Vice President's Conversation on the Future

Trend Research: Energy Sources, Demands, and Cost

Descriptor Definition

This descriptor white paper centers on the changes in the total energy sources and consumption in Ohio, with an emphasis on the cost impacts to Ohioans. It provides information on both primary and secondary sources of energy. (Primary sources of energy, such as coal, natural gas, and petroleum are consumed directly. Electricity is a secondary form of energy that is created from primary energy sources.) It includes additional energy use information specific to population demographics and energy expenditures as a percentage of Ohio's current dollar gross domestic product (GDP). It also considers energy expenditures per person compared to other states, which is specifically relates Ohio's energy consumption and cost to Ohio residents in relation to other regions.

Author Insight[1]: Descriptor Relevance

Total world energy use rose by 83% from 283 quadrillion British thermal units (Btu) to in 1980 to more than 507 Btu in 2010. Looking forward, the 2012 International Energy Outlook Report estimates additional growth in worldwide energy consumption to reach 630 quadrillion Btu in 2020 and to 820 quadrillion Btu in 2040. Much of the worldwide growth in energy consumption is occurring in developing countries, where countries with strong, established economies drive steady demand. Second only to China, the United States consumed 18% of the world energy total in 2011, and Ohio ranked as the sixth highest energy consuming state in the nation. Energy development in Ohio is important for the future vitality of the state as it influences both economic growth and the general quality of life of Ohioans. Ohio's economy competes daily on a global scale, which is driven by its strong manufacturing sector, primarily due to high energy-intensive industries, such as strong metals fabrication and chemical production industries. In order for Ohio's manufacturing sector to remain competitive, it is critical Ohio employers have access to reliable, yet affordable sources of energy. New methods of harnessing, controlling, and using energy has led to a much higher standard of living than that of previous generations. As a result, access to affordable energy directly influences our quality of life. Energy development can also affect a variety of environmental issues. For instance, energy-related carbon dioxide emissions produced through the combustion of fossil fuels (i.e. liquid fuels, natural gas, and coal) account for much of the world's greenhouse gas emissions. As a result, energy consumption and the source of generation are critical factors in the global climate change debate as well.

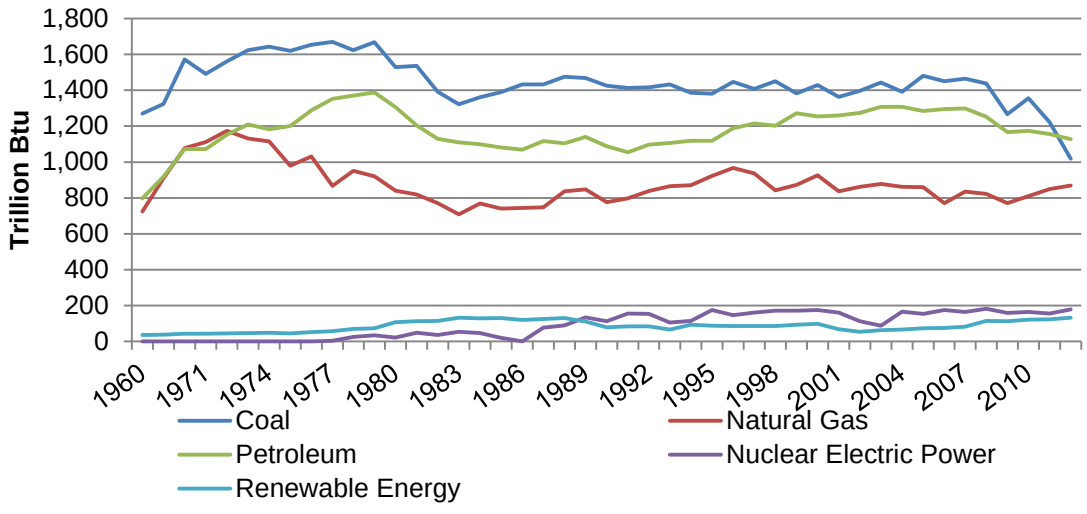
Trend Information and Interpretation

Energy Demand

Due to its large population and strong industrial economy, Ohio ranked sixth in the nation in total energy consumption and fourth in total retail electricity sales in 2012. Between 1960 and 2012, total

energy consumption in Ohio increased by 23 percent. The most notable change occurred when the consumption of petroleum rose by 75 percent between 1960 and 1979, but has declined 18 percent since then (Figure 1). Still, Ohio is among the top petroleum-consuming states ranking sixth in the nation in 2012. Total petroleum demand in the state far exceeds the state's production. Most of the petroleum consumed in Ohio is used as transportation fuels, either as motor gasoline or diesel fuel (EIA Ohio Profile, 2014). In 2012, Ohio was the fourth largest coal consuming state in the nation behind Texas, Indiana, and Pennsylvania. Roughly 90% of the coal consumed in Ohio is used for electric power generation. While coal has traditionally been the greatest source of energy in Ohio, the consumption of coal in Ohio has decreased by 28 percent from 2000 to 2012.

Figure 1: Ohio Energy Consumption by Source 1960 - 2012

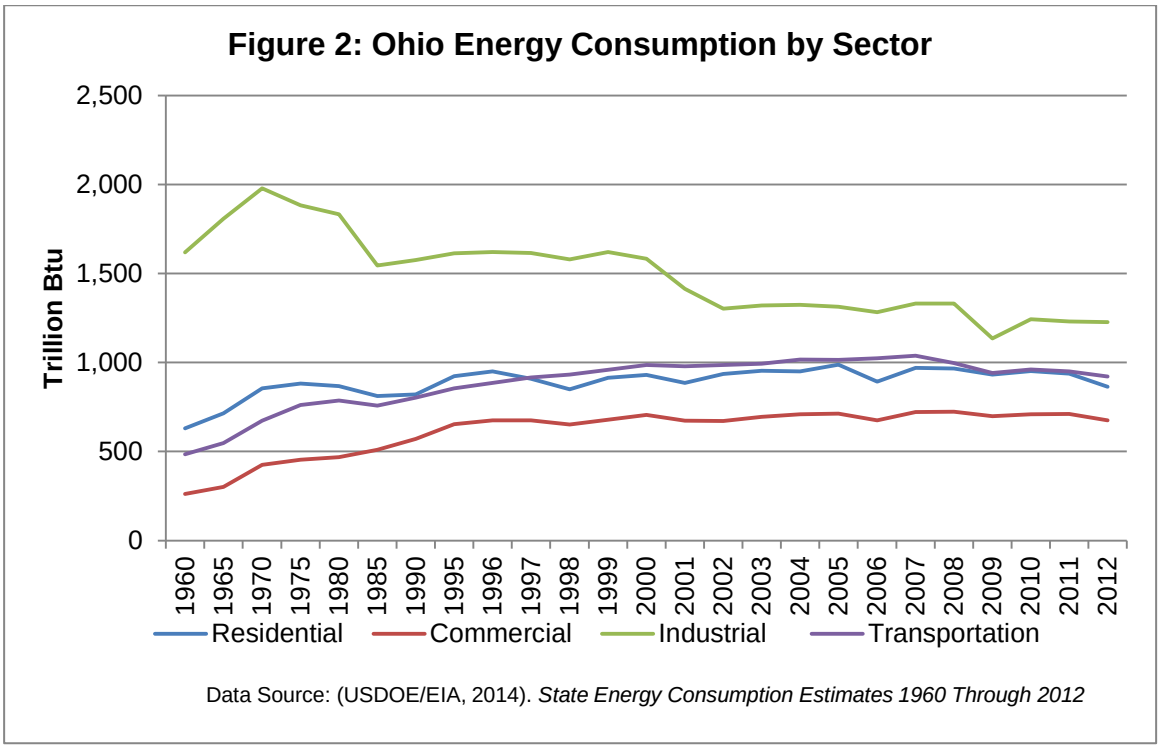


Data Source: (USDOE/EIA, 2014). *State Energy Consumption Estimates 1960 Through 2012*

In 2012, the industrial sector represented the largest energy-consuming sector in the state at 33 percent, followed by the transportation sector (25 percent), residential sector (24 percent), and commercial sector (18 percent). Between 1960 and 2012, the greatest reduction in energy consumption was achieved in the industrial sector, which fell considerably by 38 percent between those years. Conversely, during the same time period there was a moderate increase in the consumption of energy for the residential sector at 37 percent and transportation sector at 89 percent, while the greatest increase in consumption was in the commercial sector, which rose 158 percent (Figure 2).

In 2012, total energy use per person (or per capita consumption) in Ohio was 319 million Btu, which declined 4.7 percent compared to 2010, and was 19 percent less than the per capita consumption in

1978. Generally, the energy consumption per capita in Ohio is higher than the national average (Appendix A).



Author Insights – Energy Demand

Energy consumption is influenced by a number of factors such as population growth, transportation, economic activity, climate (extreme warm or cold conditions), per capita income, and the quality of life. Energy intensity is defined as energy consumption per unit of GDP and can help measure the energy efficiency and structural changes of an economy. A high-energy intensity indicates a high price or cost of converting energy into GDP, while a low energy intensity indicates a lower price or cost of converting energy into GDP. Ohio posted a mediocre energy intensity score of 8.4 in 2011, which ranked 29th in the nation and was exactly one point higher than the national average. However, since 1970, there has been a downward trend in energy intensity in Ohio, dropping 7.6 percent from 2000 to 2011. This indicates an an increase in the energy efficiency of production processes in Ohio combined with structural changes in the economy, shifting away from the production of energy intensive materials such as primary metals production. This trend also supports the reduction in the overall energy consumption within the industrial sector from 1960 to 2012, as identified in Table 2 above.

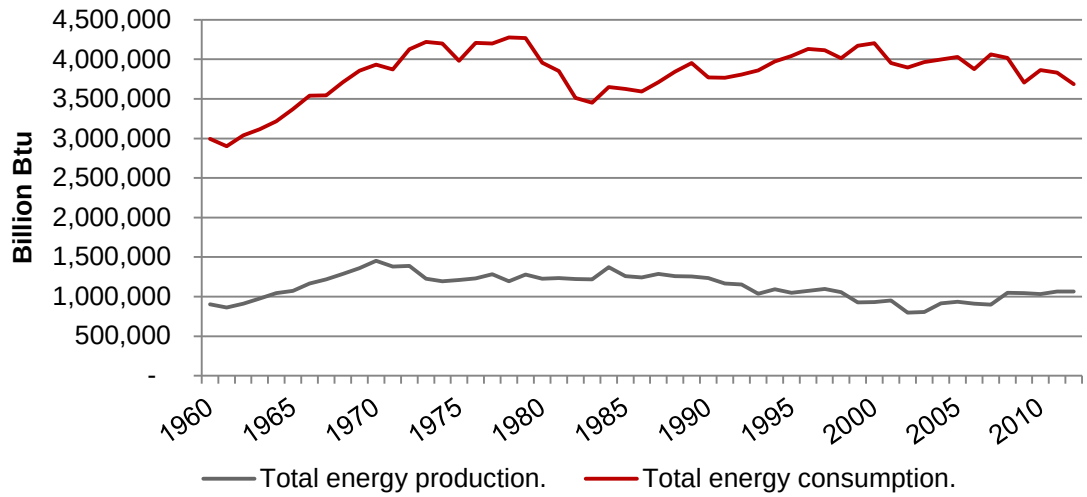
Yet, as illustrated by the overall 23 percent increase in Ohio's total energy consumption over the past 50 years, theses energy efficiency increases are more than offset by factors such as population growth, quality of life, and changes in consumer behavior such as an increase in vehicle miles traveled by drivers. According to Yergin, "over the next couple of decades, 2 billion people, about a quarter of

the world's population will gain a significant pay raise. They will move from a per capita income of under $10,000 a year, to between $10,000 and $30,000 a year. Even with much greater energy efficiency these raising incomes will mean much greater need for energy" (Yergin, p. 719, 2012). While Yergin's example is from a global perspective, it is essential to consider how demographic shifts impact energy trends in Ohio. From 1960 and 2010, Ohio's population has increased by 19 percent. If population growth increases in the future, so will the need for additional education, health care, and social services and the energy required to provide them (IEO, 2013).

Energy Source

In 2012, Ohio ranked 18th in the nation in total energy production, producing 1,064,404 Billion Btu of energy. As a heavy consumer of energy, Ohio's energy production on average accounts for 30 percent of the energy needed to meet demand (Figure 3). As a result, the state imports additional coal, natural gas, and petroleum and is also among the major importers of electricity.

Figure 3: Ohio Energy Production vs. Consumption

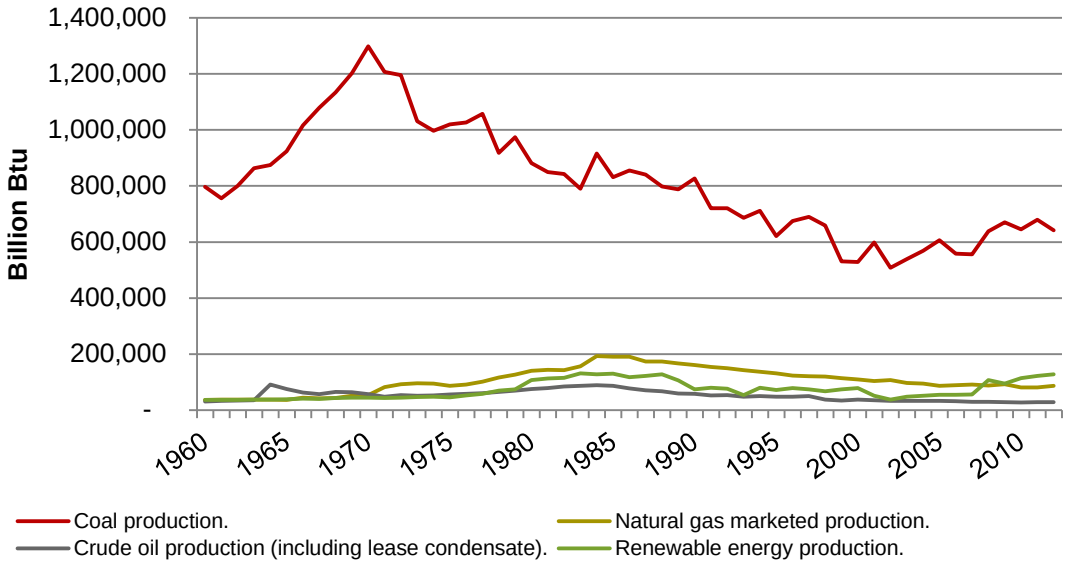


Source: (USDOE/EIA, 2012). *State Energy Production Estimates 1960 Through 2012*

The most prominent energy source in Ohio is coal, accounting for 60 percent of the Ohio total energy production in 2012. While Ohio's energy production from coal has dropped by 50 percent since its peak in 1970, the state ranked 8th in the country in coal production for 2012, producing 642,149 Billion Btu (Table 4). Traditionally a moderate producer of petroleum, Ohio ranked 18th in the nation in crude oil production in 2012, producing 28,287 Billion Btu of energy. Since reaching a peak of 88,572 Billion Btu of crude oil production in 1984, Ohio has experienced a 68 percent decrease in production (Table 4). However, oil- producing wells in the Utica shale formation produced 635,876 barrels in 2012, increasing by 478 percent in 2013 to a total of 3,677,734 barrels (not included in table data). By 2015, it is projected that shale wells will produce about 73 percent of Ohio's oil (ODNR Shale Report, 8/26/2014). Ohio is consistently one of the top 10 refining states, home to 4 refineries with a combined capacity of 530,000 barrels of crude oil per calendar day to process crude oils into finished products.

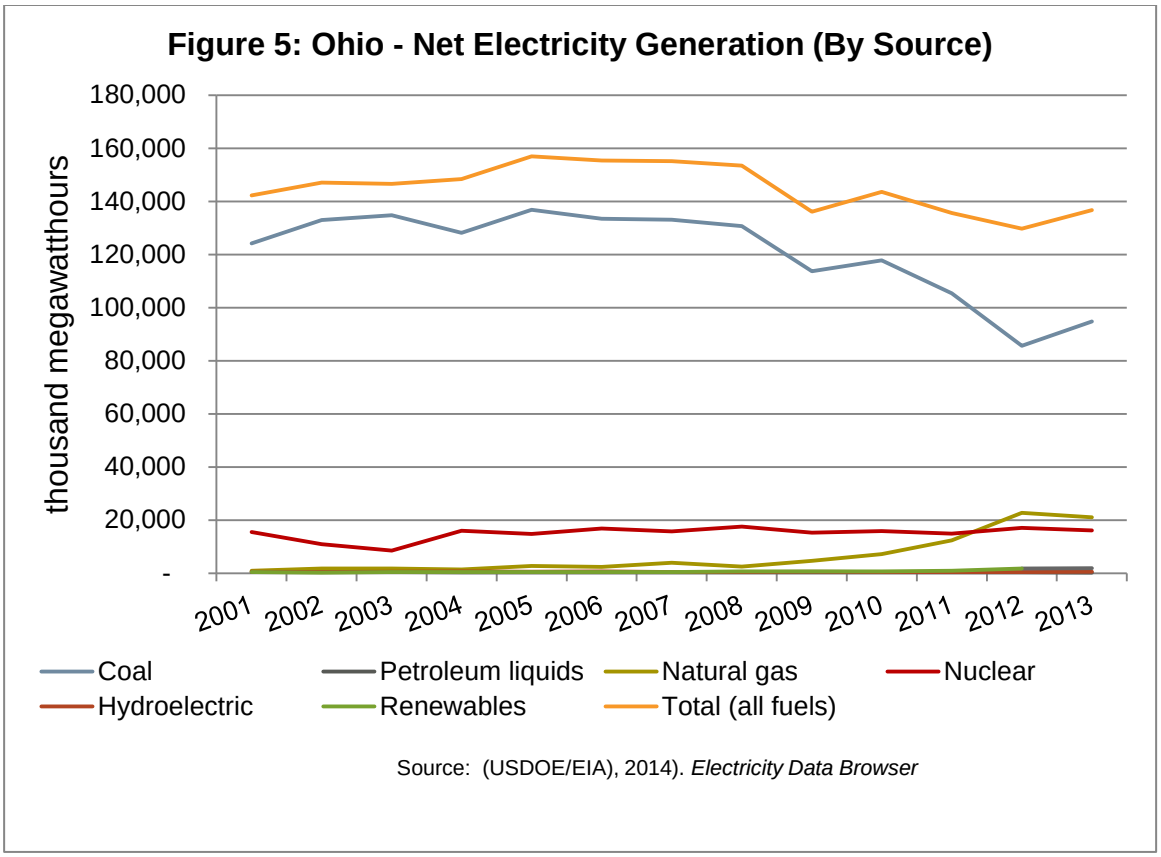
Additionally, Ohio has significant ethanol production with 7 ethanol plants currently in operation. Since its peak in 1984, natural gas production in Ohio has declined by 58 percent. Ohio ranked 19th in the country in natural gas production for 2012, producing 87,417 Billion Btu (Figure 4). However, shale gas production from horizontal hydraulic fracturing in the Marcellus and Utica shale formation is expected to dramatically improve natural gas production in the state moving forward. To meet peak demand in the winter season, Ohio also has substantial natural gas storage infrastructure with a capacity totaling 580 billion cubic feet. In 2012, Ohio ranked 22th in the nation in renewable energy production, producing 127,497 Billion Btu of energy. In 2010, Ohio experienced vast investments renewable energy generation facilities including two wind farms totaling 403 megawatts of capacity and a 12 megawatt solar farm. Additionally, Ohio's ethanol production, which increased from 231 Billion Btu in 2005, to 60,081 Billion Btu in 2012, contributes to the states renewable energy production.

Figure 4: Ohio Energy Production (By Source)



Source: (USDOE/EIA, 2012). *State Energy Production Estimates 1960 Through 2012*

While Ohio is one of the top states for electric generation, its generation does not meet demand; therefore the state is also a major importer of electricity. The primary source for electrical generation in Ohio is coal, which has decreased by 24 percent since 2001 (Figure 5). Conversely, the use of natural gas as a fuel source for electric generation has increased significantly, accounting for 15 percent of total electricity generation in 2013. Nuclear power generates most of the remainder at 12 percent of the 2013 total, while renewable energy provides less than 2 percent.



Author Insights – Energy Source

The eastern third of Ohio is part of the Appalachian Basin, which contains an abundance of coal as well as many crude oil and natural gas resources. Since 1984, there has been a persistent long-term downtrend in the production of energy using coal (Figure 4). Two critical factors influencing this trend are 1) policy and regulatory decisions driven by concerns over carbon dioxide emissions from electric power generation and 2) the aging electric generation infrastructure in Ohio. In total, 39 percent of Ohio's electric generation capacity comes from facilities that are 41 years or older, and 61 percent of the state's coal generation capacity is 41 years or older.

Over the next several decades, significant investments in electric generation are needed to update Ohio's electric generation facilities. In recent years the state also has experienced significant development of natural gas and crude oil resources from the Marcellus and Utica shale formations. As a result, natural gas use for electric power generation in Ohio has increased markedly in recent years as domestic natural gas production has increased. Additionally, Ohio's renewable energy policy which is currently under review, has driven significant investments in large scale wind farms, solar fields, and investments in on-site distributed electric generation by Ohio business and residents. When considering the mix of future energy sources "it is important that we do not underestimate the persistence and adaptability of old resources, remember that coal is still more important globally than natural gas" (Smil, p. 162, 2010). Research of clean coal technologies, such as the coal-direct chemical looping technology developed at the Ohio State University Clean Coal Research Laboratory,

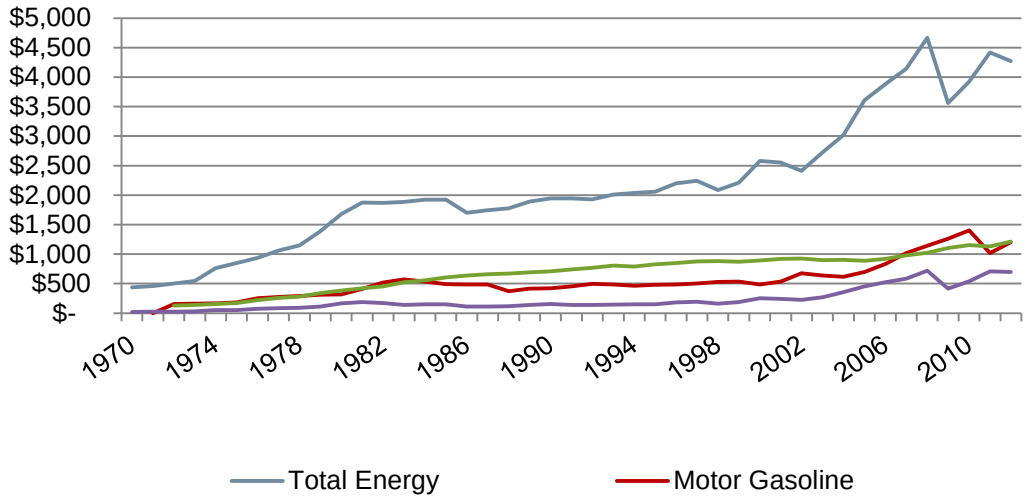
could reverse recent trends and increase the use of coal in the future. It is important to remember that energy transitions are naturally prolonged affairs lasting decades, not years as infrastructure upgrades are necessary to implement change. Ohio is currently experiencing this as the state is scrambling to develop midstream processing facilities and pipeline distribution infrastructure to maximize the state's oil and gas resource potential.

Energy Cost

As a state, Ohio spends more on energy than all but 5 states, but ranks a favorable 38th in the nation in price per million Btu of energy at $20.37. Historically in Ohio, the prices of coal, natural gas, and petroleum have all shown a notable increase. Of the primary sources of energy, petroleum experienced the most volatile and violent price increase. The Ohio crude oil first purchase price grew by a massive 240 percent from $28.27 (Dollars per Barrel) in June of 2000 to $96.37 (Dollars per Barrel) in June of 2014 (Appendix C). Likewise, residential natural gas prices increased considerably from less than a dollar per thousand cubic feet (Mcf) in 1970 to its peak of $14.53 per Mcf in 2008. Since 2008 residential natural gas prices have decreased by 34 percent (Appendix B). Between 2008 and 2013 the cost per short ton of coal shipments to the electric power sector in Ohio has increased 15 percent from $46.90 to $54.34 (Appendix D).

The per capita energy expenditures in Ohio have grown from $462 in 1970 to $4,269 in 2012 (Figure 6). More recently, from 2002 to 2012 the per capita energy expenditures in Ohio have increased by 77 percent. While the total energy expenditures per person in Ohio has risen significantly in recent years to $4,269, Ohio currently ranks 30th in the nation in this category and is significantly lower than the top five states 1) Alaska ($10,484), 2) North Dakota ($10,049), 3) Wyoming ($9,828), 4) Louisiana ($8,544), and 5) Texas ($5,983).

Figure 6: Ohio Per Capita - Energy Expenditures



Data Source: (USDOE/EIA, 2014). *State Energy Consumption Estimates 1960 Through 2012*

Author Insights – Energy Costs

Changes in relative fuel prices for primary energy input sources such as coal, natural gas, and petroleum are not seen on electric bills or our receipt at the gas pump, yet they greatly influence the cost of energy to Ohioans. Since 1970, the per capita income for Ohioans has increased on a similar trajectory to the per capita energy expenditures (Appendix F). Generally, Ohioans spend 12 percent of their per capita income on energy expenditures. In 2012, motor gasoline accounted 35 percent of the total per capita energy expenditures ($4,269) in the Ohio, while retail electric sales accounted for an additional 28 percent, followed by 16 percent for distillate fuel oil (Appendix G). Distillate fuel oil is a classification of petroleum fractionations that includes diesel fuels used to power automobiles and trucks, as well as off-highway engines, such as railroad locomotives and agricultural machinery. Combined, motor gasoline and distillate fuel oil accounted for 51 percent of Ohioans' total per capita energy expenditures in 2012. Driven in large part by rising crude oil prices, regular gasoline retail prices in Ohio have increased by 137 percent from $1.48 per gallon in June 2003 to $3.51 per gallon in July of 2012, while diesel prices have increased on a similar schedule from $1.40 to $3.82 over the same time period (Appendix H). Although the cost of transportation fuels has increased, it is not reflected in consumer decisions to travel less. According to the Ohio Department of Transportation, in Ohio the total Thousands of Daily Vehicle Miles Traveled (kDVMT) increased by 22 percent from 250,146.04 kDVMT in 1990 to 305,391.53 kDVMT in 2013 (ODOT, 2014).

A second factor that most directly influences the energy expenditures to Ohioans is electricity. The average retail price per kilowatt-hour of electricity (all sectors) in Ohio has increased by 61 percent from 5.89 cents per kWh in 1990 to 9.50 cents per kWh in 2014 (Appendix E). According to the 2014 Annual Energy Outlook Report, accelerated retirements of coal-fired and nuclear electricity generation capacity will cause natural gas and renewables to gain an increased share in the nation's electricity generation mix and the rising use of natural gas in the electric power sector will result in price increases for both natural gas and electricity in all sectors (USDOE/EIA, 2014).

Overall Summary of Trend Information

While energy consumption has increased significantly over the past 50 years, energy consumption in Ohio has been decreasing since the year 2000. The primary factor for the recent decrease in energy consumption in Ohio (Figure 3) was the economic downturn from 2008 through 2010 that caused a reduction in energy use in the industrial sector. Other factors, such as efficiency improvements associated with electrical appliances, industrial equipment, and buildings as well as an increase in the miles per gallon ratings for light duty vehicles, have slowed energy demand as well. Ohio production of oil and gas has increased dramatically in the past few years. Higher levels of oil and gas production in the state should have a positive impact on energy prices for petroleum based products and natural gas. However, Ohio's future growth potential of oil and gas production are based on key assumptions in well production decline rates and lifespan. In addition to consumption patterns and energy resources, advancements in technology for energy production of all energy sources will also greatly influence future production mix and prices in Ohio.

Author Insights – Possible Trends for the Future

Since 2005, energy consumption had decreased, while energy production and per capita energy expenditures have increased. Looking out to the year 2035, there are three likely outcomes for the trend in energy demands, energy sources, and energy costs including a priori probabilities of occurrence. Probabilities of occurrence are estimations (given the information available and knowing it will likely change) that provide a starting point for conversations about the future. They can be illustrated as: (1) best outcomes possible or trends that go one direction; (2) the status quo are maintained; or (3) trends go a different/opposite direction.

A. Energy consumption and generation in Ohio will increase, much like it did in the 1960s, due primarily to increasing population and employment opportunities, which is driven by a resurgence of energy intensive manufacturing clusters. For example, energy intensive manufacturing sectors such as fabricated metals, plastics and rubber, petrochemicals, iron and steel, and agricultural chemicals will boost the Ohio economy for years to come as exploration and extraction of oil and gas from the Utica and Marcellus shale formations provides cheaper natural gas liquids and stimulates economic growth. An increasing population is expected to support short-term employment related to drilling and pipeline construction and long term employment opportunities in energy-related manufacturing sectors. Increases in energy consumption and generation might also occur with advancements in technology for clean coal, renewable energy, and biofuel feedstock and production. For example, large investments in clean coal could create strong resurgence in employment in the electric power generation from coal sector, maintaining and growing critical employment opportunities in rural communities throughout Ohio. Also, increased population and strong economy will likely raise the state's per capita income and quality of life and thereby increase the per capita energy consumption in Ohio. Based on 2014 trend information, this outcome appears to be the most likely with an *a priori* probability of occurrence of 0.50.

B. Energy consumption in Ohio continues to decrease, while the states energy generation increases moderately similar to Ohio trends from 2000-2014. In this outcome, improved efficiency of energy use in the residential and transportation sectors will help to stabilize the per capita energy consumption in Ohio. Energy production form coal will continue to go down due to aging facilities, policy, and environmental regulatory standards. Meanwhile, shale energy development from the Marcellus and Utica Shale formations will maintain steady growth in energy production from petroleum and natural gas, while renewables maintain slow growth similar to the trends from 2008 to 2014, further diversifying the state's energy portfolio. In addition, energy related employment in shale energy will likely continue to grow, but jobs associated with coal production and power generation may see significant declines in specialized rural economies that depend on them. Based on 2014 trend information, this outcome has an a priori probability of occurrence of 0.40.

C. In this scenario, compounding factors create significant challenges leading to a rapid decrease in both energy consumption and generation in Ohio. A combination of environmental emission regulations, a lack of energy resources, climate change and extreme weather conditions may affect the ability of Ohio to produce and distribute energy to residents and businesses. Increasing water

temperatures and fluctuation in the water level of the Ohio River directly impacts energy generation and energy cost in Ohio. For example, in May 2011, nearly 20 percent of barge terminals along the Ohio River were closed due to flooding, impacting coal and petroleum transportation patterns. Conversely, when river levels decrease, barge operators reduce their loads, which also impacts the transportation of coal and petroleum products. In addition, many of Ohio's electric generation plants depend on the Ohio River Basin as a source for cooling water. The cumulative effect of multiple plants discharging high-temperature waters into a receiving body with already elevated temperatures may result in violation of environmental regulations (DOE-PI/NREL, 2013). As the ability to produce energy in Ohio decreases, jobs directly employed in the energy sector are lost and the overall cost of energy in the state increases. Raising energy costs in Ohio will reduce the competitiveness of the industrial sector, weakening the state's economy. Based on 2014 trend information, this outcome has an a priori probability of occurrence of 0.10. What makes this probability the lowest is the unlikely possibility that the life expectancy of horizontal wells drilled in the Marcellus and Utica Shale formations are significantly less than projections, due to increased decline curves that would reduce the amount of oil and gas recovered on the back end of a well's productive lifetime.

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Author(s) and date

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10/8/2014

[1] Along with the research-based data and statistics included in this document, is information provided by the research paper author(s). Although these author insights are not directly cited with research references, they reflect research, observation, logic, intuition, and well-considered expectations compiled by the author(s). The Author Insights sections of this paper are offered for discussion and to help provide a wider perspective for incorporating the descriptor data into the possible future trends. These conclusions are drawn by the author(s) using their knowledge of the scholarly references and their years of professional experience related to the descriptor, and are provided to help the reader more effectively envision the future impact and effects of the descriptor.

Bruce McPheron, Ph.D., Vice President for Agricultural Administration & Dean

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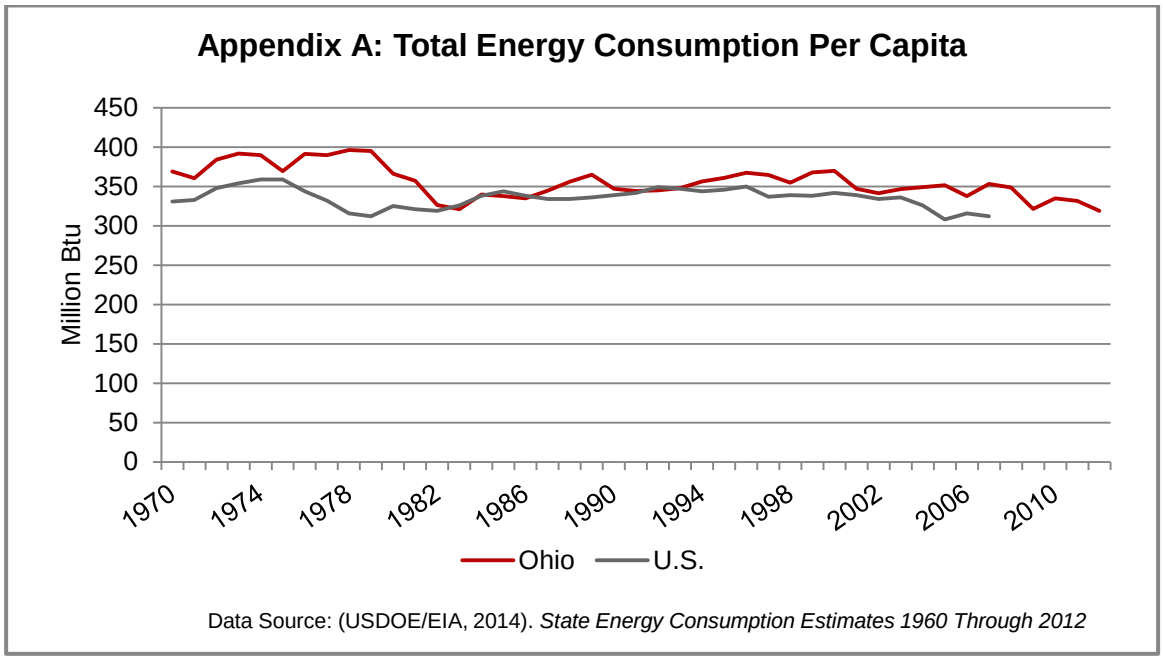
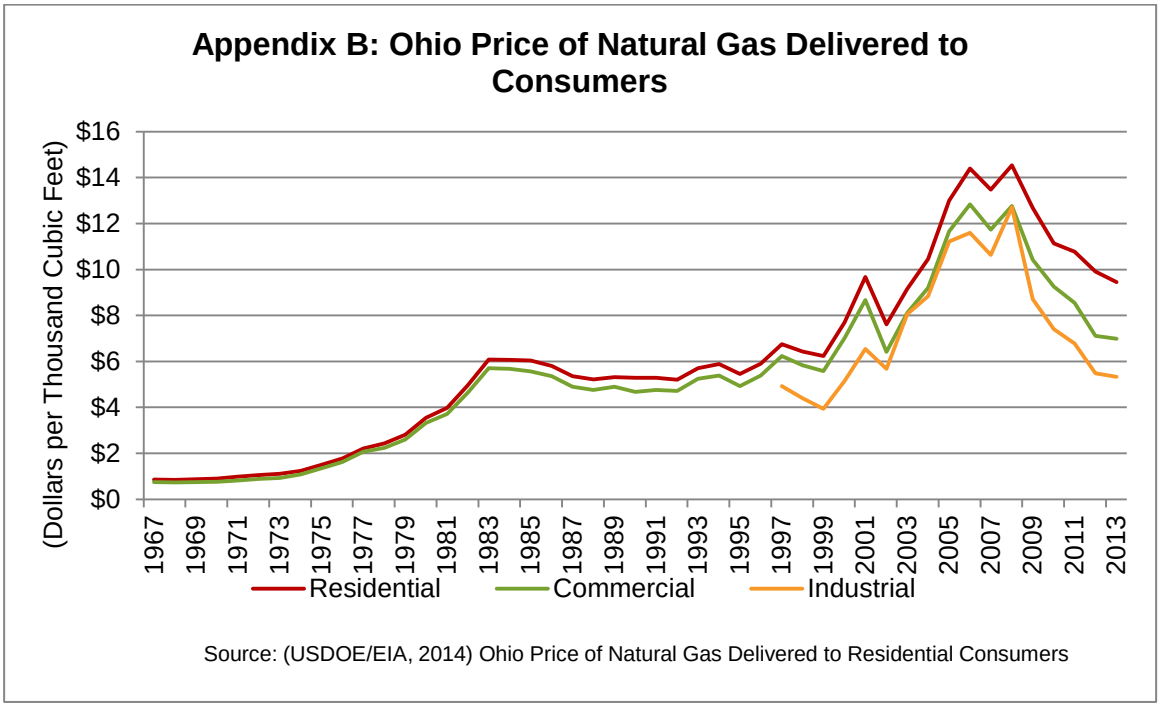
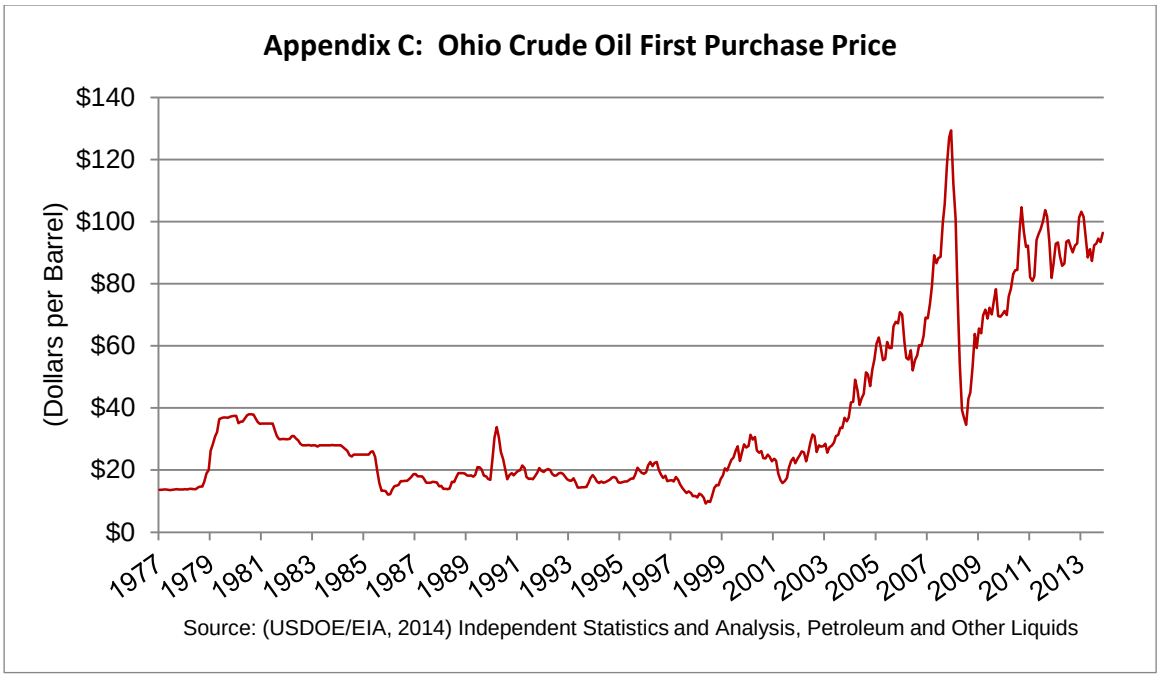
Appendix

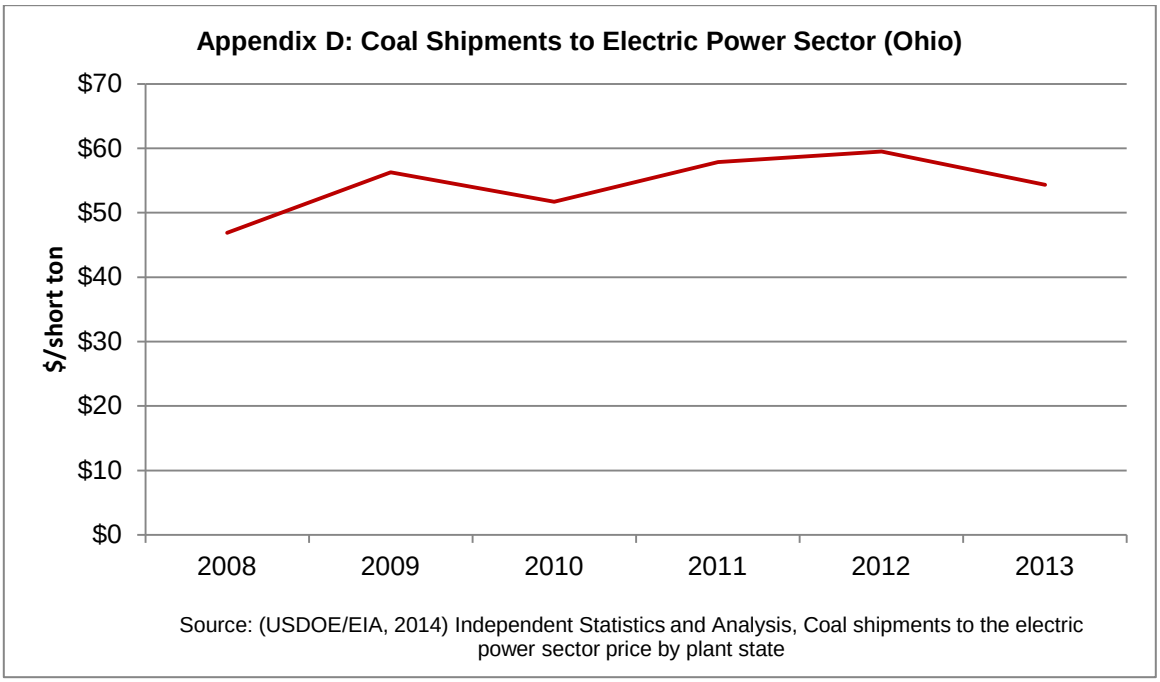


Data Source: (USDOE/EIA, 2014). *State Energy Consumption Estimates 1960 Through 2012*

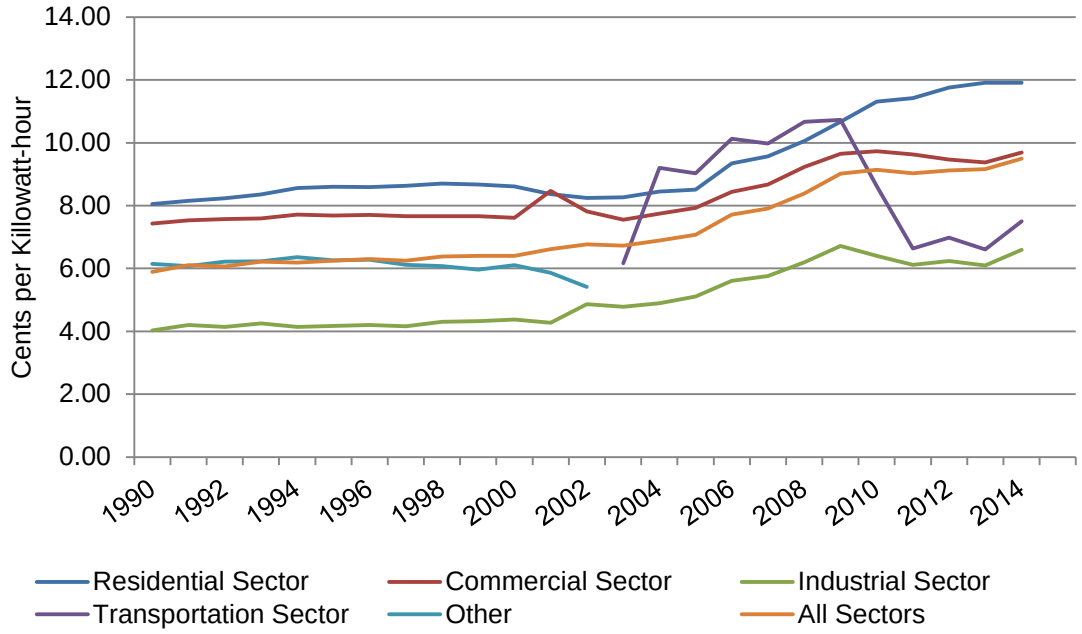


Source: (USDOE/EIA, 2014) Ohio Price of Natural Gas Delivered to Residential Consumers


Appendix C: Ohio Crude Oil First Purchase Price
$140
$120
$100
$80
$60
$40
$20
$0
(Dollars per Barrel)
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
Source: (USDOE/EIA, 2014) Independent Statistics and Analysis, Petroleum and Other Liquids

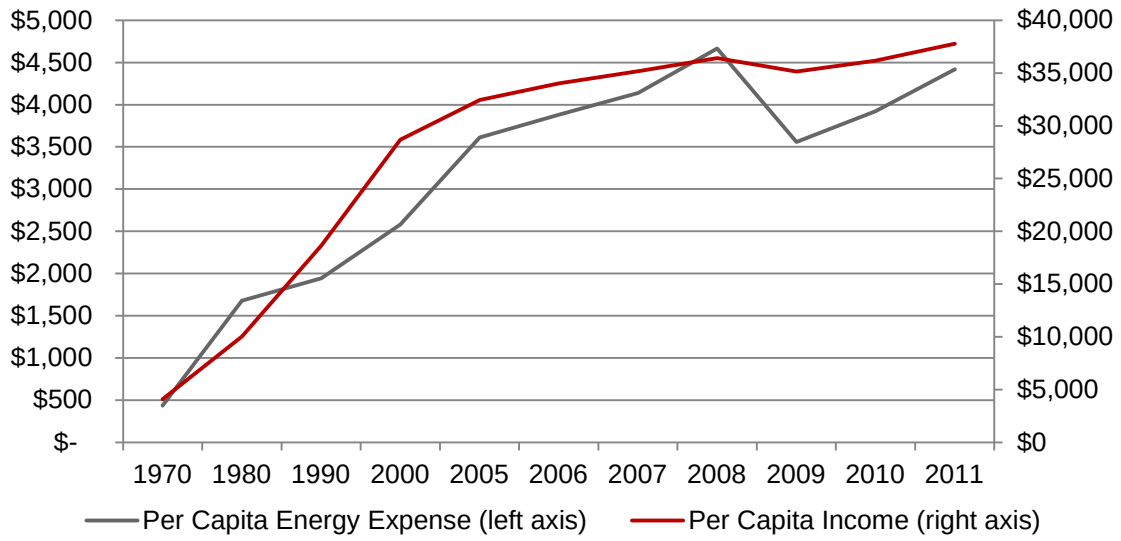

Appendix D: Coal Shipments to Electric Power Sector (Ohio)
$70
$60
$50
$40
$30
$20
$10
$0
$/short ton
2008
2009
2010
2011
2012
2013
Source: (USDOE/EIA, 2014) Independent Statistics and Analysis, Coal shipments to the electric power sector price by plant state

Appendix E: Average Retail Price of Electricity in Ohio

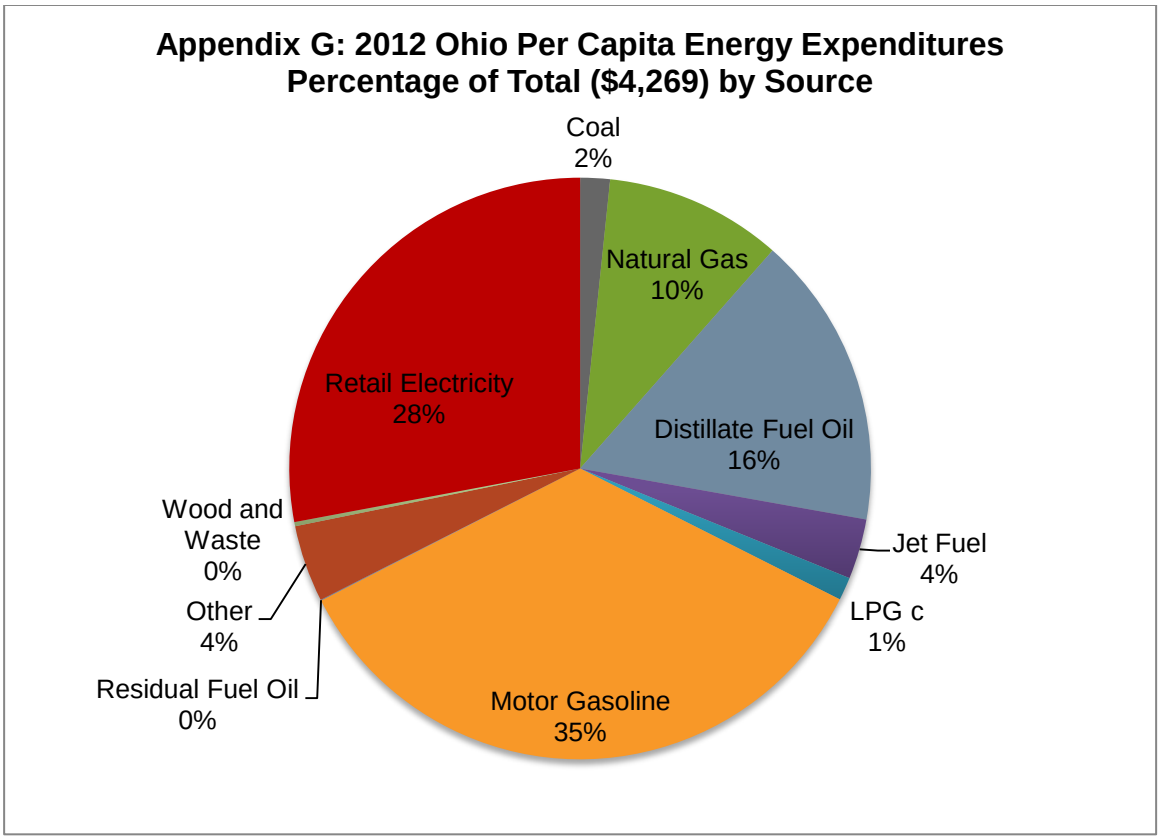


Source: (USDOE/EIA, 2014) *The Current and Historical Monthly Retail Sales, Revenues and Average Revenue per Kilowatthour by State and by Sector*

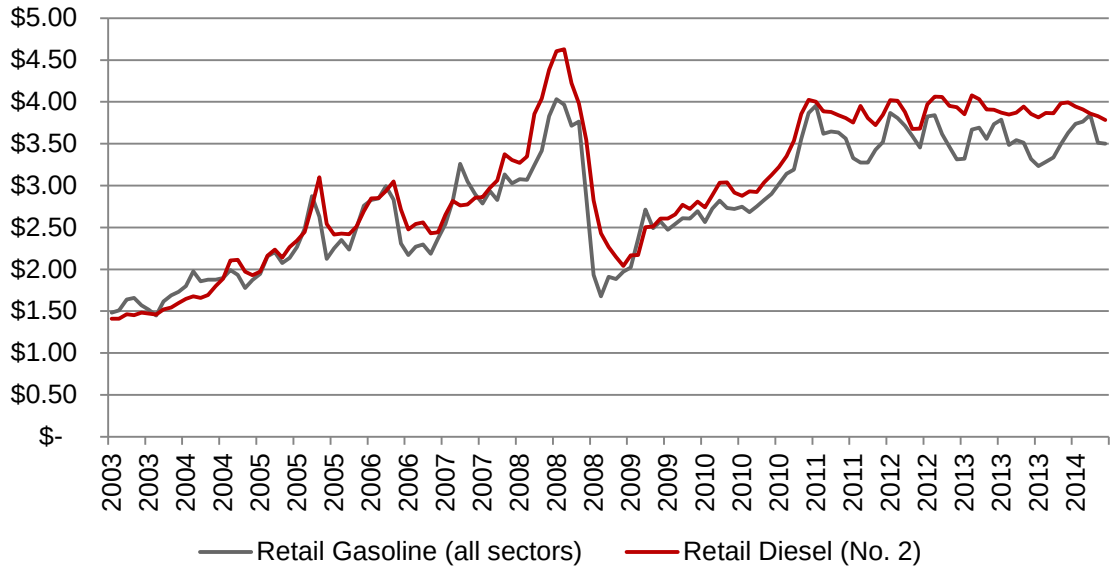
Appendix F: Ohio Per Capita Income vs. Energy Expense



Data Source: (USDOE/EIA, 2014). *State Energy Consumption Estimates 1960 Through 2012*


Appendix G: 2012 Ohio Per Capita Energy Expenditures
Percentage of Total ($4,269) by Source
Coal
2%
Natural Gas
10%
Distillate Fuel Oil
16%
Jet Fuel
4%
LPG c
1%
Motor Gasoline
35%
Residual Fuel Oil
0%
Other
4%
Wood and
Waste
0%
Retail Electricity
28%

Appendix H: Fuel Prices in the Midwest and Ohio Region



Source: (USDOE/EIA), 2014). *Petroleum &Other Liquids - Weekly Retail Gasoline & Diesel Prices*