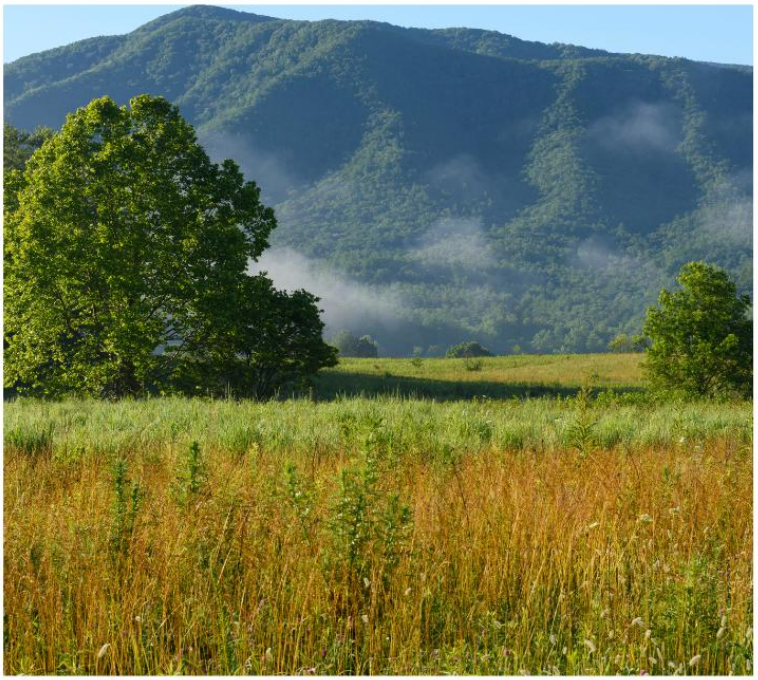

Appendices

BREATHE

A Climate Action Plan for the Knoxville Region

CITY OF KNOXVILLE

CITY OF ALCOA

CITY of MARYVILLE
PEOPLE are the KEY

CITY OF OAK RIDGE
TENNESSEE

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Appendix A: BREATHE Engagement

Engagement Overview

The Knoxville MSA BREATHE Plan was shaped through a year-long stakeholder engagement process that brought together local governments, regional agencies, community organizations, and technical experts. Beginning in fall 2024, a diverse set of Working Groups including those focused on buildings and energy, transportation and land use, waste and natural systems, workforce development, and equity helped establish the Plan's vision, identify existing activities to build upon, and define community outcomes to guide decision-making. By spring 2025, these groups were integrated into a single collaborative forum that refined 19 measures and provided critical input on implementation considerations such as actions, partners, barriers, funding, and equity.

Complementary engagement included a regional public survey administered by TPO's subcontractor FINN Partners, which provided broader community perspectives on climate action. The process concluded with a review period in fall 2025, when Working Group members were invited to provide feedback on the full draft plan. Taken together, these activities ensured that the BREATHE Plan reflects local priorities and technical realities while laying a foundation for regional coalition-building and long-term implementation.

Engagement Initiatives

A variety of engagement strategies were employed to identify community needs and priorities. Throughout the Plan development process, working groups offered consistent and valuable feedback, while the community survey also served as a key instrument in shaping the Plan's direction. The community provided invaluable feedback, concerns, and support to ensure the BREATHE Plan adequately addresses local experiences.

Working Groups

The BREATHE Working Group process was the centerpiece of engagement. Initially organized into three sector-based groups—covering buildings and energy; transportation and land use; and waste, agriculture, and natural working lands—along with two additional groups on equity and workforce development, the working groups provided a structured forum for participants across the Knoxville metropolitan statistical area (MSA) to share their concerns and perspectives. In fall 2024, participants helped establish the Plan's vision, identified existing local activities to build upon, and defined a set of community outcomes that reflect equity considerations and regional priorities. The workforce group further contributed

insights on training opportunities, funding needs, and workforce gaps related to the clean energy transition. The fall 2024 meeting laid the groundwork for effective planning and ongoing collaboration efforts.

By spring 2025, the working groups merged into a single forum to advance the design of specific measures. This allowed participants to share insights across sectors and to refine 19 measures covering all areas of emissions reduction. The working group also contributed directly to the Plan's implementation considerations, identifying actions, partners, barriers, funding opportunities, and equity needs. The group's input informed nearly every component of the BREATHE Plan, particularly the measures and priorities detailed in Chapter 4.

Sector Specific Groups

The following sections provide a snapshot of some of the concerns and solutions discussed during the Working Group meetings.

Buildings and Energy

- Community concerns
    - A lack of sufficient qualified and vetted contractors to meet current demand.
    - A need for updated building codes.

- Key opportunities/partnerships
    - Incorporate neighborhood associations and town halls into the process.
    - SEEED's Green Construction Bootcamp is a great resource to promote workforce development opportunities in the green housing sector.

- Challenges
    - Information is not currently disseminated effectively to community members.
    - Aging housing stock across Knoxville disproportionately impacts low-income communities.

Transportation and Land Use

- Community concerns
    - Gentrification and the influx of developers in the region.

- Key opportunities/partnerships
    - Updating public transportation infrastructure such as bus stops to promote ridership.

- To encourage EVs, there will need to be accessible charging infrastructure developed to establish community trust.

- Challenges
  - EVs are currently cost prohibitive to many residents and small businesses.
  - Need to communicate these efforts across political lines to reach all community members.

Waste, Agriculture, and Natural and Working Lands

- Community concerns
  - Farmers and agricultural workers are concerned about land lost to development.
  - Farming has become more expensive, and it is more challenging for farmers to turn profits.

- Key opportunities/partnerships
  - Implementing an interdependent/regional food system to support farmers and communities.
  - Developing city wide composting programs.

- Challenges
  - Occupations in agriculture and natural working lands are often passed down generationally. An emphasis on other avenues to enter the workforce in these fields could help.
  - Unpredictable weather events have made long-term and short-term planning decisions difficult.

Workforce Development

- Community concerns
  - Educational and language barriers currently make it challenging to connect some workers to career development opportunities.
  - Current government contracting practices disincentivize climate friendly efforts due to low-bid requirements.

- Key opportunities/partnerships
  - East Tennessee Apprenticeship Readiness Program provides training for the clean energy workforce.

- ORNL provides internships opportunities in decarbonization and clean energy that are targeted toward underrepresented communities.

- Challenges
  - Need to re-frame what a “Green job” is to community members to broaden their perspective.
  - Need to show community members that clean tech/environmental jobs are not threats to existing jobs, rather opportunities for professional development and career advancement.

Equity and Community

- Community concerns
  - Need to build community trust through translators, increased visibility on planning efforts, and by delivering updates through trusted community members.

- Key opportunities/partnerships
  - Work with community institutions (e.g., churches, grocery stores, and community centers) to deliver information on the BREATHE Plan to foster trust and increase accessibility.
  - Ensure elected officials are aware of planning efforts.

- Challenges
  - Language barriers pose a challenge to ensuring all community members are aware of the BREATHE Plan.

Public Survey

Broader community perspectives were also gathered through a public survey administered in Fall 2024 by FINN Partners, a subcontractor to TPO. The survey provided complementary insights into community priorities, awareness, and support for climate action, reinforcing and broadening the findings from the working group process. Some high level findings from the survey include:

- Over half of respondents (54%) are familiar with "climate change" and have personally experienced extreme weather.
- 1 in 10 do not believe climate change is real. However, among households taking little to no climate action, 86% do not identify as climate change deniers.

- 54% of respondents report taking 3-6 actions to address climate change.
- Respondents strongly agree that businesses (82%) and government (79%) should do more to protect the planet.
- Climate change ranks low (11th) among community issues and only 15% report direct household impact from climate change.

Review Period

To close the engagement cycle, all past Working Group participants were invited to review and comment on the draft BREATHE Plan in fall 2025 from October 20 to 31. While this review was not a formal public comment period, the City of Knoxville and TPO considered the Working Group's feedback before final adoption. The BREATHE Plan was officially launched on November 12, 2025.

Outcomes

Overall, the engagement process succeeded in two central objectives: (1) strengthening coalition-building for climate action across the Knoxville MSA and (2) building a more complete technical understanding of local emissions reduction activities and opportunities. The Working Group process ensured that community voices and local expertise shaped the measures, priorities, and outcomes of the BREATHE Plan, leaving a strong foundation for implementation and future collaboration.

Public Outreach

The BREATHE Team attended a variety of public events to share project information and connect with community members:

- TreeFest – April 5, 2025
- University of Tennessee Sustainability Lunch and Learn – April 9, 2025
- Dogwood Arts Festival – April 25-26, 2025
- Vestival – May 10, 2025
- Oak Ridge Farmers' Market – June 28 & July 26, 2025
- City of Knoxville Neighborhood Resource Fair – August 9, 2025

Community members were invited to vote on which BREATHE Plan measures they viewed as highest priority and to pledge their own personal climate actions. In total,

262 votes were received across the BREATHE Plan measures, and 321 personal climate actions were pledged.

Meeting Information

Throughout the development of the BREATHE Plan, the Working Groups were convened eight times to offer their input. These meetings ranged from measure development and prioritization of actions to sharing ideas on metrics, partners, and challenges. The groups provide crucial insights that have informed the creation of the BREATHE Plan.

Timing	Meeting Description	Goals and Outcomes
August 2024	Kickoff Meeting	**Goal:** Introduce working group participants to the BREATHE Plan development process. **Outcome:** Defined roles for plan development assigned to working groups, TPO, the City of Knoxville, FINN Partners, Three[3], and ICF.
October 2024	Sector Working Groups Round 1 Meeting	**Goal:** Discuss climate risks and impacts and evaluate initial community and workforce considerations. **Outcome:** Identification of regional climate risks, a brainstorm of future climate actions, an acknowledgement of barriers, and challenges to implementation.
November 2024	Sector Working Groups Round 2 Meeting	**Goal:** Utilize mural boards to evaluate the opportunities, available programs, and barriers to new and pre-existing measures from the PCAP within sector groups. **Outcome:** An evaluation of sector specific considerations and barriers for each measure.
December 2024	Equity and Workforce Development Working Groups Round 1 Meeting	**Goal:** To determine workforce, equity, and community needs and identify potential support partners. **Outcome:** A deeper understanding of community, equity, and workforce needs, pre-existing initiatives, and challenges.
March 2025	2nd Kickoff Meeting	**Goal:** Re-introduce the working groups to the BREATHE Plan development process. **Outcome:** Increased awareness of working group roles, progress, and upcoming engagement opportunities.

April 2025	Sector Working Groups Round 3 Meeting	**Goal:** To gain insight into ways equity can be incorporated into the Plan and to determine measure milestones, metrics, authority and equity concerns through a measure fair. **Outcome:** Further development of measure milestones, metrics, authority, and equity concerns expressed during the measure fair.
June 2025	Sector Working Groups Round 4 Meeting	**Goal:** Provide updates to the working groups on workforce analysis development, survey results, and examples of successful climate action. Develop the outcomes matrix using stakeholder feedback. **Outcome:** Received stakeholder feedback on the outcomes matrix and provided participants with updated information on the BREATHE Plan's progress.
October 2025	Final Review	**Goal:** Gain final insights and edits before publishing the BREATHE Plan. **Outcome:** Received feedback on final adjustments and prepared the document for submission to EPA.

List of Working Group Organizations

The following list features every organization and department that was present during Working Group meetings:

- AIA East Tennessee
- Algaeo
- Alliance for Community Transformation
- Ameresco
- Appalachian Renewable Resources
- Appalachian Voices / Energy Democracy TN
- BarberMcMurry Architects
- Bike Walk Knoxville
- Bridge Refugee Services
- Centro Hispano de East Tennessee
- City of Alcoa
- City of Knoxville
- City of Maryville
- City of Oak Ridge
- Clayton Homes
- East Tennessee Clean Fuels Coalition / Drive Electric TN
- East Tennessee Development District
- East Tennessee REALTORS®
- Energy Home Basic
- Great Smoky Mountains Institute at Tremont
- Housing Systems Advisory Council
- Keep Knoxville Beautiful
- Knox Climate Watch
- Knox County Air Pollution Control Board

- Knox County Schools
- Knoxville Chamber of Commerce
- Knoxville Electric Vehicle Association (KEVA)
- Knoxville Utilities Board (KUB)
- Knoxville-Knox County Community Action Committee (CAC)
- Knoxville-Knox County Food Policy Council
- Labor at the Table
- Maryville College
- McCarty Holsaple McCarty Architects, Inc.
- Metropolitan Knoxville Airport Authority – Board of Commissioners
- Microbial Insights
- Museum of Infinite Outcomes
- Oak Ridge National Laboratory (ORNL) Rooted East
- Sanders Pace Architecture
- Sierra Club – Harvey Broome Group
- Socially Equal Energy Efficient Development (SEEED)
- Solar Alliance
- SOULar Equity Project
- Southern Alliance for Clean Energy (SACE)
- Tennessee Advanced Energy Business Council
- Tennessee Composting Council
- Tennessee Interfaith Power and Light (TIPL)
- Tennessee Solar Energy Industries Association (TenneSEIA)
- The Bredesen Center
- Trees Knoxville
- Union of Concerned Scientists
- United Way of Anderson County
- United Way of Greater Knoxville
- University of Tennessee
- Women With Vision

List of Community Members not Representing Organizations

- Chris Wetherall
- Karen Gertz
- Ken Wilson
- Madelyn Collins
- Roberta Boone

Appendix B: MSA Greenhouse Gas Emissions Inventory

Introduction

The purpose of this document is to outline the methodology ICF used to develop the 2022 comprehensive greenhouse gas (GHG) emissions inventory for the Knoxville MSA, defined as the following nine counties: Anderson, Blount, Campbell, Grainger, Knox, Loudon, Morgan, Roane, and Union. ICF has ensured that the methodology is compliant with the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) BASIC level requirements.

Inventory Methodology

The methodology that ICF used to develop the MSA's inventory is described in the sections below by sub-sector.

Sector	Key Data Source	Downscaling methodology
Stationary Energy		
Buildings	- EPA State Inventory Tool (SIT) (EPA, 2025e) - EIA State Energy Data System (SEDS) (EIA, 2024) - EPA eGRID (EPA, 2025a) - U.S. Census Bureau (U.S. Census Bureau, 2025) - U.S. Bureau of Labor Statistics (Bureau of Labor Statistics, 2025) - EPA Greenhouse Gas Reporting Program (GHGRP) Facility-Level Information on Greenhouse Gas Tool (FLIGHT) (EPA, 2024a) - Fugitive data from EIA Form 176 (EIA, 2025)	Based on population and employment data
Power Generation and/or Consumption	- EPA eGRID (EPA, 2025a) - EPA GHG Emission Factor Hub (EPA, 2025c)	Data at local level
Industrial Process and Product Use (IPPU)		
Industrial Processes	- EPA SIT Industrial Process Module (EPA, 2025e) - EPA GHGRP FLIGHT (EPA, 2024a) - Employment data (Bureau of Labor Statistics, 2024)	Direct emissions from facilities are used where available from GHGRP; remaining categories are downscaled from SIT based on employment data
Product Use	- EPA SIT Industrial Process Module (EPA, 2025e)	Based on population
Transportation		
On-road Transportation	- EPA Motor Vehicle Emissions Simulator (MOVES5) (EPA, 2025d) - eGRID (EPA, 2025a)	Data at local level

Sector	Key Data Source	Downscaling methodology
Railways	- U.S. DOT Freight Analysis Framework (Bureau of Transportation Statistics, 2025) - Bureau of Transportation Statistics (BTS) National Transportation Atlas Database (NTAB) (Bureau of Transportation Statistics, 2022) - CSX and Norfolk Southern corporate reports (CSX, 2022; Norfolk Southern, 2022) - Association of American Railroads Freight Rail and Climate Change (Association of American Railroads, 2023) - EPA GHG Emission Factor Hub (EPA, 2025c)	Based on local rail route information
Waterborne	- California Air Resources Board (CARB) Commercial Harbor Craft (California Air Resource Board, 2021) - Waterborne Commerce Statistics Center (U.S Army Corps of Engineers, 2024) - McDonough Marine Services vessel characteristics (McDonough Marine Services, n.d.) - EPA MOVES5 (EPA, 2025d)	Data at local level
Aviation	- Federal Aviation Administration's Operations Network (FAA OPSNET) (FAA, 2025) - EPA MOVES5 (EPA, 2025d)	Data at local level for TYS
Off-road Transportation	- EPA MOVES5 (EPA, 2025d) - EPA GHG Emission Factor Hub (EPA, 2025c)	Data at local level
Waste		
Solid Waste	- GHGRP FLIGHT (EPA, 2024a) - Municipal solid waste disposal data - Tennessee waste composition data (Tennessee Department of Environment and Conservation, 2008)	Data at local level
Wastewater	- EPA Enforcement and Compliance History Online (EPA, 2025b)	Data at local level
Agriculture		
N_2O from Soils	- EPA SIT Agriculture Module (EPA, 2025e) - IPCC emission factors (IPCC, 2006)	Based on share of state cropland
Livestock	- USDA Quick Stats (National Agricultural Statistics Service) data (USDA, 2022) - U.S. Inventory of GHG Emissions and Sinks (EPA, 2024b) - USDA NASS data (USDA, 2017)	Data at local level
Liming	- EPA State Level Disaggregates inventory data (EPA, 2024d) - IPCC emission factors (IPCC, 2006)	Based on share of state cropland
Urea	- EPA SIT Agriculture Module (EPA, 2025e) - USDA Quick Stats (National Agricultural Statistics Service) data (USDA, 2022) - IPCC emission factors (IPCC, 2006)	Based on share of state cropland

Sector	Key Data Source	Downscaling methodology
Field Burning of Agricultural Residues	- EPA SIT Agriculture Module (EPA, 2025e) - USDA Quick Stats (National Agricultural Statistics Service) data (USDA, 2022)	Data at local level
Natural and Working Lands		
Forest Carbon Flux	- EPA SIT Land Use Module (EPA, 2025e)	Based on National Land Cover Dataset (USGS, 2021) share of land cover types
Urban Trees	- Urban Tree Canopy Assessment (Trees Knoxville, 2021) - U.S Inventory of GHG Emissions and Sinks (EPA, 2024b) - Urban and Rural (U.S. Census Bureau)	Based on urban area by county
Landfilled Yard Trimmings and Food Scraps	- EPA SIT Land Use Module (EPA, 2025e)	Based on population
Forest Fires	- EPA SIT Land Use Module (EPA, 2025e) - Measuring Trends in Burn Severity dataset (Measuring Trends in Burn Severity, 2024)	Based on urban tree canopy area (Trees Knoxville, 2021)
Soils	- EPA SIT Land Use Module (EPA, 2025e)	Based on National Land Cover Dataset (USGS, 2021) share of land cover types

Stationary Energy (Buildings)

Residential Buildings

Methodology

Stationary energy emissions from residential buildings were calculated using Tennessee's electricity, natural gas, and other fuel consumption data as derived from EPA's State Inventory Tool (SIT) Stationary Combustion and CO_2 from Combustion of Fossil Fuel modules (EPA, 2025e). The state-level data were then scaled to the counties within the MSA based on a population scaling factor (U.S. Census Bureau, 2025).

Residential electricity emissions were calculated using U.S. Energy Information Administration's (EIA) State Energy Data System (SEDS) residential sector energy consumption estimates for total electricity use for the state of Tennessee (EIA, 2024). The consumption data were multiplied by the 2022 grid emission factor for the SRTV eGRID region (EPA, 2025a). The state electricity emissions data were then scaled to each county using population.

Commercial and Institutional Buildings and Facilities

Methodology

Emissions for commercial buildings were calculated using electricity, natural gas, and other fuel consumption data acquired from EPA's SIT Stationary Combustion and CO_2 from Combustion of Fossil Fuel

modules (EPA, 2025e). The state-level data were then scaled to the counties within the MSA based on an employment scaling factor (Bureau of Labor Statistics, 2025).

Commercial electricity emissions were calculated by scaling SEDS commercial electricity consumption data for the state of Tennessee using the employment scaling factor. The consumption data were then multiplied by the electric grid emissions factor for the SRTV eGRID region for 2022 (EPA, 2025a).

Manufacturing Industries and Construction

Methodology

Emissions for stationary industrial buildings were calculated using two data sources: SIT (EPA, 2025e) and facility-specific data obtained from EPA's Greenhouse Gas Reporting Program (GHGRP) (EPA, 2024a). SIT data downscales national data to the state level whereas GHGRP requires annual reporting of greenhouse gas emissions from large industrial greenhouse gas emitters.

The emissions data from SIT were scaled down to the county level using employment data population and then compared with GHGRP emission data for each county. If GHGRP emissions were larger than SIT emissions for a county, the GHGRP value was used. If scaled SIT emissions were larger, the difference between the SIT and GHGRP emissions were noted, and the SIT value was used as a conservative approach.

Electricity consumption for the state of Tennessee was calculated using industrial megawatt hours values from SEDS (EIA, 2024). To calculate emissions for the state, the consumption data were multiplied by the electric grid emissions factor for the SRTV eGRID region for 2022 (EPA, 2025a). The emissions were then downscaled from the state to county level using employment data.

Energy Industries

Methodology

Emissions from energy industries include all emissions from energy production and energy use in energy industries, such as emissions from generation of energy for grid-distributed electricity, steam, heat, and cooling. Calculation of these emissions depends on whether the GHG inventory is a consumption-based or generation-based inventory.

Consumption-based: For a consumption-based GHG inventory, the only emissions calculated for this subsector were emissions from any energy consumed directly by an energy production facility. For example, electricity consumed at an electricity generation facility. To estimate these emissions, the consumption data were multiplied by the following emission factors:

- Region-specific CO_2, CH_4, and N_2O emission factors from utilities or obtained from EPA's eGRID (EPA, 2025a).
- Fuel-specific CO_2, CH_4, and N_2O emission factors from EPA's GHG Emission Factor Hub (EPA, 2025c).

Otherwise, emissions from energy production (e.g., electricity generation) were allocated to the end-use sector where that energy is ultimately used (e.g., residential buildings, commercial buildings, transportation, etc.) as Scope 2 emissions.

Generation-based: For a generation-based GHG inventory, Scope 1 emissions from individual energy production facilities within the MSA were calculated based on the type of fuel consumed, amount of fuel consumed, and/or amount of energy generated. These emissions were not allocated to their end-use sectors due to lack of available data. As a result, Scope 2 emissions within the MSA were not calculated for any sector to avoid double-counting. To estimate these emissions, these data were acquired from EPA's eGRID 2022 dataset, which contains 2022 CO_2, CH_4, and N_2O emissions data for all power plants in the MSA. Emissions for each gas were multiplied by the IPCC AR5 GWP and summed as carbon dioxide equivalent emissions.

It was assumed that eGRID's adjusted CO_2 emissions represent fossil emissions, and that the difference between eGRID's unadjusted and adjusted CO_2 emissions represents biogenic CO_2 emissions. eGRID's unadjusted CH_4 and N_2O emissions were used in the inventory to ensure non-CO_2 emissions from biogenic sources were accounted for. Note, generation-based emissions were only used for informational purposes.

Fugitive Emissions from Oil and Natural Gas Systems

Methodology

Fugitive methane emissions from oil and natural gas systems were calculated using utility leakage data (EIA, 2025). The utility-level methane leakage quantity was scaled to the county level using the percent of population in each county served by each utility.

Transportation

On-Road

Methodology

Emissions from on-road transportation were calculated using a bottom-up approach using EPA's Motor Vehicle Emissions Simulator (MOVES5) (EPA, 2025d). MOVES5 accounts for on-road vehicles through categorization of fuel type, vehicle class, and model year. For each category of vehicle, MOVES provides a quantification of the population of vehicles, vehicle miles traveled, and emissions allocated by county. To calculate emissions from electric vehicles, the energy consumption for each vehicle class from MOVES was multiplied by emission factors from the SRTV eGRID region (EPA, 2025a).

To separate biogenic CO_2 emissions from fossil CO_2 emissions, it was assumed that gasoline contains 10% ethanol by volume and that E-85 contains 85% ethanol by volume. The volume of fuel consumed by on-road vehicles was found by dividing the gasoline and E-85 energy consumption by their energy densities, and each component fuel was multiplied by the applicable emission factor to obtain CO_2 emissions.

Railways

Methodology

To calculate emissions from railways, freight rail activity data from the Bureau of Transportation Statistics (BTS) Freight Analysis Framework (FAF) (Bureau of Transportation Statistics, 2025). FAF provides the number of ton-miles originating in and bound for a given destination. These data were allocated by county and by freight rail provider using GIS data from the BTS National Transportation Atlas Database (Bureau of Transportation Statistics, 2022). Railway track miles were tabulated by county and freight provider to allocate ton-miles bound for and originating in Knoxville.[1]

Fuel usage data in ton-miles per gallon were then multiplied by the activity data to acquire fuel quantities. Fuel usage for the two freight providers in Knoxville, CSX and Norfolk Southern, were provided in company sustainability reports (Norfolk Southern, 2022; CSX, 2022). For smaller freight rail operating in the area (e.g., Knoxville & Holston River Railroad, and the Heritage Railroad Corp) a default fuel usage from the association of American Railroads was used (Association of American Railroads, 2023). The fuel quantities were then multiplied by emission factors from EPA's GHG Emission Factor Hub to determine GHG emissions (EPA, 2025c).

Waterborne Navigation

Methodology

Emissions from tugs, pushing barges, excursion boats, commercial fishing boats and work boats were calculated using California Air Resources Board (CARB) harbor craft emissions

[1] Half of the total ton miles from the FAF are included in the Knoxville inventory per guidance in GPC protocols to avoid double counting with other jurisdictions.

inventory methodology (California Air Resource Board, 2021). The total amount of fuel used was calculated by multiplying ton-miles activity data (U.S Army Corps of Engineers, 2024) by a fuel usage value of 544.5 gallons per ton-mile developed by Iowa State University (Baumel, Hurburgh, & Lee, 1991). Vessel characteristics including model year and number of propulsion and auxiliary engines were acquired from McDonough Marine Services website (McDonough Marine Services, n.d.). Other activity data including hours and vessel characteristics were acquired from the CARB harbor craft model and used Sacramento as proxy port for Knoxville to calculate emissions (California Air Resource Board, 2021).

Emissions associated with pleasure craft were calculated using EPA's MOVES5 tool's NONROAD module (EPA, 2025d). This tool provides an estimate for population, source hours, sector, fuel type, and emissions for nonroad equipment. Emissions associated with pleasure craft were attributed to the waterborne navigation category in this inventory.

Aviation

Methodology

To calculate aviation emissions, activity data were acquired from the Federal Aviation Administration (FAA) through The Operations Network (OPSNET) (FAA, 2025). OPSNET provides the number of landings and takeoffs (LTO) from local and itinerant flights from McGhee Tyson Airport (IATA code TYS). OPSNET does not provide data for small private airports, and thus LTO data for Knoxville MSA are only available for TYS. Emissions from aircraft were calculated using IPCC GHG inventory guidelines for aircraft (IPCC, 1996).

Emissions from aircraft support equipment were also attributed to the aviation sector. Emissions associated with aircraft support equipment were derived using EPA's MOVES tool's NONROAD module (EPA, 2025d). This tool provides an estimate for population, source hours, sector, fuel type, and emissions for nonroad equipment.

Off-Road

Methodology

Emissions from off-road vehicles were calculated using EPA MOVES's NONROAD module (EPA, 2025d). This module accounts for vehicles based on the fuel type, horsepower, and sector[2] and provides information on equipment population, hours running, and load factor. These values were used to calculate a horsepower hour value which was then converted to fuel quantity. From fuel quantity, emission factors from EPA's GHG Factor Hub were used to calculate GHG emissions based on the specific combination of fuel type and vehicle type (EPA, 2025c).

[2] Some sectors are determined to be in close relation to another sector of the transportation inventory and accounted for with that sector and not in the off-road total. This includes airport support equipment and pleasure craft.

Waste

Disposal of Solid Waste Generated in the MSA

Methodology

Emissions from waste generated in the MSA were calculated using the methane commitment method from the Global Protocol for Community-Scale GHG Inventories (World Resources Institute, 2021). This method calculates downstream emissions associated with solid waste sent to landfills during each inventory year. The methane commitment method takes a lifecycle approach, calculating landfill emissions based on the amount of waste disposed in a given year and assigning emissions to the year of waste generation under the assumption that the emissions will actually occur in future years as waste decays and produces methane.

The methane commitment estimate for solid waste sent to landfill was calculated based on the mass of solid waste sent to landfill during the inventory year, the methane generation potential of waste based on the waste composition, the fraction of methane recovered at the landfill, and the oxidation factor for the landfill. Activity data on the amount of waste generated and disposed of in landfills in 2022 was obtained from TDEC in a file titled, "All Municipal Solid Waste Disposal Generated within the Region (Completed by TDEC)". The methane generation potential of waste was calculated using default multiplication factors from GPC (World Resources Institute, 2021) and a Tennessee waste composition study (Tennessee Department of Environment and Conservation, 2008). The fraction of methane recovered and the oxidation factors were acquired from GHGRP FLIGHT for eight landfills in the MSA (EPA, 2024a). For landfills without GHGRP FLIGHT data, the average fraction of methane recovered from the eight landfills and the default oxidation factor from GPC were used (World Resources Institute, 2021). The methane commitment equation from GPC (World Resources Institute, 2021) to was used to calculate emissions from each landfill within the MSA and these values were summed to obtain the emissions for the entire MSA.

Biological Treatment of Waste Generated in the MSA

Methodology

Emissions from the biological treatment of waste generated in the MSA were assumed to be zero.

Incineration and Open Burning of Waste Generated in the MSA

Methodology

Knoxville does not have any incineration sites according to GHGRP FLIGHT data. Therefore, emissions from the incineration and open burning of waste generated in the MSA are assumed to be zero.

Wastewater Generated in the MSA

Methodology

Wastewater emissions were calculated using the GPC equations for methane and nitrous oxide from wastewater treatment plants (WWTPs) (World Resources Institute, 2021). The quantity of wastewater flowing through each WWTP and the biological oxygen demand (BOD) from each WWTP was obtained from the U.S. EPA's Enforcement and Compliance History Online database (EPA, 2025b). One WWTP in the MSA did not have BOD data in ICIS; the BOD for this facility was estimated using a flow-weighted average BOD using the data from all other WWTPs in the MSA. The flow-weighted average was used because there was not a linear relationship between flow and BOD data so the BOD could not be estimated based on flow. Data on organic component removed as sludge, nitrogen removed with sludge, and methane recovery were not available and therefore assumed to be zero. One WWTP provided a value for the organic component removed as sludge for 2022, so this value was included. Total population served by the WWTPs was estimated using the county population and the WWTP's average flow rate.

Industrial Processes & Use

Industrial Processes

Methodology

Industrial process emissions were calculated using a combination of emissions data from EPA's SIT and EPA's GHGRP FLIGHT. GHGRP FLIGHT has emissions data directly from facilities while SIT estimates emissions for the entire state from national data. GHGRP only requires large facilities to report, whereas SIT would estimate emissions for the entire industrial processes sector, including from non-reporter facilities that are not required to submit data under GHGRP.

First, the IP Module from SIT was used to calculate emissions from the entire state for limestone and dolomite usage, soda ash, iron and steel production, and urea consumption. These state-level emissions were downscaled to each county using employment data from BLS (Bureau of Labor Statistics, 2024). Secondly, Tennessee's GHGRP FLIGHT data were compiled for the following sectors: chemicals, other, minerals, metals, and pulp and paper. Reporting facilities within the Knoxville MSA were identified in the GHGRP dataset. For those facilities, the reported GHGRP subpart was used to assign emissions to the appropriate Industrial Process subsector. Emissions from facilities that only reported to Subpart C, General Stationary Fuel Combustion, were excluded as this is not relevant to the Industrial Processes sector.

The FLIGHT data from reporting facilities were then combined with the SIT data to account for non-reporters for sectors that have data in both datasets. If the FLIGHT emissions value was greater than SIT's emissions value, the SIT data were not used. If scaled SIT emissions were larger, the difference between the SIT and GHGRP emissions were noted and the SIT value was used. Cement manufacturing and lime manufacturing are "all-in" sectors in GHGRP,

meaning that there is no minimum threshold for reporting and all facilities must report emissions. Therefore, GHGRP data from these sectors were not combined with SIT data.

Product Use

Methodology

Product use emissions were calculated using EPA's SIT IP module (EPA, 2025e). The IP Module from SIT was used to calculate emissions from the entire state for ODS substitutes and electric power transmission and distribution systems. These state-level emissions were then downscaled to each county using population data (U.S. Census Bureau, 2025).

Natural and Working Lands

Forest Carbon Flux

Methodology

The EPA SIT Land Use, Land Change and Forestry module was used to estimate carbon sequestration in forested lands in Tennessee using the default SIT inputs for forest carbon flux (EPA, 2025e). The output data from SIT were downscaled to the county level by multiplying by the ratio of forested area in the county and state (USGS, 2021).

Urban Trees

Methodology

Carbon sequestration from urban tree canopies was estimated using tree cover percentages and urban area estimates. The tree canopy percentage for Knox County was sourced from the Knoxville tree canopy study, and this percentage was assumed for the entire MSA (Trees Knoxville, 2021). Urban area in square kilometers for 2010 and 2020 were acquired from the Census Bureau (U.S. Census Bureau). Note that the Census changed their definition of an "urban area" from 2010 to 2020, from a minimum threshold of 2,500 people to a minimum threshold of 2,000 housing units or 5,000 people. The data were projected between 2010 and 2020, and the 2022 urban area was estimated in square kilometers for each county using a linear projection. The urban area was then multiplied by the percentage of total tree cover for each county. Emissions were calculated by multiplying the urban tree canopy area by the average net carbon emissions per area of tree cover from the U.S. Inventory (EPA, 2024b).

Landfilled Yard Trimmings and Food Scraps

Methodology

SIT was used to calculate sequestration from the landfilled yard trimmings and food scraps subsector (EPA, 2025e). SIT default values were used for the composition of yard trimmings, annual quantity of landfilled yard trimmings and food scraps, carbon content, dry weight to wet weight ratio, proportion of carbon from each material stored indefinitely in landfills, and the half-life of degradable carbon in each material. The output from SIT was downscaled to the county level using population (U.S. Census Bureau, 2025).

Forest Fires

Methodology

SIT was used to estimate emissions from forest fires, which produce CO_2, N_2O, and CH_4 emissions. SIT's default emission factors and combustion efficiencies were used. The non-CO_2

emissions from Forest Fires worksheet uses the area burned per year (Measuring Trends in Burn Severity, 2024). The forest fire emissions were downscaled using the urban tree canopy area (Trees Knoxville, 2021).

A future improvement of this methodology would involve using the U.S. Forest Service's LANDFIRE dataset to obtain an improved estimate of area burned and use this value instead of downscaled national default data in SIT.

Soils

Methodology

SIT's LULUCF module was used to estimate N_2O emissions resulting from fertilizer application to settlement soils (EPA, 2025e). To calculate N_2O emissions from settlement soils, the amount of synthetic fertilizer applied was multiplied by the emission factor for direct N_2O emissions. The module also estimates agricultural soil carbon flux and includes carbon flux from aboveground biomass, belowground biomass, deadwood, and litter in cropland and grassland ecosystems. The net change in agricultural soil carbon is the change in the amount of carbon stored primarily in mineral and organic soils over time. The SIT output was downscaled to the county level using the National Land Cover Dataset (USGS, 2021). To calculate the N_2O emissions from settlement soils and agricultural soil carbon flux, the ratio of county to state developed areas were multiplied by the Tennessee data derived from SIT. To calculate the N_2O emissions from agricultural soil carbon flux, the ratio of county to state cropland areas were multiplied by the Tennessee data derived from SIT.

Agriculture

N_2O from Soils

Methodology

Data from SIT was used to estimate nitrous oxide emissions from fertilizer use (EPA, 2025e). Nitrous oxide emissions from soils were separated into direct and indirect emissions from synthetic fertilizer and organic fertilizer (i.e., manure, activated sewage sludge, and other organic materials).

Data from SIT was scaled using the method described in EPA's Guidance for County and Regional Inventories for Agriculture and Land Management with slight variations (EPA, 2023). SIT data were pulled for the state of Tennessee for all historic years. SIT had proxied fertilizer use from 2016 for years 2017-2024; instead, this inventory used linear interpolation to generate fertilizer use estimates from 2017-2022. Then, EPA guidance was followed to convert fertilizer years to annual years.

Estimates of calendar year fertilizer consumption were generated based on EPA assumptions of percent application of various fertilizer (EPA, 2023) for synthetic nitrogen, manure, activated sewage sludge, and other organic materials for Tennessee. Because the value reported represents commercial fertilizer use, this inventory deviated from the EPA method and assumed that this value represented the total use of synthetic fertilizer. Values for all other fertilizer types were derived

based on this assumption and then scaled these totals to the county level using the percent of state cropland.

Direct emissions were calculated by multiplying the consumption of fertilizer by the IPCC direct emission factor for kg N_2O/kg N (IPCC, 2006). Indirect emissions were calculated by multiplying the consumption of fertilizer by the percent of total nitrogen volatilized from organic matter, the total nitrogen leached from organic matter and IPCC emission factors for volatilization of nitrous oxide and leaching of nitrous oxide (IPCC, 2006).

Livestock

Methodology

Emissions from livestock come from two processes: enteric fermentation, which produces CH_4, and manure management, which produces both CH_4 and N_2O. The amount of CH_4 emitted by enteric fermentation depends on the number of livestock, type of livestock (i.e., type of digestive system), and amount of feed consumed. CH_4 from enteric fermentation is calculated using equation 10.1 from GPC (World Resources Institute, 2021).

Manure releases CH_4 as it decomposes under anaerobic conditions and emits N_2O through nitrification and denitrification. CH_4 emissions depend on the number of head and livestock type. CH_4 from manure management was calculated equation 10.2 from GPC (World Resources Institute, 2021). The amount of N_2O released by manure management practices depends on the total amount of nitrogen excretion for the management system. This requires calculating the average nitrogen excretion rate per head for each livestock category as well as the fraction of annual excretion that is managed within the system, which was calculated using equation 10.4 from GPC (World Resources Institute, 2021). N_2O from manure management was calculated using equation 10.3 from GPC (World Resources Institute, 2021).

Livestock data for alpaca, cattle including calves, chickens (broilers, layers, pullets, roosters), horses and ponies, mules (including burros and donkeys), goats, hogs, llamas, sheep (including lambs, hair sheep, and wool sheep), and turkeys was acquired from the USDA Quick Stats data portal (USDA, 2022). Due to emission factors limitations, turkeys, llamas, and alpacas were eliminated from the dataset. Chicken data were aggregated into two categories: broilers and roosters; and layers and pullets. Dairy and beef cattle were separated by multiplying cattle population totals by the average percent proportion of dairy to beef cattle in the state of Tennessee (EPA, 2024b). The chicken population was also modified according to IPCC guidance (IPCC, 2006).

Because detailed data on subspecies populations, excretion rates, average weights, etc., were not available at the state or county level, implied emission factors were used for enteric fermentation and manure management per head. EPA's State Level Disaggregates of the U.S. Greenhouse Gas Inventory were used for emission totals (EPA, 2024c), dividing by the population of each animal to find overall emission factors per emission source. All emissions estimates were Tennessee-specific. The livestock

populations by county (USDA, 2017) were multiplied by these emission factors to find total emissions for each type of livestock.

Liming

Methodology

Liming emissions were calculated using the EPA's State Level Disaggregates inventory data for 2021 as a proxy for 2022 (EPA, 2024d). Total emissions from limestone and dolomite consumption in Tennessee were divided by the IPCC emissions factor to find tons of limestone and dolomite consumed in the state (IPCC, 2006). These data were then scaled to the county level using percent of state cropland. This county-level tonnage data were then multiplied by the IPCC emissions factor to find emission totals by county.

Urea

Methodology

Urea emissions were calculated using the state total of urea consumption from SIT (EPA, 2025e). Tennessee's annual consumption of urea in 2022 was scaled to the county level using percent of state cropland per county (USDA, 2022). The estimated state consumption was then multiplied by the IPCC emission factor for urea fertilization to find total emissions by county (IPCC, 2006).

Field Burning of Agricultural Residues

Methodology

The number of acres planted with crops with high rates of field burning of agricultural residues: corn, soybeans, cotton, lentils, rice, sugarcane, and wheat were acquired from USDA (USDA, 2022). This acreage data were multiplied by the residue to crop ratio, fraction residue burned, dry matter fraction, burning efficiency, combustion efficiency, and carbon content for each crop using assumptions from SIT (EPA, 2025e).

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Appendix C: CCAP Measure Methodology Introduction

Introduction

The purpose of this document is to outline the methodology used to model the greenhouse gas (GHG) emissions reductions from the Comprehensive Climate Action Plan (CCAP) measures for the Knoxville MSA, defined as the following nine counties: Anderson, Blount, Campbell, Grainger, Knox, Loudon, Morgan, Roane, and Union.

Measure List

The methodology used to develop the MSA's inventory is described in the sections below by sub-sector.

Sector	Measure
Buildings	B1. Increase energy efficiency and weatherization of buildings
	B2. Upgrade energy efficiency in and decarbonize public buildings
	B3. Electrify residential, commercial and industrial buildings
Energy	E4. Accelerate the deployment of clean and distributed energy
Transportation	T5. Accelerate the adoption of electric vehicles across the region
	T6. Transition to electric and alternative fuel vehicles in public fleets
	T7. Expand publicly accessible and private electric vehicles and alternative fueling infrastructure
	T8. Optimize and improve efficiency of freight routes
	T9. Improve transportation systems through sustainable construction practices
	T10. Improve transportation system efficiency to reduce traffic volume, congestion, and idling
	T11. Improve public transit infrastructure
	T12. Boost active transportation systems
Waste	W13. Reduce or divert waste going to landfills and wastewater going to water treatment plants
	W14. Implement organic waste management programs
Natural & Working Lands	NWL 15. Enhance tree canopy particularly in urban heat islands
	NWL 16. Evaluate policies and opportunities to reduce sprawl
	NWL 17. Conserve and expand natural lands and community green spaces
Agriculture	A18. Increase urban and micro farming
	A19. Improve agricultural practices

Measure Methodology

Buildings

B1: Increase energy efficiency and weatherization of buildings

Methodology[3]

GHG emission reductions associated with energy efficiency and electrification retrofits in new and existing residential and commercial buildings were estimated using ICF's proprietary Distributed Energy Resources Planner (DER Planner) tool. DER Planner is built on ICF's CO_2Sight platform and incorporates modeling best practices established in the National Action Plan for Energy Efficiency (NAPEE). The tool quantifies changes in energy consumption and associated emissions by simulating a range of retrofit measures for new and existing buildings, including building envelope improvements (e.g., insulation, air sealing, windows), the conversion of space and water heating equipment to high-efficiency alternatives, building controls, efficient appliances and lighting.

The analysis applies these measures across a variety of building types—including single-family homes, multifamily buildings, office buildings, schools, and food service establishments—and relevant end uses. For this measure, rates of technology adoption were modeled based on NREL's Electrification Futures Study high-adoption scenario. Building stock characteristics and energy consumption data were derived from the NREL's ResStock and ComStock datasets, which integrate public and proprietary data sources, statistical sampling methods, and high-performance computing to generate county-level resolution building stock data. Emissions factors were then attributed to these savings amounts, resulting in total energy and emissions savings estimates from energy efficiency across the MSA. As a note, building stock samples from ResStock and ComStock were reweighted to align with Knoxville MSA's GHG inventory to ensure consistency with regional energy and emissions baselines.

Key Assumptions

- County-level building characteristics and energy use data for residential and commercial buildings, derived from NREL's ResStock and ComStock datasets.
- Measures include the conversion of space and water heating equipment to high-efficiency alternatives, building envelope improvements, HVAC controls, efficient appliances and lighting.
- Energy savings per measure (e.g., transitioning from a furnace to an air-source heat pump).
- Participation rate curves are used to model the rate of technology adoption for different measures based on NREL's Electrification Future Study and expert assessments. Selected curves assume a high level of energy efficiency retrofits (e.g., LED lighting, ENERGY STAR appliance upgrades), considering variables such as costs, supporting infrastructure, ownership, policy incentives, and other influencing factors.
- Systems are assumed to be either replaced in kind, upgraded to more efficient models, or converted to electric alternatives as they reach the end of their useful life.

[3] Modeling methods, assumptions, data sources, and tools for this measure are the same as those in measure B2.

Key Data Sources

- NREL's ResStock and ComStock datasets
- NREL's Electrification Futures Study
- EIA 2023 Technology Forecast Updates
- NREL National Residential Efficiency Measures Database

Tools Used

- ICF's proprietary DER-Planner tool

Summary Table

Output	Approach
Emissions data/pollutants	Annual emissions reductions by sector (residential, commercial), fuel/energy source, building-type, and end-use (e.g., appliances for heating/cooling, water heating, cooking)
Energy data	Annual energy reductions by sector (residential, commercial), fuel/energy source, building-type, and end-use (e.g., appliances for heating/cooling, water heating, cooking)
Other activity data	Annual stock of building components/appliances (e.g., heat pumps, gas furnaces, boilers) for each end-use (heating/cooling, water heating, building envelopes, cooking)
Granularity (geographic, temporal, etc.)	Annual MSA level

B2: Upgrade energy efficiency in and decarbonize public buildings

Methodology

To model the decarbonization of new and existing municipal buildings, fuel and electric energy usage from Knox County public buildings was first totaled by building type, which was then matched to ComStock building groups and scaled as a proxy for the full Knoxville MSA.

This data was then used as an input for ICF's DER Planner tool, and followed the same procedure as outlined in measure B1: Increase energy efficiency and weatherization of buildings . Public buildings were assigned a more aggressive upgrade/retrofit schedule, reflecting the greater control that municipalities have over public building energy usage and upgrades compared to residential and commercial buildings.

Key Assumptions

- Municipal facility-level energy usage details provided for Knox County
- Growth rates for municipal buildings incorporate historical trends and expected growth across the commercial building sector
- Energy savings per measure applied to each commercial building type (e.g., transitioning from a gas furnace to an air-source heat pump in a small office building)
- Participation rate curves are used to model the rate of technology adoption for different measures based on NREL's Electrification Future Study high-adoption scenario and expert assessments
- Systems are assumed to be either replaced in kind, upgraded to more efficient models, or converted to electric alternatives as they reach the end of their useful life

Key Data Sources

- NREL's ResStock and ComStock datasets
- NREL's Electrification Futures Study
- EIA 2023 Technology Forecast Updates
- NREL National Residential Efficiency Measures Database
- City of Knoxville Facilities Inventory

Tools Used

- ICF's proprietary DER-Planner tool

Summary Table

Output	Approach
Emissions data/pollutants	Annual emissions baseline and reduction potential in municipal buildings
Energy data	Annual energy reductions by fuel/energy source, building-type, and end-use (e.g., appliances for heating/cooling, water heating, cooking)
Other activity data	Annual stock of building components/appliances (e.g., heat pumps, gas furnaces, boilers) for each end-use (heating/cooling, water heating, building envelopes, cooking)
Granularity (geographic, temporal, etc.)	Annual MSA level

B3: Electrify residential, commercial, and industrial buildings

Methodology[4]

This measure was modeled using the same approach as measure B1: Increase energy efficiency and weatherization of buildings but applied to a different set of retrofit measures. ICF's DER Planner model was used to simulate changes in energy consumption and GHG emissions resulting from the adoption of electrification measures across both new and existing residential and commercial buildings. Modeled measures included the electrification of space heating, water heating, cooking, and appliance end uses.

Key Assumptions

- County-level building characteristics and energy use data for residential and commercial buildings, derived from NREL's ResStock and ComStock datasets.
- Measures include end-of-life electrification for space heating, water heating, cooking, and drying end-uses.
- Energy savings per measure (e.g., transitioning from a gas furnace to an air-source heat pump).
- Participation rate curves are used to model the rate of technology adoption for different measures based on NREL's Electrification Future Study high-adoption scenario and expert assessments. Adoption curves incorporate variables such as costs, supporting infrastructure, ownership, policy incentives, and other influencing factors.
- Systems are assumed to be either replaced in kind, upgraded to more efficient models, or converted to electric alternatives as they reach the end of their useful life.

[4] Modeling methods, assumptions, data sources, and tools for this measure are the same as those in measure B2.

Key Data Sources

- NREL's ResStock and ComStock datasets
- NREL's Electrification Futures Study
- EIA 2023 Technology Forecast Updates
- NREL National Residential Efficiency Measures Database

Tools Used

- ICF's proprietary DER-Planner tool

Summary Table

Output	Approach
Emissions data/pollutants	Annual emissions reductions by sector (residential, commercial), fuel/energy source, building-type, and end-use (e.g., appliances for heating/cooling, water heating, cooking)
Energy data	Annual energy reductions by sector (residential, commercial), fuel/energy source, building-type, and end-use (e.g., appliances for heating/cooling, water heating, cooking)
Other activity data	Annual stock of building components/appliances (e.g., heat pumps, gas furnaces, boilers) for each end-use (heating/cooling, water heating, building envelopes, cooking)
Granularity (geographic, temporal, etc.)	Annual MSA level

B1 and B3[5]: Industrial Buildings

Two of the Knoxville MSA buildings measures (B1, B3) are expected to reduce GHG emissions in the industrial sector. These reductions are modeled separately from residential and commercial buildings due to the different decarbonization approaches and datasets. For industrial buildings, emissions will be reduced by developing a long-term regional plan to identify industrial sites with opportunities for hydrogen production and/or use, carbon capture, electrification, or other low-carbon fuels. The assumptions and approaches for the following two measures are outlined below:

- Increase uptake of energy efficiency and weatherization of industrial buildings through: increased marketing, education and outreach around technologies, funding opportunities, and maintenance and behavior changes; provide new or expanded incentives to support implementation; and, consider and implement solutions to incentivize landlords to make upgrades with managing resident costs. (B1)
- Study, plan for and implement targeted electrification of industrial buildings. (B3)

Methodology

This modeling approach utilizes ICF's Industrial Decarbonization tool. The tool is built from the Environmental Protection Agency's (EPA) Greenhouse Gas Reporting Program (GHGRP) datasets, which provides location-based point source emissions for industrial facilities. All reference data listed below are imported for the relevant geography. Fuel type splits of facility emissions - including Residual Fuel Oil, Distillate Fuel Oil, Natural Gas, Hydrocarbon Gas

[5] B3's measure name is: Electrify residential, commercial, and industrial buildings

Liquids (HGL), Coal, and Coke - are determined on a subsector basis using values from the Energy Information Administration (EIA) Manufacturing Energy Consumption Survey (MECS) Data based on North American Industry Classification System (NAICS) code.

After standardizing unit conversions to MMBTU, gas and fuel oil splits for energy use from combustion sources are further refined and utilized to disaggregate energy shares from stationary combustion values. Once disaggregated energy shares are determined, the values are used to assume a GHG emissions share using emissions factors and the other energy disaggregation for each fuel type. These GHG emission shares are then used to calculate the emissions share of the stationary combustion value provided by the 2023 GHGRP by matching on NAICS code.

Using emission factors and unit conversions, an approximate estimation of emissions is then determined for each facility within the relevant geography. For electricity estimates, an electricity ratio was calculated from EIA MECS data and multiplied by the sum of disaggregated energy values. Process emissions are determined by summing all emissions in certain categories.3 Once these approximate estimations of emissions are determined, they are used to calculate a Business-As-Usual (BAU) scenario for industrial use by facility, assuming various trends through 2050 depending on the industry and fuel type.

To model impacts of the industrial sector, a range of sources are used to determine decarbonization of the various industries including the DOE's Industrial Decarbonization Roadmap to determine alternative scenarios for the decarbonization through energy efficiency, electrification, process emission changes, and/or carbon capture technologies. Three levels of decarbonization potential curves, Moderate, Advanced, and Near Zero, are modeled after the DOE's Industrial Decarbonization Roadmap.

Key Assumptions

- 2021 emission factors and 2022 NAICS code were used assuming these factors do not change drastically from year to year within 5 years of their publication. Therefore, these factors can be used across various years of data.
- Adoption rates for alternative technologies are based on DOE and EPA projections and case studies of pilot projects
- Future grid decarbonization will contribute to additional emissions reductions as industrial electrification increases
- Energy efficiency improvements are estimated at their upper limit and assumed they will be deployed alongside fuel switching and electrification, reducing overall energy demand
- CCS will be deployed at facilities with large point-source emissions where other interventions are not feasible, assuming a 90% capture efficiency
- Fuel switching is assumed to follow a cost-effective trajectory, prioritizing sectors where decarbonization technologies are already commercially viable

Key Data Sources

- EPA GHGRP data for industrial emissions
- Department of Energy (DOE) Industrial Decarbonization Roadmap
- U.S. Energy Information Administration (EIA) Manufacturing Energy Consumption Survey (MECS)
- Regional utility grid mix and emissions factor projections from the EPA's eGRID database
- State and local industrial energy consumption reports, where available
- Literature reviews and case studies on industrial decarbonization technologies

Tools Used

- ICF CO2Sight Industrial Decarbonization Tool

Summary Table

Output	Approach
Emissions data/pollutants	Annual CO2 emissions reductions at moderate, advanced, and near-zero emissions alternatives compared to BAU
Energy data	Baseline electricity and energy use by fuel type, electricity and energy savings by fuel type
Other activity data	N/A
Granularity (geographic, temporal, etc.)	Annual data pertaining to the Knoxville MSA

Energy

E4: Accelerate the deployment of clean and distributed energy

Methodology

The modeling for this measure was based on key NREL datasets and reports identifying rooftop solar technical potential by county, market and economic adoption potential, and estimates of rooftop square footage area for residential and commercial buildings from ResStock and ComStock.

A spreadsheet analysis was used to estimate rooftop solar adoption using these datasets using the following steps:

1. Rooftop square footage was compiled for residential and commercial buildings by county from ResStock and ComStock.
2. The technical potential for rooftop solar was identified by downscaling NREL state estimates to counties using the rooftop area ratio from county to state.
3. 2050 solar targets were identified based on NREL's *Advanced PV* adoption scenario.
4. Capacity build up through 2050 was estimated by applying the identified adoption percentage target as a share of the county-level technical potential estimates.
5. Avoided GHG emissions totals were calculated using the grid electricity emissions factor.

Key Assumptions

- Targets used NREL's Advanced PV adoption scenario

Key Data Sources and Tools

- State technical potential by building category for rooftop solar based on NREL's Rooftop Solar PV Technical Potential Report (Technical Report NREL/TP-6A20-65298; January 2016)
- Solar adoption potential based on NREL's Distributed Solar and Storage Outlook report (TP-7A40-79790. https://www.nrel.gov/docs/fy21osti/79790.pdf), part of the Electrification Futures Study series
- County share of state technical potential based on ResStock and ComStock rooftop area

Tools Used

- Excel-based tool

Summary Table

Output	Approach
Emissions data/pollutants	Annual emissions reductions by sector (residential, commercial),
Energy data	Annual energy generated by sector (residential, commercial)
Other activity data	Rooftop solar capacity, estimated number of rooftops by county and residential vs commercial building type
Granularity (geographic, temporal, etc.)	Annual data pertaining to the Knoxville MSA

Transportation

T5: Accelerate the adoption of electric vehicles across the region

Methodology

ICF's proprietary CO_2Sight Turnover Projections for On-Road Transportation (TPORT) tool was used for modeling this measure. It is a Python-based tool that models zero emissions vehicle (ZEV) adoption based on a MOVES5 baseline and a user-defined sales curve. The following sales curves were assumed for this modeling:

Vehicle Category	Sales Curve Assumption
Light-duty vehicles	100% of new light-duty vehicles sales are ZEVs by 2050
Medium- and heavy-duty vehicles	ZEV sales are 20% higher than BAU in 2050

For each model year, a fraction of VMT was designated as BEV, FCEV, or PHEV based on the sales curve. The resulting energy consumption was found by multiplying the VMT by ZEV energy efficiencies from MOVES5, DOE, and other sources. Scope 1 emissions were estimated by reducing baseline ICEV emissions by the ZEV sales fraction. Scope 2 emissions were estimated using the ZEV electricity emission factor projections.

Key Assumptions

- ZEVs exist in the vehicle fleet for the same length of time as ICEVs
- ZEV activity/use is identical to ICEV
- The annual ZEV sales fraction applies to every fuel type
- Light-duty vehicles will be 100% of new vehicle sales by 2050 (increasing linearly from baseline year)
- Medium and heavy-duty vehicles will be 20% more than the BAU by 2050 (increasing linearly from baseline year)

Key Data Sources

- EPA MOVES5 for projected VMT and vehicle populations

Tools Used

- ICF's CO2Sight TPORT tool

Summary Table

Output	Approach
Emissions data/pollutants	Annual emissions by vehicle type and fuel type
Energy data	Annual energy consumption by vehicle type and fuel type
Other activity data	Vehicle miles traveled (VMT) and vehicle population by vehicle type and fuel type
Granularity (geographic, temporal, etc.)	Annual data by county

T6: Transition to electric and alternative fuel vehicles in public fleets

Methodology

In addition to the overall fleet electrification measure (T5), the portion of fleet electrification and emissions that could be attributed to public fleets was disaggregated based on fleet data provided by the cities of Knoxville and Oak Ridge. First, Knoxville and Oak Ridge's shares of the total MSA on-road emissions in 2024 were found to be 0.16% and 0.3%, respectively. Then, the ratio of county and city (Alcoa and Maryville, who provided vehicle population data) vehicle populations compared to Knoxville's vehicle population found. These ratios were multiplied by 0.16% to find what each city or county's share of the total MSA emissions would be. Finally, these results were summed to find that 0.97% of MSA on-road emissions were attributable to municipal fleets, so 0.97% of the emissions projected for each year were attributed to municipal fleets.

Key Assumptions

- The share of on-road transportation emissions from public fleets compared to the MSA is assumed to remain constant over time.

Key Data Sources

- The Knoxville 2024 GHG inventory was used to determine what percentage of transportation emissions currently come from public fleets.

Tools Used

- N/A

Summary Table

Output	Approach
Emissions data/pollutants	Annual emissions by vehicle type and fuel type for the public/municipal fleet
Energy data	N/A
Other activity data	N/A
Granularity (geographic, temporal, etc.)	Annual data by county

T7: Expand publicly accessible and private electric vehicle and alternative fueling infrastructure

Methodology

This measure's quantification was bundled with the quantification of the passenger electric car measure (T5), because this measure does not reduce emissions on its own and instead supports and enables emission reductions due to electrifying passenger vehicles.

Key Assumptions

- N/A

Key Data Sources

- N/A

Tools Used

- N/A

Summary Table

Output	Approach
Emissions data/pollutants	Annual emissions by vehicle type and fuel type
Energy data	Annual energy consumption by vehicle type and fuel type
Other activity data	Vehicle miles traveled (VMT) and vehicle population by vehicle type and fuel type
Granularity (geographic, temporal, etc.)	Annual data by county

T8: Optimize and improve efficiency of freight routes

This measure was not quantified due to a lack of data.

T9: Improve transportation systems through sustainable construction practices

Methodology

This measure based calculations on the construction equipment population and energy consumption from the EPA MOVES5 nonroad module. The fuel consumption outlined in MOVES was converted to electric equipment based on the equipment's annual operating hours, fuel consumption per equipment, and electric equipment fuel efficiency from AFLEET. Scope 2 emissions were found using electricity consumption from electrified equipment and electricity emission factor projections. Scope 1 emissions were reduced based on reduction of conventional fuel consumption.

Key Assumptions

- Electrified equipment activity is identical to conventional equipment activity

Key Data Sources

- EPA MOVES5 for construction equipment populations
- AFLEET for electric equipment fuel efficiency

Tools Used

- MOVES5
- AFLEET

Summary Table

Output	Approach
Emissions data/pollutants	Annual emissions by fuel type
Energy data	Annual energy consumption by fuel type
Other activity data	Equipment population by fuel type
Granularity (geographic, temporal, etc.)	Annual data by county

T10: Improve transportation system efficiency to reduce traffic volume, congestion, and idling

This measure was not quantified.

T11: Improve public transit infrastructure

Methodology

This measure models the resulting GHG emission reductions from shifting transportation mode share away from passenger vehicles and toward public transit. The Trip Reduction Impacts of Mobility Management Strategies (TRIMMS) tool was used for modeling. This tool calculates VMT reduction due to these actions based on elasticities built into the tool. The TRIMMS tool outputs a percent VMT reduced resulting from the transit travel time and fare reductions input into the tool.

The percent reductions were applied to projected VMT, energy consumption, and emissions after the ZEV adoption was modeled.

Key Assumptions

- Free fixed-route public transportation
- 30% decrease in public transportation trip time

Key Data Sources and Tools

- American Community Survey for baseline mode share
- Replica for trip purpose, transit trip length, and identification of urban, suburban, and rural regions
- Current transit cost by trip for Knox County was provided by Knoxville Area Transit (KAT), for both fixed routes and demand response
- TRIMMS Tool

Summary Table

Output	Approach
Emissions data/pollutants	Total emissions reduced
Energy data	Total energy consumption reduced by fuel type
Other activity data	Total VMT reduced

Output	Approach
Granularity (geographic, temporal, etc.)	Annual VMT reductions for the full MSA

T12: Boost active transportation systems

Methodology

This measure models the resulting GHG emission reductions from shifting transportation mode share away from passenger vehicles and bicycle, pedestrian, and other active transportation modes. A new mode share distribution was calculated based on what could feasibly result from improvements in bicycle and pedestrian infrastructure together with investments in electric bikes and scooters. The difference in passenger VMT between the baseline and GHG reduction scenarios was acquired and that percent reduction in VMT was applied to emissions from passenger vehicles. The percent reductions were applied to projected VMT, energy consumption, and emissions after the ZEV adoption was modeled.

Key Assumptions

- 50% increase in active transportation mode share resulting from improved micromobility options and infrastructure

Key Data Sources and Tools

- American Community Survey for baseline mode share
- Replica for trip purpose, transit trip length, and identification of urban, suburban, and rural regions
- Current transit cost by trip for Knox County was provided by Knoxville Area Transit (KAT), for both fixed routes and demand response

Summary Table

Output	Approach
Emissions data/pollutants	Total emissions reduced
Energy data	Total energy consumption reduced by fuel type
Other activity data	Total VMT reduced
Granularity (geographic, temporal, etc.)	Annual VMT reductions for the full MSA

Waste

W13: Reduce or divert waste going to landfills and wastewater going to water treatment plants

Methodology

Modeling for this measure is based on the methane commitment method that was used to calculate the inventory for solid waste. The methane commitment method takes a lifecycle approach, calculating landfill emissions based on the amount of waste disposed in a given year and assigning emissions to the year of waste generation under the assumption that the emissions will actually occur in future years as waste decays and produces methane. The

methane commitment estimates for solid waste sent to landfill is calculated based on the mass of solid waste sent to landfill during each year, the methane generation potential of waste based on the waste composition, the fraction of methane recovered at the landfill, and the oxidation factor for the landfill.

To calculate the reduction in landfill emissions due to diversion for recycling, the following steps were applied:

1. The waste generated under the BAU scenario was determined using the waste landfilled from the existing BAU and the current landfill rate.
2. Using the waste composition study, the percentage of currently landfilled waste that could be recycled was calculated.
3. A linear increase in the diversion rate was developed, reaching 80% of landfilled recyclable materials by 2050.
4. The quantity of waste diverted from the landfill was calculated using the diversion rate.
5. Landfill emissions were then calculated using this reduced landfill quantity and compared to the BAU estimates to determine the reductions.

To estimate the reduction in landfill emissions resulting from waste reduction, a percentage reduction was applied to the total amount of waste landfilled and the emissions were calculated based on the decreased waste quantity.

Key Assumptions

- By 2050, recycle 80% of recyclable material that is currently landfilled.
- Assume a linear increase in recycling from 2025 to 2050.

Key Data Sources and Tools

- 2008 Tennessee Waste Composition Study: https://www.epa.gov/sites/default/files/2015-09/documents/2008_tn_wste_charac_stdy.pdf
- 2024 City of Knoxville Waste Profile: https://www.tn.gov/content/dam/tn/environment/solid-waste/documents/solid-waste/sw_2025-plan-final.pdf

Summary Table

Output	Approach
Emissions data/pollutants	Annual emission reductions ($MTCO_2e$)
Energy data	N/A
Other activity data	Quantity of waste landfilled, quantity of waste recycled
Granularity (geographic, temporal, etc.)	Entire MSA; 2025-2050

W14: Implement organic waste management programs

Methodology

Modeling for this measure is based on the methane commitment method that was used to calculate the inventory and BAU for solid waste. The methane commitment method takes a lifecycle approach, calculating landfill emissions based on the amount of waste disposed in a given year and assigning emissions to the year of waste generation under the assumption

that the emissions will actually occur in future years as waste decays and produces methane. The methane commitment estimates for solid waste sent to landfill is calculated based on the mass of solid waste sent to landfill during each year, the methane generation potential of waste based on the waste composition, the fraction of methane recovered at the landfill, and the oxidation factor for the landfill.

To calculate the reduction in landfill emissions due to diversion for composting, the following steps were applied:

1. The waste generated under the BAU scenario was determined using the waste landfilled from the existing BAU and the current landfill rate.
2. Using the waste composition study, the percentage of currently landfilled organic waste that could be diverted was calculated.
3. A linear increase in the diversion rate was developed, reaching 80% of landfilled organic materials by 2050.
4. The quantity of organic waste diverted from the landfill was calculated using the diversion rate.
5. Landfill emissions were then calculated using this reduced landfill quantity and compared to the BAU estimates to determine the reductions.

Additionally, the emissions from composting were calculated using composting emission factors from GPC. These emissions factors were multiplied by the amount of waste diverted to composting each year to calculate the emissions from increased composting.

Key Assumptions

- By 2050, divert 80% of organic material that is currently landfilled.
- Assume a linear increase in composting from 2025 to 2050.

Key Data Sources and Tools

- 2008 Tennessee Waste Composition Study: https://www.epa.gov/sites/default/files/2015-09/documents/2008_tn_wste_charac_stdy.pdf
- 2024 City of Knoxville Waste Profile: https://www.tn.gov/content/dam/tn/environment/solid-waste/documents/solid-waste/sw_2025-plan-final.pdf
- Global Protocol for Community-Scale Greenhouse Gas Inventories (GPC): https://ghgprotocol.org/sites/default/files/standards/GPC_Full_MASTER_RW_v7.pdf

Summary Table

Output	Approach
Emissions data/pollutants	Annual emission reductions in $MTCO_2e$
Energy data	N/A
Other activity data	Quantity of waste landfilled, quantity of waste composted
Granularity (geographic, temporal, etc.)	Entire MSA; 2025-2050

Natural and Working Lands

NWL15: Enhance tree canopy especially in urban heat islands

Methodology

The enhancement of Knoxville's tree canopy was modeled through the increased sequestration resulting from tree planting. The model simulates tree planting scenarios using a specified number of native tree species and their associated sequestration rates from i-Tree MyTree and projecting carbon sequestration in $MTCO_2e$ over time.

Key Assumptions

- Number of trees planted – 2,500 trees planted per year from 2028 to 2050
- A list of 10 native tree species to be planted in urban areas:
  - Sycamore
  - American Holly
  - Red Maple
  - Black Gum
  - Serviceberry
  - Redbud
  - White Ash
  - Carolina Buckthorn
  - River Birch
  - Tulip Poplar

Key Data Sources and Tools

- i-Tree MyTree
- Population Projections
- Knoxville Native Trees List https://www.knoxvilletn.gov/government/city_departments_offices/neighborhoods/programs/community_wildlife_habitats/native_trees_of_knoxville

Summary Table

Output	Approach
Emissions data/pollutants	Sequestration from new trees
Energy data	N/A
Other activity data	Number of new trees planted
Granularity (geographic, temporal, etc.)	County-level

NWL16: Evaluate policies and opportunities to reduce sprawl

Methodology

Land cover and land cover change analyses are available from nationally compiled sources (listed in Key Data Sources). Land cover within the MSA was analyzed for cover types that require dividing into sub-types to more accurately account for land cover types that exhibit large variations in carbon stock density (e.g. deciduous versus mixed conifer forest). The land cover types, and sub-types were then be mapped to carbon stock densities. Changes in management or cover type were calculated to determine the corresponding effects on ecosystem carbon stock. For modeling the creation of greenspaces, NLCD land cover types

Grassland/Herbaceous & Shrub/Scrub in urban areas were used to find the carbon stocks within each and serve as the greenspace baseline. Changes in management were calculated to determine the corresponding effects on ecosystem carbon stock in urban greenspaces.

Key Assumptions

- National Land Cover Data (NLCD) land cover change over time (i.e. hectares of forest converted to developed land from 1990 to 2022).
- Soil organic carbon, above ground biomass, and below ground biomass carbon pools stored within forested areas from 1990 to 2022.
- Reduction of 15% of new building permits permitted in urban edge by 2050 per county

Key Data Sources and Tools

- Soil Survey Geographic Database (SSURGO) | Natural Resources Conservation Service
- National Land Cover Database (NLCD) Land Cover (LndCov)
- National Land Cover Database (NLCD) Land Cover Change (LndChg)
- USDA Forest Service FSGeodata Clearinghouse - Forest Biomass across the Lower 48 States and Alaska
- 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
- Local and regional zoning and land use data (as available)

Summary Table

Output	Approach
Emissions data/pollutants	Avoided emissions from improved land management
Energy data	N/A
Other activity data	Improved carbon stock over time
Granularity (geographic, temporal, etc.)	MSA level

NWL17: Conserve and expand natural lands and community green spaces

Methodology

Land cover and land cover change analyses are available from nationally compiled sources (listed in Key Data Sources). Opportunities to reduce urban sprawl were identified in a two-pronged approach.

First, land cover change was evaluated for a 10-year period (2012 to 2022) to identify regions of the MSA that have been converted to residential/urban spaces. These areas were compared to residential/urban zoning categories to identify opportunities to implement urban density infill, along with the benefits of avoided land conversion along the urban/rural interface.

Secondly, zoning was overlaid with public transit routes (e.g. rail lines) and existing use to identify further opportunities to implement urban infill, along with the benefits of further avoided land conversion. Avoided emissions were estimated by approximating the avoided acreage of land that will not be converted from green space to housing units due to this measure.

Key Assumptions

- National Land Cover Data (NLCD) land cover change from 2012 to 2022

- Future urban sprawl will be located on the edges of historical sprawl
- Avoided emissions are limited to the avoided loss of ecosystem carbon due to land use conversion

Key Data Sources

- Soil Survey Geographic Database (SSURGO) | Natural Resources Conservation Service
- National Land Cover Database (NLCD) Land Cover (LndCov)
- National Land Cover Database (NLCD) Land Cover Change (LndChg)
- 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
- Zoning in the Knoxville MSA
- Location of public transit paths in the MSA

Tools Used

- ArcGIS Pro

Summary Table

Output	Approach
Emissions data/pollutants	Avoided emissions from avoided land conversion
Energy data	N/A
Other activity data	Improved carbon stock over time
Granularity (geographic, temporal, etc.)	MSA level

Agriculture

A18: Increase urban and micro farming

Methodology

GHG reductions from this measure are included in Measure A19 strategies for sustainable farming.

Key Assumptions

- N/A

Key Data Sources

- N/A

Tools Used

- N/A

Summary Table

Output	Approach
Emissions data/pollutants	N/A
Energy data	N/A
Other activity data	N/A

Output	Approach
Granularity (geographic, temporal, etc.)	N/A

A19: Improve agricultural practices

Three specific agricultural practices (strategies) were modeled to quantify GHG reductions for Measure A19.

Strategy 1: Nutrient Management Strategies (Nitrification Inhibitors (N_2O from Synthetic Fertilizer Application)

A nitrification inhibitor (NI) is a substance that inhibits the biological oxidation of ammoniacal-N to nitrate-N and nitrate-N is a precursor for nitrification and denitrification, both of which release nitrous oxide (N_2O). NIs slow the breakdown of nitrogen (N) in the soil, slowing the processes that result in N_2O emissions and increased plant N uptake (enhanced N use efficiency).

NI are expected to reduce N_2O emissions in two ways:

- Reduce emissions per metric tonnes (MT) of synthetic nitrogen applied to major field crops, with specific emissions reductions factors per major field crop
- Reduce total synthetic nitrogen applied due to enhanced NUE.

The projected emissions reductions of NIs applied to major field crops (corn, wheat, soybeans, sorghum and cotton) were modeled using the same formulas described in Chapter 8, Enhanced Efficiency Fertilizers of the USDA Marginal Abatement Cost Curve Methodology Report[1]. Only corn, soybeans and wheat are grown in Knoxville MSA. The historical acres where nitrification inhibitors have been applied in Knoxville MSA or relevant regions (e.g., TN or Appalachia) were derived from research of USDA reporting. This quantification assumes that applicable acres for mitigation are all remaining acres where N fertilizer is applied. This modeling assumed that NI option would increase 5% annually to estimate NI application on all modeled applicable acres. The method includes the following estimation steps:

- Applicable Acres = Acres planted * proportion acres receiving N fertilizer - Acres planted * proportion acres already receiving NI
- N applied = Applicable acres * N application rate per acre
- Baseline direct emissions = N applied * direct EF * N_2O-N emissions ratio * N_2O GWP
- Baseline indirect emissions = (N applied * fraction volatilized * volatilization EF ratio + N applied * fraction leached/runoff * leaching/runoff EF) * N_2O-N emissions ratio * N_2O GWP
- Baseline emissions = baseline direct emissions + baseline indirect emissions
- Mitigated emissions = Unmitigated emissions * % reduction in emissions

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- Assume 10 percent reduction in N application rate for all crops in all regions
- Percent reduction in emissions per major field crop as detailed in the table (Jones, J., and J.K. O'Hara, 2023)
- Impacts to soil carbon sequestration will not be analyzed under this measure implementation scenario.
- 5% annual increased rate of NI option

- Jones, J., and J.K. O'Hara (Eds), 2023. Marginal Abatement Cost Curves for Greenhouse Gas Mitigation on U.S. Farms and Ranches. Office of the Chief Economist, U.S. Department of Agriculture, Washington, DC.
- U.S. EPA State Inventory Tool, underlying BAU model data and emissions factors (from which mitigation modelling was built): https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool
- USDA NASS Quick Stats, data for acres planted for major field crops: https://quickstats.nass.usda.gov/
- USDA ERS Fertilizer Use and Price, data on fertilizer application rates for major field crops: https://www.ers.usda.gov/data-products/fertilizer-use-and-price

- ICF Agriculture Sector Mitigation Modelling Tool

NIs will act on all soil N pools including N from crop residues, organic fertilizers such as animal manure applied as fertilizer and N in soils due to asymbiotic fixation or other processes. NI impacts by N pool were not accounted for as there is currently insufficient data to estimate these effects, so the effect of NIs will be assumed only for synthetic N applied to soils.

There is uncertainty in the potential minimum and maximum reduction rate as nitrous oxide emission rates are highly variable depending on crop, soil, and climate conditions. It is unclear yet what data and literature will support uncertainty estimation.

Summary Table

Output	Approach
Emissions data/pollutants	Estimated agricultural soils emissions reductions (MTCO2e)
Energy data	N/A
Other activity data	Synthetic fertilizer (kg-N) reduced (not otherwise applied)
Granularity (geographic, temporal, etc.)	County level (Knoxville MSA). Crop-specific as available.

Strategy 2: Cover Crops (Soil Organic Carbon Sequestration and N2O Reduction)

Cover crops are plants grown primarily to benefit the soil rather than for crop yield. They play a crucial role in enhancing soil organic carbon (SOC) sequestration, which can lead to reduced nitrous oxide (N_2O) emissions by improving soil health and reducing the need for synthetic fertilizers. Modelling was based on increased adoption of cover crops grown on available (i.e., without cover crops) planted acres in the Knoxville MSA. Cover crops are expected to increase soil carbon sequestration and reduce N_2O emissions in the following ways:

- Increase soil organic carbon, therefore increasing carbon sequestration per acre where field crops are grown.
- Reduce N_2O emissions per acre from decreased synthetic nitrogen applied to major field crops and vegetables as less synthetic fertilizer is needed due to the N-fixing cover crops and nutrients added to the soil.

Methodology

Modeling quantified the combined projected soil carbon sequestration and N_2O emissions reductions of cover crops grown on total harvested acres which includes the major field crops (corn, wheat, soybeans, sorghum and cotton), any minor field crops, and vegetables using the same formulas described in Chapter 2, Cover Crops of the USDA Marginal Abatement Cost Curve Methodology Report. For completeness, modeling included estimated emissions from fuel use from farm machinery used to implement cover crops, as these emissions would be additional to what would otherwise occur. Data was gathered on historical acres where cover crops are grown in Knoxville MSA or relevant region (e.g., TN) and it was assumed that applicable acres for planting new cover crops are all remaining acres where cover crops are not yet grown. Assumed an annual increase of 0.8% in the rate of adoption, up to a maximum adoption of 27.5% on applicable acres in 2050. The method includes the following estimation steps:

1. Combined SOC sequestration and N_2O emissions reduction ($MTCO_2e$) = Applicable acres * regional impact factor of SOC and N_2O impact ($MTCO_2e$/acre)
2. Cover crop fuel use emissions ($MTCO_2e$) = Applicable acres * diesel fuel use per acre for planting and cultivating (gallons) * emission factor for diesel combustion ($MTCO_2e$/gallon)
3. Total cover crop emissions impact ($MTCO_2e$) = combined SOC sequestration and N_2O emissions reduction ($MTCO_2e$) + Cover crop fuel use emissions ($MTCO_2e$)

Key Assumptions

- 10 percent reduction in N application rate for all crops in all regions
- Percent reduction in emissions per major field crop as detailed in the table (Jones, J., and J.K. O'Hara, 2023)
- Impacts to soil carbon sequestration were not analyzed under this measure implementation scenario.
- The rate of adoption increases by 0.8% annually, to a maximum adoption of 27.5% on applicable acres in 2050

Key Data Sources

- Jones, J., and J.K. O'Hara (Eds), 2023. Marginal Abatement Cost Curves for Greenhouse Gas Mitigation on U.S. Farms and Ranches. Office of the Chief Economist, U.S. Department of Agriculture, Washington, DC.
- U.S. EPA State Inventory Tool, underlying BAU model data and emissions factors (from which mitigation modelling was built): https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool
- USDA NASS Quick Stats, data for acres planted for major field crops: https://quickstats.nass.usda.gov/
- USDA ERS Fertilizer Use and Price, data on fertilizer application rates for major field crops: https://www.ers.usda.gov/data-products/fertilizer-use-and-price
- 2025 EPA GHG Emission Factors Hub: https://www.epa.gov/climateleadership/ghg-emission-factors-hub

Tools Used

- ICF Agriculture Sector Mitigation Modelling Tool

Limitations

- Soil carbon sequestration factors and N2O emissions reduction factors are agriculture production region specific, which is likely a suitable level as production practices are expected to be generally similar in a given production area.

Summary Table

Output	Approach
Emissions data/pollutants	Estimated agricultural soil organic carbon and emissions reductions (MT CO2e)
Energy data	N/A
Other activity data	Synthetic fertilizer (kg-N) reduced (not otherwise applied)
Granularity (geographic, temporal, etc.)	County level (Knoxville MSA). Crop-specific as available.

Strategy 3: Livestock Feed Management (Enteric Fermentation Emissions

Enteric fermentation is a digestive process in ruminant animals that produces methane (CH_4) as a byproduct. Feed management strategies decrease enteric CH_4 emissions through dietary modifications, feed additives, and animal management practices.

Modelled feed additives include increased adoption of Monensin (Rumensin ®), an ionophore antibiotic with a methane reduction potential of 3-8% CH_4 head $^{-1}$ day $^{-1}$ for relevant livestock and is widely available, and 3-nitrooxypropanol (3-NOP), a methane inhibitor with comparably lower market readiness however is FDA approved, but a reduction potential of 38.5% CH_4 head^{-1} day $^{-1}$ for relevant livestock. The emissions reduction mechanism for Monensin is an improvement in efficiency of microbial bacteria to utilize feed energy, by shifting digestion more to certain bacteria and triggering a shift in fermentation pathways, resulting in less total enteric CH_4 emissions. This changes the bacterial composition in the rumen over time, but requires continual supplementation to remain effective. 3-NOP acts to reduce CH_4 following a similar mechanism by binding to a key enzyme of the methanogenesis pathway effectively halting methane production.

Monensin and 3-NOP improve feed efficiency, meaning these strategies do not adversely affect productivity. Feed Additives are most applicable to ruminant livestock types and production systems, specifically cattle on:

- Feedlots: easier administration due to animals feeding in confined locations
- Pasture: greater barriers to administration due to large grazing areas, potentially lower efficiency depending on distribution method

The potential for GHG reduction varies depending on factors such as diet composition, dosage, microbial resistance, and animal variation.

Methodology

Modeling efforts started with an assessment of the proportion of livestock for which either Monensin or 3-NOP is relevant for using the applicability assessment described in the USDA Marginal Abatement Cost Curves for Greenhouse Gas Mitigation on U.S. Farms and Ranches report. Next, the levels of adoption of Monensin and 3-NOP are based on government data if available, academic reports, expert opinion as well as other available

datasets. Per head emission reduction factors from the USDA MACC report, and other scientific literature were used to estimate avoided emissions from the proportion of animals for which the strategies are relevant but are not yet receiving Monensin or 3-NOP. An incremental increase in adoption of 3% and 10% per year for Monensin and 3-NOP, respectively, from current adoption levels was implemented to an estimated maximum adoption of 30% for Monensin and 100% for 3-NOP. Delayed adoption of 3-NOP was assumed with full adoption beginning in 2036 because of some cost concerns and a current lack of economic incentives. Emissions reductions were estimated annually to estimate CH_4 emission reductions compared with the baseline scenario.

- Baseline applicable livestock (# of head) = livestock population (# of head)
- Mitigation applicable livestock (# of head) = livestock population (# of head) * proportion applicable livestock adopting feed additive (%)
- Baseline enteric fermentation emissions ($MTCO_2e$) = Baseline applicable livestock (# of head) * baseline per head emission factor ($MTCO_2e$ per head)
- Mitigation feed additive emissions ($MTCO_2e$) = Mitigation applicable livestock (# of head) * mitigation per head emission factor ($MTCO_2e$ per head)
- Mitigated emissions ($MTCO_2e$) = Baseline enter fermentation emissions - Mitigation feed additive emissions

Key Assumptions

- Assumption on trends of adoption, based on literature.
- Maximum adoption is 30% for Monensin and 100% for 3-NOP of applicable animals
- Assumption on emissions reductions factor based on meta-analyses and U.S. specific studies
- Applicability factors by farm size and type are assumed to be those presented in the USDA Marginal Abatement Cost Curves for Greenhouse Gas Mitigation on U.S. Farms and Ranches.
- Not modeling manure management emission impacts due to measure implementation.

Key Data Sources

- U.S. EPA State Inventory Tool, underlying BAU model data and emissions factors (from which mitigation modelling was built): https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool
- USDA NASS Quick Stats, data for county livestock populations: https://quickstats.nass.usda.gov/
- Additional country specific EPA U.S. GHG inventory and default IPCC emission factors if necessary
- Jones, J., and J.K. O'Hara (Eds), 2023. Marginal Abatement Cost Curves for Greenhouse Gas Mitigation on U.S. Farms and Ranches. Office of the Chief Economist, U.S. Department of Agriculture, Washington, DC.
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Tools Used

- ICF Agriculture Sector Mitigation Modelling Tool

Summary Table

Output	Approach
Emissions data/pollutants	Estimated manure CH_4 emissions reductions from implementation of feed additives ($MTCO_2e$)
Energy data	N/A
Other activity data	Changes in livestock specific distribution of feed systems over time
Granularity (geographic, temporal, etc.)	County level (Knoxville MSA). Livestock-specific.

Appendix D: Air Quality Methodology

Introduction

The purpose of this document is to outline the methodology used to model the co-pollutant reductions and health impacts of the measures in Knoxville's CCAP.

In addition to greenhouse gases (GHG), emissions from criteria air pollutants (CAPs) also harm public health and the environment, and hazardous air pollutants (HAPs) are pollutants known to cause cancer and other serious health impacts. Like a GHG inventory, tracking these co-pollutants in an inventory over time provides an understanding of what pollutants are being released, how much, and their key sources.

These two categories of air pollutants affect human health and the environment:

- **Criteria Air Pollutants** include ozone, particulate matter ($PM_{2.5}$, PM_{10}), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and lead.
- **Hazardous Air Pollutants**, also known as air toxics, include over 180 chemicals such as benzene and mercury.

In addition, there are many types of pollutants that relate to both CAPs and HAPs, or that are considered a precursor pollutant that may react with other pollutants to form either a CAP or HAP and are thus important to track for air quality assessments.

Volatile organic compounds (VOCs) are gases that come from things like fertilizer use in agricultural activities, paints, varnishes, cleaning supplies, gasoline and diesel, and building materials. When VOCs react with nitrogen oxides, they create ozone, a CAP. Some VOCs are HAPs, such as benzene or formaldehyde.

Ammonia (NH_3) contributes to the formation of $PM_{2.5}$, a CAP, when it reacts with other pollutants like NO_x and SO_2.

Table 1 provides a summary of co-pollutant emissions in the region by sector and pollutant, with a focus on criteria pollutants. The data is compiled from EPA's 2022 Emissions Modeling Platform.

Table 1. Knoxville MSA Co-Pollutant Emissions (Metric Tons), 2022

Sector	CO	NO_x	VOC	PM_{10}	$PM_{2.5}$	SO_2	NH_3
AFOLU	23,741.76	1,390.25	96,107.06	5,816.68	3,071.64	159.80	3,616.52
IPPU	2,996.78	1,660.90	12,638.89	5,920.37	1,766.03	450.85	76.30
Mobile	82,122.12	10,265.24	6,133.56	802.63	413.89	46.66	636.83
Other	226.27	5.18	83.38	2,484.13	586.24	0.31	0.00
Stationary	6,602.60	2,680.71	990.22	1,306.02	1,238.79	1,987.93	145.35
Waste	4,801.23	166.10	488.58	845.46	769.09	53.80	303.97

Sector	CO	NO_x	VOC	PM_{10}	$PM_{2.5}$	SO_2	NH_3
Total	**120,490.76**	**16,168.38**	**116,441.70**	**17,175.29**	**7,845.68**	**2,699.35**	**4,778.97**

Knoxville's CCAP requires a comprehensive analysis of both greenhouse gas (GHG) and co-pollutant (non-GHG) air pollutant reductions associated with climate measures. This analysis is a core requirement under the EPA's CPRG program and is designed to quantify the benefits of GHG reduction actions across the state.

CPRG Requirements

- **Scope**: The analysis must cover the entire geographic area of Knoxville and address anticipated changes in non-GHG air pollutants (Criteria Air Pollutants (CAPs) and Hazardous Air Pollutants (HAPs)) resulting from the full suite of GHG reduction measures in the plan.
- **Pollutants Addressed**: CAPs include ozone (O_3), particulate matter ($PM_{2.5}$/PM_{10}), carbon monoxide (CO), lead (Pb), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2); HAPs include 188 regulated air toxics such as benzene and formaldehyde.
- **Quantification Approach**: Knoxville MSA is expected to provide both base year (current) and projected future emissions estimates for these pollutants. Where data or tool limitations exist, qualitative approaches are allowed.
- **Spatial Resolution**: Benefits can be analyzed at statewide, county, or finer geographic scales, depending on data availability and relevance to the Region's communities.
- **Measure-Specific Analysis**: While aggregate pollutant reduction estimates are required, Knoxville is encouraged to provide measure-specific estimates to highlight the value of individual climate actions.
- **Disbenefits Tracking**: Any potential increases in air pollution ("disbenefits") from measures must be identified, with strategies to minimize and mitigate these impacts.

Outputs

- Reductions by county, sector, and pollutant.
- Outside of county/imported electricity will be accounted for separately

Health Impacts Quantification

Outputs of co-pollutant reductions from this quantification were fed into the Co-Benefits Risk Assessment (COBRA) Model for health impacts. COBRA is a screening tool developed by the EPA to estimate the health and economic benefits of air quality improvements. COBRA models the impact of changes in emissions of key air pollutants (PM2.5, SO2, NOX, VOCs) on public health outcomes and monetizes these benefits using peer-reviewed concentration-response functions and economic valuation methods.[6]

[6] https://www.epa.gov/cobra/how-does-cobra-work

This analysis utilized the web-based version of COBRA, which offers streamlined functionality compared to the full desktop model. While both versions use the same underlying methodology, the web edition is limited to default datasets for the year 2023 and does not support custom inputs for emissions, population, or health incidence data. It also lacks some advanced features available in the desktop version, such as multi-year analysis and finer geographic resolution.[7]

COBRA translates changes in ambient air quality into changes in health outcomes using a simplified air quality model (the Source-Receptor Matrix) and then monetizes these impacts using values such as the Value of a Statistical Life (VSL), cost-of-illness estimates, and willingness-to-pay metrics. These incidence categories are aggregated to estimate the overall economic value of health improvements resulting from air quality interventions, providing a robust basis for evaluating the co-benefits of climate and sustainability strategies.[8]

Table 2. COBRA Health Impacts Categories Mapping

Aggregated Category Description	COBRA Incidence Category Included
Mortality	• Total Mortality • Infant Mortality (PM)
Hospital Visits	• Total Hospital Admits, All Respiratory • Total Emergency Room Visits, Respiratory • Emergency Room Visits, Asthma (O3) • Hospital Admits, Cardio-Cerebro/Peripheral Vascular Disease (PM) • Hospital Admits, Alzheimers Disease (PM) • Hospital Admits, Parkinsons Disease (PM) • Emergency Room Visits, All Cardiac (PM)
Missed School/Work or Restricted Activity	• Minor Restricted Activity Days (PM) • School Loss Days (O3) • Work Loss Days (PM)
Cardiovascular Conditions	• Nonfatal Heart Attacks (PM) • Cardiac Arrest, Out of Hospital (PM) • Stroke (PM)
Respiratory Conditions	• Total Asthma Onset • Total Asthma Symptoms • Lung Cancer (PM) • Total Hay Fever/Rhinitis

Scaling to County Level

To input co-pollutant reductions into COBRA for health impacts, quantification must be conducted at the county level.

Transportation VMT

[7] https://www.epa.gov/cobra/cobra-questions-and-answers
[8] https://www.epa.gov/system/files/documents/2024-04/how-cobra-works_17-april-2024.pdf

BAU scenarios, VMT reduction, EV adoption, and off-road construction equipment electrification measures are already at the county level.

Building Fuel Usage

BAU and mitigation modeling results for new buildings will be scaled to the county level using 2024 census data on population share for the residential sector and employment share for commercial sector.

Industry Buildings Fuel Usage

BAU and mitigation modeling results for industrial buildings for fuel use are already at the county level.

Waste

Data will be downscaled by population at the county level.

Methodology by Sector

Buildings

When the region implements energy efficiency or fuel-switching measures in the buildings sector, less fuel is used in both new and existing buildings. This not only reduces greenhouse gas emissions but also decreases emissions of other harmful pollutants that are released during fuel combustion. ICF will use the following methodology to quantify co-pollutant emission reductions in the building sector:

1. **Quantify Fuel Saved**: Determine the amount of each fuel type saved by comparing the baseline scenario to the mitigation scenario.
2. **Apply Emission Factors**: Use standard EPA AP-42 emissions factors for each fuel type to estimate how much NO_x, SO_2, Lead, CO, VOC, and PM would have been emitted if the fuel had been used.
3. **Calculate Emissions Reductions**: Multiply the amount of each fuel saved by its corresponding emission factor to estimate the avoided emissions for each pollutant.

On-Road Transportation

For the Region's transportation sector, co-pollutant reductions were quantified using MOVES5-derived emission ratios for two scenarios: reduced VMT and increased EV adoption.

For the VMT and increased EV adoption reduction scenarios, MOVES5 was used to determine the emissions of each co-pollutant (e.g., CO, NOx, PM2.5) per vehicle mile traveled for each vehicle type in the baseline year (e.g., grams CO per passenger vehicle mile in 2025). These ratios were calculated by dividing total BAU emissions by total VMT for each vehicle type. The

appropriate ratio was then multiplied by the reduction in VMT (BAU minus mitigation scenario) for each vehicle category to estimate avoided emissions.

Off-Road Transportation

Off-road transportation emissions were quantified by using usage hours in the construction sector by county. The following approach was used:

1. **Develop Emission Ratios by county**: Emissions of each co-pollutant per hour of equipment operation for each fuel type was calculated. These ratios are created by dividing total BAU emissions by total usage hours for each county and represent baseline emissions intensity
2. **Estimate Usage Hours Saved**: Determine the difference in equipment usage hours between the BAU and mitigation scenarios, disaggregated by county.
3. **Calculate Total Emission Reductions**: Multiply the emission ratio by the total reduction in usage hours to estimate avoided emissions for each pollutant

Waste

When Knoxville MSA implements waste reduction measures, less waste is sent to landfills. This not only reduces greenhouse gas emissions but also decreases emissions of other harmful pollutants, specifically NO_x, CO, VOC, and PM2.5, that are released when landfill gas is flared.

1. **Quantify Waste Diverted**: Determine the amount of waste that prevented from entering landfills due to the waste reduction initiative.
2. **Estimate Methane Generation Avoided**: Calculate how much methane would have been produced by this diverted waste if it had been landfilled.
3. **Apply Emission Factors**: Use standard EPA emission factors to estimate how much NOx, CO, and PM2.5 would have been emitted from flaring the methane generated by the landfilled waste.

Natural & Working Lands

To assess the co-benefits of natural and working lands (NWL), EPA's i-Tree Landscape Module was utilized to estimate ecosystem services provided by tree cover. The assessment was conducted at the county level and looked at avoided runoff, rainfall interception, transpiration, air pollution removal.

Power

The Knoxville measures trigger both benefits and disbenefits related to changes in electricity consumption and associated emissions. However, the actual health impacts are not necessarily realized within the MSA itself because the region typically imports electricity generated from power plants located elsewhere in the state. As a result, while Knoxville's

energy use drives demand on the grid, the emissions reductions or increases occur at generation facilities outside the local area.

Avoided emissions resulting from solar energy generation were calculated by multiplying the projected megawatt-hour (MWh) output by pollutant-specific emissions factors sourced from EPA's AVERT tool. The emissions factors represent the quantity of co-pollutant emissions, such as NO_x, SO_2, and PM, that would have been produced by conventional electricity generation and are thus offset by solar. To avoid overstating future emission reductions, the values for each pollutant through 2050 were not assumed to remain static but were instead projected using the trend in NREL CO_2 emissions factor observed between 2025 and 2045. This approach accounts for ongoing grid decarbonization, ensuring that estimated reductions reflect anticipated declines in marginal emissions over time and remain consistent with sector-wide changes in electricity generation.

Electrification in the buildings sector results in increased electricity consumption within buildings, but this is outweighed by building efficiency, making electricity use decrease in buildings. To estimate the corresponding decrease in power sector emissions due to this decreased demand, emissions factors identified previously were applied to the incremental electricity use. The adoption of electric vehicles (EVs) increases electricity consumption for transportation purposes, and the emissions impact from this increased load was calculated by multiplying the same emissions factors by the additional electricity consumed.

Emission Factors

Table 3. Building and Industry Fuels Emission Factors

Fuel	Notes	Units	NO_x	SO_2	PM	CO	Lead	VOC
Gas[9]	Uncontrolled small boiler or controlled (recirculation) large boiler	Boiler Ef (lb/1000000 scf)	100	0.6	7.6	84	0.0005	5.5
Gas	Residential furnace	Ef lb/1000000 scf	94	0.6	7.6	40	0.0005	5.5
Oil[10]	<100 MMBTU	Boiler Distillate oil fired Ef (lb/1000 gal)	20	7.1	2	5	0.0015	4.68154
LPG[11]		Propane Ef (lb/1000 gal)	13	0.05	0.7	7.5		0.4565
Coal	Source: AP 42, spreader stoker, bituminous	common in medium sized boilers, assuming use in industrial buildings (lb/ton)	11	76	66	5		0.4565

[9] https://www.epa.gov/sites/default/files/2020-09/documents/1.4_natural_gas_combustion.pdf
[10] https://www.epa.gov/sites/default/files/2020-09/documents/1.3_fuel_oil_combustion.pdf
[11] https://www.epa.gov/sites/default/files/2020-09/documents/1.5_liquefied_petroleum_gas_combustion.pdf

Table 4. Conversion and Heat Factors

Fuel	Conversion	Units	Source
Natural gas	1036	BTU/scf	EIA
Distillate oil heating value	140	MMBTU/1000 gal	EPA
Residual oil heating value	150	MMBTU/1000 gal	EIA
Propane heating value	91.5	MMBTU/1000 gal	EIA
Coal	0.04829	Coal MMbtu to Tons	EPA

Table 5. Sulfur Content Estimates

Fuel	Value	Units
Assumed S content of distillate oil	0.05	% by weight (500 ppm)
Assumed S content of propane	0.5	% by weight
Assumed S content of 6 oil	0.5	% by weight
Assumed S content of 6 bituminous coal	2	% by weight

Table 6. Waste Emissions Factors from EPA AP-42[12]

Control Device	Notes	Units	NOx	PM (Primary)	CO	VOC
Flare	Emission rates for secondary compounds exiting control devices	Lb/10^6 dscf Methane	40	17	750	4.1

Results

This section presents the quantified outcomes of co-pollutant reductions and associated health benefits for the MSA, as estimated using the above methodology as well as the COBRA model. The results are organized in two tiers: first, a Region-wide summary provides an aggregated view of total emissions reductions and health impacts across all sectors. Following this, sector-specific analyses detail the contributions of individual sectors to both pollutant reductions and public health improvements.

Each sectoral subsection includes:

[12] https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s04.pdf

- Co-pollutant reductions, covering carbon monoxide (CO), particulate matter ($PM_{2.5}$), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and, where applicable, lead (Pb) and Volatile Organic Compounds (VOC).
- Health impact estimates, derived from COBRA, presented at the available level of granularity for each pollutant and sector. These include both incidence counts and monetized benefits across categories such as mortality, hospital visits, restricted activity days, and respiratory/cardiovascular conditions.

Results by County and Pollutant

Table 7. Co-pollutant Reductions by County

County	Pollutant	Cumulative Reductions (MT) (2025-2050)
Anderson County	CO	5,279.93
Anderson County	NOx	901.85
Anderson County	PM	251.09
Anderson County	SO2	220.92
Anderson County	VOC	70.52
Blount County	CO	7,979.71
Blount County	NOx	2,308.00
Blount County	PM	191.47
Blount County	SO2	33.05
Blount County	VOC	159.52
Campbell County	CO	3,292.90
Campbell County	NOx	352.76
Campbell County	PM	29.37
Campbell County	SO2	6.50
Campbell County	VOC	27.15
Grainger County	CO	1,458.43
Grainger County	NOx	197.94

Grainger County	PM	16.49
Grainger County	SO2	2.88
Grainger County	VOC	16.05
Knox County	CO	33,207.89
Knox County	NOx	5,791.51
Knox County	PM	890.84
Knox County	SO2	571.01
Knox County	VOC	452.97
Loudon County	CO	6,390.13
Loudon County	NOx	2,863.74
Loudon County	PM	224.03
Loudon County	SO2	50.22
Loudon County	VOC	150.76
Morgan County	CO	861.93
Morgan County	NOx	151.58
Morgan County	PM	13.12
Morgan County	SO2	2.23
Morgan County	VOC	14.09
Roane County	CO	3,942.85
Roane County	NOx	502.66
Roane County	PM	41.79
Roane County	SO2	9.47
Roane County	VOC	40.95
Union County	CO	1,257.14
Union County	NOx	494.81
Union County	PM	39.18
Union County	SO2	14.58
Union County	VOC	28.44

Note: Lead and VOC emissions could not be calculated for all sectors

Table 8. Total Knoxville Co-Pollutant Reductions

Pollutant	Cumulative Reductions (MT) (2025-2050)
NO_x	13,564.86

Pollutant	Cumulative Reductions (MT) (2025-2050)
SO_2	910.87
PM	1,697.37
CO	63,670.92
Lead	0.08
VOC	960.47

Results by Health Impact

The table below presents the cumulative health benefits and associated monetary values resulting from quantified co-pollutant reductions in the Region between 2025 and 2050. These estimates are derived from the COBRA model and reflect the total change in incidence, the number of avoided cases, for each health impact category. The monetary benefits represent the economic value of these avoided outcomes, including reduced mortality, fewer hospital visits, and improved productivity through fewer missed school and workdays. This summary provides a statewide overview, which is followed by sector-specific results detailing pollutant reductions and health impacts at a more granular level.

At the state level, the table provides a range of estimates, low and high, for both health outcomes and their monetized benefits for mortality. These ranges reflect uncertainty in the underlying epidemiological and economic assumptions, such as the sensitivity of populations to air pollution and the valuation of avoided health outcomes.[13] The low estimate represents a more conservative scenario, while the high estimate assumes stronger health effects and higher economic valuations. This range helps contextualize the potential variability in benefits.

Table 9. Health Impact Results for Knoxville

Health Impact	Cumulative Monetary Benefits (2025-2050)	Cumulative Incidence Reduction (2025-2050)
Mortality	$787,164,509 - $1,286,653,602	54 - 88
Hospital Visits	$1,087,359	117
Missed School/Work or Restricted Activity	$21,010,833	30,959
Cardiovascular Conditions	$4,436,285	53
Respiratory Conditions	$20,575,908	28,476

Results by Sector

In the sector-specific results that follow, only the low-end estimates from COBRA are shown. This approach is intended to maintain a conservative and cautious interpretation of the data. By focusing on the lower bound of potential benefits, the analysis avoids overstating impacts

[13] https://www.epa.gov/cobra/cobra-questions-and-answers

while still capturing the meaningful health and economic gains associated with co-pollutant reductions.

Buildings

In the Buildings sector, the modeled strategies have led to significant cumulative reductions in key pollutants from 2025 to 2050. NOx emissions are projected to decrease by 6,040.97 metric tons, SO_2 by 100.63 metric tons, PM by 452.32 metric tons, CO by 2,478.46 metric tons, lead by 0.04 metric tons, adn VOC by 645.39 metric tons. The buildings sector has the highest cumulative reductions for NOx and VOC. These reductions are primarily driven by a suite of building-focused strategies aimed at improving energy efficiency and electrification. Measures included in this modeling are increasing energy efficiency and weatherization of buildings, upgrading energy efficiency and decarbonizing public buildings, and expanding electrification of buildings plays a critical role in reducing emissions in both residential and commercial buildings.

Table 10. Co-Pollutant Results for the Buildings Sector

Pollutant	Cumulative Reductions (MT) (2025-2050)
NOx	6,040.97
SO2	100.63
PM	452.32
CO	2,478.46
Lead	0.04
VOC	645.38

Translated into health impact quantification, using the results provided from COBRA, the building residential sector is estimated to achieve substantial public health benefits between 2025 and 2050.

Table 11: Health Impact Results for the Residential and Commercial Buildings Sector

Health Impact	Cumulative Monetary Benefits (2025-2050)	Cumulative Incidence Reduction (2025-2050)
Mortality	$295,380,074 - $446,355,321	20-31
Hospital Visits	$358,398	44
Missed School/Work or Restricted Activity	$9,060,054	10,920
Cardiovascular Conditions	$1,338,564	16
Respiratory Conditions	$8,613,318	11,288

The commercial and residential parts of the buildings sector show strong health co-benefits, these include avoided mortality valued at approximately $370.86 million, along with reductions in hospital visits, missed school and workdays, cardiovascular conditions, and respiratory conditions. Buildings remain a key contributor to statewide health improvements.

The incidence reductions reflect consistent annual gains, particularly in respiratory and productivity-related outcomes, reinforcing the sector's importance in air quality and health policy planning.

Industrial Buildings

In Industrial Buildings, the modeled strategies have led to significant cumulative reductions in key pollutants from 2025 to 2050. NOx emissions are projected to decrease by 5,363.30 metric tons, SO_2 by 730.40 metric tons, PM by 1,796.52 metric tons, CO by 2,182.74 metric tons, and VOC by 15.11 metric tons. The industrial buildings sector has the highest cumulative reductions for PM.

Table 12. Co-Pollutant Results for the Industrial Buildings Sector

Pollutant	Cumulative Reductions (MT) (2025-2050)
NOx	5,363.30
SO2	748.25
PM	974.11
CO	4,341.18
Lead	0.04
VOC	244.27

The industrial sector's cumulative mortality benefits total about $549.27 million, with meaningful gains in hospital visits, missed activity days, and respiratory conditions. Compared to other sectors, Industrial Buildings has the highest monetary value reductions compared to those of the commercial and residential building sectors and higher than Transportation. In doing COBRA analysis, we assumed that SO_2 was net zero from 2040 onwards due to discrepancies with COBRA's baseline SO_2 emissions.

Table 13. Health Impact Results for the Industrial Buildings Sector

Health Impact	Cumulative Monetary Benefits (2025-2050)	Cumulative Incidence Reduction (2025-2050)
Mortality	$398,434,149 - $700,112,532	27 - 48
Hospital Visits	$616,824	60
Missed School/Work or Restricted Activity	$9,072,856	16,602
Cardiovascular Conditions	$2,682,239	32
Respiratory Conditions	$9,230,112	13,615

Transportation

In the Transportation sector, the modeled strategies have led to substantial cumulative reductions, with NOx emissions projected to decrease by 1,892.63 metric tons, SO_2 by 61.99 metric tons, PM by 157.05 metric tons, and CO by 51,827.08 metric tons. CO emissions were reduced the highest in the transportation sector, due to decreases in tailpipe emissions.

These reductions are driven by a comprehensive set of strategies focused on vehicle electrification, infrastructure expansion, and modal shifts.

Table 14. Total Co-Pollutant Results for the Transportation Sector

Pollutant	Cumulative Reductions (MT) (2025-2050)
NO_x	1,892.63
SO_2	61.99
PM	157.05
CO	51,827.08

On-Road

Table 15. Co-Pollutant Results for VMT Reduction& EV Adoption On-road Transportation

Pollutant	Cumulative Reductions (MT) (2025-2050)
NO_x	1,593.97
SO_2	61.38
PM	104.57
CO	44,631.11

Off-Road

Table 16. Co-Pollutant Results for Construction Equipment Off-road Transportation

Pollutant	Cumulative Reductions (MT) (2025-2050)
NO_x	298.67
SO_2	0.61
PM	52.48
CO	7,195.96

The Transportation sector stands out as the most impactful in terms of health-related co-benefits from pollutant reductions. It leads all sectors in cumulative monetary benefits across every health category, including mortality (Average $94.03 million), hospital visits, missed school/workdays, cardiovascular conditions, and respiratory conditions. These benefits are accompanied by the highest incidence reductions statewide, with thousands of avoided cases in missed school/workdays and respiratory conditions. The scale and consistency of these outcomes highlight Transportation as a critical sector for maximizing public health gains through air quality improvements.

Table 17. Health Impact Results for On-road and Off-road Transportation

Health Impact	Cumulative Monetary Benefits (2025-2050)	Cumulative Incidence Reduction (2025-2050)
Mortality	$77,918,712 - $110,140,756	5-8
Hospital Visits	$84,444	11

Missed School/Work or Restricted Activity	$2,627,639	2,757
Cardiovascular Conditions	$285,645	3
Respiratory Conditions	$2,454,746	3,107

Waste

In the Waste sector, the modeled strategies have led to modest cumulative reductions in pollutants from 2025 to 2050. NOx emissions are projected to decrease by 267.96 metric tons, PM by 113.88 metric tons, CO by 5,024.20 metric tons, and VOC by 27.47 metric tons. These reductions are achieved through strategies that improve waste management practices and reduce methane and fossil fuel emissions. Modeled measures include reducing methane emissions from solid waste and wastewater treatment facilities (W1) and diverting organic waste to composting and recovery (W4).

Table 18. Co-pollutant Results for the Waste Sector

Pollutant	Cumulative Reductions (MT) (2025-2050)
NOx	267.96
PM	113.88
CO	5,024.20
VOC	27.47

The Waste sector yields less health benefits in comparison to other sectors. Cumulative monetary values are low across all categories, with mortality benefits totaling $22.73 million with other smaller yet still significant gains in hospital visits, missed activity days, and public health outcomes. While not a major driver of statewide benefits, the Waste sector may still offer localized improvements.

Table 19. Health Impact Results for the Waste Sector

Health Impact	Cumulative Monetary Benefits (2025-2050)	Cumulative Incidence Reduction (2025-2050)
Mortality	$15,431,574 - $30,044,993	1.1 – 2.1
Hospital Visits	$27,693	2.3
Missed School/Work or Restricted Activity	$250,284	679.9
Cardiovascular Conditions	$129,837	1.6
Respiratory Conditions	$277,732	465.6

While the waste sector shows a small cumulative monetary benefit to mortality, COBRA estimates maximum 2.1 avoided cases over the 2025-2050 period. Hospital visits and cardiovascular conditions are similar in comparison. However, missed activity day and respiratory condition incidence are reduced by a notable amount.

Appendix E: Knoxville Workforce Development

Workforce Development Analysis

Labor Market Data

Table 20. Occupations Impacted by CCAP Measures

SOC	Description	Relevant Sectors
11-9013	Farmers, Ranchers, and Other Agricultural Managers	Agriculture, Forestry, and Other Land Use
11-9021	Construction Managers	Buildings
13-1041	Compliance Officers	Buildings
17-2051	Civil Engineers	Transportation (on and off Road)
17-2071	Electrical Engineers	Energy
19-1013	Soil and Plant Scientists	Agriculture, Forestry, and Other Land Use
19-1031	Conservation Scientists	Agriculture, Forestry, and Other Land Use
19-1032	Foresters	Agriculture, Forestry, and Other Land Use
19-4012	Agricultural Technicians	Agriculture, Forestry, and Other Land Use
19-4071	Forest and Conservation Technicians	Agriculture, Forestry, and Other Land Use
45-1011	First-Line Supervisors of Farming, Fishing, and Forestry Workers	Agriculture, Forestry, and Other Land Use
45-2091	Agricultural Equipment Operators	Agriculture, Forestry, and Other Land Use
45-2092	Farmworkers and Laborers, Crop, Nursery, and Greenhouse	Agriculture, Forestry, and Other Land Use

SOC	Description	Relevant Sectors
45-2093	Farmworkers, Farm, Ranch, and Aquacultural Animals	Agriculture, Forestry, and Other Land Use
45-2099	Agricultural Workers, All Other	Agriculture, Forestry, and Other Land Use
45-4011	Forest and Conservation Workers	Agriculture, Forestry, and Other Land Use
47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	Buildings, Transportation (on and off Road)
47-2031	Carpenters	Buildings
47-2061	Construction Laborers	Buildings, Transportation (on and off Road)
47-2071	Paving, Surfacing, and Tamping Equipment Operators	Transportation (on and off Road)
47-2073	Operating Engineers and Other Construction Equipment Operators	Buildings, Transportation (on and off Road)
47-2111	Electricians	Buildings, Transportation (on and off Road)
47-2131	Insulation Workers, Floor, Ceiling, and Wall	Buildings
47-2152	Plumbers, Pipefitters, and Steamfitters	Buildings
47-2181	Roofers	Buildings
47-2231	Solar Photovoltaic Installers	Buildings, Energy
47-3012	Helpers--Carpenters	Buildings
47-3013	Helpers--Electricians	Buildings
47-3015	Helpers--Pipelayers, Plumbers, Pipefitters, and Steamfitters	Buildings
47-3016	Helpers--Roofers	Buildings
47-4011	Construction and Building Inspectors	Buildings
47-4051	Highway Maintenance Workers	Transportation (on and off Road)
49-2093	Electrical and Electronics Installers and Repairers, Transportation Equipment	Transportation (on and off Road)

SOC	Description	Relevant Sectors
49-2095	Electrical and Electronics Repairers, Powerhouse, Substation, and Relay	Energy
49-2096	Electronic Equipment Installers and Repairers, Motor Vehicles	Transportation (on and off Road)
49-3023	Automotive Service Technicians and Mechanics	Transportation (on and off Road)
49-9021	Heating, Air Conditioning, and Refrigeration Mechanics and Installers	Buildings
49-9031	Home Appliance Repairers	Buildings
49-9051	Electrical Power-Line Installers and Repairers	Energy
49-9081	Wind Turbine Service Technicians	Energy
51-8012	Power Distributors and Dispatchers	Energy
51-8013	Power Plant Operators	Energy
53-3032	Heavy and Tractor-Trailer Truck Drivers	Transportation (on and off Road), Solid Waste and Waste Water
53-3033	Light Truck Drivers	Transportation (on and off Road)
53-3052	Bus Drivers, Transit and Intercity	Transportation (on and off Road)
53-6041	Traffic Technicians	Transportation (on and off Road)
53-7051	Industrial Truck and Tractor Operators	Solid Waste and Waste Water
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	Solid Waste and Waste Water
53-7081	Refuse and Recyclable Material Collectors	Solid Waste and Waste Water

Table 21. Employment Trends and Projections 2015-2035

SOC	Description	Relevant Sectors	2015 Jobs	2020 Jobs	2025 Jobs	2030 Jobs	2035 Jobs
11-9013	Farmers, Ranchers, and Other	Agriculture, Forestry, and Other Land Use	1,690	1,218	869	728	632

	Agricultural Managers						
11-9021	Construction Managers	Buildings	1,307	1,769	1,822	1,918	1,997
13-1041	Compliance Officers	Buildings	608	980	1,123	1,199	1,249
17-2051	Civil Engineers	Transportation (on and off Road)	700	798	1,048	1,118	1,164
17-2071	Electrical Engineers	Energy	435	441	447	482	504
19-1013	Soil and Plant Scientists	Agriculture, Forestry, and Other Land Use	50	68	41	43	45
19-1031	Conservation Scientists	Agriculture, Forestry, and Other Land Use	56	79	47	50	52
19-1032	Foresters	Agriculture, Forestry, and Other Land Use	16	14	9	9	9
19-4012	Agricultural Technicians	Agriculture, Forestry, and Other Land Use	32	50	49	52	54
19-4071	Forest and Conservation Technicians	Agriculture, Forestry, and Other Land Use	68	89	108	110	110
45-1011	First-Line Supervisors of Farming, Fishing, and Forestry Workers	Agriculture, Forestry, and Other Land Use	98	82	76	78	78
45-2011	Agricultural Inspectors	Agriculture, Forestry, and Other Land Use	48	36	37	40	42
45-2091	Agricultural Equipment Operators	Agriculture, Forestry, and Other Land Use	112	89	81	81	82
45-2092	Farmworkers and Laborers, Crop, Nursery, and Greenhouse	Agriculture, Forestry, and Other Land Use	890	674	756	756	753

45-2093	Farmworkers, Farm, Ranch, and Aquacultural Animals	Agriculture, Forestry, and Other Land Use	374	278	226	204	189
45-2099	Agricultural Workers, All Other	Agriculture, Forestry, and Other Land Use	185	175	145	136	129
45-4011	Forest and Conservation Workers	Buildings, Transportation (on and off Road)	39	69	64	68	70
47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	Buildings	1,754	1,827	2,607	2,724	2,774
47-2031	Carpenters	Buildings, Transportation (on and off Road)	2,270	2,705	2,908	2,963	2,969
47-2061	Construction Laborers	Transportation (on and off Road)	3,843	4,517	5,363	5,616	5,758
47-2071	Paving, Surfacing, and Tamping Equipment Operators	Buildings, Transportation (on and off Road)	294	288	298	314	322
47-2111	Electricians	Buildings, Transportation (on and off Road)	2,234	2,910	2,842	3,013	3,112
47-2131	Insulation Workers, Floor, Ceiling, and Wall	Buildings	163	218	169	172	174
47-2152	Plumbers, Pipefitters, and Steamfitters	Buildings	1,063	1,679	1,629	1,748	1,811
47-2181	Roofers	Buildings	343	404	476	491	494
47-2231	Solar Photovoltaic Installers	Buildings, Energy	17	<10	40	47	52
47-3012	Helpers--Carpenters	Buildings	187	201	156	158	158
47-3013	Helpers--Electricians	Buildings	237	211	272	275	275
47-3015	Helpers--Pipelayers, Plumbers, Pipefitters, and Steamfitters	Buildings	195	236	161	174	181

47-3016	Helpers--Roofers	Buildings	14	18	9	9	9
47-4011	Construction and Building Inspectors	Buildings	161	196	243	257	265
47-4051	Highway Maintenance Workers	Transportation (on and off Road)	169	150	167	186	201
49-2093	Electrical and Electronics Installers and Repairers, Transportation Equipment	Transportation (on and off Road)	33	17	14	14	15
49-2095	Electrical and Electronics Repairers, Powerhouse, Substation, and Relay	Energy	46	46	85	89	90
49-2096	Electronic Equipment Installers and Repairers, Motor Vehicles	Transportation (on and off Road)	16	20	16	15	13
49-3023	Automotive Service Technicians and Mechanics	Transportation (on and off Road)	2,629	2,565	2,740	2,850	2,918
49-9021	Heating, Air Conditioning, and Refrigeration Mechanics and Installers	Buildings	1,130	1,383	1,510	1,645	1,726
49-9031	Home Appliance Repairers	Buildings	121	96	110	108	107
49-9051	Electrical Power-Line Installers and Repairers	Energy	387	384	366	388	397
49-9081	Wind Turbine Service Technicians	Energy	9	9	10	11	11
51-8012	Power Distributors and Dispatchers	Energy	28	9	9	9	9
51-8013	Power Plant Operators	Energy	102	133	98	94	90

53-3032	Heavy and Tractor-Trailer Truck Drivers	Transportation (on and off Road), Solid Waste and Waste Water	7,353	7,075	8,026	8,506	8,797
53-3033	Light Truck Drivers	Transportation (on and off Road)	2,613	3,853	3,762	4,118	4,345
53-3052	Bus Drivers, Transit and Intercity	Transportation (on and off Road)	414	303	299	311	321
53-6041	Traffic Technicians	Transportation (on and off Road)	76	60	49	51	53
53-7051	Industrial Truck and Tractor Operators	Solid Waste and Waste Water	1,142	1,333	1,519	1,648	1,711
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	Solid Waste and Waste Water	7,715	8,441	9,927	10,632	11,042
53-7081	Refuse and Recyclable Material Collectors	Solid Waste and Waste Water	352	371	487	528	550

Table 22.Growth and Projected Growth (2015-2025 and 2025-2035)

SOC	Description	Relevant Sectors	Growth 2015-2025	Projected Growth 2025-2035	Percent Growth 2015-2025	Projected Percent Growth 2025-2035
11-9013	Farmers, Ranchers, and Other Agricultural Managers	Agriculture, Forestry, and Other Land Use	-821	-237	-49%	-27%
11-9021	Construction Managers	Buildings	516	175	39%	10%
13-1041	Compliance Officers	Buildings	515	127	85%	11%
17-2051	Civil Engineers	Transportation (on and off Road)	348	116	50%	11%

17-2071	Electrical Engineers	Energy	12	57	3%	13%
19-1013	Soil and Plant Scientists	Agriculture, Forestry, and Other Land Use	-10	4	-19%	10%
19-1031	Conservation Scientists	Agriculture, Forestry, and Other Land Use	-10	5	-17%	10%
19-1032	Foresters	Agriculture, Forestry, and Other Land Use	-7	0	-43%	0%
19-4012	Agricultural Technicians	Agriculture, Forestry, and Other Land Use	17	5	53%	10%
19-4071	Forest and Conservation Technicians	Agriculture, Forestry, and Other Land Use	40	3	58%	2%
45-1011	First-Line Supervisors of Farming, Fishing, and Forestry Workers	Agriculture, Forestry, and Other Land Use	-22	2	-23%	2%
45-2011	Agricultural Inspectors	Agriculture, Forestry, and Other Land Use	-11	5	-23%	13%
45-2091	Agricultural Equipment Operators	Agriculture, Forestry, and Other Land Use	-31	0	-28%	1%
45-2092	Farmworkers and Laborers, Crop, Nursery, and Greenhouse	Agriculture, Forestry, and Other Land Use	-134	-3	-15%	0%
45-2093	Farmworkers, Farm, Ranch, and Aquacultural Animals	Agriculture, Forestry, and Other Land Use	-148	-36	-40%	-16%
45-2099	Agricultural Workers, All Other	Agriculture, Forestry, and Other Land Use	-40	-17	-21%	-11%

45-4011	Forest and Conservation Workers	Buildings, Transportation (on and off Road)	25	6	66%	10%
47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	Buildings	852	167	49%	6%
47-2031	Carpenters	Buildings, Transportation (on and off Road)	637	61	28%	2%
47-2061	Construction Laborers	Transportation (on and off Road)	1,520	395	40%	7%
47-2071	Paving, Surfacing, and Tamping Equipment Operators	Buildings, Transportation (on and off Road)	4	25	1%	8%
47-2111	Electricians	Buildings, Transportation (on and off Road)	609	270	27%	9%
47-2131	Insulation Workers, Floor, Ceiling, and Wall	Buildings	6	6	4%	3%
47-2152	Plumbers, Pipefitters, and Steamfitters	Buildings	566	182	53%	11%
47-2181	Roofers	Buildings	133	18	39%	4%
47-2231	Solar Photovoltaic Installers	Buildings, Energy	23	12	132%	31%
47-3012	Helpers--Carpenters	Buildings	-31	2	-16%	2%
47-3013	Helpers--Electricians	Buildings	34	4	14%	1%
47-3015	Helpers--Pipelayers, Plumbers,	Buildings	-34	20	-18%	12%

	Pipefitters, and Steamfitters					
47-3016	Helpers--Roofers	Buildings	-5	0	-36%	0%
47-4011	Construction and Building Inspectors	Buildings	82	22	51%	9%
47-4051	Highway Maintenance Workers	Transportation (on and off Road)	-3	34	-1%	20%
49-2093	Electrical and Electronics Installers and Repairers, Transportation Equipment	Transportation (on and off Road)	-18	0	-56%	2%
49-2095	Electrical and Electronics Repairers, Powerhouse, Substation, and Relay	Energy	39	5	84%	6%
49-2096	Electronic Equipment Installers and Repairers, Motor Vehicles	Transportation (on and off Road)	0	-2	-3%	-16%
49-3023	Automotive Service Technicians and Mechanics	Transportation (on and off Road)	111	178	4%	6%
49-9021	Heating, Air Conditioning, and Refrigeration Mechanics and Installers	Buildings	380	216	34%	14%
49-9031	Home Appliance Repairers	Buildings	-11	-4	-9%	-3%
49-9051	Electrical Power-Line Installers and Repairers	Energy	-21	31	-5%	8%

49-9081	Wind Turbine Service Technicians	Energy	1	0	13%	5%
51-8012	Power Distributors and Dispatchers	Energy	-19	0	-68%	0%
51-8013	Power Plant Operators	Energy	-4	-8	-4%	-8%
53-3032	Heavy and Tractor-Trailer Truck Drivers	Transportation (on and off Road), Solid Waste and Waste Water	673	771	9%	10%
53-3033	Light Truck Drivers	Transportation (on and off Road)	1,149	583	44%	16%
53-3052	Bus Drivers, Transit and Intercity	Transportation (on and off Road)	-115	21	-28%	7%
53-6041	Traffic Technicians	Transportation (on and off Road)	-26	3	-35%	7%
53-7051	Industrial Truck and Tractor Operators	Solid Waste and Waste Water	377	192	33%	13%
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	Solid Waste and Waste Water	2,212	1,115	29%	11%
53-7081	Refuse and Recyclable Material Collectors	Solid Waste and Waste Water	135	64	38%	13%

Table 23. Employment Concentration 2015-2035

SOC	Description	Relevant Sectors	2015 Employment Concentration	2020 Employment Concent	2025 Employment Concent	2030 Employment Concentration	2035 Employment Concentration

				ratio n	ratio n		
11-9013	Farmers, Ranchers, and Other Agricultural Managers	Agriculture, Forestry, and Other Land Use	1.10	0.71	0.55	0.45	0.39
11-9021	Construction Managers	Buildings	1.33	1.34	1.12	1.09	1.08
13-1041	Compliance Officers	Buildings	0.85	1.06	1.01	1.01	1.01
17-2051	Civil Engineers	Transportation (on and off Road)	0.90	0.91	1.03	1.03	1.03
17-2071	Electrical Engineers	Energy	0.90	0.86	0.84	0.85	0.86
19-1013	Soil and Plant Scientists	Agriculture, Forestry, and Other Land Use	1.06	1.40	0.68	0.67	0.66
19-1031	Conservation Scientists	Agriculture, Forestry, and Other Land Use	0.94	1.12	0.60	0.60	0.60
19-1032	Foresters	Agriculture, Forestry, and Other Land Use	0.62	0.48	0.17	0.18	0.22
19-4012	Agricultural Technicians	Agriculture, Forestry, and Other Land Use	0.80	1.13	0.89	0.89	0.88
19-4071	Forest and Conservation Technicians	Agriculture, Forestry, and Other Land Use	0.75	0.93	1.10	1.08	1.06
45-1011	First-Line Supervisors of Farming, Fishing, and Forestry Workers	Agriculture, Forestry, and Other Land Use	0.64	0.57	0.46	0.44	0.42
45-2011	Agricultural Inspectors	Agriculture, Forestry, and Other Land Use	1.09	0.87	0.90	0.92	0.94

45-2091	Agricultural Equipment Operators	Agriculture, Forestry, and Other Land Use	0.57	0.43	0.38	0.36	0.34
45-2092	Farmworkers and Laborers, Crop, Nursery, and Greenhouse	Agriculture, Forestry, and Other Land Use	0.50	0.40	0.46	0.44	0.43
45-2093	Farmworkers, Farm, Ranch, and Aquacultural Animals	Agriculture, Forestry, and Other Land Use	0.79	0.58	0.46	0.41	0.37
45-2099	Agricultural Workers, All Other	Agriculture, Forestry, and Other Land Use	1.06	0.90	0.58	0.52	0.47
45-4011	Forest and Conservation Workers	Buildings, Transportation (on and off Road)	0.99	1.27	1.03	1.04	1.04
47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	Buildings	1.06	0.97	1.07	1.06	1.05
47-2031	Carpenters	Buildings, Transportation (on and off Road)	0.84	0.96	1.02	1.00	0.99
47-2061	Construction Laborers	Transportation (on and off Road)	1.12	1.24	1.35	1.33	1.32
47-2071	Paving, Surfacing, and Tamping Equipment Operators	Buildings, Transportation (on and off Road)	2.00	2.27	2.22	2.21	2.21
47-2111	Electricians	Buildings, Transportation (on and off Road)	1.24	1.45	1.23	1.21	1.20
47-2131	Insulation Workers, Floor, Ceiling, and Wall	Buildings	2.28	2.37	1.50	1.48	1.46
47-2152	Plumbers, Pipefitters, and Steamfitters	Buildings	0.88	1.28	1.14	1.15	1.16

47-2181	Roofers	Buildings	0.89	0.93	0.98	0.96	0.95
47-2231	Solar Photovoltaic Installers	Buildings, Energy	0.56	0.09	0.50	0.50	0.50
47-3012	Helpers--Carpenters	Buildings	1.79	2.33	2.44	2.41	2.42
47-3013	Helpers--Electricians	Buildings	1.21	1.03	1.34	1.32	1.31
47-3015	Helpers--Pipelayers, Plumbers, Pipefitters, and Steamfitters	Buildings	1.29	1.56	1.19	1.21	1.23
47-3016	Helpers--Roofers	Buildings	0.50	0.81	0.16	0.18	0.18
47-4011	Construction and Building Inspectors	Buildings	0.60	0.57	0.59	0.60	0.61
47-4051	Highway Maintenance Workers	Transportation (on and off Road)	0.44	0.37	0.39	0.41	0.42
49-2093	Electrical and Electronics Installers and Repairers, Transportation Equipment	Transportation (on and off Road)	0.66	0.51	0.49	0.46	0.45
49-2095	Electrical and Electronics Repairers, Powerhouse, Substation, and Relay	Energy	0.67	0.65	1.03	1.04	1.04
49-2096	Electronic Equipment Installers and Repairers, Motor Vehicles	Transportation (on and off Road)	0.44	0.67	0.62	0.63	0.59
49-3023	Automotive Service Technicians and Mechanics	Transportation (on and off Road)	1.27	1.26	1.21	1.20	1.20
49-9021	Heating, Air Conditioning, and Refrigeration Mechanics and Installers	Buildings	1.33	1.29	1.18	1.19	1.20

49-9031	Home Appliance Repairers	Buildings	1.03	0.96	0.98	0.95	0.92
49-9051	Electrical Power-Line Installers and Repairers	Energy	1.24	1.20	1.04	1.03	1.03
49-9081	Wind Turbine Service Technicians	Energy	0.36	0.20	0.26	0.22	0.20
51-8012	Power Distributors and Dispatchers	Energy	0.83	0.15	0.02	0.02	0.02
51-8013	Power Plant Operators	Energy	0.97	1.40	1.04	1.01	0.99
53-3032	Heavy and Tractor-Trailer Truck Drivers	Transportation (on and off Road), Solid Waste and Waste Water	1.42	1.25	1.24	1.23	1.23
53-3033	Light Truck Drivers	Transportation (on and off Road)	1.11	1.40	1.24	1.24	1.23
53-3052	Bus Drivers, Transit and Intercity	Transportation (on and off Road)	0.88	0.68	0.52	0.51	0.50
53-6041	Traffic Technicians	Transportation (on and off Road)	3.27	2.53	1.86	1.85	1.84
53-7051	Industrial Truck and Tractor Operators	Solid Waste and Waste Water	0.77	0.75	0.69	0.70	0.71
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	Solid Waste and Waste Water	1.13	1.08	1.17	1.17	1.17
53-7081	Refuse and Recyclable Material Collectors	Solid Waste and Waste Water	1.04	1.04	1.17	1.19	1.21

Table 24. Wages 2025

SOC	Description	Relevant Sectors	Avg. Annual Earnings	Median Annual Earnings	Pct. 10 Annual Earnings	Pct. 25 Annual Earnings	Pct. 75 Annual Earnings	Pct. 90 Annual Earnings

11-9013	Farmers, Ranchers, and Other Agricultural Managers	Agriculture, Forestry, and Other Land Use	$61,086	$34,470	$5,504	$16,226	$66,340	$146,323
11-9021	Construction Managers	Buildings	$88,311	$72,758	$26,632	$49,597	$100,442	$145,342
13-1041	Compliance Officers	Buildings	$69,265	$62,681	$38,435	$47,431	$84,392	$106,014
17-2051	Civil Engineers	Transportation (on and off Road)	$99,764	$86,603	$62,909	$74,206	$113,793	$134,735
17-2071	Electrical Engineers	Energy	$100,038	$87,508	$59,423	$65,716	$118,378	$158,647
19-1013	Soil and Plant Scientists	Agriculture, Forestry, and Other Land Use	$67,874	$62,398	$47,818	$51,886	$76,740	$85,192
19-1031	Conservation Scientists	Agriculture, Forestry, and Other Land Use	$94,555	$97,758	$74,773	$84,862	$106,588	$119,109
19-1032	Foresters	Agriculture, Forestry, and Other Land Use	Insf. Data	Insf. Data	Insf. Data	Insf. Data	Insf. Data	Insf. Data
19-4012	Agricultural Technicians	Agriculture, Forestry, and	$43,733	$40,839	$34,181	$34,522	$46,605	$51,422

		Other Land Use						
19-4071	Forest and Conservation Technicians	Agriculture, Forestry, and Other Land Use	$37,203	$33,096	$24,100	$28,646	$46,662	$53,795
45-1011	First-Line Supervisors of Farming, Fishing, and Forestry Workers	Agriculture, Forestry, and Other Land Use	$55,407	$51,207	$22,677	$34,674	$65,926	$83,290
45-2011	Agricultural Inspectors	Agriculture, Forestry, and Other Land Use	$42,276	$38,946	$27,711	$31,587	$49,916	$58,416
45-2091	Agricultural Equipment Operators	Agriculture, Forestry, and Other Land Use	$40,934	$36,545	$17,861	$27,867	$46,158	$58,664
45-2092	Farmworkers and Laborers, Crop, Nursery, and Greenhouse	Agriculture, Forestry, and Other Land Use	$33,259	$29,387	$15,635	$23,236	$36,789	$44,615
45-2093	Farmworkers, Farm, Ranch, and Aquacultural Animals	Agriculture, Forestry, and Other Land Use	$36,127	$29,653	$15,081	$19,957	$39,394	$54,746

45-2099	Agricultural Workers, All Other	Agriculture, Forestry, and Other Land Use	$51,644	$45,308	$17,926	$27,726	$72,706	$83,626
45-4011	Forest and Conservation Workers	Buildings, Transportation (on and off Road)	$41,699	$29,032	$16,550	$21,381	$42,782	$54,762
47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	Buildings	$69,257	$64,166	$44,576	$51,525	$78,777	$98,615
47-2031	Carpenters	Buildings, Transportation (on and off Road)	$54,484	$46,568	$27,298	$36,346	$56,746	$71,827
47-2061	Construction Laborers	Transportation (on and off Road)	$46,757	$41,620	$27,535	$33,996	$51,472	$62,402
47-2071	Paving, Surfacing, and Tamping Equipment Operators	Buildings, Transportation (on and off Road)	$44,671	$44,112	$31,125	$37,572	$49,678	$56,606
47-2111	Electricians	Buildings, Transportation (on and off Road)	$56,117	$50,217	$35,213	$40,234	$62,976	$78,151

47-2131	Insulation Workers, Floor, Ceiling, and Wall	Buildings	$41,919	$35,865	$28,902	$31,914	$48,257	$60,692
47-2152	Plumbers, Pipefitters, and Steamfitters	Buildings	$55,578	$48,615	$35,035	$40,596	$62,678	$73,920
47-2181	Roofers	Buildings	$48,900	$43,418	$28,783	$35,959	$51,676	$61,984
47-2231	Solar Photovoltaic Installers	Buildings, Energy	$37,206	$34,963	$28,673	$31,382	$41,712	$49,437
47-3012	Helpers--Carpenters	Buildings	$32,146	$30,737	$23,189	$24,259	$37,218	$41,054
47-3013	Helpers--Electricians	Buildings	$36,983	$34,911	$29,541	$31,452	$38,794	$47,360
47-3015	Helpers--Pipelayers, Plumbers, Pipefitters, and Steamfitters	Buildings	$39,487	$38,667	$34,520	$36,195	$42,211	$43,474
47-3016	Helpers--Roofers	Buildings	Insf. Data	Insf. Data	Insf. Data	Insf. Data	Insf. Data	Insf. Data
47-4011	Construction and Building Inspectors	Buildings	$66,531	$57,854	$34,801	$45,864	$73,772	$87,301
47-4051	Highway Maintena	Transportation	$44,288	$43,983	$35,139	$38,941	$49,172	$56,568

	nce Workers	(on and off Road)						
49-2093	Electrical and Electronics Installers and Repairers, Transportation Equipment	Transportation (on and off Road)	$59,237	$54,252	$47,621	$49,109	$70,229	$79,448
49-2095	Electrical and Electronics Repairers, Powerhouse, Substation, and Relay	Energy	$97,388	$100,316	$85,964	$93,919	$108,205	$109,889
49-2096	Electronic Equipment Installers and Repairers, Motor Vehicles	Transportation (on and off Road)	$49,791	$43,566	$37,323	$39,910	$51,553	$84,823
49-3023	Automotive Service Technicians and Mechanics	Transportation (on and off Road)	$48,236	$45,388	$27,996	$34,176	$60,108	$76,499
49-9021	Heating, Air Conditioning, and Refrigeration Mechani	Buildings	$54,156	$48,225	$36,818	$39,426	$62,821	$77,525

	cs and Installers							
49-9031	Home Appliance Repairers	Buildings	$51,136	$46,786	$20,888	$35,817	$57,317	$78,438
49-9051	Electrical Power-Line Installers and Repairers	Energy	$76,392	$85,016	$39,379	$56,769	$100,364	$101,483
49-9081	Wind Turbine Service Technicians	Energy	Insf. Data	Insf. Data	Insf. Data	Insf. Data	Insf. Data	Insf. Data
51-8012	Power Distributors and Dispatchers	Energy	Insf. Data	Insf. Data	Insf. Data	Insf. Data	Insf. Data	Insf. Data
51-8013	Power Plant Operators	Energy	$96,377	$102,722	$70,269	$93,358	$108,057	$109,159
53-3032	Heavy and Tractor-Trailer Truck Drivers	Transportation (on and off Road), Solid Waste and Waste Water	$54,625	$50,036	$35,171	$42,847	$62,863	$74,283
53-3033	Light Truck Drivers	Transportation (on and off Road)	$45,799	$39,654	$25,917	$32,783	$54,291	$85,322
53-3052	Bus Drivers, Transit and Intercity	Transportation (on and off Road)	$45,248	$42,829	$30,119	$35,673	$52,246	$53,146

53-6041	Traffic Technicians	Transportation (on and off Road)	$57,189	$54,536	$39,293	$45,627	$68,347	$75,436
53-7051	Industrial Truck and Tractor Operators	Solid Waste and Waste Water	$41,607	$38,029	$32,992	$35,860	$44,588	$57,238
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	Solid Waste and Waste Water	$37,259	$35,610	$28,735	$32,997	$39,834	$47,103
53-7081	Refuse and Recyclable Material Collectors	Solid Waste and Waste Water	$33,021	$32,431	$19,365	$21,786	$37,281	$47,346

Table 25. Gap Analysis

Occupations Impacted by CCAP Measures	**Relevant Sector**	**Total Employment 2024**	**Projected Employment 2025**	***Supply***	***Demand Subtotals***		***Shortage or Surplus***	**Percent of Total Workforce**
				2025 Hires	**Growth (New Jobs) 2025**	**Projected Separations 2025**	**Potential Workforce Shortage for CCAP Implementation 2025**	
Construction Laborers	Transportation (on and off Road)	5,273	5,363	3,805	90	3,642	**73**	1.4%
Carpenters	Buildings,	2,882	2,908	1,290	26	1,195	**69**	2.4%

	Transportation (on and off Road)							
Electricians	Buildings, Transportation (on and off Road)	2,782	2,842	1,522	61	1,396	**66**	2.3%
Roofers	Buildings	471	476	342	5	285	**51**	10.8%
Helpers--Electricians	Buildings	269	272	571	3	520	**48**	17.6%
Heating, Air Conditioning, and Refrigeration Mechanics and Installers	Buildings	1,465	1,510	916	45	825	**46**	3.1%
Farmers, Ranchers, and Other Agricultural Managers	Agriculture, Forestry, and Other Land Use	914	869	78	(44)	77	**45**	5.2%
Plumbers, Pipefitters, and Steamfitters	Buildings	1,584	1,629	956	45	867	**44**	2.7%
First-Line Supervisors of Construction Trades and Extraction Workers	Buildings	2,562	2,607	1,091	45	1,008	**37**	1.4%
Helpers--Pipelayers, Plumbers, Pipefitters, and Steamfitters	Buildings	156	161	367	5	330	**31**	19.5%

Helpers--Carpenters	Buildings	154	156	402	2	376	**25**	16.3%
Bus Drivers, Transit and Intercity	Transportation (on and off Road)	297	299	111	2	91	**18**	5.9%
Compliance Officers	Buildings	1,098	1,123	421	24	383	**14**	1.2%
Construction Managers	Buildings	1,793	1,822	510	30	468	**12**	0.7%
Farmworkers, Farm, Ranch, and Aquacultural Animals	Agriculture, Forestry, and Other Land Use	232	226	138	(6)	138	**7**	3.2%
Forest and Conservation Technicians	Agriculture, Forestry, and Other Land Use	107	108	41	1	35	**5**	4.3%
Agricultural Workers, All Other	Agriculture, Forestry, and Other Land Use	148	145	98	(3)	98	**3**	2.4%
Home Appliance Repairers	Buildings	111	110	35	(1)	32	**3**	3.0%
Electrical and Electronics Installers and Repairers, Transportation Equipment	Transportation (on and off Road)	14	14	12	(0)	9	**3**	21.9%
Construction and Building Inspectors	Buildings	239	243	80	4	73	**3**	1.1%
Insulation Workers,	Buildings	168	169	118	1	114	**2**	1.3%

Floor, Ceiling, and Wall								
Traffic Technicians	Transportation (on and off Road)	49	49	24	1	21	**2**	4.3%
Refuse and Recyclable Material Collectors	Solid Waste and Waste Water	472	487	297	15	280	**2**	0.4%
Agricultural Technicians	Agriculture, Forestry, and Other Land Use	48	49	20	1	17	**2**	3.8%
Highway Maintenance Workers	Transportation (on and off Road)	161	167	49	5	42	**1**	0.9%
Conservation Scientists	Agriculture, Forestry, and Other Land Use	46	47	20	1	17	**1**	3.1%
First-Line Supervisors of Farming, Fishing, and Forestry Workers	Agriculture, Forestry, and Other Land Use	76	76	55	0	54	**1**	1.9%
Agricultural Equipment Operators	Agriculture, Forestry, and Other Land Use	81	81	67	0	65	**1**	1.5%
Soil and Plant Scientists	Agriculture, Forestry, and	40	41	16	1	13	**1**	3.0%

	Other Land Use							
Power Plant Operators	Energy	99	98	21	(1)	21	**1**	0.8%
Forest and Conservation Workers	Buildings, Transportation (on and off Road)	62	64	37	2	35	**1**	1.1%
Agricultural Inspectors	Agriculture, Forestry, and Other Land Use	36	37	14	1	12	**1**	1.4%
Electrical and Electronics Repairers, Powerhouse, Substation, and Relay	Energy	84	85	38	1	36	**1**	0.6%
Electronic Equipment Installers and Repairers, Motor Vehicles	Transportation (on and off Road)	16	16	5	(0)	5	**0**	0.4%
Foresters	Agriculture, Forestry, and Other Land Use	9	9	5	0	5	**0**	0.0%
Helpers--Roofers	Buildings	9	9	5	0	5	**0**	0.0%
Power Distributors and Dispatchers	Energy	9	9	0	0	0	**0**	0.0%
Wind Turbine Service Technicians	Energy	10	10	5	0	5	**0**	1.6%

Solar Photovoltaic Installers	Buildings, Energy	37	40	35	2	34	**0**	1.0%
Automotive Service Technicians and Mechanics	Transportation (on and off Road)	2,704	2,740	1,557	37	1,521	**-1**	0.0%
Electrical Engineers	Energy	433	447	153	14	144	**-5**	1.0%
Farmworkers and Laborers, Crop, Nursery, and Greenhouse	Agriculture, Forestry, and Other Land Use	755	756	704	1	711	**-8**	1.1%
Civil Engineers	Transportation (on and off Road)	1,026	1,048	385	22	372	**-9**	0.9%
Electrical Power-Line Installers and Repairers	Energy	357	366	211	9	214	**-12**	3.2%
Paving, Surfacing, and Tamping Equipment Operators	Buildings, Transportation (on and off Road)	292	298	175	6	182	**-13**	4.4%
Industrial Truck and Tractor Operators	Solid Waste and Waste Water	1,470	1,519	1,064	49	1,039	**-23**	1.5%
Light Truck Drivers	Transportation (on and off Road)	3,641	3,762	2,529	121	2,480	**-73**	1.9%
Laborers and Freight, Stock, and	Solid Waste and	9,680	9,927	10,326	247	10,216	**-138**	1.4%

Material Movers, Hand	Waste Water							
Heavy and Tractor-Trailer Truck Drivers	Transportation (on and off Road), Solid Waste and Waste Water	7,864	8,026	4,507	162	4,578	**-233**	2.9%

Top Certifications

Table 26. EV Maintenance

Certification
Electric Vehicle Infrastructure Training Program (EVITP)
Electric Vehicle Fundamentals (EVF) Certification
ASE xEV Certification
Automotive Service Excellence (ASE) Certification
ASE Advanced Engine Performance Certification
ASE Medium-Heavy Truck Certification
Automobile Parts Specialist Certification
ASE Auto Maintenance and Light Repair Certification
ASE Automobile Service Consultant

Table 27. Energy Auditor

Certification
BPI Home Energy Professional Energy Auditor certification
Certified Energy Auditor (CEA)
Home Energy Professional (HEP) Energy Auditor
Building Energy Assessment (BEAP) certification
Home Energy Auditor InterNACHI
Certified Industrial Energy Auditor (CEIA)
LEED Accredited Professional (AP)
Certified Energy Manager
Building Energy Modeling Professional Certification
Certified Electrical Safety Compliance Professional
Certified Building Commissioning Professional
Professional Engineer (PE) License
Operator Certification

System Operator Certification

Table 28. Construction Laborer

Certification
10-Hour OSHA General Industry Card
Commercial Driver's License (CDL)
CDL Class A License
30-Hour OSHA General Industry Card
NICET Certification (National Institute for Certification In Engineering Technologies)
OSHA Certification
Flagger Certification
ASNT Non-Destructive Tester
10-Hour OSHA Construction Card
Certified Crane Operator
Tanker And Hazmat Combo X Endorsement
Hazmat Endorsement
Tanker Endorsement
Forklift Certification
CDL Class C License
NCCER Core Curriculum
NCCER Construction Craft Laborer

Table 29. Roof Top Solar

Certification
NABCEP PV Installation Professional (PVIP) Certification
Photovoltaics Installer/Designer (PV2) certification
PV Installation Professional (PVIP) Board Certification
PV Installer Specialist (PVIS) Board Certification
PV Technical Sales (PVTS) Board Certification
NABCEP Solar Installation Company Accreditation
SEI Solar Professionals Certificate Program (SPCP)
OSHA Construction Safety for Solar Installers
30-Hour OSHA General Industry Card
10-Hour OSHA General Industry Card
NCCER Electrical
NCCER Solar Photovoltaics

Table 30. Heat Pump

Certification
EPA Section 608 Technician Certification
NATE Certification with Heat Pump Installation Specialty
NATE Certification with Heat Pump Service Specialty
HVAC Excellence Heat Pump Service
HVAC Excellence Heat Pump Installer
HVAC Excellence Employment
Ready Heat Pump Certification
EPA Universal Certification
National Center For Construction Education & Research (NCCER) Certification
3rd Class Power Engineer Certificate
EPA 608 Technician Certification
10-Hour OSHA General Industry Card
HVAC Certification

Table 31. HVAC

Certification
EPA 608 Technician Certification
EPA 608 Certification
HVAC Excellence Certification
North American Technician Excellence (NATE) Certification
Refrigeration Service Engineers Society (RSES) Certification
HVAC/R Certification
EPA Universal Certification
HVAC Excellence Professional Level Certification
Master HVAC License
10-Hour OSHA General Industry Card
30-Hour OSHA General Industry Card

Table 32. Farmers

Certification
Pesticide Applicator License
Accredited Farm Manager (AFM)

Table 33. Landscapers

Certification

Landscape Industry Certified (LIC) Programs (NALP)
Landscape Industry Certified Horticultural Technician (LIC-HT)
Landscape Industry Certified Lawn Care Technician (LIC-LCT)
Certified Landscape Irrigation Auditor (CLIA)
Certified Irrigation Technician (CIT)
Certified Landscape Irrigation Water Manager
Certified Arborist (ISA):
Certified Professional Landscape Designer (CPLD)
Certified Horticultural Technician (CHT)
Pesticide Applicator License
Commercial Driver's License (CDL)
CDL Class B License
Herbicide Applicator License

Table 34. Electricians

Certification
Certified Electrical Safety Compliance Professional (CESCP)
Master Electrician Certificate
Certified Electrical Safety Worker (CESW)
Electrical Project Management Institute (EPMI) Certification
Certified Electrical Safety Technician (CEST)
Journeyman Electrician License
Certified Energy Manager
LEED Green Associate
NCCER Solar Photovoltaics
Apprentice Electrician
Green Energy Certification
NCCER Electrical
NCCER Pipeline Electrical & Instrumentation
NICET Certification (National Institute For Certification In Engineering Technologies)
NICET Electrical Power Testing

Table 35. Electrical Engineers

Certification
Bachelor of Science (BS), Electrical Engineering
Bachelor of Engineering (BEng)
Professional Engineer (PE) License
Certified Energy Manager (CEM)
Certified Automation Professional (CAP)

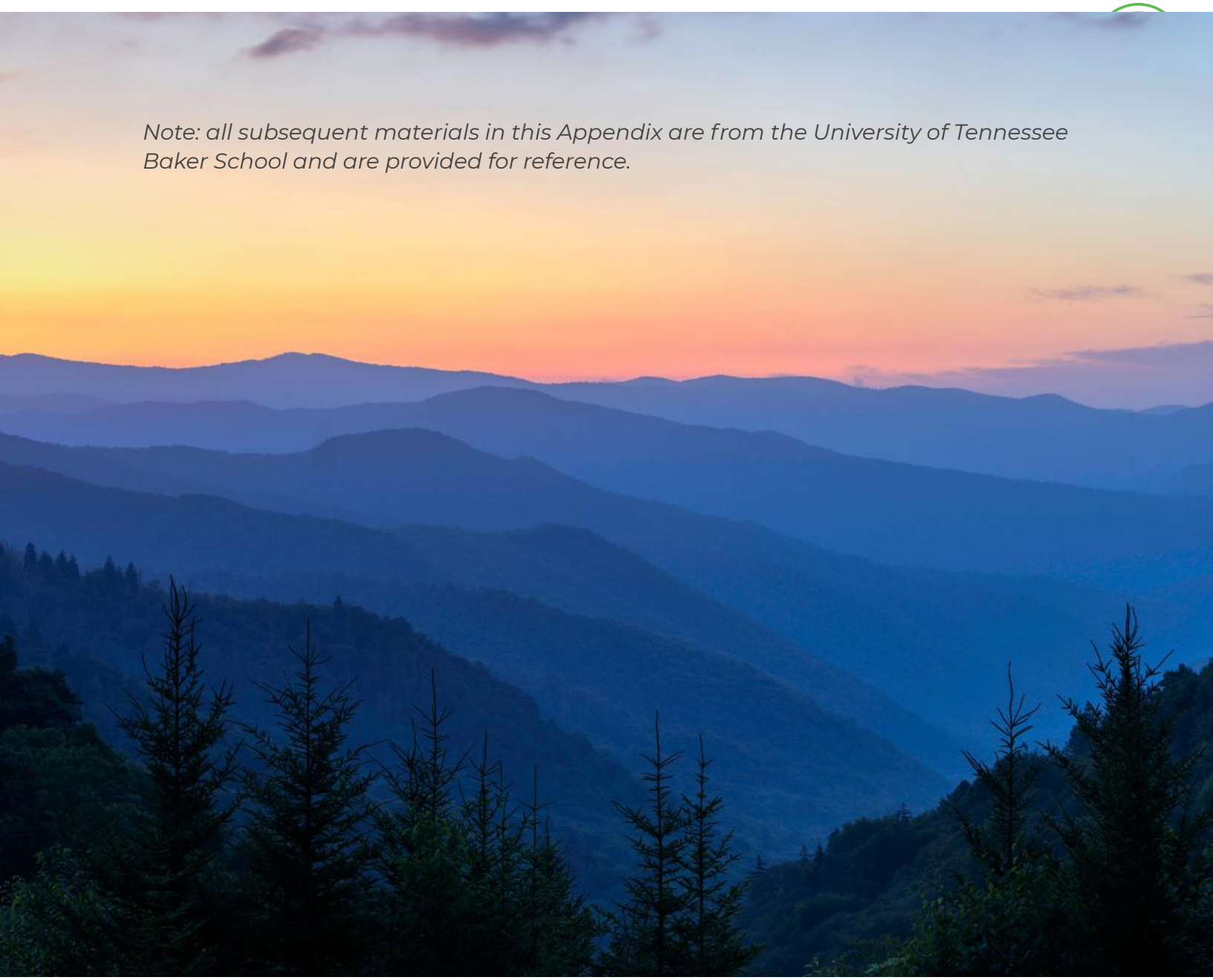
National Institute for Certification in Engineering Technologies (NICET)
LEED Accredited Professional (AP)
Project Management Professional Certification
Certified Information Systems Security Professional
Institute of Electrical and Electronics Engineers (IEEE)
Engineer in Training (EIT)
Certified Power Quality Professional

Table 36. Heavy Tractor-Trailer Drivers

Certification
Commercial Driver's License (CDL)
CDL Class A License
CDL Class B License
Tanker Endorsement
Transportation Worker Identification Credential (TWIC) Card
Hazmat Endorsement
Tanker And Hazmat Combo X Endorsement
Forklift Certification
CDL Class C License
Doubles Endorsement
DOT Certification
Triples Endorsement
Hazardous Materials Certification
Certified Crane Operator
Flagger Certification
Pallet Jack Certification

Table 37. Bus Drivers Transit

Certification
Commercial Driver's License (CDL)
Passenger Endorsement
CDL Class B License
Cardiopulmonary Resuscitation (CPR) Certification
First Aid Certification
CDL Class A License
Automated External Defibrillator (AED) Certification
CDL Class C License



Note: all subsequent materials in this Appendix are from the University of Tennessee Baker School and are provided for reference.

Energy Transition and Workforce Planning in Tennessee

Prepared for the Tennessee Department of Environment & Conservation

by the University of Tennessee, Knoxville | March 2025\\\

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Acronyms and Abbreviations

Btu	British Thermal Unit
CBO	Community-Based Organization
CIP	Classification of Instructional Programs
EIA	Energy Information Administration
DOE	Department of Energy
EPA	Environmental Protection Agency
ERS	Emission Reduction Sector
ERM	Emissions Reduction Measures
ERPAC	Emissions Reduction Planning Advisory Committee
EV	Electric Vehicle
GDP	Gross Domestic Product
ICE	Internal Combustion Engine
LPC	Local Power Company
MSA	Metropolitan Statistical Area
NAICS	North American Industrial Classification System
NETL	National Energy Technical Laboratory
OEP	Office of Energy Programs
SOC	Standard Occupational Code
TDEC	Tennessee Department of Environment and Conservation
TDLWD	Tennessee Department of Labor and Workforce Development
TN	Tennessee
TVA	Tennessee Valley Authority
TVERS	Tennessee Volunteer Emission Reduction Strategy
VPS	Tennessee Valley Authority's Valley Pathways Study

Key Definitions

Btu – British Thermal Unit
A British Thermal Unit (Btu) is a measure of heat energy. It is defined as the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit.

CBO – Community-Based Organization
A Community-Based Organization (CBO) is typically a nonprofit entity that operates within a specific community or geographical area, aiming to address local needs and improve the well-being of its residents.

CIP – Classification of Instructional Programs
The Classification of Instructional Programs (CIP) provides a taxonomic scheme that supports the accurate tracking and reporting of academic fields of study and program completion activity.

DOE – Department of Energy
The U.S. Department of Energy (DOE) manages the United States' nuclear infrastructure and administers the country's energy policy. The Department of Energy also funds scientific research in the field.

Fossil Fuels
An energy source formed in the Earth's crust from decayed organic material. The common fossil fuels are petroleum (crude oil), coal, and natural gas.

EIA – Energy Information Administration
The U.S. Energy Information Administration (EIA) is the statistical and analytical agency within the U.S. Department of Energy. EIA collects, analyzes, and disseminates independent and impartial energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment.

Electrification of Economy
The electrification of the economy refers to the increasing use of technologies that run directly on electricity rather than fossil fuels.

Energy Innovation
Energy innovation refers to the process of creating and scaling new technologies, systems, or strategies that improve the performance, affordability, and sustainability of energy systems.

Energy Transition
The **energy transition** refers to the global shift from fossil fuel-based energy systems to sources like wind, solar, hydropower, and other renewables.

EPA – Environmental Protection Agency
The Environmental Protection Agency (EPA) is a United States federal agency established in 1970, tasked with protecting human health and the environment.

ERM – Emissions Reduction Measures
Emission reduction measures refer to measures to contribute to the minimization of greenhouse gas (GHG) emissions generated by an individual, organization, or country.

ERS – Emission Reduction Sector
An Emission Reduction Sector is a designated region identified for focused efforts to reduce emissions due to its significant contribution to air pollution levels.

ERPAC – Emissions Reduction Planning Advisory Committee
The Emissions Reduction Planning Advisory Committee (ERPAC) includes representatives from agencies and offices involved in environmental and workforce development efforts to align climate planning with job quality and workforce development.

EV – Electric Vehicle
An Electric Vehicle (EV) is a vehicle that is powered entirely or partially by electricity. Types include Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Fuel Cell Electric Vehicles (FCEVs).

GDP – Gross Domestic Product
The Gross Domestic Product (GDP) refers to the total monetary value of all goods and services produced within a country or region over a specific period, typically a year or a quarter.

ICE – Internal Combustion Engine
An Internal Combustion Engine (ICE) is an engine in which the combustion of fuel occurs with an oxidizer (usually air) in a combustion chamber.

MSA – Metropolitan Statistical Area
A Metropolitan Statistical Area (MSA) is defined by the U.S. Office of Management and Budget as a region featuring at least one urbanized area with a minimum population of 50,000, along with adjacent territories that have a high degree of social and economic integration with the core.

NAICS – North American Industry Classification System
The North American Industry Classification System (NAICS) is a collaborative business classification system developed by the United States, Canada, and Mexico to standardize and compare business activity statistics across these countries.

NETL – National Energy Technology Laboratory
The National Energy Technology Laboratory (NETL) is a U.S. Department of Energy laboratory that focuses on applied research for the clean production and use of domestic energy resources.

OEP – Office of Energy Programs
The **Office of Energy Programs** is a division within the **Tennessee Department of Environment and Conservation (TDEC) that serves as the state's** primary agency for energy-related policy, planning, and program implementation.

Recoverable Reserves
Recoverable reserves refer to the portion of a natural resource that can be **technically and economically extracted** from known deposits under current conditions.

SOC – Standard Occupational Classification
The Standard Occupational Classification (SOC) system is used by federal statistical agencies to classify workers into occupational categories for the purpose of collecting, calculating, or disseminating data.

TDEC – Tennessee Department of Environment and Conservation
The Tennessee Department of Environment and Conservation (TDEC) is the state agency responsible for protecting and improving the quality of Tennessee's air, land, and water through a responsible regulatory system.

TDLWD – Tennessee Department of Labor and Workforce Development (TDLWD)
The **Tennessee Department of Labor and Workforce Development (TDLWD)** is a state agency responsible for administering programs and services that support workforce development, labor standards, and economic opportunity across Tennessee.

TN – Tennessee
TN is the postal abbreviation for the state of Tennessee in the United States.

TVA – Tennessee Valley Authority
The Tennessee Valley Authority (TVA) is a federally owned corporation in the United States that provides electricity for business customers and local power companies, serving parts of seven southeastern states.

TVERS – Tennessee Volunteer Emission Reduction Strategy
The Tennessee Volunteer Emission Reduction Strategy (TVERS) is an initiative aimed at reducing greenhouse gas emissions in Tennessee through various programs and policies.

VPS – Tennessee Valley Authority's Valley Pathways Study
The Valley Pathways Study (VPS) by the Tennessee Valley Authority is a comprehensive analysis aimed at identifying strategies for achieving a net-zero carbon energy future in the Tennessee Valley region.

Executive Summary

This report responds to the needs of businesses, individuals, education service providers, and other stakeholders to address workforce development challenges arising from the ongoing energy transition. The **energy transition** refers to the global shift from fossil fuel-based energy systems based on crude oil, coal, and natural gas, to sources like wind, solar, hydropower, and other renewables.[14] This transition also encompasses improvements in energy efficiency, electrification of end-use sectors, and the modernization of power grids.[15] The energy transition—driven largely by electrification—will impact nearly every sector at both the national and state levels.

As stakeholders navigate shifting business landscapes and labor market demands, there is a critical need for guidance on effective education and training programs. This report serves two primary purposes. *First*, it provides industry employment and occupational projections for Tennessee and its three largest metropolitan statistical areas (MSAs): Knoxville, Memphis, and Nashville related to the energy transition. *Second*, it offers an overview of education and training resources available to support the projected needs for workforce adaptation and shifts in market demands.

Key Findings

- **Identifying workforce and business training needs is essential to effective service delivery.** A key aspect of this process involves forecasting future labor demands linked to the energy transition. While economic projections for Tennessee and the broader U.S. incorporate the energy transition alongside other macroeconomic trends, isolating its specific impact remains challenging due to its interconnectedness with broader economic forces.

[14] Yu Yang, Siyou Xia, Ping Huang, and Junxi Qian, "Energy Transition: Connotations, Mechanisms and Effects," *Energy Strategy Reviews* 52 (2024): 101320, https://doi.org/10.1016/j.esr.2024.101320. Accessed April 2025.

[15] Matthew N. Murray, *Energy Transition: An Annual Assessment of the Tennessee Energy Sector: 2024*, prepared for the Tennessee State Energy Policy Council (Nashville: Baker School of Public Policy and Public Affairs, August 2024), https://comptroller.tn.gov/content/dam/cot/energy-policy-council/documents/reports/sepc-reports/reports-of-2024/SEPCAnnualAssessment2024FINAL.pdf

- **Employment projections take a dual approach.** This analysis examines both business sectors likely to experience direct effects from the energy transition and the evolving occupational needs that accompany industry shifts.

- **Tennessee offers a robust network of education and training programs.** State and local governments, nonprofit organizations, and other entities provide a wide range of workforce development programs and initiatives. Research conducted for this report indicates that these programs are both flexible and effective, largely due to strong collaboration between businesses and education providers—enhancing communication, responsiveness, and overall program success.

Introduction

Overview

Energy innovation— the process of creating and scaling new technologies, systems, or strategies that improve the performance, affordability, and sustainability of energy systems[16]— is becoming increasingly critical as global consumption is forecast to rise at its fastest pace in recent years, growing at close to 4% annually through 2027.[17] In his State of the State address on February 10, 2025, Governor Bill Lee of the State of Tennessee noted, "the Volunteer State is on track to be the epicenter of energy innovation" noting that the decision of companies to locate in the state, "hinges on two questions: do you have the energy, and do you have the workers?" [18]

The answers to these questions are especially urgent for Tennessee, which consumes over three times more energy than it produces. [19] The state's ability to expand energy production is constrained by the limited availability of **recoverable reserves**[20]— the portion of a natural resource that can be **technically and economically extracted** from known deposits under current conditions— for extraction.[21] The lack of recoverable reserves in Tennessee mean that **fossil fuels**, which include crude oil, coal, and natural gas,[22] account for less than 1% of Tennessee's state-sourced energy production. For instance, the state no longer produces coal, as recoverable reserves total just 0.2% of the U.S. supply.[23] Existing natural gas and crude oil recoverable reserves are similarly minimal, resulting in limited in-state production. As a result, Tennessee's state-sourced energy production depends largely on nuclear power (78%) and renewable sources (21%), specifically wood, waste,

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[16] U.S. Department of Energy. "Why Energy Innovation Matters." *Office of Energy Efficiency and Renewable Energy*. Accessed June 2, 2025. https://www.energy.gov/eere/why-energy-innovation-matters.
[17] International Energy Agency (IEA), *Growth in Global Electricity Demand is Set to Accelerate in the Coming Years as Power-Hungry Sectors Expand*, https://www.iea.org/news/growth-in-global-electricity-demand-is-set-to-accelerate-in-the-coming-years-as-power-hungry-sectors-expand. Accessed March 2025.
[18] Office of the Governor of Tennessee, *2025 State of the State Address*, https://www.tn.gov/governor/sots/2025-state-of-the-state-address. Accessed March 2025.
[19] U.S. Energy Information Administration (EIA), *Tennessee State Energy Profile and Analysis*, https://www.eia.gov/state/analysis.php?sid=TN. Accessed March 2025.
[20] Elsevier. "Recoverable Reserve." *ScienceDirect Topics*. Accessed May 15, 2025. https://www.sciencedirect.com/topics/engineering/recoverable-reserve.
[21] Such as coal, natural gas, and crude oil.
[22] U.S. Energy Information Administration. "Fossil Fuel." *EIA Glossary*. Accessed May 10, 2025. https://www.eia.gov/tools/glossary/index.php?id=Fossil%20fuel.
[23] There are ligate coal reserves in West Tennessee, but it is not considered economically effective to recover them. Ligate coal is the lowest grade of coal due to its low heating value and high moisture content. For more information see: https://www.tn.gov/environment/program-areas/tennessee-geological-survey/geology-redirect/tennessee-s-mineral-industry.html

biofuels, and hydroelectric power.[24] However, these sources only cover approximately one-third of the state's energy needs. To meet existing demand, the state is importing approximately two-thirds of the energy it consumes, making it vulnerable to price volatility and supply disruptions. Tennessee's current energy portfolio underscores the urgent need for more efficient and long-term energy solutions.

Over the last decade, energy initiatives have gained momentum across Tennessee. The **Tennessee Department of Environment and Conservation's (TDEC)** and its **Office of Energy Programs (OEP)** have played pivotal roles in this transformation, offering funding, technical assistance, and educational outreach. Tennessee is currently exploring an expansion of nuclear power production[25] and has been developing wind and solar as the most viable additions to the state's energy production portfolio.[26] The **Tennessee Valley Authority (TVA)** has led these efforts and has established the **Dispersed Power Production Program**, allowing customers to sell excess energy back to the grid, supporting the decentralization and diversification of production by networking disparate providers.[27] In parallel, the **EmPower TN Program** has provided incentives for energy-efficient upgrades in public buildings and schools, highlighting that efficiency is as vital as generation in achieving energy sustainability.[28] Nonetheless, challenges remain in scaling Tennessee's energy portfolio while maintaining grid reliability and cost control.

A crucial driver of this transition is the **electrification of the economy**— the replacement of fossil-fuel-powered systems with electric technologies across transportation, industry, construction, commercial establishments and agriculture.[29] Tennessee has positioned itself as a national leader in this shift. Although Tennessee's overall energy consumption exceeds its state-produced supply, as noted above, it produces low-cost electricity relative to the national average, approximately 12% less per kilowatt-hour across all

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[24] U.S. Energy Information Administration. 2024. "State Energy Data System (SEDS)." Last modified June 28, 2024. https://www.eia.gov/state/seds/.
[25] U.S. Department of Energy. "Oak Ridge Multibillion-Dollar Nuclear Project Is Largest Investment in Tennessee History." *Office of Environmental Management*, March 22, 2024. https://www.energy.gov/em/articles/oak-ridge-multibillion-dollar-nuclear-project-largest-investment-tennessee-history.
[26] U.S. Energy Information Administration. "Tennessee State Energy Profile." Last modified October 17, 2024. https://www.eia.gov/state/analysis.php?sid=TN.
[27] Tennessee Valley Authority. 2025. "Dispersed Power Production Program." Last modified May 19, 2025. https://www.tva.com/energy/valley-renewable-energy/dispersed-power-production-program.
[28] Tennessee Department of Environment and Conservation. "EmPower TN Energy Efficiency Projects." Accessed May 15, 2025. https://www.tn.gov/environment/program-areas/energy/state-energy-office--seo-/programs-projects/programs-and-projects/special-energy-projects0/empower-tn-energy-efficiency-projects.html.
[29] U.S. Department of Energy. "What Is Electrification?" *Electricity Insights*. Accessed June 2, 2025. https://www.energy.gov/electricity-insights/what-electrification.

sectors.[30] In addition, the state is becoming a destination for energy innovation in automotive manufacturing. According to the **Tennessee Department of Economic and Community Development**, more than 20,000 Tennesseans are employed by companies with **electric vehicle (EV)** operations, with $16.2 billion in capital from EV projects having been invested since 2017.[31] It is clear that the future of energy will increasingly rely on electrification, spurred by emerging technology, evolving consumer behavior, and policy shifts. Electrification, fueled by technological innovation, consumer demand, and evolving policy, will shape the future of work across all sectors. As such, workforce development will be essential to ensure the state can adapt to disruption and seize emerging opportunities.

A proactive approach is needed to support both declining and emerging industries. Targeted education and re-skilling—whether within current employment contexts or through new job pathways—will be critical to mitigating displacement. At the same time, rising sectors will require specialized talent. For example, TVA's consideration of **small modular reactors (SMRs)**,[32] highlights the importance of aligning workforce readiness with infrastructure and technology deployment. Federal investments tied to grid modernization and renewable energy initiatives will further shape workforce needs. To maximize the impact of these resources, Tennessee must prioritize timely, accessible, and strategically aligned workforce development—ensuring that all communities benefit from the state's transition to a more innovative and sustainable energy future.

Without a coordinated approach, Tennessee risks weakening its strong manufacturing economy and forfeiting its competitive edge. However, if managed effectively, the energy transition can fuel job creation while simultaneously advancing state-based energy production and emission reduction activities. This report draws on labor market projections to identify the skills and occupations most likely to be in demand and outlines strategies

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[30] U.S. Energy Information Administration. "Table 5.6.A. Average Price of Electricity to Ultimate Customers by End-Use Sector, by State." *Electric Power Monthly*, May 22, 2025. https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a.
[31] Tennessee Department of Economic and Community Development. "Electric Vehicle Manufacturing." Accessed June 2, 2025. https://tnecd.com/industries/electric-vehicle-manufacturing/.
[32] Matthew N. Murray, Elis Vllasi, and Jilleah G. Welch, "Economic Impacts of Construction and Operation of a Small Modular Reactor on Tennessee, prepared for the Tennessee Nuclear Advisory Council, October 29, 2024. https://www.tn.gov/content/dam/tn/environment/energy/documents/tneac/tneac_baker-center-smr-eia_final_oct-28-2024.pdf . The East Tennessee Economic Council maintains a Nuclear Industry Hub and has tracked employment and training needs tied to the nuclear sector. https://www.eteconline.org/nuclear-industry-hub/

for education, training, and retraining to build a resilient workforce aligned with energy sector needs.

Report Structure

This report presents a two-part analysis of the workforce and economic impacts of the energy transition. The *first component* examines industries directly affected by the transition, particularly those influenced by federal energy-related grants and evolving consumer and business spending patterns. These industries are critical not only because they will experience direct economic impacts but also because they serve as a nexus of workforce education and training—especially through employer-provided on-the-job training. Industries identified as significantly impacted by the energy transition are categorized within TDEC's eight **emission reduction sectors (ERS)**,[33] making them prime candidates for workforce development initiatives:

1. Transportation
2. Electricity Generation
3. Industry
4. Agriculture
5. Commercial and Residential Buildings
6. Waste and Materials Management
7. Wastewater
8. Land Use, Land Use Change, and Forestry

For this report, these sectors are mapped onto the **North American Industrial Classification System (NAICS)** which includes business organizations of all forms, such as corporations and companies of all sizes.[34] These industries are then mapped onto the **Standard Occupational Code (SOCs)** system which supports data and statistical analysis for workers within and across job classifications to define the labor force needs. As a final step, this labor force is mapped onto the **Classification of Instructional Programs (CIP)**, which is used by the U.S. Department of Education to classify academic programs at institutions of higher education. This mapping is reflected in **Diagram 1** below.

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[33] U.S. Environmental Protection Agency. *Tennessee Priority Climate Action Plan*. February 2024. https://www.epa.gov/system/files/documents/2024-02/tn-pcap.pdf.
[34] U.S Census Bureau, North American Industrial Classification System, https://www.census.gov/naics/

Diagram 1. Report Mapping Strategy

To support policy decisions, employment projections from 2022 to 2032 are provided for the state and three major **metropolitan statistical areas (MSAs)**: Knoxville, Memphis, and Nashville. The first component of the report begins by examining Tennessee's overall economic landscape, offering a foundational understanding of regional development patterns across the state. It provides context for interpreting current disparities in economic performance by analyzing geographic trends in population, employment, and industry growth. Rather than focusing solely on outcomes, this section introduces the reader to the broader forces shaping economic change in both urban and rural areas.

Following this overview, the report transitions into a detailed analysis of key industry sectors and projected employment trends. This includes an exploration of how the energy transition—driven by technological innovation, environmental policy, and shifting market demands—is expected to influence labor markets across Tennessee. Together, these sections lay the groundwork for understanding where opportunities and challenges may arise as the state adapts to a changing energy and economic landscape.

The *second component* of the analysis focuses on occupations affected by the energy transition. As industries evolve, workforce skill requirements will also change—impacting both existing jobs and emerging roles. Some occupations will decline or disappear altogether, while others will experience increased demand as market dynamics and technological advancements reshape the labor landscape.

The report then presents a landscape analysis of existing educational and training programs for labor market sectors affected by the energy transition, offering a framework for developing a comprehensive and strategic approach to talent pipeline development. The final section of the report connects those employment and jobs to in-state education programs at the K-12 and post-secondary levels. One purpose of this section is to highlight schools and

programs where, in the coming years, student and employer demand may grow as the energy transition moves ahead. Research has consistently shown that students respond to changes in labor market demand. Enrollment grows in programs that lead to growing fields of work, and likewise, enrollment declines in areas that are contracting.[35] Another purpose of this section is to signal where new firm locations or expansions may take place. Firms have more of an incentive to locate near education programs that could supply their workforce needs.[36]

The conclusion of this report summarizes key findings on the workforce and economic impacts of Tennessee's energy transition, highlighting major industry and occupational shifts. It also discusses the implications for workforce development, education, and policy, emphasizing the need for strategic investments in training programs and infrastructure to support a changing labor market. Additionally, the conclusion addresses ongoing uncertainties in employment projections and market dynamics, reinforcing the importance of adaptability in policy and workforce planning.

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[35]The following are a few of the studies show evidence of post-secondary student and college responses to labor market changes: Acton, R. K. (2021). Community college program choices in the wake of local job losses. *Journal of Labor Economics*, *39*(4), 1129-115; Weinstein, R. (2022). Local labor markets and human capital investments. *Journal of Human Resources*, *57*(5), 1498-1525; Conzelmann, Johnathan G., Steven W. Hemelt, Brad Hershbein, Shawn Martin, Andrew Simon, and Kevin M. Stange. (2024). "How Higher Education Responds to Labor Market Demand." Policy and Research Brief. Kalamazoo, MI: W.E. Upjohn Institute for Employment Research. At the K-12 level, high school students tend to choose career and technical education programs that resemble local labor markets, although unlike postsecondary students, there is little to no short-term adjustment in CTE choices when local labor markets change. Carruthers, C. K., Dougherty, S., Goldring, T., Kreisman, D., Theobald, R., Urban, C., & Villero, J. (2024). Career and Technical Education Alignment Across Five States. *AERA Open*, *10*, 23328584241276504.

[36] In industries where training is borne by workers or schools (as opposed to on-the-job), firms will prefer to locate in industry clusters near workers with the right skills. Almazan, A., De Motta, A., & Titman, S. (2007). Firm location and the creation and utilization of human capital. *The Review of Economic Studies*, *74*(4), 1305-1327. Switzerland's establishment of new Universities of Applied Sciences potentially provides one example of this dynamic in action. Schlegel, T., & Backes-Gellner, U. (2023). The role of fields of study for the effects of higher education institutions on regional firm location. *Small Business Economics*, *61*(4), 1587-1656.

Regional Economic Performance and Labor Outlook

Overview

Tennessee has a dynamic economy, characterized by a mix of industry sectors that contribute to its growth and development. From agriculture and manufacturing to healthcare and technology, the state has built a reputation as a leading player in several national and global markets. As of recent years, the state has experienced steady economic expansion, benefiting from a robust business environment, a strategic location in the southeastern United States, and a growing workforce.

Tennessee's economy presents a complex landscape, with notable differences between its urban, suburban, and rural areas. At the heart of the state's economic engine are its metropolitan regions, which consistently outperform the state average.[37] Cities like Nashville, Memphis, and Knoxville serve as economic anchors, driving growth in sectors such as business services, retail trade, and health care. These urban hubs benefit from a variety of industries, robust infrastructure, and a concentration of highly skilled labor. The state's manufacturing sector, however, is more dispersed, with a heavier concentration in suburban and exurban areas production processes are supported by transportation networks, supply chains, and access to a flexible workforce.[38]

To contextualize the employment and occupational projections presented below, this section provides a brief overview of Tennessee's economic performance, focusing on three major metropolitan areas: Knoxville, Memphis, and Nashville. **Economic performance** refers to the ability of an economy to produce goods and services, manage resources efficiently, and achieve growth, stability, and prosperity over time. It is often assessed through various indicators such as Gross Domestic Product (GDP), unemployment rates, inflation, and productivity. A strong economic performance typically reflects high levels of economic output, low

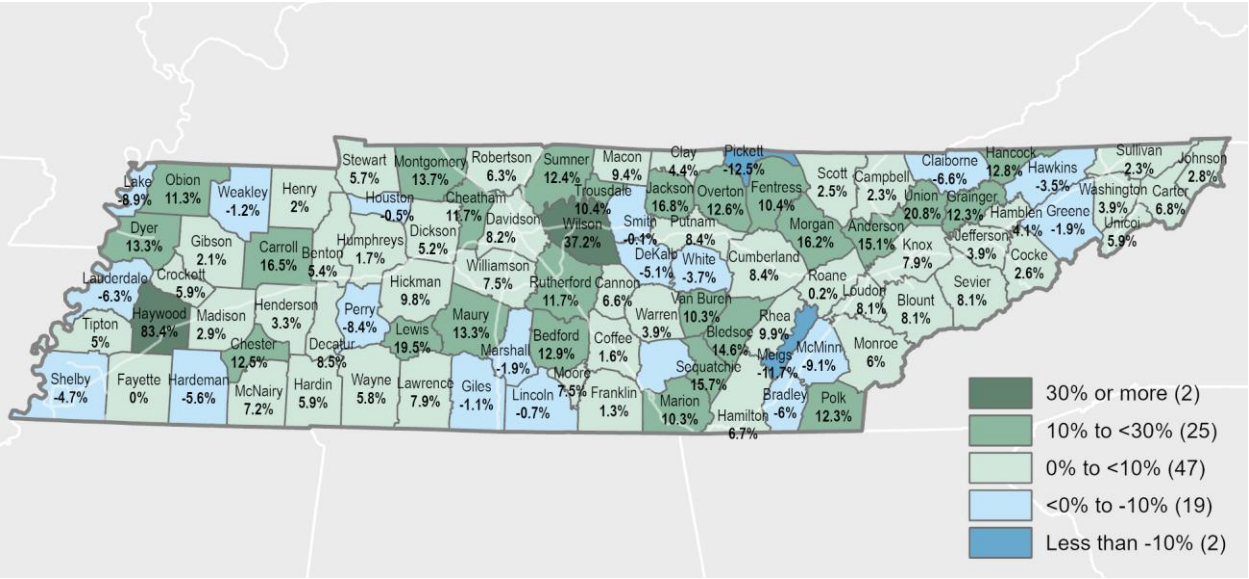
[37] For background and data, see the annual Boyd Center for Business and Economic Research. *An Economic Report to the Governor of Tennessee, 2024.* Haslam College of Business, University of Tennessee. https://haslam.utk.edu/publication/economic-report-to-the-governor-2024/. Accessed January 2025.
[38] Tennessee Department of Economic and Community Development. "Tennessee Economic Growth," https://www.tn.gov/ecd. Accessed April 2025.

unemployment, and controlled inflation, leading to improved living standards. These broad economic trends are critical, as they form the foundation upon which workforce development efforts must be built. Additionally, this section examines the potential impacts of the energy transition on jobs and occupations across the state, laying the groundwork for the detailed analysis that follows.

Regional Economic and Labor Outlook Analysis

In this section, we examine recent trends in employment, unemployment, and population growth across Tennessee's 95 counties to establish the foundation for regional and labor market projections. By analyzing job growth since 2019, current unemployment rates, and population forecasts through 2032, we identify where economic momentum is strongest—and where challenges persist. These indicators are critical to understanding the dynamics shaping Tennessee's workforce, as job creation and population growth tend to reinforce one another. Areas experiencing strong employment gains and rising populations are more likely to sustain a robust labor force in the decade ahead, while regions facing job losses and outmigration may struggle to retain talent and attract new investment. These trends inform the geographic and sector-specific projections presented throughout the remainder of the report.

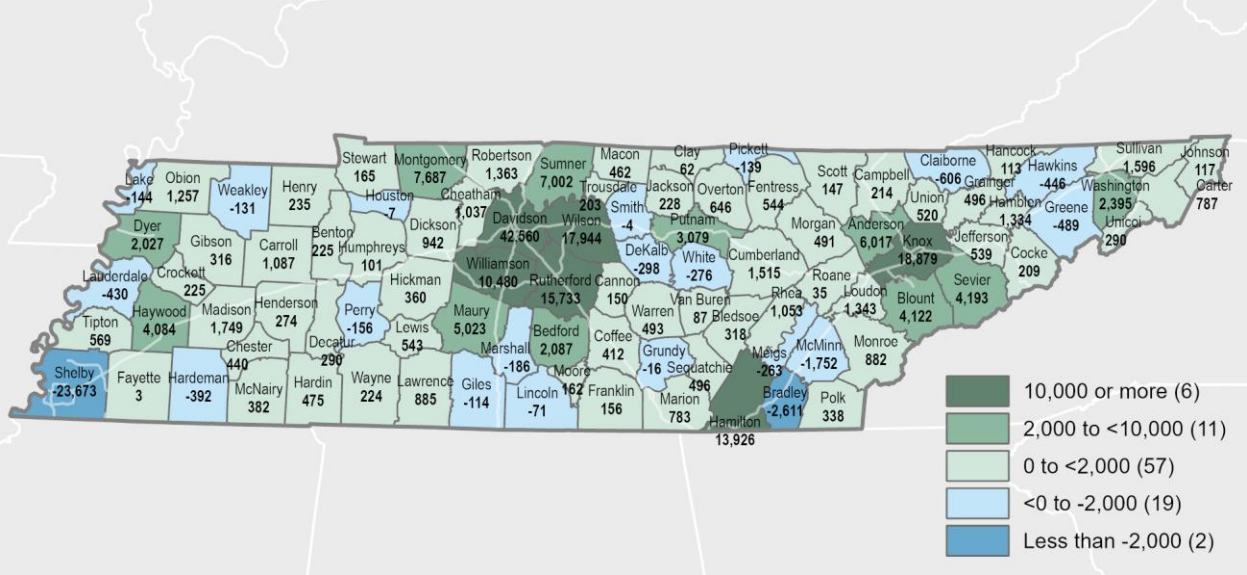
Figure 1. Percentage Change in Jobs by County, 2019Q2 to 2024Q2



Source: U.S. Bureau of Labor Statistics. *Quarterly Census of Employment and Wages, 2019Q2–2024Q4.* U.S. Department of Labor. Accessed January 2025. https://www.bls.gov/cew/.

Figure 1 presents job growth across all 95 Tennessee counties from the second quarter of 2019 (before the onset of the worldwide COVID-19 pandemic) to the second quarter of 2024 (the most recent quarter for which data are available). Statewide employment grew 7.8 percent over this period yielding 238,830 new jobs. In percentage terms, Haywood County in West Tennessee saw the strongest job growth, advancing by over 83 percent. However, this represented a relatively modest increase of around 4,000 jobs (see **Figure 2**). This highlights a key point for decision-making. While some counties experienced significant and positive percentage increase in job growth, between 10 to 30 percent, the relatively small absolute number of jobs added in many localities does not provide a sufficient critical mass for large-scale workforce development or economic planning initiatives.

Figure 2. Change in Number of Jobs by County, 2019Q2 to 2024Q2



Source: U.S. Bureau of Labor Statistics. *Quarterly Census of Employment and Wages, 2019Q2–2024Q4.* U.S. Department of Labor. Accessed January 2025. https://www.bls.gov/cew/.

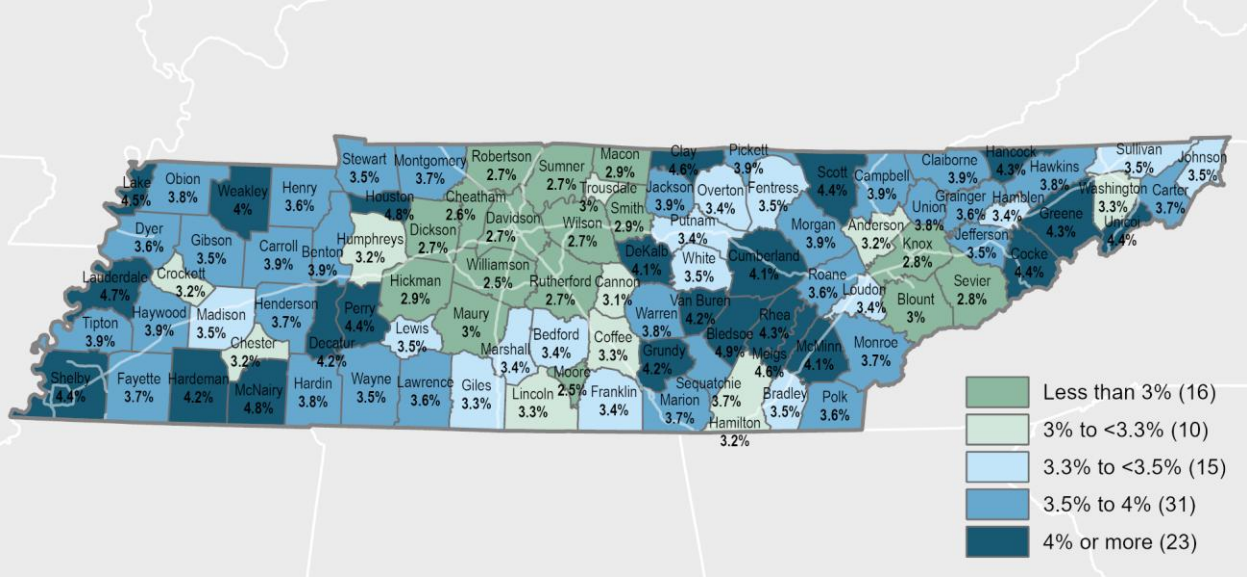
Importantly, Haywood County is the location of Ford's Blue Oval City electric vehicle manufacturing plant.[39] Also note that the counties containing or surrounding Tennessee's larger metropolitan areas saw strong gains. Davidson County added nearly 43,000 jobs during this period, while counties surrounding Davidson also saw boosts in employment. Knox County added over 18,000 jobs, and Hamilton County added nearly 14,000. Conversely,

[39] Samuel Smith, "What to Know: The New Ford BlueOval City Plant Poised to Reshape West Tennessee," *Tennessee Lookout*, September 13, 2024, https://tennesseelookout.com/2024/09/13/what-to-know-the-new-ford-blueoval-city-plant-poised-to-reshape-west-tennessee/.

Shelby County saw the workforce contract by 4.7 percent, representing a net decrease of over 22,000 jobs. Aside from Shelby County, the general pattern in Tennessee has been stronger job growth in the metropolitan areas, especially in Middle Tennessee, and slower growth or job losses in the counties further away from the metropolitan areas.

Figure 3 reports county level unemployment rates for 2024, measured as the annual average across January 2024 through December 2024. The Tennessee annual average was 3.3 percent. Once again, healthier labor markets are near the larger metropolitan areas, as indicated by commonly lower unemployment rates. This is especially apparent in Middle Tennessee where unemployment rates are consistently below 3 percent. Similarly, Knox County had an annual average unemployment rate of 2.8 percent in 2024. Hamilton County's unemployment rate was slightly higher, at 3.2 percent, while Shelby saw one of the higher rates of unemployment in the state, at 4.4 percent. Even rural communities experienced low unemployment rates. These all represent historically low rates of unemployment in Tennessee and nationally.[40]

Figure 3. Unemployment Rates Across Tennessee— 2024 Annual Average

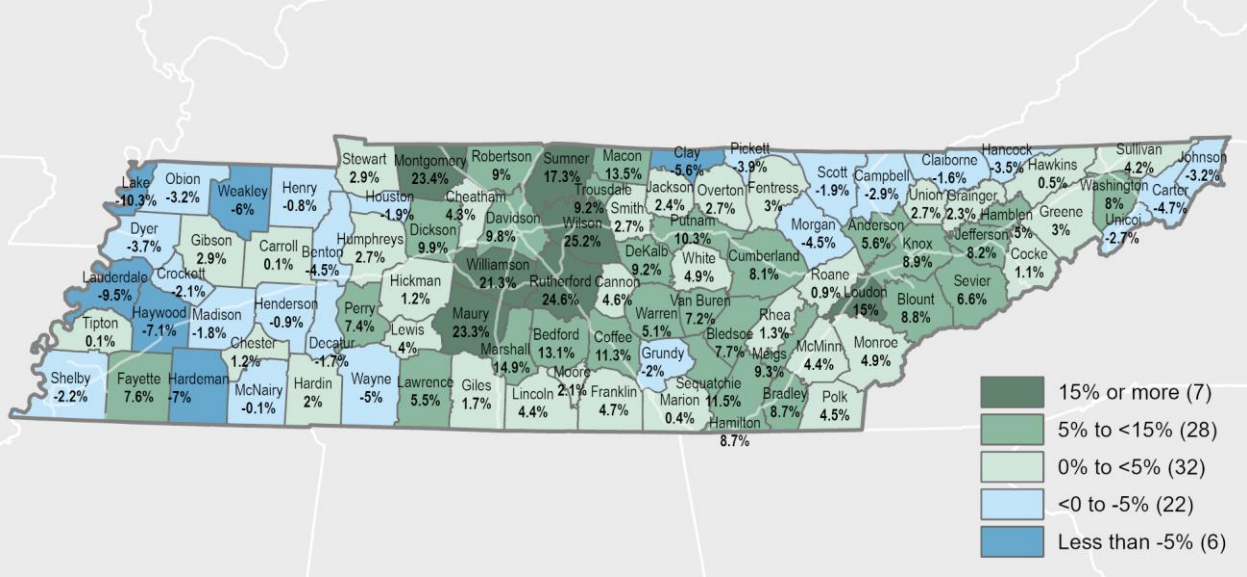


Source: U.S. Bureau of Labor Statistics. *Local Area Unemployment Statistics: State and Local Data.* U.S. Department of Labor. Accessed January 2025. https://www.bls.gov/lau/stalt.htm. Dates are not seasonally adjusted.

[40] These are all U-3 measures of unemployment commonly reported by public entities and the media. As such, they do not account for discouraged workers, marginally attached workers, or part-time workers who would like more hours. See U.S. Bureau of Labor Statistics, "Local Area Unemployment Statistics," https://www.bls.gov/lau/stalt.htm

Population growth is a key driver of labor force expansion because, fundamentally, it increases the number of people available to participate in the workforce—particularly among the working-age population, typically defined as ages 16–64. As regions attract more residents, they often see a corresponding rise in labor force size, which can support economic growth by meeting employer demand for workers. However, population growth alone does not guarantee a well-matched labor supply. If new residents lack the skills required by emerging industries—such as advanced manufacturing, clean energy, or information technology—gaps between labor availability and labor readiness can persist. This underscores the importance of aligning workforce development strategies with regional economic trends. As such, while a growing population creates the potential for labor force expansion, realizing that potential depends on sustained access to upskilling, credential attainment, and workforce-aligned education that equips individuals with the skills needed to meet evolving industry demands.

Figure 4. Projected Percent Population Change by County— 2022 to 2032 Annual Average



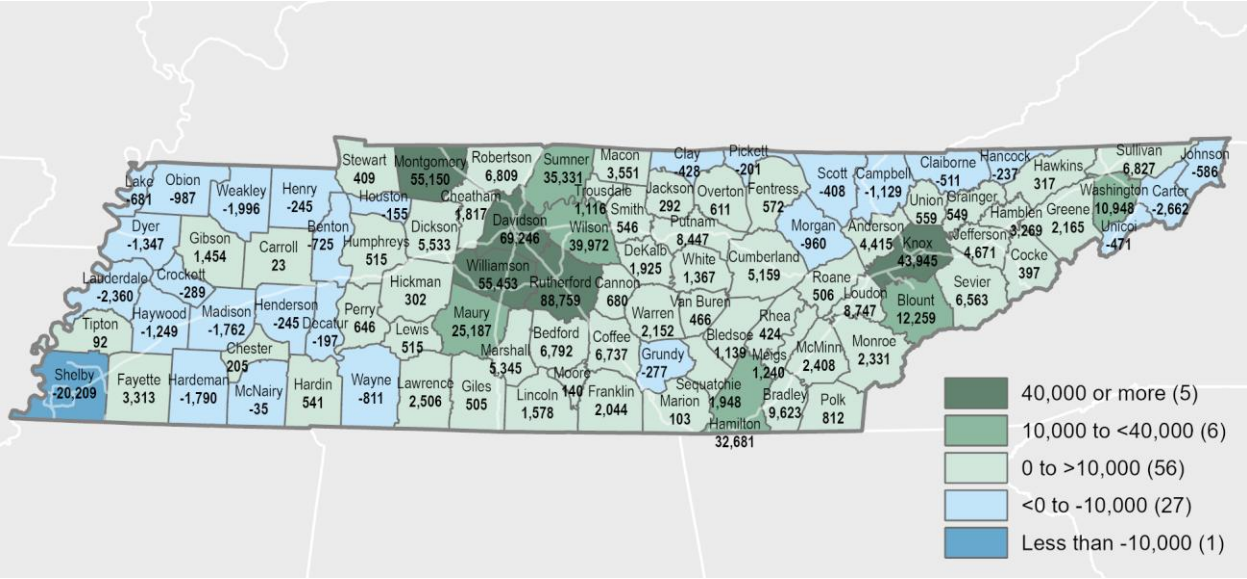
Source: Tennessee State Data Center. "Boyd Center Population Projections." *Boyd Center for Business and Economic Research*, University of Tennessee, Knoxville. Last modified August 7, 2024. https://tnsdc.utk.edu/estimates-and-projections/boyd-center-population-projections/.

Figure 4 presents population projections for all Tennessee counties from 2022 through 2032. If current trends persist, the overall state population is expected to grow by 7.9 percent by 2032. Regionally, population gains are projected to be strongest in Middle Tennessee, with Davidson County and the eight bordering counties all seeing strong population growth. Counties in East Tennessee will also see healthy growth, especially those surrounding

Knox County. In general, stronger population growth will take place in the larger metropolitan areas and their surrounding counties, along with smaller but more widespread increases among rural counties in the eastern two-thirds of the state. Contrary to the projected trends in Middle and East Tennessee, the population of Shelby County is projected to fall over the next decade.

Figure 5 shows the projected numerical growth in Tennessee county population extending to 2032. The state's population is expected to rise by 559,696. Rutherford County will see the largest population growth (88,759), followed by Davidson County (69,246), and Williamson County (55,543). Twenty-eight counties will experience population contractions, which will likely translate into a declining workforce as well. Most of these counties are rural and many are in the western part of the state. East Tennessee's growth will be centered around Knox County which will experience a population gain of nearly 44,000, Hamilton County with population growth of 32,681, and Washington County with population growth of 10,948.

Figure 5. Projected Population Growth by County— 2022 to 2032 Annual Average



Source: Tennessee State Data Center. "Boyd Center Population Projections." *Boyd Center for Business and Economic Research*, University of Tennessee, Knoxville. Last modified August 7, 2024. https://tnsdc.utk.edu/estimates-and-projections/boyd-center-population-projections/.

An important conclusion from this section is that economic performance varies markedly across the state, with the strongest growth taking place among the identified metropolitan areas of middle (Nashville) and east Tennessee (Knoxville), while the Memphis metropolitan area has shown slower expansion. Meanwhile, areas of rural Tennessee that are not spatially

proximate enough to be experiencing spill-over benefits from nearby urban growth, continue to struggle for economic vitality, with many communities losing both people and jobs over time.

Key Trends

- **Metropolitan Economic Performance:** Tennessee's major metropolitan areas—Knoxville, Memphis, and Nashville—consistently outperform the state, serving as hubs for key industries like business services, retail, and health care. Manufacturing is more prominent in suburban and exurban areas. This is particularly the case for Nashville, which generally outperforms the rest of the state. Strong levels of educational attainment help drive this growth.

- **Rural Economic Challenges:** Rural regions face persistent economic struggles, including lower incomes, fewer job opportunities, and lower educational attainment.

- **Job Growth Trends:** Tennessee experienced overall job growth, with the strongest increases occurring in metropolitan areas. Some regions saw rapid expansion due to major industrial projects, while others, faced job losses.

- **Unemployment Trends:** Unemployment remained low across the state, with metropolitan regions generally having lower rates than rural areas. Some counties experienced notably higher unemployment due to economic challenges.

- **Population Growth Projections:** Tennessee's population is expected to grow, with the highest increases in and around major cities. In contrast, some rural areas are projected to see population declines, which could affect local labor markets.

Together, the labor market and population data presented in this section offer a foundational understanding of where Tennessee is experiencing the strongest growth, as well as where additional support and investment may be needed to unlock full economic potential. In the sections that follow, this regional analysis is paired with industry-specific employment projections and

workforce demand data to build a more complete picture of the state's future economy and the potential impact of the energy transition.

Industry Outlook: The Energy Transition

Overview

The **U.S. Energy Information Administration (EIA)** defines primary energy sources as fossil fuels (i.e., petroleum, natural gas, and coal), nuclear energy, and renewable sources of energy (i.e., geothermal, solar, hydroelectric, wind, biomass).[41] Electricity is a secondary energy source that is produced from primary energy sources. In addition, the EIA defines energy-use sectors as the major energy-consuming groups, which are: residential, commercial, industrial, transportation, and electric power.[42] **Table 1** provides the distribution of energy consumption by energy source and energy sector as a percentage share of total energy consumption in the United States in 2023. **Table 2** provides the distribution of energy consumption by energy source and energy sector for Tennessee in 2022 as a share of total energy consumption in the United States. These tables are intended to provide context for the sources and uses of energy for the purpose of this report.

Table 1. Total Primary Energy Consumption, United States, 2023

Total Primary Energy Consumption in the United States By fuel/energy source	**93.50 quadrillion btu** share of total
Petroleum	38%
Natural Gas	36%
Renewable Energy	9%
Coal	9%
Nuclear Electric Power	9%
By sector and share of total U.S. primary energy consumption	share of total
Electric power	34%
Transportation	30%
Industrial	24%
Residential	7%
Commercial	5%

Source: U.S. Energy Information Administration, "U.S. Energy Facts: Data and Statistics," Accessed March 2025. https://www.eia.gov/energyexplained/us-energy-facts/data-and-statistics.php.

[41] U.S. Energy Information Administration, "U.S. Energy Facts Explained," Accessed March 2025. https://www.eia.gov/energyexplained/us-energy-facts/.
[42] U.S. Energy Information Administration, "Energy-Use Sector," Accessed March 2025. https://www.eia.gov/tools/glossary/index.php?id=Energy-use%20sector.

Table 2. Total Primary Energy Consumption, Tennessee, 2022

Total Primary Energy Consumption in Tennessee By fuel/energy source	**2,102 trillion btu** share of U.S. total
Petroleum	1.9%
Natural Gas	1.2%
Renewable Energy	*Not available*
Coal	2.2%
Nuclear Electric Power	*Not available*
By sector and share of total U.S. primary energy consumption	share of U.S. total
Transportation	2.4%
Industrial	1.7%
Residential	2.6%
Commercial	2.5%

Source: U.S. Energy Information Administration, "Tennessee State Energy Data," 20 February 2025. https://www.eia.gov/state/data.php?sid=TN#ConsumptionExpenditures.

Tennessee's energy profile reflects a diverse mix of generation sources and consumption patterns shaped by the state's industrial base and energy infrastructure. While nuclear and hydroelectric power dominate electricity generation, fossil fuels like coal and natural gas remain key contributors as part of imported energy sources. Tennessee is also unique in the energy utility sector in that TVA, a federally-owned corporation, provides electricity to approximately 99.7 percent of the electricity service territory in the state.[43] TVA works closely with the 153 local power companies (LPCs) that distribute TVA power in the Tennessee Valley region, which includes parts of seven states. [44] TVA, which is self-regulated with regard to fuel mix and associated power generation, will be a significant contributor to any energy transition choices.

[43] Tennessee Department of Environment and Conservation. "Solar Energy." Last modified May 19, 2025. https://www.tn.gov/environment/program-areas/energy/state-energy-office--seo-/solar-energy.html.
[44] Tennessee Valley Authority. "Public Power for the Valley." Last modified August 7, 2024. https://www.tva.com/energy/public-power-partnerships.

The **Tennessee State Energy Profile** provided by the EIA[45] offers an in-depth overview of the state's energy landscape, encompassing production, consumption, and electricity generation.

Energy Consumption and Production:

- Tennessee consumes over three times more energy than it produces, ranking among the top one-third of U.S. states in total energy consumption.
- The transportation sector is the largest energy consumer, accounting for more than 30% of the state's total energy use.
- The industrial sector, including the manufacture of food, beverages, and tobacco products; motor vehicles and automotive parts; chemicals; fabricated metal products; and paper, contributes about 25% to the state's energy consumption.
- Residential and commercial sectors account for approximately 24% and 20% of energy use, respectively.

Electricity Generation:

- The Tennessee Valley Authority (TVA) owns 92% of the state's utility-scale electricity generating capacity, including the 10 largest power plants.
- TVA's facilities comprise 29 hydroelectric dams, 17 natural gas-fired plants, 4 coal-fired plants, 3 nuclear plants, and 1 pumped-storage hydroelectric plant.
- In 2023, nuclear power provided 48% of Tennessee's total net electricity generation, placing the state among the top 10 in the nation for nuclear generation.
- Coal and natural gas each contributed roughly 20% to the state's electricity generation since 2020, though Tennessee's coal-fired power plants rely on imported coal delivered by rail and river barge from other states, primarily Kentucky, Wyoming, and Illinois due to its lack of recoverable reserves.
- Renewable resources supplied about 14% of Tennessee's total in-state electricity net generation in 2023, with the majority (12%) from

[45] U.S. Energy Information Administration. "Tennessee State Energy Profile." Last modified October 17, 2024. https://www.eia.gov/state/analysis.php?sid=TN.

hydroelectric power, making Tennessee the sixth-largest hydroelectric power producer in the U.S.

As the state continues to transition toward renewable energy sources and adapts to evolving market demands, Tennessee's energy strategy will play a crucial role in regional economic development. Importantly, the energy transition in Tennessee will be impacted by demand and supply-side changes. On the demand-side, industry and consumer behavior related to energy efficiency, technological adoption, and policy incentives will play a crucial role in shaping consumption patterns. In particular, the rate of changes toward electrification in transportation, industrial processes and energy choices, and residential heating, alongside the adoption of smart grid technologies and demand-response mechanisms, will further influence energy demand. On the supply-side**,** the energy transition will be influenced by **the state's commitment to the diversification of energy sources, advancements in energy storage, grid modernization, and policy choices.**

Tennessee's economic development initiatives, such as attracting energy-intensive data centers[46] and supporting EV expansion[47, 48] and growth in solar and wind energy jobs—many of which offer high wages without requiring a college degree[49]— among other strategies, have significantly shifted energy demand and sources. Forecasting workforce needs for the energy transition, however, is complicated by the fact that the economy is already shifting to resources other than fossil fuels. This indicates that the energy transition is well underway. Nationally, the market share for electric and hybrid vehicles is growing and reached 21 percent in 2024.[50] TVA has been planning to close fossil fuel power plants, and at the same time, is placing a greater emphasis on nuclear power education, research, and generation.[51] In Tennessee, clean energy jobs grew by 5.9 percent from 2022 to 2023, and jobs in energy

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[46] See Tennessee Valley Authority, "Economic Development," *Annual Report FY20*, Accessed February 2025. https://www.tva.com/about-tva/reports/annual-report-fy20/economic-development.
[47] Tennessee Department of Environment and Conservation, "Drive Electric Tennessee," Accessed January 2025. https://www.tn.gov/environment/program-areas/energy/state-energy-office--seo-/programs-projects/programs-and-projects/sustainable-transportation-and-alternative-fuels/sustainable-transportation-and-alternative-fuels/drive-electric-tennessee.html.
[48] International Council on Clean Transportation , "CHARGING UP AMERICA: The growth of United States electric vehicle charging infrastructure jobs." (2024). https://theicct.org/publication/US-EV-charging-infrastructure-jobs-jan24/.
[49] Curtis, E. M., & Marinescu, I. (2023). Green energy jobs in the United States: what are they, and where are they?. *Environmental and Energy Policy and the Economy*, *4*(1), 202-237.
[50] U.S. Energy Information Administration, "U.S. share of electric and hybrid vehicle sales reached a record in the third quarter." (2024). https://www.eia.gov/todayinenergy/detail.php?id=63904.
[51] SSTI, "Tennessee Governor requests nearly $100M for energy innovation in proposed spending plan." (2025). https://ssti.org/blog/tennessee-governor-requests-nearly-100m-energy-innovation-proposed-spending-plan.

efficiency grew by 2.9 percent.[52] These growth rates meet or exceed the overall employment growth of 0.3 – 3.0 percent over the past three years in Tennessee.[53] This indicates that clean energy jobs are already drivers for Tennessee's labor market growth and are likely to provide more opportunities in the future.

Current national and state-level employment forecasts include these existing and anticipated trends, because observational data reflect historical and current dynamics and choices. However, the pace of future energy transition remains uncertain, dependent on regulation, public investment, and private sector decisions. To be clear it is impossible to isolate the contribution of choices, investments, and hiring patterns specific to the energy transition. As such, despite these priorities and investment shifts, not all stakeholders are optimistic about the net positive impact of the energy transition. For example, concerns remain about job losses in traditional fossil fuel industries and the challenges of retraining displaced workers,[54] while at the same time, higher energy costs could also reduce employment in other sectors. Importantly, the lack of a standardized methodology for forecasting net job creation complicates predictions in combination with these dynamics.[55]

This uncertainty makes it difficult to confidently predict the overall impact on employment, much less the effect on employment in specific fields. For example, in March 2025 the Volkswagen plant in Chattanooga, Tennessee, announced a plan to reduce the number of shifts due to the EV market being slower to evolve than previously anticipated.[56] This is an example where despite positive market trends, firm-level decisions led to a significant number of workers who have been negatively impacted. Rather than attempting to project employment and occupations from an uncertain baseline, this report highlights industry sectors and jobs most likely to be impacted by Tennessee's energy transition. The occupational analysis focuses on workforce needs where demand will be greatest.

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[52] U.S. Department of Energy, "United States Energy & Employment Report 2024." (2024). https://www.energy.gov/sites/default/files/2024-09/USEER%202024%20States_0913.pdf.
[53] Authors' calculations using the Current Employment Statistics, U.S. Bureau of Labor Statistics.
[54] Curtis, E. M., O'Kane, L., & Park, R. J. (2024). Workers and the green-energy transition: Evidence from 300 million job transitions. *Environmental and Energy Policy and the Economy*, *5*(1), 127-161.
[55] Lambert, R. J., & Silva, P. P. (2012). The challenges of determining the employment effects of renewable energy. *Renewable and Sustainable Energy Reviews*, *16*(7), 4667-4674.
[56] Mike Pare, "VW Offering Voluntary Buyouts as Chattanooga Plant Goes to Just Two Shifts," *Chattanooga Times Free Press*, March 13, 2025, https://www.timesfreepress.com/news/2025/mar/13/vw-offering-voluntary-buyouts-as-chattanooga/.

Industry and Employment Analysis

National, state and local efforts to reduce greenhouse gas and other air pollutants coupled with the electrification of energy systems is leading to a restructuring of the economy. This means that some industries[57] and occupations may experience stagnation or slower growth— notably those tied to fossil fuels— while others may experience rapid growth due to multilayered investments to reduce emissions, like those tied to energy storage and clean energy production. For instance, natural gas will likely serve as a bridge in electricity supply and electrification of transportation, and the investment in the security of those assets may grow. Of course, they will also be subject to challenges with market volatility due to consumer choice and other factors. The industry and employment analysis for the energy transition is further complicated by the evidence of both a skill and spatial mismatch for jobs with declining demand and those of growing importance, especially within the energy sector.[58] Effective job training, including reskilling and upskilling programs, will be needed to address these dynamics and realign the workforce to labor demands.

This report refers to industries and occupations. Occupations are embedded within business establishments, whether the business is a sole proprietor or a large multistate corporation. As industry transitions, so will its workforce needs. A focus on industry offers an important complement to efforts to promote workforce development through education and training since the workplace is where considerable formal and informal training takes place. There are numerous benefits and advantages from taking an industry perspective to workforce development.

First, industry is the gateway to employment for new entrants to the labor market as well those transitioning from an existing job or to a different professional opportunity. Potential workers must be attracted to jobs by the nature of work and associated compensation packages; they must have the requisite skills and experience to be attractive candidates to employers. Employment provides opportunities for advancement within the firm through apprenticeships, on-the-job training, and formal education and training. Workers also use their experience to cultivate job opportunities and make themselves competitive elsewhere in the labor market. Good

[57] "Industry" and "business" are used interchangeably in this discussion.
[58] Jacob Greenspon and Daniel Raimi, "Matching Geographies and Job Skills in the Energy Transition," Resources for the Future Working Paper 22-25, October 2022. https://media.rff.org/documents/WP_22-25_PnkcURf.pdf

information is required to ensure that individuals can effectively scan labor market opportunities and secure the education and training they need for advancement. Employers must be able to respond to changing market conditions and ensure that their workers have the skills needed to allow the firm to be competitive.

Second, as the energy transition and efforts to reduce greenhouse gas emissions continue, primary impacts will initially be felt by business establishments as consumer and business spending change. Consumers may shift spending toward more energy efficient appliances which will in turn impact business production, supply chains, and workforce skill needs. Similarly, business acquisition of alternatively fueled vehicles will affect the training needs for vehicle operators and maintenance crews; downstream impacts on energy and vehicle supply chains may also change the skill needs of firms and workers. Tracking industry performance can help identify potential skills gaps that need to be backfilled. This can be done in part using data like that presented below; good on-the-ground intelligence is also needed to guide policy.

Third, policy may benefit from a focus on business establishments in affected sectors. For example, one way to reduce methane releases from landfills is to change waste storage and disposal practices by restaurants and food service facilities. This in turn may require changes in business practice from the management level all the way down to the line worker and dish washer. The construction of energy-efficient structures will affect a variety of trades and their skill requirements for contractors. In these instances, systemic training at the firm level may be the best option.

Fourth, industry is commonly a target for recruitment and retention by the state, local communities, and TVA, often through the deployment of economic development incentives, from tax breaks for capital investment to job training. Tennessee's recruitment focus currently falls on industries including advanced manufacturing and appliances and electrical equipment manufacturing.[59] Like many communities across the state, Nashville has its own focus areas.[60] For TVA, targets include four industries: advanced

[59] See the dropdown menu for *Industries* at the Tennessee Department of Economic and Community Development, https://www.tn.gov/content/tn/ecd.html/
[60] For example, see Target Incentives, Nashville Area Chamber of Commerce, https://www.nashvillechamber.com/economic-development/target-industries/

manufacturing, transportation manufacturing, data centers, and food processing.[61]

Aligning recruitment and retention programs with industries that have strong growth trends along with the potential to reduce emissions, would provide state level benefits in both an economic and environmental sense. For example, the construction industry is essential to commercial and industrial building efficiency, renewable energy generation, and residential weatherization and efficiency; heat pumps are produced within the manufacturing industry and require installation by specialty trade contractors; nuclear power generation falls within the utility industry, while its supply chain is spread across a host of other areas Importantly, industry targeting can yield training resources to meet the unique needs of employers and workers. For example, Tennessee's existing incentive programs include training grants and special provisions for lower income areas deemed "distressed counties."[62] These training resources can be tailored to the unique needs of a company's workforce. Many local communities will provide training assistance to businesses as well through Chambers of Commerce, Industrial Development Boards and other local bodies utilizing public resources (e.g. community colleges) and private education service providers.

A good example of industry-based training is the **Battery Workforce Initiative** facilitated by DOE's **National Energy Technical Laboratory (NETL)**:

The Battery Workforce Initiative, led by the U.S. Department of Energy, finalized a key tool to help aide in the development of a skilled workforce for the nation's competitive domestic battery industry. Crafted in concert with the U.S. Department of Labor, the National Guideline Standards (NGS) for the Battery Machine Operator occupation provides a detailed list of the skill requirements and competencies for workers in advanced battery manufacturing facilities. Employers, joint labor-management organizations, educators, and others may use this framework to design and implement job training programs that are responsive to the needs of the industry for workers, both entry-level

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[61] "Target Industries," https://www.tva.com/economic-development/attract-new-companies/target-industries
[62] See Tennessee Department of Economic and Community Development's Fasttrack Job Training Assistance Program and Tax Credits, https://tnecd.com/advantages/incentives-grants/

employees and incumbent workers, who wish to upgrade their skills and knowledge. The standards are certified by the U.S. Department of Labor. [63]

This is an *all-hands-on-deck* approach to addressing a strategic energy sector, requiring the engagement of a wide variety of key stakeholders.

Energy and Climate Industry Cluster Targeting

Tracking industry clusters is a prime means of monitoring the performance of important economic sectors, including those tied to energy and climate change. A timely example is a recent report documenting Tennessee's "advanced energy industry," which accounts for renewable energy activities in the state. The report shows that advanced energy-related jobs, business payroll expenditures, and the number of business establishments have generally outpaced overall state economic growth dating back to 2015.[64] Especially significant is the finding that jobs in the advanced energy sector provide an average salary of $74,025, a 31 percent premium over the average annual salary in Tennessee.

Importantly, this upward trend appears to be driven by market forces, technological innovation, and private-sector investment. This suggests that Tennessee is organically trending toward a more energy- and technology-intensive economy. While future developments are difficult to quantify with precision, these data points offer strong evidence that the energy transition is already shaping the state's economic and workforce trajectory in meaningful ways.

The ***U.S. Energy and Employment Report***, an annual report developed by the **U.S. Department of Energy (DOE)** also uses an industry approach to track U.S. energy-related economic activity.[65] DOE uses five technology areas to capture energy-related employment: electric power generation, energy efficiency, fuels, motor vehicles and energy transmission, distribution and storage. Motor vehicles is the largest industry, followed by energy efficiency;

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[63] U.S. Department of Energy, National Technical Laboratory, "Battery Workforce Initiative," https://netl.doe.gov/bwi
[64] Murray, Matthew N. and Jilleah G. Welch, "2024 Tennessee Advanced Energy Economic Impact Report," prepared for the Tennessee Advanced Energy Council, November 2024. Available at https://www.tnadvancedenergy.com/advanced-energy-economic-impact-report/
[65] U.S. Department of Energy, United States Energy & Employment Report 2024 (USEER), https://www.energy.gov/sites/default/files/2024-10/USEER%202024_COMPLETE_1002.pdf

electric power generation showed the strongest employment growth in 2023. Like the report on Tennessee's advanced energy sector noted above, this report's measure of energy sector employment shows jobs increasing faster than overall employment growth in 2023. Importantly, the report identifies factors affecting employer's hiring difficulties. For example, for the motor vehicle industry, primary challenges include "Lack of experience, training or technical skills."[66] Business survey respondents in other industry groupings also commonly noted challenges in filling job vacancies.

Another annual report (dating back to 2016) tracks low-emissions energy jobs for the national economy and individual states, centered on the renewable energy, grid and storage, energy efficiency, renewable fuels, and vehicle industries. Low-emissions energy jobs advanced much more rapidly than overall employment in 2023 with employment totaling 3.5 million workers in 2023. Tennessee ranked 13th for the number of low-emissions energy jobs in 2024 and 15th for low-emissions energy job growth.[67] These figures suggest that Tennessee is already undergoing an energy transition shaped by workforce demand, innovation, and industry investment, even in the absence of regulatory mandates.

Especially relevant is TVA's recently released ***Valley Pathways Study* (VPS)**.[68] Like TVERS, the VPS takes a voluntary approach to addressing pollution and the energy transition. The goal of the VPS is to realize substantial reductions in emissions by 2050. While not structured around industry sectors, it does emphasize the importance of key clusters like industry, buildings, and transportation, similar to TDEC's emission reduction sectors. Investments in education and training have been identified as important ingredients to the effective reduction of emissions in the Tennessee Valley region.

Industry Accounting

A formal accounting system is generally required to track economic activity. Industry data are generally accounted for using the **North American Industrial Classification System (NAICS)** which includes business organizations of all forms, corporations for example, and companies of all

[66] U.S. DOE, USEER, page 184.
[67] E2, Clean Jobs America 2024, https://e2.org/reports/clean-jobs-america-2024/ See Appendix Tables A and B. The report includes detailed state, metropolitan area, and county data tables for selected economic metrics. The analysis is a deep dive into the data collected for the DOE USEER report.
[68] Tennessee Valey Authority and Baker School of Public Policy and Public Affairs, Valey Pathways Study, February 2024, https://baker.utk.edu/research-centers/cetep/valley-pathways-study/

sizes.[69] For the labor force, a commonly used tool is the **Standard Occupational Code (SOCs)** system which supports data and statistical analysis for workers within and across job classifications. These data are widely used by the public and private sectors to track the economy, project its anticipated performance, and guide public policy. The data are rooted in surveys of business establishments across the country. Business establishments and the occupational categories that are supported within firms are intrinsically linked. The NAICS data are arrayed in a hierarchical fashion using six-digit codes. The highest level includes just two digits and classifies broad industries, sub industries— typically referred to as subsectors— which are represented by three-digit codes, and industry groups that are represented by four-digit codes. Additional detail drills down further to highly specific industries. Because the data reflect individual businesses, it is generally aggregated to avoid disclosure of confidential firm-level information. Confidentiality is generally not a problem for large regional economies like a state where there are many firms operating within the same industry category. The challenge becomes more acute for small regions and highly specific industry groups. For example, employment data for a business subsector in a county may be masked (i.e. subject to nondisclosure) if there are only one or two firms in operation. An important implication is that detailed NAICS data are commonly not available to the public to support analysis and policy. In practice, most analyses that focus on industry rely on two or three-digit NAICS because of the availability of data. Unfortunately, even in these instances there can be disclosure problems as will be noted below. **Table 3** provides a summary of two-digit NAICS codes that are linked to the U.S. Census Bureau. The embedded links allow one to learn more about each industry and its composition. Sub industries within these industries are assigned to the emission reduction sectors and used as the basis for employment projections in this report.

Table 3. NAICS. North American Industrial Classification System (NAICS)

Industry	Description
11	Agriculture, Forestry, Fishing and Hunting
21	Mining, Quarrying, and Oil and Gas Extraction
22	Utilities
23	Construction
31-33	Manufacturing

[69] U.S Census Bureau, North American Industrial Classification System, https://www.census.gov/naics/

42	Wholesale Trade
44-45	Retail Trade
48-49	Transportation and Warehousing
51	Information
52	Finance and Insurance
53	Real Estate and Rental and Leasing
54	Professional, Scientific, and Technical Services
55	Management of Companies and Enterprises
56	Administrative and Support and Waste Management and Remediation Services
61	Educational Services
62	Health Care and Social Assistance
71	Arts, Entertainment, and Recreation
72	Accommodation and Food Services
81	Other Services (except Public Administration)
92	Public Administration (not covered in economic census)

Source: U.S. Census Bureau, *North American Industry Classification System (NAICS)*, Accessed January 2025. https://www.census.gov/naics/?99967.

Industries Mapped to Emission Reduction Sectors

Beneath TDEC's emission reduction sectors is a diverse array of industries at the two-digit NAICS level and sub-industries at the three-digit NAICS level. While a more detailed analysis of NAICS industries for Tennessee, Knoxville, Nashville and Memphis is desirable, it is simply not possible because of data disclosure limitations for all four geographies. The eight high-level sectors and three-digit NAICS sub-industries are matched building on the energy and climate industry cluster analysis reports discussed above, along with the expertise of the research team. Emphasis is placed on sub industries that will bear the first-round effects of addressing emission reduction challenges and responding to the energy transition rather than other businesses, including potentially impacted supply chains.

Table 4 provides a summary of this matching exercise. Shown in the table are the eight sectors and the three-digit NAICS sub industries that have been assigned to each. In total, 39 unique NAICS sub industries have been identified. Some sub industries—for example, professional, scientific, and technical services (541)—appear in more than one emission reduction sector. Educational services (611) and religious, grant making, civic, professional, and similar organizations (813) are assigned to the industry emission reduction sector. However, their influence will spread across each emission reduction

sector. Education and training needs will arise throughout the economy; because TVERS is voluntary, nonprofits, civic organizations, and other groups will play a prominent role in emission reduction. Together the sub industries shown in the table provide business targets for facilitation of projects outline in the TVER's strategy initiative.

Tennessee Employment Projections

There are too many influences on labor markets to isolate (i.e. statistically *identify*) the unique effects of the energy transition on the state's workforce development needs.[70] Especially notable is the voluntary nature TVERS, which means the path forward depends on the individual actions of people, local governments, nonprofits, and other groups, all of which are inherently unpredictable. Another complicating factor is TVA's voluntary *Valley Pathways Study* noted above which seeks to "develop a roadmap for a Net Zero greenhouse gas (GHG) emission economy by 2050."[71] The VPS may have its own unique influence on how employment evolves in Tennessee.

[70] Intuitively, identification would mean that you could causally-link facets of the energy transition to employment and training needs.
[71] Tennessee Valley Authority and Baker School of Public Policy and Public Affairs, "Valley Pathways Study," https://www.tva.com/environment/valley-pathways-study

Table 4. Three-Digit NAICS Industries Mapped to Eight Priority Emission Reduction Activities

Agriculture	Buildings	Electricity Generation	Industry	Land-Use	Transportation	Waste and Materials Management	Wastewater
Forestry and logging (113)	Construction of buildings (236)	Oil and gas extraction (211)	Construction of buildings (236)	Forestry and logging (113)	Computer and electronic product manufacturing (334)	Utilities (221)	Forestry and logging (113)
Fishing, hunting and trapping (114)	Heavy and civil engineering construction (237)	Mining (212)	Heavy and civil engineering construction (237)	Fishing, hunting and trapping (114)	Electrical equipment, appliance and component manufacturing (335)	Food manufacturing (311)	Fishing, hunting and trapping (114)
Support activities for agriculture and forestry (115)	Specialty trade contractors (238)	Support activities for Mining (213)	Specialty trade contractors (238)	Support activities for agriculture and forestry (115)	Transportation equipment manufacturing (336)	Waste management (562)	Support activities for agriculture and forestry (115)
Food manufacturing (311)	Electrical equipment, appliance and component manufacturing (335)	Utilities (221)	Food manufacturing (311)	Waste management and remediation services (562)	Motor vehicle and parts dealers (441)	Food services and drinking places (722)	Oil and gas extraction (211)
	Building material and garden equipment (444)	Construction of buildings (236)	Petroleum and coal products manufacturing (324)		Air transportation (481)		Mining (212)
	Professional, scientific and technical services (541)	Heavy and civil engineering construction (237)	Computers and electronic products manufacturing (334)		Water transportation (483)		Support activities for Mining (213)
	Waste management and remediation services (562)	Specialty trade contractors (238)	Machinery manufacturing (333)		Truck transportation (484)		Utilities (221)
	Repair and maintenance (811)	Petroleum and coal products manufacturing (324)	Electrical equipment, appliance and component manufacturing (335)		Transit and ground passenger transportation (485)		Food manufacturing (311)
		Electrical equipment, appliance and component manufacturing (335)	Warehousing storage (493)		Pipeline transportation (486)		Data processing, hosting and related services (518)
		Pipeline transportation (486)	Data processing, hosting and related services (518)		Couriers and messengers (492)		Waste management and remediation services (562)
		Telecommunications services (517)	Waste management and remediation services (562)		Warehousing and storage (493)		
		Professional, scientific and technical services (541)	Educational services (611)		Professional, scientific and technical services (541)		
		Waste management and remediation services (562)	Repair and maintenance (811)				
		Repair and maintenance (811)	Religious, grant making, civic, professional and similar organizations (813)				

The approach taken here relies on existing statewide projections of employment at the three-digit NAICS level provided by the **Tennessee Department of Labor and Workforce Development**.[72] Important features of these data include their public availability and regular updating. Embedded in the projections will be the influence of the energy transition as well as all the other factors that affect business development and employment. Note that these "other" factors can be very important in practice. For example, despite the growing role played by EVs, traditional gasoline stations and fuel dealers will generally see employment continue to expand over the next ten years. However, the longer-term outlook for these establishments is less certain. Their future will likely depend on how effectively they evolve to meet the needs of both internal combustion engine (ICE) and alternatively fueled vehicles. Those traditional fuel stations that adapt may remain relevant or even expand, while others may decline as the EV market continues to mature.

Table 5 provides statewide employment projections to 2032 for the three-digit NAICS sub industries linked to the emission reduction sectors.[73] For all industries across the state, there are expected to be 477,580 new jobs by 2032; for the industry sub industries linked here to TDEC's eight emission reduction sectors, the new job figure is projected to be 214,058, representing roughly 45 percent of the statewide employment in 2032. Note that the projected rate of growth for the identified NAICs industries (14.2 percent) is slightly higher than rate of growth for the overall state economy (13.9).

The strongest percentage growth rates in employment are expected to take place in data processing (85.8 percent), repair and maintenance (44.7 percent), and computer and electronic product manufacturing (34.9 percent). These three sub industries alone are expected to add 21,102 workers to employers' payrolls by 2032. The next six high-growth sub industries are projected to see employment rise more than 20 percent by 2032.

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[72] Alternative databases and projections all suffer from data limitations. For example, Woods and Poole Economics (www.woodsandpoole.com) provides forecasts for states and counties, but employment data are at the two-digit NAICS level. The Boyd Center for Business and Economic Research at the University of Tennessee produces employment forecasts for the state under the umbrella of the *Economic Report to the Governor* (https://haslam.utk.edu/publication/economic-report-to-the-governor-2025/) but these statewide forecasts are also at the two-digit NAICS level. (Note that the Tennessee Department of Labor and Workforce Development's projections rely in part on projections from the *Economic Report to the Governor*.) The U.S. Bureau of the Census County Business Patterns (https://www.census.gov/programs-surveys/cbp.html) data series provides more granular industry detail including at the county level, but because of disclosure issues there are many missing data fields.

[73] The online appendix for Knoxville, Memphis and Nashville include each metropolitan area's estimated share of the statewide employment totals.

Some caution needs to be exercised when looking at the percentage changes because of the scale of the data. For example, waste management should see jobs grow by 28.5 percent for a numerical increase of 2,867; building materials will see a much lower rate of job growth of 14.6 percent but will produce nearly twice as many jobs (5,664). A similar issue can arise with national employment projections. For example, the Bureau of Labor Statistics has indicated that the strongest six-digit NAICs employment growth between 2023 and 2033 will take place in solar electric power generation, wind power generation, other electric power generation, geothermal electric power generation, and other electrical equipment component manufacturing. Despite exceptionally high percentage changes (e.g. 275.9 percent for solar and 115.1 percent for wind), total job growth for these five industries will be just 111,000 out of a total of 6.7 million new jobs. Geothermal power will see 42.1 percent growth but will yield only 500 new jobs.[74] Despite the small-to-modest numbers, training will nonetheless be required for many of these workers.

Seven of the sub industries should create more than 10,000 new jobs by 2032. Growth will be led by food services (43,158 jobs), educational services (42,638 jobs), and professional, scientific and technical services (36,789). These three high-growth sub industries will yield 122,585 new positions within Tennessee business establishments.

Seven sub industries are projected to experience job losses by 2032. Crop production will see the largest percentage (30.7 percent) and numerical (5,450) loss in jobs. Credit intermediation and related activities, securities, commodity contracts, and other financial investments and religious, grantmaking, civic and professional organizations will all be down by more than 1,000 jobs. Together the jobs losses for all the declining sub industries should total 11,628. However, the state's comprehensive plan includes consideration of strategies to conserve and manage farmland—aimed at reducing emissions associated with land development and farmland loss—which may help stabilize employment in some of these sectors and mitigate projected job declines.

There are many important nuances to these data. **First, some of the sub industries have a limited number of business establishments and small labor counts or another issue that leads to disclosure and thus projection**

[74] https://www.bls.gov/emp/tables/industries-fast-grow-employment.htm

challenges. At the state level, this includes forestry and logging; fishing, hunting, and trapping; support activities for mining; and petroleum and coal. The problem becomes more acute with the sub-state data discussed below. Railroad transportation is uniquely unreported because the sector does not rely on the state's unemployment insurance system, which serves as a foundation for the collection of County Business Patterns data. Finally, TVA is not included because it is embedded in data for federal employment. One would generally expect TVA employment to follow the path of the utility sector.

Second, the employment figures represent positions within firms and are fluid with the ongoing entry and exit of workers. For example, a business may have a solar installer position, but over time several individuals may hold this same position. This could arise through worker exit from the firm or worker advancement/reassignment within the firm, creating the need for a new hire. Data for the U.S. indicate that employment *quit rates* (i.e. the share of workers quitting their job) hovered around 2 percent in 2024.[75] In practice, a given job position may require the training of multiple people over time for the same job position.

Third, the NAICS industry employment data apply to the location of business establishments, not where employees live. Many workers cross state, county, and metropolitan area borders as they commute to their place of work. This has implications for workforce planning and education and training programs. **Employee-based training** could take place within the firm, online, in the communities where workers live, or where education and training services are provided. **Employer-based training**, on the other hand, would commonly occur at the workplace. Providing training at the firm level and at the workplace offers efficiencies in service delivery by potentially capturing the entire workforce in one place, avoiding unnecessary travel.

[75] Data on job openings and job transitions can be found at U.S. Bureau of Labor Statistics, Job Openings and Labor Turnover Survey, https://data.bls.gov/toppicks?survey=jt. Also see https://www.bls.gov/jlt/jlt_statedata.htm

Table 5. Tennessee Employment Projections for Identified Industries

NAICS 3-Digit Code	Industry	Employment 2022	Projected Employment 2032	# change	% change
	Total TN employment	**3,423,768**	**3,901,356**	**477,588**	**13.9%**
	Total employment in identified sectors	**1,507,698**	**1,721,756**	**214,058**	**14.2%**
111	Crop Production	17,756	12,306	-5,450	-30.7%
112	Animal Production and Aquaculture	9,848	10,872	1,024	10.4%
113	Forestry and logging	--	--	--	--
114	Fishing, hunting and trapping	--	--	--	--
115	Support activities for agriculture and forestry	7,646	7,815	169	2.2%
211	Oil and gas extraction				
212	Mining (except oil and gas)	3,341	3,881	540	16.2%
213	Support activities for mining	--	--	--	--
221	Utilities	4,112	4,828	716	17.4%
236	Construction of buildings	31,772	39,172	7,400	23.3%
237	Heavy and civil engineering construction	18,916	23,278	4,362	23.1%
238	Specialty trade contractors	94,691	106,991	12,300	13.0%
311	Food manufacturing	39,398	41,305	1,907	4.8%
324	Petroleum and coal products manufacturing	--	--	--	--
334	Computer and electronic product manufacturing	6,674	9,002	2,328	34.9%
335	Electrical equipment, appliance, and component manufacturing	19,045	20,149	1,104	5.8%
336	Transportation equipment manufacturing	72,250	93,592	21,342	29.5%
441	Motor vehicle and parts dealers	51,464	54,888	3,424	6.7%
444	Building material and garden equipment and supplies dealers	38,862	44,526	5,664	14.6%
457	Gasoline Stations and Fuel Dealers	25,280	27,724	2,444	9.7%
481	Air transportation	2,969	3,007	38	1.3%
482	Rail Transportation	--	--	--	--
483	Water transportation	2,007	1,931	-76	-3.8%
484	Truck transportation	58,555	60,613	2,058	3.5%
485	Transit and ground passenger transportation	6,126	6,633	507	8.3%
486	Pipeline transportation	228	233	5	2.2%
491	Postal Service	13,126	12,853	-273	-2.1%
492	Couriers and messengers	53,041	56,317	3,276	6.2%
493	Warehousing and storage	53,626	64,478	10,852	20.2%
517	Telecommunications	8,744	7,908	-836	-9.6%
518	Data processing, hosting, and related services	6,811	12,626	5,815	85.4%
522	Credit intermediation and related activities	53,411	51,619	-1,792	-3.4%
523	Securities, commodity contracts, and other financial investments, etc.	17,100	15,742	-1,358	-7.9%
541	Professional, scientific, and technical services	163,489	200,278	36,789	22.5%
562	Waste management and remediation services	10,061	12,928	2,867	28.5%
611	Educational services	258,924	301,562	42,638	16.5%
722	Food services and drinking places	261,872	305,030	43,158	16.5%
811	Repair and maintenance	28,970	41,929	12,959	44.7%

813	Religious, grantmaking, civic, professional, and similar	67,583	65,740	-1,843	-2.7%

Source: Tennessee Department of Labor and Workforce Development (jobs4TN). Note that missing values denoted by (--) indicate that employment numbers were not available for that industry or were suppressed

Metropolitan Area Projections: Knoxville, Memphis, and Nashville

The Knoxville, Memphis, and Nashville metropolitan areas are developing their own emission reductions, complementing the state's plan. To help guide their workforce planning activities and ensure coordination and harmony with the state, MSA industry projections for 2032 have been derived from the data presented above. The U.S. Census Bureau County Business Patterns data series is used to calculate industry-specific subsector employment shares for each MSA in 2022. These subsector employment shares are then used to allocate the state projections presented above down to each of the three MSAs.[76]

Key Trends

- **Employment Projections for 2032:** Workforce projections for the three MSAs are derived using industry-specific employment shares from 2022, ensuring alignment with state-level trends.

- **Knoxville Employment Trends:**
  - Employment in key energy transition-related industries is expected to grow by 15.4% by 2032.
  - The largest job gains will occur in professional services, food services, and transportation equipment manufacturing.
  - Some sub industries, such as credit intermediation and religious organizations, will see modest job losses.

- **Memphis Employment Trends:**
  - Emission reduction-related sub industries are projected to grow by 13.5%, adding over 40,000 jobs.
  - Strong job growth is expected in educational services, food services, and warehousing and storage.

[76] This allocation procedure ensures that the MSA projections properly *add up* and are consistent with state-level projections.

- Employment declines will be minimal, with religious and grant-making activities experiencing the largest job losses.

- **Nashville Employment Trends:**
  - The largest of the three MSAs, Nashville accounted for over one-third of Tennessee's employment in 2022.
  - Emission reduction sector-related industries will add over 83,000 jobs by 2032, with the highest growth in education, professional services, and food services.
  - Some financial and nonprofit industries, including securities and credit intermediation, will experience small job losses.

- **Overall Job Growth vs. Losses:**
  - Job growth in emission reduction-related sectors will outpace losses in all three MSAs.
  - Despite job declines in select sub industries, workforce exits may create new opportunities requiring education and training.

Knoxville. The Knoxville metropolitan area accounted for 12.6 percent of total statewide employment in 2002. The estimates indicate that 180,910 jobs in the Knoxville area are tied to one of the emission reduction sectors, which was 12.0 percent of statewide employment in the identified sub industries. Employment in the identified sub industries is expected to see growth of 15.4 percent by 2032 (representing an increase of 27,829 jobs) compared to 13.9 percent for all employment in the MSA.[77] This includes agricultural-related industries, as well as oil and gas extraction, support for mining activities, petroleum and coal products manufacturing, rail transportation, and water transportation.

The largest job gains will take place in professional, scientific, and technical services (7,335), food services (5,803), and transportation equipment manufacturing (3,328). Gasoline stations and fuel dealers will continue to see growth (276 jobs) despite the energy transition. Five sub industries are

[77] As shown in the online appendix, nine sub industries show empty employment cells due to small numbers of firms/jobs or other reporting issues.

expected to experience employment losses between 2022 and 2032. The largest setbacks will take place in credit intermediation (-291 jobs), religious and grantmaking organizations (-266 jobs), and telecommunications (-128 jobs). Together the number of lost jobs is relatively small compared to the number of new jobs. As noted above, even though some sub industries may experience net job losses, there may be some new job opportunities due to worker exits that give rise to education and training needs.

Memphis. There were 654,917 total jobs in the Memphis metropolitan area in 2022, representing 19.1 percent of the state's jobs. For sub industries tied to the emission reduction sectors, employment stood at 300,086 in 2022, or 45.8 percent of the MSA total. The emission reduction-related sub industries are expected to grow by 13.5 percent by 2032 while overall metropolitan area employment grows by 13.9 percent. A total of 40,377 new jobs will be created in the identified sub industries by 2032. Like the other metropolitan areas, data limitations mean that several sub industries are not represented in the figures. Exceptionally robust growth will take place in educational services (8,779 jobs), food services (7,580 jobs), and warehousing and storage (6,321 jobs). Six sub industries will experience jobs losses by 2032, with the largest losses taking place in religious and grantmaking activities (-417 jobs). Total losses for all the contracting sub industries total to 1,176 jobs, a small share of the region's employment base.

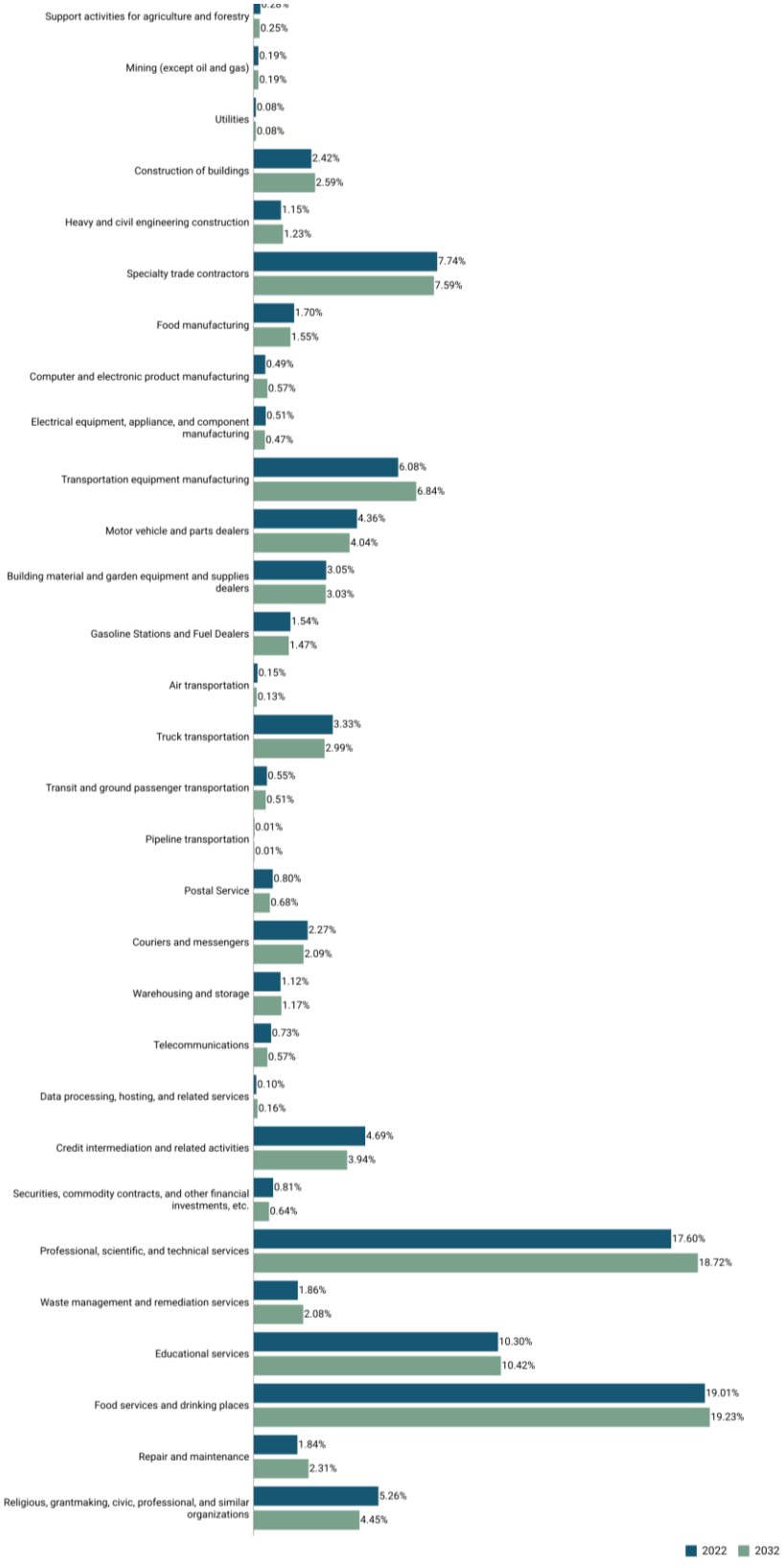
Nashville. The Nashville MSA had over 1.1 million jobs and accounted for just over one-third of total state employment in 2022. Employment in industries associated with the emission reduction sectors was 546,386 in 2022, or 47.7 percent of total identified employment. The identified sectors will together see jobs grow by 83,104 by 2032. Eight sub industries show no employment in the Nashville MSA, similar to Knoxville and Memphis. Large employment gains are expected in educational services (19,806), professional services (14,576), and food services (14,884). Six sub industries will have identifiable jobs losses between 2022 and 2032. The largest losses will take place in securities (-774), religious and grantmaking activities (-599), and credit intermediation services (-571). Total losses for all six contracting sub industries are projected to be 2,367.

Table 6. Knoxville MSA Employment Projections for Identified Industries

NAICS 3-Digit Code	Industry	Employment 2022	Projected Employment 2032	# change
	Total Knoxville MSA employment	**430,563**	**490,623**	**60,060**
	Total employment in identified sectors	**185,250**	**213,324**	**28,075**
115	Support activities for agriculture and forestry	523	535	12
212	Mining (except oil and gas)	354	412	57
221	Utilities	153	180	27
236	Construction of buildings	4,487	5,532	1,045
237	Heavy and civil engineering construction	2,124	2,614	490
238	Specialty trade contractors	14,334	16,196	1,862
311	Food manufacturing	3,144	3,297	152
334	Computer and electronic product manufacturing	905	1,221	316
335	Electrical equipment, appliance, and component manufacturing	938	993	54
336	Transportation equipment manufacturing	11,265	14,593	3,328
441	Motor vehicle and parts dealers	8,074	8,611	537
444	Building material and garden equipment and supplies dealers	5,642	6,464	822
457	Gasoline Stations and Fuel Dealers	2,857	3,133	276
481	Air transportation	276	280	4
484	Truck transportation	6,170	6,387	217
485	Transit and ground passenger transportation	1,010	1,094	84
486	Pipeline transportation	14	15	0
491	Postal Service	1,483	1,452	-31
492	Couriers and messengers	4,204	4,464	260
493	Warehousing and storage	2,077	2,498	420
517	Telecommunications	1,344	1,215	-128
518	Data processing, hosting, and related services	187	347	160
522	Credit intermediation and related activities	8,688	8,396	-291
523	Securities, commodity contracts, and other financial investments, etc.	1,492	1,373	-118
541	Professional, scientific, and technical services	32,597	39,932	7,335
562	Waste management and remediation services	3,451	4,434	983
611	Educational services	19,084	22,227	3,143
722	Food services and drinking places	35,211	41,014	5,803
811	Repair and maintenance	3,406	4,930	1,524
813	Religious, grantmaking, civic, professional, and similar organizations	9,753	9,487	-266

Source: TN Department of Labor & Workforce Development jobs4TN and U.S. Census Bureau County Business Patterns.
*NAICS Industries were only included for identified sectors in which state-level data were available through job4TN & metro-level employment data were available through County Business Patterns

Figure 6. Knoxville: Knoxville MSA Employment Projections for Identified Industries, % Share (2022, 2032)



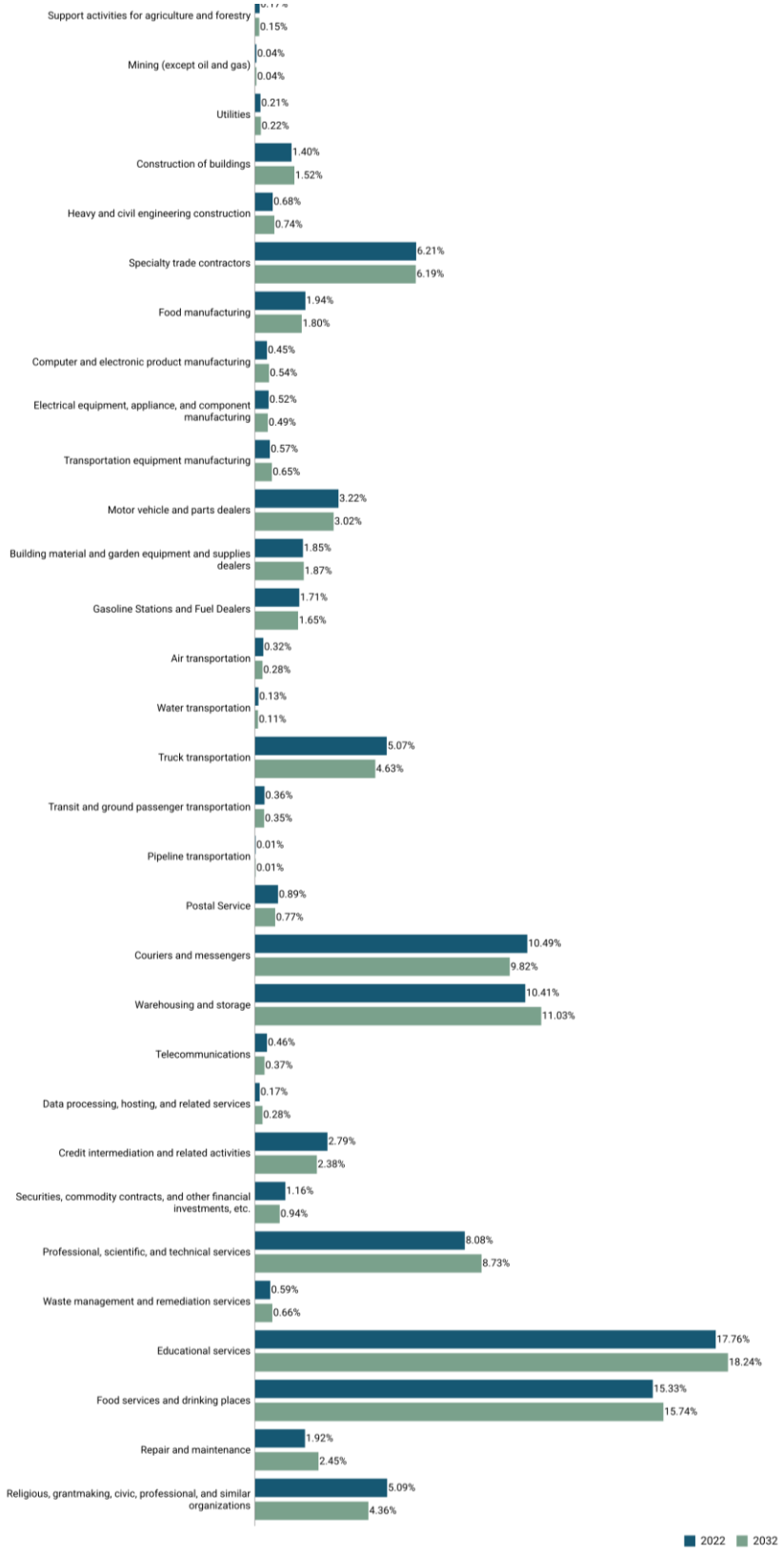
Source: Graph illustrates the total percentage share of the MSA's relevant NAICS industries based on 2022 figures and 2032 projections from Table 6. Knoxville MSA Employment Projections for Identified Industries.

Table 7. Memphis MSA Employment Projections for Identified Industries

NAICS 3-Digit Code	Industry	Employment 2022	Projected Employment 2032	# change
	Total Memphis MSA employment	**654,917**	**746,273**	**91,356**
	Total employment in identified sectors	**300,086**	**340,463**	**40,377**
115	Support activities for agriculture and forestry	503	514	11
212	Mining (except oil and gas)	116	135	19
221	Utilities	631	741	110
236	Construction of buildings	4,198	5,176	978
237	Heavy and civil engineering construction	2,053	2,526	473
238	Specialty trade contractors	18,641	21,063	2,421
311	Food manufacturing	5,831	6,113	282
334	Computer and electronic product manufacturing	1,352	1,823	471
335	Electrical equipment, appliance, and component manufacturing	1,563	1,654	91
336	Transportation equipment manufacturing	1,719	2,226	508
441	Motor vehicle and parts dealers	9,648	10,290	642
444	Building material and garden equipment and supplies dealers	5,552	6,362	809
457	Gasoline Stations and Fuel Dealers	5,132	5,628	496
481	Air transportation	947	959	12
483	Water transportation	391	376	-15
484	Truck transportation	15,225	15,760	535
485	Transit and ground passenger transportation	1,086	1,176	90
486	Pipeline transportation	26	26	1
491	Postal Service	2,665	2,609	-55
492	Couriers and messengers	31,477	33,421	1,944
493	Warehousing and storage	31,233	37,554	6,321
517	Telecommunications	1,391	1,258	-133
518	Data processing, hosting, and related services	522	968	446
522	Credit intermediation and related activities	8,369	8,089	-281
523	Securities, commodity contracts, and other financial investments, etc.	3,467	3,192	-275
541	Professional, scientific, and technical services	24,252	29,709	5,457
562	Waste management and remediation services	1,761	2,263	502
611	Educational services	53,309	62,087	8,779
722	Food services and drinking places	45,995	53,575	7,580
811	Repair and maintenance	5,757	8,332	2,575
813	Religious, grantmaking, civic, professional, and similar organizations	15,274	14,857	-417

Source: TN Department of Labor & Workforce Development jobs4TN and U.S. Census Bureau County Business Patterns.
*NAICS Industries were only included for identified sectors in which state-level data were available through job4TN & metro-level employment data were available through County Business Patterns

Figure 7. Memphis: Memphis MSA Employment Projections for Identified Industries, % Share (2022, 2032)



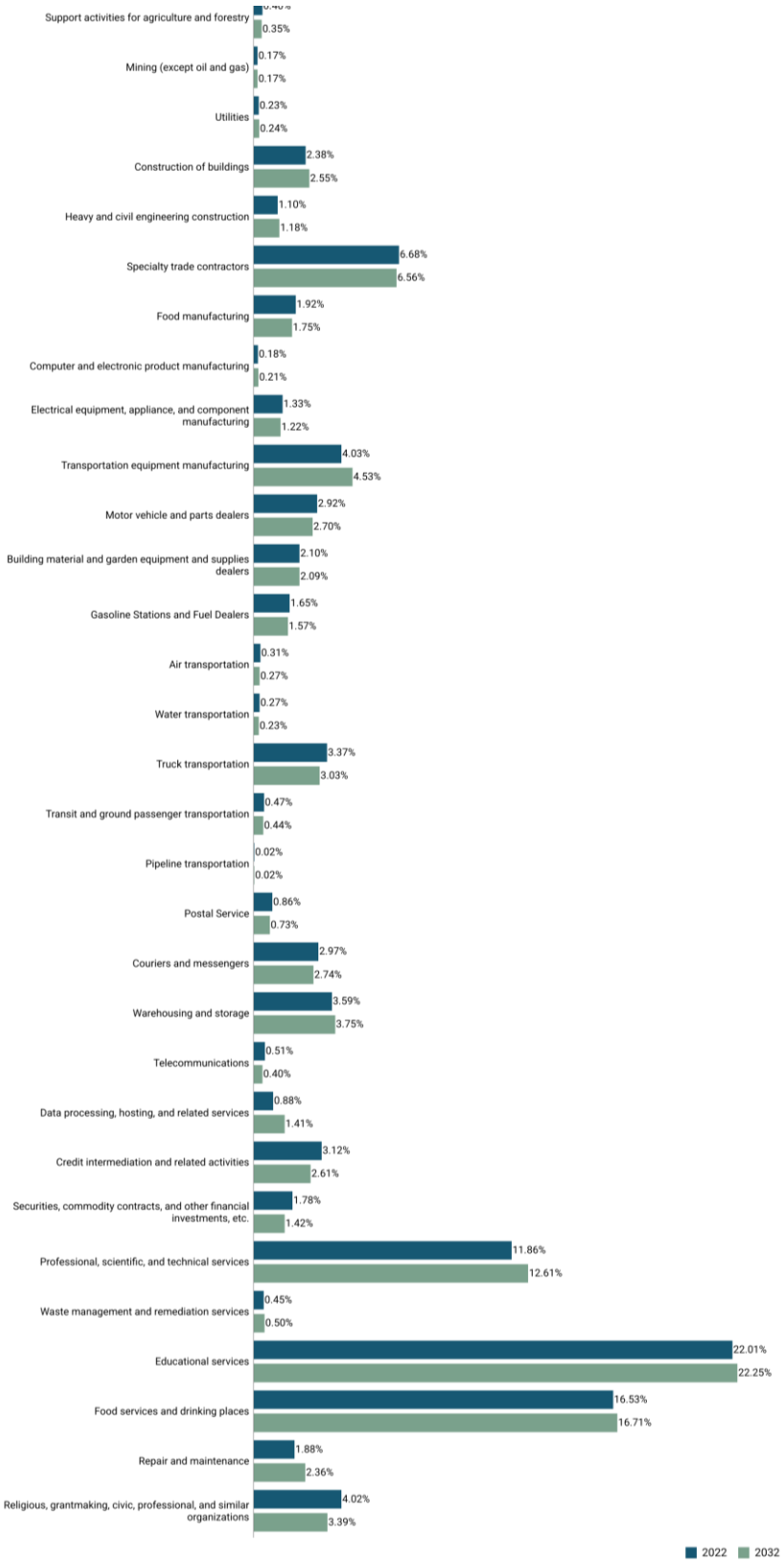
Source: Graph illustrates the total percentage share of the MSA's relevant NAICS industries based on 2022 figures and 2032 projection from Table 7. Memphis MSA Employment Projections for Identified Industries.

Table 8. Nashville: Nashville MSA Employment Projections for Identified Industries

NAICS 3-Digit Code	Industry	Employment 2022	Projected Employment 2032	# change
	Total Nashville MSA employment	**1,146,615**	**1,306,558**	**159,943**
	Total employment in identified sectors	**546,386**	**629,490**	**83,104**
115	Support activities for agriculture and forestry	2,173	2,221	48
212	Mining (except oil and gas)	941	1,093	152
221	Utilities	1,265	1,486	220
236	Construction of buildings	13,000	16,028	3,028
237	Heavy and civil engineering construction	6,012	7,398	1,386
238	Specialty trade contractors	36,520	41,264	4,744
311	Food manufacturing	10,512	11,021	509
334	Computer and electronic product manufacturing	983	1,326	343
335	Electrical equipment, appliance, and component manufacturing	7,278	7,700	422
336	Transportation equipment manufacturing	21,994	28,490	6,497
441	Motor vehicle and parts dealers	15,959	17,021	1,062
444	Building material and garden equipment and supplies dealers	11,462	13,133	1,671
457	Gasoline Stations and Fuel Dealers	9,025	9,897	873
481	Air transportation	1,682	1,704	22
483	Water transportation	1,493	1,437	-57
484	Truck transportation	18,401	19,047	647
485	Transit and ground passenger transportation	2,546	2,757	211
486	Pipeline transportation	136	139	3
491	Postal Service	4,686	4,589	-97
492	Couriers and messengers	16,250	17,253	1,004
493	Warehousing and storage	19,640	23,615	3,974
517	Telecommunications	2,810	2,542	-269
518	Data processing, hosting, and related services	4,796	8,891	4,095
522	Credit intermediation and related activities	17,029	16,458	-571
523	Securities, commodity contracts, and other financial investments, etc.	9,741	8,967	-774
541	Professional, scientific, and technical services	64,777	79,354	14,576
562	Waste management and remediation services	2,439	3,134	695
611	Educational services	120,275	140,081	19,806
722	Food services and drinking places	90,313	105,197	14,884
811	Repair and maintenance	10,283	14,883	4,600
813	Religious, grantmaking, civic, professional, and similar organizations	21,962	21,363	-599

Source: TN Department of Labor & Workforce Development jobs4TN and U.S. Census Bureau County Business Patterns.
*NAICS Industries were only included for identified sectors in which state-level data were available through job4TN & metro-level employment data were available through County Business Patterns

Figure 8. Nashville MSA Employment Projections for Identified Industries, % Share (2022, 2032)



Source: Graph illustrates the total percentage share of the MSA's relevant NAICS industries based on 2022 figures and 2032 projection from Table 8. Nashville MSA Employment Projections for Identified Industries.

Occupational Outlook: Workforce Needs

Overview

The discussion above focused on industry-level employment projections for Tennessee and its major metropolitan areas. The focus here shifts to occupations and the energy transition induced occupational outlook. Like NAICS and industry analysis, there is a formal hierarchical accounting scheme for occupations referred to as the **Standard Occupational Code (SOCs)** system which supports data and statistical analysis for workers within and across job classifications.

Occupational Analysis

According to the U.S. Bureau of Labor Statistics, there are 867 occupations arrayed into "459 broad categories, 98 minor groups, and 23 major groups."[78] The system is especially useful since each occupational category has largely similar job duties and education and training requirements. To identify workforce and education needs from an energy transition, the analysis in this report starts from **15 priority emission reduction measures (ERMs) in Tennessee's Priority Plan** below.

Tennessee Emission Reduction Measures
1. Soil management practices
2. Farmland preservation
3. Commercial and industrial buildings efficiency
4. Residential weatherization and efficiency
5. Nuclear energy
6. Renewable energy generation
7. Heat pumps
8. Oil and methane gas recovery
9. Preserve forest land, including urban forests
10. Wetland and grassland conservation
11. Electric vehicle adoption
12. Community electric vehicle charging
13. Transit, biking, and walking
14. Divert food and yard waste
15. Landfill methane gas recovery

[78] U.S. Bureau of Labor Statistics, Standard Occupational Classification, https://www.bls.gov/soc/

This report identifies occupations that are most relevant to this set of ERMs. Sources include large language model analysis of the 15 ERMs, the Urban Institute's list of "clean energy" jobs,[79] and other state's priority plans.[80] Each job title is connected to a numeric code in the SOC system, which we use to find total Tennessee employment for each job, as well as average annual pay, projected employment growth over 2022 – 2032, entry-level education requirements, and aligned education programs in Tennessee.[81]

Constructing energy-efficient buildings, renovating existing buildings to be more energy efficient, and building of electric vehicle infrastructure are all labor-intensive activities, so the workforce demand is concentrated in these five ERAs.

From this methodology, 103 specific job titles are identified as related to ERMs. These are reduced to the 36 jobs for which there is a high-degree of confidence that a significant number of workers would be involved in the ERMs listed above. We use **three criteria** to identify the smaller set of jobs:

1. appearing in our **Tennessee-specific sources of occupations related to ERMs,** or in more than one of all sources,
2. having **Tennessee employment of at least 100 in 2022,**[82] and
3. **projected to grow 7 percent or more between 2022 and 2023,** which would match or exceed population growth over that window of time.[83]

Finally, we exclude job titles that are too broad or too diffuse to be informative on this question, such as "General and Operations Managers" and "General Maintenance and Repair Workers." One example, "Surface Mining Excavating and Loading Machine and Dragline Operator" is a job that fails the first criteria.[84] They would be direct contributors to Tennessee's prioritized

[79] Urban Institute, "Clean Energy Job Quality and Education Data." (2024). https://datacatalog.urban.org/dataset/clean-energy-job-quality-and-education-data.
[80] Massachusetts and Colorado PCAPs listed specific occupations related to clean energy, which we incorporate into our analysis. Other states listed industries where they anticipated effects, reported an estimated number of total jobs created, or described the workforce needs for specific projects.
[81] Data sources Tennessee Department of Labor and Workforce Development for employment, projected employment growth, and average annual pay; the U.S. Bureau of Labor Statistics for entry-level education requirements and aligned academic programs; and the Tennessee Higher Education Commission for the in-state supply of aligned academic programs.
[82] Less than 1% of Tennessee workers are in an occupation with fewer than 100 statewide total employment.
[83] Tennessee State Data Center, Boyd Center for Business and Economic Research, *2022 to 2070 Tennessee Population Projections*. https://tnsdc.utk.edu/estimates-and-projections/boyd-center-population-projections/
[84] For example, this occupation is listed in Colorado's priority plan but not our other sources. "Petroleum Engineer" and "Solar Photovoltaic Installer" are two jobs that fail the second criteria.

ERMs (specifically, oil and gas methane recovery, and renewable energy), but there are very few people who hold these jobs in Tennessee. Their employment and pay data are suppressed in the state labor projections. Finally, “Forester” and “Forest and Conservation Technician” are two examples of jobs that meet the first and second criteria, but not the employment growth criteria. Employment in these occupations is expected to grow by 3 to 4 percent between 2022 and 2032, which would not keep pace with the state population.

The key point is while we might expect that ERMs will be a bigger part of day-to-day work for petroleum engineers, solar installers, and foresters over time, the workforce needs that arises out of an energy transition will be more acute for jobs markets that are large and growing. For instance, Nuclear Technicians meet all four criteria, and they would contribute to the nuclear energy ERM There were 141 nuclear technicians working in Tennessee in 2022, and the Tennessee Department of Labor and Workforce Development forecasted that this would grow by 13 percent to 159 in 2032. Note that we do not know if an energy transition would increase demand for nuclear technicians by more than the baseline 10-year forecast. It is possible that demand for nuclear technicians has already risen during the current and recent phases of the energy transition, and that ERMs are implicit in some part of the state’s 13 percent forecast.

The same is true for all the 36 emission reduction jobs we highlight in **Table 9.** The table lists jobs identified as (1) related to one or more of Tennessee priority emission reduction activities, (2) having total statewide employment of at least 100 in 2022, and (3) projected to grow by at least 7 percent between 2022 and 2032. Average annual pay is in 2022 dollars. There are 36 jobs where a significant number of workers would likely be involved in emission reduction activities. Sources include the Tennessee Department of Labor and Workforce Development for employment and pay data, the Tennessee Higher Education Commission for "in demand" and key industry indicators, and the U.S. Bureau of Labor Statistics for typical entry-level education and apprenticeship requirements. **Table 10** provides the CIP codes for each related SOC, based on Lightcast data.[85] **Table 11** provides Metropolitan Service Area (MSA) data on postings, educational requirements, academic program

[85] Lightcast, "Lightcast Data: Basic Overview," Lightcast Knowledge Base. Accessed February 2025, https://kb.lightcast.io/en/articles/6957498-lightcast-data-basic-overview. Lightcast gathers and integrates economic, labor market, demographic, education, profile, and job posting data from public and private-sector sources, creating a comprehensive and current industry, occupation, and education dataset.

availability, completions, and openings using Lightcast Data. **Table 12** provides a summary from Lightcast for Tennessee in each occupational area identified.

Table 9. Tennessee Related Emissions Reduction Activities Impacted Occupations (36 total)

SOC Code	Job Title	Tennessee Employment in 2022	Forecasted Tennessee Employment in 2032	Forecasted Percentage Growth in Tennessee Employment	Average Annual Pay	"In Demand" Occupation	Occupation is in a Key Economic Development Industry	Typical Entry-Level Education Requirement	Apprenticeship Required
11-3071	Transportation, Storage, and Distribution Managers	5,544	6,420	15.8	$101,888		X	High School Diploma Or Equivalent	
11-9021	Construction Managers	10,755	13,157	22.33	98,395	X		Bachelor's Degree	
11-9041	Architectural and Engineering Managers	2,705	2,995	10.72	146,347		X	Bachelor's Degree	
13-1051	Cost Estimators	3,733	4,116	10.26	75,201	X	X	Bachelor's Degree	
17-2051	Civil Engineers	4,044	4,413	9.12	95,814		X	Bachelor's Degree	
17-2071	Electrical Engineers	1,959	2,293	17.05	102,599		X	Bachelor's Degree	
17-2072	Electronics Engineers, Except Computer	871	1,137	30.54	103,358		X	Bachelor's Degree	
17-2081	Environmental Engineers	1,202	1,458	21.3	85,172		X	Bachelor's Degree	
17-2141	Mechanical Engineers	2,387	2,782	16.55	99,186		X	Bachelor's Degree	
17-2161	Nuclear Engineers	299	338	13.04	133,778			Bachelor's Degree	
17-3023	Electrical and Electronics Engineering Technologists and Technicians	2,292	2,763	20.55	61,859	X	X	Associate's Degree	
19-1013	Soil and Plant Scientists	202	223	10.4	65,033			Bachelor's Degree	
19-1031	Conservation Scientists	205	222	8.29	75,107			Bachelor's Degree	
19-2042	Geoscientists, Except Hydrologists and Geographers	322	380	18.01	82,996			Bachelor's Degree	
19-4051	Nuclear Technicians	141	159	12.77	90,223			Associate's Degree	
37-3011	Landscaping and Groundskeeping Workers	19,909	22,197	11.49	37,173	X		No Formal Educational Credential	
47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	16,067	18,862	17.4	71,065			High School Diploma Or Equivalent	
47-2031	Carpenters	13,084	15,494	18.42	48,871	X		High School Diploma Or Equivalent	X
47-2061	Construction Laborers	32,751	40,868	24.78	42,235	X		No Formal Educational Credential	
47-2111	Electricians	17,869	20,107	12.52	57,707		X	High School Diploma Or Equivalent	X
47-2131	Insulation Workers, Floor, Ceiling, and Wall	1,106	1,263	14.2	40,894			No Formal Educational Credential	
47-2132	Insulation Workers, Mechanical	378	412	8.99	49,966			High School Diploma Or Equivalent	X
47-2152	Plumbers, Pipefitters, and Steamfitters	9,464	10,230	8.09	55,232	X	X	High School Diploma Or Equivalent	X
47-2181	Roofers	2,316	2,647	14.29	43,430			No Formal Educational Credential	
47-2221	Structural Iron and Steel Workers	1,655	1,835	10.88	54,611			High School Diploma Or Equivalent	X
47-3012	Helpers--Carpenters	869	992	14.15	36,921			No Formal Educational Credential	
49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	11,772	13,950	18.5	72,285		X	High School Diploma Or Equivalent	
49-2096	Electronic Equipment Installers and Repairers, Motor Vehicles	473	542	14.59	45,430			High School Diploma Or Equivalent	
49-3023	Automotive Service Technicians and Mechanics	18,846	22,458	19.17	49,509	X	X	Postsecondary Nondegree Award	
49-9021	Heating, Air Conditioning, and Refrigeration Mechanics and Installers	10,335	11,314	9.47	50,411	X	X	Postsecondary Nondegree Award	
49-9051	Electrical Power-Line Installers and Repairers	3,142	3,789	20.59	71,116			High School Diploma Or Equivalent	
49-9052	Telecommunications Line Installers and Repairers	1,520	1,932	27.11	59,447	X		High School Diploma Or Equivalent	
49-9098	Helpers--Installation, Maintenance, and Repair Workers	2,222	2,554	14.94	36,206	X		High School Diploma Or Equivalent	
51-4121	Welders, Cutters, Solderers, and Brazers	13,935	15,707	12.72	45,444	X	X	High School Diploma Or Equivalent	
51-8011	Nuclear Power Reactor Operators	300	332	10.67	117,596			High School Diploma Or Equivalent	
53-3032	Heavy and Tractor-Trailer Truck Drivers	64,910	71,242	9.76	55,420	X	X	Postsecondary Nondegree Award	

Table 10. CIP Codes for Related Emissions Reduction Activities Impacted Occupations (36 total)

SOC Code	Job Title	Related CIP Codes
11-3071	Transportation, Storage, and Distribution Managers	52.0101, 52.0203, 52.0213, 49.0101, 44.0401, 52.0205, 52.0305, 49.0104, 52.0209, 52.9999
11-9021	Construction Managers	52.0101, 46.0415, 52.2001, 52.0205, 15.0101, 46.9999, 15.1001, 52.9999
11-9041	Architectural and Engineering Managers	14.1901, 14.801, 14.0501, 14.1001, 14.0701, 14.3501, 26.0202, 14.2301, 04.0201, 14.0201
13-1051	Cost Estimators	52.0101, 14.1901, 27.0101, 46.0415, 52.2001, 14.1801, 15.0101, 46.9999, 15.1001
17-2051	Civil Engineers	14.0801, 14.0101, 14.0401
17-2071	Electrical Engineers	14.1001, 14.0101, 14.0901, 14.4701
17-2072	Electronics Engineers, Except Computer	52.0203, 14.1001, 14.0201, 14.0101, 52.0209
17-2081	Environmental Engineers	14.0801, 40.0601, 14.0101, 03.0104, 14.1401, 03.03103, 03.0101, 40.0101
17-2141	Mechanical Engineers	14.1901, 14.0201, 14.0101, 15.0613
17-2161	Nuclear Engineers	40.0801, 14.2301, 14.0101, 40.0101
17-3023	Electrical and Electronics Engineering Technologists and Technicians	15.0000, 15.0403, 47.0105, 15. 0613, 15.0303, 15.1201, 15.0399
19-1013	Soil and Plant Scientists	26.0101, 40.0501, 40.0601, 01.1101, 01.0000, 01.1202, 03.0501, 01.1105, 01.9999, 40.0101
19-1031	Conservation Scientists	40.0601, 01.1101, 03.0601, 31.0301, 03.0501, 30.3301, 03.0299, 15.0506, 40.0101
19-2042	Geoscientists, Except Hydrologists and Geographers	40.0501, 14.0701, 40.1001, 40.0101
19-4051	Nuclear Technicians	40.0801, 40.0101
37-3011	Landscaping and Groundskeeping Workers	31.0301, 01.0000, 04.0601, 46.0401, 01.9999
47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	46.0302, 46.0415, 52.2001, 46.9999, 46.0401, 46.0502, 15.1001, 46.0503, 04.0902
47-2031	Carpenters	46.0415, 46.9999
47-2061	Construction Laborers	46.0415, 46.9999
47-2111	Electricians	46.0302, 15.0613, 46.9999
47-2131	Insulation Workers, Floor, Ceiling, and Wall	46.0415
47-2132	Insulation Workers, Mechanical	46.0415
47-2152	Plumbers, Pipefitters, and Steamfitters	47.0201, 46.999, 46.0502, 46.0503
47-2181	Roofers	46.0415
47-2221	Structural Iron and Steel Workers	48.0508
47-3012	Helpers--Carpenters	--
49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	47.0604, 47.0201, 47.0603, 47.0303, 46.0302, 15.0613, 52.0205, 47.0600, 46.0303, 46.9999
49-2096	Electronic Equipment Installers and Repairers, Motor Vehicles	47.0201, 47.0303, 15.0403, 47.0105, 15.0303, 47.0104
49-3023	Automotive Service Technicians and Mechanics	47.0604, 47.0603, 47.0613, 47.0605, 47.0600
49-9021	Heating, Air Conditioning, and Refrigeration Mechanics and Installers	47.0201, 15.0501
49-9051	Electrical Power-Line Installers and Repairers	46.0303
49-9052	Telecommunications Line Installers and Repairers	15.1201, 11.1002, 11.1001
49-9098	Helpers--Installation, Maintenance, and Repair Workers	47.0201, 47.0303, 47.0302, 47.0605
51-4121	Welders, Cutters, Solderers, and Brazers	48.0508, 15.0614
51-8011	Nuclear Power Reactor Operators	--
53-3032	Heavy and Tractor-Trailer Truck Drivers	49.0205

Source: Lightcast, "Lightcast," accessed February 2025. https://lightcast.io/.

Table 11. Metropolitan Service Area (MSA) Related Emissions Reduction Activities Impacted Occupations (36 total) Postings, Requirements, and Program Completions

SOC Code	Job Title	2024 Unique Job Postings (Nashville MSA)	2024 Unique Job Postings (Knoxville MSA)	2024 Unique Job Postings (Memphis MSA)	No Education Requirement listed on Postings	High School or GED listed on Posting	Associate's Degree Listed on Posting	Bachelor's Degree Listed on Posting	# of Educational Programs in Tennessee	# of Completions in MSAs in related Programs (2023)	# of Openings (2023) in MSAs (Nashville, Knoxville, Memphis)
11-3071	Transportation, Storage, and Distribution Managers	1,957	432	852	42%	24%	5%	38%	12	1,819	407
11-9021	Construction Managers	2,205	607	490	51%	14%	4%	39%	8	907	429
11-9041	Architectural and Engineering Managers	696	185	171	31%	7%	55	63%	37	2,197	159
13-1051	Cost Estimators	800	222	170	54%	12%	7%	35%	14	1,658	247
17-2051	Civil Engineers	1,179	522	322	25%	5%	2%	67%	3	304	240
17-2071	Electrical Engineers	341	484	123	21%	3%	5%	74%	5	324	121
17-2072	Electronics Engineers, Except Computer	109	41	53	22%	11%	31%	45%	7	853	47
17-2081	Environmental Engineers	60	33	23	16%	1%	4%	82%	8	464	64
17-2141	Mechanical Engineers	594	440	190	23%	9%	9%	62%	4	566	151
17-2161	Nuclear Engineers	5	44	4	13%	3%	7%	71%	4	287	10
17-3023	Electrical and Electronics Engineering Technologists and Technicians	257	104	91	35%	48%	27%	10%	9	562	161
19-1013	Soil and Plant Scientists	3	30	--	18%	10%	5%	36%	11	1,301	16
19-1031	Conservation Scientists	26	6	20	30%	42%	8%	32%	10	303	21
19-2042	Geoscientists, Except Hydrologists and Geographers	44	43	8	14%	1%	2%	74%	5	350	43
19-4051	Nuclear Technicians	--	15	--	10%	29%	71%	14%	2	128	8
37-3011	Landscaping and Groundskeeping Workers	764	418	232	71%	28%	1%	2%	5	109	1,586
47-1011	First-Line Supervisors of Construction Trades and Extraction Workers	633	210	177	65%	31%	3%	4%	9	444	1,058
47-2031	Carpenters	330	229	134	87%	12%	0%	1%	2	147	687
47-2061	Construction Laborers	777	418	183	78%	21%	0%	1%	2	147	1,724
47-2111	Electricians	619	217	299	66%	28%	7%	2%	3	220	1,390
47-2131	Insulation Workers, Floor, Ceiling, and Wall	30	31	23	68%	28%	0%	4%	1	121	74
47-2132	Insulation Workers, Mechanical	4	1	1	100%	0%	0%	0%	1	121	31
47-2152	Plumbers, Pipefitters, and Steamfitters	815	272	172	74%	25%	1%	1%	4	432	649
47-2181	Roofers	307	121	82	77%	17%	0%	6%	1	121	234
47-2221	Structural Iron and Steel Workers	165	66	39	66%	29%	3%	1%	1	796	85
47-3012	Helpers--Carpenters	29	8	10	88%	11%	0%	1%	0	0	71
49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	1,886	532	742	45%	41%	9%	16%	13	1,485	803
49-2096	Electronic Equipment Installers and Repairers, Motor Vehicles	10	--	--	94%	6%	0%	0%	8	752	76
49-3023	Automotive Service Technicians and Mechanics	1,974	734	764	65%	23%	7%	12%	5	878	987
49-9021	Heating, Air Conditioning, and Refrigeration Mechanics and Installers	1,656	396	380	53%	45%	3%	1%	2	536	711
49-9051	Electrical Power-Line Installers and Repairers	218	75	57	54%	46%	4%	1%	1	28	278
49-9052	Telecommunications Line Installers and Repairers	387	174	204	82%	16%	3%	1%	5	16	194
49-9098	Helpers--Installation, Maintenance, and Repair Workers	496	238	238	55%	44%	3%	1%	4	764	172
51-4121	Welders, Cutters, Solderers, and Brazers	175	170	56	72%	27%	1%	1%	2	811	648
51-8011	Nuclear Power Reactor Operators	--	--	--	--	--	--	--	0	0	32
53-3032	Heavy and Tractor-Trailer Truck Drivers	8,060	2,797	2,917	85%	14%	0%	2%	2	906	4,747

Source: Lightcast, "Lightcast," accessed February 2025. https://lightcast.io

Table 12. Average Monthly Summary from Lightcast for Tennessee by Impacted Occupations (2024)

SOC Code	Overview
11-3071	**Transportation, Storage, and Distribution Managers:** In an average month, there were **301** newly posted job postings for *Transportation, Storage, and Distribution Managers*, and **185** actually hired. This means there was approximately 1 hire for every 2 unique job postings for *Transportation, Storage, and Distribution Managers*.
11-9021	**Construction Managers:** In an average month, there were **339** newly posted job postings for *Construction Managers*, and **338** actually hired. This means there was approximately 1 hire for every 1 unique job posting for *Construction Managers*.
11-9041	**Architectural and Engineering Managers:** In an average month, there were **115** newly posted job postings for *Architectural and Engineering Managers*, and **72** actually hired. This means there was approximately 1 hire for every 2 unique job postings for *Architectural and Engineering Managers*.
13-1051	**Cost Estimators:** In an average month, there were **125** newly posted job postings for *Cost Estimators*, and **246** actually hired. This means there were approximately 2 hires for *Cost Estimators* for every 1 unique job posting.
17-2051	**Civil Engineers**: In an average month, there were **231** newly posted job postings for *Civil Engineers*, and **167** actually hired. This means there was approximately 1 hire for every 1 unique job posting for *Civil Engineers*.
17-2071	**Electrical Engineers**: In an average month, there were **133** newly posted job postings for Electrical Engineers, and **77** actually hired. This means there was approximately 1 hire for every 2 unique job postings for Electrical Engineers.
17-2072	**Electronics Engineers, Except Computer**: In an average month, there were **21** newly posted job postings for Electronics Engineers, Except Computer, and **36** actually hired. This means there were approximately 2 hires for Electronics Engineers, Except Computer for every 1 unique job posting.
17-2081	**Environmental Engineers**: In an average month, there were **14** newly posted job postings for *Environmental Engineers*, and **44** actually hired. This means there were approximately 3 hires for *Environmental Engineers* for every 1 unique job posting.
17-2141	**Mechanical Engineers**: In an average month, there were **150** newly posted job postings for *Mechanical Engineers*, and **104** actually hired. This means there was approximately 1 hire for every 1 unique job posting for *Mechanical Engineers*.
17-2161	**Nuclear Engineers:** In an average month, there were **17** newly posted job postings for *Nuclear Engineers*, and **8** actually hired. This means there was approximately 1 hire for every 2 unique job postings for *Nuclear Engineers*.
17-3023	**Electrical and Electronics Engineering Technologists and Technicians**: In an average month, there were **58** newly posted job postings for *Electrical and Electronic Engineering Technologists and Technicians*, and **74** actually hired. This means there was approximately 1 hire for *Electrical and Electronic Engineering Technologists and Technicians* for every 1 unique job posting.
19-1013	**Soil and Plant Scientists**: In an average month, there were 3 newly posted job postings for Soil and Plant Scientists, and 9 actually hired. This means there were approximately 3 hires for Soil and Plant Scientists for every 1 unique job posting.
19-1031	**Conservation Scientists**: In an average month, there were **9** newly posted job postings for *Conservation Scientists*, and **15** actually hired. This means there were approximately 2 hires for *Conservation Scientists* for every 1 unique job posting.
19-2042	**Geoscientists, Except Hydrologists and Geographers**: In an average month, there were **10** newly posted job postings for *Geoscientists, Except Hydrologists and Geographers*, and **14** actually hired. This means there was approximately 1 hire for *Geoscientists, Except Hydrologists and Geographers* for every 1 unique job posting.
19-4051	**Nuclear Technicians**: In an average month, there were **2** newly posted job postings for *Nuclear Technicians*, and **6** actually hired. This means there were approximately 3 hires for *Nuclear Technicians* for every 1 unique job posting.
37-3011	**Landscaping and Groundskeeping Workers**: In an average month, there were **168** newly posted job postings for *Landscaping and Groundskeeping Workers*, and **1,416** actually hired. This means there were approximately 8 hires for *Landscaping and Groundskeeping Workers* for every 1 unique job posting.
47-1011	**First-Line Supervisors of Construction Trades and Extraction Workers**: In an average month, there were **121** newly posted job postings for *First-Line Supervisors of Construction Trades and Extraction Workers*, and **665** actually hired. This means there were approximately 5 hires for *First-Line Supervisors of Construction Trades and Extraction Workers* for every 1 unique job posting.
47-2031	**Carpenters**: In an average month, there were **88** newly posted job postings for *Carpenters*, and **681** actually hired. This means there were approximately 8 hires for *Carpenters* for every 1 unique job posting.
47-2061	**Construction Laborers**: In an average month, there were **174** newly posted job postings for *Construction Laborers*, and **2,229** actually hired. This means there were approximately 13 hires for *Construction Laborers* for every 1 unique job posting.
47-2111	**Electricians**: In an average month, there were **133** newly posted job postings for *Electricians*, and **1,031** actually hired. This means there were approximately 8 hires for *Electricians* for every 1 unique job posting.
47-2131	**Insulation Workers, Floor, Ceiling, and Wall**: In an average month, there were **11** newly posted job postings for *Insulation Workers, Floor, Ceiling, and Wall*, and **71** actually hired. This means there were approximately 6 hires for *Insulation Workers, Floor, Ceiling, and Wall* for every 1 unique job posting.
47-2132	**Insulation Workers, Mechanical**: In an average month, there was **1** newly posted job posting for *Insulation Workers, Mechanical*, and **23** actually hired. This means there were approximately 28 hires for *Insulation Workers, Mechanical* for every 1 unique job posting.
47-2152	**Plumbers, Pipefitters, and Steamfitters**: In an average month, there were **142** newly posted job postings for *Plumbers, Pipefitters, and Steamfitters*, and **549** actually hired. This means there were approximately 4 hires for *Plumbers, Pipefitters, and Steamfitters* for every 1 unique job posting.
47-2181	**Roofers**: In an average month, there were **55** newly posted job postings for *Roofers*, and **194** actually hired. This means there were approximately 4 hires for *Roofers* for every 1 unique job posting.
47-2221	**Structural Iron and Steel Workers**: In an average month, there were **33** newly posted job postings for *Structural Iron and Steel Workers*, and **114** actually hired. This means there were approximately 4 hires for *Structural Iron and Steel Workers* for every 1 unique job posting.

47-3012	**Helpers—Carpenters**: In an average month, there were **6** newly posted job postings for *Helpers--Carpenters*, and **194** actually hired. This means there were approximately 32 hires for *Helpers--Carpenters* for every 1 unique job posting.
49-1011	**First-Line Supervisors of Mechanics, Installers, and Repairers**: In an average month, there were **370** newly posted job postings for *First-Line Supervisors of Mechanics, Installers, and Repairers*, and **377** actually hired. This means there was approximately 1 hire for *First-Line Supervisors of Mechanics, Installers, and Repairers* for every 1 unique job posting.
49-2096	**Electronic Equipment Installers and Repairers, Motor** Vehicles: In an average month, there were **2** newly posted job postings for *Electronic Equipment Installers and Repairers, Motor Vehicles*, and **21** actually hired. This means there were approximately 14 hires for *Electronic Equipment Installers and Repairers, Motor Vehicles* for every 1 unique job posting.
49-3023	**Automotive Service Technicians and Mechanics**: In an average month, there were **407** newly posted job postings for *Automotive Service Technicians and Mechanics*, and **904** actually hired. This means there were approximately 2 hires for *Automotive Service Technicians and Mechanics* for every 1 unique job posting.
49-9021	**Heating, Air Conditioning, and Refrigeration Mechanics and Installers**: In an average month, there were **281** newly posted job postings for *Heating, Air Conditioning, and Refrigeration Mechanics and Installers*, and **583** actually hired. This means there were approximately 2 hires for *Heating, Air Conditioning, and Refrigeration Mechanics and Installers* for every 1 unique job posting.
49-9051	**Electrical Power-Line Installers and Repairers**: In an average month, there were 44 newly posted job postings for Electrical Power-Line Installers and Repairers, and 183 actually hired. This means there were approximately 4 hires for Electrical Power-Line Installers and Repairers for every 1 unique job posting.
49-9052	**Telecommunications Line Installers and Repairers**: In an average month, there were **86** newly posted job postings for *Telecommunications Line Installers and Repairers*, and **80** actually hired. This means there was approximately 1 hire for every 1 unique job posting for *Telecommunications Line Installers and Repairers*.
49-9098	**Helpers--Installation, Maintenance, and Repair Workers**: In an average month, there were **130** newly posted job postings for *Helpers--Installation, Maintenance, and Repair Workers*, and **131** actually hired. This means there was approximately 1 hire for *Helpers--Installation, Maintenance, and Repair Workers* for every 1 unique job posting.
51-4121	**Welders, Cutters, Solderers, and Brazers**: In an average month, there were **67** newly posted job postings for *Welders, Cutters, Solderers, and Brazers*, and **722** actually hired. This means there were approximately 11 hires for *Welders, Cutters, Solderers, and Brazers* for every 1 unique job posting.
51-8011	Nuclear Power Reactor Operators: no data
53-3032	**Heavy and Tractor-Trailer Truck Drivers**: In an average month, there were **1,706** newly posted job postings for *Heavy and Tractor-Trailer Truck Drivers*, and **3,837** actually hired. This means there were approximately 2 hires for *Heavy and Tractor-Trailer Truck Drivers* for every 1 unique job posting.

Source: Lightcast, "Lightcast," accessed February 2025. https://lightcast.io/

Construction, engineering, electrical, and maintenance jobs dominate: 24 are included, and many of the others are in closely related fields (such as Construction Managers, and Architectural and Engineering Managers). In Tennessee, five of the 15 ERMs drive this pattern:

1. Commercial and Industrial Building Efficiency
2. Residential Weatherization and Efficiency
3. Heat Pumps
4. Electric Vehicle Adoption
5. Community Electric Vehicle Charging

By comparison, preservation of farmlands, forests, wetlands, and grasslands would be accomplished through regulation and zoning more so than labor, and other activities like biking, walking, and diverting food and yard waste are in control of individuals and households to a greater degree than firms and workers.[86] Other ERMs are in fields where labor demand is declining, such as agricultural soil management, or that rely on capital much more than labor, such as nuclear energy, renewable energy, and oil and gas methane recovery.

Thirteen of the 36 jobs that would be relevant to ERMs are already considered "in demand" in Tennessee, meaning that the level of job postings and hires is high relative to total employment, and that typical pay is at least 80 percent of the state median wage.[87] Sixteen ERM jobs connect with one or more of Tennessee's target industries for economic development,[88] and seven jobs are considered in demand and in a target industry. Designations for being in demand or in a key industry may reflect, to some degree, current and expected workforce needs from ERMs. To the extent that ERMs increase workforce demand over and above the baseline, there would be an even more concentrated need for workers in these areas.

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[86] Diverting food waste would also involve the agricultural sector, both as producers of food waste and consumers of animal feed, biofuels, and compost converted from food waste. U.S. Environmental Protection Agency, "Recycling Economic Information Report." (2020). https://www.epa.gov/sites/default/files/2020-11/documents/rei_report_508_compliant.pdf

[87] See the Tennessee Higher Education Commission's "Academic Supply For Occupational Demand Report" for methodological details behind "in demand" designations: https://www.tn.gov/thec/data-research-reports/reports-studies-pub/supply-and-demand-report.html.

[88] Tennessee's key targeted industry sectors are Aerospace & Defense; Automotive; Chemicals; Distribution & Logistics; Electrical Equipment & Appliances; Food & Agriculture; Healthcare & Life Sciences; Headquarters, Finance, & Technology; and Rubber, Ceramics, & Glass Products.

Educational Outlook: Talent Pipeline

Overview

For each of the 36 highlighted jobs, we identify aligned in-state education programs at the K-12 and post-secondary levels that meet the typical entry-level education requirement shown. We emphasize up front that we cannot assemble a comprehensive set of education programs that might productively lead to a given ERM job. The available crosswalks between specific jobs and aligned education programs identify job-education combinations where there is a broad, but inexact overlap between skills and knowledge.

Instructional Programs

We collect aligned post-secondary programs using a U.S. Department of Education crosswalk between SOCs and the **Classification of Instructional Programs (CIP)**. We then filter these down to programs that are offered in Tennessee public colleges and universities, using a list of active programs maintained by the Tennessee Higher Education Commission.[89] For these, we identify aligned post-secondary certificate and diploma programs. Post-secondary certificates and diplomas may be available to high school students through dual enrollment, and they have been shown to help older workers move to new industries.[90] For all the highlighted ERA jobs, we additionally identify the most aligned K-12 **career and technical education (CTE)** cluster.[91]

For the 36 ERM jobs, we find 484 aligned post-secondary programs of study offered across 48 public Tennessee colleges and universities. Of those, 340 are certificate and diploma programs offered in community colleges and Tennessee Colleges of Applied Technology. The remaining programs include 19 that award associate degrees and 126 that award bachelor's degrees. About 33 percent of aligned programs are in the broad Construction Trades area of study, which is consistent with the dominance of architecture and construction jobs in our list of ERM jobs. Another 21 percent of programs are

[89] https://thec.ppr.tn.gov/AcademicProgramInventorySearch/Reports
[90] Carruthers, C. K., & Sanford, T. (2018). Way station or launching pad? Unpacking the returns to adult technical education. *Journal of Public Economics*, *165*, 146-159.
[91] We identify CTE clusters from a SOC-cluster crosswalk developed by the Economic Development and Employer Planning System. CTE cluster designations follow the 16-cluster framework used by the Tennessee Department of Education.

in fields of study related to Mechanical and Repair Technologies. The third most common field is Engineering, which describes 14 percent of post-secondary programs aligned with ERM jobs. ERM jobs were also aligned with six CTE career clusters offered in public K-12 schools. Just under half of the ERM jobs we identified—17 out of 36—fit within the Architecture and Construction career cluster. The next most common clusters are Science, Technology, Engineering, and Math (STEM), and Manufacturing, which respectively align with 7 and 5 of the ERM jobs. Supplementary data include a comprehensive inventory of aligned post-secondary programs and CTE clusters for each ERM job can be found in the online data appendix. We find that 200 of the post-secondary programs that are aligned with ERMs are in a rural county, representing 41 percent of all aligned programs. Just 13 programs (3 percent) are in a distressed county. [92] All of these are at TCAT Oneida in Scott County. The Knoxville area has 40 aligned programs, Nashville has 63, and Memphis has 15.

Taking advantage of opportunities and mitigating challenges in labor markets requires an effective workforce delivery system that can serve the needs of both individuals and employers. Good information is essential to enable individuals to track into the best-fitting workforce education and training program that meets their needs. Tennessee has a rich and robust array of workforce development programs, several of which are present in the state's secondary schools. Post-secondary opportunities are similarly rich in scope. Beneath the surface of these programs and institutions are unique niche programs offered by stakeholders including unions, religious organizations, and community-based organizations. Ensuring effectiveness is an ongoing concern and activity for all these service providers. Finally, it is important that education and training services be available to all Tennesseans, particularly population segments in certain regions such as rural areas and inner cities that confront unique needs and circumstances. These considerations are addressed in the discussion that follows.

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[92] Distressed counties are designated by the Appalachian Regional Council as being in the bottom 10 percent of all U.S. counties in terms of unemployment, per capita income, and poverty. Tennessee had 9 distressed counties in 2025: https://www.tn.gov/transparenttn/state-financial-overview/open-ecd/openecd/tnecd-performance-metrics/openecd-long-term-objectives-quick-stats/distressed-counties.html. Institutions are marked as being in the Knoxville, Nashville, or Memphis area if they are located in the core-based statistical area (CBSA) for one of those cities. Rural counties are those with "less than 50 percent of their population living within a 2020 Census Urbanized Area with a population of more than 50,000." By this definition, 78 Tennessee counties are rural, and 17 are urban. We use rural county indicators and CBSA designations from the Tennessee State Data Center, https://tnsdc.utk.edu/2023/09/28/2023-tennessee-county-geographic-classifier-reference-file/.

Expand Clean Energy Career Awareness

Promoting accurate, engaging, and thorough information about clean energy careers is key to raising awareness about these opportunities. This should include details on the specific roles within the clean energy sector, such as the necessary knowledge, skills, qualifications, and education. Additionally, it's important to highlight entry-level and advanced wages, typical career progressions, and available training programs across the state.

Box 1. Career Awareness Resources

Map a Career in Energy | Department of Energy

Home - Green Workforce Connect

https://www.youtube.com/@HVAC-CareerPathways

Home - Get Into Energy

Find Energy Employers in Your State - Get Into Energy

Career Maps - Interstate Renewable Energy Council (IREC)

Clean Energy Careers | Slipstream (videos from Wisconsin)

Home | Green Buildings Career Map

TDOE EOP Education and Outreach

There are several national and regional organizations that provide tools to help disseminate this information in the "Career Awareness Resources" list in the adjacent text.

Successful career awareness campaigns should also incorporate feedback from the target audience to maximize their impact. This is because the messages that resonate tend to differ across demographics and communities. Representation in informational campaigns is crucial as well. In conversations with **community-based organization (CBO)** leaders and staff, many stressed the importance of job seekers seeing people "like them" in these careers, which helps foster a stronger sense of belonging and possibility. This representation should span all areas of the energy sector and other related sectors. Maximizing career awareness can be achieved through strong partnerships with organizations at the forefront of career and workforce development. Tennessee's nine Local Workforce Development Boards and American Job Centers, training providers, post-secondary institutions,

CBOs, and the K-12 education system are all in a prime position to help break down informational barriers and attract more people to the energy-related workforce. Ensuring these organizations have access to, and the ability to navigate, clean energy career and training information will enhance their outreach to the communities they serve and support. There are many models of existing initiatives focused on early career awareness and exploration that provide strong avenues for increasing awareness.

For example, the Blount Partnership in Maryville hosts an annual **Blount County Career Exploration Fair** that introduces rising high school students to business leaders and employers while giving them brief hands-on experiences as they ponder potential career paths with local companies. More than 1500 students from both public and private schools participate and employers represent a wide array of career opportunities. Soft skills sessions are also offered to give students guidance on handshakes, interview etiquette, dressing for success, and quick pitches.

One of the most exciting features of the new college, **career and technical (CTE)** center in Cocke

Box 2. Career Exploration Initiatives

Pathways 2 Prosperity (P2P) and Manufacturing Day in **Jackson, TN**, are key initiatives designed to connect students with high-demand career opportunities in advanced manufacturing and technical industries. Pathways 2 Prosperity is a regional workforce development effort that helps students and job seekers explore career pathways through hands-on experiences, industry partnerships, and educational resources. Every eighth-grader in the Jackson, TN region had the opportunity to participate in this exploration opportunity.

A **new innovation center** opened its doors in **Cocke County** to introduce middle school students to different careers in the trades. It's now a part of the county's curriculum. The career center targets sixth-graders and introduces them to high-tech equipment, exposing them to learning about different careers and giving them a chance to do some hands-on activities.

County is the interactive career center being developed by Brainchild Creative, a company with high-profile clients such as Ripley's Attractions and Universal Studios. Brainchild Creative offers experience in designing immersive and interactive experiences.[93]

In addition to in-school opportunities, students throughout the state can take advantage of other programs designed to provide young people with valuable career exploration and work experience. For example, the **Boys & Girls Club YouthForce program** connects teens, ages 14-18, with businesses that invest in their training and development. YouthForce offers a variety of activities to help teens develop essential skills for workforce success, including finding a job based on their interests and talents, applying for jobs, developing strong soft skills, and determining the educational and career path they wish to pursue. YouthForce University is an intensive training program that focuses on workplace professionalism and financial literacy to simulate a high-quality work experience for teens. It includes two parts: training and interning. The training portion involves twelve hours of job readiness skills and career pathway development. Upon completing the program, teens earn a 60-hour paid internship at a local business.[94]

[93] Tennessee Department of Education, College, Career and Technical Education, 2023-2024 Overview, https://www.tn.gov/content/dam/tn/education/ccte/CCTE_Overview_2023-24-compressed.pdf
[94] Boys & Girls Clubs of the Tennessee Valley, YouthForce, https://bgctnv.org/youthforce/

Box 3. Clean Energy Training Resources

U.S. DOE Building America Solution Center

New York State Energy Research and Development Authority (NYSERDA) Clean Energy Training Resources

U.S. DOE Building Science Education Solutions Center

Clean Energy Clearinghouse - Sustainable Energy Action Committee

National Energy Education Development Project

Global Guidance for Education on Green Jobs

Clean Energy Economy & Workforce Preparation Toolkit

Current Energy Training Landscape

Tennessee is experiencing increasing investment in sectors tied to the energy transition and sustainability, driving demand for a skilled workforce. A wide array of training and educational programs—ranging from technical certifications and industry-specific apprenticeships to degree programs—are available through community colleges, universities, technical schools, and workforce development initiatives.

While many of these programs are not explicitly labeled as clean energy training, they equip workers with essential skills highly relevant to energy transition roles. Core competencies, such as those required for electricians, remain unchanged even when applied to clean energy projects. Existing programs have the potential to support high-demand roles, but expanding their impact will require additional resources. Investments in updated clean energy equipment, enhanced instructor training, new curricula (See **Box 3** for details), and stronger partnerships with clean energy employers are essential to maximizing their effectiveness.

Reskilling will be essential for workers in industries impacted by the clean energy transition. Training programs in advanced manufacturing, construction, and skilled trades leverage existing mechanical and problem-solving skills, while opportunities in coding, IT, and cybersecurity support the

shift toward remote and digital jobs. Tennessee and its educational partners offer financial aid and support services to help adult learners upskill and transition into emerging fields (See **Box 4** for additional information).

Vocational and Technical High Schools and Programs

Tennessee's CTE programs of study are meant to provide a relevant framework of industry-aligned, rigorous courses that progress a student in knowledge and skills year after year. According to the Tennessee Department of Labor and Workforce Development:

Box 4. The Future of Education in Tennessee

The ***College, Career and Technical Education 2023-2024*** report included two new initiatives set to reshape Tennessee's educational landscape: the **FutureReadyTN Portal** and **Career Cluster Realignment Project**.

The **FutureReadyTN Portal** will streamline high school-to-career transitions by offering a centralized platform for High School and Beyond Plans, financial aid, and job applications, with pilot feedback ensuring its effectiveness.

The **Career Cluster Realignment** will modernize **Career and Technical Education (CTE)** to better align with workforce demands, introducing a new **Energy cluster** and providing professional development for educators ahead of its July 2025 rollout. These initiatives aim to equip Tennessee students with the skills needed for a rapidly evolving job market.

Review the full report here.

CTE provides a pathway for students beginning in early and middle grades and progressing through secondary and postsecondary into aligned occupations. To support this progression, academic, technical content, and employability skills are provided through culminating content and experiences necessary to be successful in high-skill, high-wage, and/or in-demand occupations, including emerging labor and workforce opportunities.[95]

Middle colleges allow students to earn a college degree while still in high school. Roane State Community College has operated a Middle College since 2013 and this fall will be offering high school students the opportunity to begin courses towards their nuclear technician degree program which launched this spring.

The ***Strengthening Career and Technical Education in Tennessee State Plan 2024-2028***[96] outlines the state's strategic approach to enhancing CTE over a four-year period. The plan emphasizes expanding advanced opportunities for all students to explore career pathways, develop personalized plans of study, earn meaningful industry credentials, and engage in capstone projects or work-based learning experiences leading to high-wage, in-demand, high-skill careers in existing or emerging fields. The plan focuses on foundational career awareness in elementary and middle grades, expansion of advanced CTE programs, and increased STEM opportunities. It also highlights the importance of targeted support for historically underserved students and the need for strong data practices to inform policy and program improvements.

The plan provides the following guidance:

1. **Expand career awareness, exploration, and planning**, specifically in elementary and middle school grades, advisement, leadership, and employability skill development through new courses, nontraditional and

[95] Tennessee Department of Education, Strengthening Career and Technical Education in Tennessee, 2020-2024, https://www.tn.gov/content/dam/tn/education/ccte/TN_2020_State_Plan.pdf

[96] Tennessee Department of Education, "2025-26 CTE Career Cluster Framework." Accessed January 2025. https://www.tn.gov/content/dam/tn/education/ccte/2025-26_CTE_Career_Cluster_Framework.pdf.

special populations opportunities, and data gathered through required career aptitude and assessment surveys.

2. **Expand participation for all students in advanced career and technical programs in secondary and postsecondary**, rethinking time, space, and modes of learning, which prepare students to seamlessly transition into high-wage, in-demand, and/or high-skill occupations, including purposeful opportunities for special populations.

3. **Expand STEM opportunities**, with emphasis on advanced mathematics and science, engineering, and technology in all CTE programs, including computer and data sciences, needed to meet the changing workforce demands of Tennessee.

Early Post-Secondary Opportunities (EPSOs) enable high school students to earn college credit while still in high school. This is especially important since several of the 36 ERM relevant occupations identified above require only a high school degree. Many of the foundational courses necessary to pursue degrees in clean energy related areas are offered as dual enrollment with local community colleges, technical colleges, and four-year institutions. An interesting example of a dual enrollment program closely aligned with employer needs is the **Associated Builders and Contractors Greater Tennessee's Regional Dual Enrollment Training program** offered at the Knox County START Center. Students earn college credit through courses taught by the **Tennessee College of Applied Technology-Knoxville**, National Center for Construction Research Core Certification, and receive hands-on learning opportunities with an industry partner. Since many clean energy jobs intersect with construction occupations, this program can be expanded to include additional skills necessary to move into jobs like solar panel installer or weatherization technician as demand grows.

Work-based learning (WBL) is a proactive approach to bridging the gap between high school and high-demand, high-skill careers in Tennessee. Students build on classroom-based instruction to develop employability skills that prepare them for success in postsecondary education and future careers. Through experiences like internships, apprenticeships, and paid work experience, juniors and seniors (16 years or older) may earn high school credit for capstone WBL experiences. WBL coordinators are educators who are

trained and certified by the department to coordinate these WBL experiences for students (see examples below).

- **Jackson-Madison County L.O.O.P.- Local Options and Opportunities Program** is a unique work-based learning opportunity where students attend a modified school day for academic credit. Each day, students engage in an online-learning lab, with teacher support, followed by work experience at their placement with an industry partner for the remainder of the day. For some industry partner assignments, this experience takes place at the industry site instead of the traditional high school. Students must apply to this program. There is also a summer LOOP program.
- **Grainger County Work-Based Learning Program** had 129 students in Grainger County participating in a work-based learning experience at 109 different work sites in 2024. All WBL students complete OSHA-10 General Industry Certification before being released to their placement sites for work.
- The **Blount Partnership** hosts an event every year called **Job Signing Day**. This event celebrates high school students who take career and technical education, earn industry certifications, or participate in work-based learning and internships and graduate with a job. This event is a true testimony to the fact that hands-on industry training in high school increases those workforce pipelines. The event started 6 years ago with 7 students signing on to jobs in the boardroom of the Blount Partnership, and last year over 60 students were graduating with jobs.

An example that encompasses all these opportunities is **The Academies of Nashville**, recognized by the White House as a national high school transformation model. The Academies notes, “Every student in our 12 zoned Academies of Nashville schools have a choice of 35 different academies. Whether a student is interested in pursuing a career in healthcare or engineering, every academy will enhance the student’s high school experience while preparing them with skills applicable to any career field. More than 365 community partners are committed to ensuring students gain exposure and experience within each class. Additionally, local colleges and universities have teamed up with the Academies of Nashville to create access

to a range of dual credit, dual enrollment, and industry credentials that will better prepare every student to be college or career ready."[97]

Post-Secondary Schools and Programs

Tennessee's higher education landscape is dynamic, with a mix of public universities, private institutions, and a strong community and technical college system. The state has taken significant steps to expand access to higher education, particularly through initiatives like the **Tennessee Promise** and **Tennessee Reconnect**, which offer tuition-free community and technical college opportunities for recent high school graduates and adult learners.

Tennessee's public universities are primarily governed by two systems the University of Tennessee (UT) System and the Tennessee Board of Regents (TBR) plus six Locally Governed Universities. Tennessee has a well-developed community and technical college system through the Tennessee Board of Regents, which oversees:

- 13 community colleges offering two-year associate degrees and transfer pathways.
- 27 Tennessee Colleges of Applied Technology (TCATs) providing specialized technical and vocational training.

Tennessee is also home to 29 private institutions which offer a wide range of undergraduate and graduate programs, with strengths in liberal arts, business, health sciences, music, and law, among others. Tennessee Promise and Tennessee Reconnect are free tuition programs that have significantly increased college enrollment and workforce development across the state. The growth of online and hybrid learning modalities are helping to make pursuing a degree more accessible and higher education institutions are working closely with industries like healthcare, automotive manufacturing, and clean energy to ensure graduates are career-ready.

Overall, Tennessee's higher education system is focused on accessibility, workforce development, and innovation, making it a leader in educational attainment and job readiness programs. A helpful example of this focus on accessibility, workforce development, and innovation is the recent opening of the TCAT at Stanton near the Blue Oval project with Ford Motor Company.

[97] Academies of Nashville, https://www.mnps.org/learn/academics/academies-of-nashville

Officials from TCAT met with Ford and SK Innovation to make sure that TCAT curricula lined up with the needs for these employers' workforce. While 90% of the curricula was already taught within the TCAT system, personnel at TCAT developed and added standards and tests to the existing curriculum. Discussions with SK about the battery plant and some of those processes were new in the electric battery portions of training. TCAT also met with their partner in Kentucky who is conducting battery training as well to make sure they were doing the same training for SK.

Earn and Learn programs at Tennessee's community colleges are an innovative approach to meeting local workforce needs while providing students with paid, hands-on experience.

At **Jackson State Community College**, the **Advanced Maintenance Technician (AMT) Co-op Program** allows students to earn an Associate of Applied Science (AAS) degree in Engineering Systems Technology while working with a consortium of 30 industry partners. Participants earn a starting wage of $17 per hour, with the potential to make up to $39,000 over two years. With support from Tennessee Promise, grants, and scholarships, students can graduate debt-free while gaining two years of real-world experience that enhances job readiness in high-demand skilled trades.

At **Cleveland State Community College**, the **Advanced Technologies Institute** provides a true cooperative education model. Select students in Advanced Technologies programs split their time between the classroom and paid, professional work—attending classes two days per week and gaining industry experience the remaining three.

Pellissippi State Community College offers Earn and Learn options in **Electrical Engineering Technology** and **Water Quality Technology**, partnering with employers such as Arconic, DENSO, JTEKT, KUB, TRDA, WKUD, and NEKUD.

These programs not only address skilled labor shortages but also provide students with a direct pathway to high-wage, high-demand careers.

A specific energy transition example is the **Clarksville Lineman Training**: **Austin Peay State University (APSU)** teamed up with the **North American Lineman Training Center (NALTC)** to help address pressing workforce shortages in the region. The partnership provides essential training to individuals seeking careers in the vital field of electrical power line installation, maintenance, and repair. The NALTC program equips students with a blend of classroom instruction and hands-on fieldwork, emphasizing the safety and practical skills needed to work with high-voltage electrical systems. Graduates emerge as highly trained linemen, ready to fill critical roles in maintaining the country's infrastructure.

An additional source for energy-related job training come in the form of **non-credit/continuing education** offerings at higher education institutions. There are many examples in states with a more robust renewable energy employment base. Salt Lake Community College[98] is a prime example of short-term not-for-credit programs which are ideal for individuals seeking to gain practical skills and knowledge for immediate application in the job market. They can be a quicker route to workforce entry or advancement. Also, TDEC's **Office of Energy Programs (OEP)** partners with the **Institute of Energy Professionals (IEP)** to offer a Professional Energy Manager training called the Energy Management Diploma Program. In addition, there are many private and non-profit organizations that provide training for a variety of clean energy occupations. Partnerships with these organizations could help jump-start local training if needed.

The **Community Health Worker Training Program of Tennessee (CHWTPT)** offers training and certification for **community health workers (CHWs)**. The program includes virtual training, on-the-job learning, and field placements or apprenticeships. The CHWTPT is a partnership between Vanderbilt University School of Nursing, the **Tennessee Community Health Worker Association (TNCHWA)**, and the **Rural Health Association of Tennessee (RHA)**. The program's training/education hours include self-paced modules through an online learning platform, virtual educational practice sessions with a trainer, as well as written assignments and projects. Importantly, the program is free for trainees, trainees receive a $7,500 stipend to help with costs and have opportunities to work in various settings, including clinics, hospitals, schools, and health departments.

While many training programs aren't specifically labeled as energy programs, they are highly relevant to occupations and industries impacted by the energy transition, as these roles often share the same foundational training as their counterparts in other industries. For instance, the basic training and certification required for an HVAC technician remains the same, whether they are working on clean energy projects or traditional ones. Existing training programs can be expanded to meet the growing demand for many roles in the energy sector. However, for these programs to be most effective, they will

[98] Salt Lake Community College. "Energy." *SLTech Energy Department*. Accessed June 3, 2025. https://www.slcc.edu/sltech/areas/energy/index.aspx.

need additional resources, such as updated clean energy equipment, more training for instructors, new curricula, and stronger partnerships with clean energy employers.

In Tennessee, fields like cybersecurity and advanced manufacturing have made strong efforts to brand and communicate clear career pathways. For example:

- **The Tennessee Cybersecurity Network** uses visual maps and stackable credentials to help learners understand how certifications and degrees lead to various cybersecurity roles.[99]
- **Advanced Manufacturing Technician (AMT) programs in Tennessee** are coordinated through community colleges and industry partners. These programs widely recognized and marketed as a direct pipeline to high-paying manufacturing jobs—even though the foundational training overlaps with energy-related roles.[100]

These models can inform similar efforts in the energy sector. For instance, a construction technology student might not realize their skills are transferable to solar array installation or grid modernization work unless those connections are made visible. Some best practices to consider include:

- **Create energy sector career maps** that build on existing credentials (and show how they apply to clean energy occupations.
- **Involve employers** in labeling and validating which traditional skills apply to renewable energy contexts.
- **Use labor market data** to brand programs as “renewable energy ready” or “energy transition aligned,” even if the base training is cross-sectoral.
- **Leverage funding** to equip existing programs with up-to-date tools to reflect industry shifts.

Tennessee has a strong base of technical training infrastructure. The next step is to **link, label, and leverage** those programs to align with emerging sectors like renewable energy, much as has already been done in cybersecurity and manufacturing. This not only helps students understand

[99] Tennessee Department of Finance and Administration. "TN Citizens Cybersecurity – for Students." *TN.gov*. Accessed May 4, 2025. https://www.tn.gov/cybersecurity/tn-citizens-cybersecurity/tn-citizens-cybersecurity---for-students.html.
[100] FAME USA. "Tennessee FAME." *FAME USA*. Accessed May 4, 2025. https://fame-usa.com/fame-program-locations/tennessee-fame/.

their options but also enhances recruitment, employer engagement, and long-term economic competitiveness.

Training Centers, Apprenticeship and Pre-Apprenticeship

Training centers and employers in Tennessee, including interviews conducted for this report, consistently report that one of the most immediate barriers to program success—especially for youth and first-time workers—is lack of workplace readiness. Interviewees cite common behavioral challenges such as a failure to adhere to basic professional expectations, such as punctuality and technology use during training or work hours and having difficulty adapting to structured environments and authority. While these behaviors may seem minor, they can significantly impact retention and employment outcomes in programs like pre-apprenticeships, co-ops, and vocational training. To help address this need, the **Tennessee Department of Labor and Workforce Development (TDOL&WFD)** recently launched the **Youth Employment Program (YEP)** to offer young people (ages 14 to 24) a paid employment opportunity paired with valuable first-hand work experience and educational learning. The program offers eight weeks of paid wages per participant, year-round.

Five of the ERM-relevant jobs identified above typically require an **apprenticeship**— a registered, industry-driven, high-quality career pathway where employers can develop and prepare their future workforce, and individuals can obtain paid work experience, classroom instruction, and a portable, nationally recognized credential.[101] Apprenticeship programs help employers develop a skilled, dedicated workforce that meets their unique needs, improves productivity, reduces recruitment costs, and strengthens company culture. For businesses looking to stay competitive, offering apprenticeships is an investment in their future. Pre-apprenticeship programs offer a crucial stepping-stone for individuals who want to pursue skilled trades or technical careers but may not yet have the experience or qualifications required for an apprenticeship. They benefit both the workers—by improving their skills and confidence—and the employers—by providing a more prepared, committed workforce. These programs play a key role in increasing access to career opportunities, improving apprenticeship success

[101] U.S. Department of Labor. *Code of Federal Regulations*. Title 29, Part 29, Section 29.2. Washington, D.C.: U.S. Government Publishing Office, 2022. https://www.ecfr.gov/current/title-29/subtitle-A/part-29/section-29.2.

rates, and addressing skills gaps in critical industries. The State of Tennessee has made a commitment to increasing the use of this tool to help address critical workforce needs throughout the state. The state has recognized the value of apprenticeships in fostering a highly-skilled workforce, creating pathways for high-paying jobs, and ensuring that businesses have access to qualified workers. Some of the key initiatives and actions Tennessee has taken to encourage apprenticeship opportunities include the following:

The **Tennessee Apprentice Grant Program**[102] helps employers offset the cost of developing apprenticeship programs. This initiative offers financial incentives to businesses to help cover the cost of training apprentices. The program helps employers who may be hesitant to offer apprenticeships due to financial concerns, making it more affordable to invest in workforce development. In addition, the state has offered various incentives and support services. This includes guidance for setting up apprenticeship programs, recruiting apprentices, and working with educational institutions.

The **Apprenticeship Tennessee Initiative** was launched by the **Tennessee Department of Labor and Workforce Development (TDLWD)**. The state's goal is to create more apprenticeships in various sectors and make them more accessible. The program not only connects employers with training resources but also helps build awareness about the benefits of apprenticeships. Under this initiative, Tennessee has expanded the number of apprenticeship opportunities across different industries, helping to diversify the talent pool and meet the demands of a changing economy. For example, the number of apprentices served within a fiscal year grew from 5,124 in 2014 to 10,055 in 2023, with a rapid increase since 2021. Tennessee has also worked to increase the number of **Registered Apprenticeship Programs (RAPs)** by collaborating with the **U.S. Department of Labor** and other entities. Additionally, the number of active registered apprenticeships (those actively participating in a registered program) grew from 4,300 to 8,423 during the same period.[103] These programs allow apprentices to gain recognized credentials that have value across the country.

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[102] **Tennessee Department of Labor and Workforce Development.** "Apprenticeship Training Grant." https://www.tn.gov/workforce/employers/training-redirect/grants-for-training/apprenticeship-training-grant.html.
[103] Tennessee Comptroller of the Treasury. *An Overview of Registered Apprenticeships in Tennessee*. Nashville, TN: Office of Research and Education Accountability, 2024. https://www.tbr.edu/news/new-comptroller%E2%80%99s-report-registered-apprenticeship-programs-tennessee-cites-key-roles-community.

Tennessee Pathways is an initiative that provides students with clear, guided pathways to earn a degree or credential in high-demand industries and includes apprenticeship opportunities. The program aims to connect high school students, adult learners, and workers with apprenticeship programs that align with their skills and career interests. By focusing on career readiness and apprenticeship opportunities, Tennessee Pathways helps build a stronger talent pipeline for employers across the state. Tennessee has also sought to increase the number of apprenticeship opportunities available to youth by partnering with high schools, local businesses, and training providers. These efforts help young people gain valuable skills and experience while still in school, providing them with a head start in their careers. Tennessee has seen growing interest in youth apprenticeship programs, which often serve as a stepping-stone into full-time apprenticeships and careers.

Through the **Workforce Innovation and Opportunity Act (WIOA)**, Tennessee has received federal funding to expand access to apprenticeship opportunities for individuals, particularly those from disadvantaged populations. WIOA funding has been used to support apprenticeship initiatives for youth, veterans, minorities, and individuals with disabilities, ensuring that apprenticeship programs are inclusive and accessible to all Tennessee residents. Tennessee has received several federal grants[104] aimed at expanding apprenticeship programs:

- **Apprenticeship State Expansion (ASE) Grant**: In July 2019, the U.S. Department of Labor awarded Tennessee $1.4 million to create 800 apprenticeships and 80 new programs, focusing on sectors like healthcare, transportation, and advanced manufacturing.
- **Building State Capacity to Expand Apprenticeship through Innovation Grant**: In June 2020, Tennessee received $450,000 to develop structures ensuring apprenticeship quality, increase capacity, and improve data sharing.
- **State Apprenticeship Expansion Formula (SAEF) Grant**: In June 2023, Tennessee was awarded $746,000 to build apprenticeship

[104] Ibid.

opportunities in sectors including tourism, advanced energy, construction, public sector, and healthcare.

Tennessee has also taken steps to **extend apprenticeship opportunities** to rural and underserved areas of the state. By working with local chambers of commerce, workforce development boards, and community organizations, the state has ensured that individuals in these regions have access to the resources and opportunities needed to participate in apprenticeships. This helps address regional disparities and create more economic opportunities across the state.[105] Many occupations in the energy sector have not yet been recognized as "apprenticeable" by the U. S. Department of Labor (USDOL). However, some common jobs have equivalents in other industry sectors. The **Apprenticeships in Clean Energy (ACE) Network**, a coalition led by the **Interstate Renewable Energy Council (IREC)** and supported by the USDOL, offers free technical assistance to help employers establish Registered Apprenticeship programs. Recently, the IREC and the **Solar Energy Industries Association (SEIA)** received approval from the USDOL for national

[105] To learn more about these initiatives, visit ApprenticeshipTN.

guidelines for apprenticeship standards for the Construction Craft Laborer occupation.[106]

Despite the success of training and apprenticeship programs in Tennessee, there is a clear need for **more coordinated state leadership** to identify, formalize, and scale apprenticeship opportunities in the renewable energy space. Without this coordination, Tennessee risks underutilizing its apprenticeship infrastructure at a critical moment in the energy transition.

The Role of Community-Based Organizations

Incorporating more CBOs into the energy workforce development ecosystem

Box 5. Apprenticeship Program Examples

- Apprenticeships - Get Into Energy
- Florida Solar Energy Apprenticeship Program – Providing a Pathway to Becoming a Florida Solar Contractor
- Tennessee Valley Youth Apprenticeships – TVYA... Partnerships that Work!
- Youth Apprenticeship | Apprenticeship Carolina - a division of the SC Technical College System
- Georgia Work-Based Learning
- Youth Apprenticeship - Jobs for the Future (JFF)
- Youth Apprenticeships | Urban Institute
- Apprenticeships in Clean Energy Network - Interstate Renewable Energy Council (IREC)
- Apprenticeable Occupations in Clean Energy

— both as training providers and partners in delivering wraparound support services — is crucial for expanding access to clean energy job opportunities for individuals in disadvantaged communities across the State. To appropriately engage these organizations, they must be able to provide:

- clear, accessible and customizable information about clean energy careers,

[106] Learn more here.

- reliable data about job demands and timing,
- support building relationships with clean energy employers,
- robust and reliable funding for comprehensive training programs and support services, and
- an asset-based approach to engaging the communities and participants (recognizing what people in those communities already bring to the table).

An example that demonstrates the potential of workforce development with community-based organizations is the recent launch in Middle Tennessee of the partnership of Goodwill, TVA and Accenture clean energy jobs training program.[107] Several other Tennessee entities also provide workforce development programs with an environmental or energy focus. For example, Knoxville's **Socially Equal Energy Efficient Development Program (SEEED)** is a green community development non-profit focusing on creating and sustaining jobs for the city's urban young people, as well as ensuring clean energy technologies are available for low-income residents. SEEED creates pathways out of poverty for young adults through clean energy career readiness training, while equipping communities with environmental literacy skills.

Chattanooga hosts the **Build it Green (BIG) program** which fits neatly with building-focused ERMs. BIG prepares young adults with untapped potential for careers in construction and energy service through a 4 month to 1 year leadership and workforce development program. Through a partnership with **Build Me a World** and **AmeriCorps Opportunity Youth Service Initiative**, BIG aims to generate pathways out of poverty for young adults through job readiness training, community organizing and outreach training, and technical training in the green building field. BIG utilizes a unique blend of community outreach, personal development, and technical training to create workforce ready young adults.

The **Native American Indian Association of Tennessee** offers financial assistance to cover the cost of tuition, books, supplies, and fees for Native American Indian (or descendant), Native Hawaiian, or Alaska Natives who are unemployed or underemployed. The program can help participants get the

[107] See Goodwill is Growing the Clean Energy Workforce - SACE | Southern Alliance for Clean EnergySACE | Southern Alliance for Clean Energy and NES Teams Up With Goodwill, TVA and Accenture to Launch Clean Energy Jobs Training Program in Middle Tennessee - Nashville Electric Service News

skills needed to enter a rewarding career in one of today's high-growth, in-demand fields. Individuals receive one-on-one career counseling and a needs assessment to determine any additional services. Upon completion of training, the Association also provides job search and placement assistance.[108]

Improving Program Quality: Best Practices for Support Services and Increased Coordination

Based on interviews and case-study research, this section provides guidance on best practices. The recommendations focus on three critical phases:

1. **Program Design**
2. **Outreach and Recruitment**
3. **Placement and Advancement**

Best practices include engaging employers in training development, removing participation barriers, fostering collaboration among programs, and providing tailored support services. Additionally, effective outreach strategies emphasize community involvement, early career awareness, and hands-on training. Finally, strong job placement support, mentorship opportunities, and career advancement pathways help ensure long-term success for participants. **Table 13** below outlines these best practices in greater detail. s

[108] See Native American Indian Assoc. of TN | Natives working for Natives

Table 13. Best Practices for Clean Energy Workforce Development Programs

Phase	Best Practices
Program Design	• Engage employers in training design to ensure that the skills and experience prioritized in the training program meet the market needs. • Revisit program design, outcomes and opportunities for improvement regularly with employers as market needs continually evolve. • Evaluate participation requirements and remove unnecessary requirements that may act as a barrier to participation among populations with limited resources and support. • Offer support services and referrals to help interested individuals overcome barriers and access training. • Review training materials and methods to improve learner accessibility for participants. Include instructional modifications to address barriers and determine what additional academic supports will be offered prior and alongside programming. • Consider how partner organizations can provide services beyond those included in the training program. • Prioritize collaboration over competition. Workforce development programs should collaborate to avoid "reinventing the wheel" and developing a new program from scratch when examples of successful programs exist in other communities. Ongoing collaboration among different programs benefits all parties and leads to increased opportunities to share curricular resources and insights gathered from employer partners.
Outreach and Recruitment	• Design outreach and recruitment with input from members of the target populations and communities. • Be mindful that exposure and awareness of clean energy jobs vary, and messaging may resonate differently from one community to the next. • Consider engaging community advocates and recent program participants as part of the outreach plan. • Provide clear information and opportunities to explore the target occupation, possible work environments and career pathway options as part of the recruitment strategy. • Help potential participants understand the challenges and opportunities of the occupation positions programs. • Provide staff who are working on outreach and recruitment with referral information for alternate programs in the area provide options for individuals who do not indicate strong interest or fit for the program's occupational focus. • Participate in early awareness efforts in the communities that the program seeks to serve, even if youth and young adults are not part of the target population. Early awareness and exposure to clean energy careers can address existing disparities in career access and be part of an intentional two-generation programmatic strategy. • Build multiple methods for skills assessment into the training program and share progress evaluations with participants regularly. • Align assessment tools directly to relevant industry certification tests and partner employers' expectations. • Provide relevant soft or work-readiness skills alongside technical skills and include time for participants to reflect on and debrief about progress. • Leverage hands-on training opportunities and, whenever possible, work-based learning components to provide participants with practical knowledge and application of skills through authentic work and projects that closely mirror current work of prospective employers. • Prioritize funding models that allow participants who would not otherwise be able to access training to receive robust support services, wages and benefits during training. • Build robust partnerships with CBOs and local workforce agencies to maximize participant access to support services. • Ensure that program support staff directly understand public benefits or partner to provide support through referrals. • Continue the career exploration process throughout the programming to help participants increase their understanding of not only immediate target occupations but also longer-term career path opportunities. • Engage current workers as mentors and help participants develop a clean energy professional network prior to completing the program.
Placement and Advancement	• Establish pathways for job placements for trainees and provide support for participants in the job search process, both during and after the training. • Help participants overcome barriers, such as resume development, by supporting the creation of essential career acquisition assets. • Continually debrief with participants about the job search process.

Best Practice: Essential Support Services

Support services play a critical role in workforce development by addressing the barriers that can prevent individuals from successfully entering or advancing in the workforce. While training and skill-building are essential components, support services ensure that job seekers can fully engage with and complete these programs, leading to greater long-term success. Here are some key roles that support services fulfill in workforce development:

1. Removing Barriers to Participation: Many job seekers face external challenges, such as childcare issues, unreliable transportation, housing instability, or financial strain, which can prevent them from attending training programs or securing employment. Support services like childcare assistance, transportation subsidies, and housing support help remove these barriers, allowing participants to focus on training and career advancement.

2. Providing Financial Stability: For individuals who are transitioning into new careers or attending training programs, a living wage stipend or financial support can have a significant impact. This helps alleviate the stress of managing day-to-day expenses, allowing job seekers to dedicate themselves to developing their skills or starting new positions without the distraction of financial insecurity.

3. Offering Mentorship and Guidance: Job seekers often benefit from having a mentor or coach who can provide ongoing support, guidance, and encouragement. Mentorship helps participants navigate the job search, overcome obstacles, and stay motivated. It can also be a valuable resource for career advice and professional growth, ensuring that workers continue to thrive long after completing initial training.

4. Facilitating Job Placement and Career Advancement: Placement support services connect job seekers with potential employers, helping them find job opportunities that match their newly developed skills. Ongoing professional development, check-ins, and career counseling help workers adapt to their new roles, ensuring that they continue to grow and advance in their careers.

5. Fostering Long-Term Success: Support services do not end once someone is placed in a job. Ongoing assistance, such as additional training opportunities, career coaching, or family support services, helps individuals

maintain their positions, develop professionally, and pursue upward mobility. These services also address the "soft skills" necessary for career advancement, such as workplace communication, conflict resolution, and leadership.

6. Building a Holistic Support System: Workforce development programs that integrate multiple support services (like health services, mental health counseling, and financial literacy) create a more holistic approach to career development. This "whole-person" approach acknowledges that people bring multiple life circumstances and challenges into the workplace, and addressing these elements can significantly improve their chances of success.

Create opportunities for all Tennesseans: Labor Market Re-Entry

To meet the workforce demand across all sectors, efforts must be made to include individuals who aren't currently in the workforce, such as those impacted by the criminal justice system or those in rehabilitation programs from substance abuse. Tennessee has implemented several initiatives to assist individuals transitioning from incarceration in re-entering the workforce:

- **Tennessee Office of Reentry (TOOR):** Established in July 2021 within the Department of Labor and Workforce Development, TOOR coordinates comprehensive workforce services for "justice-involved" individuals through the state's network of American Job Centers (AJCs). These centers offer job seekers assistance with employment opportunities, adult education, and supportive services. Employers interested in second-chance hiring can also collaborate with TOOR for guidance and resources. Although the program is still developing, in 2022 it reported new enrollments of 7,120 self-identified justice involved individuals in JOBS4TN, achieving 360% of its primary KPI.[109]
- **American Job Centers (AJCs):** Located throughout Tennessee, AJCs provide direct services to justice-involved individuals, including job

[109] U.S. Department of Labor. *Program Year 2022 WIOA Statewide Annual Performance Report Narrative: Tennessee*. Washington, D.C.: Employment and Training Administration, 2023. https://www.dol.gov/sites/dolgov/files/ETA/Performance/pdfs/PY2022/TN_PY22%20WIOA%20Statewide%20Annual%20Performance%20Report%20Narrative.pdf.

placement assistance, skills training, and supportive services. Comprehensive AJCs have reentry advisors trained to address the unique challenges faced by this population.

There are also numerous **Community-Based Programs:**

- **RISE Re-Entry Program:** Operated by the Knoxville Area Urban League, this program offers personalized support to reduce recidivism and empower individuals for successful workforce re-entry. Services include skills assessment, resume development, legal service referrals, and job placement assistance.
- **Middle Tennessee Rural Re-entry Program:** Serving Franklin, Coffee, and Warren counties, this program has significantly reduced recidivism rates and achieved a 64 percent job placement rate for participants. It focuses on training inmates in marketable skills and preparing them for gainful employment.
- **Davidson County Sheriff's Office Programs:** The Offender Re-Entry Center provides settings that promote positive social behavior through mentoring, employment, programs, and counseling. The Work Release program allows inmates to engage in employment or continue educational/vocational training, fostering self-support and personal accomplishment.
- **Cookeville / Putnam / Highlands Economic Partnership**: The Partnership received a grant from the state of Tennessee to assist individuals receiving government assistance. Leveraging these resources, the Highlands Economic Partnership established the Highlands Training Center, dedicated to facilitating workforce re-entry. Accredited by the state of Tennessee, the center offers the Aim High certification program. Aim High focuses on essential workforce principles, including loyalty to employers, punctuality, effective team communication, emotional intelligence, conflict resolution, and comprehensive professional development opportunities, among others. Once the classroom portion of the Aim High certification is complete, the Partnership introduces graduates to industry partners based on their profiles to give them the highest likelihood of success possible in their new role.

In the same vein, there are many programs across the state that work with individuals recovering from substance abuse. Workforce development programs that align with drug courts, non-profits and other organizations can also enable individuals to re-enter the workforce. [110]

Timing is Critical

Getting the timing right between training and job availability is crucial for ensuring that the skills acquired align with current job market demands. This is delicate to manage in practice but doing so maximizes employment opportunities, avoids skill obsolescence, provides a better return on investment, aligns with industry trends, helps bridge the experience gap, and leverages emerging opportunities. Many times, funding will be made available for training long before the jobs are available. This can be perfectly appropriate to enable completion of workforce training to coincide with new employment. But there is the risk of preparing workers for jobs that never materialize.

The Hemlock Semiconductor plant in Clarksville, Tennessee, is an example of where unforeseen market conditions significantly impacted a fully-aligned industry and workforce development plan. In 2008 Hemlock Semiconductor announced its intention to build a Clarksville-based plant that would employee up to 900 people to create polysilicon, a key component for making solar panels.[111] Tennessee provided tax and other incentives, community leaders broke ground, and nearby Austin Peay State University, even added a related associate's degree at to train future workers.[112] Ultimately, however, the plant never fully opened because a shift in economic conditions crashed the polysilicon market.[113] As an additional example, from 2009 to 2012, many community colleges across the state offered non-credit training in various energy-related courses (Fundamentals of Solar Hot Water Heating, Photovoltaic System Design and Installation, BPI Building

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[110] Additional re-entry resources can be found at Reentry Programs in Tennessee and Tennessee Reentry Programs.
[111] Tennessee Department of Economic and Community Development. "Bredesen, Kisber Announce Hemlock Semiconductor Coming to Clarksville." *TN.gov*. December 14, 2008. https://www.tn.gov/news/2008/12/14/bredesen-kisber-announce-hemlock-semiconductor-coming-to-clarksville.html.
[112] "Austin Peay State University Launches Hemlock Semiconductor Training Program." *MLive*, October 2010. https://www.mlive.com/business/mid-michigan/2010/10/austin_peay_state_university_l.html.
[113] "Hemlock Closing Clarksville Plant Permanently." *The Leaf-Chronicle*, December 17, 2014. https://www.theleafchronicle.com/story/news/local/clarksville/2014/12/17/hemlock-closing-clarksville-plant-permanently/20536529/.

Analyst/Energy Auditor Training, etc.).[114] These programs were very popular, but graduates were challenged to find professional opportunities due to shifts in the U.S. housing market and an unintentional oversupply of expertise. The key insight is to exercise caution and avoid building purely aspirational programs that rely on the success of a single, even significant, industry project. A related caution is to avoid program redundancy even in the face of workforce needs. It is a fine line to balance workforce training with the practical needs of the labor market.

At the same time, it is important to recognize that the energy transition is not new—it has been unfolding across Tennessee for over a decade. Unlike earlier efforts that were often tied to the promise of a single facility or short-term federal funding, this analysis reveals that current labor market trends show sustained growth in sectors such as advanced manufacturing, electrified transportation, and energy efficient infrastructure related to growth in energy-intensive technologies. These are areas where job growth is not only projected but already materializing, particularly in regions with strong employer engagement and educational alignment. While the cautionary tales are instructive, they should not preclude bold, evidence-based investments in workforce pipelines where the demand signal is clear. Other states are aggressively positioning themselves to meet this demand, and Tennessee risks falling behind if it adopts an overly conservative posture. The task is to act strategically, that is to identify where strong job growth is likely to persist and ensure that education and training programs are calibrated to meet it, but not so overly proscriptive as to limit the applicability of gained knowledge and skills of the labor force.

Conclusions and Future Directions

The economic and industry outlooks presented in this report suggest a complex but promising landscape. On one hand, several sectors associated with emissions reduction activities—such as advanced manufacturing, construction, transportation, and utilities—are projected to experience steady or strong growth, particularly for certain emission measures. This is notable

[114] For example, see: City of Kingsport. "Free Solar Photovoltaic Technology Training Course Offered in Tri-Cities." *KingsportTN.gov*, November 24, 2011. https://www.kingsporttn.gov/free-solar-photovoltaic-technology-training-course-offered-in-tri-cities/.

given the absence of binding statewide mandates related to GHG emissions or requirements for renewable energy development. On the other hand, the lack of clear policy drivers introduces volatility and makes it difficult to predict whether job growth will scale in line with emissions-reduction goals.

The key takeaway is that while projections vary by region and sectors, many of the same emission reduction sectors that currently show strong or emerging growth in relevant industries are also those most likely to benefit from voluntary programs detailed in TVERS and TVA's Valley Pathways Study. Even though these programs are non-binding, their implementation is expected to amplify existing labor demand—especially for roles related to energy efficiency, electrification, and grid modernization. This alignment suggests that Tennessee is already on a trajectory toward transition-related labor growth, even in the absence of aggressive policy interventions to advance the energy transition.

This mixed landscape underscores the report's central conclusion: Tennessee should pursue a dual approach—balancing cautious, data-informed program development with more proactive investment in areas of demonstrated and predicted growth. Rather than waiting for perfect alignment between policy and market demand, the state can position itself competitively by identifying where voluntary, employer-driven, and community-based efforts are already yielding momentum, and then leveraging those as workforce development focal points.

Tennessee stands at a pivotal moment in the ongoing energy transition, with significant workforce and economic implications. As industries evolve in response to electrification and increased energy demands, workforce development must remain a top priority to ensure the state remains competitive. This report highlights both the challenges and opportunities that lie ahead, providing employment projections and an analysis of existing education and training resources.

The findings underscore the need for a dual approach: supporting workers in declining industries through targeted reskilling initiatives while expanding training programs to meet the demands of emerging energy-related occupations. Tennessee's existing workforce development infrastructure—including technical schools, community colleges, and industry partnerships—provides a strong foundation for this effort. However, additional investments

are needed to enhance training capacity, update curricula, and strengthen collaboration between education providers and employers.

Furthermore, regional disparities in economic performance require tailored strategies to ensure that workforce development efforts benefit both urban and rural communities. Programs must be designed to provide access to training and employment opportunities, particularly for displaced workers and underrepresented populations.

For future directions, Tennessee may consider the following actions:

- **Enhance Data and Labor Market Analysis**: Continuously track workforce trends, employment projections, and training program effectiveness to inform policy and investment decisions focused on the energy transition. The Tennessee Department of Environment and Conservation, Tennessee Department of Labor and Workforce Development, as well as the Boyd Center for Business and Economic Research at the University of Tennessee, Knoxville, may consider a standing collaboration to provide quarterly market updates on sectors most impacted by the energy transition.

- **Monitor Policy and Market Shifts**: Stay adaptable to changes in energy policy, technological advancements, and employer needs to maintain a responsive and future-ready workforce strategy. The Tennessee Department of Environment and Conservation, Tennessee Valley Authority, and the Baker School of Public Policy and Public Affairs at the University of Tennessee, Knoxville may consider a standing collaboration to provide quarterly policy updates on energy changes most likely to have labor market and industry impacts.

- **Strengthen Industry-Education Partnerships**: Enhance collaboration between employers and training providers to ensure workforce programs align with evolving industry needs. The Tennessee Higher Education Department along with workforce advisory groups made up from members of development boards and chambers of commerce throughout the state could provide invaluable ongoing insights into opportunities and challenges related to talent development in the energy sector or impacted industries.

- **Foster Innovation in Workforce Solutions**: Explore new training models, including work-based learning, modular credentialing, and online education, to make training more accessible and effective. Institutions such as Tennessee's community colleges, technical schools, and workforce development boards might explore partnerships with energy sector employers to pilot cutting-edge training programs that incorporate emerging technologies, such as virtual reality (VR) and augmented reality (AR) for hands-on learning experiences.

- **Support Reskilling and Upskilling Initiatives**: Develop targeted programs for workers transitioning from declining industries to new energy-related roles, including financial aid and support services. The Tennessee Department of Labor and Workforce Development, in collaboration with employers and regional economic development organizations, may consider expanding scholarship and grant programs to ensure that displaced workers and adult learners can access high-quality training in high-demand fields like advanced manufacturing, renewable energy, and smart grid technology.

- **Expand Workforce Training Capacity**: Invest in educational infrastructure, updated curricula, and instructor training to support the growing demand for energy-related occupations. The Tennessee Board of Regents, the Tennessee Higher Education Commission, and private industry stakeholders may collaborate to modernize training facilities, integrate energy technologies into existing curricula, and provide specialized instructor training in new and emerging fields such as battery technology and energy-efficient construction.

- **Address Regional Disparities**: Implement tailored workforce development strategies to support economic growth in both urban and rural areas, ensuring access to training and job opportunities. The Tennessee Department of Economic and Community Development, alongside local workforce boards, may consider prioritizing investments in training hubs, employer-sponsored training programs, and transportation assistance for rural residents to ensure comprehensive access to workforce development opportunities.

- **Leverage Federal and State Resources**: Maximize funding from federal energy transition grants, state workforce development programs, as well as form private industry, to drive innovation and job creation. Agencies such as the Tennessee Department of Labor and Workforce Development, the Tennessee Valley Authority, and the Tennessee Department of Economic and Community Development may consider working together to ensure that Tennessee employers and training providers take full advantage of available funding opportunities.

- **Expand Early Career Awareness**: Increase exposure to clean energy careers through K-12 programs, apprenticeships, and outreach efforts to build a strong talent pipeline. The Tennessee Department of Education, in collaboration with industry leaders, should integrate energy-related career exploration into STEM curricula, expand work-based learning and pre-apprenticeship programs, and launch marketing campaigns to raise awareness of clean energy job opportunities among students, parents, and educators.

Ultimately, the success of Tennessee's energy transition will depend on its ability to cultivate a skilled workforce capable of adapting to industry shifts. By prioritizing workforce readiness, aligning training programs with employer needs, and leveraging state and federal resources effectively, Tennessee can position itself as a leader in energy innovation while fostering long-term economic resilience.

Appendix F: Community Outcomes Matrix Toolkit

Overview

The Community Outcomes Matrix Toolkit is a first step for designing projects, programs, or policies (both to help implement the BREATHE Plan or other projects) that align with community members' values and priorities -- across Knoxville and beyond.

The development of this toolkit began several years ago when Knoxville organizations and change leaders explored the ramifications of a local, just, and equitable food system rooted in community. The original outcomes were developed by a diverse group of people and stakeholders who participated in data and story gathering during a recent food systems assessment (2022-2024). [115]

The original authors and community members who contributed to the development of this tool envision a future where all people are able to enjoy the multiple benefits of investments and innovations here in Knoxville. To that end, this toolkit is publicly available to guide decision-making that ensures various community programs, policies, interventions, or initiatives are centered in equity and other valued outcomes.

Terms Used in the Outcomes Toolkit

An Outcomes Matrix (also known as an "Evaluation Matrix") is a tool that helps people compare and assess different initiatives by first defining valued outcomes and then screening the initiatives through the lens of those outcomes. A matrix can help identify the strengths and weaknesses of ideas while also identifying potential risks or consequences, short- and long-term benefits, and impacts (positive or negative) on different groups or populations.

Outcome Measure

An outcome measure summarizes a desired result from a proposed idea or action. Complex strategies, like climate action, often aim to achieve multiple outcomes or results. This set of outcomes might include a range of benefits including economic, environmental, and social impacts. Outcome measures should not focus on a narrow target goal or objective but should not be so broad that they are then too difficult to measure. The outcome measures described in this toolkit are good examples of reasonable outcomes.

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[115] *For the original set of outcomes developed for the Community Food Systems Outcomes Matrix please contact: Erin Rose at erose@threecubed.org OR visit the United Way of Greater Knoxville's Food Systems site.

About the Outcomes

The outcomes below were created to screen proposed climate action measures for equity during the development of the BREATHE Plan: A Comprehensive Climate Action Plan for the Knoxville Region. The plan serves as a roadmap for the region to reduce greenhouse gas emissions and other pollution. These outcomes serve as criteria for determining whether the proposed actions developed during the planning process are likely to result in the desired benefits.

Outcome Measures

Environmental Resilience

Climate action can provide benefits at individual, neighborhood, and community levels through intentional planning of green spaces, improved preparedness and response to climate hazards, and reduced exposure to increasingly frequent and severe weather events – such as poor air quality, flooding, and heat waves. This outcome covers a range of issues and can be targeted as needed depending on the action being evaluated.

Access to Innovation

This outcome captures community and stakeholder commitment to ensuring equitable access to new or innovative technologies, opportunities, and partnerships likely to result from the proposed climate action. Access to emerging technologies and new partnerships allows for participation in the design of important programs and use of technologies that aim to improve quality of life, reduce cost of living, and contribute to a clean environment.

Economic Opportunity

This outcome includes economic benefits that accrue directly from the climate action, such as contracting opportunities for small, minority- and women-owned businesses; access to quality jobs, workforce development and union work; and entrepreneur opportunities. When screening an idea or action for economic opportunity, reviewers might focus on what groups or populations are most likely to financially benefit from the work opportunities or capital investments.

Community- and Capacity-Building

Climate action planning and investment involve both sharing knowledge and creating capabilities at all levels of community and across sectors, such as housing and transportation. This outcome area helps determine how a climate action values, builds upon, and advances local knowledge. The outcome measure also asks if the proposed action is likely to create or lead to inclusive education, training, and capacity building opportunities for all.

Quality of Life

This outcome captures the extent to which a climate action improves access for all to life essentials including affordable, adequate, and secure housing and utilities; nutritious food; safe and reliable transportation; clean air and water; health and well-being; and other basic needs. Although it is unrealistic to expect that a single climate action will improve all categories of quality of life, the proposed strategy should improve some basic needs.

Future Generations

Climate action impacts both current and future generations. When future generations are meaningfully considered in climate action planning, long-term benefits are more likely to be achieved. This outcome area helps identify and measure benefits – and possible unintended consequences – for generations not yet born. This outcome area intends to ensure the impacts of climate action extend beyond immediate benefits and are not at the expense of future generations.

The Outcomes Matrix Worksheet

Designing Your Project

Develop your project idea so it aligns with one of the Example Goals (below) or Outcome Measure areas (shown on the previous two pages).

Example Goals

1. What do you hope to achieve through the project or action?
2. What strengths or assets does the project build upon?
3. What problem or need is being solved by this project?
4. What are the expected project or action outputs?

Objectives

The worksheets below can be used to help determine whether and how the priority climate action will fulfill the action measures and any benefits or possible negative impacts if implemented.

Completing the Outcomes Matrix Worksheet

1. Identify the climate change action identified in the BREATHE Plan.
2. Write the applicable climate change sector (e.g., buildings, transportation) and/or 'measure' that the project falls under at the bottom of the table.
3. Add a project purpose statement that states what project goals are and achievement may be through the work. This will guide the screening and communicate priorities and details important for measuring outcomes or impacts.
4. Add "Likely benefits." The suggested outcome areas can now be screened for likely benefits or even burden. Add 'other benefits' that may be important.
5. List the key partner(s) who are critical to the success of the project.
6. Write down any important considerations and unintended consequences, such as what funding or resources are needed, or what other issues need to be addressed (e.g., transportation, engagement strategies, agreements between partners).
7. Note if this project or action is recommend to move forward for funding, adoption, or implementation after completing the other parts of the table.

Community Outcomes Matrix for Climate Actions

Action:	Environmental Resilience	Access to Innovation	Economic Opportunity	Community + Capacity Building	Quality of Life	Future Generations	Other Benefit	Other Benefit
Likely Benefits:								
Project Purpose Statement:								
Key Partners: [Who needs to be included?]								
Important Considerations and Unintended Consequences:								

Key (for Benefits)

- ● Major potential benefits
- ◐ Moderate potential benefits
- ○ Some potential benefits
- ▬ No anticipated benefits and might add burden

CCAP Sector or Climate Measure:

	Yes	No	Recommend with Reservations
Recommend Moving Forward:			

Climate Action Example for the Waste Sector

The example list of actions below is copied from the BREATHE Plan Waste Measure 14: Implement organic waste management programs (page 96).

Core Actions

Phase 1: Explore | **Phase 2: Build** | Phase 3: Scale

- Partner with universities or private partners to establish a regional commercial composting facility that is open to the public.

Phase 1: Explore | Phase 2: Build | **Phase 3: Scale**

- Expand access to backyard and community composting programs through educational workshops.
- Collaborate with organizations to raise awareness about food insecurity, food recovery, and organic waste diversion.
    - Example: UTK's food4VOLS collection program or Second Harvest of East Tennessee's food collection/redistribution effort.
- Provide public compost drop-off sites, tools, and ongoing support to individuals and businesses who wish to compost.
    - Example: City of Knoxville's Compost Project, with Green Heron Compost Services, and community farms.
- Add leaf and brush pickup to collection programs to divert grass clippings, leaves, and other yard waste from landfills.

Supplementary Actions

Phase 1: Explore | **Phase 2: Build** | Phase 3: Scale

- Connect restaurants, grocery stores, and institutions with unrecoverable food waste to farms and organics processing facilities to promote a circular organics economy.

Bonus Actions

Phase 1: Explore | Phase 2: Build | Phase 3: Scale

- Integrate food waste pickup with government-operated brush and leaf pickup.

Climate Action Planning for Different Outcomes

The following questions might be useful when considering how beneficial an action might be to achieve different outcomes.

Environmental Resilience

Question: To what extent does this action prepare populations vulnerable to increasing local heat, storm, and flooding events expected from climate change?

Question: How does the action address urban sprawl and insufficient green space and urban heat islands? For example, does the action address lack of shade in different places across communities, including at bus stops and other gathering places?

Access to Innovation

Question: How does the action advance access to innovative or new technologies? For example, clean energy technologies like distributed energy resources and community solar?

Question: What is the plan for ensuring community-ownership in innovation or technology when feasible and if desired?

Question: Does the action increase access to innovation and/or clean energy technologies through affordability? How does the action address high upfront costs for energy efficiency upgrades, electrification, and solar installation likely to deter participation, especially for low-income households? What are the mechanisms for addressing limited access to financing and high interest rates, which make it challenging for contractors, homeowners, and renters to invest in new technologies?

Economic Opportunity

Question: To what extent does this action affect the number of local, quality jobs in the climate workforce?

Question: How does the action contribute to workforce training programs or apprenticeship programs to increase access and participation in new workforce opportunities? For example, who are the partners for training programs needed for solar panel installations or battery production to support economic resilience and create job opportunities?

Question: How does the action identify and reduce barriers to potential economic opportunities and ownership? For example, does the action intend to assess barriers during contractual negotiations and in training opportunities? Does the action include these benefits and workforce protections in procurement and contracts?

Community- and Capacity-Building

Question: To what extent does this action support peer-to-peer or network learning opportunities about climate hazards and resources?

Question: How does the planning process intentionally include community education and participation? For example, are community conversations, workshops, town halls, or other intentional outreach activities planned?

Question: Are the planned communication strategies and outreach activities accessible for all community members? Do they use shared and accessible language (including interpretation and translation)? Do they use direct communication channels and trusted messengers to reach target groups and communities? How do the engagement activities ensure safe and accessible spaces for community members?

Quality of Life

Question: To what extent does this action improve health and safety, especially for groups, populations, and communities historically exposed to climate hazards, such as poor air quality?

Question: To what extent does this action prevent gentrification and displacement? Does the plan or measure plan to evaluate the impacts of gentrification and displacement on local areas?

Question: How does the action address increasing energy and housing prices that put strains on affordability, especially for low-income households? For example, how does the action repurpose abandoned buildings for affordable housing or mixed-use development to revitalize communities while addressing energy-efficiency and environmental justice goals?

Question: How will the action benefit community members in tangible ways (food security, housing, utility costs, health, community resilience, air pollution)?

Future Generations

Question: Are young people intentionally being engaged in meaningful roles in participation? How are future generations being considered in the planning of the climate actions?

Question: In what ways does the action integrate workforce development to promote quality employment opportunities? How does the action build upon existing capabilities and programs and invest in needed workforce programs to ensure access for underrepresented groups and populations? What is the strategy for engaging with, recruiting, and training youths to be ambassadors and stewards for this work in the future?

Additional Equity Considerations

Additional questions and examples illustrating equity considerations that may be relevant for projects and BREATHE Plan implementers include:

1. **How will we identify key stakeholders and involve them in this action's planning process – especially individuals who could be most negatively affected by climate change and/or the proposed action?**

   Examples: Individuals with high exposure to outdoor elements, individuals with respiratory health risks, youth, neighborhoods adjacent to project location.

2. **Which outreach strategies can we employ to make this planning process accessible and inviting to all community members?**

   Examples: Simplifying language, translating materials, communicating through multiple channels, hosting meetings in community 'safe spaces', providing childcare and food at meetings, compensation for time spent participating in the process.

3. **How will we minimize 'stakeholder fatigue' in the collection of data?**

   Examples: Researching prior related efforts, honoring and compensating participants for their time, avoiding extractive processes, and using empowerment models.

4. **Does this action address long-term funding and sustainability of investment?**

   Examples: Funding and investment commitments beyond a grant cycle, establishment of working groups or committees to ensure sustainability of the project or investment.

5. **Does the action have measurable impacts that are either immediate (short-term) or long-term? Does the action provide a timeframe for projected short and/or long-term benefits?**

   For example, how many people or neighborhoods were able to access or benefit from the climate action and over what period of time? Did the

benefits from the action impact those groups immediately or are the benefits likely to be observed in 2 to 5 years or longer?

6. **What are the existing policies that might hinder implementation of this action?**
   Examples: State laws that limits local regulations, zoning laws.
7. **How can implementation of this action ensure equity within and across each of the outcome areas?**
   For example, to ensure equity in Economic Opportunity, reviewers might recommend strategies for including historically underrepresented groups in workforce programs, contracting, and neighborhood investments or capital improvements.

Appendix G: Works Cited in Sector Overviews

Introduction

This document cites sources for key data introduced in the sector overview sections of the main text of the CCAP.

Sources by Sector

Buildings

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