic activity, with the stimulus effect being the largest through the second half of the 2020s and peaking at 2030, when GSP is 1.5% greater than baseline. After this significant investment, the long-term positive impacts are more modest, with GSP increases of 0.5% compared to the baseline in 2050. The investment required to deliver a Net Zero Economy provides a much larger stimulus and reduces costs to businesses and households in the long run relative to baseline. Combined, the additional investments and increases in consumer spending result in a Florida economy that is nearly 2% larger compared to the baseline in 2050.

Employment Impacts

The E3-US model estimates job impacts for 71 individual sectors and 9 aggregated sectors including: electricity, construction, industry, services, transport, agriculture, extraction, other utilities, and government (given their smaller impacts, the latter four are shown collectively in Figure 5.2 as "Other"). The industry aggregated sector captures the two-digit NAICS equivalent for the manufacturing sector. Some individual sectors within industry include computer and electronic products, electrical equipment, and other transportation equipment. Individual sectors within Services include vehicle and parts dealers, food and drink stores, administrative and support services, accommodations and other retail, among others. See Appendix C for a full list individual sectors comprising the aggregated sectors.

Through the latter half of the 2020s and first half of the 2030s, employment gains are concentrated in the industry and services sectors in both scenarios. The creation of new manufacturing jobs in both scenarios is linked to the projected up-front capital investments made in building out supply chains providing intermediate and final goods required for clean electricity generation, such as

Figure 5.1. Florida GSP results (% difference from baseline)

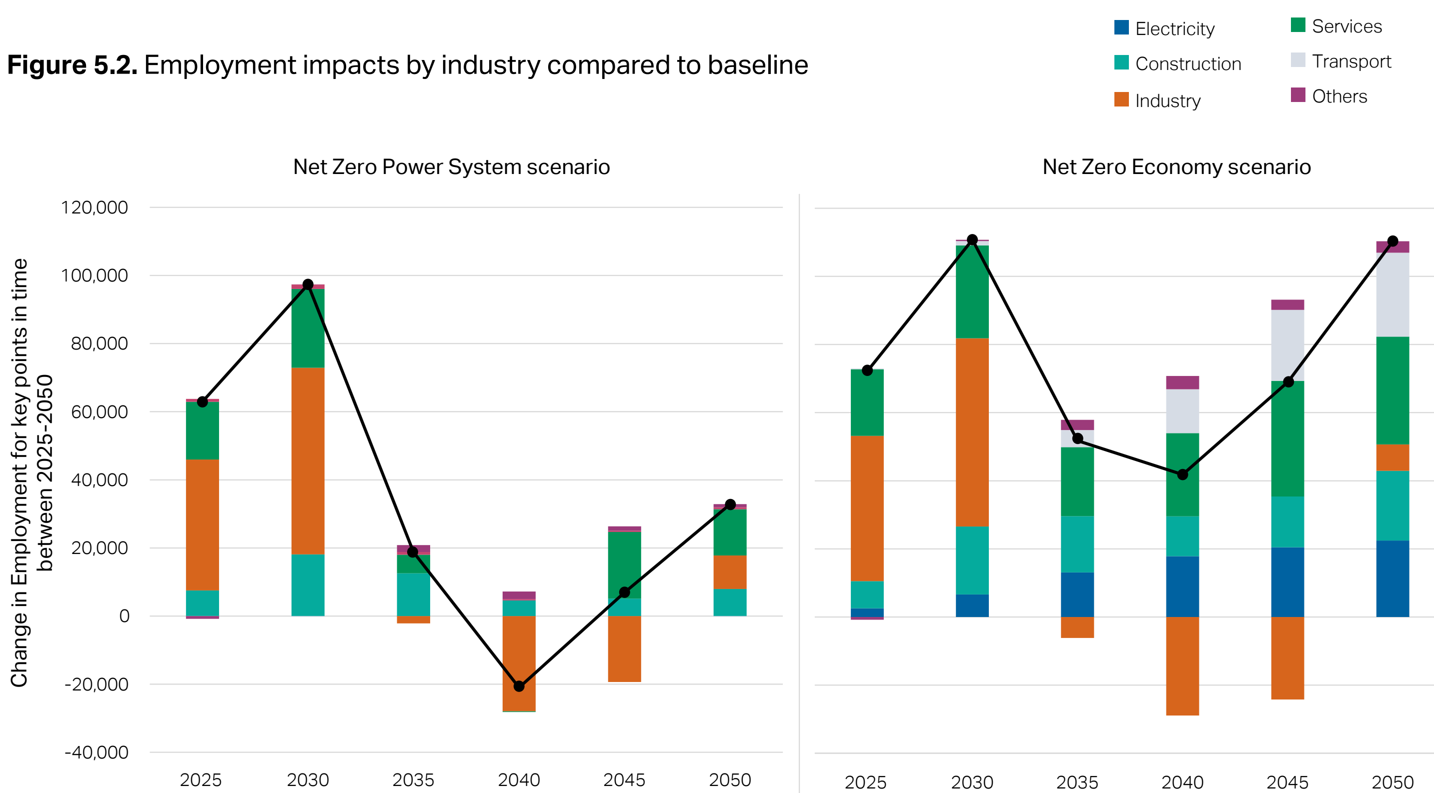


transformers and solar panels. In the Net Zero Economy, employment gains are also projected for the transport sector as decarbonization pathways for transportation requires additional investment in low carbon heavy-duty truck technologies. The spending associated with the new wages from these jobs and from consumer savings increases demand for consumer services (more on this below). In addition, large scale deployment and installation of new clean energy, particularly solar capacity in both scenarios, is also projected to increase employment in the construction sector relative to baseline throughout the timeframe of analysis.

In 2035 and after, the industry sector experiences net losses until 2050. In both scenarios, the significant amount of upfront investment in the solar generation increases demand and productivity in industry, but when this demand falls after 2035, the efficiency gains (i.e., labor productivity) from this investment stimulus causes employment to decline relative to the baseline. In the long run, industry employment is generally greater than in the baseline, due to higher demand from increased consumer spending. For the Net Zero Economy scenario, there are also significant increases in the electricity sector due to increased demand in electricity from electrification.

The employment impacts will vary across geographies. Statewide impacts were regionalized to the county level using current industry shares with data from the US Bureau of Labor Statistics (BLS) by industry (NAICS) code. Employment in certain industries, such as construction, is relatively distributed across the state based on employment density. Conversely, sectors characterized by concentrated employment will have disproportionate impacts in certain regions. Brevard County, Florida's Space Coast, is a leader in the computer and electronic individual sector, meaning both the growth and declines in that sector disproportionately impact the county. In the Net Zero Economy scenario, employment gains in the services aggregated sector contribute to job growth in nearly every county. Similarly,

Figure 5.2. Employment impacts by industry compared to baseline



Note: Figures shows changes in employment relative to baseline for specific years of the analysis between 2025 and 2050.

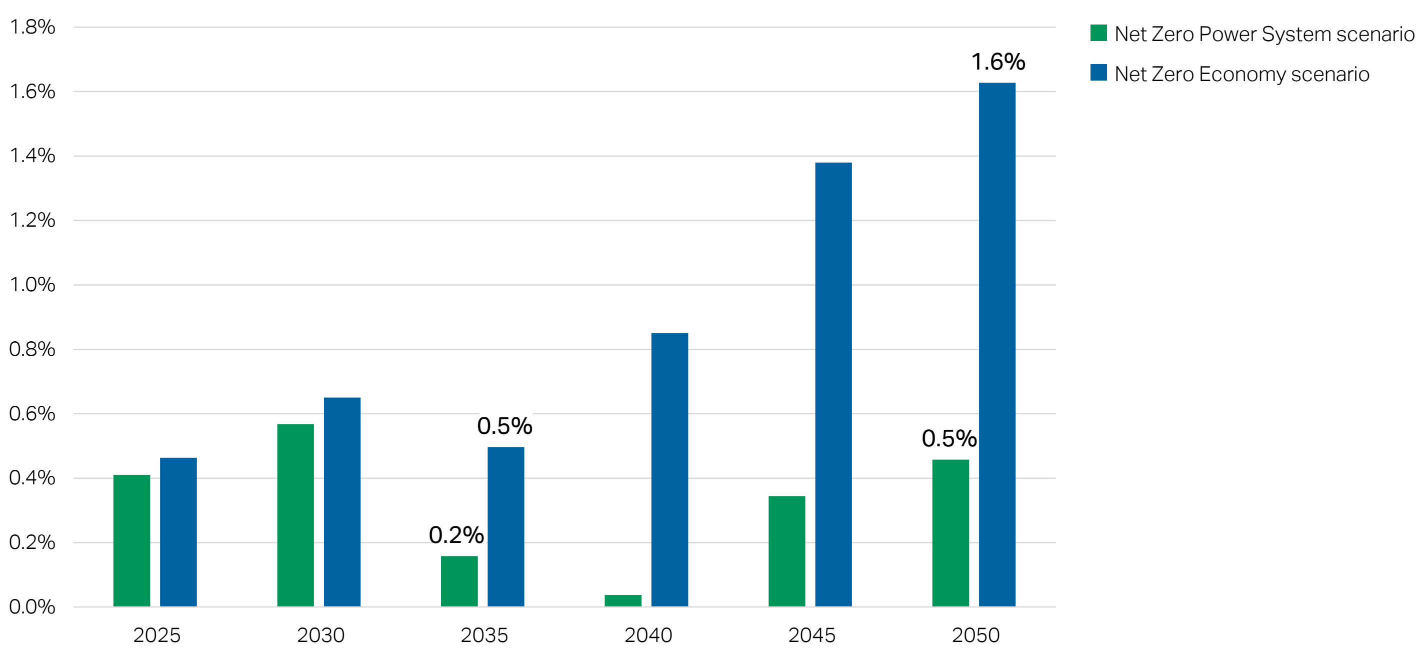
the construction sector adds jobs in every county, but particularly Miami-Dade, which currently has the highest proportion of the state's construction jobs. Employment gains in the aggregated transport sector are estimated to be higher than the losses in the vehicle and parts dealers individual sector. Assuming similar composition to today, counties like Miami-Dade, Orange, and Duval would disproportionately benefit from transport employment gains, while vehicle and parts dealer job losses would be distributed more equally across the state.

Spending

Lower energy and personal vehicle costs, employment gains, and the lower costs of electricity for businesses (which are expected to outweigh the higher costs of transportation), all increase real consumer spending power relative to baseline. Local consumers will spend most of the money on more goods and services, a substantial proportion of which will be sourced from within Florida, leading to positive multiplier effects as this creates new economic activity and jobs across the consumer service sectors (and upstream through supply chains). These impacts will occur throughout the period to 2050, due to the lower electricity prices persisting throughout, although these impacts can be expected to be most pronounced from 2035 onwards, when the reductions in the cost of electricity are greatest. Figure 5.3 shows the percentage change in consumer spending relative to baseline for both scenarios.

Through the latter half of the 2020s and the first half of the 2030s, the scale of the positive impact of decarbonization on consumer spending is similar for both scenarios. In the Net Zero Economy scenario, the scale of decarbonization's impact on consumer spending is projected to increase through the 2040s pushing consumer spending to 1.6% above the baseline by 2050. The increase in consumer spending in this scenario becomes more pronounced from 2035 onwards as reductions in the cost of electricity continue to occur (with LCOE reaching 17% lower than 2050 baseline levels), and increased savings are realized from energy efficiency savings and the transition to cheaper personal electric vehicles.

Figure 5.3. Consumer spending impacts (% difference from baseline)



5.2 Workforce Development

Key Takeaways

The workforce is already experiencing shifts from decarbonization, including a nearly 13% annualized growth rate for renewable jobs in the state between 2018 and 2022.

In the Net Zero Power System scenario, job growth is estimated in sectors that are higher paying than the baseline, with higher typical minimum levels of education attainment. Specialized skills and knowledge, such as installation, programming, and design, will experience higher demand relative to the current economy.

In the Net Zero Economy scenario, nearly every sector of the economy will be impacted. Job growth is particularly notable in sectors with lower typical levels of education, but with a larger percentage paying between 1x and 2x living wage relative to baseline. Growth is driven by jobs in sectors such as electricity and transportation. Transportation, mechanical, and operation and control, are some skills and knowledge requirements that will experience higher demand relative to the current economy.

Other knowledge and skills with current high prevalence, such as customer and personal service, will continue to be in demand under both decarbonization scenarios.

Current Landscape of Decarbonization Workforce in Florida

While decarbonization will ultimately mean a transition impacting all sectors of the economy, certain industries, such as the energy industry, are already experiencing shifts. Across the United States, there has been growth in clean energy employment. According to the US Department of Energy's US Energy and Employment Jobs Report (USEER), clean energy jobs grew nearly 4% nationwide from 2021 to 2022. The USEER defines clean jobs as those in technologies that align with a net zero future, including those related to renewable energy, grid technologies and storage, and clean vehicles and components. Across this whole aggregated sector, energy efficiency, including technical and trade jobs for the servicing and installation of ENERGY STAR appliances, high-efficiency HVAC equipment, and LED lighting, remains the single biggest sector with a total national employment of 2.2 million. The fastest growing clean energy sector was clean vehicles, which saw a 26% increase in total employment between 2021 and 2022.

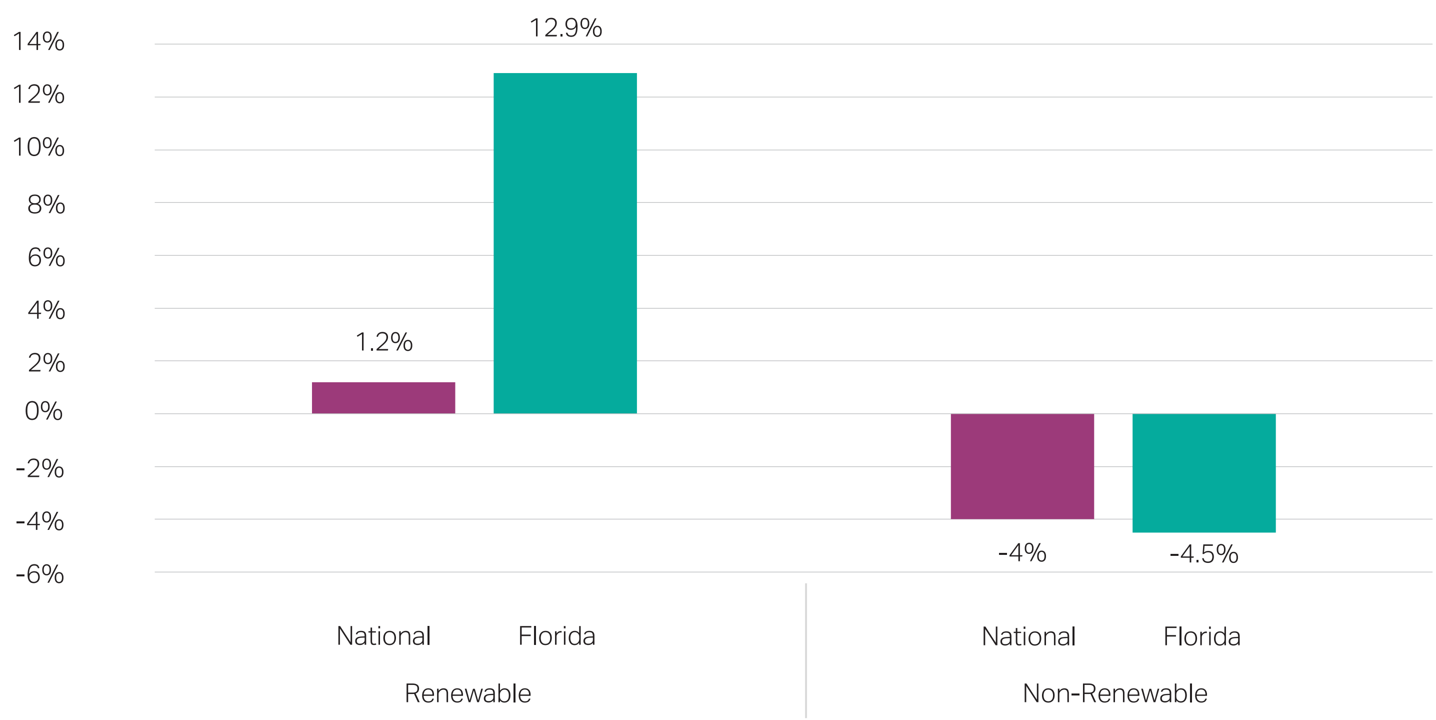
In line with this national employment landscape, Florida has also seen rapid growth in clean energy employment. In 2021, Florida ranked 4th in the country in total clean energy employment with nearly 160,000 jobs, or nearly 2% of the statewide workforce. The job growth in renewable energy jobs over recent years has been significant. Figure 5.4 shows the change in energy generation jobs in Florida and nationwide split between renewable and non-renewable sources, showing a nearly 13% annualized growth rate increase in the state between 2018 and 2022. Specifically, the Florida solar power industry has accelerated growth in recent years, with the state ranking second in the nation in terms of solar power jobs and third in solar electric installation capacity (Glover and Allen 2023; Riley 2023).

In response to the rising demand for solar installers, St. Petersburg College is partnering with the University of Central Florida to create the first state-approved solar apprenticeship program in Florida. The students will graduate as certified solar panel technicians, providing economic mobility to students and their communities.

Other universities throughout Florida are also taking a growing role in supporting technological advancements and workforce training, as noted (along with a cleantech cluster map) in a 2021 report on clean energy and technology by the State University System of Florida. Some highlights include University of Florida's Florida Energy Systems Consortium, University of Central Florida's Florida Solar Energy Center, and Florida Atlantic University's Southeast National Marine Renewable Energy Center, among others, which are all supporting clean energy research and collaboration (State University System of Florida 2021). At the same time, efforts from the non-profit and public sector (including the South Florida Climate Resilience Tech Hub, Miami-Dade Beacon Council's Opportunity Miami, and others), are both supporting collective training and collaboration and bringing in needed investment towards workforce training.

Other sectors have also been experiencing growth beyond just energy. Published in 2021, *Miami Forever Carbon Neutral* identified trends in the green economy, which they define as any group of businesses or organizations that reduce the negative impact of human activity on the environment, including those that supply or consume a green output (City of Miami 2021). Sectors of the economy classified as "green" include transportation energy, buildings, waste management, research and development, regulations and advocacy, and climate resilience infrastructure; these sectors experienced 20% growth between 2014 and 2019 and were less impacted by the COVID-19 pandemic than the traditional job sector.

Figure 5.4. Annualized growth rate for energy generation jobs, national and Florida, 2018 to 2022



ESA

Provided by ESA

ESA delivers large-scale solar energy and storage projects across the US. Founded in 2017, the company has 8-gigawatts of solar energy projects in its portfolio. With the passing of the Inflation Reduction Act, which provided new tax incentives and opportunities for clean energy, ESA saw increased demand for its services leading to both revenue and employment growth. ESA has partnered with the University of Central Florida for an internship program to help develop the next generation of solar energy engineers and project developers (ESA Solar 2023).

Recently, the company completed the first phase of a new 3.6 MW solar farm in Central Florida for a cannabis grower. For cannabis growing operations, electricity can amount to 30% or 50% of costs, leading them to turn to on-site solar and energy storage systems to lower their energy costs. ESA's three-phased project is expected to help cut costs meeting the electricity demand for all the indoor growing operation electricity needs for the indoor growing operation (Schoeck 2023). In 2020, Advent Health, one of Florida's major healthcare systems, completed a solar parking deck project in partnership with ESA for its Orlando hospital campus (Central Florida Division Corporate Communications 2020). As part of the project, ESA installed more than 1,800 solar panels in the parking garage, generating more than 1.3 million kilowatt hours (kWh) annually and saving Advent Health over $4.6 million in energy costs. Currently, ESA Solar is building a 6,000-panel rooftop solar system on Advent Health's new corporate headquarters in Altamonte Springs, Florida. This project is anticipated to help Advent save 35% in energy costs at the location.

There are also economic opportunities associated with in-state manufacturing. Currently, manufacturing jobs comprise less than 5% of Florida's employment and a high percentage (65%) of industry input purchases from the manufacturing industry was imported in 2022. Auto manufacturing specifically accounts for <0.1% of jobs in the state (Lightcast 2023). However, recently businesses are relocating to Florida to support solar, wind and electric vehicle production. In Jacksonville, for example, the EV technology startup Cenntro established a new assembly facility for electric commercial trucks to be sold in the southeast United States and Central America. SolarTech Universal and JinkoSolar are two leading solar manufacturing companies in the country both located in Florida. As noted below, General Electric is manufacturing and assembling components for wind energy.

WIND ENERGY MANUFACTURING

Thanks in large part to the Inflation Reduction Act, the US wind industry is seeing a "second renaissance" that will allow manufacturing in the sector to establish itself more firmly. Florida, with existing presence of major manufacturers Mitsubishi and General Electric (GE), is well-positioned to reap benefits from this trend. General Electric's Wind Energy plant in Pensacola, Florida assembles 2.5 megawatt turbines and hit a milestone in 2020 having achieved a combined 20 gigawatts of installed capacity in 23 US states and 10 countries (Kellner 2022). In addition, the same plant also produces nacelles and hubs for GE's popular 3 megawatt turbines (Kessler 2023). More recently the company announced that it will invest an additional $20 million into the facility to expand production capacity and introduce new products in anticipation of a rebound in the domestic market (Kessler 2023). Another major player in the sector that has a presence in Florida is Mitsubishi Powers. Established in 2001 and expanded in 2008, the company's 190,000 square-foot Orlando Service Center serves as a repair, service, and manufacturing center. The facility manufacturers vanes, blades, and compressor blades totaling approximately 15,000 parts a year.

Job Characteristics of Decarbonization Scenarios

Having a better understanding the job characteristics of the projected change in employment from the decarbonization investments is important for formulating policy and business actions and designing workforce development programs. Studies have found that jobs in "green" industries tend to have higher wages and lower educational requirements, particularly for renewable energy jobs that often require on-the-job training (Muro et al. 2019). In 2019, nationwide trends indicated that the median hourly wage for clean energy jobs[13] of $23.90 is about 25% higher than the national median wage, which was $19.10 (E2 2020). In particular, solar energy generation had an even higher median hourly wage of $24.5, which is 28% higher than the national median wage (E2 2020).

Data on staffing patterns that show the occupational makeup (SOC) of each industry were used to better understand the wages, education, skills and knowledge of the jobs in industries with expected growth.[14,15]

SOUTH FLORIDA CLIMATE RESILIENCE TECH HUB

Led by Miami-Dade County Innovation and Economic Development Office, the South Florida Climate Resilience Tech Hub was officially designated as one of 31 Tech Hubs in the county in October 2023 by the US Department of Commerce's Economic Development Administration (EDA) (Miami-Dade County 2021). The designation allows the region to be eligible for upwards of $75 million in federal grants and represents a strong endorsement of the region's plans to supercharge their technological industries for workforce development and strengthen national competitiveness (US Economic Development Administration 2023). The South Florida Climate Resilience Tech Hub will focus on the commercialization of four technological industries including: 1) Coastal resilience and marine infrastructure, 2) Clean cement, 3) Energy-efficient construction and utilities, and 4) Clean energy generation, transmission, and storage (Miami-Dade County 2023).

Wages and Education

For each occupation code, the BLS provides average hourly wages paid to workers of that occupation across the state as well as typical entry-level educational requirements. Average wages are compared against a measure of Florida's Living Wage, which is defined as the hourly rate an individual in a household must earn to support themselves and their family. Each occupation is sorted into categories of either paying under the living wage, between one and two times the living wage, and above double the living wage.[16] Using this threshold, nearly 70% of Florida's jobs pay a rate below the livable wage, roughly 29% pay between one to two times the livable wage, while around 4% pay more than double the statewide livable wage. However, it is worth noting that comparing a statewide living wage threshold against wages averaged across the state does not account for the within state variability of cost of living and wage rates.

Lightcast provides information on the typical education level most often needed in order to enter an occupation. Similar to categorization of wages, occupations were sorted based on these typical education levels. Occupations with a high school diploma or equivalent as the typical education level are categorized as "low educational level", occupations with some college or associate's degree are considered "medium educational level", and with typical educational levels of a four-year degree or higher are considered "high educational levels". Using this classification, just over 64% of jobs in Florida's current economy fall into "low educational level" occupations, around 11% fall in "medium educational level" occupations, and roughly a quarter of jobs into fall in "high educational level" occupations.

[13] Within the E2 (Environmental Entrepreneurs) report, clean energy jobs are defined as occupations found across a variety of value chain activities including manufacturing, construction, wholesale trade, and professional services related to clean energy production.
[14] The Standard Occupational Codes (SOC) system classifies all private, public, and military occupations.
[15] The workforce analysis in the following sections on wages, education, and skills adapts methodology AECOM used in support of "Miami Forever Carbon Neutral: Growing the New Green Economy" (AECOM 2021).
[16] Living wages are determined by the MIT Living Wage Calculator, which estimate the living wage at the county level depending on family size. This analysis considers a living wage for two working adults with two children as the baseline since this is the approach established by the National Fund for Workforce Solutions and PolicyLink in their "Advancing Workforce Equity" research. For a household with two working adults and two children, the living wage per adult in Florida is equal to $25.07 as of December 2023 (for a single adult without children, the amount is $17.72).

Figure 5.5 and Figure 5.6 show the change in the share of jobs for typical entry level education and wages relative to the baseline in the shown year for the Net Zero Power System scenario and Net Zero Economy scenario, respectively. In the longer term, the Net Zero Power System and Net Zero Economy scenarios both result in more jobs created in the services, industry, and construction sectors. The construction sector experiences consistent job growth in the short and long term relative to baseline in both the Net Zero Economy and Net Zero Power System scenarios. Nearly a third of construction jobs pay a living wage, while over three-quarters of them have low typical education levels. Occupations in general retail and admin and support are lower paying with a lower barrier to entry, while other service industries are expected to grow, including other professional services, insurance, and banking/financial services will create jobs in higher-skill occupations with higher wages. In the Net Zero Economy scenario, the industry sector would also experience job growth in the longer term, with an estimated increase in jobs in chemical product occupations, other transportation equipment, food and drink, and machinery sector relative to baseline. Other than food and drink, each of these occupations has a higher proportion of occupations that pay above a living wage than the current state mix, and 70% have typical education entry levels of a high school diploma.

Electricity and transport experience job growth in the Net Zero Economy scenario. The electricity sector, which sees significant long run job growth in the Net Zero Economy scenario, is an industry with one of the highest shares of jobs that pay a living wage, with 67% paying between one and two times the living wage. The transport sector experiences significant long term job growth in the Net Zero Economy scenario relative to baseline driven by gains in land and rail transportation.[17] Nearly 90% of land transportation jobs are currently within an occupation paying below a living wage, although just over half have typical education levels above a high school diploma. However, rail transportation jobs have one of the highest shares of occupations paying above a living wage, at 83%, a high school diploma is the typical entry level education for 87% of the jobs.

[17] *Land Transportation includes all of Truck Transportation, Transit, and Pipeline Transportation*

Figure 5.5. Change in the share of jobs by typical education levels and wage categories relative to the baseline in 2030 for the Net Zero Power System scenario

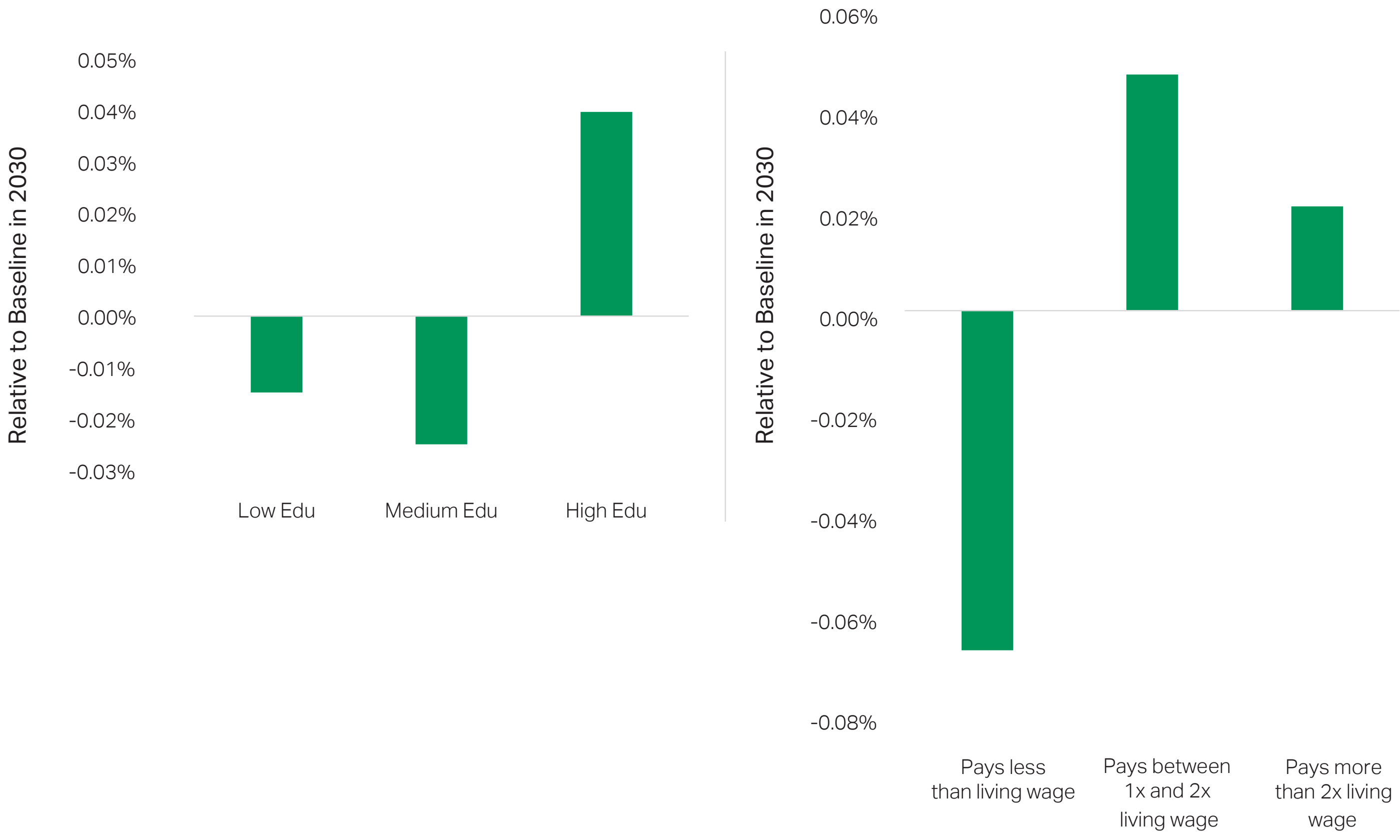
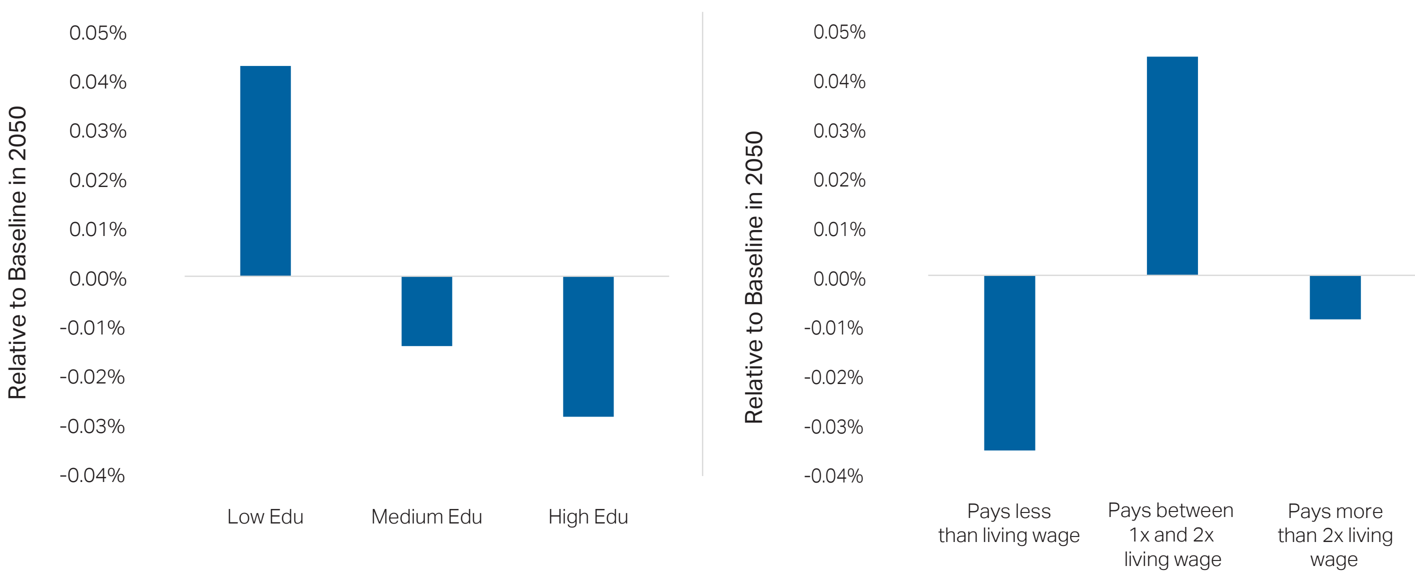


Figure 5.6. Change in the share of jobs by typical education levels and wage categories relative to the baseline in 2050 for the Net Zero Economy scenario



Skills and Knowledge

To match occupations to specific skills, O*NET's[18] occupational descriptions were used. O*NET maps each SOC code to a set of unique skills and knowledge subjects used in that occupation,[19] drawing from a set of over 120 options. For example, the most used knowledge in Florida's current occupational mix, customer and personal service, is used in just over 5% of jobs, whereas knowledge of design is used in only 0.4%. Figure 5.7 through Figure 5.10 highlight the specific skills and knowledge areas required in the occupations that are likely to experience growth under the two decarbonization scenarios. The charts show both the number of jobs that are estimated to utilize that skill, and the percent growth in the jobs utilizing that skill relative both to the current economy and the baseline in 2030 (for the Net Zero Power System scenario) and 2050 (for the Net Zero Economy scenario).

Some of the most frequently used skills and knowledge areas in the occupations making up the current economy – such as customer and personal service or English language – will continue to be in demand in the future under both decarbonization scenarios. However, occupations with more specialized skills including installation, programming, and design will experience some of the highest growth in demand with occupations that use them increasing by 12%, 11% and 10% respectively by 2030 relative to the current economy. Some of the commonly used skills and knowledge subjects with the largest percentage growth of occupations that use them in the Net Zero Economy in 2050 relative to the current economy are: transportation (40%), mechanical (34%), and operation and control (33%). In particular, new jobs in occupations in the transportation, electricity, and construction sectors drive the demand for workers with this set of knowledge and skills.

FLORIDA SOLAR ENERGY CENTER (FSEC)

Created by the State legislature in 1975, the Florida Solar Energy Center (FSEC) based at the University of Central Florida, serves as the State's premier energy research institute. Along with conducting research in solar technologies, high performance buildings, hydrogen and fuel cells, EVs, and energy storage, FSEC tests, certifies, and sets statewide standards for all solar thermal and solar electric systems in the state. FSEC also plays a pivotal role in addressing the workforce demands associated with a clean energy transition. The center serves as a crucial training and education ground, offering various courses, workshops, and professional certification support that empower better prepares students and professionals to excelfor employment in the clean energy sector. These professional certification pathways include Residential Energy Modeling, Energy Auditing, HERS Rating, Weatherization, and Energy Code Training. By bridging the gap between academia and industry, FSEC's educational and training programs provide hands-on experiences, research opportunities, industry partnerships, and career advancement pathways that aim to fill the workforce needs of Florida's rapidly transforming energy sector.

*[18]Occupational Information Network (O*NET) is an online database sponsored by the Department of Labor that describes occupations in terms of the knowledge, skills, and abilities required.*
[19]While data is also available on "abilities", those were not include for the purposes of this report.

Figure 5.7. Net Zero Power System scenario relative to current economy

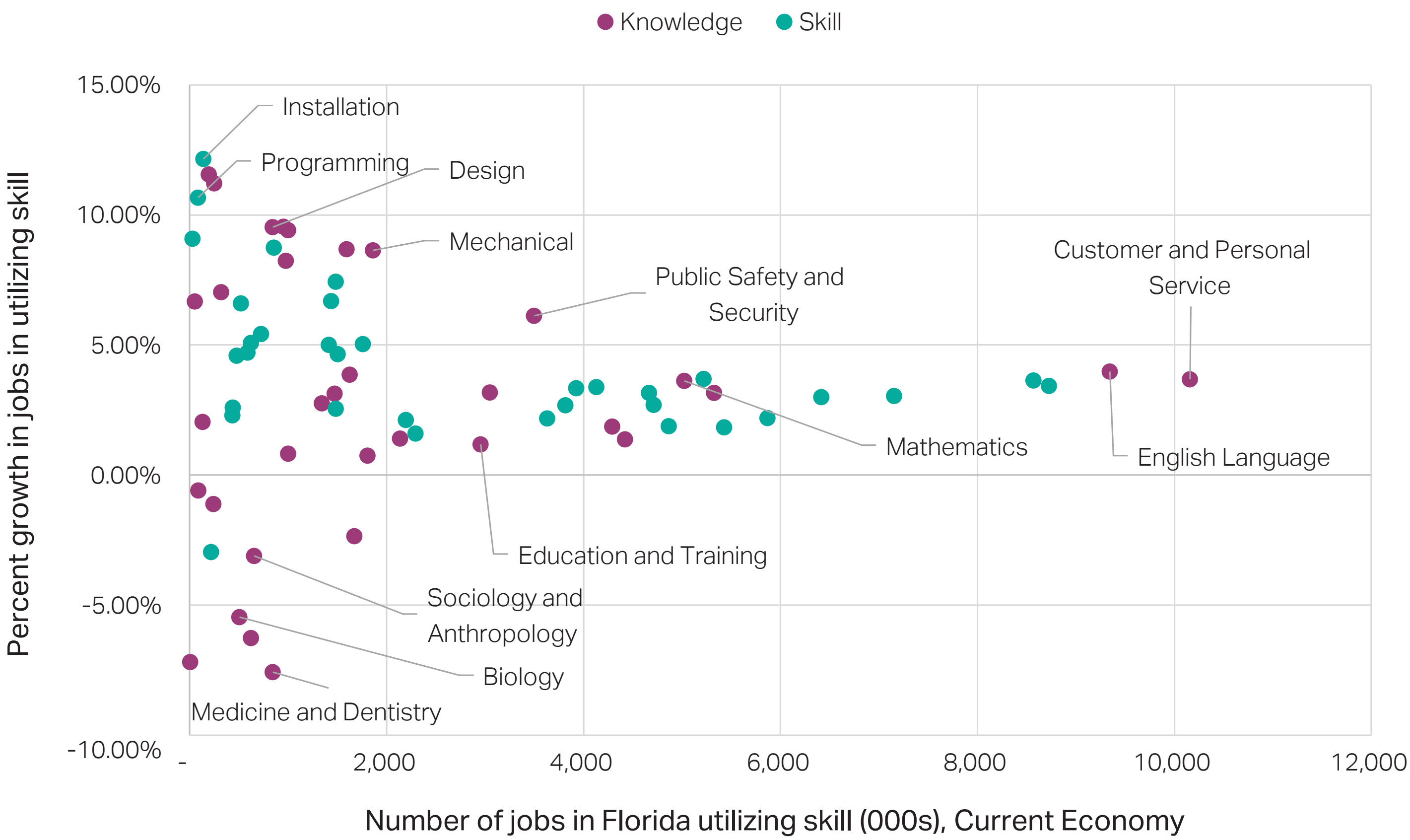


Figure 5.8. Net Zero Power System scenario relative to baseline in 2030

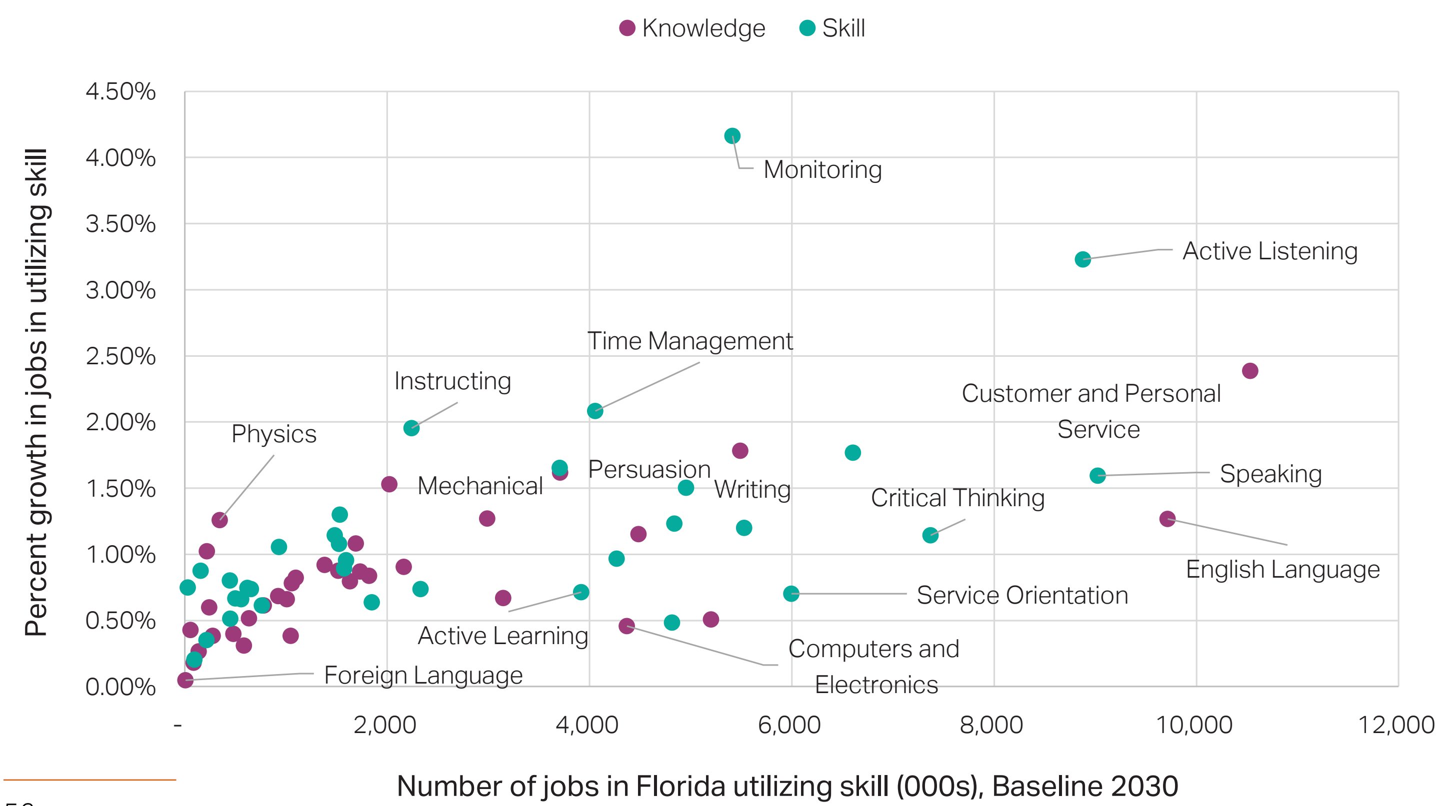


Figure 5.9. Net Zero Economy scenario relative to current economy

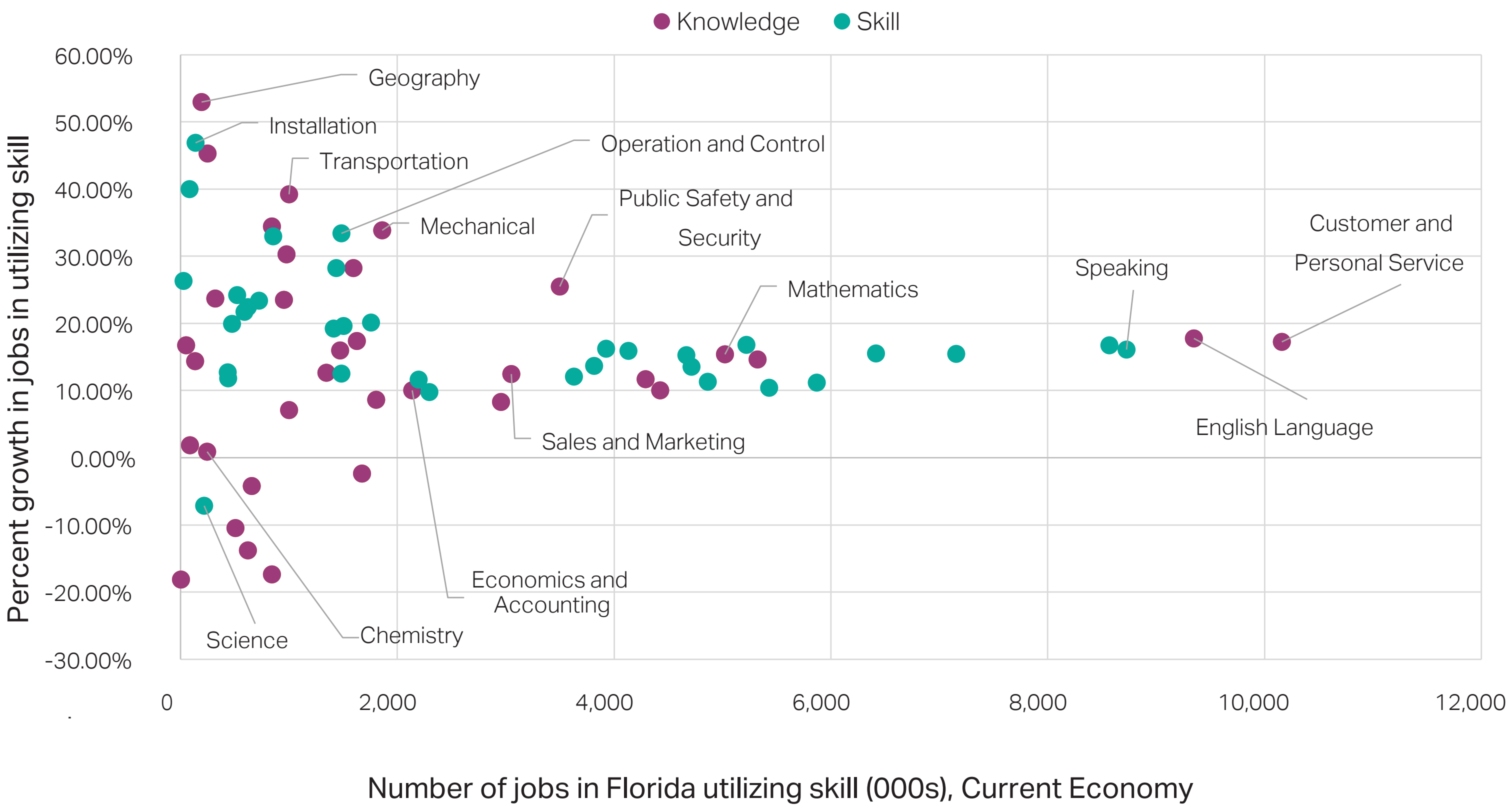
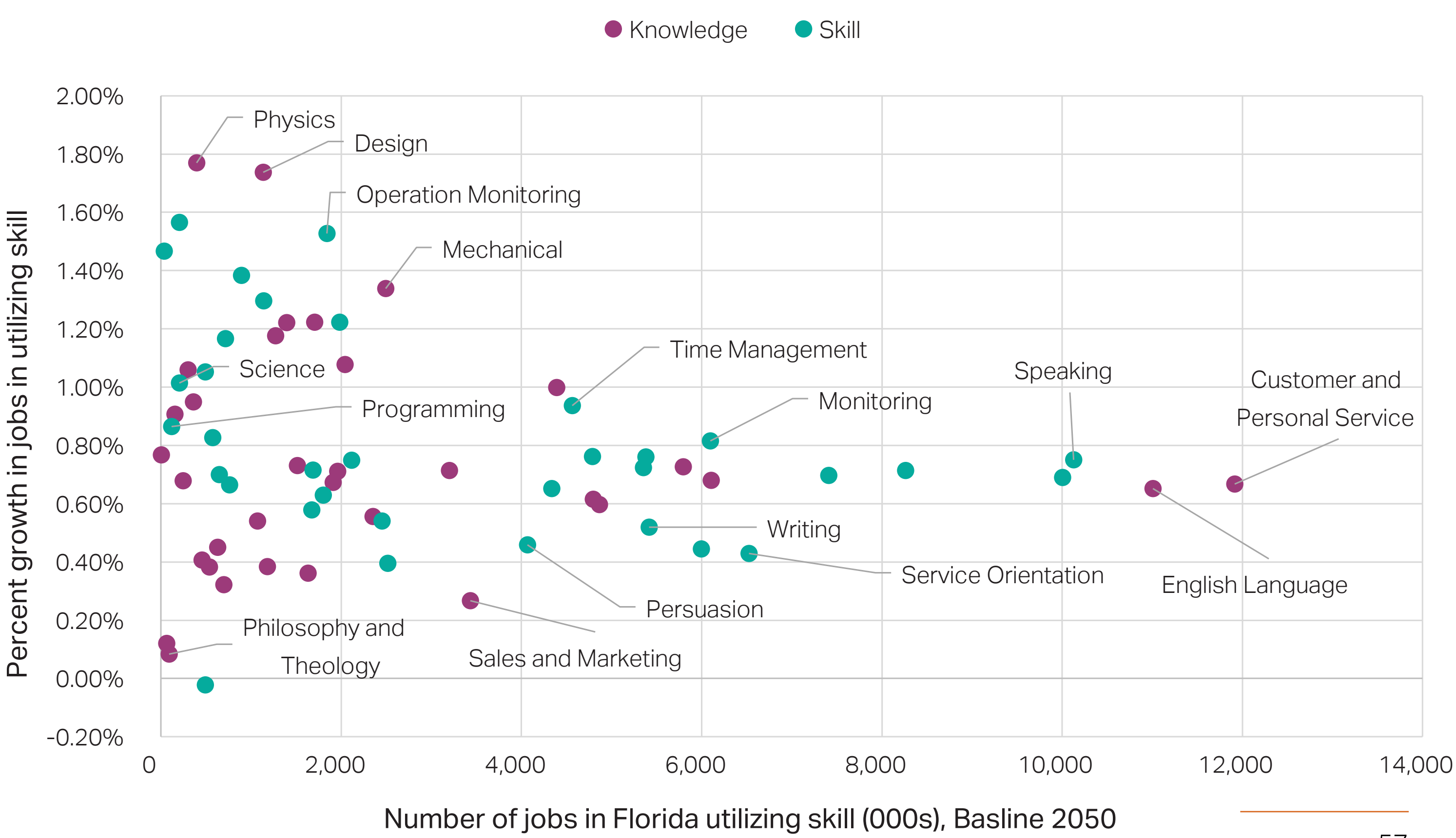


Figure 5.10. Net Zero Economy scenario relative to baseline in 2050



Information about skill and education requirements was combined to better understand the barrier to entry into an occupation through a skills/education index. This index was calculated based on three components (provided by O*NET): intensity of skills required for the occupation, the importance of skills, and education required (which incorporates consideration for professional certification in the O*NET database). The analysis uses an index to understand an occupation's barriers to entry, with a scoring of 100 as the most difficult. The occupation with the highest calculated index value in Florida is Preventative Medicine Physicians with a score of 100, compared to the state median index of 38.

According to the skills/education index, electricians have an index of 54, and rank 80th percentile for skills but only 32nd for educational attainment requirements. Solar Photovoltaic Installers have an index of 41, and fall in the 66th percentile for skills and 46th percentile for educational attainment requirements. Heating, Air Conditioning, and Refrigeration Mechanics and Installers, who will be crucial in transitioning Florida's building stock to electric heat pumps have an index of 36, ranking in the 68th percentile for skills requirements but only 29th percentile for educational attainment.

Other industries expected to grow under the decarbonization scenarios have lower barriers to entry. For example, Construction Laborers have a composite score of 15, which is in the 10th percentile of occupations. Jobs in Machinery, which are expected to increase under both scenarios, include Welders, Cutters, Solderers, and Brazers rank 13 on the skills/education index. As demand for general merchandise and other retail increase under the decarbonization scenarios, occupations such as Cashiers, Retail Salespersons, and Stockers and Order Fillers will be required, all of which fall lower on the skills/education index.

Provided by the City of Tallahassee

06 Conclusion

Image source: Adobe Stock Images

This study aims to better understand the investment required, and the economic benefits associated with two decarbonization scenarios in Florida: a Net Zero Power System by 2035 and a Net Zero Economy by 2050. Both modelled scenarios result in increased GSP and employment growth relative to the baseline in the E3-US model. In the near-term these impacts are felt in specific industries that supprt the transition to a Net Zero Power System, but new wages and consumer savings in the longer term result in economy-wide benefits particularly as shifts occur across sectors in the Net Zero Economy scenario. To achieve an equitable transition, effective workforce development is critical. Specific skillsets, such as those associated with energy generation and electrification, will be in high demand. Importantly, many of the jobs with expected growth have both lower barriers to entry and pay higher wages, helping to support upward mobility in a state with increasingly high costs of living.

Public agencies, utilities, businesses, and residents in Florida area are already progressing decarbonization goals. Key market drivers, including decreasing costs for solar energy and EVs, are making certain low-carbon investments more attractive and are estimated to continue to do so into the future. As life cycles reach their end on assets such as municipal vehicles and county buildings, commitments from local and regional climate action strategies have significant market share impact. Leading academic institutions are supporting both research and development and workforce training programs, while the private sector is finding opportunity in manufacturing, low-carbon development, and solar generation.

Florida is uniquely suited to both achieve and benefit from decarbonization, with abundant sunshine, a service-driven economy, and a highly electrified residential building portfolio. While achieving a Net Zero Power System by 2035 and a Net Zero Economy by 2050 will require substantial collective action, this study finds that continued efforts towards decarbonization can benefit Florida’s economy and consumers.

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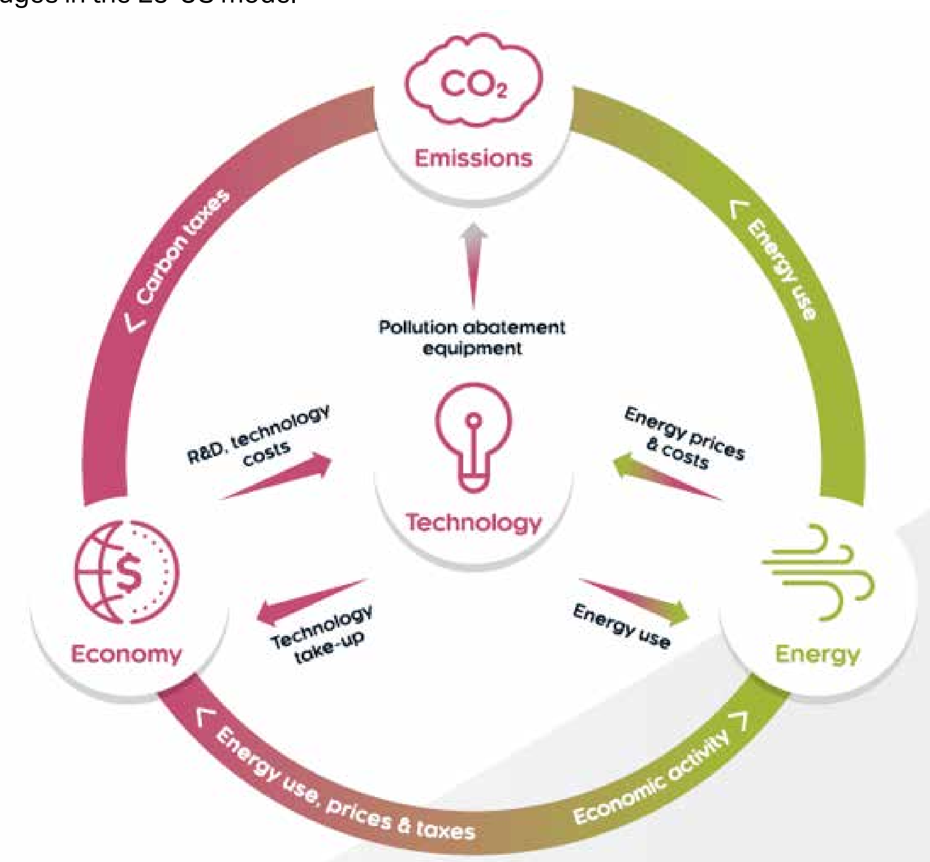
Appendix A

THE E3-US MODEL

E3-US is an advanced software tool that can be used to assess energy-economy linkages at US-state level. The model design centers on evaluating the economic impacts of potential policies – such as multi-sector decarbonization pathways – on stakeholders.

Figure A.1 shows how the three components (modules) of the model - energy, environment and economy - fit together. The economy module provides measures of economic activity and general price levels to the energy module, which inform energy use; the energy module estimates energy use and energy price levels, which feeds back to the economy module via key variables such as consumer expenditure and intermediate demand for energy sectors. The environment module calculates emissions based on energy use outcomes from the energy module. Further interactions between these modules are determined by policy inputs, such as carbon taxes or regulations. The technical development of the model was carried out by Cambridge Econometrics. E3-US is similar in design to the internationally recognized E3ME model, also developed by Cambridge Econometrics (see www.e3me.com).

Figure A.1. E3 linkages in the E3-US model



Structure and data

The structure of E3-US is based on the system of national accounts, with further linkages to energy demand and environmental emissions. The labor market is also covered in detail, including both voluntary and involuntary unemployment. In total there are 16 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, international trade), prices and energy demand. Each equation set is disaggregated by state and by sector.

Econometrics model such as E3-US is often compared to Computable General Equilibrium (CGE) models. In many ways the modelling approaches are similar; they are used to answer similar questions and use similar inputs and outputs. However, underlying this there are important theoretical differences between the modelling approaches.

In a typical CGE framework, optimizing behavior is assumed, output is determined by supply-side constraints, and prices adjust fully so that all the available capacity is used. In E3-US, the determination of output comes from a post-Keynesian, demand-driven accounting framework and it is possible to have spare capacity in the economy. It is not assumed that prices always adjust to market clearing levels.

The differences have important practical implications, as they mean that in E3-US, policies and investments may lead to increases in output if they are able to draw upon spare economic capacity.

The econometric specification of E3-US gives the model a strong empirical grounding. E3-US uses a system of error correction, allowing short-term dynamic (or transition) outcomes, moving towards a long-term trend. The dynamic specification is important when considering short and medium-term analysis (e.g. up to 2020) and rebound effects, which are included as standard in the model's results

E3-US's historical database covers the period 1970-2021 and the model projects forward annually to 2050. The main data sources are Bureau of Economic Analysis (BEA) and Bureau of Labor Statistic (BLS), supplemented by energy data from US Energy Information Administration (EIA) and United States Environmental Protection Agency (EPA), and other sources where appropriate. Levelized costs of electricity (LCOE) are drawn from International Energy Agency data, which provide estimates of LCOE by country and generating technology. Gaps in the data are estimated using customized software algorithms.

The main dimensions of E3-US are:

- 50 states
- 71 industry sectors, based on standard international classifications
- 20 categories of household expenditure
- 5 different users of 5 different fuel types
- 14 types of air-borne emission (where data are available) including the 6 GHGs monitored under the Kyoto Protocol

Standard outputs

As a general model of the economy, based on the full structure of the national accounts, E3-US is capable of producing a broad range of economic indicators, which will be focused on state of Florida impacts. In addition, it includes a range of energy and environment indicators.

The following list provides a summary of the most common model outputs:

- GDP and the aggregate components of GDP (household expenditure, investment, government expenditure and internal and international trade)
- sectoral output and GVA, prices, trade and competitiveness effects
- trade by sector
- consumer prices and expenditures
- sectoral employment, unemployment, sectoral wage rates and labor supply
- energy demand, by sector and by fuel, energy prices by fuel
- detailed power sector technologies
- CO_2 emissions by sector and by fuel

This list is by no means exhaustive, and the delivered outputs often depend on the requirements of the specific application. In addition to the sectoral dimension mentioned in the list, all indicators are produced at the state and national level and annually over the period up to 2050.

Appendix B

Additional Information on Scenarios from Laying the Groundwork for 'Getting to Neutral' in the State of Florida

- Business as Usual (BAU), or the Reference scenario, considers existing actions of the state such as reducing electricity from coal and increasing adoption of EVs.
- Clean electricity by 2035 relies on decarbonizing the power supply sector and transitioning to a 100% clean electrical grid throughout Florida. Assumptions include:
  - Non-renewable energy sources gradually retired and replaced by clean energy, mostly solar, with a percentage reduction applied starting in 2023, cumulatively reaching 100% by 2035.
  - 34% emissions reduction in 2050 compared to BAU.
- Net zero by 2050 assumes additional GHG emission reduction and an increase in carbon capture deployment alongside the Clean Electricity by 2035 scenario assumptions, and ultimately results in negative emissions by 2050. Assumptions include, among others:
  - Improving residential, commercial, industrial, and public building efficiency.
  - Decarbonizing the grid by incentivizing transition to renewables, mainly solar, but also increasing wind, geothermal, hydroelectric, and biomass capacity along with increasing grid storage.
  - Facilitating statewide network of EV charging stations and increasing alternative last mile transportation options.
  - Replacing proportion of non-renewable energy consumption in commercial and industrial sectors with methane regenerated from landfilled municipal solid waste.
  - Adopting highway heavy-duty diesel vehicle carbon capture technology.
  - Substituting distillate fuels for biodiesel in non-highway heavy duty vehicles.
  - Eliminating GHG emissions from carbon-intensive cultivation of drained organic soils and using less carbon-intensive agricultural products.
  - Increasing revegetation and afforestation.
  - Restoring lost coastal wetlands and increasing carbon uptake from degraded seagrass meadows.

Appendix C

Individual and Aggregated Sectors in the E3-US Model

Individual Sector	E3-US Aggregated Sector
1 Farms	Agriculture
2 Forestry and fishing	Agriculture
3 Oil and gas extraction	Extraction
4 Mining, exc oil and gas	Extraction
5 Support for mining	Extraction
6 Electricity	Electricity
7 Gas	Other utilities
8 Water and sewerage	Other utilities
9 Construction	Construction
10 Wood products	Industry
11 Non-metallic minerals	Industry
12 Primary metals	Industry
13 Fabricated metal	Industry
14 Machinery	Industry
15 Computer and electronic	Industry
16 Electrical equipment	Industry
17 Motor vehicles	Industry
18 Other transport equip	Industry
19 Furniture	Industry
20 Other manufacturing	Industry
21 Food, drink and tobacco	Industry
22 Textiles	Industry
23 Leather products	Industry
24 Paper products	Industry
25 Printing and reproduction	Industry
26 Petroleum and coal	Industry
27 Chemical products	Industry
28 Plastics and rubber	Industry

Individual Sector	E3-US Aggregated Sector
29 Wholesale trade	Services
30 Vehicle and parts dealers	Services
31 Food and drink stores	Services
32 General merch. stores	Services
33 Other retail	Services
34 Air transportation	Transport
35 Rail transportation	Transport
36 Water transportation	Transport
37 Land transport	Transport
38 Other transportation	Transport
39 Warehousing and storage	Services
40 Publishing	Services
41 Motion picture ind.	Services
42 Telecommunications	Services
43 Data and info serv.	Services
44 Fed Reserve banks	Services
45 Financial services	Services
46 Insurance	Services
47 Aux financial serv.	Services
48 Housing services	Services
49 Other real estate	Services
50 Rental and leasing	Services
51 Legal services	Services
52 Computer systems	Services
53 Other professional	Services
54 Company management	Services
55 Admin and support serv.	Services
56 Waste management	Services
57 Educational services	Services
58 Ambulatory healthcare	Services
59 Hospitals	Services
60 Residential care	Services
61 Social assistance	Services
62 Arts, sport, museums	Services
63 Recreational industry	Services
64 Accommodation	Services
65 Food services	Services
66 Other services	Services
67 Fed gov. (defense)	Government
68 Fed gov. (non-def.)	Government
69 Fed gov. enterprises	Government
70 State gov. general	Government

Source: Cambridge Econometrics

General Limiting Conditions

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