An Assessment of the Energy Sector in Tennessee

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Prepared by

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TABLE OF CONTENTS

TABLES AND FIGURES

Figure 4.8. Oil Fields in Tennessee are Mainly on the Cumberland Plateau or the Eastern Highland Rim **29**

CHAPTER 1: INTRODUCTION

The State Energy Policy Council (SEPC) was established by an act of the General Assembly with a mandate to create a comprehensive energy plan for the state of Tennessee.[1] Included in the enabling legislation was the requirement to produce an annual assessment of the state's energy sector to inform the public and policymakers and lay the groundwork for development of a state energy plan. This report represents the annual assessment for 2020. It has been structured to be largely consistent with an earlier report published in 2014—A Profile of the Energy Sector in Tennessee—developed by the Howard H. Baker Jr. Center for Public Policy to support policy development.

Monitoring the state's energy sector on an ongoing basis is important to help guide policy that can reap the greatest benefits for the state and its residents, protect the state's natural environment, and promote economic development opportunities. The energy sector is subject to ongoing change; many of these forces of change lay beyond the borders of Tennessee. A timely example is the COVID-19 pandemic, which has led to sharp contractions in global economic activity and the demand for energy, while at the same time reducing the human impact on the environment. Another example is the upcoming presidential election, which could lead to significant changes in the direction of national energy policy that would in turn affect energy outcomes in Tennessee. A host of other factors, both short-term and long-term, are affecting the energy sector, the environment, and the economy in Tennessee. The state needs to be informed and poised to react strategically to these external forces as they arise and evolve over time.

This report provides a detailed, data-driven analysis of the state's energy sector. Chapter 2 examines energy consumption, both by energy source (e.g. coal, solar, etc.) and end-use sector (e.g., transportation, residential, etc.). Also examined is per capita energy consumption in Tennessee relative to other states in the Southeast. The focus of Chapter 3 is electricity generation, including producers, energy sources, generator retirements, and retail sales. Chapter 4 evaluates the resource base available to produce electricity, ranging from coal to natural gas reserves. This represents the asset portfolio that can potentially be harnessed to the benefit of the state and its residents. Chapter 5 considers the job benefits that accrue to Tennessee from the state's energy sector; this material was not addressed in the 2014 report referenced above. Finally, Chapter 6 looks at the environmental and health issues related to the state's energy sector.

Together, the data and analysis here is foundational information for those interested in the direction of the state's energy sector. An understanding of the broad pattern of data described below will enhance the capacity of the state and its residents to define its own future through the development of energy policy that reflects the preferences and interest of Tennessee.

1 Tenn. Code Ann. § 68-24-101, et. seq.

CHAPTER 2: ENERGY FLOWS AND CONSUMPTION IN TENNESSEE

Introduction

Tennessee relies on a diverse portfolio of primary energy sources to meet the needs of the residential, commercial, industrial, and transportation sectors. In some instances, energy is used directly by end-users, as is the case with the use of petroleum by automobiles within the transportation sector. In other cases, most prominently with electricity generation, primary energy sources must first be transformed into electric energy that is distributed across the power grid for use by consumers. It is noteworthy that *rejected energy*—waste and inefficiency—accounts for more energy usage than the energy services directly consumed by end users in Tennessee.

In this chapter, we highlight overall energy flows in Tennessee, by primary energy source and major end-use sector. Per capita energy consumption data are also presented and placed in a Southeastern context for comparison.

Energy Consumption: Sources and Use

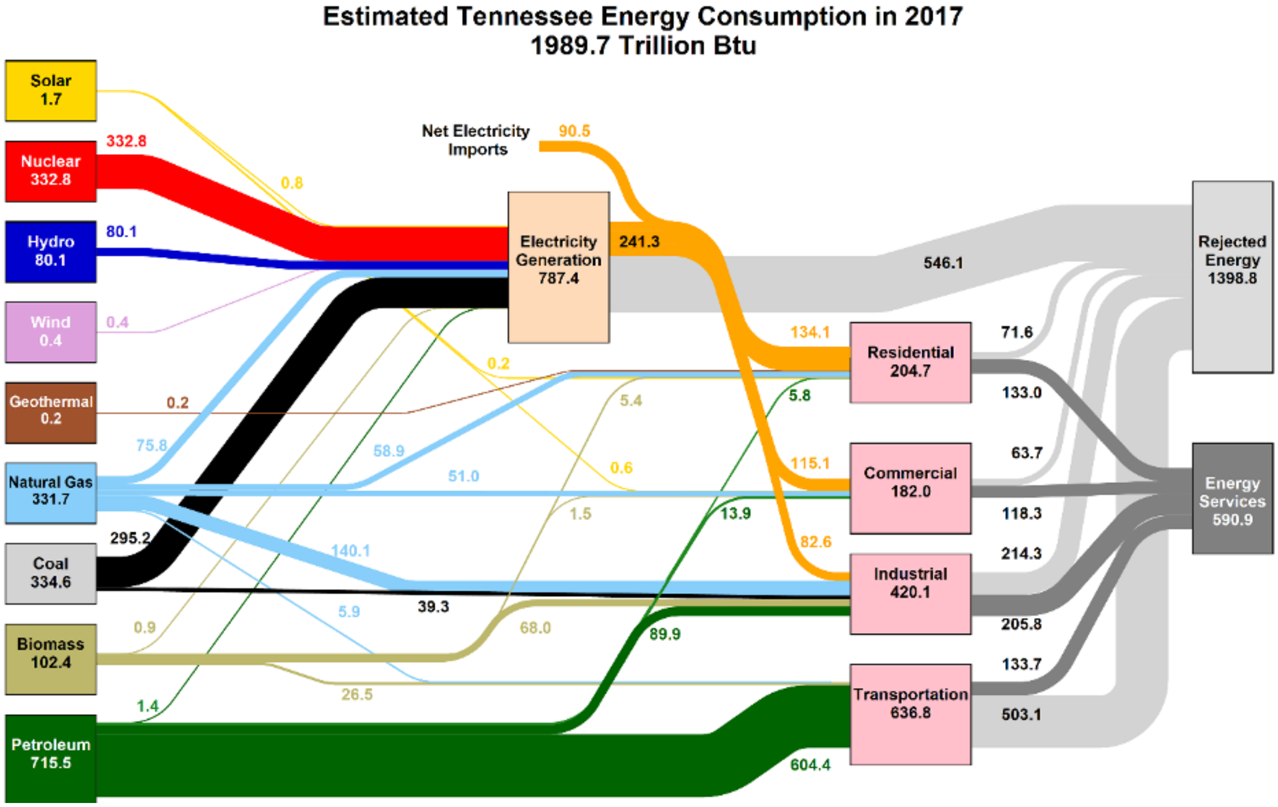
An especially useful tool for summarizing energy consumption is a Sankey diagram, which exhaustively traces primary energy sources ranging from nuclear and biomass to their respective sectoral consumers: residential households, commercial establishments (including public sector and educational facilities), industrial firms, and the transportation sector (including aircraft and motor vehicles). The analysis presented here relies on the framework developed by Lawrence Livermore National Laboratory (LLNL) and consumption estimates from the U.S. Energy Information Administration (EIA).[2, 3, 4]

2. Energy consumption estimates are from EIA, State Energy Data System, All Consumption Estimates in Btu for All States, 1960-2017. Additionally, for all states, energy consumption estimates by fuel source are shown in Table C3. Electric power sector consumption estimates are shown in Table C9. Energy use by fuel type for the residential, commercial, industrial, and transportation sectors are available in Table C5, C6, C7, and C8. Fuel ethanol is excluded from the petroleum estimates and is instead included in the biomass estimates. All of the aforementioned data is available here : https://www.eia.gov/state/seds/seds-data-complete.php#Consumption

3. Net electricity imports is the sum of the net interstate flow of electricity and net imports of electricity into the U.S., which are reported in millions of kilowatt hours and converted to trillion BTUs using the heat content of electricity (3,412 Btu per kilowatt hour). Data are from EIA, State Energy Data System, All Consumption Estimates in Physical Units for All States, 1960-2017, which is available here: https://www.eia.gov/state/seds/seds-data-complete.php#Consumption

4. State Energy Data System (SEDS) data for two years prior is finalized by EIA annually, typically in the third quarter of the calendar year

Figure 2.1: Sankey Diagram of Energy Flows and Consumption in Tennessee, 2017



Sources: Framework for presentation of energy flows is from Lawrence Livermore National Lab. Data are from EIA, State Energy Data System, All Consumption Estimates in Btu for All States, 1960-2017. Accessed on May 18, 2020. https://www.eia.gov/state/seds/seds-data-complete.php#Consumption and https://flowcharts.llnl.gov/

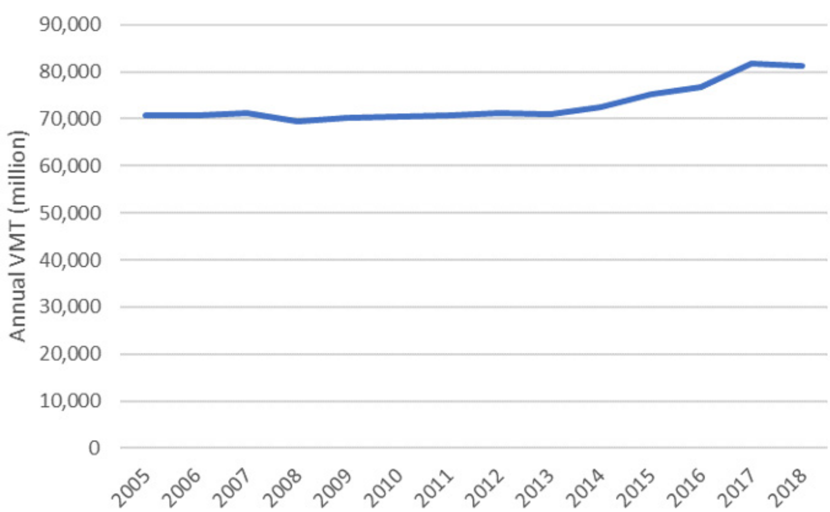
As shown in Figure 2.1, final energy services consumption totaled 590.9 trillion British thermal units (Btu) in 2017. Rejected energy that is wasted at various stages of production, distribution, and use was 1,398.8 trillion Btu. Rejected energy includes things like waste heat from automobile engines, home appliances, commercial lighting systems, and industrial processes. Together, Tennessee consumed 1,989.7 trillion Btu of energy in 2017, 70.4 percent of which was rejected energy. Just 90.5 trillion Btu were imported from outside the state for in-state consumption and use. The transportation sector, discussed in greater detail below, accounted for 636.8 trillion Btu or 32.0 percent of all energy consumed in the state. The industrial sector came in second (420.1 trillion Btu), followed by the residential (204.7 trillion Btu) and commercial (182.0 trillion Btu) sectors.[5]

Nine different primary energy sources contribute to energy services provision. The largest contributor, by a wide margin, is petroleum, which is the source of 715.5 trillion Btu of energy. As shown in Figure 2.1, the majority of petroleum consumption falls within the transportation sector (604.4 trillion Btu or 94.9 percent of the total), though smaller amounts also flow to the residential, commercial, and industrial sectors as well as to electricity generation.

5. LLNL has changed their methodology since 2012. For the 2017 data reported in Figure 2.1, end-use efficiencies were estimated to be 65 percent for the residential sector, 65 percent for the commercial sector, 49 percent for the industrial sector and 21 percent for the transportation sector. For 2012, end-use efficiencies were estimated to be 65 percent for the residential sector, 70 percent for the commercial sector, 80 percent for the industrial sector and 25 percent for the transportation sector.

Coal, nuclear, and natural gas were the second, third, and fourth largest sources of energy in Tennessee in 2017. Most coal used in the state supports electricity generation, but 11.8 percent is for industrial purposes. All nuclear power is used for electricity generation. Natural gas is used directly by all end-use sectors, with the industrial sector being the largest; 22.9 percent of natural gas is used for electricity generation. Hydropower and biomass are the fifth and sixth largest contributors to the state's energy portfolio. Solar, wind, and geothermal power[6] are relatively small sources of energy in Tennessee.

Figure 2.2. Vehicle Miles Traveled in Tennessee Grows Slowly from 2005 to 2018



Source: Tennessee Department of Transportation, Highway Performance Monitoring System, VMT Reports, 2005 through 2018. Accessed on May 18, 2020. https://www.tn.gov/tdot/long-range-planning-home/longrange-road-inventory/longrange-road-inventory-highway-performance-monitoring-system.html

The transportation sector is going through a major transformation due to improvements in fuel economy, the increased deployment of alternative fuel vehicles and the ongoing development of autonomous vehicles. A recent report funded by the Department of Energy's Vehicle Technologies Office shows that the disruption that connectivity and automation brings to the transportation sector could result in a potential 200 percent increase in 2050 baseline energy consumption, or a 60 percent decrease[7] in energy use. Thus, careful planning through policy development may be necessary to direct the proliferation of autonomous and connected vehicles in the future.

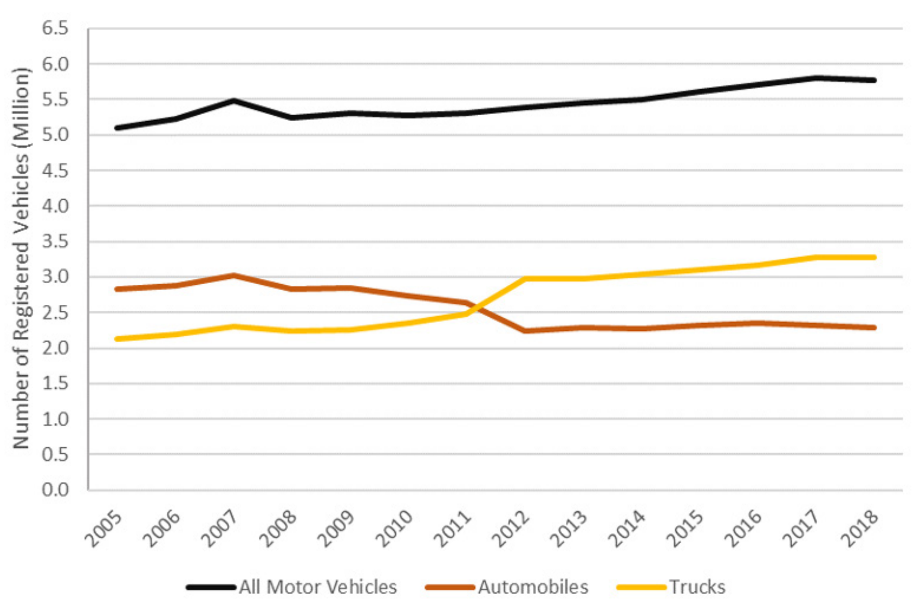
A key trend affecting the transportation sector and associated energy consumption has been a slight increase over time in vehicle miles traveled (VMT). As shown in Figure 2.2, VMT was flat from 2005 to 2013, and then showed an upward drift into 2017 before flattening once again. COVID-19 has likely led to a dramatic drop in VMT in the second quarter of 2020, based on mobility data from cell phones and other sources. VMT likely rebounded in the summer as state economies moved toward re-opening; further growth will likely take place as schools across the country re-open. Since many workers are still working remotely and do not have a need to travel to the workplace, there may be longer-term downward pressure on VMT and a considerable period of time before a full recovery of VMT.

6. Geothermal energy is heat that comes from the sub-surface of the earth. Wells are used to access steam or hot water, which can be used for heating, cooling, or to generate electricity

7. https://www.nrel.gov/docs/fy17osti/67216.pdf

Since 2012, VMT has grown from 71,129 million to a peak in 2017 at 81,717 million and a slight decline to 81,355 million in 2018. The VMT trends in Tennessee are consistent with national trends. This increase in VMT is partly due to the recovery from the 2008 financial crisis as well as relatively lower gasoline prices, particularly after 2014. However, the long-term weak growth in VMT, when coupled with fuel economy gains, has put significant downward pressure on gasoline tax collections.

Figure 2.3. Truck Registrations Rise While Automobile Registrations Fall in Tennessee, 2005 to 2018



Source: Vehicle registration data are from U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, 2005-2018, Vehicles, State Motor-Vehicle Registrations, Table MV-1. Accessed on June 5, 2020. https://www.fhwa.dot.gov/policyinformation/statistics/2018/

Notes: Total vehicle registrations include private, commercial, and publicly owned automobiles, buses, trucks, and motorcycles. While vehicle registrations for buses and motorcycles are included in the total, they are not separately shown in the figure and account for a comparably small portion of the total, an average of 0.41 and 2.92 percent, respectively, over the time period shown.

Trends in motor vehicle registrations are shown in Figure 2.3. Total registered vehicles in Tennessee has continued to rise, growing from 5,392,661 in 2012 to 5,770,874 in 2018 (a 7 percent increase).[8] Truck registrations have increased over time, growing by 53.9 percent from 2005 to 2018.[9] On the other hand, automobile registrations have decreased by 19.3 percent over the same time period. Beginning in 2012, trucks accounted for the largest share of vehicle registrations, illustrating the continued increase in demand for sport utility vehicles coupled with lower gasoline prices.

In 2018, light-duty passenger vehicles represented 39.6 percent of the motor vehicle fleet in Tennessee while trucks comprised 56.7 percent of the fleet. The trends for vehicle registrations in Tennessee are consistent with those for the U.S.

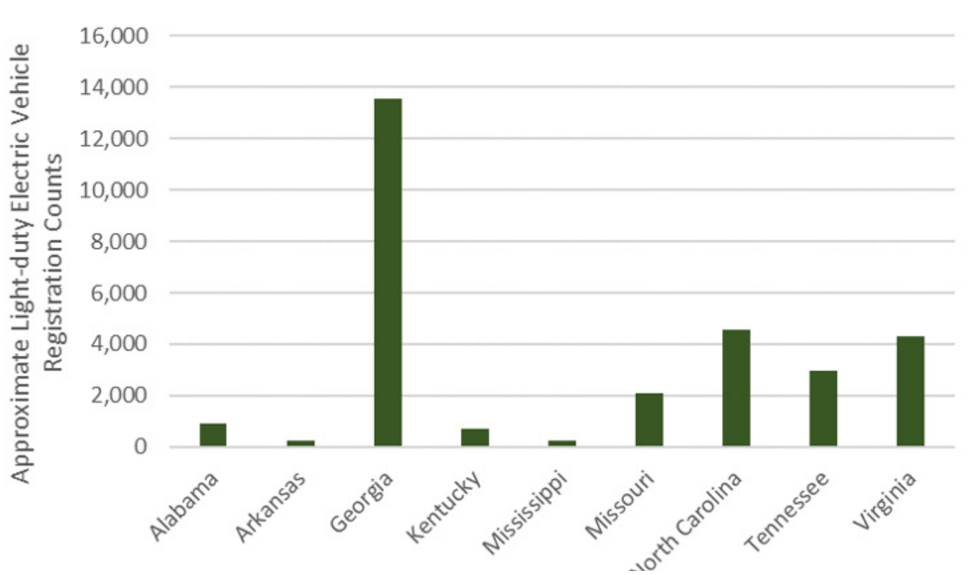
8. Vehicle registration data is from U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, 2018, Vehicles, State Motor-Vehicle Registrations, Table MV-1. Accessed on June 5, 2020. https://www.fhwa.dot.gov/policyinformation/statistics/2018/

9. Trucks include public, private and commercial vehicles and account for truck tractors, farm trucks, pickups, vans, sport utility vehicles and other light trucks. See https://www.fhwa.dot.gov/policyinformation/statistics/2018/pdf/mv9.pdf

Alternative Fuel Vehicles

The vast majority of alternative fuel vehicles are flex fuel vehicles[10], which represent 81.6 percent of light-duty alternative fuel vehicles in the U.S. However, while flexible fuel vehicles are designed to run on gasoline or gasoline-ethanol blends up to 85 percent ethanol (E85), flexible fuel vehicles generally use conventional gasoline. Hybrid electric vehicles represent 15.5 percent of light-duty alternative fuel vehicles in the U.S. Thus, hybrid electric vehicles are arguably the leader in light-duty alternative fuel vehicle adoption in the U.S. All-electric vehicles and plug-in hybrid-electric vehicles are ranked third and fourth in the U.S., with each accounting for 1.4 percent of light-duty alternatively-fuel vehicle registrations. Other alternative fuels include biodiesel, compressed natural gas, liquefied natural gas, liquified petroleum gas (propane autogas), and hydrogen; vehicles powered by these fuels each represent less than one percent of alternative fuel vehicle registrations in the U.S.[11]

Figure 2.4. Tennessee lags behind in electric vehicle adoption



Source: National Renewable Energy Laboratory derived data from HIS Markit light-duty vehicle registrations in 2017. Includes all-electric vehicles and excludes plug-in hybrid electric vehicles. Alternative Fuels Data Center. Access on June 25, 2020. https://afdc.energy.gov/data/10962

Tennessee lags behind other states in electric vehicle adoption. In comparison to all states, Tennessee ranked 21st in all-electric vehicle registrations in 2017. Figure 2.4 illustrates how Tennessee compares to several other Southeastern states with regard to electric vehicle adoption.[12] By a significant margin, Georgia has the highest number of light-duty electric vehicle registrations, followed by North Carolina and Virginia. In the middle is Tennessee, ranking fourth with 2,970 electric vehicle registrations in 2017. Mississippi and Arkansas are at the bottom, with less than 270 electric vehicle registrations in each state. In Tennessee, there are a total of 1,228 electric charging outlets (including Level 1, Level 2, and DC Fast), and 1,062 of the outlets are public outlets.[13]

10. Flex fuel vehicles are vehicles that can use gasoline ethanol blends of up to 85 percent.

11. Source: National Renewable Energy Laboratory (NREL) derived data from HIS Markit Light-duty Vehicle Registrations. https://afdc.energy.gov/data/10861

12. Figure 2.4 only includes all-electric vehicles and excludes plug-in hybrid electric vehicles. According to data from the Tennessee Department of Environment and Conservation, which was provided by the Department of Revenue, there are 9,271 all-electric and plug-in hybrid electric vehicle registrations in Tennessee as of June 2020.

13. Source: Alternative Fuels Data Center, Alternative Fueling Station Counts by State. Accessed on June 25, 2020. https://afdc.energy.gov/stations/states

Per Capita Energy Consumption

Per capita net energy consumption data are presented in Table 2.1 for the four end-use consumption sectors. The transportation sector is the largest energy-consuming end-use sector in Tennessee, followed by the industrial, residential, and commercial sectors. Per capita residential, industrial, and transportation consumption has fallen since 2012 while per capita commercial energy consumption has grown by 4.6 percent. Note that residential, commercial, and transportation energy use are all highly correlated with population. Industrial energy use, on the other hand, is driven by the nature of the industry mix and its production processes; state-level industrial activity will have a weaker linkage to state population since a large share of industrial production is exported to other states and countries for use and consumption.

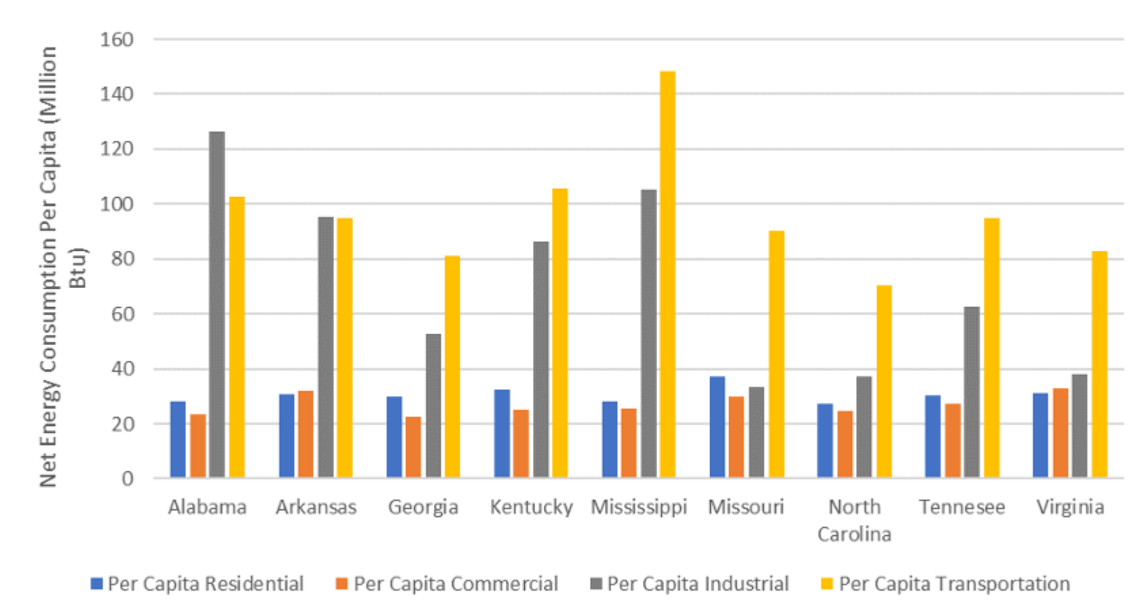
Table 2.1. Tennessee's Transportation Sector was the Largest Net Energy Consumer in 2017

Sector	Per Capita Net Energy Consumption (Million Btu)
Residential	30.51
Commercial	27.13
Industrial	62.62
Transportation	94.92

Source: EIA, State Energy Data System, Energy Consumption Estimates by Sector (Table C5, C6, C7, and C8). Resident population from EIA, State Energy Data System, All Consumption Estimates in Btu for All States, 1960-2017. Access on May 18, 2020. https://www.eia.gov/state/seds/seds-data-complete.php#Consumption

To place the state per capita data in perspective, Figure 2.4 shows comparable data for the end use sectors across the southeastern states. Tennessee's residential consumption per capita is in line with its neighboring states. Commercial energy consumption per capita shows somewhat greater variation, but is still within a relatively tight band, with the highest use occurring in Virginia and the lowest use in Georgia. Alabama's net energy consumption per capita in the industrial sectorWw is higher than the other states by a wide margin. Tennessee is ranked fifth across these states in industrial energy use per capita. Finally, per capita consumption in the transportation sector is highest in Mississippi; Tennessee finds itself near the median.

Figure 2.5. Per Capita Net Energy Consumption by Sector, Tennessee and Bordering States, 2017



Source: EIA, State Energy Data System, Energy Consumption Estimates by Sector (Table C5, C6, C7, and C8). Resident population from EIA, State Energy Data System, All Consumption Estimates in Btu for All States, 1960-2017. Access on May 18, 2020. https://www.eia.gov/state/seds/seds-data-complete.php#Consumption

CHAPTER 3: ELECTRICITY GENERATION

Introduction

As shown in the Sankey diagram in the previous chapter (see Figure 2.1), electricity is the largest energy flow consumed in Tennessee. Electricity was traditionally generated by large, centralized power plants, under the regulatory influence of the federal government and the states. This power would flow across the power grid to local power companies, which were tasked with the final distribution to end-use consumers.

While this model continues to be the norm, it is changing. Electricity markets are increasingly characterized by the use of distributed energy resources (DER), including rooftop solar, gas turbines, and battery storage systems that may be connected to the grid or used independently. Combined heat and power (CHP) systems are also important and can exploit waste heat for power generation. The role of independent power producers is rising over time. While the use of non-traditional fuels like biomass and solar is changing electricity markets, the penetration of these alternatives remains modest.

This chapter provides detail on electricity generation in Tennessee. Included is a discussion of the type of producer, fuel sources used to produce electricity, power generating units and retirements, electricity consumption in Tennessee, and retail sales in the U.S. and in Tennessee.

Generators of Electricity

In 2018, 81.6 million megawatt-hours (MWh) of electricity were produced in the state, with small amounts of electricity imported from out-of-state. As shown in Table 3.1, the vast majority of electricity generated in Tennessee—96.7 percent—is produced by TVA. This electricity flows through the distribution network to local power companies (i.e. retailers) across the state as well as to a number of large, directly-served industrial customers. TVA's role is unique as a federally-owned utility since the state's Public Utility Commission does not regulate TVA's electric rates or the generation mix for its service territory in Tennessee.

Table 3.1. Utilities Accounted for Most of the State's Electricity Generation in 2018

Type of Producer	Net Generation (Megawatt Hours)	Percent
Electric Utilities	78,854,061	96.69
Independent Power Producers	288,652	0.35
Combined Heat and Power, Commercial Power	228,945	0.28
Combined Heat and Power, Industrial Power	2,183,259	2.68
Total	**81,554,917**	**100**

Source: EIA, Detailed State Data, 1990-2018 Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923). Accessed May 18, 2020. https://www.eia.gov/electricity/data/state/

Independent power producers (often referred to as non-utility generators or NGUs) generate and sell electricity to entities like TVA. Their purpose is to diversify generation capacity and put downward pressure on prices. These entities generated just 288.7 thousand MWh of electricity in 2018, or 0.4 percent of overall generation.

CHP or cogeneration systems rely on waste energy (heat) to generate electricity at the point of use. An example is a gas-fired generation unit that produces heat as a byproduct of its use; this waste heat is used to generate electricity. Together, commercial and industrial CHPs yielded only about 3 percent of all electricity generated in Tennessee, mostly coming from industrial applications and hospitals.

Fuel Sources

Electricity is a secondary energy source that is derived from the transformation of primary energy like the sun or coal. Table 3.2 shows the various primary energy sources that are used in Tennessee by TVA. Accounting for 45.9 percent of the total in 2018, nuclear dominates the TVA portfolio. This is a marked change from 2012 when nuclear was 33.5 percent of the total. Coal's contribution to electricity generation stood at 45.7 percent in 2012; by 2018, coal's contribution had fallen to 25.8 percent. Natural gas has seen its contribution grow by just over 5 percentage points between 2012 and 2018. Petroleum has seen little change since 2012. Solar's contribution is only 958 MWh.

Table 3.2. Nuclear Dominates the Electric Utility Generation Portfolio (2018)

Fuel Type	Operator Name	Net Generation (Megawatt Hours)	Percent by Fuel Type
Coal	Tennessee Valley Authority	20,319,519	25.77
Hydroelectric Conventional	Tennessee Valley Authority	7,770,390	
	U.S. Army Corps of Engineers Nashville District	1,642,601	
	Brookfield Smoky Mountain Hydropower LLC[a]	879,734	
Subtotal Hydroelectric		*10,292,725*	*13.05*
Natural Gas	Tennessee Valley Authority	12,549,432	
	State-Fuel Level Increment[b]	8,015	
Subtotal Natural Gas		*12,557,448*	*15.92*
Nuclear	Tennessee Valley Authority	36,176,382	45.88
Petroleum	Tennessee Valley Authority	117,406	
	Powell Valley Electric Coop[c]	598	
	McMinnville Electric System[c]	986	
	State-Fuel Level Increment[b]	7,884	
Subtotal Petroleum		*126,873*	*0.16*
Pumped Storage	Tennessee Valley Authority	-619,844	-0.79
Solar	Nashville Electric Service[d]	958	0.00
Total		**78,854,061**	**100.00**

Source: EIA-923, 2018. Accessed May 18, 2020. https://www.eia.gov/electricity/data/eia923/

[a]Brookfield Smoky Mountain Hydropower LLC operates four dams on the Little Tennessee and Cheoah Rivers in Tennessee and North Carolina, which provide power to Alcoa's operations in Alcoa, Tennessee.

[b]"State-Fuel Level Increment" is aggregated net generation for plants whose data was either missing or erroneous and thus imputed by EIA

[c]Powell Valley Elecrtric Cooperative and McMinnville Elecrtric System produce relatively small amounts of power, which generally help TVA during peak demand.

[d]Nashville Electric Service operates Music City Solar, a solar park in Nashville which was part of TVA's Distributed Solar Solutions pilot program and began generating power in 2018.

Table 3.3 details the independent power producers in Tennessee along with their generation and fuel source in 2018. Compared to 2012, net generation MWh are up 152.5 percent from 2012. Solar accounted for 156,235 MWh of electricity or 54.1 percent of the total, compared to 10,069 MWh and 8.9 percent of the total in 2012. The contribution of wind has declined from 47,492 MWh in 2012 to 41,009 in 2018. Natural gas, which was not even listed as a fuel source because of its inconsequential role in 2012, provided 4.8 percent of the electricity from independent power producers in 2018. Like natural gas, petroleum now has a positive yet small place in the portfolio. Energy production from landfill gas has grown significantly since 2012, but the growth of other energy sources has pushed its portfolio contribution down to 26.8 percent versus 49.6 percent in 2012.

Table 3.3. Independent Producers Accounted for a Small Share of Overall Electricity Generation (2018)

Fuel Type	Plant Name	Operator Name	Net Generation (Megawatt Hours)	Percent by Fuel Type
Solar	Volkswagen Solar System	SR Enterprise South LLC	11,630	
	West Tennessee Solar Farm	UT West Tennessee Solar	5,011	
	Mulberry Farm LLC	Dominion Renewable Energy	25,483	
	Selmer Farm LLC	Dominion Renewable Energy	25,642	
	Providence Solar	Providence Solar Center, LLC	30,928	
	Selmer I	Selmer North Solar I, LLC	29,531	
	Selmer II	Selmer North Solar II, LLC	15,535	
	Millington Solar Farm	SR Millington, LLC	29	
	Latitude Solar Center	Latitude Solar Center, LLC	704	
	SR Jonesborough	SR Jonesborough II, LLC	49	
	Wildberry	Wildberry Solar Center	11,693	
Subtotal Solar			*156,235*	*54.13*
Wind	Buffalo Mountain Energy Center	Invenergy Services LLC	41,009	14.21
Natural Gas	Mountain Home Energy Center	Energy Systems Group LLC	13,874	4.81
Petroleum	Mountain Home Energy Center	Energy Systems Group LLC	300	0.10
Landfill Gas	Chestnut Ridge Gas Recovery	WM Renewable Energy LLC	29,794	
	West Camden	WM Renewable Energy LLC	35,974	
	Bi-County Gas Producers	Cube District Energy, LLC	11,466	
Subtotal Landfill Gas			*77,234*	*26.76*
Total			**288,652**	**100.00**

Source: EIA-923, 2018. Accessed May 18, 2020. https://eia.gov/electricity/data/eia923/

Electricity generation by CHP units of commercial and industrial producers is shown in Table 3.4 and 3.5. Commercial CHP units provided 228,945 MWh of electricity using natural gas and solar. Natural gas dominates with a 98.2 percent share of total generation. Vanderbilt University's power plant alone produced well over one-half of all CHP generation in 2018. CHP generation on the part of commercial establishments was up 75.6 percent in 2018 compared to 2012.

Table 3.4. Generation by Combined Heat and Power, Commercial Producers and Fuel Type, 2018

Fuel Type	Plant Name	Operator Name	Net Generation (Megawatt Hours)	Percent by Fuel Type
Natural Gas	Vanderbilt University Power Plant	Vanderbilt University	120,338	
	University of Tennessee Steam Plant	University of Tennessee	34,835	
	Opryland USA	Gaylord Entertainment	33,299	
	MTSU Power Co-Gen Plant	Middle Tennessee State University	36,335	
Subtotal Natural Gas			*224,807*	*98.19*
Solar	Chattanooga Metropolitan Airport Solar	Chattanooga Metropolitan Airport	2,347	
	IKEA Memphis 508	IKEA Property Inc	1,791	
Subtotal Solar			*4,138*	*1.81*
Total			**228,945**	**100.00**

Source: EIA-923, 2018. Accessed May 18, 2020. https://eia.gov/electricity/data/eia923/

Table 3.5. Generation by Combined Heat and Power, Industrial Producers, 2018

Fuel Type	Plant Name	Operator Name	Net Generation (Megawatt Hours)	Percent by Fuel Type
Coal	Packaging Corp of America	Packaging Corp of America	518	
	Tennessee Eastman Operations	Eastman Chemical Co-TN Ops	646,676	
Subtotal Coal			*647,194*	*29.64*
Natural Gas	Domtar Kingsport Mill	Domtar Paper Co LLC Kingsport	13,605	
	Packaging Corp of America	Packaging Corp of America	55,220	
	Tennessee Eastman Operations	Eastman Chemical Co-TN Ops	488,542	
	Bowater Newsprint Calhoun	Resolute Forest Products	45,208	
Subtotal Natural Gas			*602,574*	*27.60*
Other Gases	Tennessee Eastman Operations	Eastman Chemical Co-TN Ops	11,175	0.51
Petroleum	Domtar Kingsport Mill	Domtar Paper Co LLC Kingsport	1,931	
	Packaging Corp of America	Packaging Corp of America	452	
Subtotal Petroleum			*2,382*	*0.11*
Solar	Haywood Solar	Haywood Solar	6,263	0.29
Wood and Wood Waste	Domtar Kingsport Mill	Domtar Paper Co LLC Kingsport	287,850	
	Packaging Corp of America	Packaging Corp of America	331,034	
	Bowater Newsprint Calhoun	Resolute Forest Products	276,344	
Subtotal Wood and Wood Waste			*895,227*	*41.00*
Sludge Waste (Other Renewables)	Tennessee Eastman Operations	Eastman Chemical Co-TN Ops	8,086	
	Bowater Newsprint Calhoun	Resolute Forest Products	1,899	
Subtotal Sludge Waste			*9,986*	*0.46*
Other (Tire-derived Fuels & Other Fuel)	Packaging Corp of America	Packaging Corp of America	6,358	
	Tennessee Eastman Operations	Eastman Chemical Co-TN Ops	253	
	Bowater Newsprint Calhoun	Resolute Forest Products	1,847	
Subtotal Other			*8,457*	*0.39*
Total			**2,183,259**	**100.00**

Source: EIA-923, 2018. Accessed May 18, 2020. https://eia.gov/electricity/data/eia923/

Industrial producers that utilize CHP technology generated 2,183,259 MWh of electricity in 2018, reflecting a decline of 14.3 percent from 2012. Especially large changes have taken place for coal, which is down sharply from 1,149,985 MWh to 647,194 MWh, and natural gas, which has grown sharply from 41,109 MWh to 602,574 MWh. These changes are consistent with broader patterns of change in electricity generation across the country.

Net electricity generation for Tennessee and the U.S. by fuel type is shown in Table 3.6. Nuclear accounted for 44.4 percent of electricity generation in 2018, up from 32.3 percent in 2012. Coal's share of electricity generation has fallen from 45.6 percent in 2012 to 25.7 percent in 2018. Natural gas has seen its share rise by about six percentage points while the share of hydroelectric power has increased slightly. These four energy sources accounted for 99.1 percent of all electricity generation in Tennessee in 2018.

Table 3.6. Net Electricity Generation by Fuel Type in Tennessee and U.S., 2018

Fuel Type	Tennessee		U.S.	
	Net Generation (Megawatt Hours)	Percent by Fuel Type	Net Generation (Megawatt Hours)	Percent by Fuel Type
Coal	20,966,713	25.71	1,149,487,339	27.51
Hydroelectric Conventional	10,292,725	12.62	292,523,989	7.00
Natural Gas	13,398,703	16.43	1,468,932,452	35.16
Nuclear	36,176,382	44.36	807,084,477	19.32
Other	8,457	0.01	12,973,204	0.31
Other Biomass	87,220	0.11	20,895,765	0.50
Other Gases	11,175	0.01	13,462,749	0.32
Petroleum	129,555	0.16	25,225,618	0.60
Pumped Storage	-619,844	-0.76	-5,904,539	-0.14
Solar	167,594	0.21	63,825,315	1.53
Wind	41,009	0.05	272,667,454	6.53
Wood and Wood Derived Fue	895,227	1.10	40,936,159	0.98
Geothermal			15,967,134	0.38
Total	**81,554,917**	**100.00**	**4,178,077,114**	**100.00**

Source: EIA, Detailed State Data, 1990-2018 Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923). Accessed May 18, 2020. https://www.eia.gov/electricity/data/state/

Pumped storage is the movement of water from one reservoir to another reserve at a higher elevation; the water at the higher elevation can return to the lower elevation reservoir through a turbine system that generates electricity. Pumped storage systems are akin to a battery that serves as a store of energy to be used during peak periods of consumption.

Tennessee's fuel portfolio differs from the U.S. portfolio in several ways. Two significant areas of difference include nuclear, where the state has a much larger share, and natural gas, where the state's share is much smaller.

Dramatic changes have taken place over time in how electricity is generated (shown in Table 3.7). Despite the attention that has been given to innovative power sources like biomass, solar, and wind, there has been little penetration of these sources into the electricity mix. In Tennessee, the four electricity sources—coal, hydroelectric power, natural gas, and nuclear power—accounted for 99.2 percent of all net electricity generation in 2000 and 99.1 percent of electricity generation in 2018. All other sources combined continue to contribute less than one percentage point to power generation. The U.S., on the other hand, has seen significantly greater movement away from the top four sources. In 2000, the top four sources contributed 94.6 percent of the nation's electricity generation. This fell to 89.0 percent in 2018. Wind power has been a primary contributor to this change, as it rose from just 0.2 percent of the nation's electricity generation in 2000 to 6.5 percent in 2018. As discussed in Chapter 5, Tennessee has limited capacity for power generation from wind.

Table 3.7. Percent of Total Net Generation by Fuel Type for Tennessee and U.S., 2000, 2010, and 2018

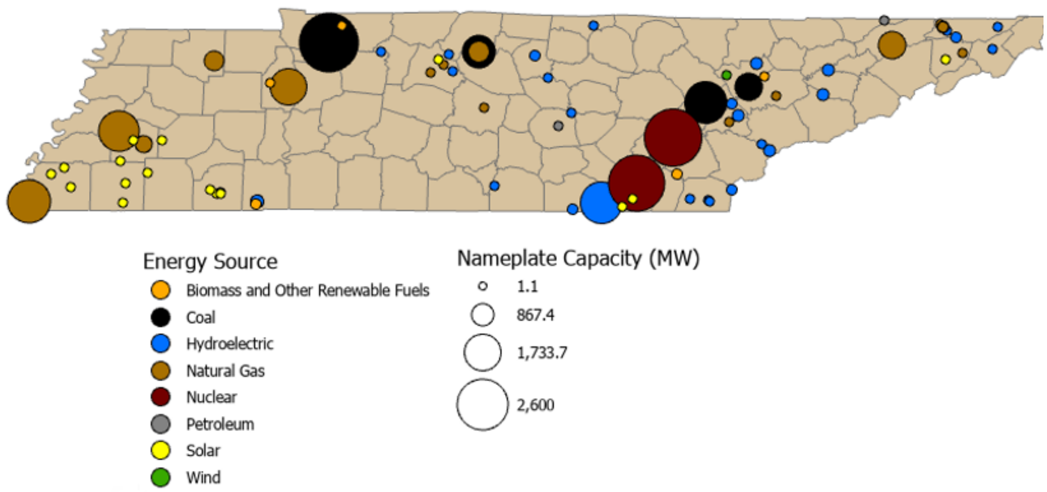
	Tennessee			U.S.		
	Percent of Net Generation by Fuel Type			Percent of Net Generation by Fuel Type		
Fuel Type	2000	2010	2018	2000	2010	2018
Coal	64.92	53.03	25.71	51.72	44.78	27.51
Hydroelectric Conventional	6.67	9.88	12.62	7.25	6.31	7.00
Natural Gas	0.68	2.80	16.43	15.81	23.94	35.16
Nuclear	26.95	33.69	44.36	19.83	19.56	19.32
Other	0.11	0.00	0.01	0.13	0.31	0.31
Other Biomass	0.04	0.04	0.11	0.61	0.46	0.50
Other Gases	0.01	0.02	0.01	0.37	0.27	0.32
Petroleum	0.59	0.26	0.16	2.93	0.90	0.60
Pumped Storage	-0.76	-0.88	-0.76	-0.15	-0.13	-0.14
Solar	0.00	0.00	0.21	0.01	0.03	1.53
Wind	0.00	0.05	0.05	0.15	2.29	6.53
Wood and Wood Derived Fuels	0.79	1.11	1.10	0.99	0.90	0.98
Goethermal				0.37	0.37	0.38
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Source: EIA, Detailed State Dtaa, 1990-2018 Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923). ccessed May 18, 2020. https://www.eia.gov/electricity/data/state/

Electric Power Generating Units in Tennessee

Generating units in Tennessee are spread across the state, as shown in Figure 3.1, but show a strong concentration in East Tennessee along the Tennessee River system and its tributaries. Water is of obvious importance to hydroelectric power generation, but it is also important for coal to move bulk product to generating sites and for nuclear to provide cooling capacity.

Figure 3.1. Distribution of Operating Generator Units by Fuel Source and Nameplate Capacity (MW) as of March 2020



Source: EIA, March 2020 Monthly Electric Generator Inventory (based on monthly Form EIA-860M which is a supplement to annual Form EIA-860). The data reports the current status of generators at electric power plants with 1 MW or greater of combined nameplate capacity. Nameplate capacity (MW) was aggregated by the authors to the plant-fuel source level for generators reported as operating. Accessed on May 28, 2020. https://www.eia.gov/electricity/data/eia860m/

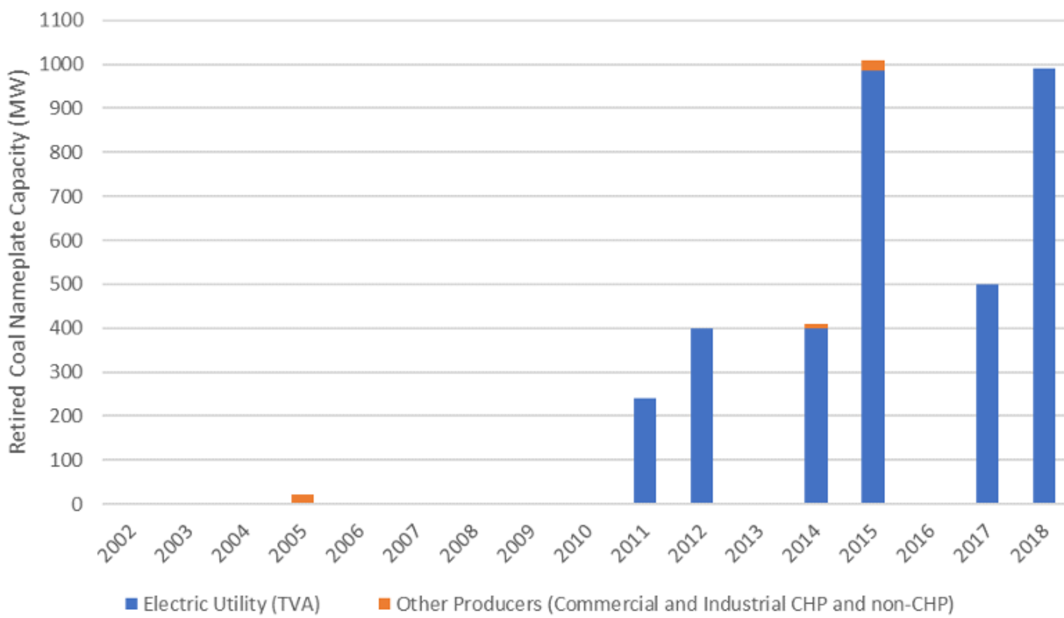
The figure shows nameplate capacity for many generators in the state, or the maximum power output of a generator in megawatts (MW) as designated by manufacturers; nameplate capacity does not reflect actual generation. The data are not comprehensive, as there is no reporting for generators at electric power plants with less than one MW of combined nameplate capacity. However, the data do account for most of the electricity generated in Tennessee, including the different types of producers (e.g., electric utilities, industrial CHP, commercial CHP, and independent power producers).

Cumberland Fossil Plant, which is located in Stewart County and has two conventional steam coal generators, accounts for the largest combined nameplate capacity at 2,600 MW. The next largest capacities stem from the Watts Bar and Sequoyah Nuclear plants, with combined capacities of 2,540 and 2,441 MW. These facilities are located in Rhea County and Hamilton County.

There are several smaller plants fueled by natural gas, hydroelectric power, or coal, with capacities ranging from 1,625 to 1,791 MW. These include: (i) Allen Combined Cycle Plant (in Shelby County) that began supplying power to the grid in 2018 using two natural gas combined cycle turbines and one combustion steam turbine; (ii) Raccoon Mountain (in Hamilton County), which is a pumped-storage hydroelectric plant; (iii) Kingston Fossil Plant (in Roane County), which has nine conventional steam coal generators; and (iv) Lagoon Creek (in Haywood County), which is a natural gas combined cycle plant. All of the aforementioned plants are part of TVA's portfolio. Figure 3.1 also shows 17 operating solar facilities, many of which are located in West Tennessee in Shelby, McNairy, Haywood, or Fayette County. Most are owned by independent power producers but have long term contracts to provide this power to TVA.

As the fuel mix for electric power generation has evolved over time and as facilities have aged, some generating units have been retired. Figure 3.2 shows how much coal nameplate capacity has been retired since 2002 in Tennessee. TVA has retired a number of coal-fired plants, including Watts Bar Fossil Plant (four coal generators in 2011), John Sevier Fossil Plant (two in 2012 and two in 2014), Johnsonville Fossil Plant (six in 2015 and four in 2017), and Allen Fossil Plant (three in 2018). The average per unit nameplate capacity for these coal generators was 167 MW, and the total retired capacity is 3,515 MW. Coal generator retirements have increased since 2011, partly in response to the flattening of demand for electricity (discussed below), lower natural gas prices stemming from the development of hydraulic fracturing and horizontal drilling, and policy and market initiatives to move toward cleaner energy sources.

Figure 3.2. Coal Generating Unit Retirements Grow in Tennessee (2002-2018)



Source: EIA, March 2020 Monthly Electric Generator Inventory (based on monthly Form EIA-860M which is a supplement to annual Form EIA-860). The data reports the current status of generators at electric power plants with 1 MW or greater of combined nameplate capacity. Nameplate capacity (MW) was aggregated by the authors to the plant-fuel source level for generators reported as operating. Accessed on May 28, 2020. https://www.eia.gov/electricity/data/eia860m/

Retail Sales and Prices

As shown in Table 3.8, retail sales of electricity in Tennessee totaled 102,911,183 MWh in 2018, representing growth of just 6.7 percent since 2012 and a 2.7 percent share of total U.S. retail sales in 2018 (Tennessee's population was 2.1 percent of the national population in 2018).[14] Similar to in 2012, residential customers accounted for 85 percent of total customers (2,882,992 customers) in 2018. However, residential customers accounted for just over 40 percent of total sales. The commercial sector made up about 15 percent (491,567 customers) of all customers and consumed 36 percent of all retail sales in 2018. Industrial customers accounted for less than one percent of customers (1,010 customers) but more than one-fifth of total electricity sales in the state in 2018.[15] Transportation accounted for just 0.2 percent of sales in the U.S. in 2018, while there were no sales to the transportation sector in Tennessee in the same year.

14. Source: U.S. Census Bureau, Population and Housing Unit Estimates Datasets. https://www.census.gov/programs-surveys/popest/data/data-sets.2018.html
15. Energy Information Agency, Detailed State Data, 1990-2018 Number of Retail Customers by State by Sector (EIA-861). Accessed May 18, 2020. https://www.eia.gov/electricity/data/state/

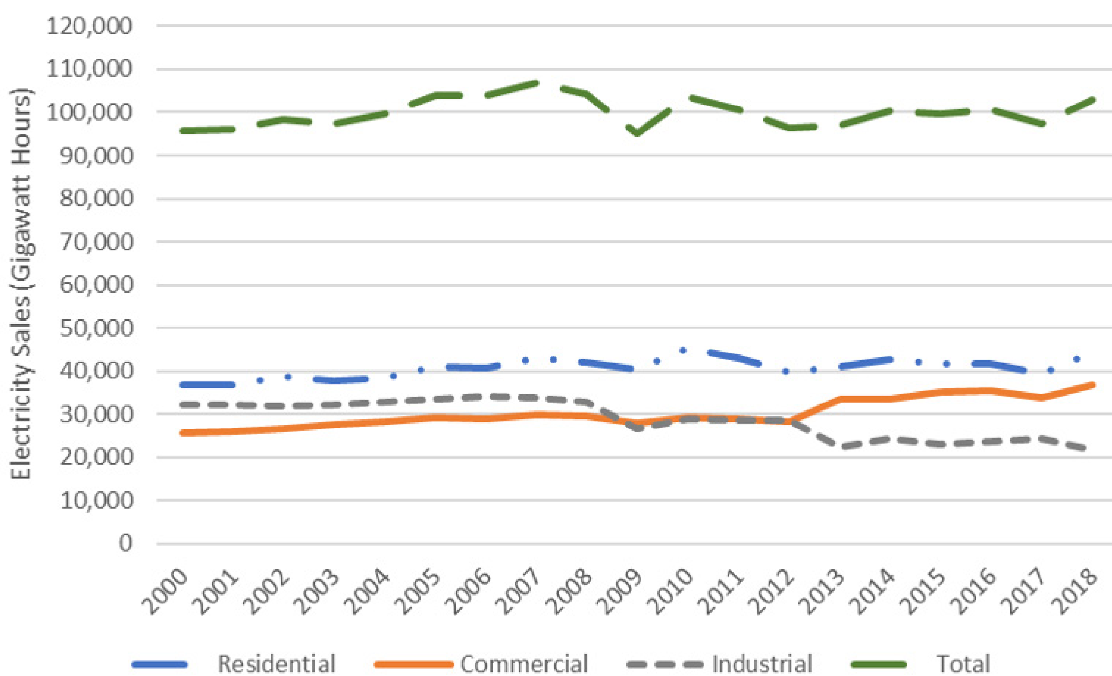
Table 3.8. Retail Sales of Electricity by Sector in Tennessee and U.S., 2012 and 2018

Sector	Tennessee			U.S.		
	Percent by Sector		Sales (Megawatt Hours)	Percent by Sector		Sales (Megawatt Hours)
	2012	2018	2018	2012	2018	2018
Residential	41	43.1	44,381,957	34	38.1	1,469,093,059
Commercial	29	35.9	36,930,451	38	35.8	1,381,754,845
Industrial	30	21.0	21,598,775	28	25.9	1,000,672,553
Transportation		0.0	0		0.2	7,664,804
Total	**100**	**100.0**	**102,911,183**	**100**	**100.0**	**3,859,185,261**

Source: EIA, Detailed State Data, 1990-2018 Retail Sales of Electricity by State by Sector by Provider (EIA-861). Accessed May 18, 2020. https://www.eia.gov/electricitydata/state/

Total sales have remained relatively flat, as shown in Figure 3.3, increasing from almost 96,000 gigawatt hours (GWh) to 103,000 GWh from 2000 to 2018 (a growth of only 8 percent). Sales in the commercial sector increased the most (43 percent), growing from 26,000 GWh in 2000 to 37,000 GWh in 2018. Residential sales increased by about half as much (21 percent), as sales grew from 37,000 GWh to 44,000 GWh. At the same time, sales in the industrial sector decreased by 33 percent, and are now below 22,000 GWh.

Figure 3.3. Electricity Sales by Sector in Tennessee, 2000-2018: Flat Growth



Source: EIA, Detailed State Data, 1990-2018 Retail Sales of Electricity by State by Sector by Provider (EIA-861). Accessed May 18, 2020. https://www.eia.gov/electricity/data/state/

These trends for Tennessee are largely similar to those at the national level. However, industrial sales have decreased more in Tennessee, declining by 33 percent compared to a 6 percent decline at the national level between 2000 and 2018. Multiple factors could contribute to the subdued growth of electricity sales including efficiency improvements across all sectors, weather patterns which impact electricity demand, and changes in the level and mix of industrial activity. For example, in 2000, manufacturing represented 18 percent of the Tennessee workforce, and this share decreased to 11 percent in 2018.[16] The shift from manufacturing to more service-oriented sectors contributes to the decline in electricity sales in the industrial sector, adding to the impact of energy-efficient, process improvements. Another factor is the increased use of distributed generation, such as growth in customer-owned rooftop solar panels, which have become more cost-effective for homes and businesses alike.

Electricity costs are significant for residential, commercial, and industrial customers. For residential households, electricity is a necessity and high costs can contribute to economic insecurity, particularly for rural communities. In a report by the American Council for an Energy-Efficient Economy (ACEEE), an analysis showed that the median energy burden was among the highest for rural households in the East South Central region in the U.S., which includes Tennessee in addition to Alabama, Kentucky, and Mississippi.[17] Rural households in this region had a median energy burden of 5.1 percent and the highest overall upper quartile energy burden (9.4 percent). Nationally, the median energy burden for all rural households was 4.4 percent while the energy burden for metropolitan households was 3.1 percent. This demonstrates the disparity in energy burdens between metropolitan and rural households. For commercial businesses, high electricity prices can contribute to higher product prices and/or lower profits. Footloose industrial firms may consider locating production facilities elsewhere if electricity costs in a given area are too high compared to competing sites. As shown in Table 3.9, retail electricity prices in Tennessee compare favorably to national average prices. It is noteworthy that both residential and industrial prices fell between 2012 and 2018.

Table 3.9. Average Electricity Retail Prices Compared Favorably to the U.S. (2012 and 2018)

	Tennessee			U.S.		
	Average Price (cents/kWh)		Percent Change	Average Price (cents/kWh)		Percent Change
Sector	2012	2018	2012 to 2018	2012	2018	2012 to 2018
Residential	10.91	10.71	-1.83	12.84	12.87	0.23
Commercial	10.47	10.51	0.38	10.51	10.67	1.52
Industrial	5.92	5.68	-4.05	6.76	6.92	2.37

Source: EIA, Detailed State Data, 1990-2018 Average Price by State by Provider (EIA-861). Accessed May 18, 2020. https://www.eia.gov/electricity/data/state/

Average retail prices across local power companies in Tennessee can vary significantly by sector. For example, in 2018, the minimum and maximum average retail prices within the residential sector were 7.23 and 13.77 cents per kilowatt-hour (kWh). Within the commercial sector, average retail prices varied between 6.81 and 16.67 cents/kWh. The minimum average retail price for the industrial sector was 4.05 cents/kWh and the maximum was 100 cents/kWh. The latter is arguably an outlier, as it was for a single customer; the second highest price was 22 cents/kWh.[18]

16. Figure 2.1 in Boyd Center for Business and Economic Research, University of Tennessee. (2020). An Economic Report to the Governor of the State of Tennessee, The State's Economic Outlook January 2020. Available here: https://haslam.utk.edu/boyd-center/publications?subject=1137

17. Ross, Lauren, Ariel Drehobl, and Brian Stickles. (2018). The High Cost of Energy in Rural America: Household Energy Burdens and Opportunities for Energy Efficiency. An American Council for an Energy-Efficient Economy (ACEEE) Report. Available here: https://www.aceee.org/sites/default/files/publications/researchreports/u1806.pdf

18. Source: EIA, Annual retail prices by state, utility, and sector, 2018. Tables 6, 7, and 8 (Data from forms EIA-861 and EIA-861S). Accessed on May 26, 2020. https://www.eia.gov/electricity/data.php

CHAPTER 4: NATURAL RESOURCE BASE AND PRODUCTION OF ENERGY

Introduction

Some regions are endowed with extensive natural resources, including both renewables and non-renewables, that enable resource extraction/use in the production of energy, including exportation out of the region. Good examples include Texas and Alaska, which possess large petroleum reserves, Midwestern states that have extensive wind capacity, and Southwestern states that have abundant solar irradiation. While Tennessee has a rich hydroelectric power base, it is not well endowed with other energy resources. Nonetheless, there are opportunities to take advantage of the resources the state does possess to support resource extraction, power generation, and economic development.

This chapter surveys the natural resource base in Tennessee in considerable detail, including all major energy-related resources. The discussion highlights opportunities for resource extraction and use across the state.

Coal

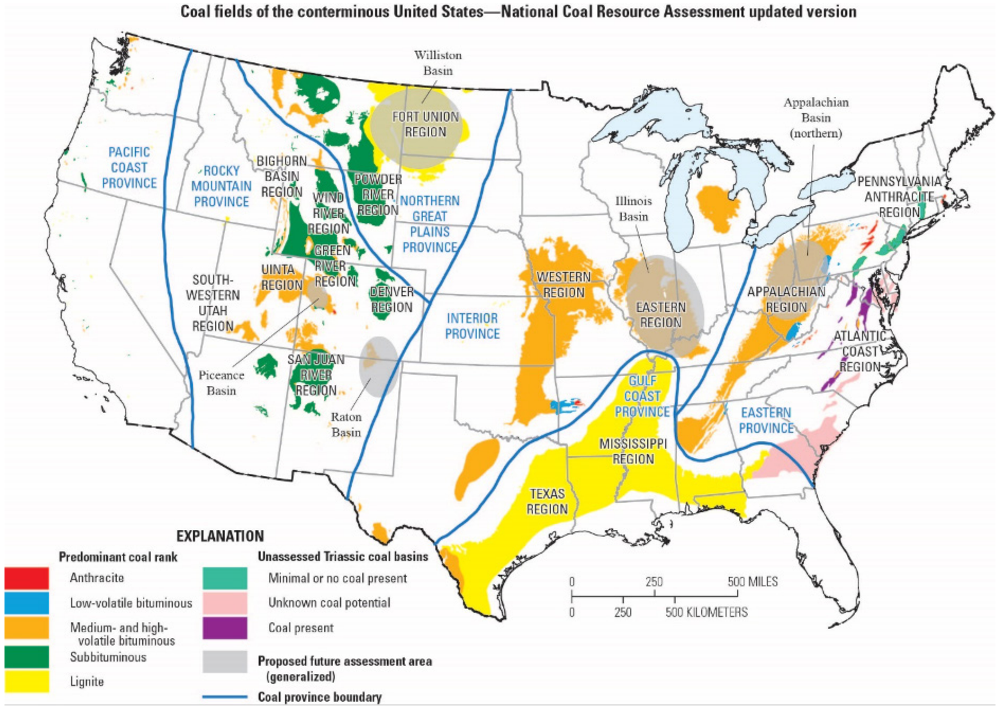
Not all coal is the same, and the differences between coal classifications help explain why some coal regions are in decline while others are stable or growing. The four major ranks (i.e. types) of coal include anthracite, bituminous, subbituminous, and lignite. Subbituminous and bituminous coal, which are mainly used to generate electricity, account for the majority of coal extracted in the U.S., representing 44.6 and 47.7 percent of total U.S. production in 2018. Bituminous coal is found in the Appalachian region, including the eastern region of Tennessee. Subbituminous coal, which is mainly found in the West (particularly in Wyoming), has a lower energy content, but its proximity to the surface results in lower extraction costs. While anthracite has the highest carbon content, it is only located in Pennsylvania and made up just 0.3 percent of U.S. coal production in 2018 due to its rarity. Lignite has the lowest energy content and made up 7.5 percent of national coal production in 2018.[19] Significant lignite coal fields are present in West Tennessee and are an extension of the Gulf Coast Coal Province, but these reserves have not been considered economically feasible to mine.[20, 21]

19. Source for coal U.S. and state coal production: EIA, Coal Production by State and Mine Type. Accessed on June 16, 2020. https://www.eia.gov/coal/data.php

20. Source: Hackley, Paul C., Peter D. Warwick, Roger E. Thomas, Douglas J. Nichols. 2011. A Review of Lignite Resources of Western Tennessee and the Jackson Purchase Area, Western Kentucky, in P.D. Warwick, A.K. Karlsen, M. Merrill, and B.J. Valentine, eds, Geologic Assessment of Coal in the Gulf of Mexico Coastal Plain, U.S.A.: AAPG Discovery Series No. 14/ AAPG Studies in Geology No. 62, p 326-347.

21. For more information on U.S. coal resources and reserves, see: Shaffer, B.N., 2017, Assessing U.S. coal resources and reserves: U.S. Geological Survey Fact Sheet 2017-3067, 6 p., https://pubs.er.usgs.gov/publication/fs20173067

Figure 4.1. Bituminous Coal Reserves are in East Tennessee



Source: U.S. Geological Survey, Energy Resources Program, U.S. Coal Resources and Reserves Assessment Project, Map of Various Coal Fields of the Conterminous United States, 2017. Accessed on June 16, 2020. https://pubs.er.usgs.gov/publication/fs20173067

Tennessee has relatively modest coal reserves, but they are a potentially important asset to their host counties across the state. Table 4.1 shows demonstrated reserves, estimated recoverable reserves, and recoverable reserves at producing mines. The demonstrated reserve base represents coal resources that meet various criteria including accessibility, quality, recoverability, and thickness based on coal type, depth, and type of mining.[22] The demonstrated reserve base is then adjusted by EIA to create an estimate of recoverable reserves, to further account for access and recovery rates. For example, land use restrictions, property rights, and environmental restrictions are additional factors that impact access in estimating recoverable reserves. Additionally, recovery rates can vary substantially based on the type of mining and geological factors. The estimation of recoverable reserves is not informed by any specific economic feasibility criteria; it is simply a measure of resource capacity. Recoverable coal reserves at producing mines essentially represents coal inventory at producing mines.[23] Therefore, as coal mines stop producing or close, the reported recoverable reserves at producing mines declines.

Table 4.1. Tennessee has Coal Reserves, Albeit Smaller Reserves Compared to Other States

Type of Mining	Demonstrated Reserve Base (Million Short Tons)	Estimated Recoverable Reserves (Million Short Tons)	Recoverable Reserves at Producing Mines (Million Short Tons)
Underground	494	271	9
Surface	251	170	-
Total	**745**	**441**	**9**

Source: EIA, Recoverable Coal Reserves at Producing Mines, Estimated Recoverable, and Demonstrated Reserve Base by Mine Type, 2018 (Table 15 in Annual Coal Report). Accessed June 2, 2020. https://www.eia.gov/coal/data/php
Notes: Recoverable reserves at producing surface mines was not reported for Tennessee as the value was less than 0.5 of the table metric.

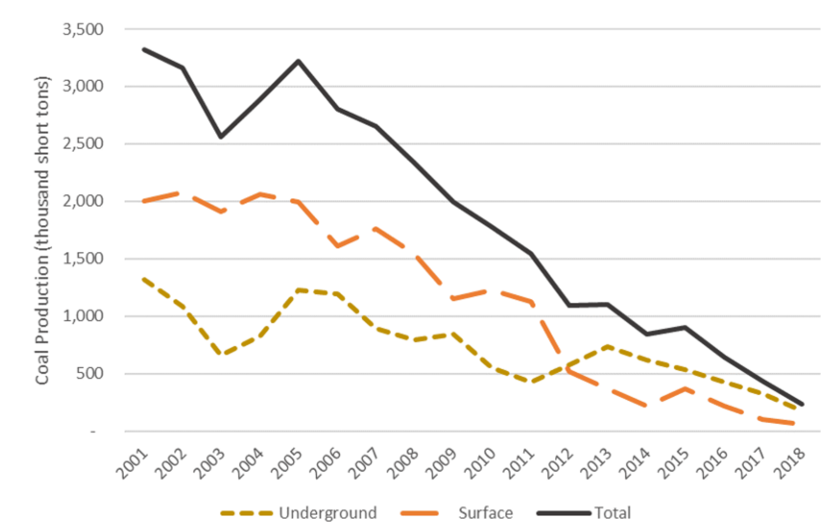
22. All reserves estimates exclude silt, culm, refuse bank, slurry dam, and dredge operations.
23. Mines producing less than 25,000 short tons are not required to provide reserve data.

In Tennessee, underground coal reserves account for about two-thirds of the total coal reserves, while surface reserves account for roughly one-third, both in terms of the demonstrated reserve base and the estimated recoverable reserves. Generally, surface reserves are easier to exploit than sub-surface reserves. Compared to 2012, Tennessee's demonstrated reserve base has decreased slightly, from 753 to 745 million short tons. Likewise, the estimated recoverable reserves declined from 445 to 441 million short tons. Tennessee's demonstrated reserve base (745 million short tons) represents just 0.16 percent of the total demonstrated reserve base in the U.S. Estimated recoverable reserves (441 million short tons) represents just 0.17 percent of the U.S. total. Recoverable reserves at producing mines (9 million short tons) accounts for a very small 0.06 percent of recoverable reserves at all producing mines in the U.S.

For perspective, the top four states with the largest shares of U.S. estimated recoverable reserves are Montana (29.4 percent), Illinois (14.9 percent), Wyoming (14.0 percent), and West Virginia (6.5 percent). Almost all states surrounding Tennessee have coal shares that are less than one percent of U.S. estimated recoverable reserves. Kentucky is the exception--its estimated recoverable reserves (13,912 million short tons) account for 5.5 percent of the U.S. total.

Figure 4.2 illustrates the decline in coal production in Tennessee dating back to 2001. Since then, coal production has decreased by 93 percent from 3,324 thousand short tons to 232 thousand short tons in 2018. In 2001, surface mining accounted for 60 percent of mining activity while underground mining represented 40 percent. Today, underground mining accounts for the majority of coal mining in Tennessee and represented 75 percent of coal production in 2018.

Figure 4.2. Annual Coal Production in Tennessee Continues to Decline, and Tennessee Ranks Last Among Coal Producing States in the U.S.



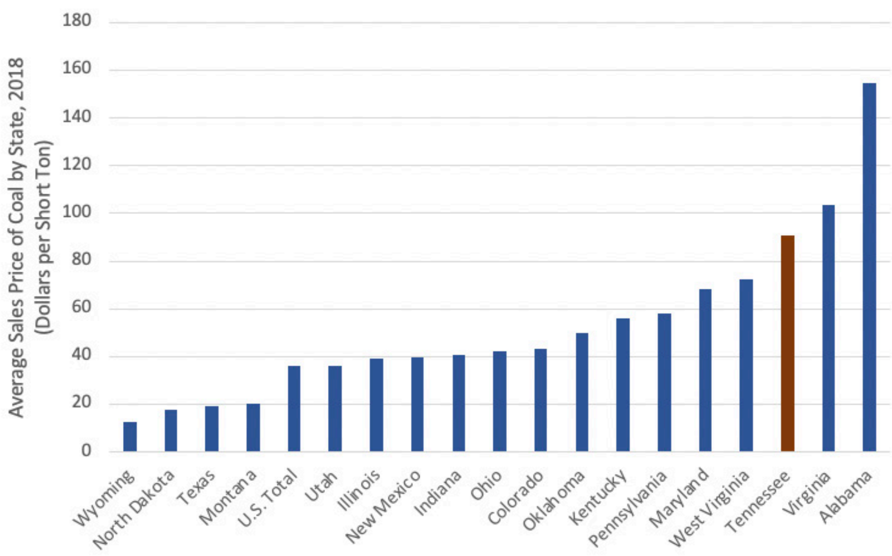
Source: EIA, Annual Coal Production by State and Mine Type, 2001 to 2018. Accessed on June 16, 2020. https://www.eia.gov/coal/data.php

As of 2018, there is only one underground mine and two surface mines in Claiborne County, which made up 75.0 and 22.8 percent of total production, respectively. A single surface mine in Campbell County accounted for the remaining production in the state (2.2 percent). All coal extracted in Tennessee to date has been bituminous coal. The decline in coal activity is not confined to Tennessee but is also seen at the national level, with total coal production decreasing from 1,127,689 thousand to 756,167 thousand short tons between 2001 and 2018 (a 32.9 percent decrease).

Tennessee coal production represented only 0.03 percent of total U.S. production in 2018; out of 23 states with positive coal production, Tennessee ranked last. Wyoming ranked first in coal production with 304,188 thousand short tons in 2018. West Virginia came in second at 95,365 thousand short tons[24], and Pennsylvania and Illinois were third and fourth, with both producing almost 50,000 thousand short tons. Together, these four states made up 66 percent of total coal production in the U.S. Total coal production from 2001 to 2018 declined for three out of the four top coal producing states; Illinois is the only current top coal producing state that experienced an increase in coal production during this time.

24. EIA, U.S. State Profile and Energy Estimates, State Rankings: Coal Production, 2018. Accessed on June 16, 2020. https://www.eia.gov/state/rankings/#/series/48

Figure 4.3. Tennessee had the Third Highest Average Sales Price of Coal in 2018



Source: EIA, Average Sales Price of Coal by State and Mine Type, Table 28, 2018, EIA-7A Form, Annual Survey of Coal Production and Preparation
Notes: EIA calculates an average sales price by dividing the total free on board (f.o.b) rail/barge value of the coal sold by the total coal sold. Mines producing less than 25,000 short tons are excluded and not required to provide data. Excludes silt, culm, refuse bank, slurry dam, and dredge operations.

Figure 4.3 presents average sales prices of coal for a number of states in 2018, including Tennessee. Average sales price excludes insurance and transportation costs and represents the value of coal at coal mines. Coal prices vary by rank, grade, mining method, and geographic location. Coal prices at surface mines are generally lower than at underground mines because costs are lower. For example, Wyoming is the top coal producing state, and over 99 percent of coal production is from surface mines. In 2018, Wyoming had the lowest average sale price of coal at $12.68 per short ton. In comparison, the average price of coal from underground mines, such as mines found in the Appalachian region where beds can be thinner or deeper, tend to be higher. Kentucky, Pennsylvania, Maryland, West Virginia, and Virginia had average prices between $55.95 and $103.77 per short ton. Among the states for which data is not withheld due to disclosure concerns, Tennessee has the third highest average sales price of coal at $90.97 per short ton. The national average sales price of coal at coal mines in 2018 was $35.99 per short ton.

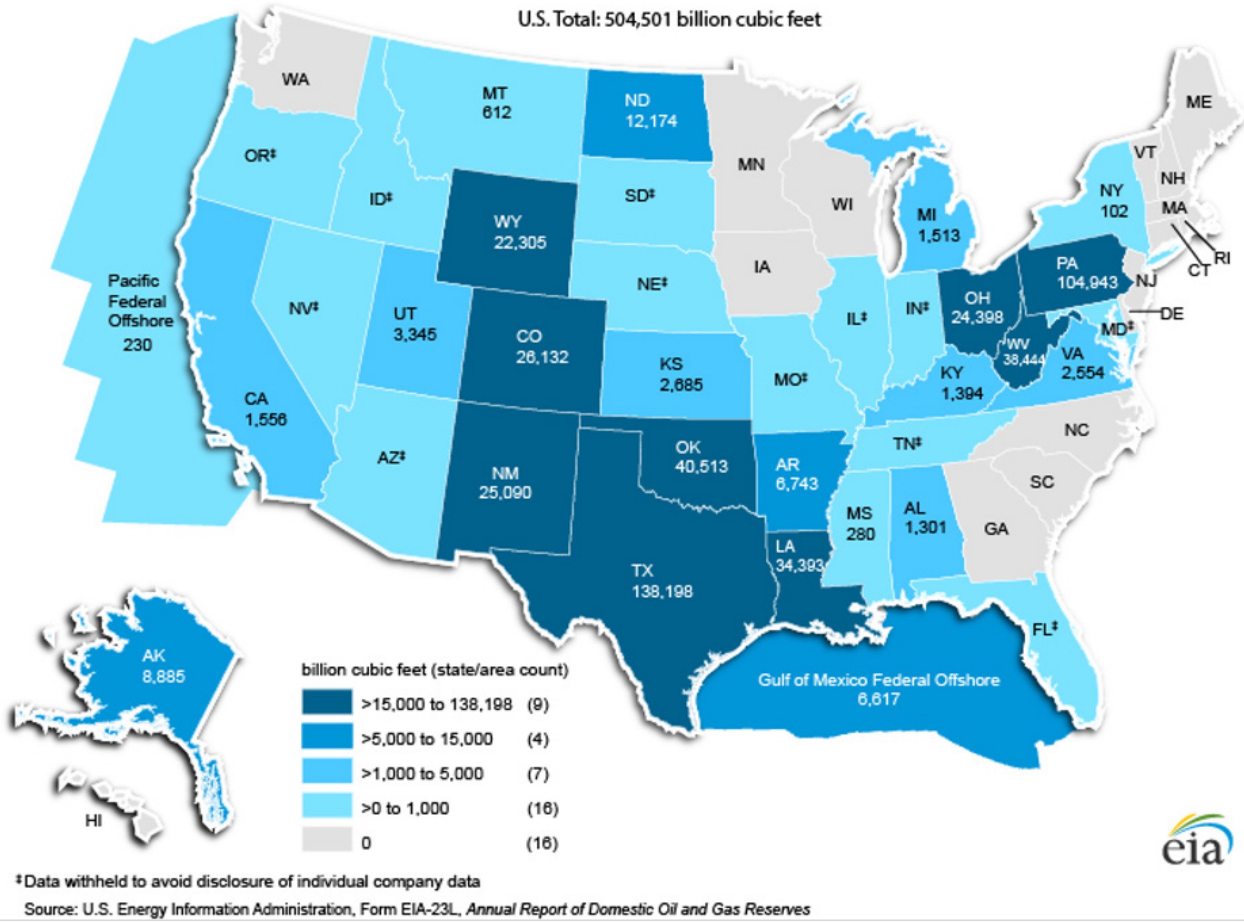
Natural Gas

EIA aggregates measures of natural gas reserves for Tennessee with other states with minimal drilling in order to avoid disclosure of data for individual companies. This disclosure issue is indicative of the small reserves available in Tennessee. The aggregate of proved reserves of natural gas for this group of states (which included Arizona, Florida, Idaho, Illinois, Indiana, Maryland, Missouri, Nebraska, Nevada, Oregon, South Dakota, and Tennessee) totaled 94 billion cubic feet in 2018. This figure represents only 0.02 percent of total natural gas proved reserves in the U.S.[25]

Tennessee shows no coalbed methane proved reserves. Beginning in 2018, EIA stopped reporting separate data for coalbed methane; this data is instead included as part of the data on conventional natural gas reserves. In 2017, total coalbed methane proved reserves only represented 2.6 percent of the U.S. total natural gas proved reserves.

25. Source: EIA, Total Natural Gas Proved Reserves, Reserves Changes, and Production, Wet After Lease Separately, 2018 (Table 10). Accessed on June 18, 2020. https://www.eia.gov/naturalgas/crudeoilreserves/

Figure 4.4. Natural Gas Proved Reserves in Tennessee are Present, but are Comparably Limited



Source: EIA, U.S. Crude Oil and Natural Gas Proved Reserves by State or Area, Year-End 2018, Figure 16. Accessed June 3, 2020. https://www.eia.gov/naturalgas/crudeoilreserves/

At the national level, natural gas proved reserves increased to a record high of 504.5 trillion cubic feet in 2018. Natural gas from shale accounted for 68 percent of total natural gas proved reserves.[26] Part of the Chattanooga Shale is located in Eastern Tennessee. There has been interest in drilling this area, particularly when natural gas prices were relatively high in 2008. Since then, natural gas prices have fallen (which is discussed more below). Given the relatively thin shale in Eastern Tennessee, interest in drilling has waned. The shale formation is at a depth of between 3,000 and 4,000 feet, with average thicknesses ranging between 80 and 200 feet.[27] The shale extends further north into Kentucky, where the thickness increases to over 1,000 feet. Future increases in natural gas prices could spark renewed interest in drilling in the Chattanooga Shale region; however, EIA predicts that natural gas prices will remain low in the near term.[28]

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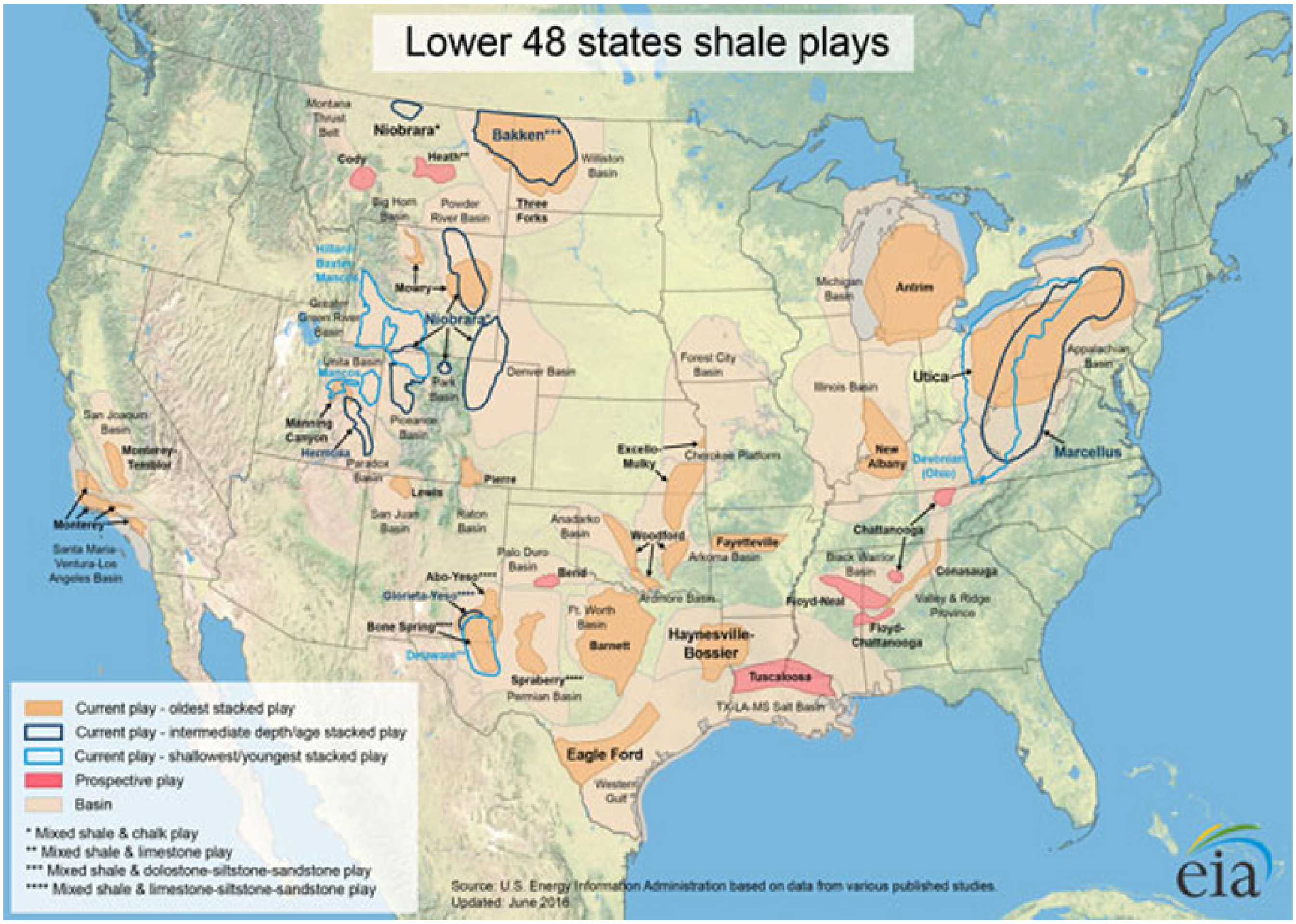
26. Natural gas reserve data is available here: EIA, U.S. Crude Oil and Natural Gas Proved Reserves, Year-End 2018 Report. Available: https://www.eia.gov/naturalgas/crudeoilreserves/
27. See: http://oilshalegas.com/chattanoogashale.html
28. See: EIA, Annual Energy Outlook 2020, https://www.eia.gov/outlooks/aeo/

Figure 4.5. Chattanooga Shale in Eastern Tennessee is Relatively Small and Thin, Implying Higher Natural Gas Prices Would Be Needed to Spur Further Exploration and Drilling



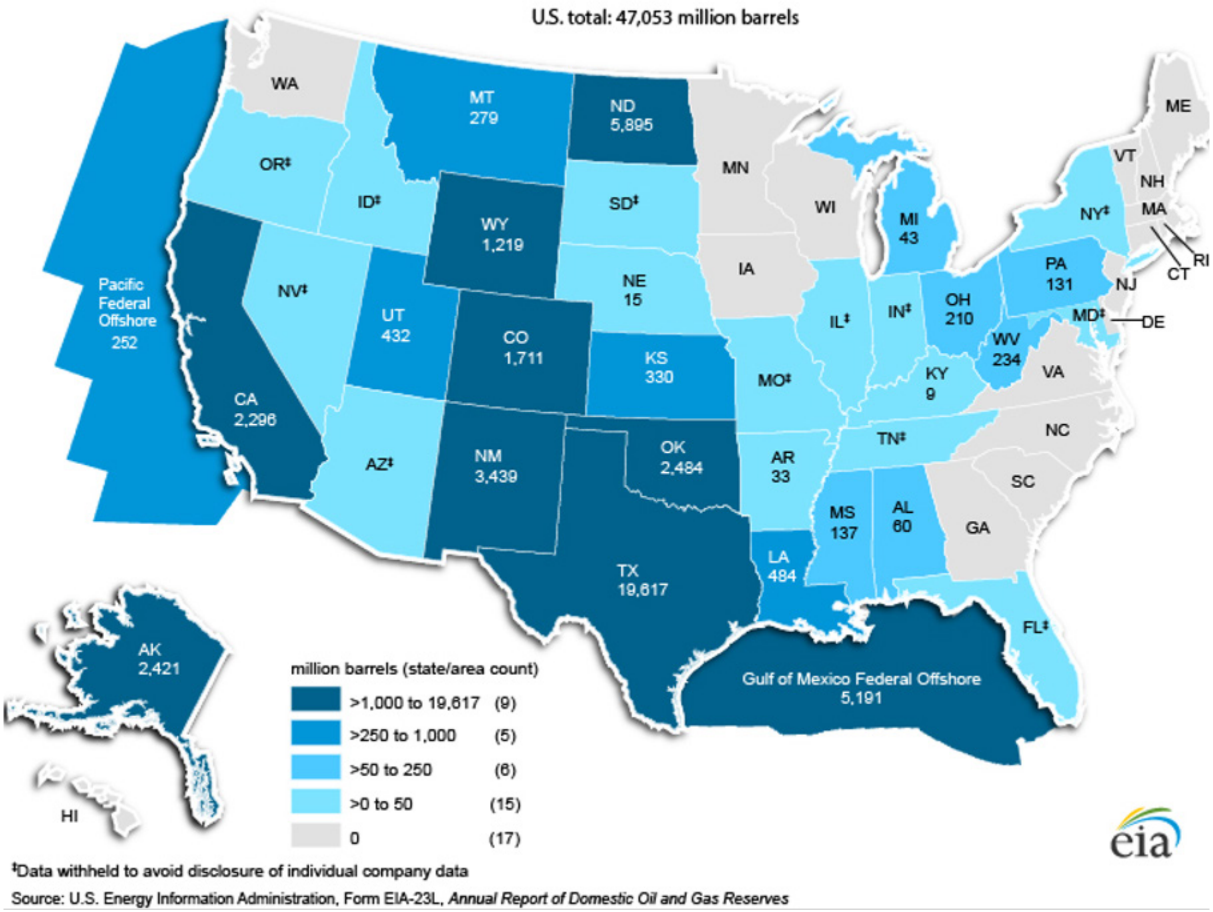
Source: EIA, Lower 48 States Shale Plays, 2016 based on data from various published studies. Accessed June 3, 2020. https://www.eia.gov/energyexplained/natural-gas/where-our-natural-gas-comes-from.php

Oil Reserves

On the national level, proved reserves of crude oil in the U.S. increased to a record high of 43.8 billion barrels in 2018; adding lease condensate increased total reserves to 47.1 billion barrels (see Figure 4.6). As with natural gas, EIA aggregates measures of crude oil reserves for Tennessee with other small-volume states to avoid disclosure of data for individual companies—a telling sign regarding the scope of the state's reserve base. The aggregate of crude oil proved reserves for this group of states (which included Arizona, Florida, Idaho, Illinois, Maryland, Missouri, Nevada, New York, South Dakota, Tennessee and Virginia) totaled 108 million barrels in 2018, which represented 0.25 percent of total crude oil proved reserves in the U.S.[29]

29. Source: EIA, Crude Oil Proved Reserves, Reserves Changes, and Production, 2018 (Table 7). Accessed on June 3, 2020. https://www.eia.gov/naturalgas/crudeoilreserves/

Figure 4.6. Tennessee has Relatively Limited Oil Reserves

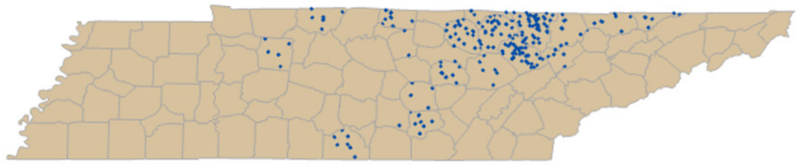


Source: EIA, U.S. Crude Oil and Natural Gas Proved Reserves, Year-End 2018, Crude Oil and Lease Condensate Proved Reserves by State or Area, Figure 14. Accessed June 3, 2020. https://www.eia.gov/naturalgas/crudeoilreserves/

EIA has discontinued field-level data (i.e., field code master list) for oil and natural gas. Currently, EIA uses data from a sample of operators to report state (and state subdivisions for a few specific states) estimates, partly because of the growth in shale gas drilling and the fact that unconventional reservoirs defied traditional definitions of a field. Figures 4.7 and 4.8 illustrate the available data on oil and natural gas fields in Tennessee. Unfortunately, these data are for 2013, when the last field master list published by EIA differentiated between oil and gas fields by county. No new fields had been added to the list since 1987. Table 4.2 below lists the number of oil and gas fields by county in Tennessee.

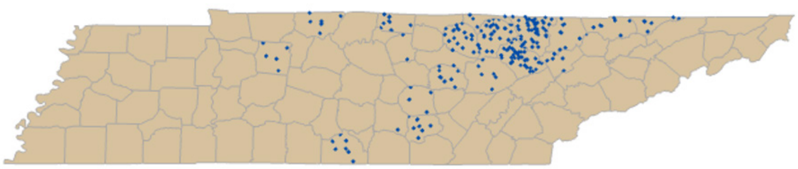
Twenty-four Tennessee counties hold oil and gas wells. The top six counties with the highest number of oil and gas well permits are Overton (3,151), Morgan (2,208), Scott (2,129), Fentress (2,042), Pickett (1,544), and Clay County (1,254). Following these top counties is Anderson County with 461 permits and Campbell County with 309 permits. Among all counties in Tennessee, the average number of permits is 171.3.

Figure 4.7. Gas Fields in Tennessee are Mainly on the Cumberland Plateau or the Eastern Highland Rim



Source: EIA, Oil and Gas Field Code Master List Archives, 2013. Gas includes nonassociated and associated dissolved gas. Accessed on June 8, 2020. https://www.eia.gov/naturalgas/fieldcode/archive/2013/fcml.php

Figure 4.8. Oil Fields in Tennessee are Mainly on the Cumberland Plateau or the Eastern Highland Rim



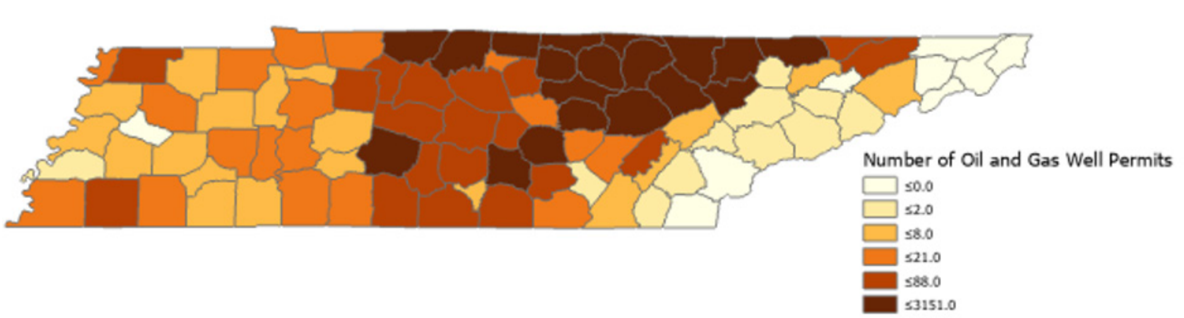
Source: EIA, Oil and Gas Field Code Master List Archives, 2013. Accessed on June 8, 2020. https://www.eia.gov/naturalgas/fieldcode/archive/2013/fcml.php

Table 4.2. The Highest Number of Oil and Gas Fields are in Morgan, Scott, and Fentress County

	Oil Fields		Gas Fields	
County	Number	Percent	Number	Percent
Anderson	7	2.46	6	2.76
Campbell	11	3.87	8	3.69
Cannon	6	2.11	0	0.00
Claiborne	7	2.46	7	3.23
Clay	30	10.56	0	0.00
Coffee	6	2.11	1	0.46
Cumberland	7	2.46	6	2.76
Dickson	1	0.35	6	2.76
Fentress	32	11.27	27	12.44
Grundy	0	0.00	8	3.69
Hancock	6	2.11	6	2.76
Jackson	10	3.52	0	0.00
Lincoln	0	0.00	7	3.23
Macon	0	0.00	9	4.15
Morgan	44	15.49	39	17.97
Overton	26	9.15	20	9.22
Pickett	20	7.04	4	1.84
Putnam	6	2.11	1	0.46
Robertson	6	2.11	6	2.76
Scott	39	13.73	42	19.35
Smith	6	2.11	2	0.92
Sumner	7	2.46	0	0.00
Warren	7	2.46	4	1.84
White	0	0.00	8	3.69
Total	**284**	**100**	**217**	**100**

Source: EIA, Oil and Gas Field Code Master List Archives, 2013. Gas includes nonassociated and associated dissolved gas. Accessed on June 8, 2020. https://www.eia.gov/naturalgas/fieldcode/archive/2013/fcml.php

Figure 4.8. Oil Fields in Tennessee are Mainly on the Cumberland Plateau or the Eastern Highland Rim



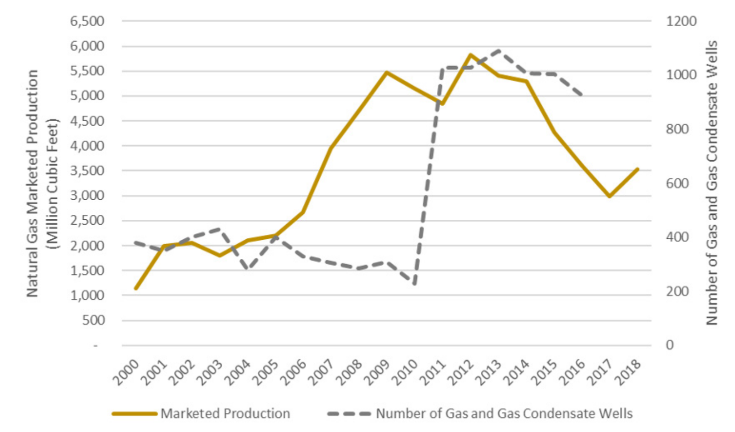
Source: Tennessee Department of Environment and Conservation, Division of Water Resources, Oil and Gas Program, Oil and Gas Well Database. Data accessed on June 9, 2020. http://tdec.tn.gov:8080/pls/enf_reports/f?p=9034:34300:0::NO:::

In recent history, oil and gas well permits have generally declined from a peak in 2007 at 417 permits to only 61 permits issued in 2019. In the last five years, permitting activity was the highest in Clay and Overton County, which accounted for 17 and 10 percent of total permits issued. This continues a trend of permit activity moving away from the Cumberland Plateau to the Eastern Highland Rim.[30]

30. For more information on oil and gas activity in Tennessee, see Tennessee Department of Environment and Conservation, Division of Water Resources, Oil and Gas Program, Oil and Gas Activity in Tennessee During 2018. Presented to the Tennessee Oil and Gas Association, May 2019. https://www.tn.gov/environment/permit-permits/redirect---other-permits/oil-and-gas-well-permit.html

Nationally, natural gas production has increased since 2005, with marketed production exceeding 32.8 trillion cubic feet in 2018. Tennessee's natural gas production is a very small portion of total production in the U.S. (.01 percent), and as of 2018, Tennessee ranked 24th out of the 34 states that produce natural gas.

Figure 4.10. Natural Gas Production Has Generally Increased in Tennessee, but Production Remains a Small Percentage of the U.S. Total



Source: EIA, Natural Gas Gross Withdrawals and Production and Number of Producing Gas Wells (Annual). Number of gas wells is not available for Tennessee in 2017 and 2018. Accessed on June 9, 2020. https://www.eia.gov/naturalgas/data.php

In Tennessee, natural gas production increased to a peak of 5,825 million cubic feet in 2012 and declined to 2,982 million cubic feet in 2017. This was followed by an uptick that reached 3,538 million cubic feet in 2018. The average number of producing gas wells in Tennessee between 2000 and 2010 was 336. In 2011, the number of gas wells significantly increased to 1,027, and remained near that level through 2016. For reference, Texas is number one in natural gas production, with a marketed production of 7.85 trillion cubic feet, followed by Pennsylvania (6.21 trillion cubic feet) and Oklahoma (2.95 trillion cubic feet).[31]

Table 4.3. Anderson, Morgan, Scott, and Claiborne Counties Account for 90 Percent of Total Natural Gas Production in Tennessee in 2018

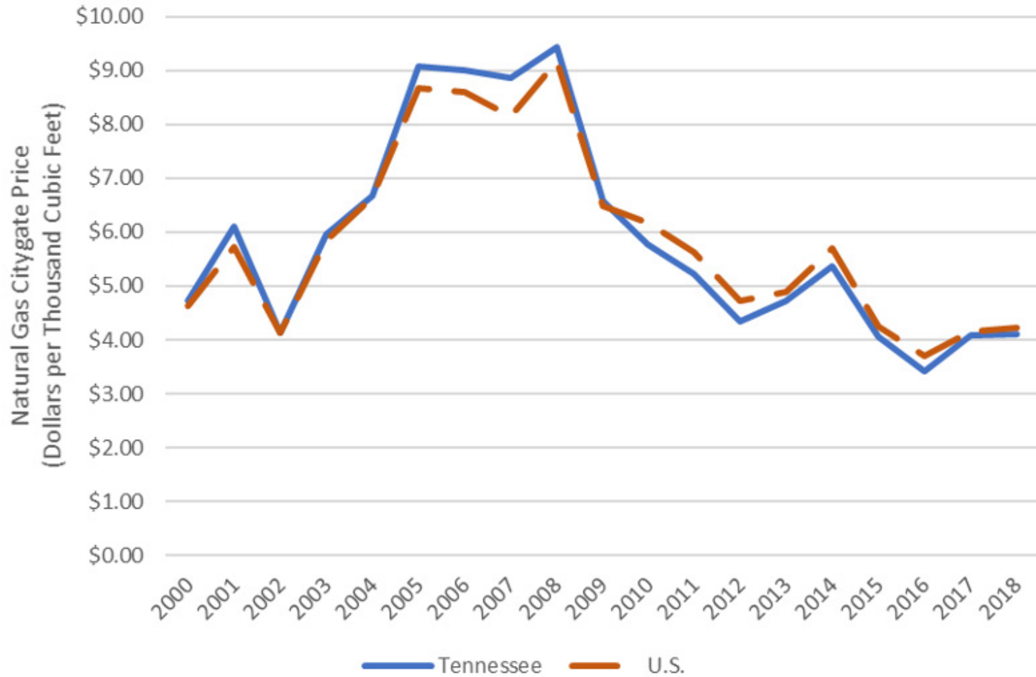
County	Production (Million Cubic Feet)	Percent of Total Producation	Number of Wells Contributing to Production
Anderson	1,298.82	36.71	307
Morgan	825.91	23.34	238
Scott	559.56	15.82	216
Claiborne	491.13	13.88	88
Campbell	258.08	7.29	87
Fentress	50.46	1.43	50
Hancock	41.86	1.18	11
Roane	12.14	0.34	1
Total	**3,537.95**	**100.00**	**998**

Source: Tennessee Department of Environment and Conservation, Division of Water Resources, Oil and Gas Program, Oil and Gas Activity in Tennessee During 2018 Report. Presented to the Tennessee Oil and Gas Association, May 2019. https://www.tn.gov/environment/permit-permits/redirect-other-permits/oil=and-gas-well-permit..html

Natural gas production comes from eight counties in Tennessee. Production was the highest in Anderson County at 1,298 million cubic feet, which accounted for 37 percent of total gas production in Tennessee in 2018. Morgan County was the second largest producer at 826 million cubic feet (23 percent of total production). Scott and Claiborne Counties production represented 16 and 14 percent of total production. Together, these four counties made up 90 percent of total natural gas production in Tennessee in 2018.

31. EIA, U.S. State Profile and Energy Estimates, State Rankings: Natural Gas Marketed Production, 2018. Accessed on June 6, 2020. https://www.eia.gov/state/rankings/#/series/46

Figure 4.11. Natural Gas Prices Trend Downward After 2008 and have Remained Low



Source: EIA, Natural Gas Prices (Annual), Citygate Price. Accessed on June 9, 2020. https://www.eia.gov/naturalgas/data.php

Natural gas wellhead price estimates by EIA were discontinued in 2013.The citygate price is the price at which a distributing gas utility receives gas from a natural gas pipeline company or transmission system, and therefore reflects wholesale/wellhead prices in addition to pipeline transportation costs. Natural gas citygate prices in Tennessee closely mimic national prices (both in terms of the level and trends in prices over time), which demonstrates the state's integration with national energy markets.

Prices in Tennessee were slightly higher than the national average from 2000 to 2010; thereafter, natural gas prices in Tennessee have fallen slightly below the national average. Tennessee prices generally increased to a maximum of $9.43 per thousand cubic feet in 2008, followed by a general decline in prices to $4.10 per thousand cubic feet in 2018. Multiple factors impact natural gas prices including production, the amount of natural gas in storage, imports and exports, weather (e.g., summer versus winter, disruptions from extreme weather), economic growth, and prices of competing energy sources.

Figure 4.12. Oil Production in Tennessee has Remained Relatively Stable and Represents a Small Percentage of Total U.S. Production

Source: EIA, Crude Oil Production by State (Annual). Accessed on June 9, 2020. https://www.eia.gov/petroleum/data.php

Tennessee's oil production represents an extremely small portion (.005 percent in 2019) of total crude oil production in the U.S. Among the 32 oil producing states, Tennessee ranks 28th. While there has been some variation in crude oil production in Tennessee, it has remained relatively stable. From 2000 to 2019, production ranged from 192 thousand to 371 thousand barrels per year, and the average annual production was 294 thousand barrels. In sharp contrast, Texas, which is number one in crude oil production, produces 5,400 thousand barrels per day, followed by North Dakota (1,425 thousand barrels per day), New Mexico (1,093 thousand barrels per day), and Oklahoma (557 thousand barrels per day).[32] Beyond a dip in production in 2016, national crude oil production has increased since 2008 to 4.46 billion barrels in 2019.

Table 4.4. Overton, Morgan, Scott, and Fentress County Made up About 82 Percent of Tennessee's Total Oil Production in 2018

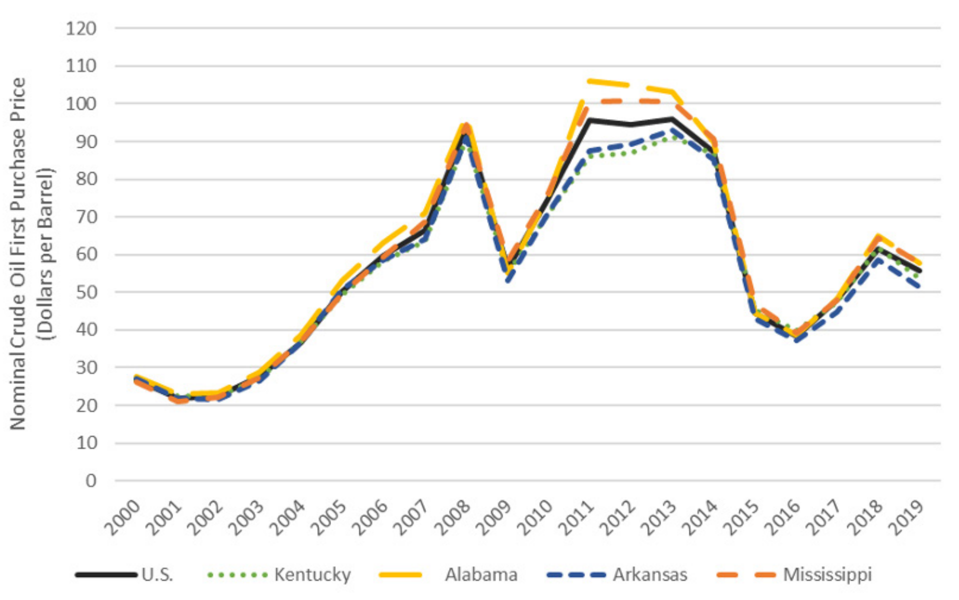
County	Production (Million Cubic Feet)	Percent of Total Producation	Number of Wells Contributing to Production
Anderson	1,298.82	36.71	307
Morgan	825.91	23.34	238
Scott	559.56	15.82	216
Claiborne	491.13	13.88	88
Campbell	258.08	7.29	87
Fentress	50.46	1.43	50
Hancock	41.86	1.18	11
Roane	12.14	0.34	1
Total	**3,537.95**	**100.00**	**998**

Source: Tennessee Department of Environment and Conservation, Division of Water Reseources, Oil and Gas Program, Oil and Gas Association, May 2019. https://www.tn.gov/environment/permit-permits/redirect---other-permits/oil-and-gas-well-permit.html

In 2018, Overton County, followed by Morgan County, produced the most oil in Tennessee, accounting for about 32 and 25 percent of total oil production. Oil production in Scott and Fentress Counties represented roughly 14 and 12 percent of the total. Together, these four counties made up about 82 percent of Tennessee's total oil production in 2018. Table 4.4 provides data for these and other counties in Tennessee where oil was produced in 2018. Note that production is not always aligned with the number of wells as some wells are more productive than others.

32. EIA, U.S. State Profile and Energy Estimates, State Rankings: Crude Oil Production, February 2020. Accessed on June 6, 2020. https://www.eia.gov/state/rankings/#/series/46

Figure 4.13. Since a Peak in 2013, Crude Oil First Purchase Prices have Decreased, with an Uptick After 2016



Source: EIA, Nominal Domestic Crude Oil First Purchase Prices by Area (Annual). Accessed on June 10, 2020. https://www.eia.gov/petroleum/data.php

Given Tennessee's limited production of crude oil, prices are not reported for the state. Thus, Figure 4.13 reports crude oil prices for the U.S. and neighboring states based on the data that are available. The prices for neighboring states closely follow the U.S. average, with the exception of a few slight departures between 2011 and 2013. One would expect prices in Tennessee to track these prices closely.

Crude oil prices increased during the 2000s, and sharply dipped after the financial crisis in 2008. Thereafter, crude oil prices increased again to a U.S. peak of $95.99 per barrel in 2013, followed by a decline in prices until 2016, when the average U.S. price was $38.29 per barrel. More recently, there has been an uptick in prices, and the average U.S. price in 2019 was $55.59 per barrel. COVID-19 caused a sharp drop in prices as mobility and economic activity was curtailed. As of July 2020, prices have shown significant gains but remain well below the 2019 average price. The ongoing resurgence in COVID-19 cases may lead to self-sheltering behavior and policy changes that once again limit personal mobility and economic activity.

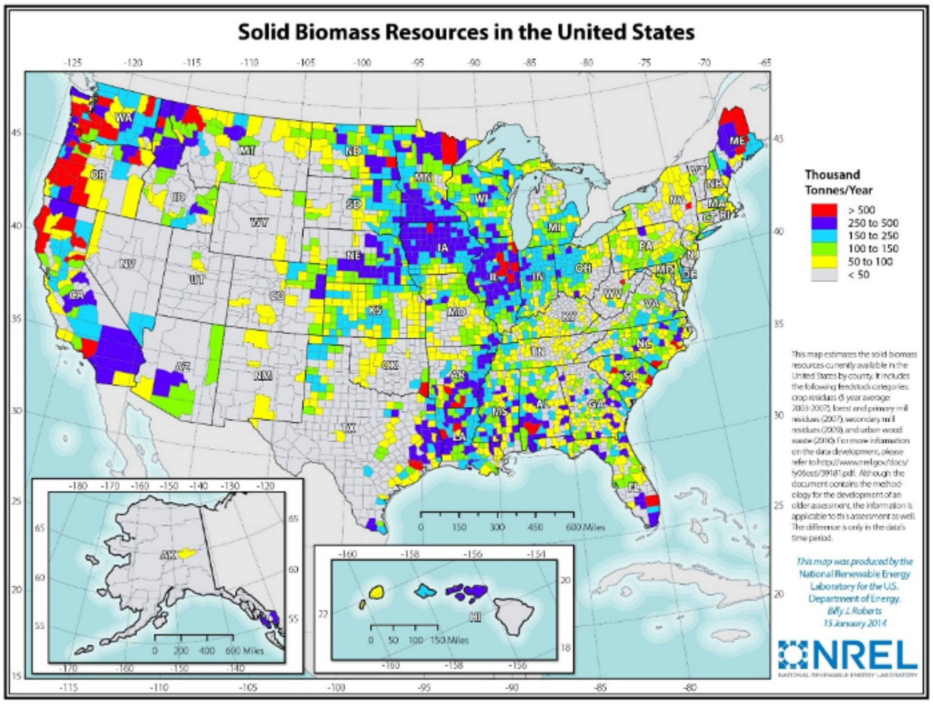
In 2019, there were 135 petroleum refineries in the U.S., one of which is the Valero Memphis Refinery. This refinery has the ability to process 180,000 barrels of crude oil per day and employs approximately 310 employees.[33]

33. Refinery capacity reports are available here: https://www.eia.gov/petroleum/refinerycapacity/

Biomass

Biomass is renewable energy recovered from plants and animal products. Solid biomass (e.g., wood) can be burned directly or can be converted into a biogas or biofuel (e.g., ethanol, biodiesel), which can be burned. Currently, biomass makes up about 5 percent of total primary energy use in the U.S.; about 46 percent of biomass is from wood and wood-derived fuels, 45 percent is from biofuels (mainly ethanol), and 9 percent is from waste (e.g., landfill gas, agricultural byproducts).[34]

Figure 4.14. Opportunities for Solid Biomass Production are in Tennessee, Particularly West Tennessee



Source: National Renewable Energy Laboratory, Biomass Resource Data, Tools, and Map Estimated Solid Biomass Resources by County, 2014. Accessed on June 12, 2020. https://www.nrel.gov/gis/biomass.html

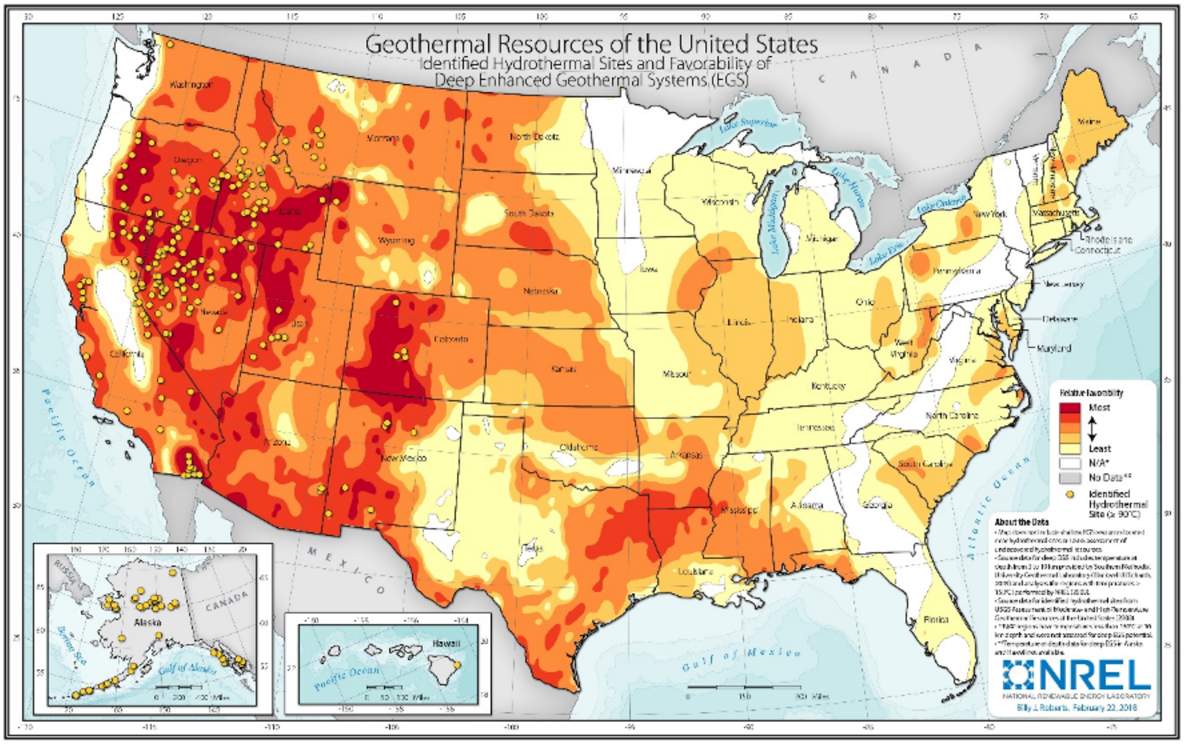
Tennessee has three pellet fuel manufacturing facilities (located in Henry, Wayne, and Marion County) with a total capacity of 170,800 tons per year.[35] Pellets, which are made of compacted sawdust and wood waste products, can be used as a heat source and for outdoor cooking. Additionally, Tennessee has three ethanol biorefineries in Obion, Loudon, and Sullivan Counties.[36]

34. EIA, Monthly Energy Review, Renewable Energy, Renewable Energy Production and Consumption by Source (Table 10.1), 2019. Accessed on June 12, 2020. https://www.eia.gov/totalenergy/data/monthly/index.php#consumption
35. EIA, Form-63C, Densified Biomass Fuel Survey Report, Densified Biomass Fuel Manufacturing Facilities in the United States by State, Region, and Capacity, February 2020. Accessed on June 15, 2020. https://www.eia.gov/biofuels/biomass/#dashboard
36. Source: Renewable Fuels Association, Ethanol Biorefinery Locations. Accessed on June 15, 2020. https://ethanolrfa.org/biorefinery-locations/

Geothermal

Geothermal energy is heat energy embedded in the earth. This energy can heat water underground and potentially create underground steam beds. Wells can be drilled to access the hot water or steam. This can then be used directly as a heat source or used to drive turbines to create electricity. Figure 4.15 shows that Tennessee does not have significant geothermal resources to exploit.

Figure 4.15. Geothermal Resources in Tennessee are Not Favorable



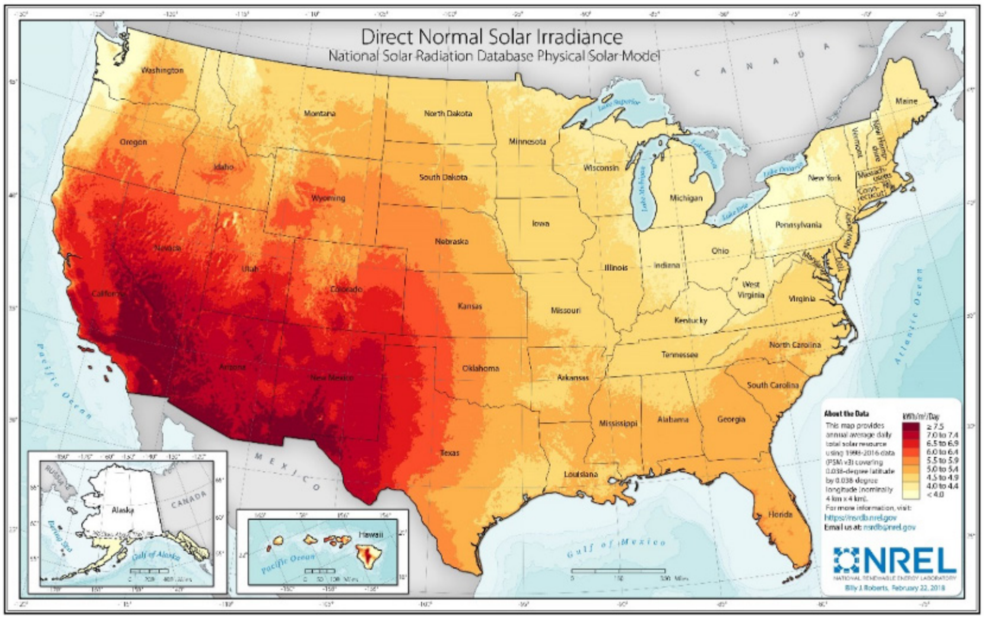
Source: National Renewable Energy Laboratory, Geothermal Resource Data, Tools, and Maps. Geothermal Resources in the U.S., 2018. Accessed on June 15, 2020. https://www.nrel.gov/gis/geothermal.html

Solar

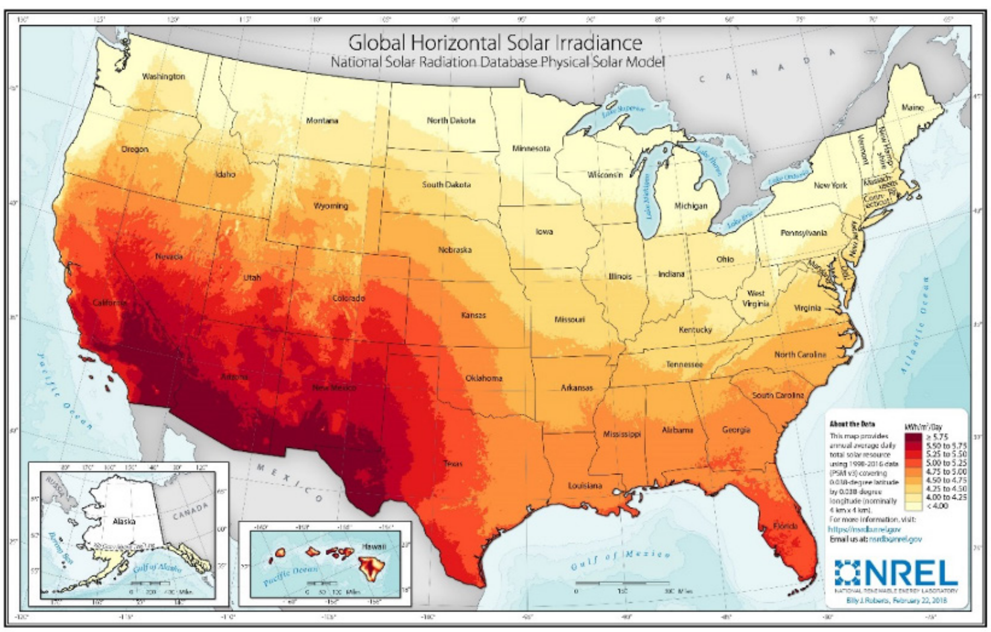
Direct normal irradiance (DNI) is used by concentrating solar energy collectors such as systems used in solar thermal-electric power plants; global horizontal irradiance (GHI) is used by flat-plate solar collectors. Figure 4.16 shows a measure of solar capacity for these two measures across the U.S. Tennessee certainly has capacity, but it is relatively modest as compared to other regions across the country.

Figure 4.16.Solar Potential in Tennessee

Annual Solar DNI Resources in the U.S., 2018



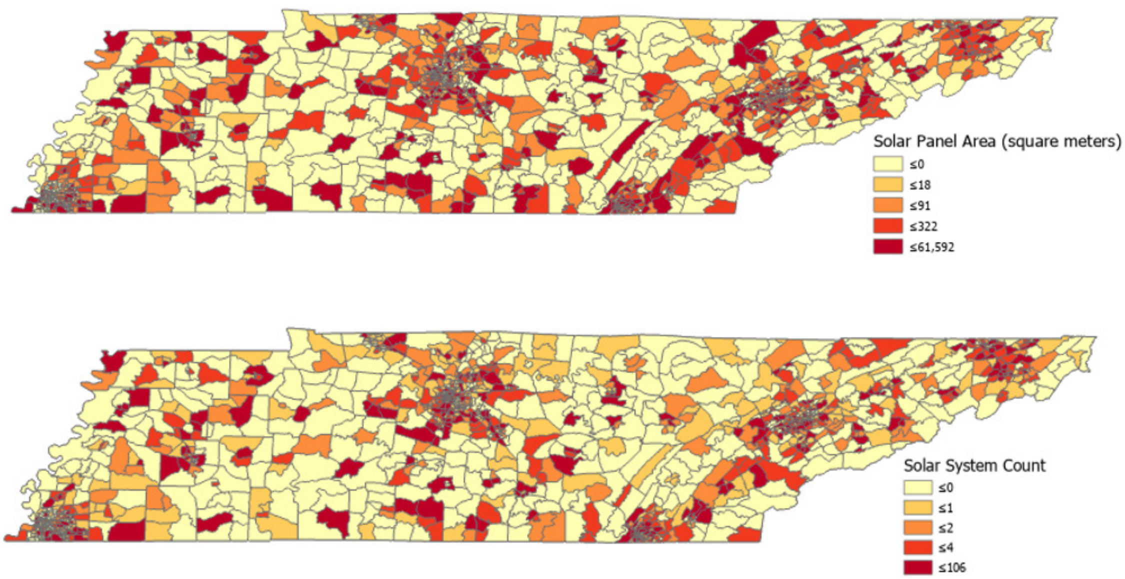
Annual Solar GHI Resources in the U.S., 2018



Source: National Renewable Energy Laboratory, Solar Resource Data, Tools, and Maps. Annual Solar GHI and DNI Resources in the U.S., 2018. Accessed on June 15, 2020. https://www.nrel.gov/gis/solar.html

Despite the somewhat limited capacity, solar is used across the state as shown in Figure 4.17. These solar data come from satellite images and are shown by census tract; the levels in the legends represent the 20th, 40th, 60th, and 80th percentiles. (Census tracts are statistical subdivisions of counties that are used by the U.S. Census Bureau. There are 1,497 census tracts in Tennessee.) The data are novel since it is the first comprehensive database of solar power installations in the U.S. Researchers from Stanford University, as part of the DeepSolar Project, used high-resolution satellite images and machine learning algorithms to identify solar power installations in the contiguous 48 states.[37]

Figure 4.17 Solar Adoption is Spread Across the State, with Concentrations in Urban Areas



Source: The DeepSolar Project Database, by Standford University. http://web.stanford.edu/group/deepsolar/home.html

By looking at total solar panel area (square meters), solar adoption appears to be spread across the state, although concentrated more so in urban versus rural areas. The number of solar systems by census tract illustrates that the solar panels in rural areas are likely larger in size and fewer in number while urban areas appear to have a higher number of smaller systems.

Of the top ten census tracts in terms of total panel area, three are within Shelby County, two are within Hamilton County, and two are within Lincoln County; the remaining three are within McNairy, Williamson, and Roane Counties. The panel area in these census tracts in McNairy and Hamilton County are significantly larger at almost 62,000 square meters. The average solar panel area among the remaining top eight census tracts is 10,953 square meters.

In terms of number of solar systems, a census tract in Shelby County has 106 solar systems, significantly more than any other census tract in the state. Coming in second, a census tract in Hamilton County (where Volkswagen Chattanooga is located) has 65 solar systems. The remaining top eight census tracts for number of systems are within McNairy, Dickson, Davidson, Shelby (2), Warren, and Hamilton Counties (2), and the average number of solar systems for these census tracts is 28.13.

37. High-resolution satellite images and machine learning algorithms were used to identify solar power installations in the contiguous 48 states. Results are published in Yu, J., Wang, Z., Majumdar, A., & Rajagopal, R. (2018). DeepSolar: A machine learning framework to efficiently construct a solar deployment database in the United States. Joule, 2(12), 2605-2617.

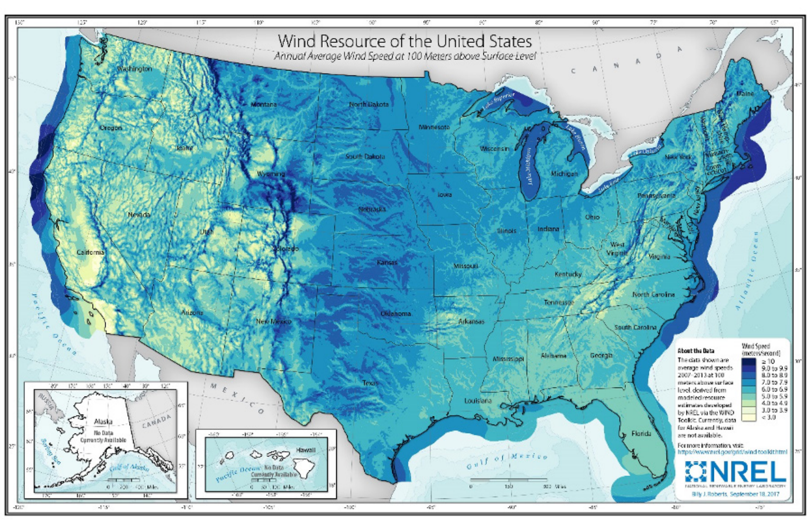
Dominion Energy has two large solar projects in McNairy County, with one located at Mulberry Farm and another at Selmer Farm.[38] In the same area, Silicon Ranch Corporation has its Selmer North I and II Solar Farms.[39] In Hamilton County, large solar projects include Volkswagen's solar farm by its Enterprise South assembly plant and Chattanooga Metropolitan Airport's solar farm.

Corporate entities such as Google and Facebook are planning to bring more solar projects to Tennessee in partnership with TVA. Google plans to source power from a solar farm that will be built in Yum Yum, Tennessee (Fayette County) in order to match its power usage from their new data center in Montgomery County. Two additional solar farms are expected to provide power for Facebook's data center in Huntsville, Alabama; one is expected to be constructed in Lincoln County, Tennessee.

Wind

Higher wind potential is concentrated in the Midwest and along coastal areas of the U.S., with limited capacity for electricity production from wind in other parts of the U.S.[40] In Tennessee, TVA receives proprietary power from Buffalo Mountain Wind Farm in Anderson County. Three wind turbines were built in 2001 and 15 additional turbines were installed in 2004, giving the site a capacity of 29 MW. In 2018, wind supplied 41,009 MWh of net generation or .05 percent of total net electricity generated in Tennessee.[41]

Figure 4.18. Higher Wind Potential is Located in the Mid-West of the U.S.



Source: National Renewable Energy Laboratory, Wind Resource Data, Tools, and Maps. U.S. Wind Speed at 100-Meters Above Surface Level, 2017. Accessed on June 15, 2020. https://www.nrel.gov/gis/wind.html

38. For more information, see: https://www.dominionenergy.com/company/making-energy/renewable-generation/solar-generation/tennessee-solar-projects
39. For more information, see: https://www.siliconranch.com/portfolio-item/selmer-i-ii/
40. For resources related to wind resource estimates in the U.S., see Draxl, C., B.M. Hodge, A. Clifton, and J. McCaa. 2015. Overview and Meteorological Validation of the Wind Integration National Dataset Toolkit (Technical Report, NREL/TP-5000-61740). Golden, CO: National Renewable Energy Laboratory; Draxl, C., B.M. Hodge, A. Clifton, and J. McCaa. 2015. "The Wind Integration National Dataset (WIND) Toolkit." Applied Energy 151: 355366; Draxl, C., B.M. Hodge, A. Clifton, and J. McCaa. 2015. "The Wind Integration National Dataset (WIND) Toolkit." Applied Energy 151: 355366; and King, J., A. Clifton, and B.M. Hodge. 2014. Validation of Power Output for the WIND Toolkit (Technical Report, NREL/TP-5D00-61714). Golden, CO: National Renewable Energy Laboratory.
41. Source: EIA, Detailed State Data, 1990-2018 Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923). Accessed May 18, 2020. https://www.eia.gov/electricity/data/state/

Primary Energy Production

To summarize, primary energy sources and their respective percent of total primary production are presented in Table 4.5. Primary energy is energy in its first form and includes fossil fuels (i.e., coal, natural gas, petroleum), nuclear energy, and renewable energy, while electricity is a secondary energy source that is produced from primary sources.[42] For comparability, all sources are presented in trillions of Btu.

Table 4.5. Nuclear and Hydroelectric Power Production Accounts for the Majority of Primary Energy Production in Tennessee

Source	Tennessee		U.S.	
	Primary Energy Production Estimates (Trillion Btu)	Percent by Source	Primary Energy Production Estimates (Trillion Btu)	Percent by Source
Coal	11.2	2.1	15,549.2	17.7
Natural Gas	3.5	0.7	33,420.3	38.0
Crude Oil	1.6	0.3	19,534.7	22.2
Nuclear Electric Power	332.8	63.4	8,419.0	9.6
Hydroelectric Power	80.1	15.2	2,767.0	3.1
Biofuels	30.7	5.8	2,137.9	2.4
Other Renewables	65.6	12.5	6,189.4	7.0
Total	**525.3**	**100.0**	**88,017.4**	**100.0**

Source: EIA, State Energy Data System, Primary Energy Production in Btu, 2017 (Table P2) and Primary Energy Consumption Estimates, 2017 (Table C3). Accessed on June 16, 2020. https://www.eia.gov/state/seds-data-complete.php?sid=US#Consumption

Notes: Other renewables includes wood energy production plus consumption of geothermal, solar, wind, and biomass waste energy. All estimates for primary energy production are directly from Table C3 except for hydroelectric production estimates, which were separated from "Other Renewables". Following technical notes in how EIA produces similar estimates at the national level, hydroelectric production was assumed to be equivalent to hydroelectric consumptiohn. Likewise, since nuclear energy is used for generation electric power, EIA assumes nuclear production is equal to consumption of power generation. See: https://www.eia.gov/state/seds/seds-technical-notes-complete.php#Production

While Tennessee has reserves and production of coal, natural gas, and crude oil, primary production estimates for these energy sources are small as a portion of Tennessee's total primary energy production. Coal production in Tennessee is estimated to be 11.2 trillion Btu, which accounts for 2.1 percent of total primary production. Tennessee's production of natural gas and crude oil are estimated to be 3.5 and 1.6 trillion Btu, respectively, with both accounting for less than one percent of total production in the state.

Nuclear and hydroelectric power production in Tennessee account for the bulk of primary energy production in the state, representing 63.4 and 15.2 percent, respectively, and 78.6 percent combined.

Coal, natural gas, and crude oil production account for significantly larger percentages of total primary energy production in the U.S. Fossil fuel production accounts for 77.8 percent of total primary energy production in the U.S. Nuclear electric power production in the U.S. comparably accounts for a much lower percent (9.6 percent) of total production. Likewise, hydroelectric power production in the U.S. only accounts for 3.1 percent of total primary energy production.

42. For more information on primary production estimates by EIA, see: https://www.eia.gov/state/seds/seds-technical-notes-complete.php#Production

CHAPTER 5: ENERGY-RELATED EMPLOYMENT AND ECONOMIC DEVELOPMENT

Introduction

Prior chapters of this report have provided a detailed overview of the state's energy sector with regard to energy-related natural resources and energy production. An important facet of the state's energy sector are the jobs that support extraction, production, and generation of energy resources. This is an important economic development perspective that should be considered when evaluating policy options in Tennessee. In this chapter we provide an overview of energy-related employment in Tennessee.

Measuring Energy-Related Employment

Historically, it has been challenging to examine energy-related employment, especially when comparing employment across different types of energy sources. Different federal agencies[43] have used varying methodologies and definitions in collecting data. Additionally, energy-specific occupations (based on the Standard Occupational Classification System, or SOC) can cross over traditional industry classifications (i.e., North American Industry Classification System) or can be grouped with non-energy jobs within a single classification. Therefore, the Bureau of Labor Statistics (BLS) implemented the use of supplemental surveys to the Quarterly Census of Employment and Wages (QCEW) program to collect employment data specifically for the energy industry. Beginning in 2016, annual reports on energy-related employment in the U.S. have been published and reports for states have been published annually since 2017.[44,45] These reports provide a comprehensive and consistent view of energy-related employment across different energy sources and technology applications.

The employment data are broken out between the following categories:

- **Fuels**: includes extraction, mining, processing, and jobs in forestry and agriculture related to the production of corn ethanol, biodiesels, and biomass.
- **Electric power generation**: includes utility and non-utility jobs related to electric power generating technologies (e.g., fossil fuels, nuclear, and renewable energy), facility construction, manufacturing of turbines and other related equipment, operations and maintenance, and wholesale distribution of electric power generation
- **Transmission, distribution, and storage**: includes jobs related to the construction, operations, and maintenance of energy infrastructure, including pipelines, railways and ports that handle petroleum products, storage facilities, and transmission and distribution lines.[46]

43. E.g., U.S. Census, Bureau of Labor Statistics, U.S. Department of Labor Mine Safety and Health Administration, and The Solar Foundation.

44. For the latest U.S. Energy and Employment Report (USEER) and more information, see: https://www.usenergyjobs.org/2020-state-reports

45. The 2016 and 2017 reports were published by the U.S. Department of Energy, using the survey data from the BLS. Annual reports between 2018 and 2020 are based on the same data and methodology, but are published by the National Association of State Energy Officials (NASEO) and Energy Futures Initiative (EFI) in partnership with BW Research Partnership.

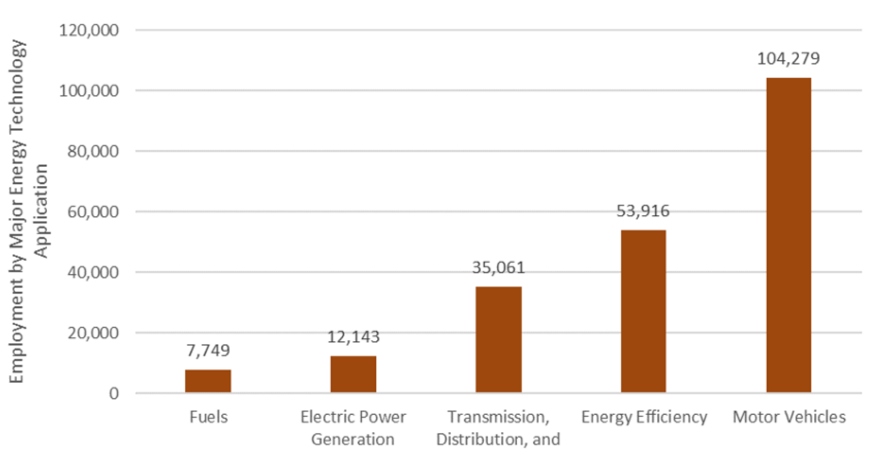
46. Excludes retail employees in gas stations and fuel dealers.

- **Energy efficiency**: jobs associated with the production and installation of energy-saving products and the provision of services that aim to decrease energy consumption.[47]

- **Motor vehicles**: jobs related to the manufacturing, wholesale distribution, transporting, and repair and maintenance of gasoline, diesel, hybrid, electric, natural gas, hydrogen and fuel cell, or other vehicle technologies for cars, light-duty and heavy-duty trucks, and trailers.

In 2019, there were 7,749 employees with work associated with fuels in Tennessee. There were 12,143 jobs related to electric power generation, and 35,061 jobs related to the transmission, distribution, and storage of energy. These three areas make up the traditional energy sector, which together employed 54,953 Tennesseans, representing 1.81 percent of total employment in Tennessee.[48] Note that wherever these jobs are across the state, they improve economic wellbeing and enhance the revenue capacity of local governments through property and sales taxes, along with other government revenue sources. Additional jobs lay behind the scenes in the business supply chain. Together, these jobs create multiplier effects that lead to the creation of additional jobs and income and further expansion of the tax base.

Figure 5.1. Total Energy Employment in Tennessee was 213,148, which Accounts for Seven Percent of Total Employment in the State



Source: 2020 U.S. Energy and Employment Report, Energy Employment by State, 2019. Accessed on June 20, 2020. https://www.usenergyjobs.org/2020-state-reports

For perspective,[49] the size of the traditional energy sector is similar to the size of the information sector in Tennessee. At a similar level of employment are jobs related to energy efficiency (53,916 workers). Lastly, motor vehicles contributed the most to energy jobs (48.9 percent) with 104,279 workers. Together, energy employment in Tennessee amounted to 213,148 jobs, which represented 7.0 percent of total employment in the state. This is roughly equivalent to the total durable goods manufacturing sector in Tennessee.[50]

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47. E.g., ENERGY STAR labeled products and construction services such as insulation, increasing the use of natural light, and other goods or services aimed at decreasing energy consumption in homes and buildings.
48. According to the BLS QCEW Program, total employment in Tennessee in 2019 was 3,033,324.
49. The information sector employed about 45.6 thousand workers in Tennessee in 2018. Source: See Table 8 in Appendix B in Boyd Center for Business and Economic Research, University of Tennessee. (2020). An Economic Report to the Governor of the State of Tennessee, The State's Economic Outlook January 2020. Available here: https://haslam.utk.edu/boyd-center/publications?subject=1137
50. Employment for the durable goods manufacturing sector in Tennessee in 2018 was about 224.3 thousand workers. Source: See Table 8 in Appendix B in Boyd Center for Business and Economic Research, University of Tennessee. (2020). An Economic Report to the Governor of the State of Tennessee, The State's Economic Outlook January 2020. Available here: https://haslam.utk.edu/boyd-center/publications?subject=1137

Table 5.1. Energy Employment in Tennessee is Roughly Equivalent to the Durable Goods Manufacturing Sector in Tennessee

Major Energy Technology Application	Tennessee		U.S.		Tennessee employment as percent of U.S. employment
	Employment	Percent	Employment	Percent	
Fuels	7,749	3.64	1,148,893	13.73	0.67
Electric Power Generation	12,143	5.70	896,830	10.72	1.35
Transmission, Distribution, and Storage	35,061	16.45	1,383,646	16.54	2.53
Energy Efficiency	53,916	25.30	2,378,893	28.44	2.27
Motor Vehicles	104,279	48.92	2,556,492	30.56	4.08
Total	**213,148**	**100.00**	**8,364,754**	**100.00**	**2.55**

Source: 2020 U.S. Energy and Employment Report, Energy Employment by State, 2019. Accessed on June 20, 2020. https://www.usenergyjobs.org/2020-state-reports

Consistent with trends in Tennessee, motor vehicles occupations in the U.S. represented the largest portion of total energy jobs, accounting for 30.56 percent of U.S. energy occupations. Tennessee's population represents 2.1 percent of the U.S. population, but motor vehicle occupations in Tennessee represented 4.1 percent of U.S. motor vehicle employment.[51] The majority of motor vehicle workers in Tennessee were within the manufacturing sector (65.94 percent). This illustrates the strong vehicle manufacturing presence in the state, which includes Nissan's North American headquarters and plant, Volkswagen Chattanooga, General Motors, and an extensive array of automobile parts suppliers.

Energy efficiency jobs and jobs associated with transmission, distribution, and storage represent similar percentages of total energy jobs for Tennessee and the U.S. Fuels-related jobs noticeably represent a smaller portion of energy workers in Tennessee as compared to the U.S.—fuels-related employment in Tennessee is 3.6 percent of total energy employment while national fuels-related employment accounts for 13.7 percent. This confirms that while Tennessee produces oil, natural gas, and coal, Tennessee is not a top producing state in the U.S.

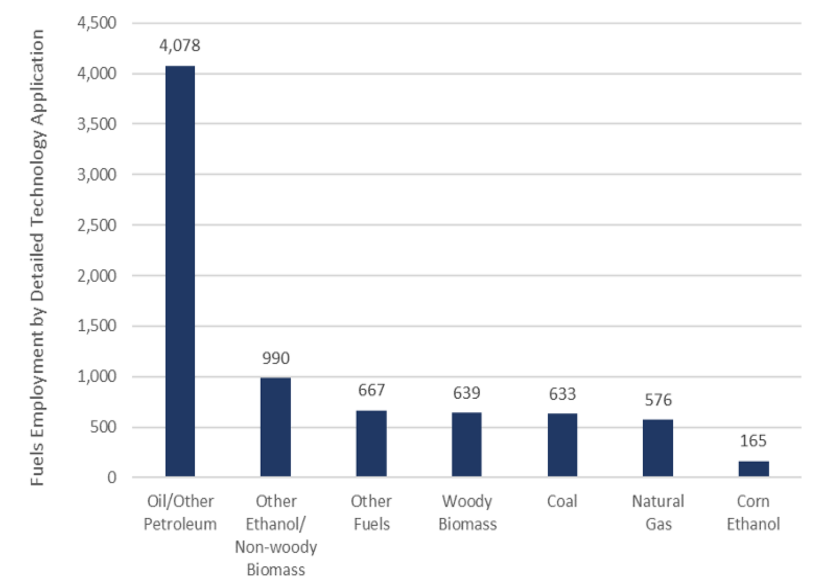
A little more than one-half (52.6 percent) of fuels-related employment in Tennessee is associated with petroleum (see Figure 5.2). Ethanol and non-woody biomass come in second at 990 workers or 12.8 percent of fuels-related employment. Woody biomass (639), coal (633), and natural gas (576) have relatively similar levels of fuels-related employment, with each accounting for about 7 to 8 percent of fuels-related employment in the state.[52] Lastly, corn ethanol has the lowest level of employment at 165 workers or 2.1 percent of fuels-related employment.

The breakout between different fuel sources is largely similar to national trends. Petroleum made up 53.6 percent of total fuels-related employment in the U.S. and coal accounted for 6.6 percent of total fuels-related employment. However, national employment related to natural gas represents a much larger share of total fuels-related employment (24.0 percent) as compared to Tennessee.

51. U.S. and state population estimates are from the U.S. Census Bureau, Population and Housing Unit Estimates, 2019. https://www.census.gov/programs-surveys/popest/data/data-sets.html

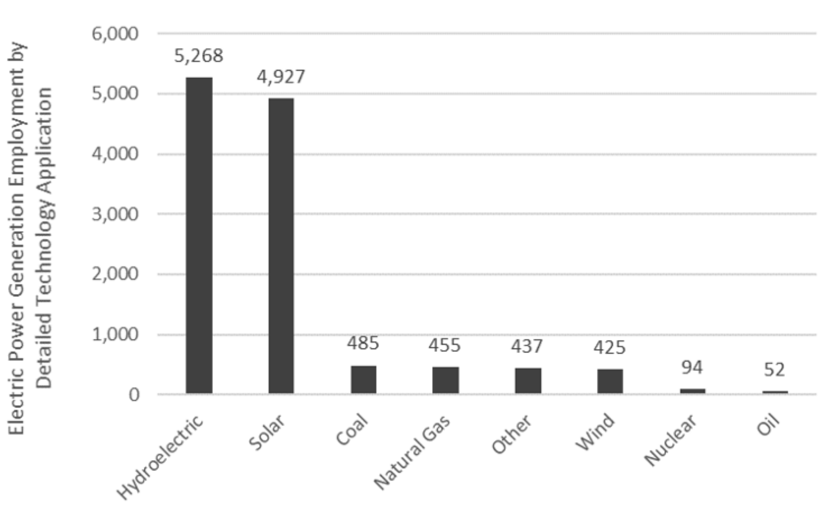
52. In 2018, an average of 12 workers worked at a surface coal mine in Campbell County. In Claiborne County, 55 employees worked at an underground mine and preparation plant, and 23 employees worked at surface mines and preparation plants. Together, there was a total of 90 employees working at coal mines in Tennessee in 2018. Data are from the U.S. EIA (EIA-7A) and U.S. Mine Safety and Health Administration (2018), available here: https://www.eia.gov/coal/data.php

Figure 5.2. One-Half of Fuels-Related Employment in Tennessee is Associated with Petroleum



Source: 2020 U.S. Energy and Employment Report, Energy Employment by State, 2019. Accessed on June 20, 2020. https://www.usenergyjobs.org/2020-state-reports

Figure 5.3. Hydroelectric and Solar Are Top Employers in Electric Power Generation in Tennessee



Source: 2020 U.S. Energy and Employment Report, Energy Employment by State, 2019. Accessed on June 20, 2020. https://www.usenergyjobs.org/2020-state-reports

Of the 7,749 fuel-related workers, most worked within professional services (35.1 percent), followed by manufacturing (28.0 percent) and trade (25.8 percent). The agriculture and forestry sector made up 6.5 percent; 4.4 percent of employees worked within mining and extraction. A very different breakout between sectors exists for U.S. fuels-related employment. Almost one-half (46.6 percent) of employment is associated with mining and extraction and 14.8 percent of national fuels-related employment is within professional services. Manufacturing as a portion of fuels employment is similar to Tennessee (21.5 percent). This demonstrates that while Tennessee has natural gas, oil, and coal reserves, these natural resources are much more limited than in other states in the U.S. that are top producers of fossil fuels.

Significant levels of employment are tied to generation across Tennessee as reported in Figure 5.3. Hydroelectric power generation employed the most people at 5,268 jobs, followed by solar at 4,927 jobs.[53] Employment levels for power generation from coal (485), natural gas (455), wind (425), and other (437)[54] were relatively similar in magnitude. Nuclear power generation employed just 94 people, and jobs associated with oil production stood at 52.

53. Estimates by The Solar Foundation are relatively similar as solar jobs in Tennessee were estimated to be 4,194 in 2019. For more information, see: https://www.thesolarfoundation.org/national/

54. E.g., Biomass, other gases, wood derived fuels

Referring back to net generation by source as discussed in Chapter 3, nuclear power generated the most electricity (44.4 percent) in Tennessee in 2018, followed by coal (25.7 percent), natural gas (16.4 percent), and hydroelectric power (12.6 percent) (see Table .6). Other sources (e.g., petroleum, biomass, solar, wind) made up 1.6 percent of net generation.[55] Yet from an employment perspective, the solar industry accounts for the second highest number of jobs within electric power generation.[56] In fact, as reported in Table 5.3, the solar industry accounts for over four times as many jobs as the coal industry. For the U.S., statistics are similar, as the solar industry accounts for the most jobs overall, but U.S. electricity production largely stems from natural gas, coal, and nuclear power, which account together for 82 percent of net generation. Nationally, about one-half of solar employees work in the construction and installation sector (53.2 percent) and 1.1 percent work in utilities. Solar-generated electricity (including rooftop solar) is expected to continue to grow, especially given the declining costs of solar.[57]

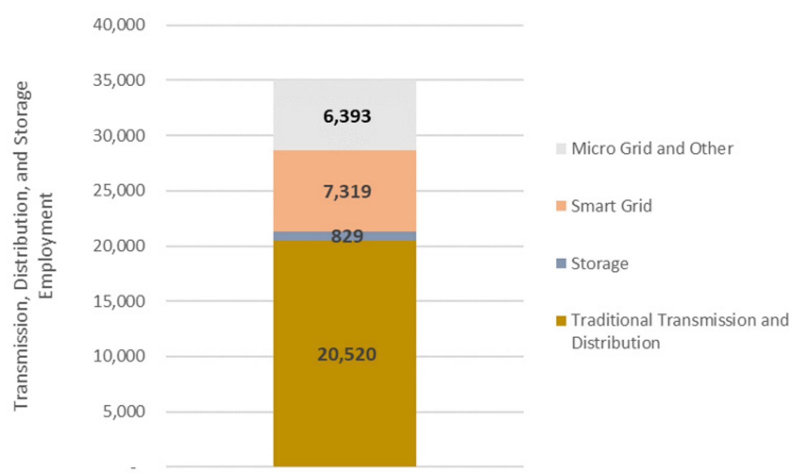
Even though nuclear power accounts for the most electricity generated in Tennessee, it is noteworthy that employment levels are relatively low for this fuel source. Nationally, the majority of employment associated with nuclear power generation is from the utilities sector (72.8 percent), while 3.6 percent is from the construction sector.

Of the total 12,143 workers in electric power generation in Tennessee, 50.8 percent are from utilities, followed by professional services (19.0 percent), construction (12.7 percent), trade (9.3 percent), manufacturing (5.8 percent), and other services (2.4 percent).

When combining fuels and power generation, employment associated with hydroelectric power, solar, and oil are the highest among fuel sources in Tennessee.

Transmission, distribution, and storage includes jobs related to the construction, operations, and maintenance of energy infrastructure, including the network of power lines, pipelines, fuel distribution, and electrical transmission equipment. Jobs data are shown in Figure 5.4 for 2019.

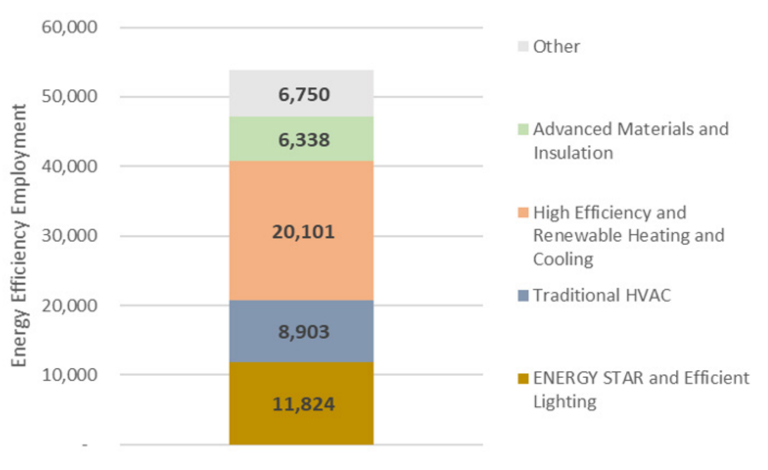
Figure 5.4. Employment Related to the Transmission, Distribution, and Storage of Energy in Tennessee was 35,061



Source: 2020 U.S. Energy and Employment Report, Energy Employment by State, 2019. Accessed on June 20, 2020. https://www.usenergyjobs.org/2020-state-reports

55. Pumped storage accounted for -619,844 MWh or -0.76 percent.
56. Of the 4,927 solar jobs, 4,194 employees are considered "majority of time solar," meaning employees spend 50 percent or more of their time on solar-related work. While 732 solar employees spend less than 50 percent of their time on solar-related work, this measurement differs from several categories used by The Solar Foundation.
57. For more information, see EIA Annual Energy Outlook 2020: https://www.eia.gov/outlooks/aeo/

Figure 5.5. There were 53,916 Employees with Work Related to Energy Efficiency in Tennessee



Source: 2020 U.S. Energy and Employment Report, Energy Employment by State, 2019. Accessed on June 20, 2020. https://www.usenergyjobs.org/2020-state-reports

Traditional transmission and distribution, which refers to the flow of electricity, petroleum, and natural gas across and between states with poles, wires, and pipes, employees 20,520 workers in Tennessee. Storage (e.g., pumped hydro storage, battery storage, thermal storage, etc.) employs 829 workers. Smart grids, which use two-way digital communications to monitor and control systems, employ 7,319 workers. Lastly, micro grids and other grids, which is a group of interconnected loads and distributed energy within a boundary such that the grid acts similar to a single grid, employs 6,393 workers.

Almost one-half of these jobs (47.3 percent) are within the construction sector, followed by manufacturing (18.0 percent). The utilities sector and the pipeline transport and commodity sector each account for roughly ten percent of employment. Lastly, trade (7.9 percent), professional services (5.9 percent), and other services (0.4 percent) account for remaining employment associated with the transmission, distribution, and storage of energy in Tennessee.

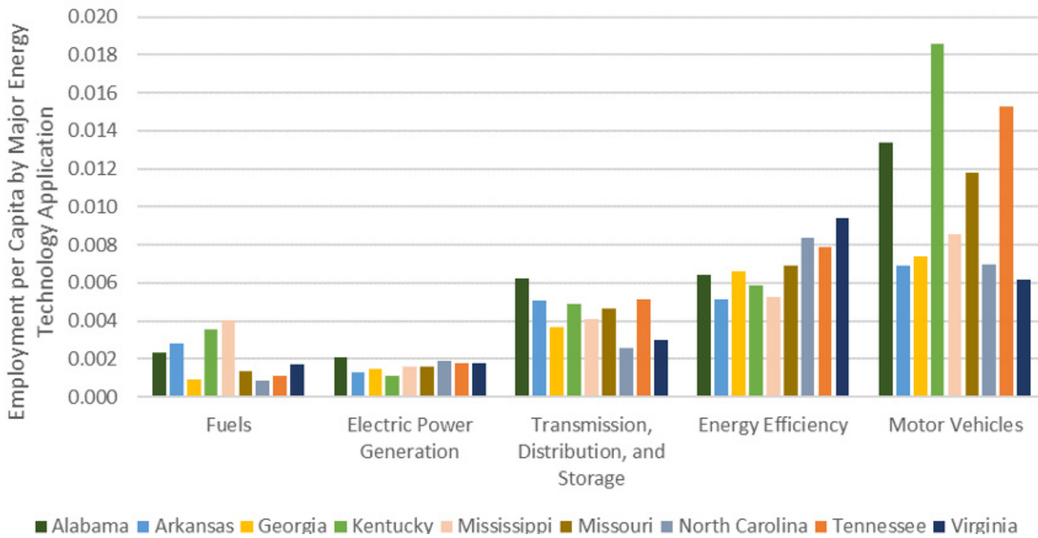
High efficiency and renewable heating and cooling make up the largest portion of energy efficiency employment at 20,101 workers. Employees associated with the Energy Star program and efficient lighting account for the second highest number of employees at 11,824.

Energy Star is a joint program between the U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy that helps consumers identify certified, energy-efficient products (e.g., appliances, electronics, and commercial equipment) for homes and buildings. Additional tools and resources are available for improving the energy efficiency of homes and buildings, including energy asset rating programs. There were 8,903 jobs related to traditional heating, ventilation, and air conditioning (HVAC) systems, including building retrofits. Lastly, over 6,000 employees were associated with both advanced materials and insulation and other energy efficiency products and services.[58] Together, there were 53,916 energy efficiency employees in Tennessee.

Most energy efficiency employees in Tennessee work within construction (58.8 percent), followed by manufacturing (22.7 percent). Remaining energy efficiency employment was in the professional services (9.5 percent), trade (7.3 percent), and other services (1.8 percent) sectors.

58. E.g., Energy auditing, rating, monitoring, metering, leak detection, LEED certification, phase-change materials, and other software, design services, or consulting that is not specific to a detailed technology.

Figure 5.6. The Distribution of Jobs per Capita by Technology Application Shows Modest Variation For Tennessee and Neighboring States



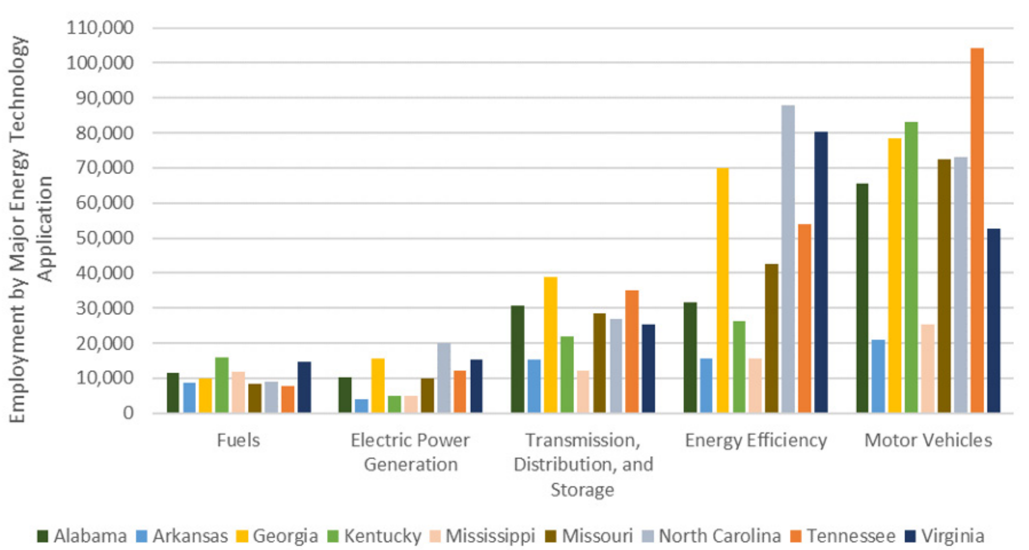
Source: 2020 U.S. Energy and Employment Report, Energy Employment by State, 2019 and U.S. Census Bureau, Population and Housing Unit Estimates, 2019. Accessed on June 20, 2020. https://www.usenergyjobs.org/2020-state-reports and https://www.census.gov/programs-surveys/popest/data/data-sets.html

A simple measure like jobs per capita is one way to show the relative importance of industries across regions. These employment-to-population ratios are show in Figure 5.6. The distribution of jobs by technology application shows modest variation outside of the motor vehicle sector.

- Mississippi and Kentucky have the highest fuels employment-to-population ratio.
- Employment per capita for electric power generation is largely similar for Tennessee and neighboring states.
- Alabama has slightly higher jobs per capita for transmission, distribution, and storage.
- Virginia has the highest employment per capita relative to energy efficiency, followed by North Carolina and Tennessee.
- Motor vehicle employment-to-population ratios are highest for Kentucky, followed by Tennessee and Alabama.

Figure 5.7 shows the absolute level of employment for each of the sectors. Tennessee is ranked last in the fuels sector; fourth in electric power; second in transmission, distribution and storage; fourth in efficiency; and first in motor vehicles.

Figure 5.7. Motor Vehicle Employment is the Highest in Tennessee Compared to Neighboring States



Source: 2020 U.S. Energy and Employment Report, Energy Employment by State, 2019. Accessed on June 20, 2020. https://www.usenergyjobs.org/2020-state-reports

Advanced Energy

Advanced energy (AE) encompasses energy and transportation and includes any technology that makes energy cleaner, safer, more secure, and more efficient. Importantly, AE is considered technology neutral and does not favor specific technologies. Examples of AE include electric and plug-in hybrid cars; lightweight composites for the automotive industry; natural gas-fueled trucks; pollution control equipment; bio energy; high-performance buildings; more efficient industrial processes; power reliability; smart grids; CHP; and wind, solar, and nuclear technologies.

In cooperation with the Tennessee Advanced Energy Business Council (TAEBC), the Howard Baker Jr. Center for Public Policy has examined the economic impact of the AE sector in Tennessee, most recently in 2018.[59] By examining previous studies on AE by other states and national organizations, 62 four-digit industry groups (i.e., North American Industrial Classification System (NAICS)) were identified as part of the Tennessee's advanced energy sector.[60] These industry groups fall into five broad, mutually exclusive categories:

- AE utilities and construction;
- AE manufacturing;
- AE information;
- AE professional, scientific, and technical services; and
- AE other services.

59. The 2018 report, Tennessee Advanced Energy Economic Impact Report, is available here: https://tnadvancedenergy.com/2018-tennessee-advanced-energy-economic-impact-report/

60. An advanced energy firm is defined as being directly involved with researching, developing, producing, manufacturing, distributing, selling, or implementing components, goods, or services related to advanced energy; energy efficiency; renewable, nuclear, and natural gas electricity generation; distributed generation; advanced manufacturing; lightweight composites for the automotive industry; electric and hybrid vehicles; pollution control technologies; smart grid; and other related technologies. This can include supporting services such as consulting, finance, tax, and legal services related to advanced energy. It includes farm workers involved in growing feedstock (corn, soy, etc.) for advanced fuels.

Using County Business Patterns (CBP) data from the U.S. Census Bureau, the economic scope of the AE sector was examined for Tennessee as well as for the state's metropolitan statistical areas and individual counties.

Summary data are presented in Table 5.2. The AE sector employed 358,360 Tennesseans in 2016, accounting for 13.8 percent of total employment in the state. AE manufacturing represented the largest share of AE employment at 41.6 percent, followed by AE utilities and construction at 27.7 percent. Total payroll expenditures for AE employees amounted to $21.4 billion and advanced energy employees earned an average wage of $59,665, compared to the state's economy-wide average of $44,317. The number of companies in the advanced energy sector in Tennessee was 18,170 in 2016. AE utilities and construction had the largest number of establishments in the state at 8,509, followed by AE professional, scientific, and technical services, which had 6,060 establishments.

Table 5.2. Advanced Energy Sector in Tennessee

	Employment		Annual Payroll ($1,000)		Number of Establishments	
Industry Group	Level 2016	% Change 2013-2016	Level 2016	% Change 2013-2016	Level 2016	% Change 2013-2016
AE Utilities and Construction	99,110	9.5%	$5,251,538	20.9%	8,509	3.4%
AE Manufacturing	149,112	6.5%	$8,864,401	48.8%	1,811	0.7%
AE Information	20,077	5.1%	$1,211,619	16.7%	900	29.3%
AE Professional, Scientific, & Technical Services	75,615	21.6%	$5,278,895	24.5%	6,060	5.2%
AE Other Services	14,446	9.6%	$775,154	4.2%	890	4.7%
Total Advanced Energy Industry	**358,360**	**10.3%**	**$21,381,607**	**31.0%**	**18,170**	**4.8%**

Source: Howard Baker Jr. Center for Public Policy, University of Tennessee in coordination with Tennessee Advanced Energy Business Council. (2018). Tennessee Advanced Energy Economic Impact Report. Data is from U.S. Census Bureau, County Business Patterns, 2016. https://tnadvancedenergy.com/2018-tennessee-advanced-energy-economic-impact-report/ and https://www.census.gov/programs-surveys/cbp.html

AE employment in Tennessee grew by 10.3 percent between 2013 (the first year a study was completed) and 2016. Notably, employment within AE professional, scientific, and technical services grew the most (by 21.6 percent); this AE sector had the highest average wage ($69,813). The number of companies in the AE sector in Tennessee grew by 4.8 percent from 2013 to 2016, and AE information experienced the largest growth in establishments.

In terms of state gross domestic product (GDP), the AE sectors generated a total of $39.7 billion in state GDP in 2016, which represents 12 percent of total GDP for the state. Estimated state and local sales tax revenues tied the to the AE sector total $823.2 million and $289.3 million, respectively.

Although the AE economy extends across all 95 counties in the state, AE activities are concentrated among a smaller number of large counties. The top 20 counties, shown in Table 5.3, employ 285,823 Tennesseans in AE jobs, which accounts for 79.8 percent of all AE jobs in the state. Annual payroll expenditures for top counties totaled $12.3 billion and the number of companies in the AE sector in the top 20 counties was 13,787, representing about three fourths of total AE establishments.

Table 5.3. Advanced Energy Sector in Tennessee

County	Employment	Annual Payroll ($1,000)	Number of Establishment	2016 Ranking	2013 Ranking
Shelby	46,621	$2,397,582	2,299	1	2
Davidson	46,317	$2,947,029	2,691	2	1
Hamilton	25,888	$1,286,573	1,279	3	4
Knox	22,272	$1,112,381	1,681	4	5
Rutherford	19,810	$605,147	706	5	6
Williamson	18,039	$1,178,929	1,227	6	7
Sullivan	16,272	$243,981	395	7	3
Anderson	13,651	$524,735	285	8	8
Blount	11,340	$125,855	365	9	13
Sumner	7,685	$357,431	503	10	9
Bradley	7,057	$64,772	219	11	15
Robertson	6,297	$91,611	198	12	11
McMinn	6,197	$136,511	93	13	19
Coffee	5,936	$210,206	142	14	18
Montgomery	5,636	$140,178	358	15	12
Maury	5,548	$196,890	203	16	17
Washington	5,485	$122,049	336	17	14
Madison	5,311	$184,591	286	18	10
Wilson	5,301	$189,545	402	19	
Hamblen	5,160	$197,873	119	20	16
Total for Top 20 Counties	**285,823**	**$12,313,869**	**13,787**		

Source: Howard Baker Jr. Center for Public Policy, University of Tennessee in coordination with Tennessee Advanced Energy Business Council. (2018). Tennessee Advanced Energy Economic Impact Report. Data is from U.S. Census Bureau, County Business Patterns, 2016. https://tnadvancedenergy.com/2018-tennessee-advanced-energy-economic-impact-report/ and https://www.census.gov/programs-surveys/cbp.html

Shelby and Davidson Counties are the largest AE employing counties in Tennessee, ranking first and second in 2016. AE employment in both of these counties was nearly 47,000, which represents 13 percent of total AE jobs in the state. At over 25,000 employees, Hamilton County is the third-largest AE county in Tennessee, followed by Knox County, which employed about 22,000 employees. Rutherford, Williamson, Sullivan, Anderson, and Blount Counties support between 10,000 and 20,000 AE jobs.

The Nashville-Davidson-Murfreesboro-Franklin metropolitan statistical area (MSA) was the largest AE MSA employer in the state, accounting for 13.9 percent of total employment in the region. The Memphis MSA was the second-largest AE employer in the state, which represented 10.4 percent of total employment in the area. Coming in third, AE employment in the Knoxville MSA represented 15.6 percent of total employment in the region.

CHAPTER 6: ENERGY AND HEALTH

Introduction

Energy production and consumption can impact human health and the environment in a number of ways. Fossil fuel combustion produces pollutants that have regional and global impacts. Energy inefficiency can exacerbate the health impacts of these pollutants both by requiring more fossil fuel combustion and by lowering indoor air quality. Preventing and alleviating these impacts requires effective environmental policies and regulations at the state and federal levels that balance environmental protection with economic development. State and federal agencies must then work together to ensure these policies are enforced.

This chapter examines pollution that is tied to the energy sector, with the focus on pollutants that stem from emissions occurring in Tennessee. Also included is an analysis of the prevalence of health impacts associated with these pollutants in Tennessee as well as a discussion of the role of energy efficiency and weatherization in improving indoor air quality and human health.

Energy-Related Pollution and Emissions

The production and consumption of fossil fuels result in emissions of air and water pollutants that threaten human health, harm wildlife, and deteriorate natural landscapes. These pollutants differ in terms of their geographic scope (regional impacts versus global impacts), health impacts, and sources of emission (power plants, vehicles, industry). In addition to having direct impacts to human health and the environment, some pollutants interact in the atmosphere to create new harmful pollutants. For example, ground level ozone is created by chemical reactions between nitrogen oxides (NOx) and volatile organic compounds (VOC).[61]

Regional (Criteria) Air Pollutants

The Clean Air Act requires the EPA to set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment. The "criteria" pollutants are regional[62] in scale which means that the health of Tennesseans is negatively impacted by energy use across the state. EPA tracks emissions of these pollutants as part of the National Emissions Inventory. EPA has set NAAQS for six principal criteria pollutants.[63]

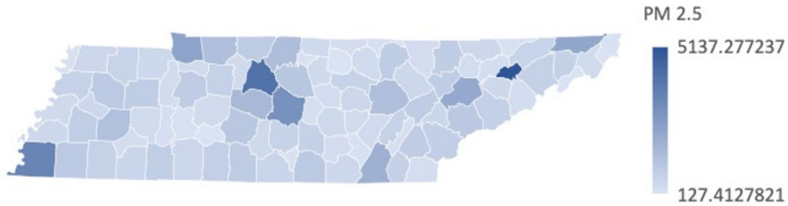
Particulate matter: The EPA defines particulate matter (PM) as "a mixture of solid particles and liquid droplets found in the air." Some PM can be observed with the human eye but much of it is so small that it can only be observed with an electron microscope. Smaller PM is a concern because these particulates can penetrate more deeply into the lungs and have been linked to adverse health impacts such as aggravated asthma, lung disease, and heart attacks.

61. https://www.epa.gov/ground-level-ozone-pollution/ground-level-ozone-basics Accessed June 4, 2020.
62. Regional here is used as a general term to differentiate from global pollutants such as methane and carbon dioxide. It does not refer to an EPA region.
63. https://www.epa.gov/criteria-air-pollutants Accessed June 12, 2020.

PM regulated by the NAAQs are generally divided into two size classes with the two most reported being:

1. PM10 – emissions that are less than 10 microns in diameter. Typical sources of PM10 include crushing and grinding operations and dust from road paving.
2. PM2.5 – emissions that are less than 2.5 microns in diameter. Typical sources of PM2.5 include motor vehicles, fossil-fuel power plants, certain industrial processes, and wood-burning.

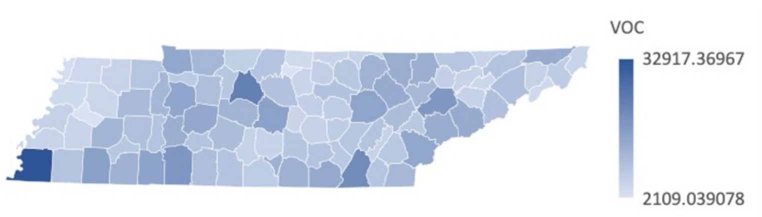
Figure 6.1. PM 2.5 Emissions in 2018 (Tons)



Source: EPA National Emissions Inventory (https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data)

PM2.5 is a great concern to the people of Tennessee. Primary health impacts of PM2.5 include premature death in people with heart or lung disease; heart attacks; aggravated asthma; and decreased lung function. County-level PM2.5 emissions in tons in 2018 are presented in Figure 6.1. The counties with the highest particulate emissions tend to be near one of Tennessee's four largest metropolitan areas or near a TVA power plant. For example, Stewart County and Hawkins County have relatively high emissions and are also home to the Cumberland coal-fired plant and John Sevier combined cycle plant, respectively.

Figure 6.2. VOCs Emissions in 2018 (Tons)



Source: EPA National Emissions Inventory (https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data)

Ground level ozone: Ozone is found in the upper regions of the atmosphere and at ground level. Both types of ozone have the same chemical composition (O3). While upper atmospheric ozone protects the earth from the sun's harmful rays, ground-level ozone (what we breathe) can harm our health. Even relatively low levels of ozone can cause health effects. People with lung disease, children, older adults, and people who are active outdoors may be particularly sensitive to ozone. Ozone also affects sensitive vegetation and ecosystems, including forests, parks, wildlife refuges, and wilderness areas. In particular, ozone harms sensitive vegetation during the growing season.

Ground-level ozone is not emitted directly into the air but is created by chemical reactions between NOx and VOCs. Ozone is likely to reach unhealthy levels on hot sunny days in urban environments. Ozone can also be transported long distances by wind. For this reason, even rural areas can experience high ozone levels. Seventy-two percent of VOC emissions in Tennessee originate from vegetation and soil due to a process known as biogenics. Emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapors, and chemical solvents are some of the major anthropogenic sources of NOx and VOC. County-level VOC emissions in tons in 2017 are presented in Figure 6.2.

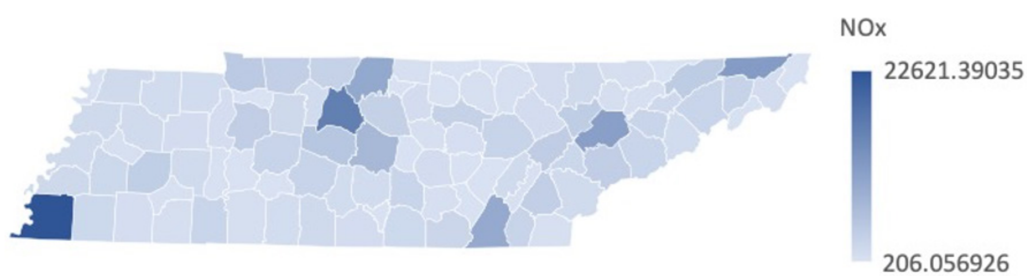
Sulfur dioxide: Sulfur dioxide (SO_2) is one of a group of highly reactive gases known as oxides of sulfur. The largest sources of SO_2 emissions across Tennessee are from fossil fuel combustion at power plants (52 percent) and other industrial facilities (33 percent). Smaller sources of SO_2 emissions include industrial processes such as the extraction of metal from ore, petroleum refineries in Shelby and Sullivan Counties, and the burning of high sulfur-containing fuels by locomotives, large ships, and non-road equipment. SO_2 is linked with a number of adverse effects including bronchoconstriction and increased asthma symptoms. County-level SO_2 emissions in tons in 2018 are presented in Figure 6.3.

Figure 6.3. Sulfur Dioxide Emissions in 2018 (Tons)

Source: EPA National Emissions Inventory (https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data)

Nitrogen Oxides: EPA's NAAQS uses NO_2 as the indicator for the larger group of nitrogen oxides that includes nitrous acid and nitric acid. NO_2 is linked with a number of adverse effects on the respiratory system. Primary health impacts include impaired lung function; increased respiratory infections in young children; and eye, nose, and throat irritation. NO_2 also contributes to the formation of ground-level ozone (see above). NO_2 forms from emissions from cars, trucks, buses, power plants, and non-road equipment (e.g., lawn mowers, fork lifts, compressors, and generators). The primary source of NO_2 emissions in Tennessee (63 percent) is from mobile sources, or the burning of fossil fuels by locomotives, large ships, and on-road equipment. All areas in the U.S. presently meet the current (1971) NO_2 NAAQS, with annual NO_2 concentrations measured at area-wide monitors occurring well below the level of the standard. NO_2 concentrations should continue to decrease in the future as a result of automobile emission standards that are taking effect. County-level NO_2 emissions in tons in 2018 are presented in Figure 6.4.

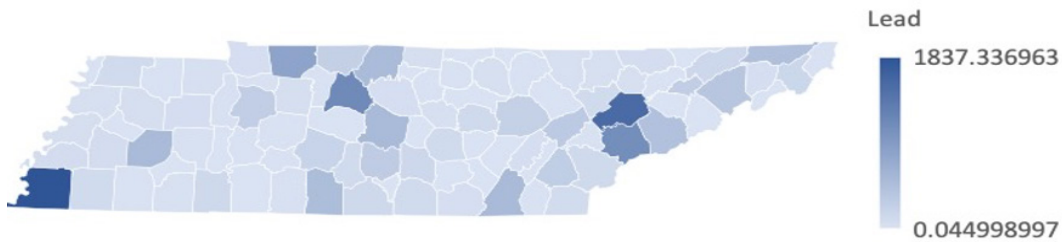
Figure 6.4. Nitrogen Oxides Emissions in 2018 (Tons)



Source: EPA National Emissions Inventory (https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data)

Lead: Lead is a metal found naturally in the environment as well as in manufactured products. Exposure may occur through the air, through the ingestion of lead in drinking water or from lead-contaminated food, as well as through incidental ingestion of lead-contaminated soil and dust. Lead can adversely affect the nervous system, kidney, immune system, reproductive and developmental systems, and the cardiovascular system. The lead effects most commonly encountered in current populations are neurological effects in children and cardiovascular effects (e.g., high blood pressure and heart disease) in adults. Infants and young children are especially sensitive to even low levels of lead, which may contribute to behavioral problems, learning deficits, and lowered IQ. The major sources of lead emissions have historically been from the combustion of transportation fuels and from industrial sources. Regulatory efforts to remove lead from motor vehicle gasoline decreased the amount of lead in the air by 94 percent between 1980 and 1999. The burning of fossil fuels by mobile sources (e.g., locomotives, large ships, cars, and trucks) is Tennessee's primary source of lead (68 percent). County level lead emissions in tons in 2018 are presented in Figure 6.5.

Figure 6.5. Lead Emissions in 2018 (Tons)



Source: EPA National Emissions Inventory (https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data)

Carbon Monoxides: Carbon monoxide (CO) is a colorless, odorless gas emitted from combustion processes. Particularly in urban areas, the majority of CO emissions into ambient air come from mobile sources. Everywhere in the country has air quality that meets the current (1971) CO standards due largely to improvements in motor vehicle emissions controls. Primary impacts include fatigue or chest pain; impaired vision and coordination; headaches; dizziness; confusion; and fatality at very high concentrations. County-level CO emissions in tons in 2018 are presented in Figure 6.6.

Figure 6.6. Carbon Monoxide Emission in 2018 (Tons)

Source: EPA National Emissions Inventory (https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data)

Table 6.1. EPA Designated Areas in Tennessee as of May 2020

Area	Pollutant (Year of Standard)*	Nonattainment	Maintenance
Benton County	Sulfur Dioxide (1971)		X
Bristol	Lead (2008)		X
Fayette County	Lead (1978)		X
Humphreys County	Sulfur Dioxide (1971)		X
Knoxville	1-Hour Ozone (1979)		X
Knoxville	8-Hour Ozone (1997)		X
Knoxville	8-Hour Ozone (2008)		X
Knoxville	PM-2.5 (1997)		X
Knoxville-Sevierville-La Follette	PM-2.5 (2006)		X
Memphis	1-Hour Ozone (1979)		X
Memphis	Carbon Monoxide (1971)		X
Nashville	1-Hour Ozone (1979)		X
Polk County	Sulfur Dioxide (1971)		X
Shelby	Lead (1978)		X
Sullivan County (Part)	Sulfur Dioxide (2010)	X	
Williamson County	Lead (1978)		X
* See EPA Green Book for details of each NAAQS standard			

Source: EPA Green Book, Current Nonattainment Counties for All Criteria Pollutants as of October 31, 2020. http://www.epa.gov/green-book.

Each criteria pollutant has at least one NAAQS. These standards are based on medical studies that indicate "safe" levels of pollutants where risk of health impacts associated with exposure is very low. The concentration of some air pollutants (for example particulate matter) can change drastically over time, necessitating a 24-hour and annual requirement to capture long-term exposure to pollutants and day-to-day changes in pollution. EPA defines a nonattainment area as "any area that does not meet (or that contributes to ambient air quality in a nearby area that does not meet) the national primary or secondary ambient air quality standard for the pollutant". In addition to areas classified as nonattainment, some areas are described as maintenance areas. Maintenance areas are those geographic areas that were classified as nonattainment but are now consistently meeting the NAAQS. Maintenance areas have been redesignated by the EPA from "nonattainment" to "attainment with a maintenance plan." These areas have demonstrated through monitoring and modeling that they have sufficient controls in place to meet and maintain the NAAQS. They also have contingency measures in place that would be implemented, should the areas start showing exceedances. Table 6.1 shows EPA nonattainment and maintenance areas in Tennessee.

Part of Sullivan County is currently in nonattainment for sulfur dioxide. In 2017, TDEC submitted a State Implementation Plan (SIP) to the EPA detailing actions that would be or are currently being taken to move Sullivan County toward attainment status. The primary SO2-emitting point source located within Sullivan County is the Eastman Chemical Company. Eastman's main SO2-emitting sources are three coal-fired boilers that provide steam for facility operations. In an effort to reduce SO2 emissions, Eastman transitioned several of their coal-fired boilers to natural gas boilers starting in 2016.

Tennessee has reduced its issues with controlling PM 2.5 and ground-level ozone since 2014. Several counties have historically struggled to meet EPA standards for PM 2.5 and ground-level ozone. As recently as 2014, five counties (Anderson, Blount, Knox, Loudon, and Roane (partial)) were nonattainment-moderate for PM 2.5. As of 2014, four counties (Anderson (partial), Blount, Knox, and Shelby) were nonattainment-marginal for ground-level ozone. In 2015, EPA strengthened the ozone standard. All Tennessee counties now meet and are in attainment with these more stringent standards for PM 2.5 and ground-level ozone.

TVA Coal-fired Generation Retirements

Over the past decade, TVA has retired nearly 8,500 MW of coal-fired generation capacity. These retirement decisions were driven by economics and specifically the age and inefficiency of these units. The capacity-weighted average age of operating coal facilities in the U.S. is 39 years, according to EIA. By comparison, the average age of the 37 coal-fired units retired during the past decade was 60 years. In fact, two of units at the former Watts Bar Fossil Plant were 69 years old when they were retired. These retirements, coupled with new investments in gas-fired generation capacity, have caused coal's share of TVA's generation portfolio to fall from 58% to 17%. These retirements will likely lead to improvements in air quality in the state and reductions in greenhouse gases emitted in the state. TVA's assessment of the Paradise plant in Kentucky found that its retirement would reduce emissions that cause lung-damaging smog by as much as 11.5 percent and cut greenhouse gas emissions by more than 4 percent.

Source: Energy Information Administration 860 data

Emissions of the six criteria pollutants come from very different sources – energy production and consumption, transportation, industrial processes, and natural processes. Table 6.2 shows the top three sources of these pollutants and the percentage of these emissions that are due to energy production or consumption in Tennessee and in the U.S. Vehicle emissions from the combustion of fossil fuels are primary source of nitrogen oxides, VOCs, lead, and carbon monoxide. Fossil fuel combustion from industrial sources and power plants is the primary contributor of PM2.5, nitrous oxides, and sulfur dioxide.

All TVA plants have some form of emission control technology in place. These technologies have been especially effective at reducing sulfur dioxide and nitrogen oxide emissions in Tennessee. Selective catalytic reduction systems and low-NOx burners can reduce nitrogen oxide emissions by about 90 percent. Wet limestone scrubbers can remove 95 percent of sulfur dioxide from plant emissions.

Table 6.2. Sources of Regional Criteria Pollution in 2019

Pollutant	Top 3 US sources	% of US emissions from energy categories†	Top 3 TN sources	% of TN emissions from energy categories†
PM2.5	1) misc. 2) fuel combustion–other 3) industrial processes	16.1	1) misc. 2) waste disposal & recycling 3) fuel combustion – electric utilities	34.3
VOC	1) misc. 2) solvent utilization 3) petroleum and related industries	33.7	1) solvent utilization 2) mobile 3) off-highway	42.3
Sulfur dioxide (SO_2)	1) fuel combustion – electric utilities 2) fuel combustion – industry 3) misc.	73.0	1) fuel combustion – electric utilities 2) fuel combustion – industry 3) fuel combustion -other	97.1
Nitrogen oxides (NOx)	1) mobile 2) off-highway engines 3) fuel combustion – industry	89.7	1) mobile 2) off-highway engines 3) fuel combustion – electric utilities	95.7
Lead	1) mobile 2) industrial processes 3) fuel combustion - industry	69.8	1) mobile 2) industrial processes 3) fuel combustion - industry	50.0
Carbon Monoxide (CO)	1) misc. 2) 3) off-highway engines	51.7	1) mobile 2) off-highway engines 3) prescribed fires	87.7
†Energy emission categories include fuel combustion – electric utilities; fuel combustion – industrial; fuel combustion – other; petroleum and related industries; mobile engines (highway vehicles, aircraft); off-highway engines				

Source: EPA National Emissions Inventory (https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data) Accessed June 24, 2020

Mercury and Air Toxics Standard

The Mercury and Air Toxics Standard (MATS), finalized in 2015, requires power plants that contribute to air pollution in Tennessee to use widely available, proven pollution control technologies to protect families from pollutants like mercury, arsenic, chromium, nickel, and acid gases. Toxic air pollutants like mercury -- a neurotoxin -- can damage children's developing brains, reducing their IQ and their ability to learn. These new standards prevented up to 370 premature deaths in Tennessee while creating up to $3 billion in health benefits in 2016. In May 2020, the EPA revised the benefits of the MATS rule and concluded that it is not "appropriate and necessary" to regulate electric utility steam generating units under section 112 of the Clean Air Act (CAA). The EPA is leaving MATS in place but has determined that no further reductions are required. The most likely consequence of EPA's recent action will be a lawsuit brought by the coal industry to try to eliminate MATS.

Sources: https://www.epa.gov/mats

https://eelp.law.harvard.edu/2020/04/backgrounder-appropriate-necessary-finding-mercury-air-toxics-mats/

Greenhouse Gases

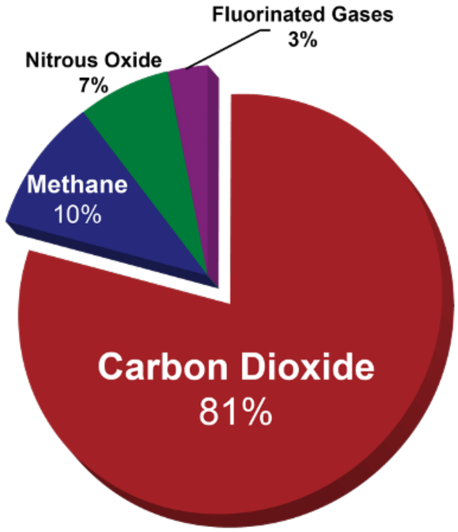
Greenhouse gases (GHGs) are gases that trap heat in the atmosphere. Many of these gases, such as carbon dioxide, methane, and nitrous oxide, naturally occur in the atmosphere. Energy production and consumption produce additional human-caused emissions of many of these gases, which elevate concentrations higher than naturally observed. These higher-than-natural concentrations of GHGs raise concerns regarding climate change.

Unlike regional *criteria pollutants*, which cause impacts to human health and the environment in the vicinity of the emission source, GHGs have global impacts irrespective of where they are emitted. Thus, impacts from GHGs experienced in Tennessee will be due to emissions of these pollutants across the globe. Likewise, emitting GHGs in Tennessee will have impacts across the globe. Human production of GHGs can be categorized as coming from stationary sources and non-stationary sources. Stationary sources include electricity generation plants, industrial facilities, mine and drill sites, and residences that burn fossil fuels. Non-stationary sources include vehicles and fires.

Figure 6.7 shows the mix of GHG emissions in 2018. Carbon dioxide is by far the most abundant GHG; however, it is also important to note that GHGs are not all equally as effective at trapping heat in the atmosphere. The two most important characteristics of a GHG in terms of climate impact are:

- How well the gas prevents energy from immediately escaping to space; and
- How long the gas stays in the atmosphere.

Figure 6.7. 2018 U.S. greenhouse gas emissions



Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018 (https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks)

The Global Warming Potential (GWP) for a gas is a measure of the total energy that a gas absorbs over a particular period of time (usually 100 years) as compared to carbon dioxide. The larger the GWP, the more warming the gas causes. Carbon dioxide has a GWP of 1 and serves as a baseline for other GWP values. Methane (CH4) has a GWP more than 20 times higher than CO2 for a 100-year time scale. Nitrous Oxide (N2O) has a GWP 300 times that of CO2 for a 100-year timescale.

In 2018, the three primary sources of GHGs in the U.S. were transportation (28 percent), electricity generation (27 percent), and industry (22 percent). Two datasets are used to capture GHG emissions in Tennessee from these diverse sources.[64] The EPA Facility Level Information on GHGs Tool (FLIGHT) provides annual emissions from large facilities in the state. These large facilities represent stationary sources of GHGs and are broken into four types:

1. Petroleum and Natural Gas Systems
2. Power Plants
3. Refineries
4. Industrial Fossil Fuel Combustion

The EPA National Emissions Inventory provides annual emissions from non-stationary, transportation-related sources of GHGs such as cars, trucks, airplanes, and off-road vehicles.

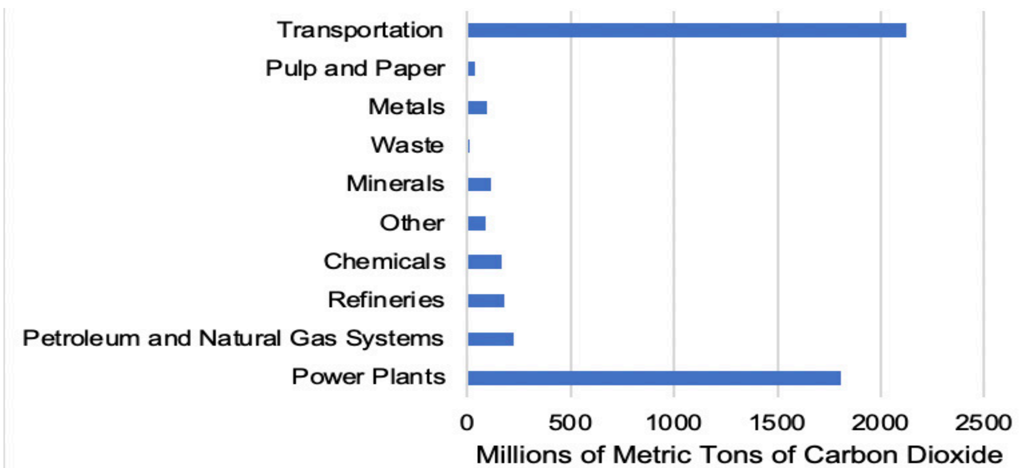
64. Combining these two sources provides a few benefits over other measures of GHG emissions. First, all the GHG emission estimates reported are from EPA sources. EPA is charged with the regulation of GHG emissions providing a regulatory incentive to view Tennessee's contribution to GHG emissions from EPA's perspective. Second, the GHG emissions from stationary sources are reported by the facility which alleviates the need to make generalizations about technology across industries. Third, these datasets provide more detail about emitting sectors of the economy that may be specific to Tennessee. EIA also provides greenhouse gas emissions for the state of Tennessee. These estimates are based on energy consumption in each sector of the economy and an average amount of GHG emissions per unit of energy consumed.

Energy production and consumption is a primary source of emissions for three GHGs: carbon dioxide, methane, and nitrous oxides.[65] The most critical opportunities for reducing GHG emissions in the near term lie in the power sector, which will enable the industrial and transportation sectors to rely on electrification to a greater extent. For example, Drive Electric Tennessee (DET) is a statewide electric vehicle consortium focused on increasing electric vehicle adoption in Tennessee to 200,000 vehicles by 2028. The climate change implications of these shifts toward electrification will be limited to non-existent unless the GHG emissions in the power sector decline. There is evidence of some improvement in GHG emissions in the power sector in Tennessee, which should be viewed as encouraging for further electrification efforts. Between 2012 and 2018, CO2 emissions from power plants dropped by 13 million metric tons. However, methane emissions from power plants grew by over 53,000 metric tons of CO2 equivalent during the same time – a five-fold increase.

Carbon dioxide (CO_2)

In 2018, CO2 accounted for 81 percent of all U.S. GHG emissions from human activities. CO2 is naturally present in the atmosphere as part of the carbon cycle (the natural circulation of carbon among the atmosphere, oceans, soil, plants, and animals). Human activities alter the carbon cycle by adding more CO2 to the atmosphere and by influencing the ability of natural features, like forests, to remove CO2 from the atmosphere through carbon sequestration.

Figure 6.8. 2018 U.S. Carbon Dioxide Emissions by Source: Dominated by Transportation & Power Plants



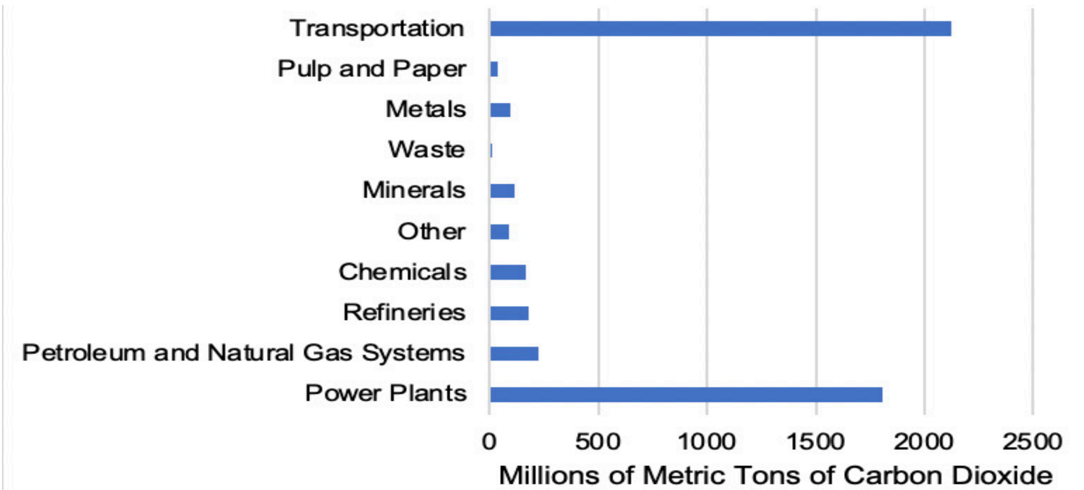
Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018 (https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks)

Figure 6.8 shows U.S. carbon dioxide emissions by source in 2018. The combustion of fossil fuels for transportation is the largest source of CO2 emissions in the nation, accounting for 44 percent of total U.S. CO2 emissions. The combustion of fossil fuels to generate electricity is the second-largest source of CO2 emissions in the nation, accounting for 37 percent of total U.S. CO2 emissions. The electricity sector's contribution to carbon dioxide emissions in the United States has declined since 2012. This is due, in part, to a shift away from coal toward natural gas and renewable energy in the power sector. To produce a given amount of electricity, burning coal will produce more CO2 than oil or natural gas. While in 2012 U.S. renewable energy generated just 500 million MWh of electricity, renewables produced about 750 million MWh in 2018.[66] Certain energy-related processes (e.g., many clean coal technologies) seek to minimize contributions of CO2 through carbon sequestration.

65. Fluorinated gases (hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride) are another category of greenhouse gases. These gases are produced primarily from industrial processes.
66. U.S. Energy Information Administration: https://www.eia.gov/todayinenergy/detail.php?id=38752

Figure 6.9 shows the source of CO_2 emissions in Tennessee in 2018. The vast majority of CO_2 emissions in the state originate from the transport of people and goods and from power plants. Over 58 percent of the CO_2 emissions in the transportation sector in Tennessee come from light duty cars and trucks. Between 2012 and 2018, CO_2 emissions from power plants dropped from over 40 million metric tons to less than 27 million metric tons. This reduction is attributable to the closing or idling of several coal-fired power plants in the state. The decline in CO_2 emissions from power plants has coincided with an increase in emissions from industrial sources (e.g., plants that generate or process chemicals, minerals, metals, pulp, and paper). As a result, total CO_2 emissions in the state decreased by a modest 15 percent between 2012 and 2018.

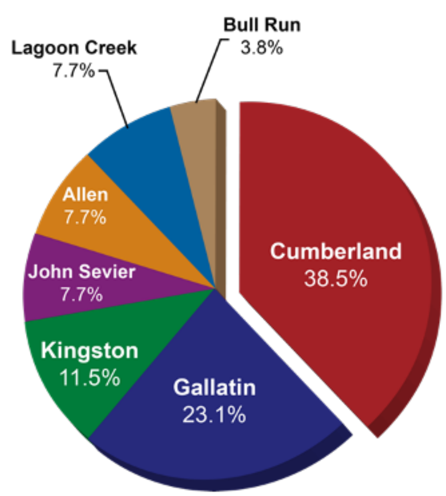
Figure 6.9. Tennessee Carbon Dioxide Emissions by Source, 2018



Source: EPA National Emissions Inventory (https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data) and EPA Facility Level Information on GHGs Tool (FLIGHT) (http://ghgdata.epa.gov/ghgp/main.do)

Figure 6.10 shows CO_2 emissions in the power plant category by plant in 2018. Nearly all of the CO_2 emitted in the power plant category in Tennessee originates from TVA's coal-fired power plants. The Cumberland Plant in Stewart County is the largest CO_2 emitter at over 10 million metric tons, followed by the Gallatin plant in Sumner County at over 5.5 million metric tons. By comparison, the largest single source of CO_2 in the country is the James H. Miller Jr. plant in Alabama at over 18 million metric tons. The Cumberland and Gallatin plants ranked as the 31st and 99th largest emitters of CO_2 in the nation in 2018. While these plants are the largest emitters of CO_2 in the TVA fleet, their emissions have improved relative to other point sources of CO_2 in the country. In 2012, the Cumberland and Gallatin plants ranked as the 13th and 96th largest emitter of CO_2 in the nation, respectively.

Figure 6.10. Tennessee Power Plant Emissions of Carbon Dioxide, 2018



Source: EPA Facility Level Information on GHGs Tool (FLIGHT) (http://ghgdata.epa.gov/ghgp/main.do)

Affordable Clean Energy Rule

In June 2019, EPA issued the Affordable Clean Energy (ACE) rule, which establishes emission guidelines for states to use when developing plans to limit CO_2 from coal-fired electric generating units. The ACE rule presents a narrower view of EPA's regulatory authority than the rule it replaces, the Clean Power Plan (CPP). Specifically, the CPP outlines three strategies (building blocks) for reducing emissions: (1) heat-rate improvements at coal-fired power plants, (2) increased utilization of natural gas combined cycle units, and (3) increased use of renewable energy. **The ACE rule does not include building blocks 2 and 3 and directs states to establish performance standards for power plants based solely on heat rate improvements.** The result is fewer emissions reductions under ACE as compared to the CPP. In the regulatory impact analysis (RIA) that accompanied the ACE rule proposal, EPA estimated that replacing the CPP with the ACE rule would result in an additional 470-1,400 premature deaths, 48,000 cases of exacerbated asthma, 42,000 lost work days, and 21,000 missed school days as compared to a baseline where the CPP was implemented. While the CPP aimed to reduce carbon dioxide emissions from existing power plants by 30 percent below 2005 levels by 2030, the ACE rule is expected to reduce cumulative national CO_2 emissions by 0.1 percent between 2021 and 2050, based on data from EPA's RIA. The ACE rule has not been implemented and is facing legal challenges from states, electric utilities, and environmental organizations.

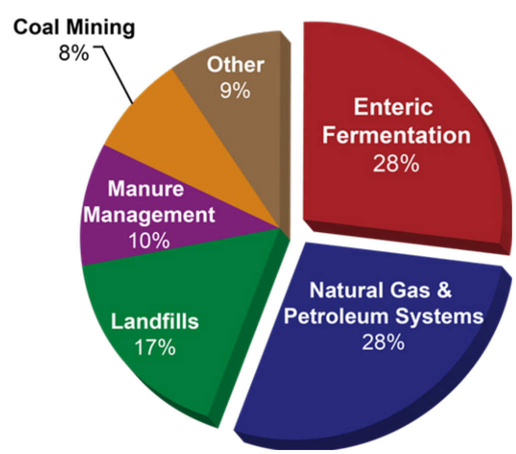
Sources:https://www.epa.gov/stationary-sources-air-pollution/affordable-clean-energy-rule#:~:text=Proposed%20Affordable%20Clean%20Energy%20Rule,fired%20electric%20utility%20generating%20units.
https://www.rff.org/publications/issue-briefs/10-big-little-flaws-in-epas-affordable-clean-energy-rule/.
https://www.epa.gov/sites/production/files/2018-08/documents/utilities_ria_proposed_ace_2018-08.pdf

Methane (CH_4)

In 2018, methane accounted for about 10 percent of all U.S. GHG emissions. While human-caused emissions of methane are far lower than carbon dioxide, methane is a far more potent GHG. Based on GWP, methane is more than 20 times more effective at trapping heat. Natural processes in the soil and chemical processes in the atmosphere help remove methane.

Figure 6.11 shows U.S. methane emissions by source. Methane is emitted from natural sources such as wetlands. It is also emitted from human activities such as the production and transport of coal, natural gas, and oil. For example, in addition to being a GHG, methane is also the primary component of natural gas. Fugitive emissions of methane arise due to natural gas flaring at the well site or escaped gas during transport and pumping. These types of fugitive emissions continue to account for nearly 30 percent of methane emissions nationwide. Other human activities that lead to methane emissions are agriculture (enteric fermentation from livestock and manure management) and the decay of organic waste in landfills.

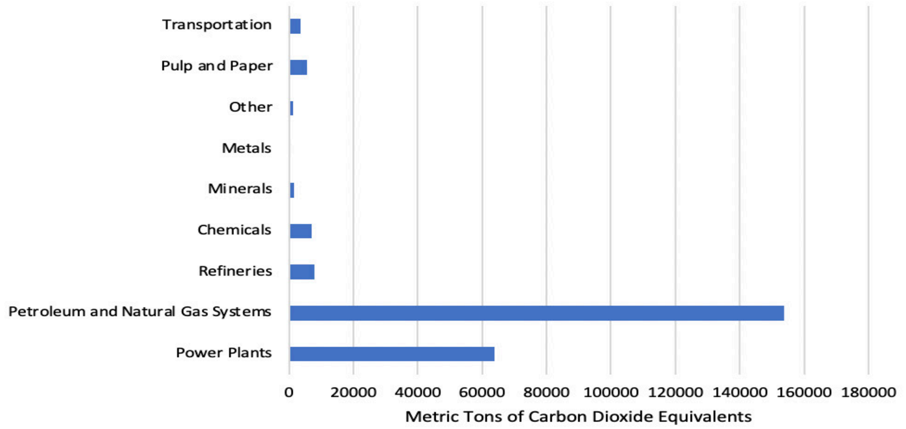
Figure 6.11 2018 U.S. Methane Emissions by Source



Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018 (https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks)

Figure 6.12 shows energy-related sources of methane emissions in Tennessee. The largest producers of methane in the state are municipal and industrial waste landfills. Methane is currently being captured at 9 landfills (see Table 6.3).

Figure 6.12. Tennessee Methane Emissions by Source, 2018



Source: EPA National Emissions Inventory (https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data) and EPA Facility Level Information on GHGs Tool (FLIGHT) (http://ghgdata.epa.gov/ghgp/main.do)

These landfill projects produce over 20 million cubic feet of landfill gas per day and reduce methane emissions by nearly 1.9 million metric tons of CO2 equivalent each year. Most of these sites use the landfill gas for onsite electricity generation and/or direct boiler use. Carter Valley, Meadow Branch, and North Shelby Landfills are treating the gas to increase its Btu and create renewable natural gas (RNG) which is used as a vehicle fuel and/or injected directly into a gas pipeline for distribution. For example, the Carter Valley Landfill will generate enough RNG to fuel more than 80 Class 8 trucks daily, displacing almost 1.5 million gallons of diesel annually. In 2016, Memphis Light Gas & Water (MLGW) began purchasing 100 percent RNG from Clean Energy Fuels which collects, cleans, and compresses the landfill gas that is produced by the North Shelby landfill. MLGW brings that gas to market through their natural gas distribution system and their two publicly accessible CNG vehicle fueling stations.

Table 6.3. Tennessee Landfill Gas Projects

Name	County	Landfill gas collected (million cubic feet per day)	Methane emissions reduced (million metric tons of CO2 equivalent per year)
Alcoa/ Maryville/ Blount County Landfill	Blount	0.523	0.0451
Bi-County Landfill	Montgomery	1.163	0.0587
Carter Valley Landfill	Hawkins	2.16	0.739
Chestnut Ridge Landfill	Anderson	2.976	0.1627
Iris Glen Environmental Center	Washington	1.606	0.1891
Meadow Branch Landfill	McMinn	2.592	0.2189
North Shelby Landfill	Shelby	2.560	0.1961
South Shelby Landfill	Shelby	5.314	0.6303
West Camden Sanitary Landfill	Benton	3.271	0.1961

Source: EPA Landfill Methane Outereach Program (LMOP) Database (https://www.epa.gov/lmop/project-and-landfill-data-state? Accessed September 30, 2020

Anaerobic Digestion as a Strategy to Reduce Landfill Gas

The Nashville metropolitan area has experienced tremendous growth in recent years and is struggling to manage its organic waste. Currently, organics (food scraps, woody waste, yard waste, and some industrial waste) comprise around 32 percent of its residential waste and 19 percent of its commercial waste. The vast majority of this waste, which is mostly food, is sent to a landfill in Rutherford County that is scheduled to close in the next five to 10 years. In the landfill, organic waste breaks down, emitting methane. An interdisciplinary team of researchers from the UT Institute of Agriculture, the UT Knoxville Tickle College of Engineering, College of Law, and the Howard H. Baker Jr. Center for Public Policy is collaborating with the nonprofit Resource Capture to develop a more sustainable way to manage the booming Nashville metropolitan area's organic wastes, reduce methane emissions from landfills in the area and, in the process, provide a valuable soil amendment for the region's farmers. The project will conduct a preliminary feasibility/economic and environmental analysis of a dry anerobic digester in the Nashville metropolitan area. A dry anaerobic digester is a fully sealed system that converts organics waste into renewable energy and nutrient-rich compost. Dry anaerobic digestion is used in only one location in North America, so this research will provide valuable insight on when and where similar systems could be utilized in the state.

Sources:https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling

https://www.epa.gov/lmop/basic-information-about-landfill-gas

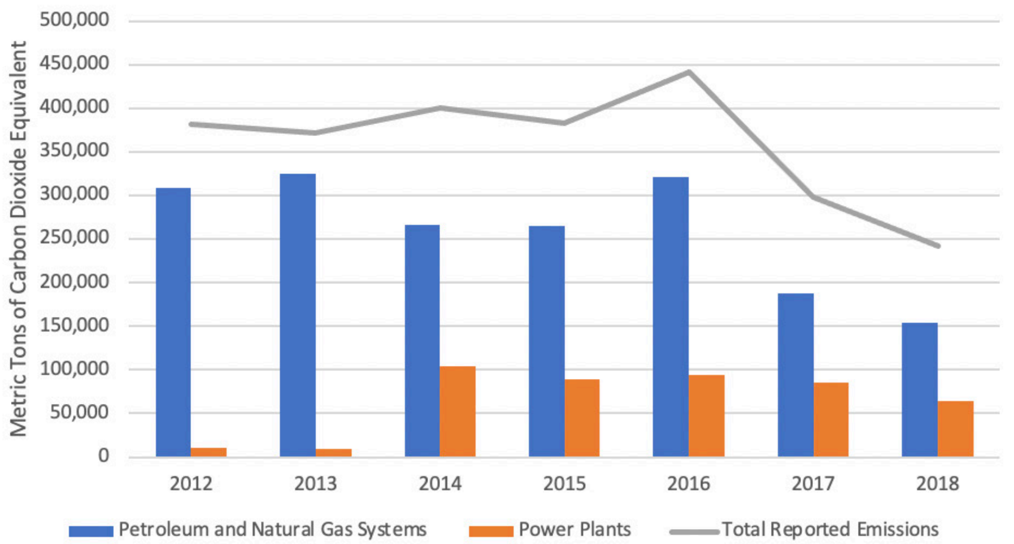
However, the vast majority of energy-related methane emissions in the state originate from the petroleum and natural gas system which includes:

- **Production and Processing**
    - Drilling and well completion
    - Producing wells
    - Gathering and boosting
    - Gas processing plants
- **Natural Gas Transmission and Storage**
    - Transmission and compressor stations
    - Underground storage
    - LNG storage
    - LNG import-export equipment
- **Distribution**
    - Distribution mains/services
    - Regulators and meters

Over 61 percent of methane emissions from the petroleum and natural gas system in the state are from compressor stations —down from 67 percent in 2012. The largest methane emitter in this category is Middle Tennessee Natural Gas Utility in Dekalb County, which emitted over 17,268 metric tons of methane. By comparison, the largest emitter of methane in the state is the Eastman Chemical Company at 239,720 metric tons. The remainder of the methane emissions in the state is attributable to municipal gas utilities. Of these utilities, Memphis Light, Gas, and Water produces the most methane at 24,499 metric tons—down from 30,725 metric tons in 2012.

Figure 6.13 shows trends in methane emissions in Tennessee. Between 2012 and 2018, methane emissions from power plants grew by over 50,000 metric tons of CO2 equivalent – a nearly five-fold increase. As of 2018, the Cumberland Plant in Stewart County is the largest methane emitter at 29,824 metric tons, followed by the Gallatin plant in Sumner County at 15,798 metric tons. By comparison, the largest single source of methane in the country is Warrior Met Coal LLC in Alabama at nearly 3.9 million metric tons. The Cumberland and Gallatin plants rank as the 1,583rd and 2,099th largest direct emitter of methane in the nation, respectively. The increase in methane emissions reflects the state's growing reliance on natural gas as a source for electricity generation. In FY 2020, 29 percent of the electricity generated by TVA was produced from natural gas. By comparison, natural gas was only 10 percent of TVA's generation portfolio in 2007. The increased reliance on natural gas in the state coincides with a decline in coal-fired electricity generation in the state.

Figure 6.13. Trends in Tennessee Methane Emissions by Source, 2012 - 2018



Source: EPA Facility Level Information on GHGs Tool (FLIGHT) (http://ghgdata.epa.gov/ghgp/main.do)

However, methane emissions from petroleum and natural gas systems in the state (e.g., pipelines, pumping stations) fell by over 500 percent between 2012 and 2018. Much of this decline is due to reductions in methane emissions from the Middle Tennessee Natural Gas Utility District. This shift from coal to natural gas, coupled with the decline in methane emissions from petroleum and natural gas systems, resulted in a 36 percent decrease in methane emissions in Tennessee.

Nitrous oxides (N_20)

In 2018, N20 accounted for about 7 percent of all U.S. GHG emissions from human activities. While human-caused emissions of N20 are far lower than carbon dioxide, N2O is a far more potent GHG. Based on GWP, the impact of 1 pound of N2O on warming in the atmosphere is over 300 times that of 1 pound of carbon dioxide.

Figure 6.14 shows U.S. nitrous oxide emissions by source. Nitrous oxide is naturally present in the atmosphere as part of the nitrogen cycle. Globally, about 60 percent of total nitrous oxide emissions come from natural sources. Human activities such as agriculture (soil and manure management), fossil fuel and solid waste combustion, and industrial activities also emit nitrous oxide. The largest human contributor of N2O is agricultural soil management and specifically, synthetic fertilizer application. Fossil fuel combustion from stationary sources and the transportation sector is a distant second in terms of nationwide N2O emissions. The proportion of various contributors to nitrous oxide emissions have remained stable over the last decade.

Figure 6.14. 2018 U.S. Nitrous Oxide Emissions by Source

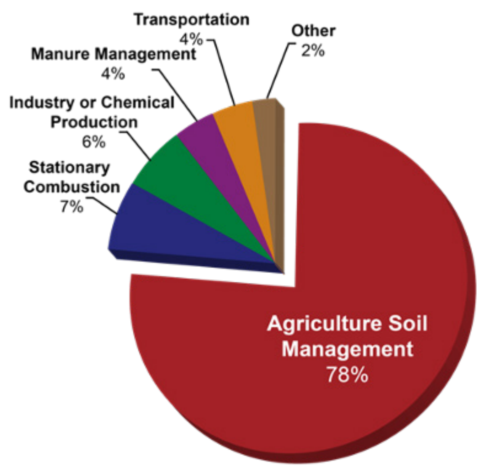
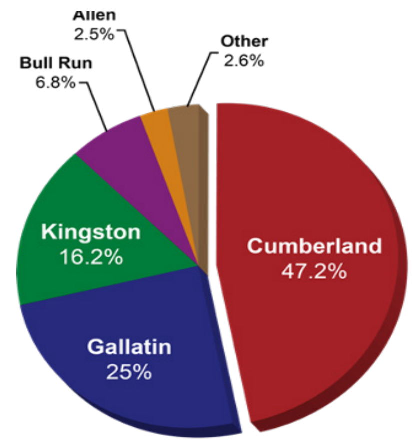


Figure 6.15. Tennessee Power Plant Emissions of Nitrous Oxide, 2018



Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018 (https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks)

Power plants in Tennessee emitted 109,500 metric tons of nitrous oxide in 2018—by far the largest contributor in the state. This represents a 47 percent reduction from 2012. Figure 6.15 shows N2O emissions in the power plant category by plant. As of 2018, the Cumberland Plant in Stewart County is the largest N20 emitter at 51,721 metric tons, followed by the Gallatin plant in Sumner County at 27,386 metric tons. By comparison, the largest single source of N2O in the country is Ascend Performance Material LLC in Florida at over 10 million metric tons. The Cumberland and Gallatin plants rank as the 49th and 111th largest direct emitter of N20 in the nation, respectively.

Health Impacts

Energy production and consumption in Tennessee create air and water pollution that negatively impacts the health of Tennesseans. Air pollutants such as PM2.5, nitrogen oxides, sulfur dioxides, and ground-level ozone have been linked to asthma, chronic obstructive pulmonary disease (COPD), heart attacks, strokes, and lung cancer. Drawing precise linkages between pollution and health outcomes is a complex task for two reasons:

1. Many factors may contribute to the incidence of a health outcome. For example, in October 2013, the International Agency for Research on Cancer (IARC), part of the World Health Organization, classified outdoor air pollution as a cancer-causing agent. However, smoking is well understood to be a major contributor to lung cancer in the U.S. The best available science estimates that outdoor air pollution accounts for 5-6 percent of lung cancers in the U.S.
2. Estimating health impacts requires that people are diagnosed. Incidence rates are commonly used to report the prevalence of a disease in a population. However, incidence rates are likely to under-report actual health impacts since many people will never be diagnosed. To address the problem with under-reporting, death rates are also used to ascertain health impacts. This is also problematic since it does not indicate how long people suffered from an ailment and many factors may contribute to death.

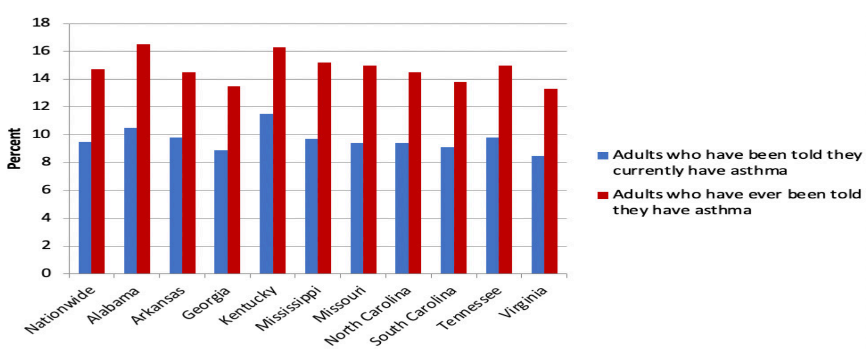
With these factors in mind, the following sections provide information on the incidence and death rates in Tennessee for health impacts related to regional pollutants associated with energy production and consumption.

Asthma

Asthma is a chronic lung condition that causes airways in the respiratory system to be swollen and produce mucus. During an asthma attack, inflammation increases and the muscles surrounding the airways tighten. The combination of swelling, mucus, and tightening of airways causes coughing, wheezing, and shortness of breath. Asthma is thought to be caused by a combination of genetic and environmental factors. Environmental factors include outdoor air pollution such as PM2.5, nitrogen oxides, sulfur dioxide, and ozone but also include allergens and environmental chemicals.

In 2018, 77 Tennesseans died due to an underlying diagnosis of asthma. These asthma mortality rates increased 17 percent between 2010 and 2018 and were similar to asthma mortality rates in other parts of the country. Asthma is more common in females than males among adults but more common in males than females among children. Adult asthma in the state is more prevalent among people with low incomes and less education. Hospital charges for a primary asthma diagnosis totaled $178.8 million in Tennessee in 2010.

Figure 6.16. Asthma Prevalence, 2018



Source: Centers for Disease Control, Behavioral Risk Factor and Surveillance System (http://apps.nccd.cdc.gov/brfss/page.asp?cat=CH&yr=2012&qkey=8411&state=TN#CH)

Figure 6.16 shows asthma prevalence rates in Tennessee, neighboring states, and nationwide. Asthma prevalence in Tennessee is comparable to other states in the region and is slightly higher than the national average. Between 2010 and 2018, asthma prevalence increased over 27 percent. By comparison, nationwide asthma prevalence increased 7 percent during the same time. Table 6.4 shows how asthma prevalence varies across the state. The Kingsport-Bristol MSA has the highest current and lifelong prevalence. The Memphis MSA has the lowest current prevalence, while the Chattanooga MSA has the lowest prevalence of lifelong asthma.

Table 6.4. Asthma Prevalence Rates in Tennessee's Metropolitan Statistical Areas, 2017

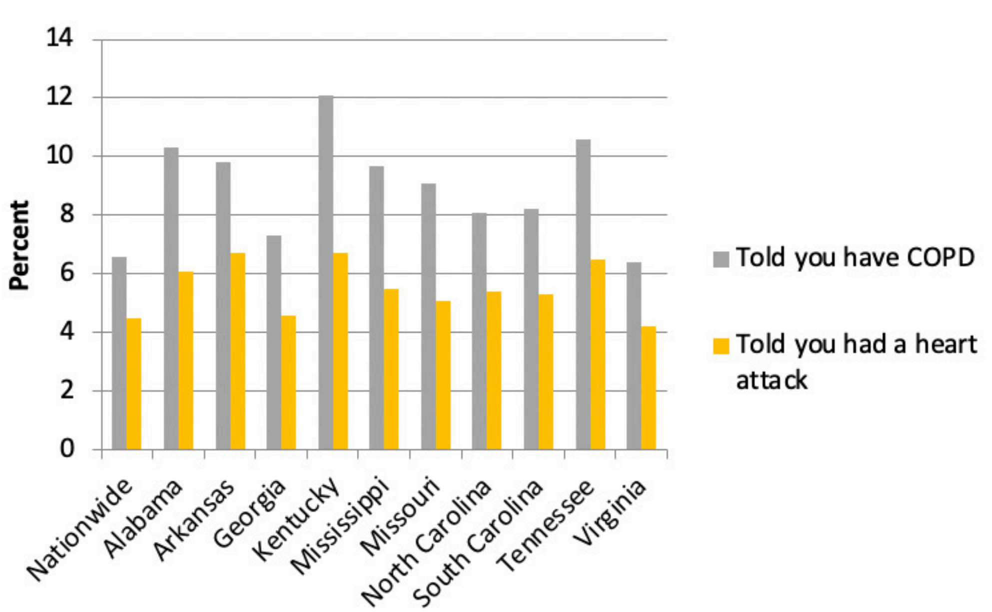
Metropolitan Statistical Area	Counties	Percent of adults who have been told they currently have asthma	Percent of adults who have ever been told they have asthma
Chattanooga, TN-GA	Catoosa County, GA; Dade County, GA; Hamilton County, TN; Marion County, TN; Sequatchie County, TN; Walker County, GA	9.9	13.5
Kingsport-Bristol, TN-VA	Bristol City, VA; Hawkins County, TN; Scott County, VA; Sullivan County, TN; Washington County, VA	14.7	19.7
Knoxville, TN	Anderson County, TN; Blount County, TN; Campbell County, TN; Grainger County, TN; Knox County, TN; Loudon County, TN; Morgan County, TN; Roane County, TN; Union County, TN	11.7	17.2
Memphis, TN-MS-AR	Benton County, MS; Crittenden County, AR; DeSoto County, MS; Fayette County, TN; Marshall County, MS; Shelby County, TN; Tate County, MS; Tipton County, TN; Tunica County, MS	8.1	14.6
Nashville-Davidson--Murfreesboro, TN	Cannon County, TN; Cheatham County, TN; Davidson County, TN; Dickson County, TN; Hickman County, TN; Macon County, TN; Maury County, TN; Robertson County, TN; Rutherford County, TN; Smith County, TN; Sumner County, TN; Trousdale County, TN; Williamson County, TN; Wilson County, TN	8.5	15

Source: Centers for Disease Control, Behavioral Risk Factor and Surveillance System (https://www.cdc.gov/brfss/index.html)

Chronic obstructive pulmonary disease

Chronic obstructive pulmonary disease (COPD) is the name for a group of diseases that restrict air flow and cause trouble breathing and includes emphysema and chronic bronchitis. Symptoms include shortness of breath and coughing. In contrast to asthma, lung function does not improve significantly with medication. Chronic lower respiratory disease, which includes COPD, was the third leading cause of death in the United States and Tennessee in 2017. The most common cause of COPD is smoking; air pollution and genetics are also thought to play a small role. People who live in large cities with higher levels of pollution also have a higher rate of COPD as compared to individuals living in rural areas. A specific link has been drawn between COPD, nitrogen oxides, and sulfur dioxide, which are primarily produced from vehicle emissions and the burning of fossil fuels at power plants. Workers in mining, automobile production, and farming have also shown an increased risk for developing COPD. However, it remains unclear whether air pollution causes COPD or exacerbates existing cases.

Figure 6.17. COPD and Heart Attack Prevalence, 2018



Source: Centers for Disease Control, Behavioral Risk Factor and Surveillance System (http://apps.nccd.cdc.gov/brfss/page.asp?cat=CH&yr=2012&qkey=8411&state=TN#CH)

Figure 6.17 shows COPD prevalence rates in Tennessee, neighboring states, and nationwide. COPD prevalence in Tennessee is higher than the national average and second highest in the region behind Kentucky. Between 2010 and 2018, the COPD prevalence rate in Tennessee increased 13 percent. Table 6.5 shows how COPD prevalence varies across the state. The Kingsport-Bristol MSA has the highest COPD prevalence within the state.

Table 6.5 COPD & Heart Attack Prevalence Rates in Tennessee's Metropolitan Statistical Areas, 2017

Metropolitan Statistical Area	Counties	Percent told you have COPD	Percent told you had a heart attack
Chattanooga, TN-GA	Catoosa County, GA; Dade County, GA; Hamilton County, TN; Marion County, TN; Sequatchie County, TN; Walker County, GA	11.5	5.8
Kingsport-Bristol, TN-VA	Bristol City, VA; Hawkins County, TN; Scott County, VA; Sullivan County, TN; Washington County, VA	17.3	8.5
Knoxville, TN	Anderson County, TN; Blount County, TN; Campbell County, TN; Grainger County, TN; Knox County, TN; Loudon County, TN; Morgan County, TN; Roane County, TN; Union County, TN	10.0	7.3
Memphis, TN-MS-AR	Benton County, MS; Crittenden County, AR; DeSoto County, MS; Fayette County, TN; Marshall County, MS; Shelby County, TN; Tate County, MS; Tipton County, TN; Tunica County, MS	6.0	2.9
Nashville-Davidson--Murfreesboro, TN	Cannon County, TN; Cheatham County, TN; Davidson County, TN; Dickson County, TN; Hickman County, TN; Macon County, TN; Maury County, TN; Robertson County, TN; Rutherford County, TN; Smith County, TN; Sumner County, TN; Trousdale County, TN; Williamson County, TN; Wilson County, TN	6.4	5.6

Source: Centers for Disease Control, Behavioral Risk Factor and Surveillance System (https://www.cdc.gov/brfss/index.html)

Heart disease

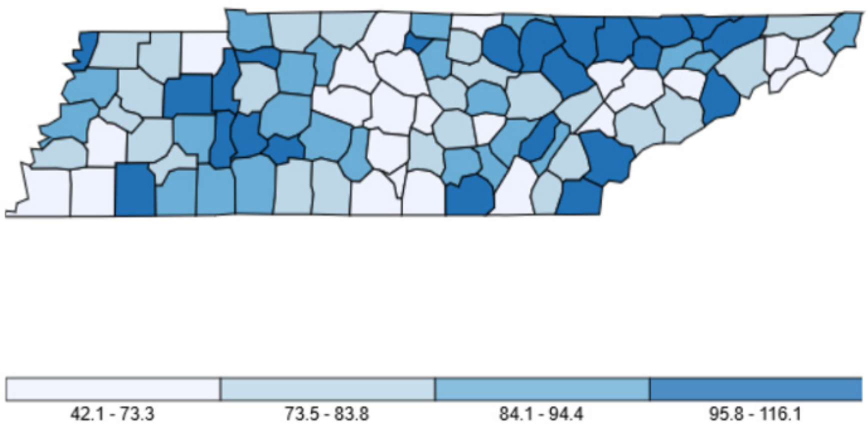
Heart attacks have been linked to elevated levels of particulate matter, which is primarily produced by the burning of fossil fuels. Heart disease is the number one killer in Tennessee and claimed the lives of 16,019 Tennesseans in 2017. Between 2010 and 2017, Tennessee's prevalence of heart disease was stable, while others in the region saw an increase in heart disease prevalence. In 2017, Tennessee had the third highest prevalence of heart disease in the region behind Kentucky and Arkansas. The Kingsport-Bristol MSA has the highest prevalence of heart disease in the state.

Cancer

Outdoor air pollution, particularly engine exhaust and particulate matter, has recently been classified as a cancer-causing agent (carcinogen) by the World Health Organization. The International Agency for Research on Cancer (IARC), part of the World Health Organization, concluded that outdoor air pollution causes lung cancer and is also linked to increased risk for bladder cancer.

In Tennessee in 2017, there were 6,044 new cases of lung cancer and 4,001 people who died of lung cancer. Tennessee was ranked fifth in rates of new lung cancer cases behind Kentucky, West Virginia, Mississippi, and Arkansas. Tennessee's rate of new cancer cases has been falling slightly over the past decade. Figure 6.18 shows lung cancer incidence rates (cases per 100,000 population per year) by county in the state. The highest incidence rates in the state are in the north Cumberland region, along the Tennessee River in west Tennessee, and in the southeastern portion of the state.

Figure 6.18. Lung Cancer Incidence Rates in Tennessee, 2017



Source: State Cancer Registry and CDC's National Program of Cancer Registries Cancer Surveillance System (NPCR-CSS)

Energy Efficiency and Human Health

The conditions inside a home can have a big impact on a person's health by affecting exposure to indoor air pollution and allergens. Energy efficiency upgrades and weatherization projects can reduce emissions of regional pollutants caused by burning fossil fuels and make homes healthier. Improving ventilation, installing insulation, and sealing doors and windows helps mitigate many of the health implications of energy-related pollutants such as asthma and COPD by reducing indoor air pollution and stabilizing indoor temperatures and humidity levels. The American Council for an Energy-Efficient Economy found that incorporating four health-focused interventions into existing energy efficiency programs in the United States would prevent over $51 million in asthma and heat-related stress impacts after one year. A recent study of over 1,200 single family homes in Knoxville found that the monetary value of health benefits produced by weatherization upgrades exceeded the cost of those upgrades. Benefits are expected to be significant in low-income and rural communities in Tennessee where the housing stock is older and mobile homes and trailers are more common.

Sources:https://www.aceee.org/program/health-environment
http://www.threecubed.org/current-projects.html