Ohio Long-Term Forecast of Energy Requirements

2020-2039

A report by the staff of the

Public Utilities Commission of Ohio

May 13, 2021

Ohio | Public Utilities Commission

Disclaimer for the *Ohio Long-Term Forecast of Energy Requirements 2020-2039* report by the staff of the Public Utilities Commission of Ohio.

Pursuant to Ohio Revised Code (R.C.) 4935.01(A), the Public Utilities Commission of Ohio (PUCO) staff presents year-by-year forecasts of the prevailing energy, economic and demographic trends in the United States of America (U.S.), Ohio and the utility service areas in Ohio over a 20-year period. The PUCO staff (staff) issues the following report which consists of forecasts that are projections dependent upon assumptions and historical data and trends. The future, however, is unknown. Periodic reviews of past forecasts are, therefore, a wise and necessary step to both test the validity of the current forecast scenarios and to identify and monitor emerging alterations in prevailing trends due to the impacts of more recent events. The forecasts presented in this report consider the anticipated developments in the national and international economic environment and assess their potential impact on Ohio. These forecasts are presented solely for the purposes of R.C. 4935.01(A) and should not be used or relied upon for any other purpose.

Table of Contents

Figures

Tables

1.0 INTRODUCTION

The *Ohio Long-Term Forecast of Energy Requirements 2020-2039* presents year-by-year forecasts of the prevailing energy, economic, and demographic trends in the U.S., Ohio, and utility service areas in Ohio, over a 20-year period. Historical patterns observed in the development of the prevailing trends, and the dynamic relationships among them, are analyzed and assessed in the formulation of the forecasting models and forecast scenarios. Anticipated alterations in the prevailing trends, due to anticipated business cycles or other severe macroeconomic shocks, are specifically included in the forecast scenarios when deemed relevant and feasible.

This publication is prepared by the Office of the Federal Energy Advocate of the PUCO. The intent of the report is to fulfill the Commission's mandate under R.C. Section 4935.01 (A), which states that:

> The Commission shall:
>
> (1) Estimate statewide and regional needs for energy for the forthcoming 5- and 10-year periods which, in the opinion of the Commission, will reasonably balance requirements of state and regional development, protection of public health and safety, preservation of environmental quality, maintenance of a sound economy, and conservation of energy and material resources. Other factors and trends which will significantly affect energy consumption such as the effects of conservation measures shall also be included.
> (2) Estimate statewide and regional demands within the state for energy for 20years ahead, to be used in formulation of long-range policies and proposals for reduction of demand, conservation of energy, development of potential sources of energy, and action to affect the rate of growth in demand for energy.

The forecasts presented in this report include the annual requirements for energy resources, including natural gas, petroleum products, coal, hydropower and nuclear energy, by the residential, commercial, industrial, transportation, and electric utilities sectors of the state of Ohio from 2020 through 2039. Peak load forecasts for the U.S., Ohio, and the service areas of investor-owned electric distribution utilities (EDUs) operating in Ohio are also presented for the 2020 through 2039 forecast horizon.

1.1 Organization of the Report

In addition to Section 1, INTRODUCTION, the report includes the following sections:

Section 2, SYSTEMIC BACKGROUND AND FORECAST ASSUMPTIONS presents an analysis of certain recurrent and non-periodic historic singularities that have induced sudden, significant, and sustained alterations in economic, demographic, and energy consumption trends in the U.S. and in Ohio. It provides an assessment of the future incidence of such singularities over the 2020-2039 forecast horizon and considers the possible impacts of such

singularities upon the business cycle and energy consumption behavior in Ohio. This section concludes with an overview of the specific assumptions underlying this year's forecasts.

Section 3, PEAK LOAD DEMAND FORECASTS, starts with a presentation of staff's annual peak load forecast for the U.S. Next, the section presents peak load growth forecasts for the service areas in Ohio of the following EDUs: AES Ohio, (Dayton Power and Light Company), Cleveland Electric Illuminating Company, Duke Energy Ohio Inc., Ohio Edison Company, Ohio Power Company, and Toledo Edison Company. Individual service area forecasts mentioned above are then combined with a consolidated forecast for Buckeye Power Inc., American Municipal Power-Ohio Inc. (AMP-Ohio), and Ohio Valley Electric Corporation (OVEC) to obtain a statewide non-coincident peak load demand forecast.

Section 4, THE DEMAND FOR ENERGY BY FUEL TYPE, presents an analysis and assessment of the total demand for each of the fuel types considered in this report (coal, nuclear, and hydro generation; natural gas; and petroleum products) and presents this information in a series of tables and graphs. Total demand for each fuel type is presented by sector (residential, commercial, industrial, transportation, and electric utilities).

Section 5, THE DEMAND FOR ENERGY BY ECONOMIC SECTOR, provides the information presented in Section 4 from a different perspective. Total demand for energy within each economic sector is presented by fuel type.

2.0 SYSTEMIC BACKGROUND AND FORECAST ASSUMPTIONS

Annual accounting time series that follow long-term trends such as income, population, inflation, and energy and peak load demands, change abruptly at or around certain critical points in time, at or during which certain historical shocks, or systemic singularities, are known to have occurred. Among the better-known examples of such systemic singularities are the onset and the conclusion of WWI, WWII, and the Great Depression. More recently, the traumatic fluctuations in crude oil prices between 1973 and 1986, and the surge in crude oil prices since 2003, would also qualify as systemic singularities, albeit of a lower magnitude or intensity. In the process of absorbing, reacting, adjusting, and adapting to such recurrent and non-periodic systemic shocks, or singularities, the world and the U.S. economies display sudden, significant, and sustained fluctuations in the time paths of critical energy and economic trends.

Unless such critical changes are explicitly accounted for during the modeling process, accurate descriptions of the historical behavior of annual accounting time series, such as population, income, inflation, and product price and consumption levels, become problematic. Similarly, if the possibility of future singularities is ignored in the design of long-term forecast scenarios, significant divergences may emerge between the *ex-ante* forecasts and the *ex-post* observations as the forecast horizon is transformed into history through the passage of time.

Figure 2.0.1 and Table 2.0.1 present the behavior of nominal crude oil prices in the U.S. between 1946 and 2019. After a period of near complete stability between 1948 and 1973, crude oil prices in nominal dollars increased over seven-fold, from $4.75/barrel in 1973 to $37.42/barrel in 1980. The surge in the relative price of crude oil was accompanied by manifold increases in the relative prices of all energy inputs. In nominal dollars, the residential price of natural gas in Ohio increased from $1.11/thousand cubic feet (Mcf) in 1973 to over $6.00/Mcf in 1982. Similarly, the price of residential electricity increased from 2.4 cents per kilowatt hour (kWh) in 1973 to 7 cents per kWh in 1982. The price of coal burned by Ohio electric utilities increased from $9.64/ton in 1973 to $40.00/ton in 1982. The surging energy prices contributed to an inflationary spiral that induced two recession-recovery cycles of 1973-1975-1978 and 1978-1982-1984, which, in turn, resulted in lower overall per capita income growth for the 1973-1984 period relative to the 1960-1973 period. The impact of the recession-recovery cycles on real per capita incomes in the U.S. and Ohio are presented in Figure 2.2.1. Inflation-adjusted crude oil prices are presented in Figure 2.0.2.

The surging crude oil prices and declining real per capita incomes reduced the rate of growth of demand for petroleum products. Among other things, demand was also reduced through public and private conservation measures, development and adoption of new and more efficient energy consumption technologies, and the enactment of mandatory efficiency standards. On the supply side, the significantly higher returns to producers encouraged exploration, discovery, and production of crude oil in novel places including the North Sea, Gulf of Mexico, and Alaska. As demand growth declined and supply growth increased, crude oil prices in nominal dollars came down from a peak of $37.42/barrel in 1980 to $14.44/barrel in 1986, a drop of more than 60 percent.

From 1986 to 2003, a new balance was established between the growth in demand for crude oil and the available supplies of crude oil, such that nominal crude oil prices remained below $28/barrel throughout this period. Crude oil prices increased steadily from $27.69/barrel in 2003 to $91.48/barrel in 2008. After falling precipitously from this level as part of the economic recession, crude prices rose once again, averaging $86.73/barrel in 2014.

The price drop of crude oil observed from 2014-2019 can be explained through both supply and demand side market fundamentals. On the supply side, new technologies have made the extraction of shale gas and oil more cost-effective. On the demand side, slow growth in international economies and increased efficiency of end uses have also exerted downward pressure on prices. It is unclear at this time whether the current low prices are more than a temporary phenomenon, and to what extent suppliers will respond to lower prices by curtailing output. Prices have indeed begun to trend upward from the lows of 2016 to the time of the publication of this report.

Staff forecasts presented in this report are designed to take into account the observed impacts of historical singularities upon the prevailing long-term trends in the time path trajectories of the

business cycle, population growth, energy prices, and energy consumption and peak load demand levels.

Trends in the long-term business cycle are defined and measured in terms of trends in the trajectory of growth of real per capita personal income. Population and real per capita personal income characterize the size and the per capita purchasing power of the U.S. and of Ohio as two interdependent economic systems.

The business cycle and energy consumption move in overlapping and interdependent cycles that vary by economic sector and fuel type. For example, demand for electricity in the residential sector is more stable than the demand for electricity in the industrial sector, which is more responsive to swings in the business cycle. In the process of forecasting, the relationships between economic, demographic, and energy trends are identified, analyzed, and assessed. An understanding of their behavior is hypothesized within the context of the past historical singularities and prevailing systemic conditions. Future trends and behavior are projected on the basis of this understanding, operating as a working hypothesis.

Pursuant to the mandate of the Ohio Revised Code, staff has been analyzing, assessing, and forecasting the magnitudes presented in this report for more than 20 years. On the other hand, the future is unknown by definition. Periodic review and updating of past forecasts is a wise and necessary process both to test the validity of the current forecast scenarios, and to identify and monitor emerging alterations in prevailing trends due to changes in the systemic conditions or the impact of more recent historical singularities.

The analytical methodology utilized for the modeling and estimation of historical time path trajectories, and for the development of most forecast scenarios, involves mathematical modeling with a generalized Gompertz spline function as the deterministic model. Generalized Gompertz spline functions are a class of S-curve spline functions through which growth, decline, or recurrent fluctuations over successive intervals of time can be modeled and measured. A multi-normal distribution function is utilized as the stochastic model. The modeling process, the estimation procedures, and the computer programming required for the application of this methodology were developed in-house using SAS computer programming language. An extensive analytical discussion of the methodology was presented in the PUCO publication *Technical Appendix to Ohio Long Term Forecast of Energy Requirements 1995-2015* (PUCO, 1996).

2.1 Demographic Background: Historical Perspective and Forecast Implications

Table 2.1 and Figure 2.1.1 together present the historical behavior of U.S. population growth in terms of four successive trends. The first trend, generally referred to as the "baby boom," begins in 1947 and continues through 1964. From 1965 through 1990, population growth follows a slower growth trend. From 1991 through 2000, growth increases again. A minor downward adjustment to the post-1990 trend is observed in the 2001 through 2019 period. Without

detailing the socioeconomic and political factors influencing the establishment of these trends, staff observes that the average duration of the post-WWII trends in population growth is approximately 20 years. Staff projects a slightly lower growth trend between 2020 and 2039.

The population of the U.S. was 329 million persons in 2019. It is expected to be 350 million in 2029 and 369 million in 2039. The standard error of the forecast is 0.13 percent.

Table 2.1 and Figure 2.1.2 present the historical behavior of population growth in Ohio. In the case of Ohio, a reduction in the post-WWII fast growth trend occurs between 1972 and 1988. This trend represents no population growth, and corresponds to a period of major structural changes in the state's economy, when established traditional manufacturing industries were replaced or restructured under the influence of higher energy input costs induced by the oil price increases of 1973 and 1978, as well as the costs of compliance with the emissions requirements of the Clean Air Act. Beginning in 1989, Ohio population levels display a relatively robust positive growth trend through 1997. Population growth in Ohio slows in a discernable manner between 1998 and 2019. Staff expects this population growth trend to prevail through the forecast time horizon.

The population of Ohio was 11.7 million persons in 2019. In 2039, it is expected to be around 12 million. The standard error of the forecast is 0.18 percent.

2.2 Macroeconomic Background: Historical Perspective and Forecast Implications

Table 2.1 and Figure 2.2.1 document the dynamic behavior of real per capita personal income growth in Ohio and the United States. It is clear that Ohio closely follows the national pattern. The difference between the two patterns is increasing over time.

It is clear by inspection of Figure 2.2.1 that the growth in real per capita personal income per year does not follow a smooth trajectory over time. It follows a trajectory characterized by consecutive recession and recovery phases of the long-term business cycle. The dynamic behavior of real per capita personal income is an important determinant of expenditures on goods and services in general. It is, therefore, an important determinant of the dynamic behavior of demand for energy resources as well. Consequently, accurate analyses and assessments of the historical dynamics of growth in peak load and energy resource demands require accurate analyses and assessments of the historical dynamics of the long-term business cycle and its impact upon the trajectories of growth.

Although the timing, duration, intensity, and the precipitating cause of each long-term recession recovery cycle may be different and manifold, it is nevertheless a matter of historical fact that any consecutive 20-year period depicted in Figure 2.2.1 includes at least two recession recovery cycles of one sort or another. Based upon this fact, staff anticipates a cyclical event of mild to moderate intensity and duration between 2020 and 2039. The first recessionary phase of the forecast business cycle is associated with the economic recession that began in 2008 and the slow recovery that followed and the economic downturn associated with the COVID-19

pandemic. Another mild to moderate business cycle is projected with a recessionary phase starting in 2024 and lasting through 2026, and a recovery phase starting in 2027 and lasting through the end of the forecast horizon.

The forecasts presented in this report consider the anticipated developments in the national and international economic environment and try to assess their impact on Ohio. The forecasts are consistent with historical reality. On the other hand, the forecasts are not prophetic proclamations. They are simply attempts to provide a consistent and informed characterization of what is likely to happen. The future will always include pleasant and unpleasant surprises, as well as precedent and unprecedented developments. It is therefore essential to monitor as early as possible the macroeconomic and microeconomic developments in Ohio, the U.S., and the world at large, to detect significant deviations in actual versus predicted energy consumption patterns and in actual versus predicted economic and demographic growth patterns.. The system theoretical forecasting models utilized by staff are inherently equipped to perform this monitoring duty effectively and efficiently so that forecast scenarios may be similarly modified in a timely manner.

The future size and duration of U.S. budget and foreign trade deficits should also be closely monitored due to its possible impacts upon the business cycle. A failure to address unsustainable structural and financial conditions at the national or international level could fundamentally alter the incidence and magnitude of the business cycles projected in this report. This, in turn, would similarly alter the energy forecast trajectories presented herein.

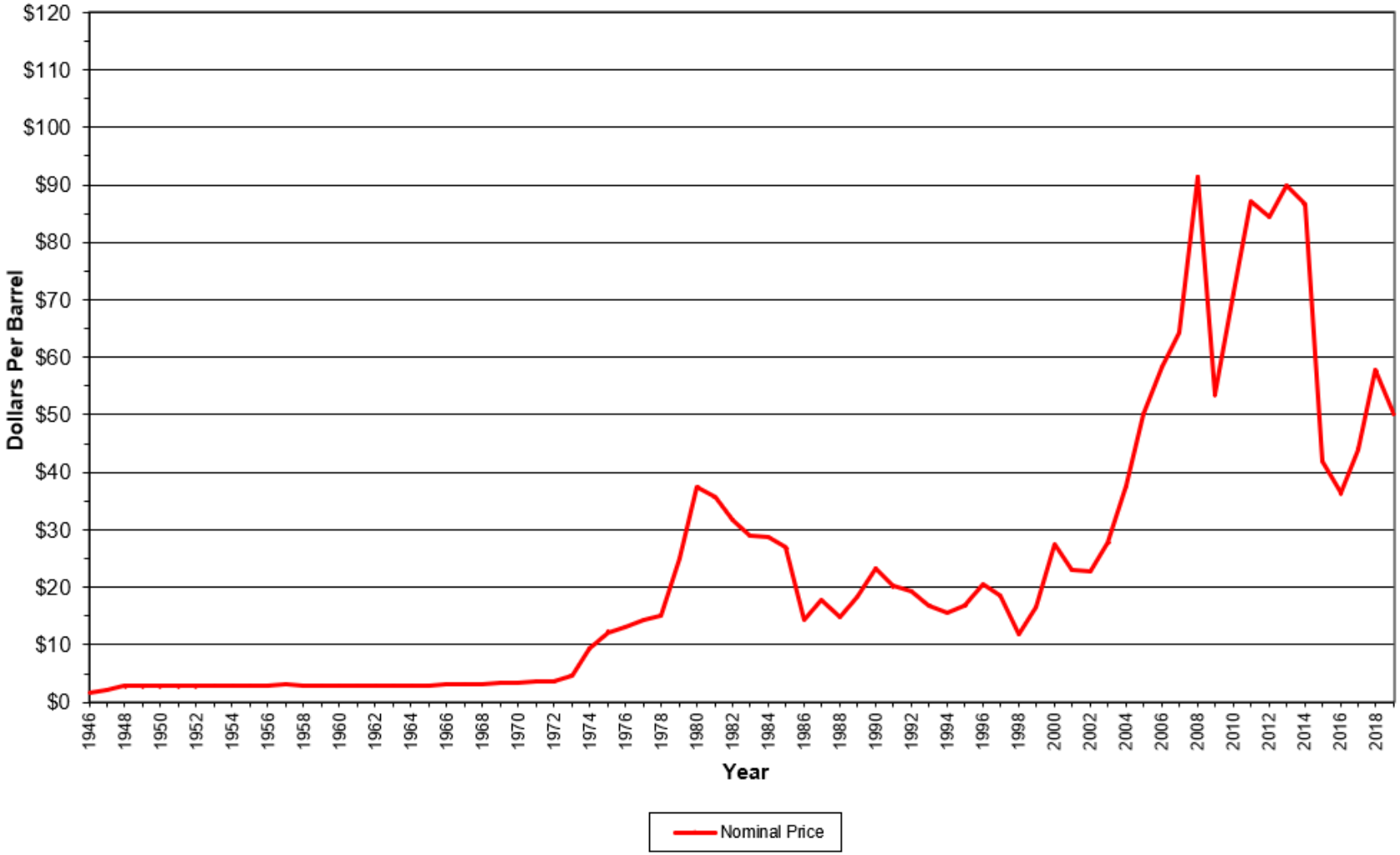
Table 2.0.1 – Domestic Crude Oil Prices (1946 - 2019)

Year	Domestic Crude Oil Prices in Nominal Dollars Per Barrel[1]	Domestic Crude Oil Prices in 1982 Dollars Per Barrel[2,3]
1946	$1.63	$8.35
1947	$2.16	$9.67
1948	$2.77	$11.51
1949	$2.77	$11.62
1950	$2.77	$11.51
1951	$2.77	$10.67
1952	$2.77	$10.44
1953	$2.92	$10.92
1954	$2.99	$11.13
1955	$2.93	$10.95
1956	$2.94	$10.82
1957	$3.14	$11.16
1958	$3.00	$10.38
1959	$3.00	$10.30
1960	$2.91	$9.83
1961	$2.85	$9.53
1962	$2.85	$9.44
1963	$2.91	$9.51
1964	$3.00	$9.68
1965	$3.01	$9.56
1966	$3.10	$9.57
1967	$3.12	$9.34
1968	$3.18	$9.14
1969	$3.32	$9.05
1970	$3.39	$8.74
1971	$3.60	$8.89
1972	$3.60	$8.61
1973	$4.75	$10.70
1974	$9.35	$18.97
1975	$12.21	$22.70
1976	$13.10	$23.02
1977	$14.40	$23.76
1978	$14.95	$22.93
1979	$25.10	$34.57
1980	$37.42	$45.41
1981	$35.75	$39.33
1982	$31.83	$32.98
1983	$29.08	$29.20
1984	$28.75	$27.67
1985	$26.92	$25.02
1986	$14.44	$13.18
1987	$17.75	$15.63
1988	$14.87	$12.57
1989	$18.33	$14.78
1990	$23.19	$17.74
1991	$20.20	$14.83
1992	$19.25	$13.72
1993	$16.75	$11.59
1994	$15.66	$10.57
1995	$16.75	$10.99
1996	$20.46	$13.04
1997	$18.64	$11.61
1998	$11.91	$7.31
1999	$16.56	$9.94
2000	$27.39	$15.91
2001	$23.00	$12.99
2002	$22.81	$12.68
2003	$27.69	$15.05
2004	$37.66	$19.94
2005	$50.04	$25.62
2006	$58.30	$28.92
2007	$64.20	$30.97
2008	$91.48	$42.49
2009	$53.48	$24.93
2010	$71.21	$32.65
2011	$87.04	$38.68
2012	$84.46	$36.79
2013	$89.84	$38.56
2014	$86.73	$36.75
2015	$41.85	$17.66
2016	$36.34	$15.14
2017	$43.96	$17.21
2018	$57.78	$22.14
2019	$50.01	$18.75

Sources:

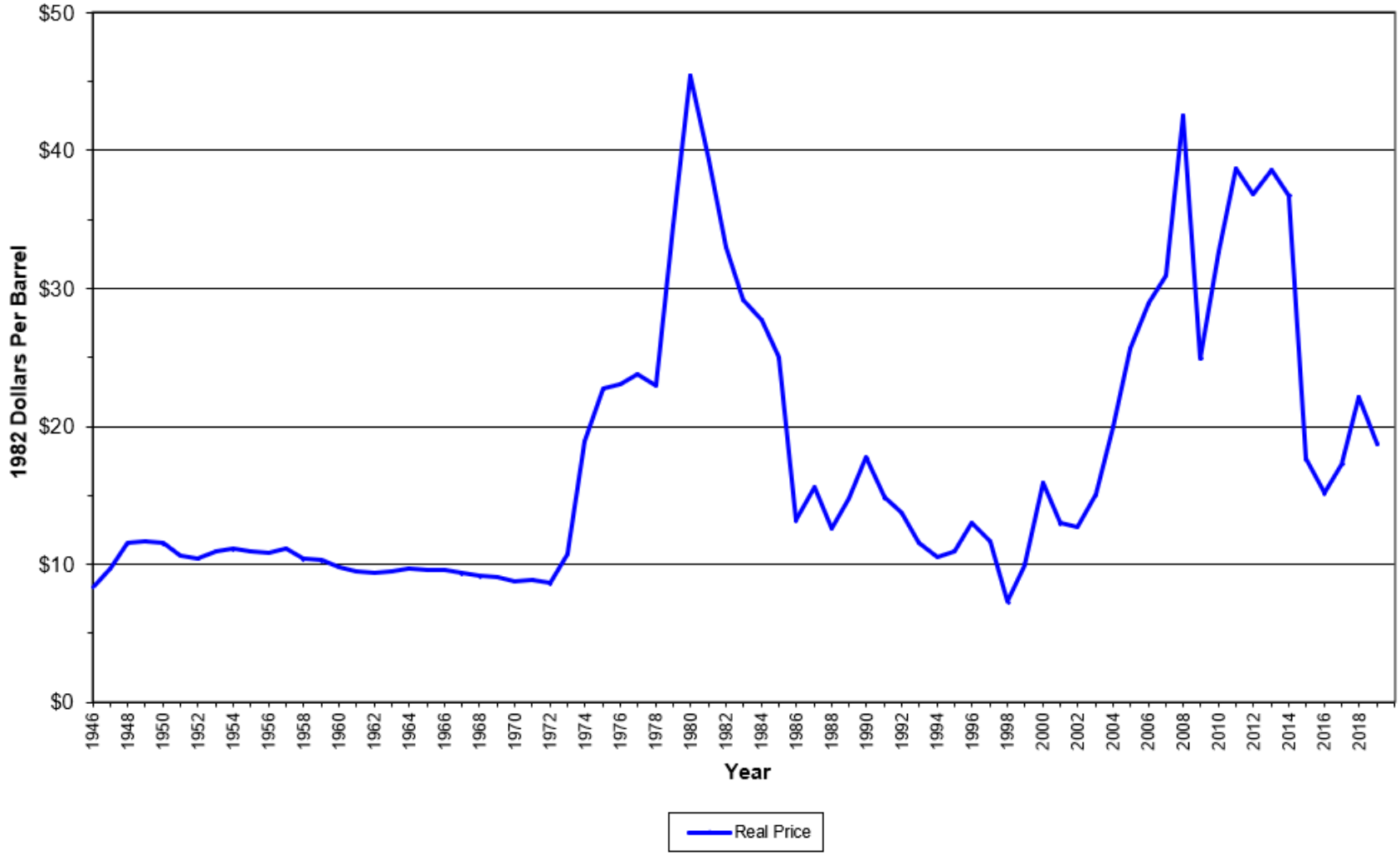
1. Illinois Oil and Gas Association (IOGA)
2. Prices in 1982 Dollars = Nominal Prices divided by CPI-U, 1982-1984 = 1.00
3. CPI-U numbers from Bureau of Labor Statistics

Figure 2.0.1 – Time Path Trajectory of Nominal Domestic Crude Oil Prices (1946 - 2019)



Sources: Illinois Oil and Gas Association (IOGA); Prices in 1982 Dollars = Nominal Prices divided by CPI-U, 1982-1984 = 1.00; CPI-U numbers from Bureau of Labor Statistics

Figure 2.0.2 – Time Path Trajectory of Domestic Crude Oil Prices in 1982 Dollars
(1946 - 2019)



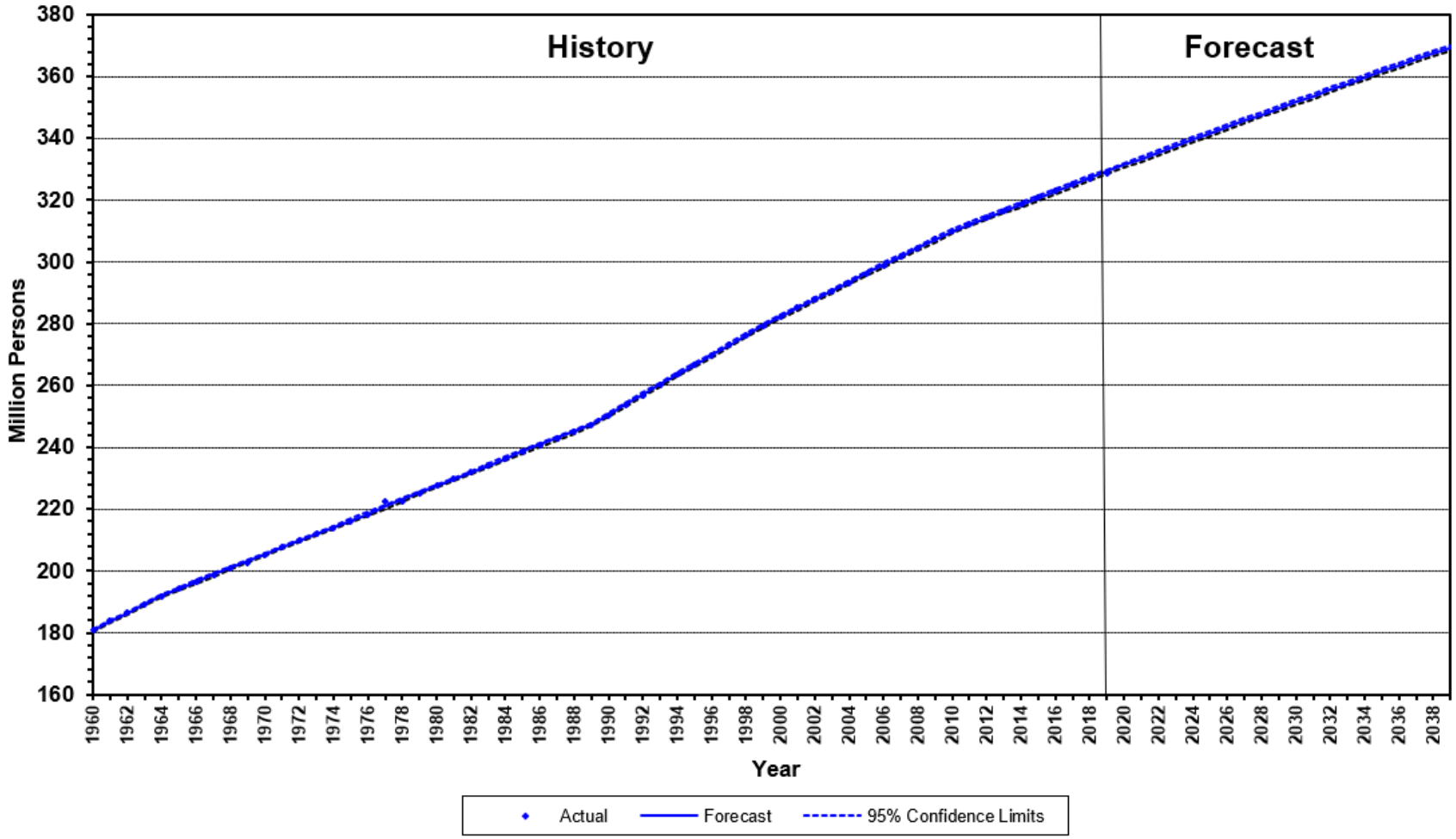
Source: Illinois Oil and Gas Association (IOGA)

Table 2.1 – U.S. & Ohio Population and Real Per Capita Personal Income
(2014 - 2039)

	Year	U.S. Population (million persons)	U.S. Real Per Capita Personal Income (thousand 1982 dollars per capita per year)	Ohio Population (million persons)	Ohio Real Per Capita Person Income (thousand 1982 dollars per capita per year)
-5	2014	319	19.87	11.61	18.05
-4	2015	321	20.67	11.62	18.73
-3	2016	323	20.83	11.64	18.83
-2	2017	325	21.26	11.67	19.09
-1	2018	327	21.74	11.69	19.39
0	2019	329	22.09	11.70	19.62
1	2020	331	22.37	11.71	20.01
2	2021	333	22.75	11.73	20.31
3	2022	335	23.13	11.75	20.61
4	2023	337	23.50	11.76	20.91
5	2024	340	23.88	11.78	21.20
6	2025	342	23.66	11.79	21.08
7	2026	344	23.44	11.81	20.96
8	2027	346	23.82	11.83	21.25
9	2028	348	24.19	11.84	21.54
10	2029	350	24.56	11.86	21.83
11	2030	352	24.93	11.88	22.12
12	2031	354	25.30	11.89	22.41
13	2032	356	25.67	11.91	22.69
14	2033	358	26.03	11.92	22.97
15	2034	360	26.40	11.94	23.25
16	2035	362	26.76	11.96	23.52
17	2036	364	27.12	11.97	23.80
18	2037	365	27.47	11.99	24.07
19	2038	367	27.83	12.00	24.33
20	2039	369	28.18	12.02	24.60
Standard Error of the Forecast		0.13%	1.61%	0.18%	1.13%

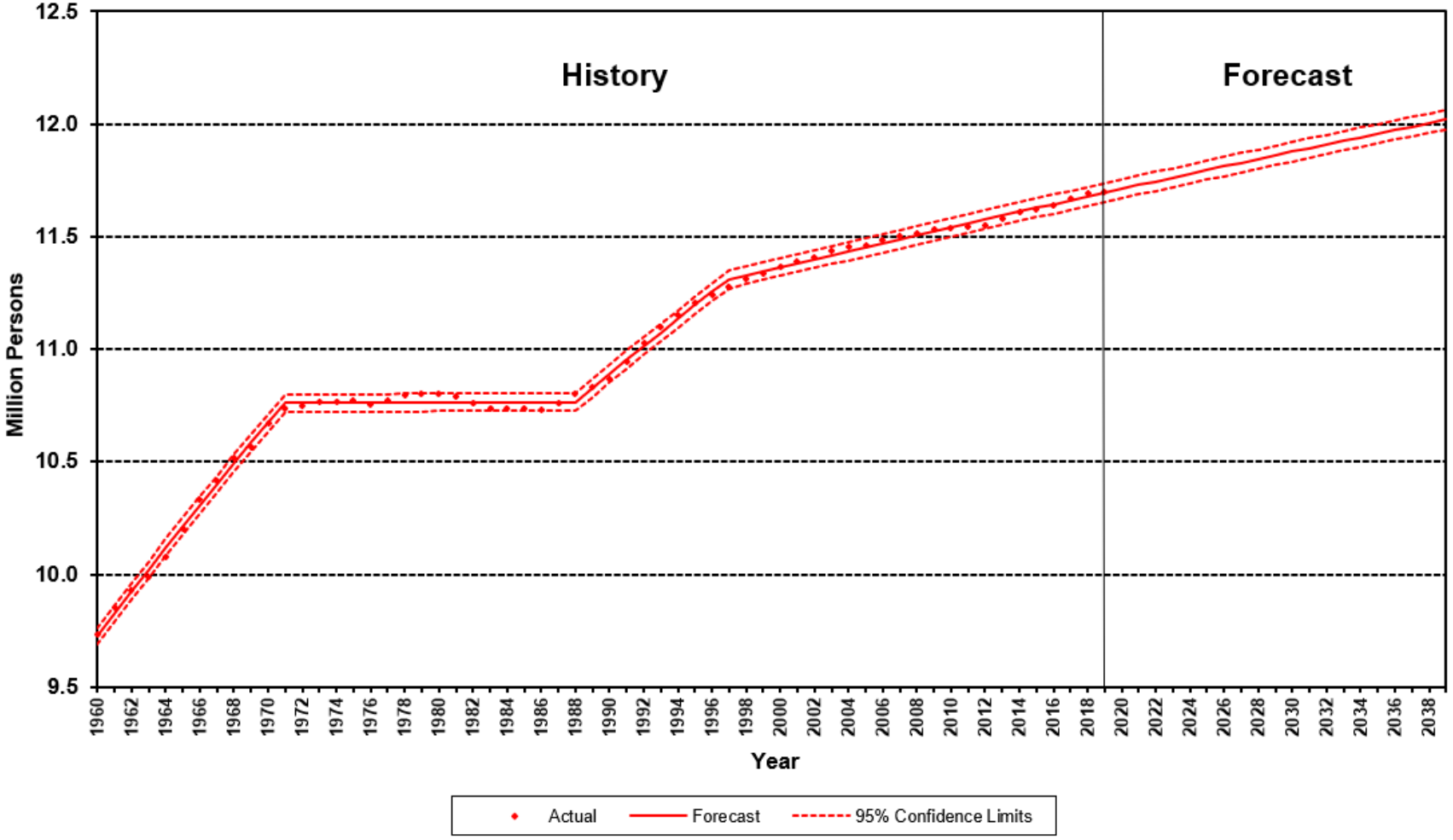
Source: Federal Reserve Economic Database; PUCO, Office of the Federal Energy Advocate

Figure 2.1.1 – Time Path Trajectory of U.S. Population
(1960 - 2039)



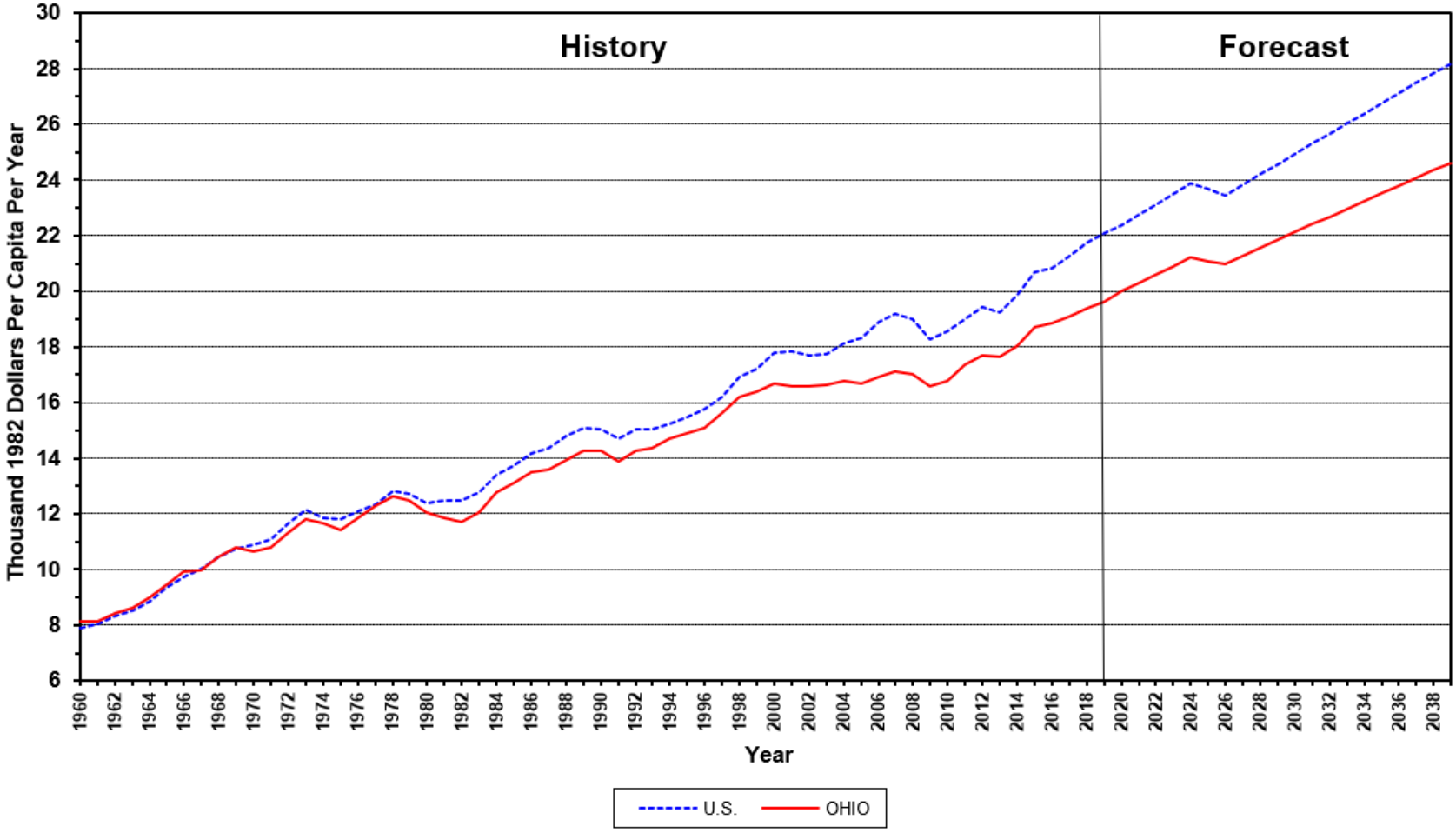
Source: Federal Reserve Economic Database; PUCO, Office of the Federal Energy Advocate

Figure 2.1.2 – Time Path Trajectory of Ohio Population
(1960 - 2039)



Source: Federal Reserve Economic Database; PUCO, Office of the Federal Energy Advocate

Figure 2.2.1 – Time Path Trajectories of U.S. and Ohio Real Per Capita Personal Incomes (1960 - 2039)



Source: Federal Reserve Economic Database; PUCO, Office of the Federal Energy Advocate

3.0 PEAK LOAD DEMAND FORECASTS

In this section, staff presents the annual peak load demand forecasts for the U.S., the non-coincident annual peak load demand forecast for the state of Ohio, and the summer peak load demand forecasts for the service areas of investor-owned EDUs operating in Ohio. The investor-owned EDUs include AES Ohio (Dayton Power and Light Company), Cleveland Electric Illuminating Company, , Duke Energy Ohio Inc., Ohio Edison Company, Ohio Power Company, and Toledo Edison Company. Note that in 2014, Columbus Southern Company and Ohio Power Company merged to become the newly formed Ohio Power Company.

3.1 U.S. Peak Load Forecast

Since 1964, the U.S. has been a summer peaking system. Therefore, since 1964, the U.S. annual peak load is the U.S. summer peak load.

Figure 3.1.1 presents the U.S. per capita annual peak load growth trajectory from 1960 through 2039. The impact of space cooling demand is a major contributing factor to the high growth trend which is visible from 1966 through 1973. The sudden, significant, and sustained reduction in this high growth trend, starting in 1974, is also visible. The increase in oil prices by a factor of five between 1972 and 1979 was the starting point of a series of economic and political repercussions, including higher inflation levels, even higher energy prices, and the implementation of voluntary and mandatory energy conservation measures, standards and policies. All of these factors may have had a share in the establishment of the post-1973 trend in U.S. of lower per capita peak load growth.

What is even more remarkable, from a historical and a practical perspective is the stability of the post-1973 trend. Between 1973 and 2005, neither the deterministic trend nor the standard error of the observations around the trend has changed significantly. However, staff observes that the geopolitical uncertainty and the associated oil price increases experienced since 2004 (in addition to the more recent rapid emergence of energy-efficient lighting e.g., LEDs[1], energy-efficient appliances, and demand-side management) have likely put a downward pressure on the U.S. per capita annual peak demand of electricity and have increased the volatility of the most recent observations through 2015[2]. A mild recession is predicted between 2024 through

[1] According to the Department of Energy, by 2016 over 450 million LEDs had been installed in the United States, up from less than 500,000 in 2009.

[2] The price of oil increased from 2003 until it peaked at $145 per barrel in mid-2008, when the U.S. began to experience a recession and the economy began to falter. The recession spread to the rest of the world. Shortly thereafter, global oil consumption and prices began to collapse, falling to a low of less than $31/barrel. Within a year of the collapse in 2009, a recovery began with the prices of oil ranging from $70 to $85 per barrel.

2026, with the accompanying mild reduction in summer peak load (for both U.S and Ohio). Slow load growth is projected to resume from 2027 to the end of the forecast horizon.

Figure 3.1.2 presents the U.S. annual peak load growth trajectory from 1960 through 2039. It is calculated by multiplying the U.S. per capita annual peak load trajectory presented in Figure 3.1.1, with the U.S. population growth trajectory presented in Figure 2.1.1. Table 3.1 presents the year-by-year forecast magnitudes for the U.S. per capita annual peak load demand, U.S. population, and U.S. annual peak load demand.

U.S. annual peak load demand was 786,165 megawatts (MW) in 2019. It is expected to be 828,8076 MW in 2029 and 911,7507 MW in 2039. The standard error of the forecast is 2.12 percent.

3.2 Peak Load Growth in Ohio

In Ohio, the growth rate of peak load demand has mostly paralleled the growth rate of U.S. peak load demand. Since 1992, the Ohio peak load growth rate has been slowly declining. The non-coincident peak load demand forecast for Ohio in this report still exhibits slightly positive load growth. Additionally, the volatility of the observations has increased. The most drastic volatility has been observed in the years following 2000.

The annual non-coincident peak load demand forecast for Ohio is performed in three stages. In the first stage, annual peak load demands for the six investor-owned utilities operating in Ohio are analyzed and forecast individually. These forecasts are presented in Table 3.2 and Figures 3.2.1 through 3.2.6. It is expected that all companies will be summer-peaking utilities.

In 2019, the non-coincident annual peak load for Ohio's six investor-owned utilities was 25,407 MW. It is expected to be 25,349 MW in 2029 and 26,507 MW in 2039. The standard error of the forecast is 3.1 percent.

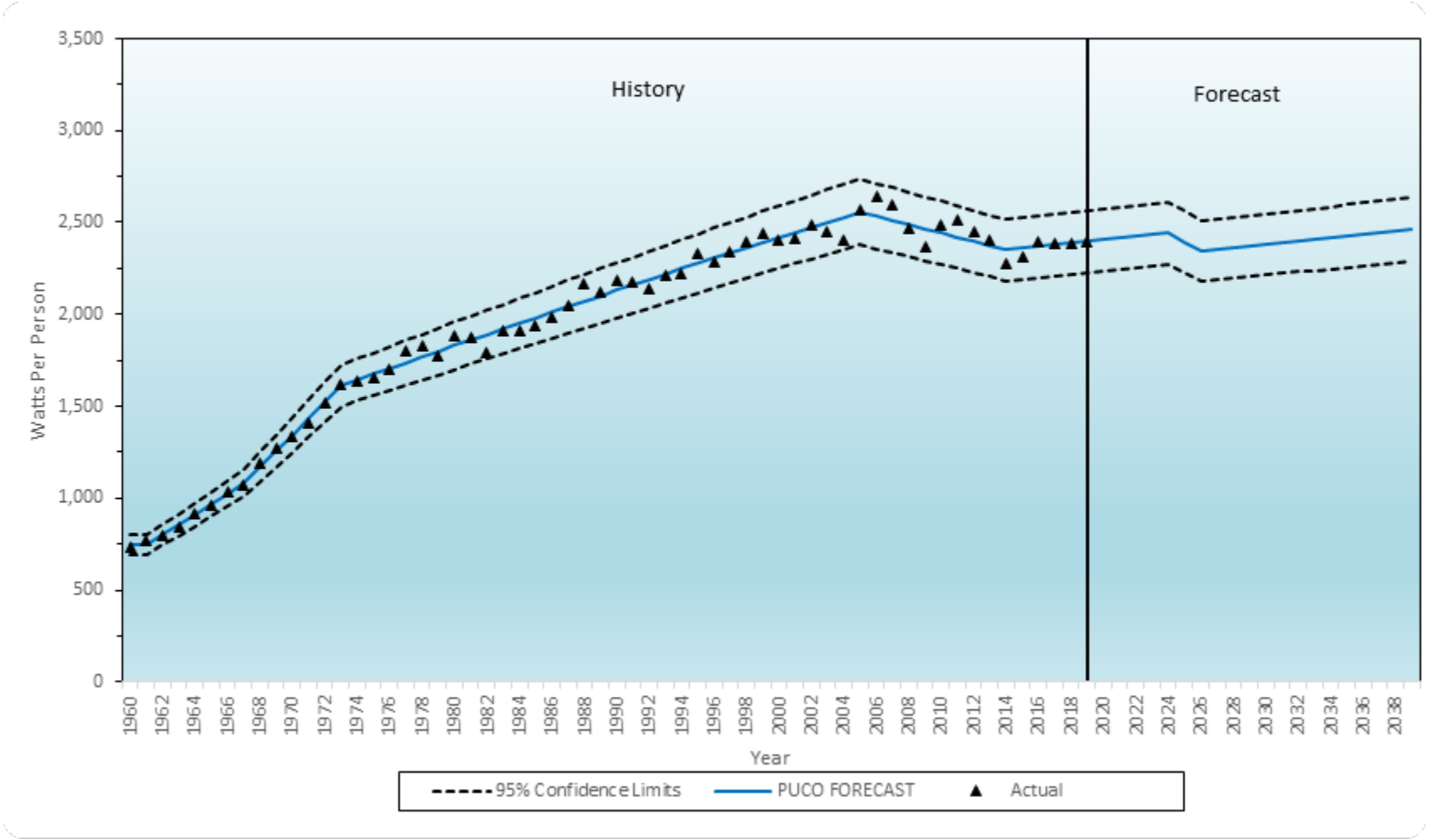
In the second stage, the summer peak load forecasts for Buckeye Power Inc., AMP-Ohio, and OVEC are consolidated into one category called "other."

In 2019, the non-coincident summer peak load for the "other" category was 3,901 MW. It is expected to be 3,831 MW in 2029 and 4,016 MW in 2039. The standard error of the forecast is 3.25 percent.

In the third stage, the peak load forecast for the "other" category is added to the consolidated forecast of the six investor-owned utilities for the total non-coincident annual peak load demand for the state of Ohio. The result is presented on Table 3.2 and Figure 3.2.7.

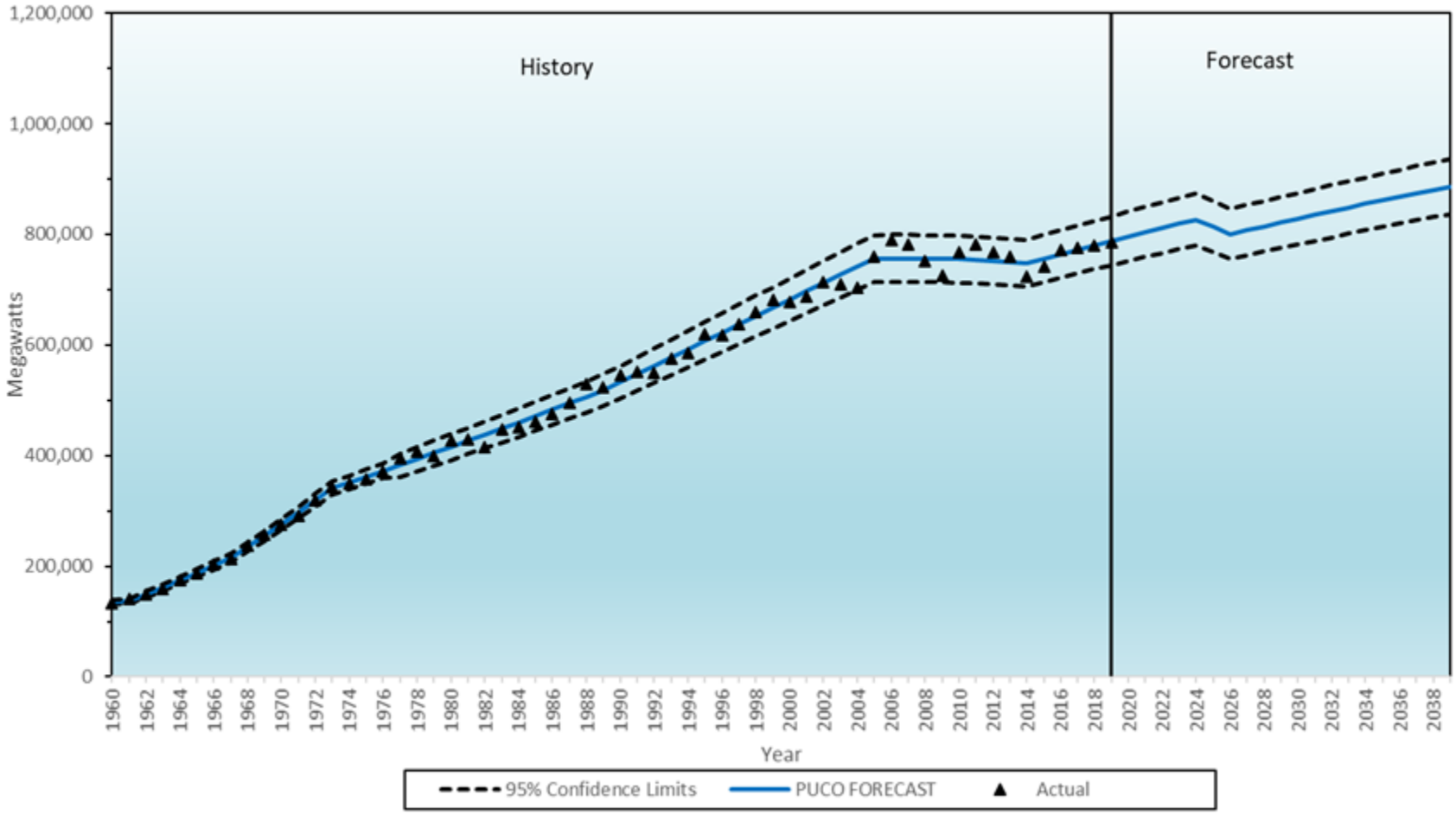
In 2019, the non-coincident summer peak load for the state of Ohio was 29,308 MW. It is expected to be 29,181 MW in 2029 and 30,523 MW in 2039. The standard error of the forecast is 3.0 percent.

Figure 3.1.1 – Time Path Trajectory of U.S. Per Capita Annual Peak Load
(1960 - 2039)



Source: *EEI Statistical Yearbook*; PUCO, Office of the Federal Energy Advocate

Figure 3.1.2 – Time Path Trajectory of U.S. Annual Peak Load
(1960 - 2039)



Source: *EEI Statistical Yearbook*; PUCO, Office of the Federal Energy Advocate

Table 3.1 – U.S. Per Capita Annual Peak Load, Population, and Annual Peak Load (2014 – 2039)

	Year	U.S. Per Capita Annual Peak Load (watts/person)	U.S. Population (million persons)	U.S. Annual Peak Load (megawatts)
-5	2014	2,270	319	724,130
-4	2015	2,309	321	741,000
-3	2016	2,390	323	772,415
-2	2017	2,387	325	776,329
-1	2018	2,384	327	779,446
0	2019	2,393	329	786,165
1	2020	2,406	331	797,035
2	2021	2,416	333	805,342
3	2022	2,426	335	813,664
4	2023	2,436	337	822,002
5	2024	2,446	340	830,352
6	2025	2,393	342	817,446
7	2026	2,340	344	804,155
8	2027	2,350	346	812,359
9	2028	2,360	348	820,575
10	2029	2,370	350	828,807
11	2030	2,380	352	837,053
12	2031	2,390	354	845,312
13	2032	2,400	356	853,582
14	2033	2,410	358	861,865
15	2034	2,420	360	870,153
16	2035	2,430	362	878,455
17	2036	2,439	364	886,766
18	2037	2,449	365	895,087
19	2038	2,459	367	903,417
20	2039	2,469	369	911,750
Standard Error of the Forecast		± 2.1%	± 0.12%	± 2.1%

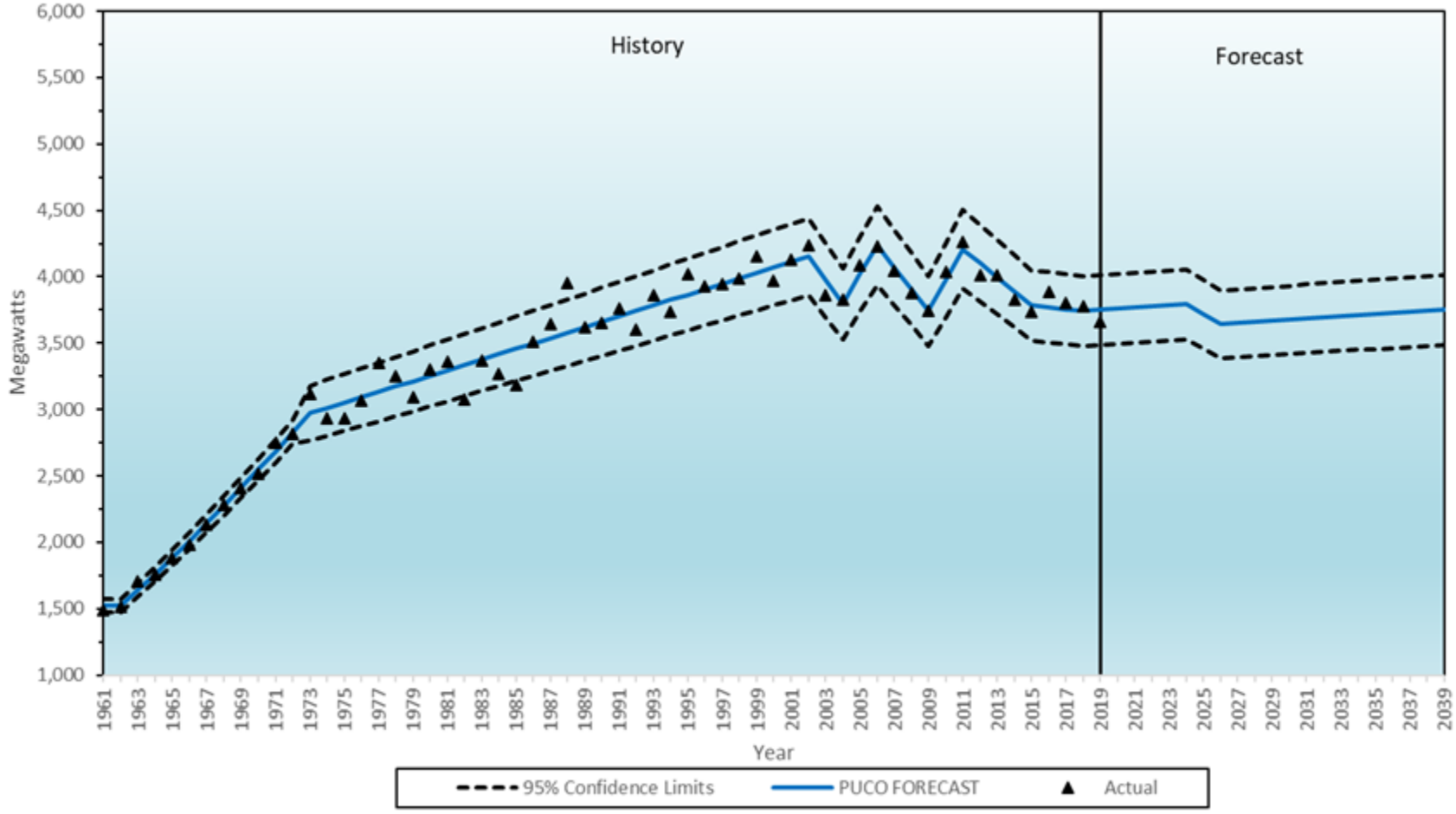
Source: *EEI Statistical Yearbook*; PUCO, Office of the Federal Energy Advocate

Table 3.2 – Annual Peak Load Forecasts for the State of Ohio and its EDU Service Areas
History (2014 – 2019), Forecast (2020 – 2039)
(Megawatts)

	Year (1)	Cleveland Electric Illuminating (2)	Ohio Power Company (3)	AES Ohio (4)	Duke Energy Ohio (5)	Ohio Edison Company (6)	Toledo Edison (7)	Investor-Owned Utility Total (8) ∑((2)-(7))	Other Ohio (9)	State of Ohio total (10) (8)+(9)
-5	2014	3,827	8,255	2,756	4,053	4,858	1,986	25,735	3,702	29,437
-4	2015	3,733	8,485	2,845	4,167	4,979	1,891	26,100	3,668	29,768
-3	2016	3,886	8,685	2,883	4,053	5,126	2,143	26,776	3,826	30,602
-2	2017	3,801	8,349	2,771	4,049	4,466	1,927	25,363	3,766	29,129
-1	2018	3,776	8,599	2,859	4,091	4,842	1,993	26,160	3,784	29,944
0	2019	3,661	8,332	2,804	3,976	4,719	1,915	25,407	3,901	29,308
1	2020	3,760	8,357	2,832	4,038	4,889	1,984	25,860	3,870	29,730
2	2021	3,768	8,416	2,848	4,047	4,905	1,992	25,977	3,889	29,865
3	2022	3,776	8,476	2,863	4,056	4,922	2,000	26,093	3,908	30,000
4	2023	3,785	8,535	2,878	4,064	4,939	2,008	26,209	3,926	30,135
5	2024	3,793	8,594	2,893	4,073	4,956	2,016	26,325	3,944	30,269
6	2025	3,718	8,275	2,836	3,969	4,868	1,997	25,663	3,860	29,524
7	2026	3,642	7,956	2,779	3,864	4,779	1,978	24,998	3,773	28,771
8	2027	3,651	8,015	2,794	3,873	4,796	1,986	25,115	3,792	28,908
9	2028	3,659	8,075	2,810	3,882	4,814	1,993	25,232	3,812	29,044
10	2029	3,667	8,134	2,825	3,891	4,831	2,001	25,349	3,831	29,181
11	2030	3,675	8,193	2,840	3,900	4,848	2,009	25,466	3,851	29,317
12	2031	3,684	8,252	2,856	3,909	4,865	2,017	25,582	3,870	29,452
13	2032	3,692	8,312	2,871	3,918	4,882	2,024	25,699	3,889	29,587
14	2033	3,700	8,371	2,886	3,927	4,899	2,032	25,815	3,907	29,722
15	2034	3,708	8,430	2,901	3,936	4,916	2,039	25,931	3,926	29,857
16	2035	3,717	8,489	2,916	3,945	4,933	2,047	26,046	3,944	29,991
17	2036	3,725	8,549	2,931	3,954	4,949	2,054	26,162	3,962	30,124
18	2037	3,733	8,608	2,945	3,963	4,966	2,062	26,277	3,981	30,258
19	2038	3,741	8,667	2,960	3,972	4,983	2,069	26,392	3,998	30,391
20	2039	3,750	8,727	2,975	3,981	4,999	2,076	26,507	4,016	30,523
Standard Error of the Forecast		± 3.0%	± 3.8%	± 3.3%	± 3.5%	± 5.1%	± 4.5%	± 2.1%	± 3.3%	± 3.0%

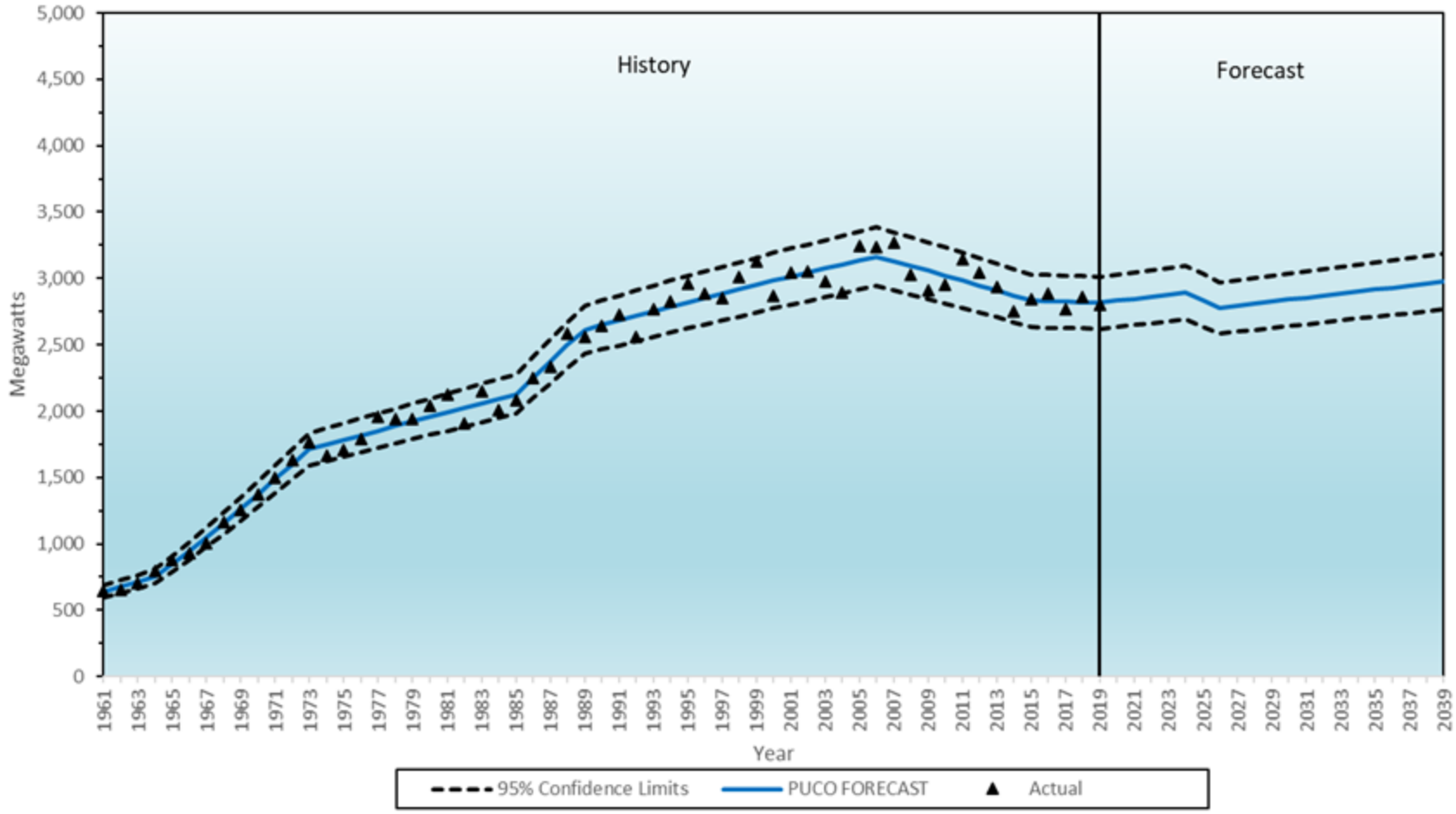
Source: PUCO, Office of the Federal Energy Advocate.
Note 1: Other Ohio includes OVEC, Buckeye Power, and AMP-Ohio. It also includes Ormet for years 1999 – 2006 when Ormet received power from non-Ohio sources.

Figure 3.2.1 – Cleveland Electric Illuminating Company Summer Peak Load
(1961 – 2039)



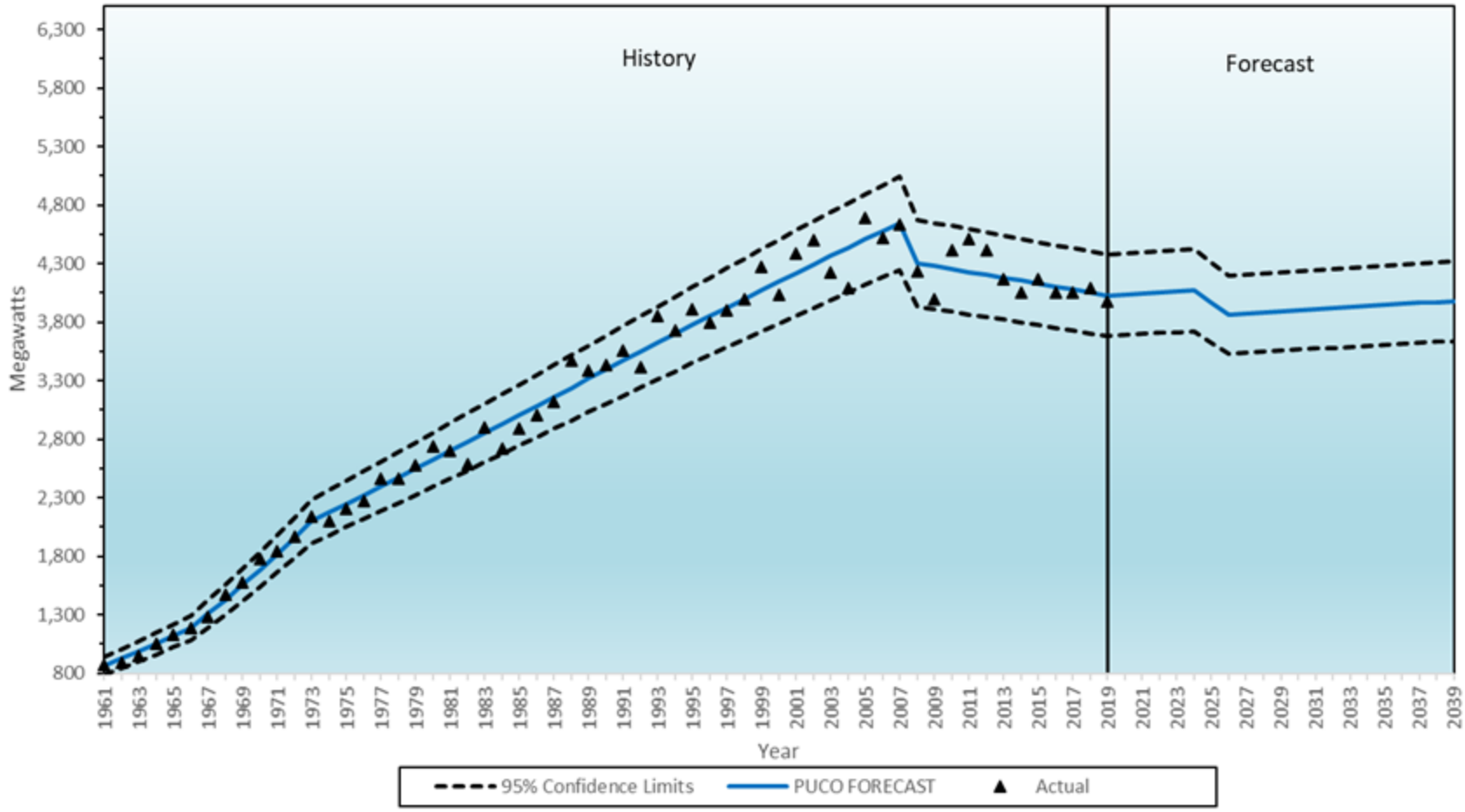
Source: PUCO, Office of the Federal Energy Advocate

Figure 3.2.2 –AES Ohio Summer Peak Load
(1961 – 2039)



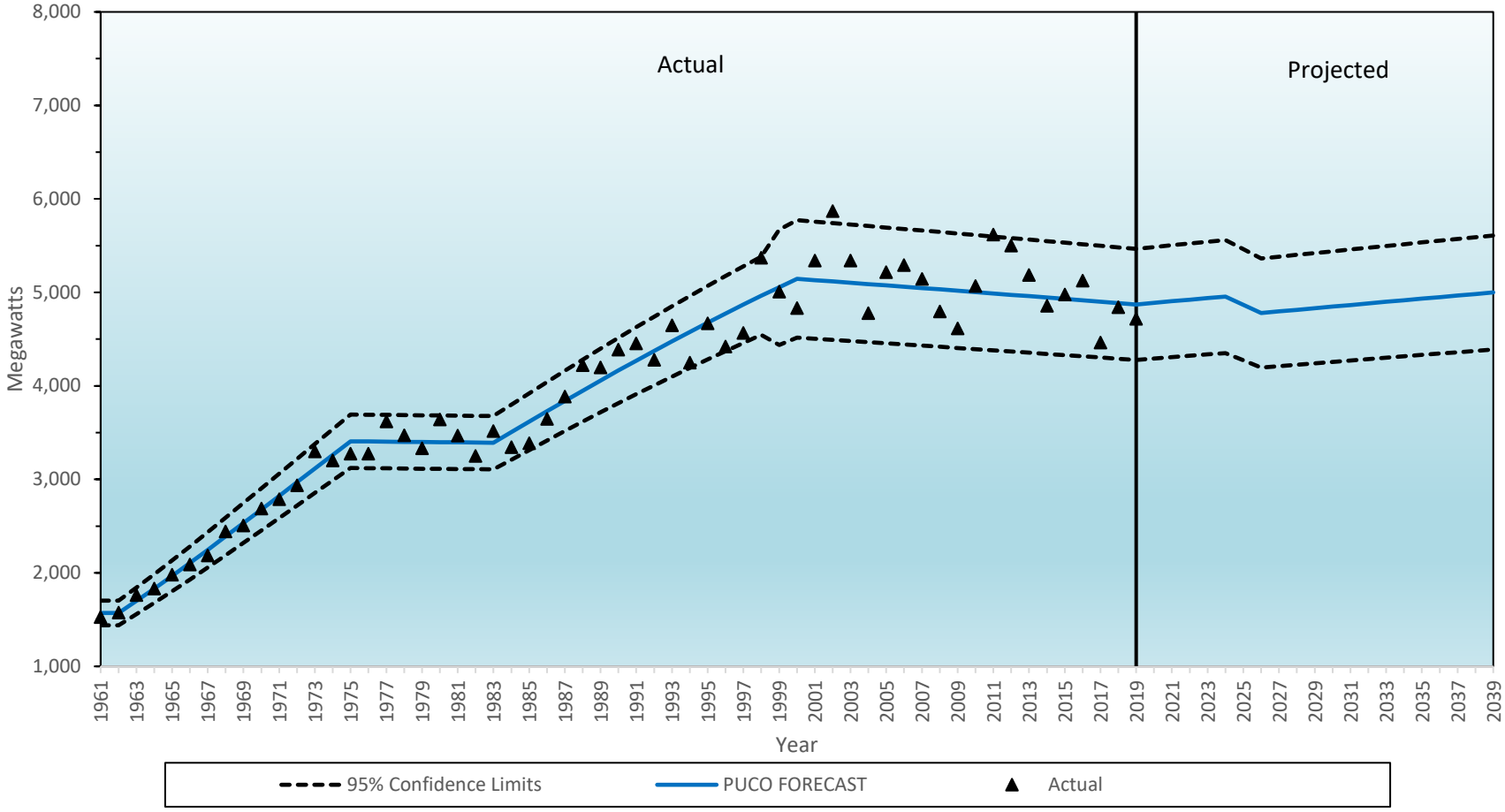
Source: PUCO, Office of the Federal Energy Advocate

Figure 3.2.3 – Duke Energy Ohio Summer Peak Load
(1961 – 2039)



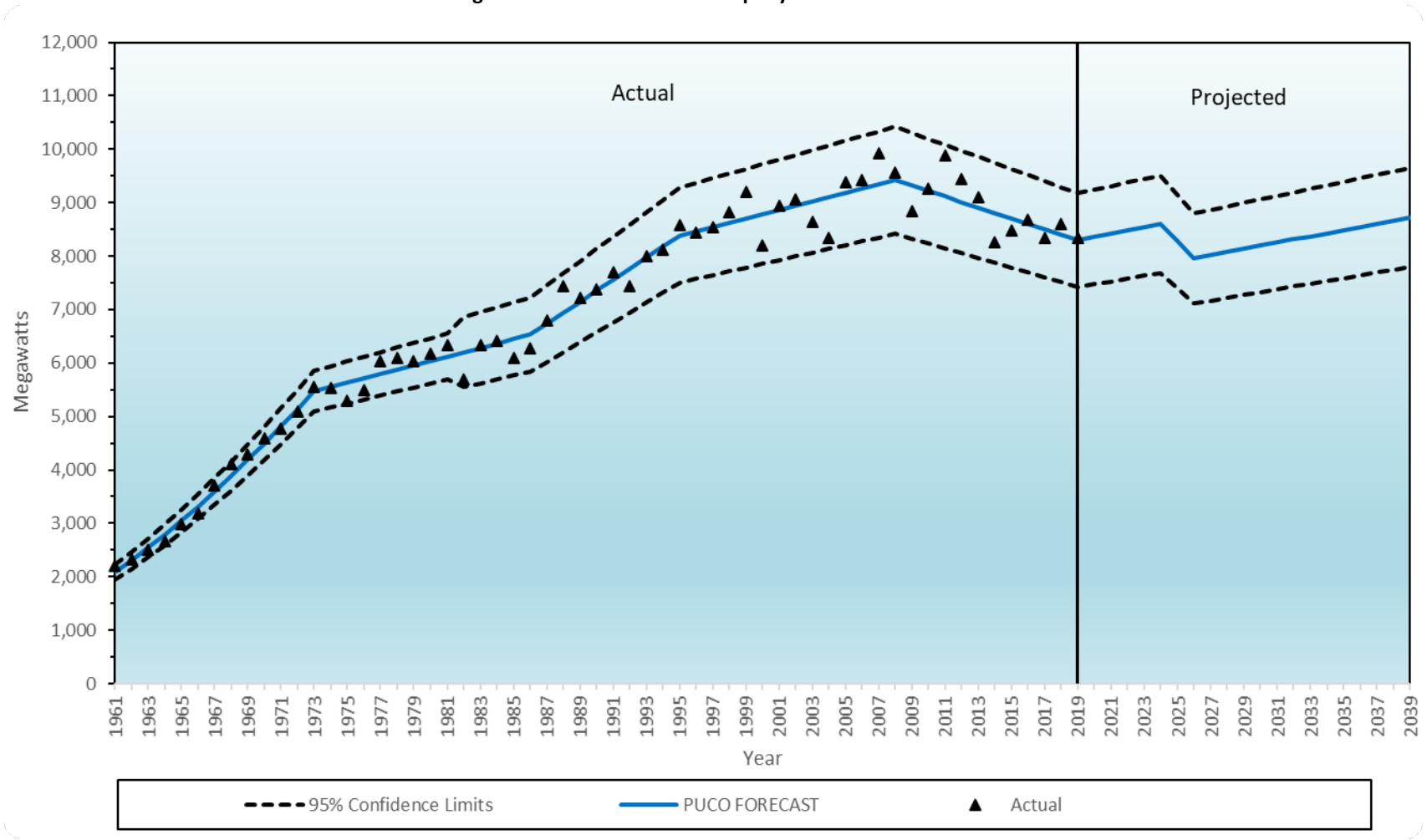
Source: PUCO, Office of the Federal Energy Advocate

Figure 3.2.4 – Ohio Edison Company Summer Peak Load
(1961 – 2039)



Source: PUCO, Office of the Federal Energy Advocate

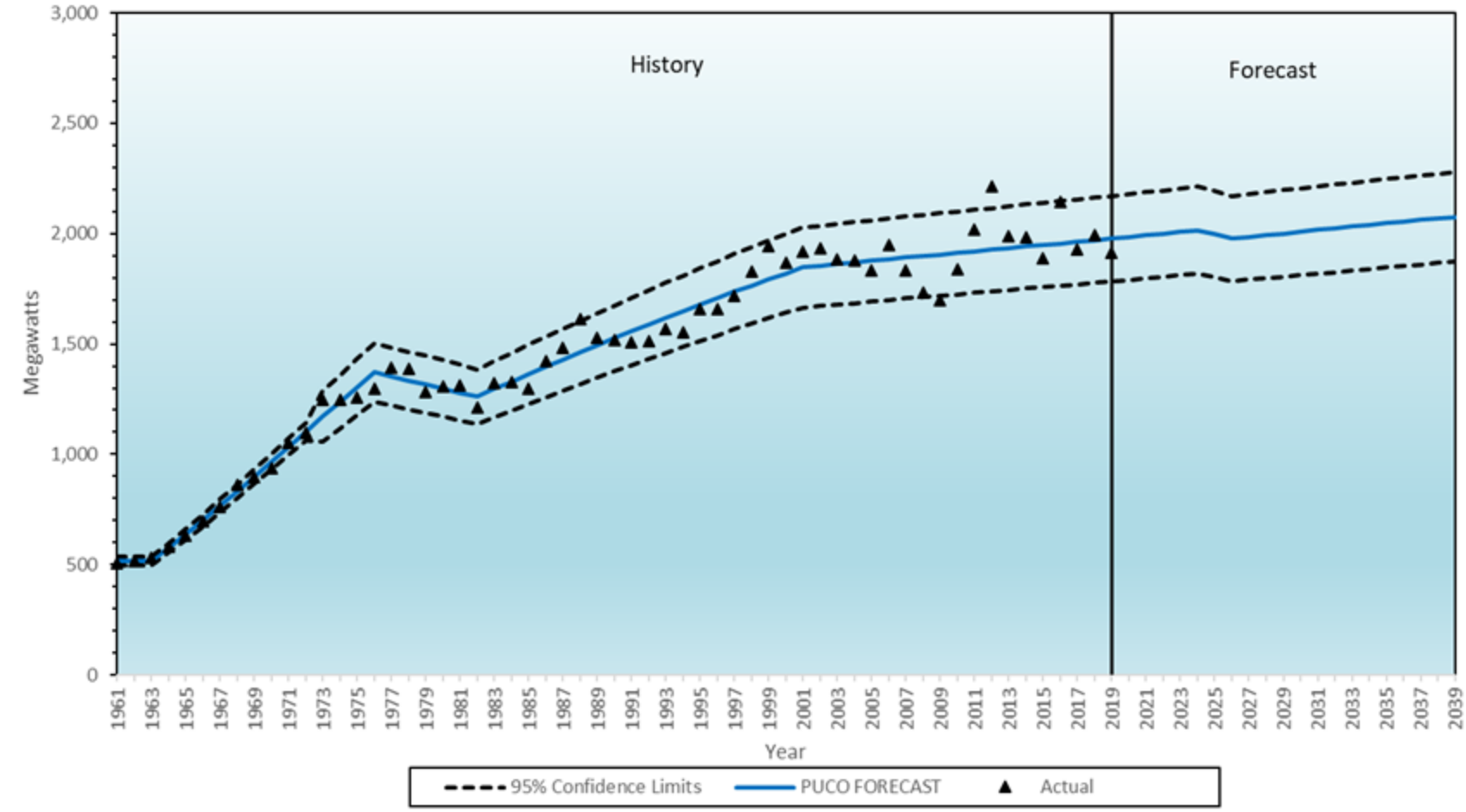
Figure 3.2.5 – Ohio Power Company Summer Peak Load



(1961 – 2039)

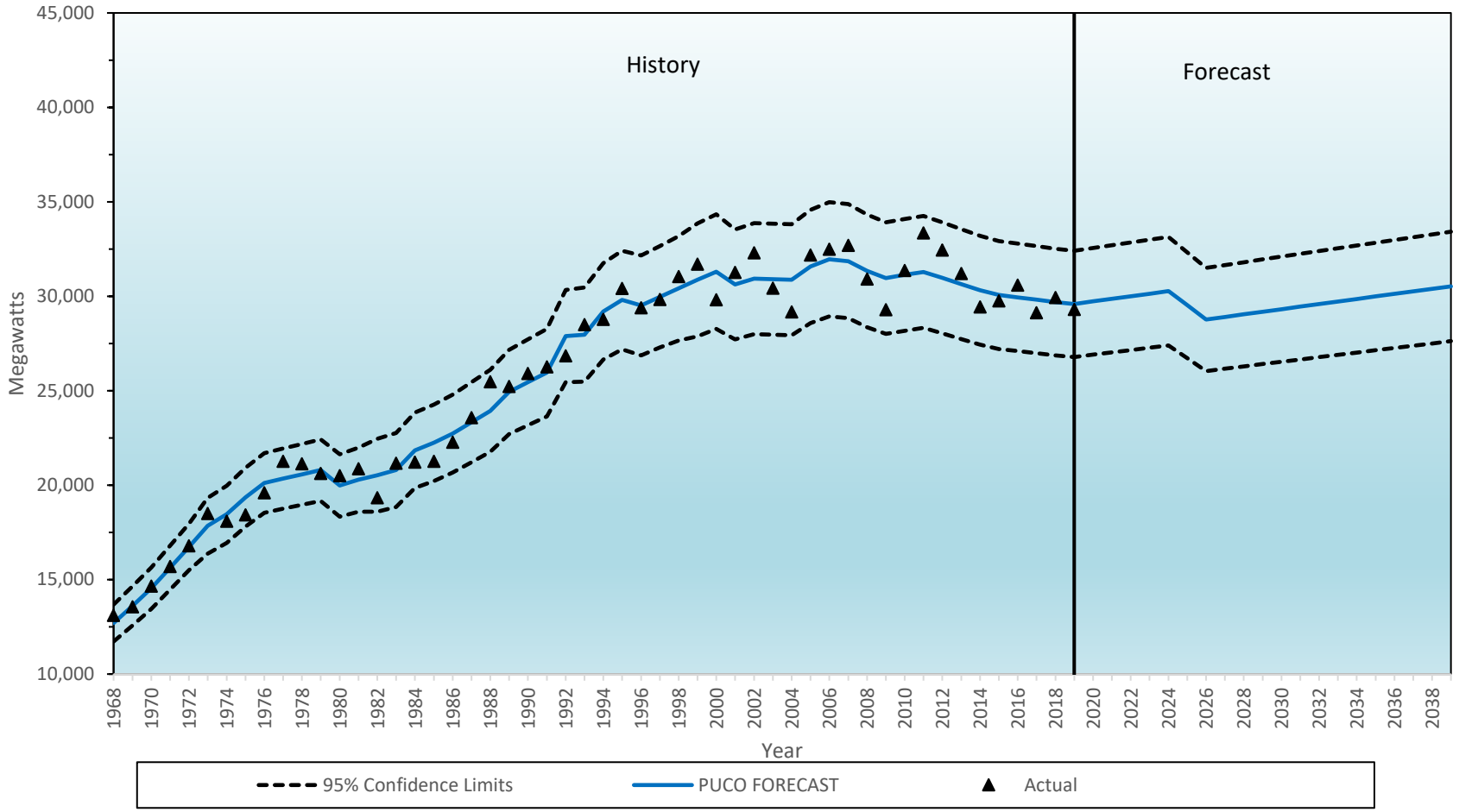
Source: PUCO, Office of the Federal Energy Advocate

Figure 3.2.6 – Toledo Edison Company Summer Peak Load
(1961 – 2039)



Source: PUCO, Office of the Federal Energy Advocate

Figure 3.2.7 – State of Ohio Non-Coincident Internal Annual Peak Load
(1968 – 2039)



Source: PUCO, Office of the Federal Energy Advocate

4.0 THE DEMAND FOR ENERGY BY FUEL TYPE

The composition of total energy requirements in Ohio in terms of primary fuels consumption is presented in Figure 4.0.1 and Table 4.0.1. Historically, growth in energy demand leveled off in Ohio between 1973 and 1978 at around 3,971 trillion British thermal units (TBtu) per year. During the 1979 to 1982 recessionary phase of the business cycle, energy demand declined sharply and bottomed out at 3,248 TBtu in 1983, reflecting in part the predicament of the rust-belt industries in Ohio. It has been increasing slowly but steadily since 1983, with mild to moderate fluctuations reflecting the sensitivity of the industrial sector's demand for energy to the business cycle. Demand for energy in Ohio, in terms of primary fuels consumption, declined slightly from 2008 through 2010, in tandem with the recessionary phase of the latest business cycle. It is projected to continue to grow slowly with the anticipated economic recovery from 2017 through 2020. Another mild to moderate recession is predicted between 2024 through 2026 with the accompanying mild reduction in energy consumption. Slow growth is projected to resume from 2027 to the end of the forecast horizon.

The estimates for TBtu were derived by converting the forecast of physical units consumed into energy content. For coal, the conversion factor is a projection based on the historic trend in the heat content of coal consumed in Ohio. That historical trend was adjusted to account for the expected impact of recent U.S. EPA rules, such as the Mercury Air Toxics Standard, on the electric generation industry, which may result in a slightly higher average heat content of coal consumed in Ohio going forward.

In 2019, the demand for energy from primary fuels in Ohio was 3,074.8 TBtu. It is expected to be 3,251.6 TBtu in 2024, and 3,327.1 TBtu in 2039. The standard error of the forecast is 3.0 percent.

4.1 Electricity

Electricity requirements in Ohio by sector are presented in Figure 4.1.1 and Table 4.1.1. The historical fluctuations in industrial demand in response to the business cycles are easily discernable in Figure 4.1.1. In the latest business cycle, the industrial load growth experienced a sharp decline beginning in 2008 but only lasting through 2009, declining from 58.6 million megawatt hours (MWh) to 49.5 million MWh due to recessionary pressure (see footnote 2 on page 14.) Since 2009, industrial electricity demand in Ohio has experienced modest recovery from the recessionary pressure that occurred in 2008 with demand rising from 49.5 million MWh in 2009 to 53.4 million MWh in 2012. From 2017 to 2019, electricity demand in Ohio experienced a decline of 4.1 million MWh. Industrial electricity demand is projected to continue to grow slowly along the forecast timeline with some fluctuation due to the projected business cycle, and the anticipated fluctuations in crude oil price levels. The slight growth in electricity demand is expected due to historic trends in the industrial sector. However, a mild recession is

anticipated between 2024 through 2026, with the accompanying mild reduction in energy consumption. Slow growth is projected to resume from 2027 to the end of the forecast horizon.

Industrial sector demand for electricity was 46.6 million MWh in 2019. Industrial sector demand for electricity is expected to be 50.8 million MWh in 2024, 46.4 million MWh in 2027, and 50.3 million MWh in 2039. The standard error of the forecast is 4.5 percent.

The commercial sector demand for electricity has experienced slow but steady growth since 1995. Electricity consumption growth in the commercial sector is expected to remain positive throughout the forecast horizon, as the number of commercial enterprises and employment in the commercial sector is expected to continue to grow over the forecast horizon. The magnitude of growth will be influenced by the impact of the projected business cycles, and the anticipated fluctuations in crude oil price levels.

Commercial sector demand for electricity was 46.5 million MWh in 2019. It is expected to be 47.2 million MWh in 2024, 47.4 million MWh in 2027, and 47.9 million MWh in 2039. The standard error of the forecast is 1.67 percent.

The residential sector demand for electricity in Ohio has declined slightly from 2007 to 2019. However, staff expects slight growth going forward throughout the forecast horizon.

Residential sector demand for electricity was 52.4 million MWh in 2019. It is expected to be 52.7 million MWh in 2024, 52.9 million MWh in 2027, and 53.6 million MWh in 2039. The standard error of the forecast is 2.4 percent.

Total end use demand for electricity was 145.5 million MWh in 2019. It is expected to be 150.7 million MWh in 2024, 146.7 million MWh in 2027, and 151.8 million MWh in 2039. The standard error of the forecast is 2.3 percent.

4.2 Coal

Energy requirements for coal by sector are presented in Figure 4.2.1 and Table 4.2.1. The generation of electricity currently accounts for 83.1 percent of the coal consumption in Ohio in 2019. In 2019, coal consumption in the electricity generation sector of Ohio was 19.6 million short tons. It is expected to be 21.0 million short tons in 2024, 19.1 million short tons in 2024, and 16.8 million short tons in 2039. The standard error of the forecast is 5 percent.

It should be noted that staff, in preparing the forecasts for this report, accounted for generation retirements that have been announced in the PJM market and some generation that has already deactivated due to a combination of low natural gas prices and the cost of retrofits required by environmental rules. Staff has adjusted the coal consumption forecast for the electricity generation sector to reflect those announced coal-fired generation deactivations. As of March 2021, there are no additional coal deactivations announced in Ohio.

Industrial sector coal consumption, both as coking coal and in other industrial utilizations, has declined from a historical peak of 29.8 million short tons in 1970 to 0.4 million short tons in 2019. The decline of the traditional iron and steel mills and the requirements of the Clean Air Act are among the contributors to the historic decline of coal consumption in the industrial sector. However, the coking coal sector has grown slightly in recent years and that growth is expected to continue into at least the near future. A steady trajectory of growth in overall industrial coal consumption is projected to continue throughout the forecast horizon due to the growth of coking coal. Industrial sector coal consumption is expected to be 5.1 million short tons in 2039. The standard error of the forecast is 39.65 percent.

Coal consumption in the residential and the commercial sectors is virtually nonexistent and is expected to remain that way throughout the forecast horizon. Additionally, coal consumption in the residential sector is trivial; therefore, it is not included in this report.

Total demand for coal was 23.58 million short tons in 2019. It is expected to be 23.16 million short tons in 2024, and 20.92 million short tons in 2039. The standard error of the forecast is 4.64 percent.

4.2.1 Nuclear and Hydro

The energy requirements for electricity generated by nuclear and hydroelectric stations are included in Table 4.0.1. Since there are no readily available measures of the energy resource inputs that go into nuclear or hydro generation (for example, pellets of radioactive fuel or cubic feet of water), staff imputes the energy input requirements of nuclear and hydro generation in terms of the additional amount, and the British thermal unit (Btu) content, of the coal that would be required to replace the kWh generated by nuclear and hydro generators with coal-fired generation.

Nuclear and hydro stations generated 17.5 million MWh in 2019. They are projected to generate 18.05 million MWh by 2039. This projection assumes that the Davis-Besse and Perry nuclear power stations will continue to operate at current levels through the forecast horizon..

4.3 Natural Gas

Sectoral natural gas requirements in Ohio are presented in Figure 4.3.1 and Table 4.3.1. Natural gas usage peaked in 1972 at 1,181 billion cubic feet. The market price of natural gas rose in tandem with the oil prices s in the 1970s. However, federal price controls at the wellhead for natural gas to be used in interstate commerce led to supply shortages in the volumes of natural gas that were actually available for interstate commerce. Consequently, in Ohio, which depended upon interstate supplies for more than 90 percent of its natural gas requirements, base allocations of natural gas were curtailed for commercial and industrial customers, and new customer hookups were banned for residential customers between 1973 and 1978. The Natural Gas Policy Act of 1978 gradually deregulated the wellhead price of natural gas between 1978 and 1985.

The increasing price of natural gas and restrictions on availability led to declines in demand in all sectors between 1973 and 1985. Technological improvements that led to higher efficiencies in natural gas burning appliances, widespread insulation of new and existing buildings, and governmental policies to encourage energy conservation were among the means through which these reductions in demand were realized. The increasing price of natural gas also led to increased investment in exploration and improved recovery methods which, in turn, led to more abundant supplies, and dampened further price increases from 1985 to until 2006 where shale gas exploration brought prices much lower in Ohio.

Between 1985 and 1996, natural gas demand increased in the commercial and industrial sectors and increased very slowly in the residential sector. Since 1996, commercial and industrial natural gas demand in Ohio has been declining slowly but steadily. In all sectors, the sensitivity of demand to weather conditions is significant.

Staff projects that commercial, and industrial demand for natural gas will be influenced by fluctuations in the phases of the forecast business cycle. Demand for natural gas is forecast to increase most dramatically in the electric utilities sector, as fuel switching occurs for purely economic reasons and in response to fixed costs associated with regulation. Growth in natural gas consumption is tempered, however, by increased adoption of energy efficiency measures, most notably in the residential sector, where per capita consumption is expected to continue its modest decline over time.

Residential sector natural gas demand was 290.1 billion cubic feet (Bcf) in 2019. It is expected to be 253.0 Bcf in 2024, 248.1 Bcf in 2027, and 228.3 Bcf in 2039. The standard error of the forecast is 5.4 percent.

Commercial sector natural gas demand was 177.4 Bcf in 2019. It is expected to be 164.0 Bcf in 2024, 161.3 Bcf in 2027, and 161.7 Bcf in 2039. The standard error of the forecast is 5.0 percent.

Industrial sector natural gas demand was 298.2 Bcf in 2019. It is expected to be 320.0 Bcf in 2024, 319.1 Bcf in 2027, and 363.3 Bcf in 2039. The standard error of the forecast is 4.7 percent.

Electric utility sector natural gas demand was 361.9 Bcf in 2019, which is more than six times the demand from 2010. A large portion of this increase can be explained by the multiple additions of natural gas electric generating capacity around the state of Ohio. Additionally, growth can be explained by the fact that natural gas electric generation costs less than most other options of electricity; therefore, plants within the PJM wholesale electric marketplace operate more often. The electric utility sector natural gas demand is expected to be 472.3 Bcf in 2024, 477.9 Bcf in 2027, and 500.5 Bcf in 2039. Forecast adjustments were made in years 2019 through 2021 representing expected new natural gas combined-cycle power plants coming into operation, as well as potential additions to the capacities of existing natural gas-fired power plants. Staff made adjustments in the forecast to account for all additional natural gas combined-cycle power plants that are certificated by the Ohio Power Siting Board and are expected to be operating by

2021 (OPSB, n.d.). For the purposes of forecasting natural gas consumption, new natural gas combined-cycle plants are assumed to operate at a 70 percent capacity factor. Uncertainty around whether these plants actually progress from certification to completion, and in what year, also represents a significant source of forecast error. The standard error of the forecast is 12.6 percent.

Natural gas demand has also been increasing in Ohio's transportation sector. Transportation sector natural gas demand was 30.0 Bcf in 2019. It is expected to be 29.7 Bcf in 2024, 30.1 Bcf in 2027, and 31.6 Bcf in 2039. The standard error of the forecast is 8.3 percent. The transportation historical data is acquired from the U.S. Energy Information Administration (EIA); therefore, the EIA definition for natural gas transportation also applies to this forecast. That definition includes both commercial vehicle demand as well as natural gas pipeline compressor station demand. Due to recent shale gas activity and commercial fleet vehicle conversion projects, natural gas demand has increased significantly in this sector. This trend is expected to continue into at least the near future as shale gas activity continues to expand and vehicle conversion projects are planned.

Total natural gas demand was 1,157.6 Bcf in 2019. It is expected to be 1,238.9 Bcf in 2024, 1,236.5 Bcf in 2027, and 1,285.4 Bcf in 2039. The standard error of the forecast is 4.0 percent.

4.4 Petroleum Products

Demand for petroleum products by sector is presented in Figure 4.4.1 and Table 4.4.1. In 2019, 78.7 percent of the total demand for petroleum products was generated by the transportation sector, and 14.6 percent was generated by the industrial sector. The remaining 6.7 percent was used by the residential, commercial, and electricity generation sectors combined.

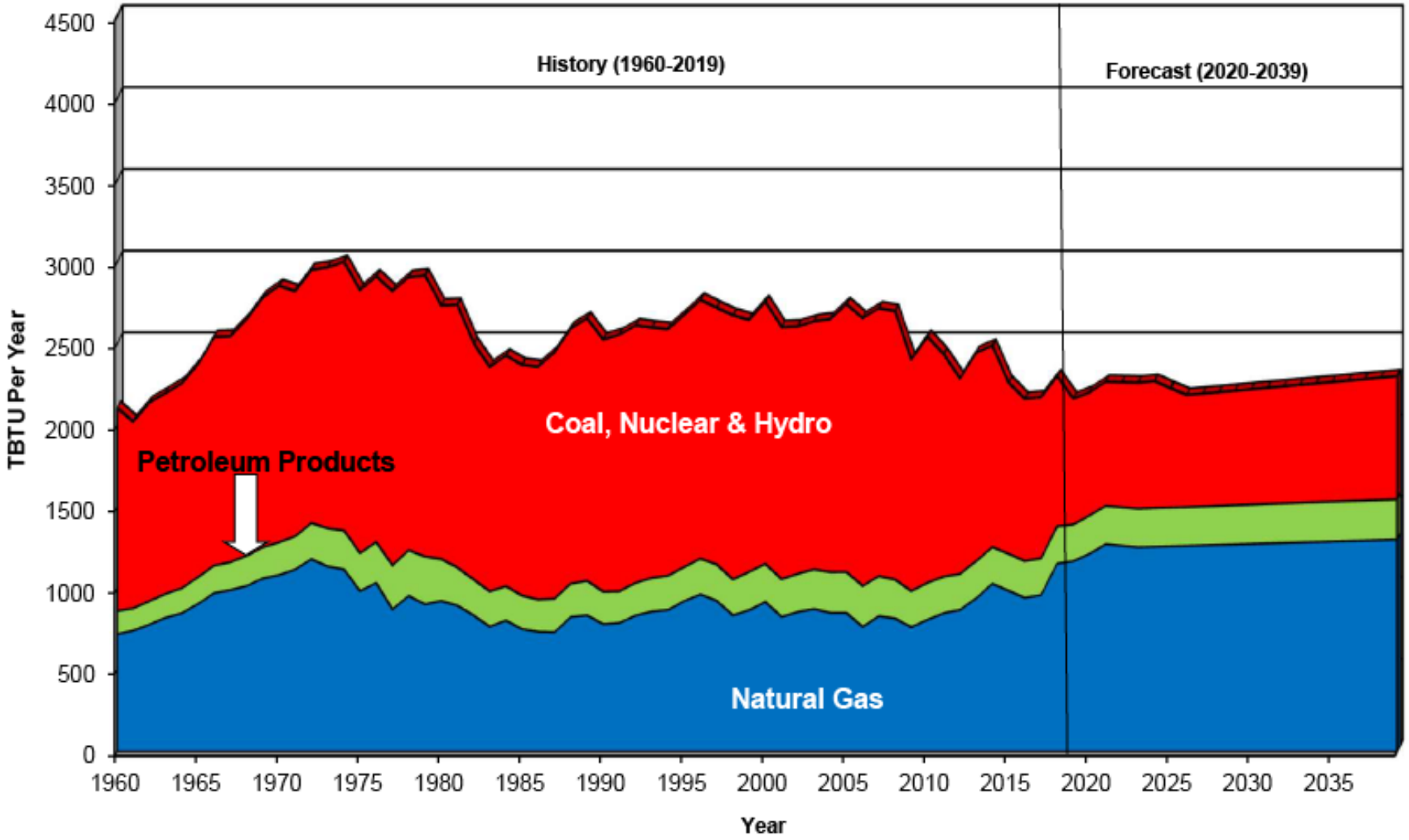
Petroleum products consumption in Ohio peaked at 250 million barrels in 1978. Between 1978 and 1983, in response to the higher crude oil and finished product prices, as well as the prevailing economic recession at the time, petroleum products consumption declined to 185 million barrels. Since 1983, petroleum products consumption levels in Ohio have increased slowly along a trajectory that fluctuates in response to the phases of the business cycle and temporary changes in crude oil prices. High crude prices and the accompanying economic slowdown resulted in significant declines in petroleum products consumption in Ohio from 2008 to 2019. A milder downturn in petroleum products consumption is anticipated from 2025 through 2027. The projections of petroleum consumption in the transportation sector have also been trending downwards in response to the Corporate Average Fuel Economy (CAFE) standards established by the Energy Independence and Security Act of 2007. Stringent CAFE standards together with government incentives for fuel efficient vehicles in the United States have accelerated the recent production of electric vehicles.

Transportation sector demand for petroleum products was 166.575 million barrels in 2019. It is expected to be 175.087 million barrels in 2025, 174.766 million barrels in 2027, and 177.147 million barrels in 2039. The standard error of the forecast is 1.59 percent.

Industrial sector demand for petroleum products was 29.5 million barrels in 2019. It is expected to be 32.916 million barrels in 2025, 33.878 million barrels in 2027, and 39.646 million barrels in 2039. The standard error of the forecast is 4.8 percent.

Total demand for petroleum products in Ohio was 211.207 million barrels in 2019. It is expected to be 223.232 million barrels in 2025, 223.89 million barrels in 2027, and 232.144 million barrels in 2039. The standard error of the forecast is 1.74 percent.

Figure 4.0.1 – Total Energy Requirements in Ohio
(1960 – 2039)



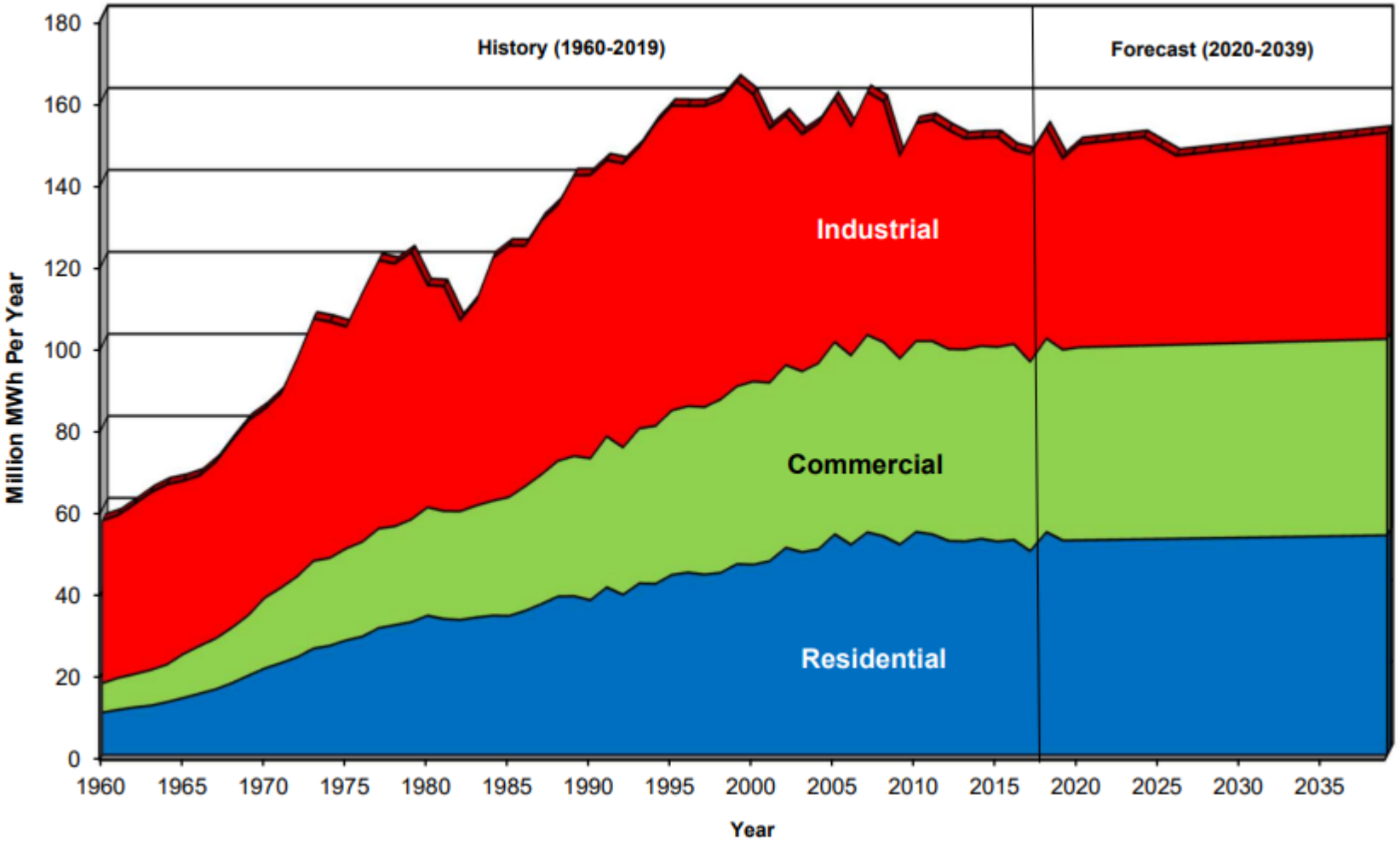
Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Table 4.0.1 – Summary of Total Energy Requirements in Ohio by Primary Fuel Types
History (2014 – 2019), Forecast (2020 – 2039)
Trillion British Thermal Units per Year

	Year	Natural Gas	Petroleum Products	Coal	Total Fossil Fuel	Nuclear &[1] Hydro	Total
-5	2014	1029.4	224.8	1,055.4	2,309.6	176.0	2,485.6
-4	2015	987.1	227.2	858.3	2,072.6	187.3	2,259.9
-3	2016	944.0	224.5	810.4	1,978.9	181.9	2,160.7
-2	2017	960.4	225.0	797.3	1,982.8	188.7	2,171.4
-1	2018	1153.5	229.2	720.8	2,103.5	194.9	2,298.4
0	2019	1168.5	224.8	587.2	1,980.5	181.3	2,161.8
1	2020	1214.3	233.9	566.7	2,014.9	185.7	2,200.5
2	2021	1272.8	235.1	572.0	2,079.9	185.9	2,265.7
3	2022	1263.2	236.2	577.4	2,076.8	186.1	2,262.9
4	2023	1253.6	237.3	582.8	2,073.7	186.3	2,260.0
5	2024	1256.6	238.4	588.2	2,083.2	186.5	2,269.7
6	2025	1259.6	238.1	541.8	2,039.4	186.7	2,226.1
7	2026	1262.5	237.8	497.8	1,998.0	186.9	2,184.9
8	2027	1265.5	238.7	502.5	2,006.7	187.1	2,193.8
9	2028	1268.4	239.7	507.2	2,015.3	187.3	2,202.6
10	2029	1271.4	240.5	512.0	2,023.9	187.5	2,211.4
11	2030	1274.3	241.4	516.9	2,032.6	187.7	2,220.3
12	2031	1277.3	242.1	521.7	2,041.1	187.9	2,229.0
13	2032	1280.2	242.9	526.6	2,049.7	188.1	2,237.8
14	2033	1283.1	243.6	531.6	2,058.3	188.3	2,246.6
15	2034	1286.1	244.2	536.5	2,066.8	188.5	2,255.3
16	2035	1289.0	244.8	541.5	2,075.4	188.7	2,264.1
17	2036	1291.9	245.4	546.6	2,083.9	188.9	2,272.8
18	2037	1294.8	245.9	551.7	2,092.4	189.1	2,281.6
19	2038	1297.7	246.4	556.8	2,100.9	189.3	2,290.3
20	2039	1300.6	246.9	562.0	2,109.5	189.5	2,299.0
Standard Error of the Forecast		± 3.98%	± 2.03%	± 4.64%	± 3.35%	±10%	± 5.54%

Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.
Note 1: This category represents the energy associated with the additional coal inputs that would be required if nuclear and hydro generation were to be replaced by coal-fired generation.

Figure 4.1.1 – Electricity Requirements in Ohio
(1960 – 2039)



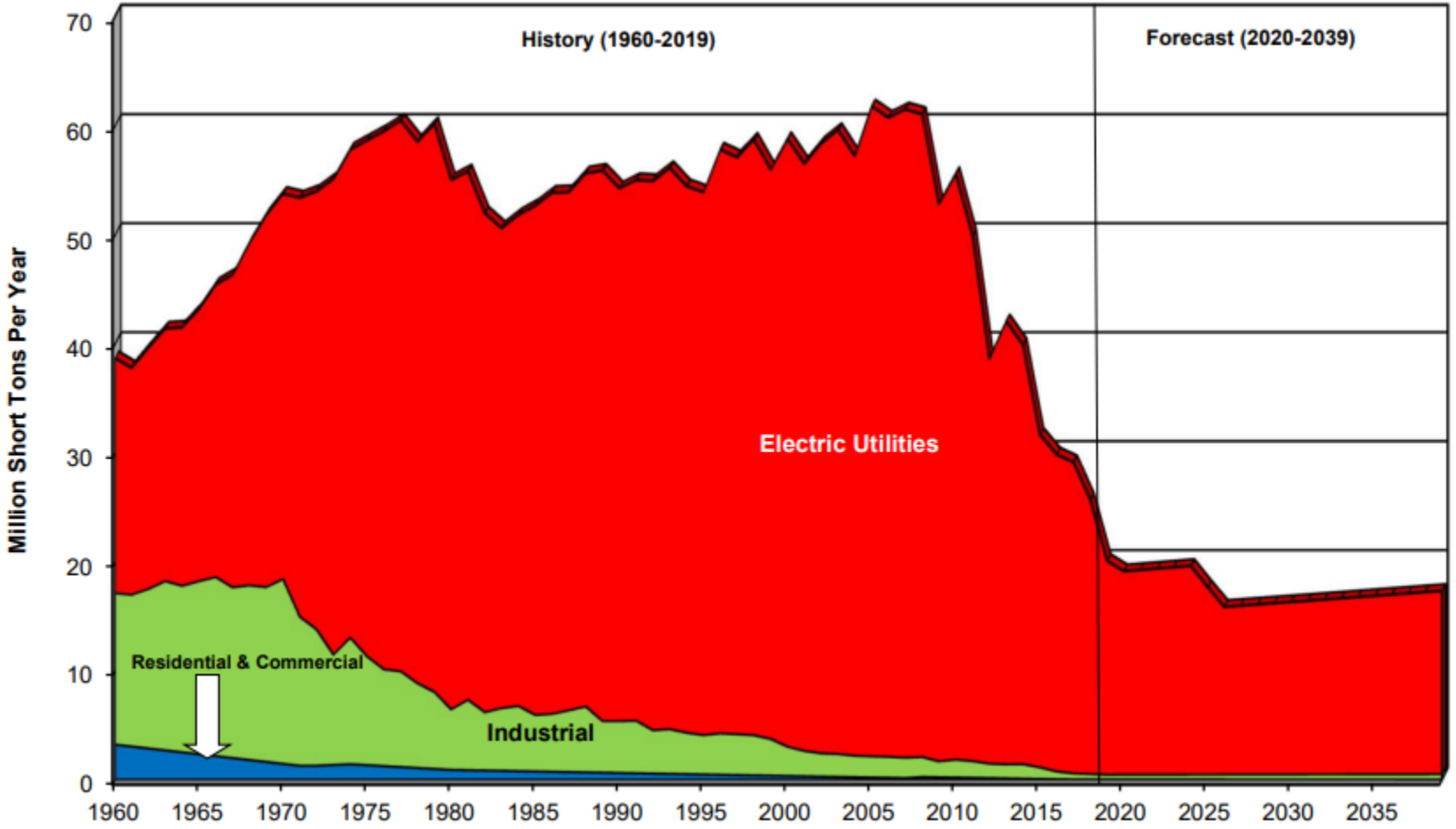
Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Table 4.1.1 – Summary of Electricity Requirements in Ohio by End Use Sectors
History (2014 – 2019), Forecast (2020 – 2039)
Million Megawatt-hours per Year

	Year	Residential	Commercial	Industrial	Total
-5	2014	52.8	47.0	50.8	150.6
-4	2015	52.1	47.5	51.1	150.7
-3	2016	52.5	47.8	47.3	147.6
-2	2017	49.8	46.2	50.7	146.6
-1	2018	54.5	47.2	51.2	152.9
0	2019	52.4	46.5	46.6	145.5
1	2020	52.4	47.1	49.5	149.0
2	2021	52.5	47.1	49.8	149.4
3	2022	52.6	47.1	50.2	149.9
4	2023	52.6	47.2	50.5	150.3
5	2024	52.7	47.2	50.8	150.7
6	2025	52.7	47.3	48.5	148.5
7	2026	52.8	47.3	46.1	146.2
8	2027	52.9	47.4	46.4	146.6
9	2028	52.9	47.4	46.7	147.1
10	2029	53.0	47.4	47.1	147.5
11	2030	53.1	47.5	47.4	147.9
12	2031	53.1	47.5	47.7	148.4
13	2032	53.2	47.6	48.0	148.8
14	2033	53.3	47.6	48.4	149.2
15	2034	53.3	47.7	48.7	149.7
16	2035	53.4	47.7	49.0	150.1
17	2036	53.4	47.8	49.3	150.5
18	2037	53.5	47.8	49.7	151.0
19	2038	53.6	47.8	50.0	151.4
20	2039	53.6	47.9	50.3	151.8
Standard Error of the Forecast		± 2.40%	±1.67%	± 4.5%	± 2.34%

Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Figure 4.2.1 – Coal Requirements in Ohio
(1960 – 2039)



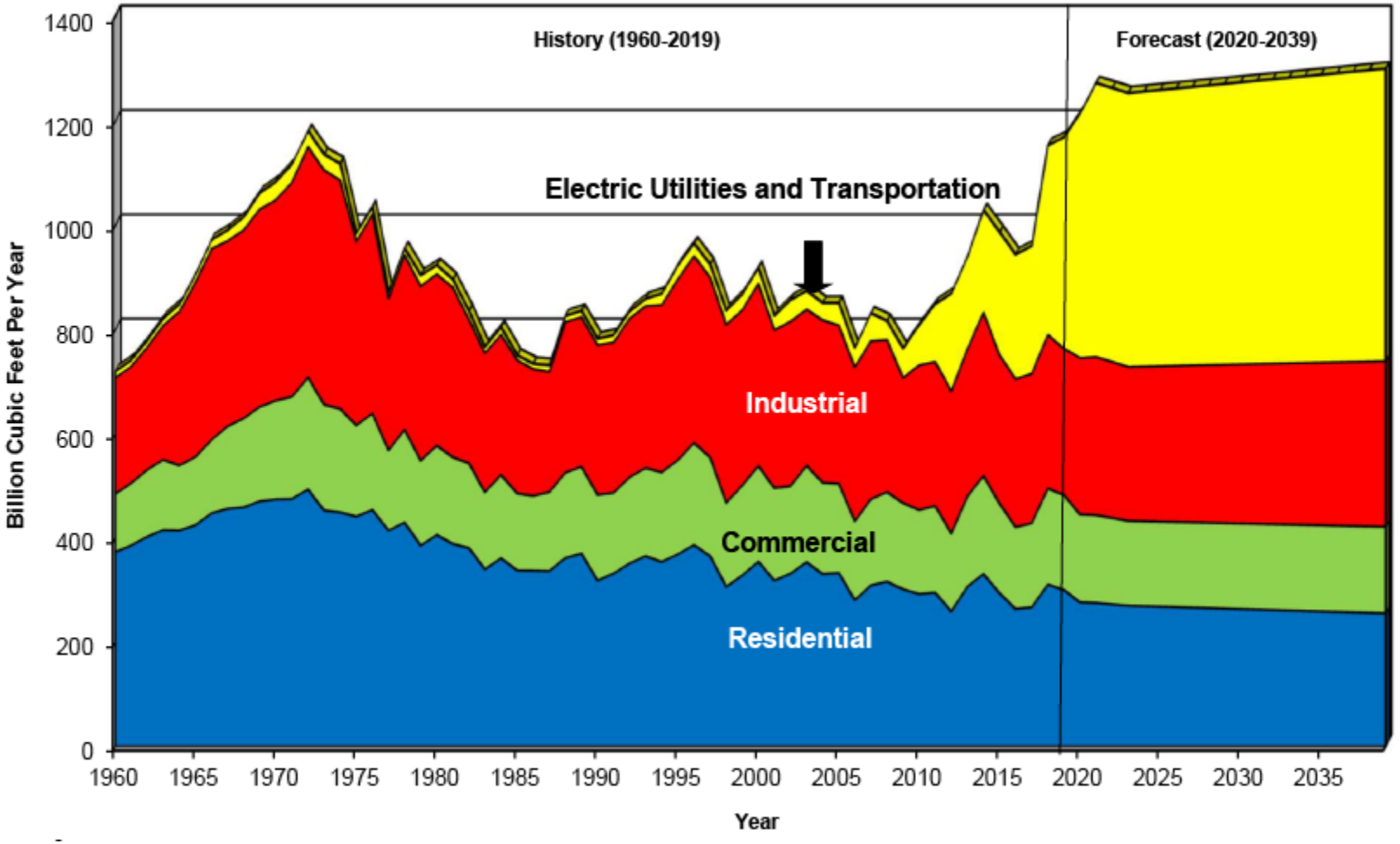
Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Table 4.2.1 – Summary of Coal Requirements in Ohio by End Use Sectors
History (2014 – 2019), Forecast (2019 – 2039)
Million Short Tons per Year

	Year	Commercial	Industrial	Electric Utilities	Total
-5	2014	0.13	1.33	38.42	39.9
-4	2015	0.08	1.06	30.52	31.7
-3	2016	0.05	0.71	29.06	29.8
-2	2017	0.00	0.56	28.52	29.1
-1	2018	0.00	0.51	25.12	25.6
0	2019	0.00	0.44	19.60	20.0
1	2020	0.03	0.45	18.63	19.1
2	2021	0.03	0.45	18.75	19.2
3	2022	0.03	0.45	18.87	19.4
4	2023	0.03	0.46	18.99	19.5
5	2024	0.03	0.46	19.12	19.6
6	2025	0.02	0.46	17.18	17.7
7	2026	0.02	0.47	15.35	15.8
8	2027	0.02	0.47	15.46	16.0
9	2028	0.02	0.47	15.57	16.1
10	2029	0.02	0.48	15.68	16.2
11	2030	0.02	0.48	15.79	16.3
12	2031	0.02	0.48	15.90	16.4
13	2032	0.02	0.49	16.01	16.5
14	2033	0.02	0.49	16.12	16.6
15	2034	0.02	0.49	16.23	16.7
16	2035	0.02	0.50	16.34	16.9
17	2036	0.02	0.50	16.45	17.0
18	2037	0.02	0.51	16.56	17.1
19	2038	0.01	0.51	16.68	17.2
20	2039	0.01	0.51	16.79	17.3
Standard Error of the Forecast		± 9.91%	± 39.65%	±4.99%	± 4.64%

Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Figure 4.3.1 – Natural Gas Requirements in Ohio
(1960 – 2039)



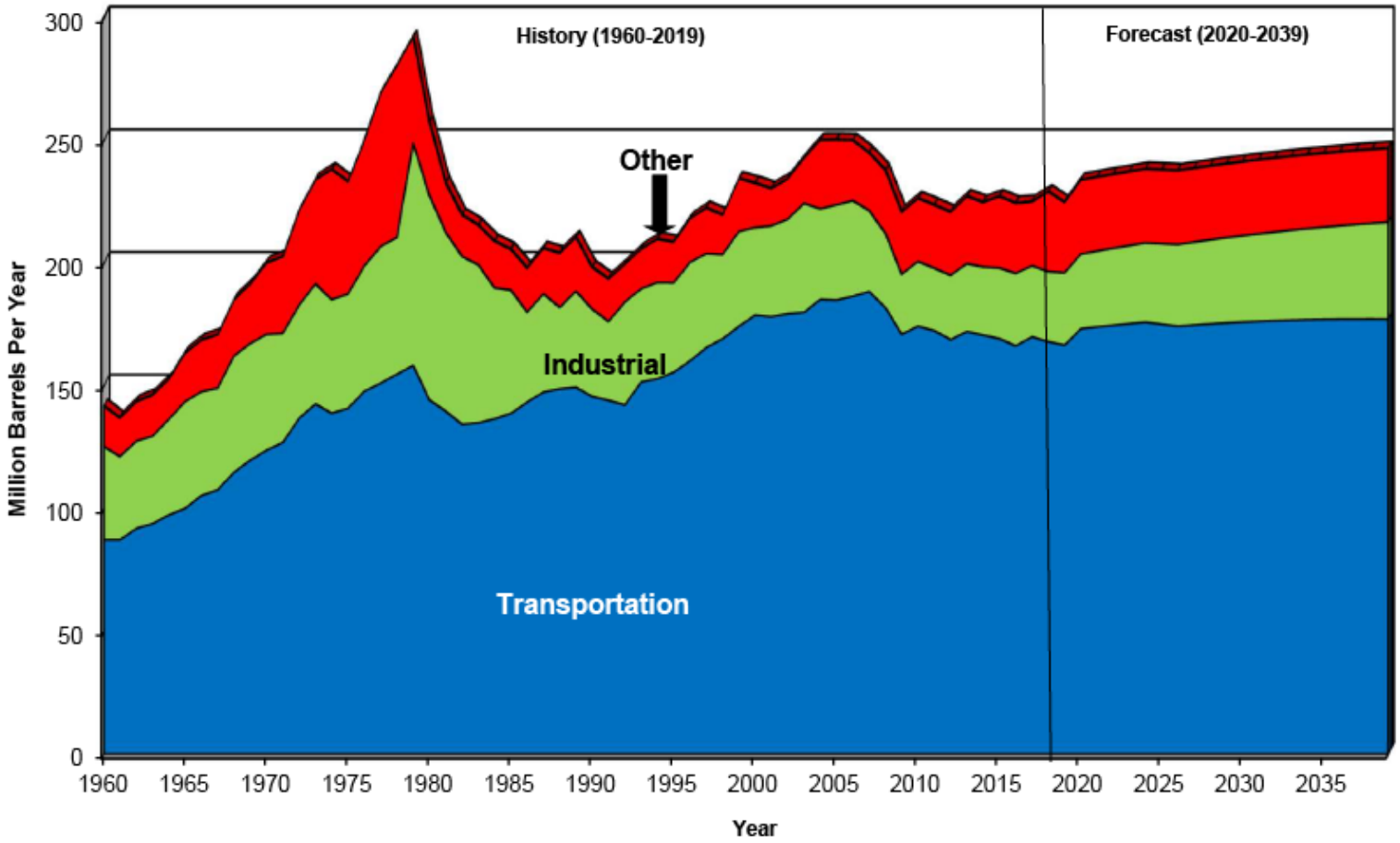
Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Table 4.3.1 – Summary of Natural Gas Requirements in Ohio by End Use Sectors
History (2014 – 2019), Forecast (2020 – 2039)
Billion Cubic Feet per Year

	Year	Residential	Commercial	Industrial	Transportation	Electric Utilities	Total
-5	2014	330.8	189.0	313.1	15.7	180.8	1029.4
-4	2015	294.4	171.9	284.8	21.0	214.9	987.1
-3	2016	264.0	157.4	284.2	19.1	219.3	944.0
-2	2017	267.0	162.0	286.7	30.7	214.1	960.4
-1	2018	310.8	184.6	294.7	30.1	333.3	1153.5
0	2019	300.7	182.4	280.9	30.9	373.5	1168.5
1	2020	276.7	169.0	300.3	26.4	441.9	1214.3
2	2021	275.4	169.0	303.5	27.3	497.5	1272.8
3	2022	272.8	166.1	299.6	27.0	497.7	1263.2
4	2023	270.1	163.2	295.6	26.8	497.8	1253.6
5	2024	269.2	163.4	297.0	26.6	500.3	1256.6
6	2025	268.3	163.6	298.5	26.4	502.7	1259.6
7	2026	267.4	163.8	299.9	26.2	505.2	1262.5
8	2027	266.5	164.0	301.2	26.0	507.7	1265.5
9	2028	265.6	164.3	302.6	25.8	510.1	1268.4
10	2029	264.7	164.5	304.0	25.6	512.6	1271.4
11	2030	263.7	164.7	305.4	25.4	515.0	1274.3
12	2031	262.8	164.9	306.8	25.2	517.5	1277.3
13	2032	261.9	165.1	308.2	25.0	520.0	1280.2
14	2033	261.0	165.4	309.5	24.8	522.4	1283.1
15	2034	260.1	165.6	310.9	24.6	524.9	1286.1
16	2035	259.2	165.8	312.2	24.4	527.3	1289.0
17	2036	258.3	166.0	313.6	24.2	529.8	1291.9
18	2037	257.3	166.2	314.9	24.0	532.2	1294.8
19	2038	256.4	166.4	316.3	23.8	534.7	1297.7
20	2039	255.5	166.7	317.6	23.6	537.2	1300.6
Standard Error of the Forecast		± 5.38%	± 5.01%	± 4.66%	± 0.08%	± 12.57%	± 3.98%

Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Figure 4.4.1 – Petroleum Products Requirements in Ohio
(1960 – 2039)



Source:

Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate

Table 4.4.1 – Summary of Petroleum Products Requirements in Ohio by End Use Sectors
History (2014 – 2019), Forecast (2020 – 2039)
Million Barrels per Year

	Year	Residential	Commercial	Industrial	Transportation	Electric Utilities	Total
-5	2014	6.2	3.0	27.9	170.6	17.1	224.8
-4	2015	5.8	5.9	28.9	169.2	17.4	227.2
-3	2016	5.8	6.1	29.6	166.2	16.8	224.5
-2	2017	5.9	6.2	29.1	169.9	13.9	225.0
-1	2018	6.5	6.4	28.7	167.9	19.7	229.2
0	2019	6.0	6.4	29.6	166.6	16.3	224.8
1	2020	6.0	6.2	30.5	173.3	17.9	233.9
2	2021	6.0	6.2	31.0	174.0	17.9	235.1
3	2022	6.0	6.2	31.5	174.7	17.9	236.2
4	2023	6.0	6.2	32.0	175.3	17.9	237.3
5	2024	6.0	6.2	32.4	175.9	17.9	238.4
6	2025	6.0	6.2	32.9	175.1	17.9	238.1
7	2026	6.0	6.2	33.4	174.3	17.9	237.8
8	2027	6.0	6.2	33.9	174.8	17.9	238.7
9	2028	6.0	6.2	34.4	175.2	17.9	239.7
10	2029	6.0	6.2	34.8	175.6	17.9	240.5
11	2030	6.0	6.2	35.3	176.0	17.9	241.4
12	2031	6.0	6.2	35.8	176.3	17.9	242.1
13	2032	6.0	6.2	36.3	176.5	17.9	242.9
14	2033	6.0	6.2	36.8	176.7	17.9	243.6
15	2034	6.0	6.2	37.2	176.9	17.9	244.2
16	2035	6.0	6.2	37.7	177.0	17.9	244.8
17	2036	6.0	6.2	38.2	177.1	17.9	245.4
18	2037	6.0	6.2	38.7	177.2	17.9	245.9
19	2038	6.0	6.2	39.2	177.2	17.9	246.4
20	2039	6.0	6.2	39.6	177.1	17.9	246.9
Standard Error of the Forecast		± 5.99%	± 9.15%	± 1.90%	± 5.90%	± 22.50%	± 2.03%

Source:

Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.

Forecast: PUCO, Office of the Federal Energy Advocate.

5.0 THE DEMAND FOR ENERGY BY ECONOMIC SECTOR

Sections 4.0 through 4.4 present the changing composition of total demand for each energy resource, namely electricity, coal, nuclear and hydropower, natural gas, and petroleum products, illustrated in terms of the demand for the resources by economic sector. Sections 5.0 through 5.5 present the same information from an alternative perspective. These sections explain the changing composition of total demand for energy in each economic sector, namely residential, commercial, industrial, transportation, and electricity generation, illustrated by fuel type.

The composition of total demand for energy in Ohio, in terms of energy requirements by sector, is presented in Figure 5.0.1 and Table 5.0.1. The industrial and transportation sectors still account for most of the energy use in the state. The net energy for generation, presented in Figure 5.0.1 and Table 5.0.1, is the difference between the total primary energy inputs into the electricity generation sector in Ohio less the total end-use demand for electricity in Ohio. Since end-use demand for electricity is already included in the energy demand by sector, it has to be subtracted from the total energy inputs into the electricity generation sector in order to avoid double counting.

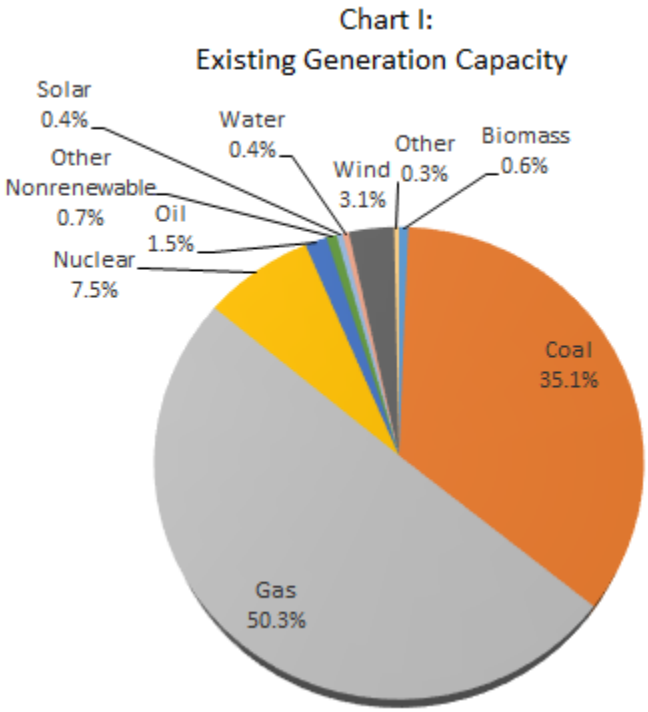
As required by Generally Accepted Accounting Principles, and the first order predicate logic requiring that the whole be equal to the sum of its parts, the trajectory of total demand for energy in Figure 5.0.1 and Table 5.0.1 is identical to the trajectory of total demand for energy in Figure 4.0.1 and Table 4.0.1.

5.1 The Electricity Generation Sector

The demand for energy resource inputs into the electricity generation sector are presented in Figure 5.1.1 and Table 5.1.1. In 2019, the demand for coal was 45.7 percent of the total demand for energy resource inputs into the electricity generation sector, the coal equivalent of nuclear and hydro generation was 17.2 percent, and natural gas and petroleum products were 37.1 percent. In 2039, energy from coal is projected to be 37.7 percent of the total demand for energy inputs into the electricity generation sector, the coal equivalent of nuclear and hydro generation is projected to be 15.8 percent, and natural gas and petroleum products are projected to be 46.5 percent. This notable change in Ohio's generation resource mix is driven primarily by anticipated generation retirements and new construction of natural gas combined-cycle resources. Furthermore, as solar panel efficiency increases and the cost of solar energy continues to substantially fall, and as electricity from coal-fired power plants continues to be less competitive, it is anticipated that contribution to the total energy from renewable sources (mainly utility-scale solar power[3]) will continue to increase nationwide and, specifically, in Ohio (see charts I & II below). As of March 26, 2021, the solar megawatts that have already been approved by the Ohio Power Sitting Board (OPSB) totaled 2,089.6. Additionally, there is

[3] Currently, solar power contributes 0.42% of Ohio's output.

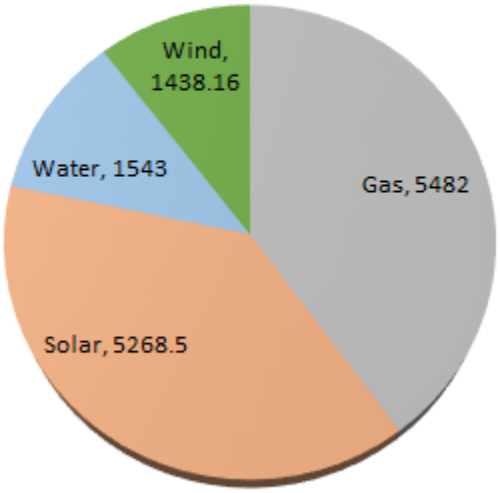
currently a total of 4,370.9 solar megawatts that are pending approval or are in the pre-application stage at OPSB. The potential solar megawatts (i.e., approved, pending, and pre-application stage) represent approximately 13 percent of Ohio's total electricity generation capacity[4] (see chart III below). The continuing increase of solar penetration into the electricity supply mix dictates that future energy forecasts also include solar energy, in addition to natural gas, coal, hydro and nuclear.



Source: S&P Global-2021

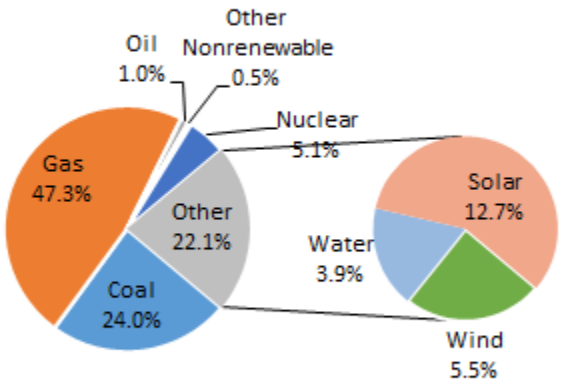
[4] There are presently approximately 794.9 operational megawatts from wind farms, with potentially 978.2 more megawatts that have either been approved, await approval, or are in the pre-application stage.

Chart II:
Planned Generation Capacity (MW)



Source: S&P Global-2021

Chart III:
Existing & Planned Generation



Source: S&P Global-2021

Generation from renewable resources other than hydro is not delineated in these forecasts, because historically low usage in Ohio makes it impractical to independently forecast their contribution. To the extent that generation from renewable resources expands in the future, the fossil fuel components of energy input for electricity generation as illustrated in Figure 5.1.1 and

Table 5.1.1 would be reduced accordingly, though not necessarily on a one-to-one energy equivalent basis.

Total energy input demand into the electricity generation sector was 1,051.8 TBtu in 2019. It is expected to be 1,184.8 TBtu in 2024, and 1,196.0 TBtu in 2039. The standard error of the forecast is 8.5 percent.

5.2 The Industrial Sector

Industrial sector energy requirements are presented in Figure 5.2.1 and Table 5.2.1. The industrial sector energy demand trajectory displays the most dynamically varying behavior among all sectors. This is attributable, in part, to the usual dynamic of the business cycle. As real per capita income declines during the recessionary phase of the business cycle so does the demand for durable goods. As industrial output is reduced to meet the lower demand levels, demand for industrial inputs, including energy inputs, is also reduced. During the recovery phase of the business cycle, as real per capita income grows so does the demand for durable goods. As industrial output increases to meet the increasing demand levels, demand for industrial inputs, including energy resources, also increases.

Historical economic singularities involving sudden, significant, and sustained increases in energy resource prices have led to sudden, significant and permanent declines in industrial demand for energy resources, as witnessed by the predicament of conventional iron and steel mills in the U.S. and in Ohio during and in the aftermath of the 1973-1984 oil price cycle. As production costs in energy-intensive industries increased in response to the nature and extent of the energy input price increases, many firms were not able to maintain their competitive advantage in the global marketplace and had to cease or scale down production. As industrial production went down, so did the demand for energy resource inputs in the industrial sector. The recessionary phases of business cycles that are preceded by, or accompanied by, sudden, significant and sustained energy price increases are, therefore, characterized by sudden, significant, and permanent reductions in the industrial demand for energy resources.

The alteration in the structure of the state's industrial base can be surmised from the behavior of the industrial demand for coal, which fell from a high of 732.5 TBtu in 1970 to a low of 8.2 TBtu in 200, an 88 percent decline in demand. This decline is clearly reflected in, among other things, the predicament of traditional manufacturing industries in Ohio, including iron and steel mills, and the decline of other direct industrial uses for coal.

Higher energy resource costs eventually led to an increase in the demand for the development and widescale adoption of more energy efficient technologies by new or surviving industrial firms. More energy efficient production technologies, in turn, led to slower growth in energy demand during the recovery phase of a business cycle associated with an energy price shock. These and other considerations are among the contributing factors to the observed stepwise

decline in the time path trajectory of industrial demand for energy in Ohio, and its rather moderated growth during the recovery phases of the business cycle, since the early 1970s.

Industrial sector energy demand peaked and stabilized at about 1,528.9 TBtu between 1969 and 1974. Demand declined to approximately 1,400 TBtu between 1975 and 1979. As production costs and competitive advantage in iron and steel production continued to shift further in favor of overseas producers during the 1979 to 1982 recessionary period, industrial energy demand declined precipitously from 1503.9 TBtu in 1979 to 1015.8 TBtu in 1983. Industrial energy demand stabilized from 1983 through 1999, fluctuating between a range of 1015.8 TBtu and 947 TBtu. Between 1999 and 2001, industrial energy demand declined from 947 TBtu to 841.1 TBtu. It stabilized again between 2001 and 2007, fluctuating within a range of 841.1 TBtu and 807.5TBtu. Subsequent to the recession, there was a period of persistent yet muted growth in industrial sector energy requirements.

PUCO staff recognizes that a significant recession has occurred in 2020 due to society's reaction to the COVID-19 virus. The last uniform observation of this forecast was 2019. Given that the recession is not within this forecast; however, PUCO staff has been tracking the impacts on energy consumption. There was a 5-15 percent decrease in consumption from the 5-year average for several weeks before stabilizing to a 1-2 percent decrease. The full impacts of COVID-19 will influence the next forecast PUCO staff produces due to the time series nature of PUCO's forecasting techniques.

Industrial sector energy demand in Ohio was 721TBtu in 2019. It is projected to be 765.7 TBtu in 2024, 763.9 TBtu in 2027, and 829.7 TBtu in 2039. The standard error of the forecast is 9.16 percent.

5.3 The Commercial Sector

Commercial sector energy requirements are presented in Figure 5.3.1 and Table 5.3.1. Since 1983, the Ohio economy has continued to become more service oriented and less manufacturing oriented. The expansion of the service sector in Ohio has led to a slow but steady growth in commercial energy demand from 287.5 TBtu in 1983 to 360.1 TBtu in 1997. Since 1997, commercial sector energy consumption has stabilized around a near zero annual growth trend until 2015. The commercial sector has experienced slight growth since 2015.

Electricity and natural gas are the fuels of choice in the commercial sector. Growth in commercial sector electricity demand has increased consistently from 90.4 TBtu in 1982 to 159.8 TBtu in 2013. Natural gas demand has been more susceptible to the phases of the business cycle, variations in weather conditions, and the fluctuations in the price of natural gas.

Commercial sector energy demand in Ohio was 376.2 TBtu in 2019. It is expected to be 357.9 TBtu in 2024, 358.9 TBtu in 2027, and 363.1 TBtu in 2039. The fluctuations in the forecast behavior of commercial sector energy requirements reflect the anticipated impacts of the

projected recession recovery cycles, and the anticipated impacts of higher electricity and natural gas prices, over the forecast horizon. The standard error of the forecast is 3.95 percent.

5.4 The Residential Sector

Residential sector energy requirements are presented in Figure 5.4.1 and Table 5.4.1. Total residential energy demand peaked in 1972 at about 678.4 TBtu. Subsequent declining demand reflects a lagged response to rising fuel prices in terms of increasing investment in weatherization and other energy conservation measures.

The impact of conservation is seen most clearly in the demand for natural gas, the most widely used fuel for space heating requirements. Natural gas demand fell from a high of 494 TBtu in 1972 to a low of 340 TBtu in 1983, a 31percent decrease. From 1983 on, residential sector natural gas consumption levels in Ohio have been declining very slowly along a long-term trend. The volatility of year-to-year observations along the trend, however, has increased fivefold from 1.1 percent, in years preceding 1972, to 5.4 percent, from 1972 to the present. In other words, natural gas conservation is very effective during moderate to mild winters but demand spikes sharply during severe winters. Staff expects the high volatility around the long-term trend to continue throughout the forecast horizon.

PUCO staff projects that residential sector demand for natural gas will be influenced by the fluctuations in the phases of the forecast business cycles. Fluctuations in future levels of crude oil prices are also expected to put similar pressures on natural gas prices, and thus further encourage conservation, keeping long-term trends in demand growth slightly negative.

Residential sector demand for natural gas was 300.7 TBtu in 2019. It is expected to be 269.2 TBtu in 2024, and 255.5 TBtu in 2039. The standard error of the forecast is 5.38 percent.

The trend characterizing the trajectory of residential electricity demand in Ohio has not changed since 1983. Staff expects the same slow but steady decline to continue throughout the forecast horizon, with minor adjustments to the magnitude of the long-term trends to reflect the possible impacts of the projected business cycles.

Residential sector demand for electricity was 178.7 TBtu in 2019 It is expected to be 179.8 TBtu in 2024, and 183 TBtu in 2039. The standard error of the forecast is 2.40 percent.

Residential sector total demand for energy resources was 506.1 TBtu in 2019. It is expected to be 475.6 TBtu in 2024, and 465.2 TBtu in 2039. The standard error of the forecast is 4.36 percent.

5.5 The Transportation Sector

Transportation sector energy requirements are presented in Figure 5.5.1 and Table 5.5.1. As of 2019, 96.7 percent of transportation sector energy requirements is comprised of petroleum products. Transportation sector demand for energy is highly susceptible to the fluctuations in the business cycle. As industrial output and the need for transportation of industrial output

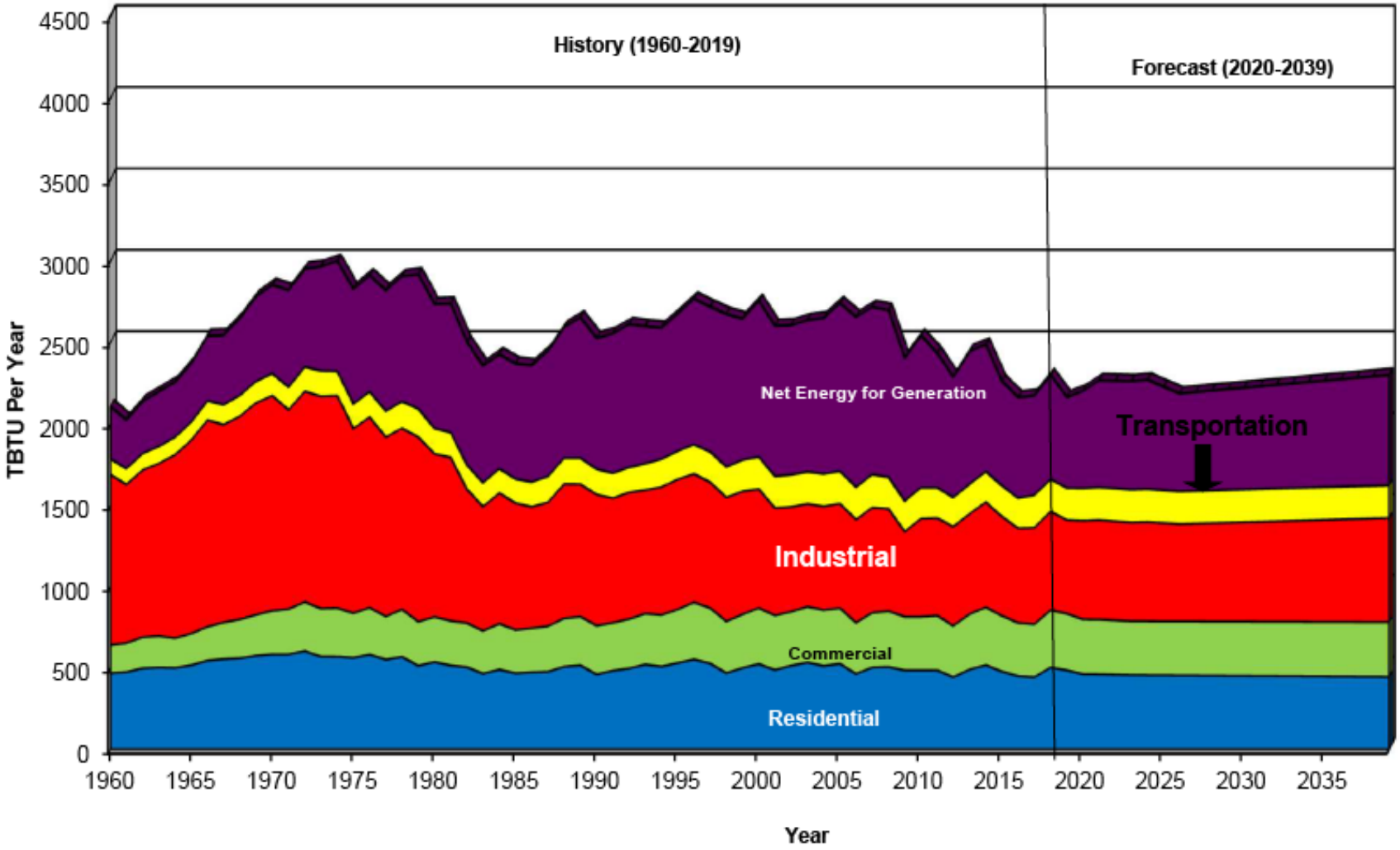
decline during the recessionary phase of the business cycle, so does the demand for commercial transportation. To the extent that nearly all of the recessionary cycles since 1973 have been accompanied by significant rises in petroleum prices, the demand for personal transportation also suffers. The price effect of higher petroleum prices exacerbates the amplitude of the fluctuations in the demand for transportation energy requirements during the business cycle. It also contributes to the slowdown in the overall long-term growth in the demand for petroleum products by encouraging the production and acceptance of more fuel-efficient vehicles.

Conversely, on the supply side, higher prices lead to increased exploration activities and production efforts, and to the development of novel and more advanced technologies to enhance exploration and production. The faster growth in supplies coupled with the slower growth in demand will eventually bring product prices down from their initial peaks. This process, however, is not instantaneous, and may take up to 10 or 12 years to work itself out.

Transportation sector energy demand in Ohio was 926.6 TBtu in 2019. It is expected to be 981.8 TBtu in 2024, 976 TBtu in 2027, and 991 TBtu in 2039. The fluctuations in the forecast behavior of transportation sector energy requirements reflect the anticipated impacts of the projected recession recovery cycles and the anticipated impacts of higher crude oil and petroleum products prices over the forecast horizon. At this time, based upon industry research, PUCO staff's forecast does not reflect significant increases in natural gas vehicle penetration above current levels. Similarly, electric vehicle adoption in Ohio has been slow to materialize with a 118% growth recorded in 2018.[5] PUCO staff will closely monitor technological, environmental, and other incentives affecting consumer behavior, should they cause electric vehicle adoption rates to increase in future years. The standard error of the forecast is 5.75 percent.

[5] Electric Vehicle Charging Study, ODOT & DriveOhio, June 2020

Figure 5.0.1 – Total Energy Requirements in Ohio by Sector
(1960 – 2039)



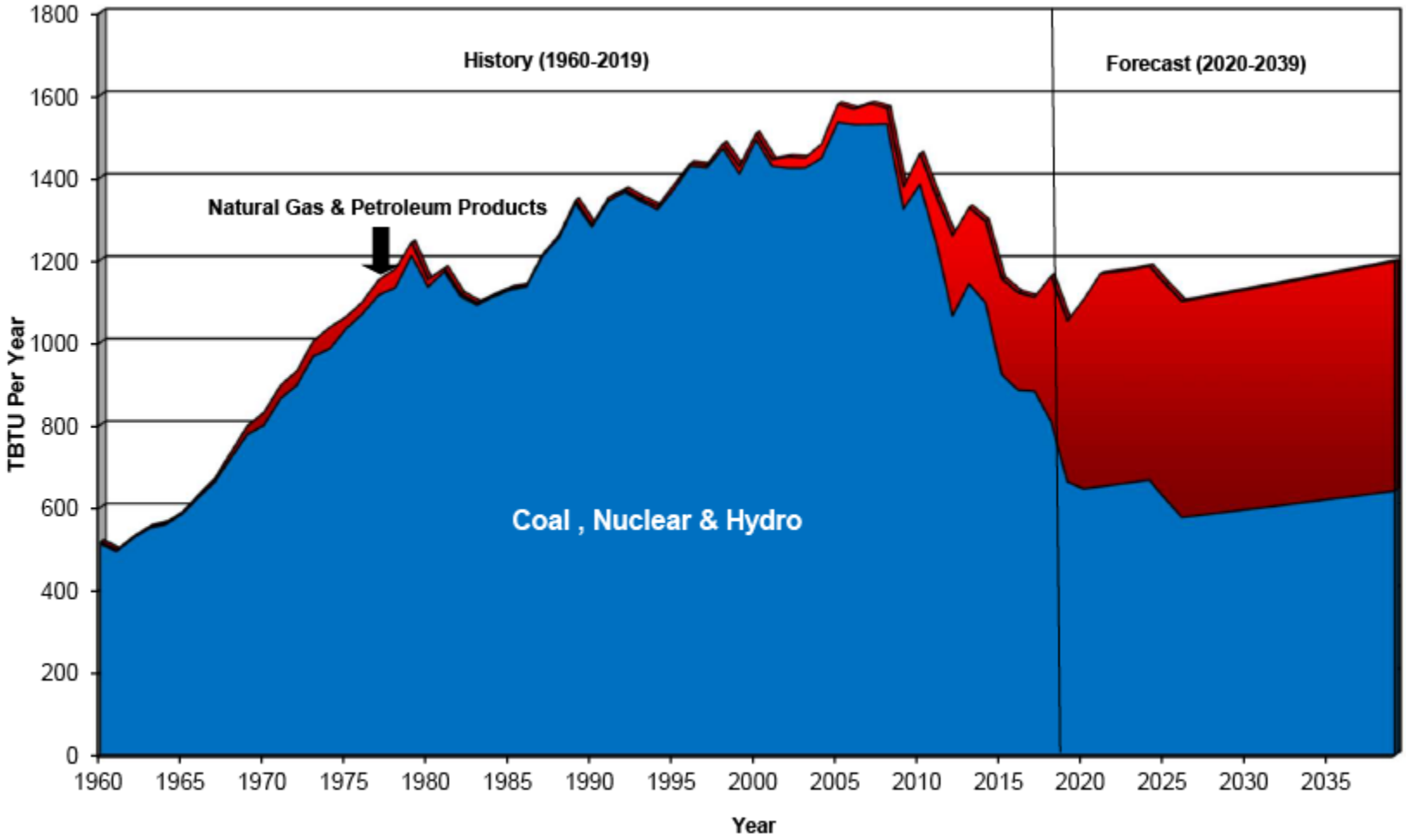
Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: Office of the Federal Energy Advocate.

Table 5.0.1 – Summary of Energy Requirements by End Use Sectors in Ohio
History (2014 – 2019), Forecast (2020 – 2039)
Trillion British Thermal Units per Year

	Year	Residential	Commercial	Industrial	Transportation	Net Energy for Generation	Total
-5	2014	517.2	355.5	646.3	186.4	554.7	2,485.6
-4	2015	478.0	341.7	610.0	190.2	640.1	2,259.9
-3	2016	449.0	327.5	581.8	185.4	604.2	2,160.7
-2	2017	442.8	325.8	592.7	200.6	452.7	2,171.4
-1	2018	503.1	352.1	605.6	198.0	435.2	2,298.4
0	2019	485.4	347.5	576.0	197.5	420.9	2,161.8
1	2020	461.7	336.5	606.3	199.7	444.6	2,200.5
2	2021	460.7	336.6	611.4	201.2	374.1	2,265.7
3	2022	458.3	333.9	609.2	201.7	410.7	2,262.9
4	2023	455.8	331.1	607.1	202.1	469.9	2,260.0
5	2024	455.1	331.4	610.3	202.5	473.7	2,269.7
6	2025	454.5	331.7	604.4	201.5	477.6	2,226.1
7	2026	453.8	332.1	598.4	200.5	483.8	2,184.9
8	2027	453.1	332.4	601.6	200.8	447.3	2,193.8
9	2028	452.4	332.8	604.8	201.1	413.3	2,202.6
10	2029	451.7	333.1	608.0	201.2	418.8	2,211.4
11	2030	451.0	333.5	611.2	201.4	424.3	2,220.3
12	2031	450.3	333.8	614.4	201.5	429.9	2,229.0
13	2032	449.5	334.2	617.6	201.6	435.5	2,237.8
14	2033	448.8	334.5	620.8	201.6	441.1	2,246.6
15	2034	448.1	334.9	624.0	201.5	446.8	2,255.3
16	2035	447.4	335.2	627.2	201.5	452.5	2,264.1
17	2036	446.7	335.6	630.4	201.4	458.3	2,272.8
18	2037	446.0	335.9	633.5	201.2	464.1	2,281.6
19	2038	445.3	336.2	636.7	201.0	469.9	2,290.3
20	2039	444.6	336.6	639.9	200.8	475.8	2,299.0
Standard Error of the Forecast		± 3.73%	± 2.81%	± 3.47%	± 2.0%	± 4.88%	± 3.0%

Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Figure 5.1.1 –Energy Requirements for Electricity Generation in Ohio (1960 – 2039)



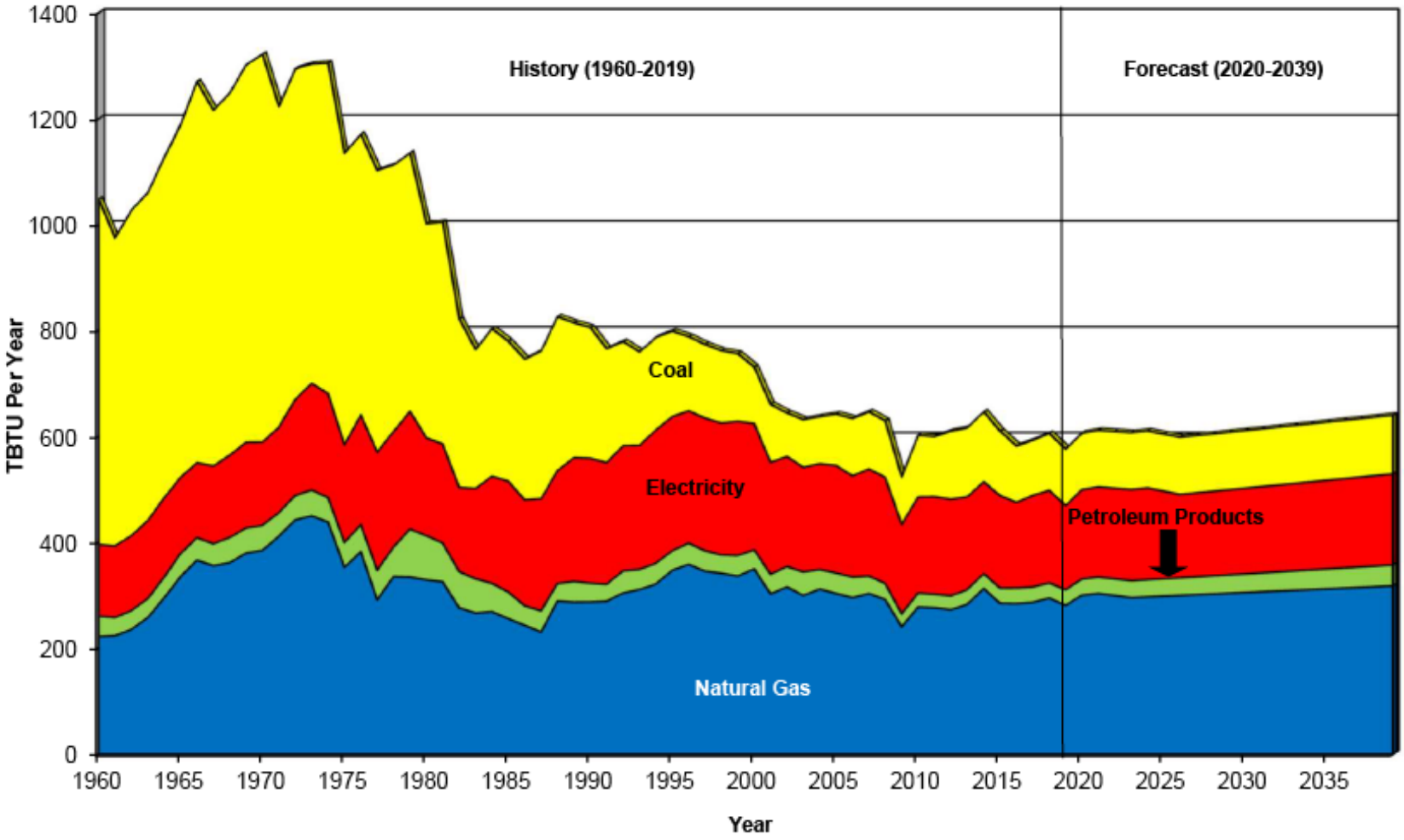
Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Table 5.1.1 – Summary of Energy Requirements for Electricity Generation in Ohio
History (2014 – 2019), Forecast (2020 – 2039)
Trillion British Thermal Units per Year

	Year	Natural Gas	Coal	Petroleum Products	Total Fossil Fuel	Nuclear & Hydro	Total	BTU Equivalent of Total Electricity Sales in Ohio	Net Energy For Generation
	(1)	(2)	(3)	(4)	(5) Σ(2)+..+(4)	(6)	(7) (5)+(6)	(8)	(9) (7)-(8)
-5	2014	180.8	920.3	17.1	1,118.2	176.0	1,294.1	501.2	793.0
-4	2015	214.9	734.6	17.4	966.9	187.3	1,154.2	502.3	651.8
-3	2016	219.3	702.7	16.8	938.8	181.9	1,120.7	503.5	617.2
-2	2017	214.1	693.1	13.9	921.1	188.7	1,109.8	504.6	605.1
-1	2018	333.3	613.3	19.7	966.3	194.9	1,161.2	505.8	655.4
0	2019	373.5	480.7	16.3	870.5	181.3	1,051.8	506.9	544.8
1	2020	441.9	459.2	17.9	919.1	185.7	1,104.8	508.4	596.3
2	2021	497.5	464.4	18.0	979.9	185.9	1,165.7	509.9	655.8
3	2022	497.7	469.5	18.0	985.2	186.1	1,171.3	511.4	659.9
4	2023	497.8	474.7	18.1	990.6	186.3	1,176.9	512.8	664.0
5	2024	500.3	479.9	18.1	998.3	186.5	1,184.8	514.3	670.5
6	2025	502.7	433.3	18.2	954.2	186.7	1,140.8	506.6	634.2
7	2026	505.2	389.0	18.2	912.4	186.9	1,099.3	498.9	600.4
8	2027	507.7	393.6	18.2	919.5	187.1	1,106.5	500.4	606.2
9	2028	510.1	398.1	18.3	926.5	187.3	1,113.8	501.8	612.0
10	2029	512.6	402.7	18.3	933.6	187.5	1,121.1	503.3	617.8
11	2030	515.0	407.3	18.4	940.7	187.7	1,128.4	504.8	623.6
12	2031	517.5	412.0	18.4	947.9	187.9	1,135.8	506.3	629.5
13	2032	520.0	416.7	18.5	955.1	188.1	1,143.2	507.7	635.5
14	2033	522.4	421.4	18.5	962.3	188.3	1,150.6	509.2	641.4
15	2034	524.9	426.1	18.6	969.6	188.5	1,158.1	510.7	647.4
16	2035	527.3	430.9	18.6	976.9	188.7	1,165.6	512.1	653.5
17	2036	529.8	435.8	18.7	984.2	188.9	1,173.2	513.6	659.6
18	2037	532.2	440.7	18.7	991.6	189.1	1,180.7	515.1	665.7
19	2038	534.7	445.6	18.8	999.0	189.3	1,188.4	516.5	671.8
20	2039	537.2	450.5	18.8	1,006.5	189.5	1,196.0	518.0	678.0
Standard Error of the Forecast		± 12.57%	± 4.99%	± 2.03%	± 8.19%	± 10.00%	± 8.5%	± 2.34%	± 13.2%

Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Figure 5.2.1 – Industrial Sector Energy Requirements in Ohio
(1960 – 2039)



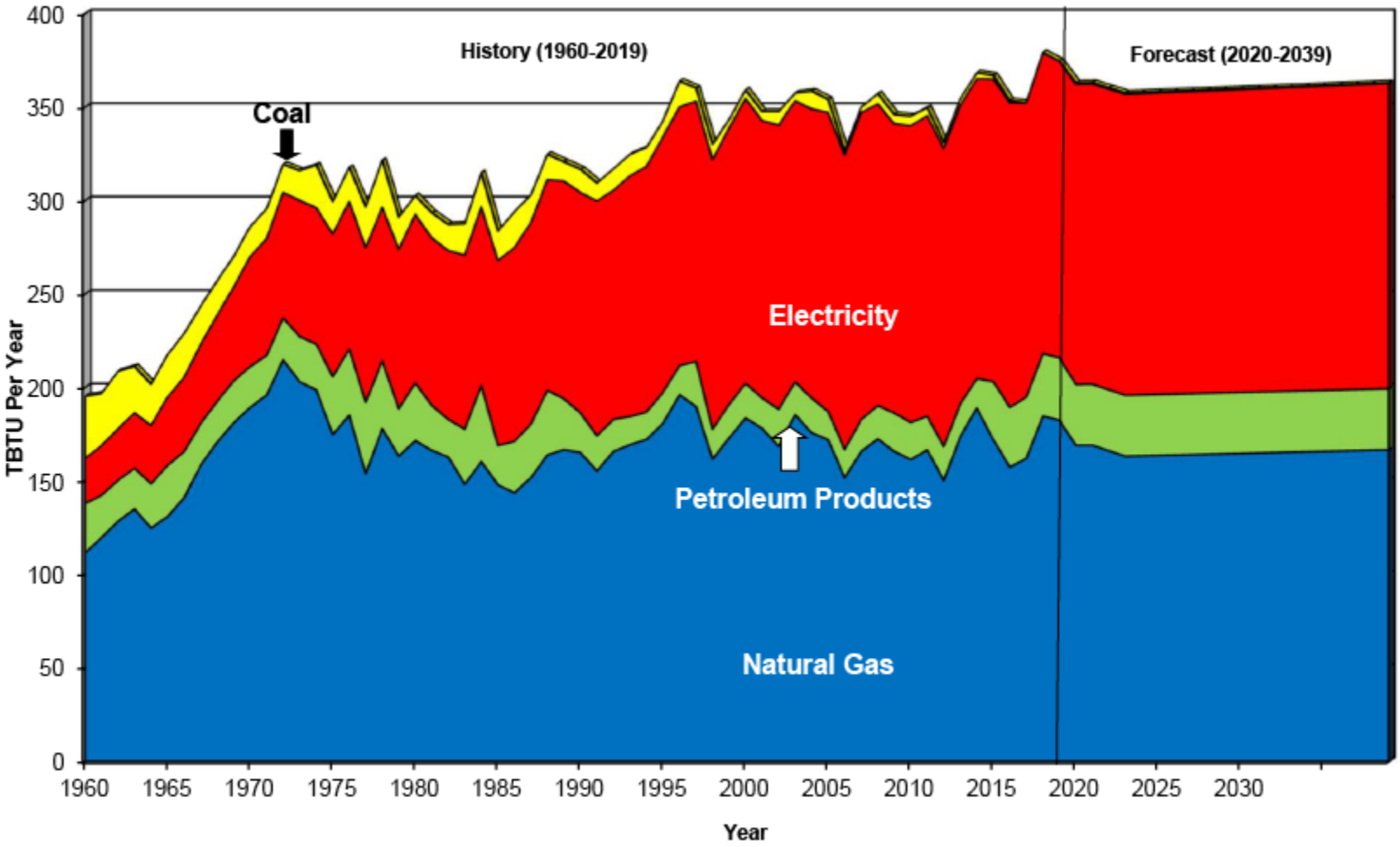
Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Table 5.2.1 – Summary of Industrial Sector Energy Requirements in Ohio
History (2014 – 2019), Forecast (2020 – 2039)
Trillion British Thermal Units per Year

	Year	Natural Gas	Coal	Petroleum Products	Electricity	Total
-5	2014	313.1	131.9	27.9	173.4	646.3
-4	2015	284.8	121.8	28.9	174.4	610.0
-3	2016	284.2	106.5	29.6	161.4	581.8
-2	2017	286.7	104.2	29.1	172.8	592.7
-1	2018	294.7	107.4	28.7	174.8	605.6
0	2019	280.9	106.6	29.6	167.8	584.8
1	2020	300.3	106.6	30.5	169.0	606.3
2	2021	303.5	106.8	31.0	170.1	611.4
3	2022	299.6	107.0	31.5	171.2	609.2
4	2023	295.6	107.2	32.0	172.3	607.1
5	2024	297.0	107.5	32.4	173.4	610.3
6	2025	298.5	107.7	32.9	165.3	604.4
7	2026	299.9	107.9	33.4	157.2	598.4
8	2027	301.2	108.1	33.9	158.3	601.6
9	2028	302.6	108.4	34.4	159.4	604.8
10	2029	304.0	108.6	34.8	160.6	608.0
11	2030	305.4	108.8	35.3	161.7	611.2
12	2031	306.8	109.1	35.8	162.8	614.4
13	2032	308.2	109.3	36.3	163.9	617.6
14	2033	309.5	109.5	36.8	165.0	620.8
15	2034	310.9	109.8	37.2	166.1	624.0
16	2035	312.2	110.0	37.7	167.2	627.2
17	2036	313.6	110.2	38.2	168.3	630.4
18	2037	314.9	110.5	38.7	169.4	633.5
19	2038	316.3	110.7	39.2	170.5	636.7
20	2039	317.6	111.0	39.6	171.6	639.9
Standard Error of the Forecast		± 4.66%	± 39.65%	± 1.9%	± 4.5%	± 9.16%

Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Figure 5.3.1 – Commercial Sector Energy Requirements in Ohio
(1960 – 2039)



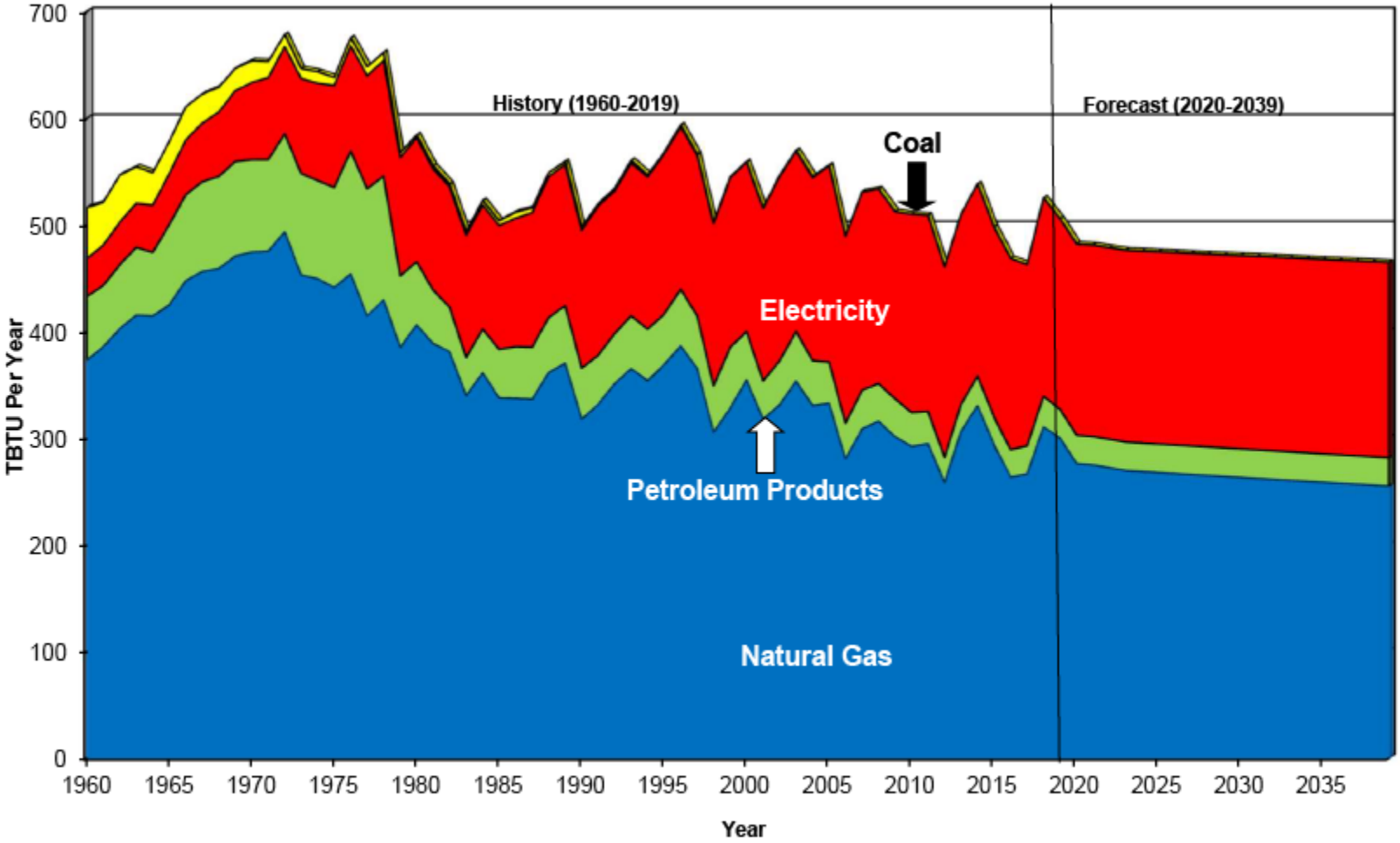
Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Table 5.3.1 – Summary of Commercial Sector Energy Requirements in Ohio
History (2014 – 2019), Forecast (2020 – 2039)
Trillion British Thermal Units per Year

	Year	Natural Gas	Coal	Petroleum Products	Electricity	Total
-5	2014	189.0	3.2	15.8	160.4	368.3
-4	2015	171.9	2.0	31.2	161.9	367.0
-3	2016	157.4	1.1	32.0	162.9	353.4
-2	2017	162.0	0.0	32.8	157.5	352.3
-1	2018	184.6	0.0	33.5	161.0	379.1
0	2019	182.4	0.0	33.3	160.4	376.2
1	2020	169.0	0.7	32.7	160.6	362.9
2	2021	169.0	0.7	32.7	160.7	363.1
3	2022	166.1	0.7	32.7	160.9	360.3
4	2023	163.2	0.7	32.7	161.0	357.5
5	2024	163.4	0.6	32.7	161.2	357.9
6	2025	163.6	0.6	32.7	161.3	358.2
7	2026	163.8	0.6	32.7	161.5	358.6
8	2027	164.0	0.6	32.7	161.6	358.9
9	2028	164.3	0.6	32.7	161.8	359.3
10	2029	164.5	0.6	32.7	161.9	359.6
11	2030	164.7	0.5	32.7	162.0	360.0
12	2031	164.9	0.5	32.7	162.2	360.3
13	2032	165.1	0.5	32.7	162.3	360.6
14	2033	165.4	0.5	32.7	162.5	361.0
15	2034	165.6	0.5	32.7	162.6	361.3
16	2035	165.8	0.4	32.7	162.8	361.7
17	2036	166.0	0.4	32.7	162.9	362.0
18	2037	166.2	0.4	32.7	163.1	362.4
19	2038	166.4	0.4	32.7	163.2	362.7
20	2039	166.7	0.4	32.7	163.4	363.1
Standard Error of the Forecast		± 5.01%	± 9.91%	± 9.15%	± 1.67%	± 3.95%

Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Figure 5.4.1 – Residential Sector Energy Requirements in Ohio
(1960 – 2039)



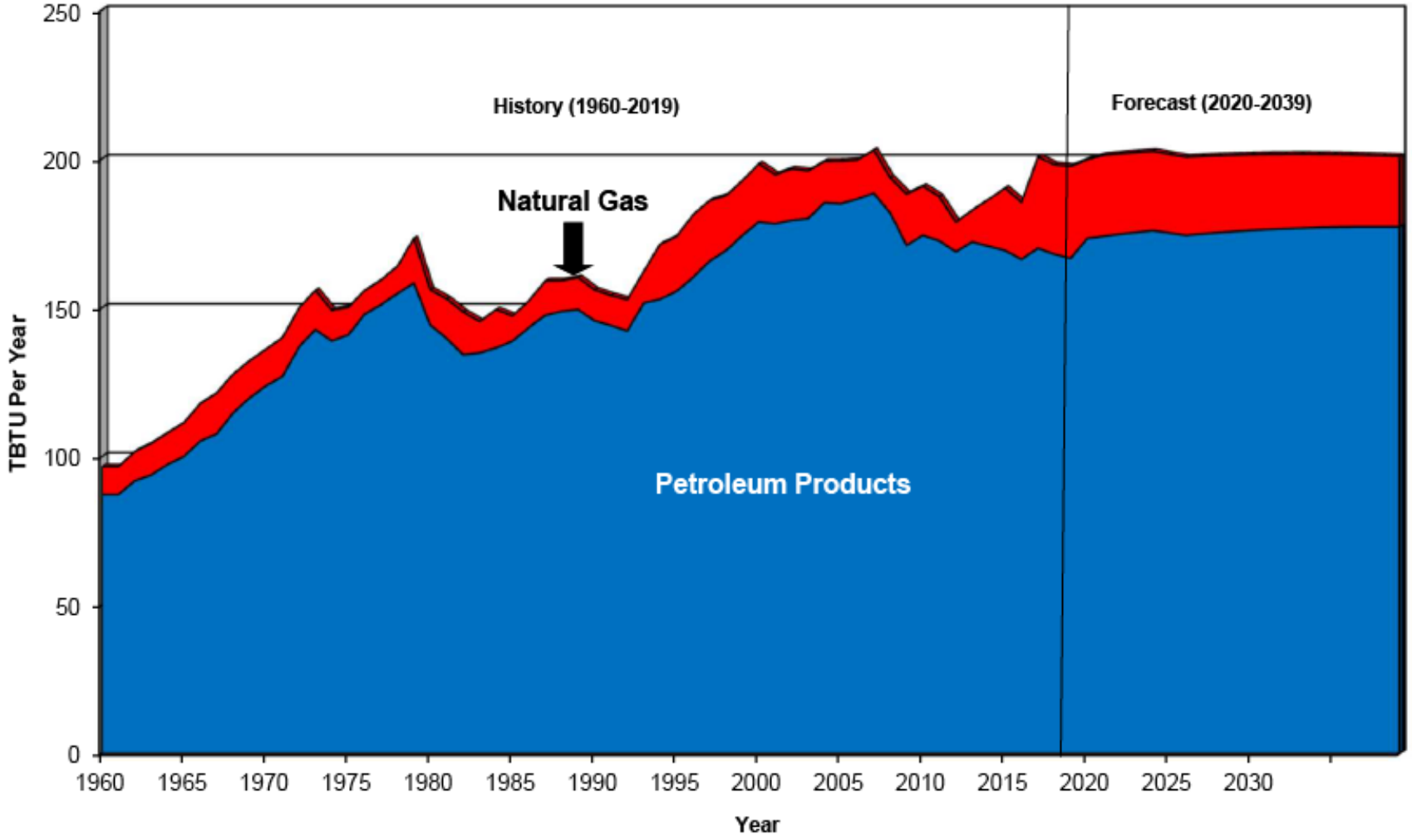
Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Table 5.4.1 – Summary of Residential Sector Energy Requirements in Ohio
History (2014 – 2019), Forecast (2020 – 2039)
Trillion British Thermal Units per Year

	Year	Natural Gas	Petroleum Products	Electricity	Total
-5	2014	330.8	6.2	180.2	517.2
-4	2015	294.4	5.8	177.8	478.0
-3	2016	264.0	5.8	179.2	449.0
-2	2017	267.0	5.9	169.9	442.8
-1	2018	310.8	6.5	185.8	503.1
0	2019	300.7	6.0	178.7	485.4
1	2020	276.7	6.0	178.9	461.5
2	2021	275.4	6.0	179.1	460.5
3	2022	272.8	6.0	179.3	458.1
4	2023	270.1	6.0	179.5	455.6
5	2024	269.2	6.0	179.8	454.9
6	2025	268.3	6.0	180.0	454.3
7	2026	267.4	6.0	180.2	453.6
8	2027	266.5	6.0	180.4	452.9
9	2028	265.6	6.0	180.6	452.2
10	2029	264.7	6.0	180.8	451.5
11	2030	263.7	6.0	181.1	450.8
12	2031	262.8	6.0	181.3	450.1
13	2032	261.9	6.0	181.5	449.4
14	2033	261.0	6.0	181.7	448.7
15	2034	260.1	6.0	181.9	448.0
16	2035	259.2	6.0	182.1	447.3
17	2036	258.3	6.0	182.4	446.6
18	2037	257.3	6.0	182.6	445.9
19	2038	256.4	6.0	182.8	445.2
20	2039	255.5	6.0	183.0	444.5
Standard Error of the Forecast		± 5.38%	± 5.99%	± 2.40%	± 4.36%

Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Figure 5.5.1 – Transportation Sector Energy Requirements in Ohio (1960 – 2039)



Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

Table 5.5.1 – Summary of Transportation Sector Energy Requirements in Ohio
History (2014 – 2019), Forecast (2020 – 2039)
Trillion British Thermal Units per Year

	Year	Natural Gas	Petroleum Products	Total
-5	2014	15.7	170.6	186.4
-4	2015	21.0	169.2	190.2
-3	2016	19.1	166.2	185.4
-2	2017	30.7	169.9	200.6
-1	2018	30.1	167.9	198.0
0	2019	30.9	166.6	197.5
1	2020	26.4	173.3	199.7
2	2021	27.3	174.0	201.2
3	2022	27.0	174.7	201.7
4	2023	26.8	175.3	202.1
5	2024	26.6	175.9	202.5
6	2025	26.4	175.1	201.5
7	2026	26.2	174.3	200.5
8	2027	26.0	174.8	200.8
9	2028	25.8	175.2	201.1
10	2029	25.6	175.6	201.2
11	2030	25.4	176.0	201.4
12	2031	25.2	176.3	201.5
13	2032	25.0	176.5	201.6
14	2033	24.8	176.7	201.6
15	2034	24.6	176.9	201.5
16	2035	24.4	177.0	201.5
17	2036	24.2	177.1	201.4
18	2037	24.0	177.2	201.2
19	2038	23.8	177.2	201.0
20	2039	23.6	177.1	200.8
Standard Error of the Forecast		± 0.08%	± 5.90%	± 5.75%

Source:
Data: USDOE-EIA; PUCO, Office of the Federal Energy Advocate.
Forecast: PUCO, Office of the Federal Energy Advocate.

BIBLIOGRAPHY

Anderson, T. W., *An Introduction to Multivariate Statistical Analysis*, New York, John Wiley, 1958.

Aramanovich, I. G., et. al., *Mathematical Analysis*, H. Moss (Trans.), I. N. Snedden (Ed.), Oxford, Pergammon, 1965.

Basmann, R. L., Modern Logic and Suppositious Weakness of the Empirical Foundations of Economic Science, Schweizerische Zeitschrift fur Volkvirtschaft und Statistik, April 1975.

Basmann, R. L., Exact Finite Sample Distributions for Some Econometric Estimators and Test Statistics: A Survey and Appraisal, M. D. Intriligator and D. A. Kendrick (editors), *Frontiers of Quantitative Economics*, Vol. II, North-Holland Publishing Co., 1974.

Basmann, R. L., Remarks Concerning the Application of Exact Finite Sample Distribution Functions of GCL Estimators in Econometric Statistical Inference, *Journal of the American Statistical Association*, 1963, Vol. 58.

Bellman, R. and Roth, R., Curve Fitting by Segmented Straight Lines, JASA, Vol. 64, Sept. 1969.

Berlinski, D., *On Systems Analysis: An Essay Concerning the Limitations of Some Mathematical Methods in the Social, Political, and Biological Sciences*, Cambridge, Ma, The MIT Press, 1976.

Bertalanffy, L. Von, Quantitative Laws in Metabolism and Growth, *The Quarterly Review of Biology*, Vol. 32, 1957.

Bjerhammar, A., *Theory of Errors and Generalized Matrix Inverses*, Amsterdam, Elsevier, 1973.

Bowden, D. C. and Steinhorst, R. K., Tolerance Bands for Growth Curves, *Biometrics*, Vol. 29, 1973.

Box, G.E.P. and G. M. Jenkins, *Time Series Analysis: Forecastinq and Control*, San Francisco, Holden-Day, 1976.

Brand, R. J., Pinnock, D. E. and Jackson, K. L., Large Sample Confidence Bands for the Logistic Response Curve and its Inverse, *The American Statistician*, Vol. 27, 1973.

Brown, B. M., *The Mathematical Theory of Linear Systems*, London, Chapman and Hall, 1965.

Carnap, T., *An Introduction to the Philosophy of Science*, Gardner, M. (Ed.), New York, Basic Books Inc., 1966.

Casti, J. L., *Dynamical Systems and Their Applications, Linear Theory*, New York, Academic Press, 1977.

Chiang, A. C., *Fundamental Methods of Mathematical Economics*, New York, McGraw- Hill, 1967.

CRC Standard Mathematical Tables, 26th Edition, Beyer, W. H. (Ed.), CRC Press, Inc., Boca Raton, Florida, 1981.

Dhrymes, P. J., *Econometrics: Statistical Foundations and Applications*, Springer-Verlag, 1974.

Draper, N. R. and Smith, H., *Applied Regression Analysis*, 2nd Edition, John Wiley and Sons, New York, 1981.

Edison Electric Institute, *Statistical Yearbook of the Electric Utility Industry*, 1977 through 2010, Washington, D.C.

Edison Electric Institute, *Statistical Yearbook of the Electric Utility Industry*, 1960 through 1976, New York, N.Y.

Edison Electric Institute, *Statistical Bulletin*, 1940 through 1959, New York, N.Y.

Edison Electric Institute, *Statistical Bulletin Number 4 through Number 7*, New York, N.Y.

Efimov, N. V. and E. R. Rozendorn, *Linear Algebra and Multi-Dimensional Geometry*, Moscow, Mir Publishers, 1975.

Erenpreiss, M.S., Wickstrom, L.H., Perry C.J., Riley, R.A., Martin, D.R., and others, 201, Areas of Utica and Marcellus potential in Ohio: Ohio Department of Natural Resources, Division of Geological Survey, scale 1 inch equals 27 miles.

Feyzioglu, G., and Wang, D., Forecasting Exogenous Variables Using SAS PROC NLIN, *Proceedings of MWSUG '91*, LeRoy Bessler (Ed.), Fox Point, MidWest SAS Users Group, 1991.

Feyzioglu, G., and Choueiki, H. M., *An S-Curve Growth Model Applied to U.S. Population, Per Capita Peak Load Demand, Per Capita Capability, and Reserve Margin Trajectories from 1920 to 2008*, IFAC/IFORS/IAEE, International Symposium on Energy Systems, Management and Economics, Oct. 1989, Tokyo, Japan.

Feyzioglu, G., Choueiki, H. M., Wang, D., and Rack, F., *Development and Analysis of the Residential and Commercial Electricity Markets in Ohio from 1937 to 2006*, National Governors Association, The Second Joint Conference on Integrating Data for Decisionmaking, Dec. 1988, Washington, D.C.

Feyzioglu, G., *A Preliminary Assessment of the Question of Invariance of the Relationship between Real GNP and AEP Internal Energy Requirements Excluding C&SOE*, Staff Report, Ohio Department of Development, Division of Energy, March 1985.

Feyzioglu, G., *The Analysis and Assessment of Time Variant Linear Trends in Annual Economic Data Series with an Application to Energy Forecasting for the State of Ohio*, Ph.D. Dissertation, Columbus, The Ohio State University, 1983.

Feyzioglu, G., The Measurement of Time Variant Linear Trends in Ohio Sectoral Electricity Disposition Levels, *Proceedings of Symposium on Computer Analysis of Electric Load Forecasting and Generating Capacity Expansion*, Nakamura, S. (Ed.), Columbus, The National Regulatory Research Institute, 1983.

Fisher, F., *The Identification Problem in Econometrics*, 1966, New York, McGraw-Hill. Galbraith, J. K., Economics and the Public Purpose, New York, Signet, 1973.

Galbraith, J. K., *Economics and the Public Purpose*, New York, Signet, 1973.

Gallucci, V. F. and Ouinn, T. J., Reparameterizing, Fitting, and Testing a Simple Growth Model, *American Fishers Society*, Vol. 108, 1979.

Gantmacher, F. R., *The Theory of Matrices*, Vol. I, New York, Chelsea, 1960.

Gellings, C. W., (Lead Author and Editor), *et al*., *Demand Forecasting for Electric Utilities*, Lilburn, The Fairmont Press, 1992.

Gellings, C. W., Forecasting Models: An Evolution in Disguise, *Proceedings of Symposium on Computer Analysis of Electric Load Forecasting and Generating Capacity Expansion*, Nakamura, S. (Ed.), Columbus, The National Regulatory Research Institute, 1983.

Glasbey, C. A., Correlated Residuals in Non-linear Regression Applied to Growth Data, *Appl. Statist*., Vol. 28, pp. 251–259, 1979.

Grizzle, J. E. and Allen, D. M., Analysis of Growth and Dose Response Curves, *Biometrics*,1969.

Haavelmo, T., The Statistical Implications of a System of Simultaneous Equations, *Econometrica*, Jan. 1943, Vol. II.

Hempel, K.G., *Aspects of Scientific Explanation and Other Essays in the Philosophy of Science*, New York, The Free Press, 1965.

Hempel, K.G., Fundamentals of Concept Formation in Physical Science, *International Encyclopedia of Unified Science*, Vol. 2, No. 7, Chicago, University of Chicago Press, 1952.

Henderson, J. M. and R. E. Quandt, *Micro Economic Theory*, New York, McGraw-Hill, 1971.

Hogg, R. V. and Craig, A. T., *Introduction to Mathematical Statistics*, 4th Edition, Macmillan Publishing Co. Inc., New York, 1978.

Illinois Oil & Gas Association, "History of Crude Oil Prices," n.d., www.ioga.com/history-of-crude-oil-prices.

Intriligator, M. D., *Mathematical Optimization and Economic Theory*, Englewood Cliffs, New Jersey, Prentice-Hall, 1971.

Johnston, J., *Econometric Methods*, McGraw-Hill, 1972.

Kalman, R. E., Dynamic Econometric Models: A System-Theoretic Critique, *New Quantitative Techniques for Economic Analysis*, Academic Press Inc, 1982.

Kalman, R. E., Identifiability and Problems of Model Selection in Econometrics, *Advances in Econometrics*, Hildebrand W. (Ed.), New York, Cambridge University Press, 1982.

Kalman, R. E., Falb, P. L. and Arbib, M. A., *Topics in Mathematical System Theory*, McGraw-Hill, Inc., 1969.

Kendall, M. G. and Stuart, A., *The Advanced Theory of Statistics*, Vol. 2, Third Edition, London, Charles Grittin and Co., 1973.

Khshirsagar, A. M., *Multivariate Analysis*, New York, Marcel Dekker Inc., 1972.

Kneale, W., Propositions and Truth in Natural Languages, *Mind*, Vol. LXXXI, April 1972.

Koizumi, T., and Lundstedt, S.B., *Mind, Culture and Economy: The Morphology of Socio-Economic Systems*, Working Paper Series, College of Administrative Science, The Ohio State University, Jan. 1985.

Koizumi, T., Economics as a Study of Man, *Otemon Economic Studies*, University of Otemon, Japan, 1978.

Koopmans, T. C., Identification Problems in Economic Model Construction, *Studies in Econometric Method*, (Hood, W. C. and T. C. Koopmans, Eds.), Cowles Commission for Research in Economics; Monograph No. 14, New York, John Wiley, 1953.

Koopmans, T. C. and W. C. Hood, The Estimation of Simultaneous Linear Economic Relationships, *Studies in Econometric Method*, (Hood, W. C. and T. C. Koopmans, Eds.), Cowles Commission for Research in Economics; Monograph No. 14, New York, John Wiley, 1953.

Koopmans, T. C., Rubin H., and R. B. Leipnik, Measuring the Equation Systems of Dynamic Economics, *Statistical Inference in Dynamic Economic Models*, (Koopmans, T.C., Ed.), Cowles Commission for Research in Economics; Monograph No. 10, New York, John Wiley, 1950.

Kuhn, T. S., *The Structure of Scientific Revolutions*, Chicago, The University of Chicago Press, 1970.

Lehmann, E. L., *Testing Statistical Hypothesis*, New York, John Wiley, 1959.

Leontief, W., What Hope for the Economy, *The New York Review of Books*, Aug. 1982.

Leontief, W., Academic Economics, *Science*, Vol. 217, July 1982.

Leontief, W., Theoretical Assumptions and Nonobserved Facts, *American Economic Review*, Vol. LXI, 1971.

Majthay, A., *Foundations of Catastrophe Theory*, Boston, Pitman, 1985.

Malinvaud, E., *Lectures on Microeconomic Theory*, Amsterdam-London, North-Holland, 1973.

Mikhail, E. M., *Observations and Least Squares*, New York, University Press of America, 1976.

Morgenstern, O., *On the Accuracy of Economics Observations*, Princeton, New Jersey, Princeton University Press, 1963.

Nering, E. D., *Linear Algebra and Matrix Theory*, New York, John Wiley, 1970.

Nikaido, H., *Convex Structures and Economic Theory*, New York, Academic Press, 1968.

OPSB, Approved Cases, accessed Mar. 29, 2018, http://www.opsb.ohio.gov/opsb/index.cfm/siting-case-breakdown/approved-cases/.

Pindyk, R. S. and D. L. Rubinfeld, *Econometric Models and Econometric Forecasts*, New York, McGraw-Hill, 1976.

Poirier, Dale J., Piecewise Regression Using Cubic Splines, *JASA*, Vol. 68, Sept. 1973.

Popper, K., *The Logic of Scientific Discovery*, London, Hutchinson, 1959.

PUCO, *Ohio Electricity Statistics 1997*, Feyzioglu, G. (Ed.), PUCO, Columbus, Ohio, April 1999.

PUCO, *Ohio Long-Term Forecast of Energy Requirements 1995-2015*, Feyzioglu, G., and Choueiki, H. M. (Ed.), PUCO, Columbus, Ohio, July 1996.

PUCO, *Ohio Long-Term Forecast of Energy Requirements 2008-2027*, Staff Report, PUCO, Columbus, Ohio, Aug. 2008.

PUCO, *Technical Appendix to Ohio Long Term Forecast of Energy Requirements 1995 - 2015*, Feyzioglu, G. and Wang, D. (Ed.), PUCO, Columbus, Ohio, April 1997.

Rao, C. R., *Linear Statistical Inference and Its Applications*, 2nd Edition, New York, John Wiley, 1973.

Rao, C. R. and S. K. Mitra, *Generalized Inverse of Matrices and Its Applications*, New York, John Wiley, 1971.

Rhodes, G., Derived Demand for a Cognitive Econometric Game and Policy Making with Econometric Models, *Schweizerische Zeitschrift fur Volks-wirtschaft und Statistik*, June 1976.

Rhodes, G., Non Theoretical Errors and Testing Economic Hypotheses, *Economic Inquiry*, Sept. 1975, Vol. 13.

Richards, F. J., A Flexible Growth Function for Empirical Use, *Journal of Experimental Botany*, Vol. 10, pp. 290–300, June 1959.

Rubin, J. E., *Set Theory for the Mathematician*, San Francisco, Holden-Day, 1967.

Schmidt, P., *Econometrics*, New York, Marcel Dekker, 1976.

Suppe, F., *The Structure of Scientific Theories*, Urbana, University of Illinois Press, 1979.

Theil, H., *Principles of Econometrics*, John Wiley and Sons, Inc., 1971.

Tibberts, N., A System Planner's View of Load Forecasting and Generating Capacity Expansion, *Proceedings of Symposium on Computer Analysis of Electric Load Forecasting and Generating Capacity Expansion*, Nakamura S. (Ed.), Columbus, The National Regulatory Research Institute, 1983.

Turner, M. E., Blumenstein, B. A. and Sebaugh, J. L., A Generation of the Logistic Law of Growth, *Biometrics*, 1969.

USDOE, Energy Information Administration, *Fuel Oil and Kerosene Sales 2010*.

USDOE, Energy Information Administration, *Natural Gas Annual 2010*, All Reports & Publications, www.eia.gov/reports.

USDOE, Energy Information Administration, *Petroleum Marketing Annual 2010*, All Reports & Publications, www.eia.gov/reports.

USDOE, Energy Information Administration, *Petroleum Supply Annual 2010*, All Reports & Publications, www.eia.gov/reports.

USDOE, Energy Information Administration, *Quarterly Coal Report October-December 2010,* All Reports & Publications, www.eia.gov/reports.

USDOE, Energy Information Administration, *State Energy Consumption, Price and Expenditure Estimate (SEDS) 2010*, All Reports & Publications, www.eia.gov/reports.

USDOE, Energy Information Administration, *Federal Energy Data System Technical Documentation* (by Fuller, R. F.), Washington, D.C., June 1978.

U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, June 1982–March 2012, Washington, D.C.

U.S. Department of Commerce, Bureau of Economic Analysis, *The National Income and Product Accounts of the United States*, 1929–76 Statistical Tables, Washington, D.C., Sept. 1981.

U.S. Department of Commerce, Bureau of the Census, *Historical Statistics of the United States*, Colonial Times to 1970, Part 1 and 2, Washington, D.C., 1975.

U.S. Department of Labor, Bureau of Labor Statistics, CPI for All Urban Consumers (CPI-U) 1982-84=100 (Unadjusted) - CUUR0000SA0.

Von Neumann, J. and O. Morgenstern, *Theory of Games and Economic Behavior*, New York, John Wiley, 1953.