BARR

Power Forecast 2019: Williston Basin Oil and Gas Related Electrical Load Growth Forecast

North Dakota

Prepared for
North Dakota Transmission Authority

May 2019

234 West Century Avenue
Bismarck, ND 58503
701.255.5460
www.barr.com

Power Forecast 2019:
Williston Basin Oil and Gas Related Electrical Load Growth Forecast

May 2019

Contents

List of Tables

List of Figures

List of Large Figures

List of Appendices

Abbreviations

bbl	barrel
bpd	barrels per day
BEPC	Basin Electric Power Cooperative
EERC	Energy & Environment Research Center, University of North Dakota
EIA	Energy Information Administration, U.S. Department of Energy
ESP	Electrical Submersible Pump
Esri	Environmental Systems Research Institute
GIS	geographic information system
MMscf/d	million standard cubic feet per day
kW	kilowatt
kWh	kilowatt hour
MDU	Montana-Dakota Utilities
MW	megawatt
MWh	megawatt hour
MWd	megawatt day
GW	gigawatt
GWh	gigawatt hour
NDIC	North Dakota Industrial Commission
NDPA	North Dakota Pipeline Association
NDTA	North Dakota Transmission Authority
NDSU	North Dakota State University
NGL	Natural Gas Liquid
PF12	Power Forecast 2012: Williston Basin Oil and Gas Related Electrical Load Growth Forecast
PF19	Power Forecast 2019: Williston Basin Oil and Gas Related Electrical Load Growth Forecast
psig	pounds per square inch gage
SWD	saltwater disposal

Definitions

Barrel: A barrel equals 42 US gallons.

Condensate: Also called natural-gas condensate or natural gas liquids, is a low-density mixture of hydrocarbons that are present as gaseous components in the raw natural gas produced from many natural gas fields, and which condense out of the gas when the temperature is reduced.

Consensus scenario: This is one of two forecast scenarios within the PF19. The consensus scenario correlates to the NDPA's Case 1 oil and gas production volume forecasts and NDSU's mid oil price scenario's population forecast. The consensus scenario reflects higher potential for growth than the PF19's low scenario.

Electric power: The instantaneous rate at which electrical energy is delivered. For example one horsepower is 550 foot-pounds force per second. Electric power is generally reported in watts, kilowatts (kW) or megawatts (MW). For example, a natural gas processing plant might require 50 MW of power to process gas at a rate of 350 million cubic feet per day.

Electrical energy: A measure of electricity that can accomplish a particular amount of work. Common units of electrical energy are kilowatt hours (kWh) or megawatt hours (MWh). For example, a natural gas processing plant might require 100 MWh of energy to process 300 million cubic feet of gas.

Electrical energy consumption: This term is used within the PF19 to describe the total electrical energy (in MWh or GWh) used within one or more calendar years.

Energy load categories: This is the term used to describe the three categories used in the PF19 to allocate baseline data and forecasted electrical consumption: oil and gas production, large industrial and commercial, and population.

Fractionation: Y-grade NGL contains varying amounts of ethane, propane, butane, pentane, and heavier hydrocarbons (referred to as C6+). NGL fractionation is the process of separating each constituent into a purified stream, each of which has a different end use.

Gas Oil Ratio: The ratio of the volume of associated gas produced to the volume of oil produced, or thousand standard cubic feet of gas/barrels of oil.

Gas Processing: The operation of removing natural gas liquids (NGL), water, and sulfur from associated gas to produce a pipeline-quality natural gas product and fractionated or unfractionated NGLs.

Low scenario: This is one of two forecast scenarios within the PF19. The low scenario correlates to the NDPA's Case 2 oil and gas production volume forecasts and NDSU's low oil price scenario population forecast. The low scenario reflects lower potential for growth than the PF19's consensus scenario.

Oil Field: A designated geographic area from which oil is produced.

Oil and gas load category: This is one of three energy load categories within the PF19; it represents the estimated electrical energy required to produce and transport oil and gas products and dispose of waste water during production activities within the Williston Basin's Bakken and Three Forks formations. The forecasted load estimates for this class were calculated prior to the other two load categories using formulae described in the methods.

Large industrial/commercial load category: This is one of three energy load categories within the PF19; it represents energy uses that are typically located in a fixed geographic location. For purposes of the PF19, the baseline data for this category includes gas processing plants, oil refineries, and oil transmission pipeline pumps. Additional large industrial/commercial energy uses with a fixed geographic location beyond those described in this definition are included in the population load category for purposes of the PF19.

Population load category: This is one of three energy load categories within the PF19; it represents the baseline total amount of electrical energy consumed in 2018 minus the oil and gas estimated load category and the large industrial/commercial uses category. Therefore, this load category includes residential end uses as well as some industrial and commercial uses not allocated as being directly related to the production of oil and gas.

Produced Water: A term used in the oil industry to describe water that is produced as a byproduct along with oil and gas.

Pump Jack: A device used in the oil industry to extract crude oil from an oil well where there is not enough pressure in the well to force the oil to the ground surface.

Specific Power: The power required to accomplish a specific task, which must be identified. For example, oil production specific power is the number of kW required to produce oil at the rate of 1 barrel per day.

Specific Energy: The energy required for a particular consumer (or unit mass). For example, population-specific energy used is the number of kWh used in 1 year by a housing unit.

Submersible Pump: A pump type of which the entire pump and motor assembly is lowered below the surface of a liquid to push it to a higher elevation.

Transload: A facility used to physically transfer product from one transportation mode or vehicle to another.

Water-Oil Ratio: The ratio of the volume of produced water to the volume of oil produced, or barrels water/barrels oil.

Report Disclaimers/Qualifying Statements

- The opinions in this report are based on information and data obtained from others and relied upon by Barr, the NDIC, and the NDTA without independent verification unless expressly noted herein. Statements suggesting certainty of power and energy usage and demand should be read with that in mind.
- This report was prepared for the NDIC and NDTA. Any use which a third party makes of this report is the responsibility of such third party. Such third party agrees that Barr, the NDIC, or the NDTA are not responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of any use of or reliance on this report.
- Barr, or any of its subcontractors and the NDIC and NDTA or any person acting on its behalf, do not:

  (A) Make any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately-owned rights; or

  (B) Assume any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report.
- The views and opinions of authors expressed herein do not necessarily state or reflect those of the NDIC or the NDTA.

Executive Summary

The North Dakota Transmission Authority (NDTA) hired Barr Engineering Co. (Barr) to update an electrical load forecast completed in 2012, "Power Forecast 2012: Williston Basin Oil and Gas Related Electrical Load Growth Forecast" (PF12.) Barr's report, "Power Forecast 2019: Williston Basin Oil and Gas Related Electrical Load Growth Forecast" (PF19) is an update of the previous study. The PF19's study area includes the Williston Basin within the state of North Dakota for 2018-2038.

The PF19 uses three broad energy load categories to organize baseline (2018) and estimated future electrical energy consumption (in MWh) totals. The three categories included:

- oil and gas production,
- large industrial and commercial (for the purpose of the PF19, this included users associated to oil and gas production) and
- population.

An Environmental Systems Research Institute (Esri) based geographic information system (GIS) database model was developed to store model inputs, parameters, and results for the PF19 study. A baseline total electrical energy consumption total was allocated to each of the three categories and then was spatially distributed within the database model.

The PF19 estimates future electrical energy consumption growth as a function of projected oil and gas production volumes available from the North Dakota Pipeline Authority (NDPA) (used for the oil and gas production and large industrial and commercial broad load categories) and projected population estimates available from North Dakota State University (NDSU) (used for the population load category). The PF19 estimated two scenarios for total electrical energy consumption: the low scenario and the consensus scenario. These estimates are based on NDPA's oil and gas production case 1 and case 2 scenarios and NDSU's estimated county populations for low and mid oil price economic scenarios. The PF19 forecasts are limited by uncertainty surrounding future oil prices, regulations, technology advancements, North Dakota policy, and other potential factors. A brief description of the methodologies used to forecast each broad load category is provided below.

<u>Oil and Gas Production Broad Load Category Forecast Method:</u> Monthly oil and gas production for each oil field in 2018 was annualized and distributed amongst North Dakota Industrial Council (NDIC)-defined oil fields. Key characteristics, such as reservoir depth, formation initial pressure, and pump efficiency were allocated or assigned to each oil field. Total energy usage for oil and gas production was compiled by applying formulae described in the PF19 report to estimate the energy required to pump products (oil, gas, and water) to the ground surface and the energy required to process the oil and gas and dispose of the waste products (i.e., the energy to pump the fluids through the gathering network to a processing, transload, or disposal site). Annual electrical energy consumption totals for the oil and gas load category were estimated on a per-oil-field basis using the total volumes of oil, gas, and water production estimated by NDPA.

Large Industrial and Commercial Broad Load Category Forecast Method: The PF19's large industrial/commercial load category includes gas processing plants, oil refineries, and oil transmission pipeline pumps. For gas processing plants, a specific energy consumption of 13.2 MWd for every 100 million standard cubic feet (MMscf) of gas processed was used to calculate gas processing energy. Data provided by NDPA identify locations for some of the planned new capacity, but additional new capacity will be required which at present is not announced and for which geographic locations have not been identified. The additional new capacity was estimated based on gas production volumes and the estimated geographic locations of produced gas volumes. For oil refineries, known existing and planned refineries were included. For oil transmission pipeline pumps, the total horsepower required to move the product through a pipeline was estimated based on capacity and diameter of the pipeline for existing pipelines. The same methodology was used for one potential future pipeline, the Liberty Pipeline.

Population Forecast Method: Forecasted electrical energy consumption totals for the population load category were determined based on the anticipated growth rates provided in the "Williston Basin 2016: Employment, Population, and Housing Forecasts" study completed by NDSU. Using baseline data from Basin Electric and Montana Dakota Utilities, Barr estimated a per capita electrical consumption rate for each county and applied the electrical consumption to the forecasted population numbers provided in the NDSU data.

Results: The PF19's estimated total amount of additional electrical energy consumption required within the study period (2018-2038) reflected an overall growth rate of approximately 44% (low scenario) to 71% (consensus scenario). At the end of the study period (2038), the low scenario forecasts a total annual consumption of 15,000 GWh and the consensus forecasts a total annual consumption of 18,000 GWh of electrical energy consumption. Compared to the baseline, this represents an increase of 4,600 GWh for the low scenario and 7,500 GWh for the consensus scenario. Consistent with the needs to meet margin requirements, this implies an increase in generation capacity of 670 megawatts (MW) to 1,000 MW (calculated using a 92% load factor and an 86% capacity factor) above the capacity demand.

The majority of the growth is in load categories which have nearly flat demand curves (i.e., oil and gas production and large industrial/commercial sources related to oil and gas production), and do not readily lend themselves to interruptible power supply. Therefore the estimated new demand will typically be supplied by base load capacity or mid-load capacity with fast dispatch rates.

The state's base load generating capacity, not including Heskett Station, is 4,380 MW. Since existing base load resources in North Dakota are operating well above industry averages, new base load or equivalent will likely be selected by utilities that need to meet this increased demand.

The total estimated energy in MWh for the low scenario and the consensus scenario is illustrated Figure ES-1.

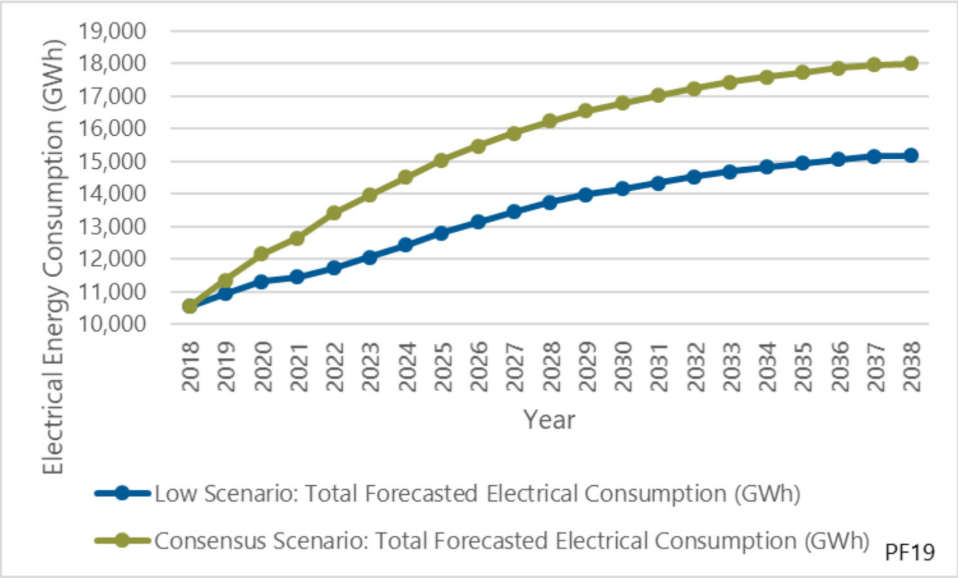


Figure ES-1 Study Area Total Forecasted Electrical Consumption

1 Study Background

The North Dakota Transmission Authority (NDTA) facilitates the development of transmission infrastructure in North Dakota. The NDTA was established "to serve as a catalyst for new investment in transmission by facilitating, financing, developing, and/or acquiring transmission to accommodate new lignite and wind energy development" (reference [1]). To be successful in electrical infrastructure planning, the NDTA wants an understanding of North Dakota's energy capabilities and needs while considering increases in electrical load growth due, in large part, to energy-intensive development of oil and gas production within the Williston Basin.

In 2012, NDTA developed an electrical load forecast in this region to better understand potential future load growth. The expected growth was anticipated to be primarily a result of oil and gas production and secondary infrastructure and associated population growth required to support production needs. This study, "Power Forecast 2012: Williston Basin Oil and Gas Related Electrical Load Growth Forecast" (PF12, reference [2]), forecasted a need for an additional 2,500 MW of capacity (or approximately three times increase over the 2012 – 2032 study period) for the PF12's study area (which included the Williston Basin within North Dakota, South Dakota, Montana, and Wyoming).

The PF12 considered population growth, commercial and industrial development, and primary and secondary employment requirements resulting from the "oil boom." Because drilling rigs were a limiting factor for development, the count of available drilling rigs, drilling rig efficiencies, and the number of producing wells within specific oil-producing regions were the most significant factors in the forecast. The PF12 used projected well counts by year to build out portions of the future oil field infrastructure model; the estimated well counts were then used to calculate demand cases for low, consensus, and high forecast scenarios.

NDTA engaged Barr Engineering Co. (Barr) to update the forecasts in the PF12 study in 2019. This report, "Power Forecast 2019: Williston Basin Oil and Gas Related Electrical Load Growth Forecast" (PF19), summarizes the findings of the updated forecast for 2018 through 2038. The PF19 update is limited to North Dakota and primarily relies on publicly available information to estimate future electrical energy consumption for 2019 through 2038. The method of forecasting total growth was changed for the PF19 (Section 1.1.1), but the goal of estimating future load growth as a function of oil and gas development was the same.

The PF19 uses North Dakota Pipeline Authority's (NDPA's) oil and gas production forecast data which is based on projected oil prices. The PF19 also incorporates population forecast data from NDSU, information on projected point-source loads (loads from large industrial/commercial energy consumers) acquired from industry contacts, and publicly available information. The PF19 forecasts are limited by uncertainty surrounding future oil prices, regulations, technology advancements, North Dakota policy, and other potential forces. More details about the sources of information and how it is used in the PF19 is provided in Section 2.

1.1 Study Purpose

The purpose of the PF19 is to estimate anticipated future electrical energy consumption demands within the state of North Dakota, primarily within the oil-producing counties, for the next 20 years. Significant changes occurred in the region after the PF12 forecast that affect electrical load growth including but not limited to oil price changes, technology advancement, and regulatory changes. Because of the number of changes and differences from key assumptions in the PF12 forecast, the previous projections were outdated. This study provides an updated estimate of electrical energy consumption growth in the region using more recent information and updated key assumptions that affect electric load growth.

While it is understood that peak demand is important for system planning, this report does not specifically estimate peak demand. The relationship between total energy consumption and peak demand is highly dependent on the type of load, and the fraction of each load type on the system. To address that, this report estimates load growth for three broad load categories and the geographic distribution of those loads. It is expected that the individual electric utilities will have the best understanding of the relationships between load type and capacity factor for their own systems, and will be able to use this data to make their own projections of peak demand.

1.1.1 PF19 Approach

The PF19 estimates future electrical energy consumption growth as a function of projected oil and gas production volumes available from NDPA. The forecast method used in PF19 differs from that used in PF12. PF19 considers the baseline and projections for three broad load categories: oil and gas production, large industrial/commercial uses related to processing needs of the oil and gas production, and population (Section 2). PF19 estimates are made directly from estimated future oil and gas production rates and the associated electrical consumption required to produce those volumes. Population growth and large industrial/commercial projections formed the basis to calculate the related change to electrical consumption in those categories. PF19 does not estimate future electrical energy consumption directly as a function of well count, rig count, or many of the other variables considered in the PF12. Instead, many of these assumptions in PF12 are now considered in oil production and population estimates from NDPA and NDSU and are incorporated into the PF19 as a function of the NDPA and NDSU forecasts which use many of those same factors as the PF12 for their forecasts (e.g., well counts).

Given the uncertainty of oil prices and other factors outside of Barr's or NDTA's control, the PF19 was designed so it may be readily updated to account for changes driven by oil prices, increased efficiencies, changes in production rates, or enhanced oil recovery methods. The GIS data based approach also allows for new information, which may not be currently available, to be incorporated into future updates.

1.2 Study Area

The study area for the PF19 is smaller than the PF12 and is limited to the state of North Dakota (to serve the needs of the NDTA). The study area is comprised of the Basin Electric Power Cooperative (BEPC) and the MDU service areas within the Williston Basin in North Dakota. This includes the 24 western North Dakota counties as shown in Figure 1-1.

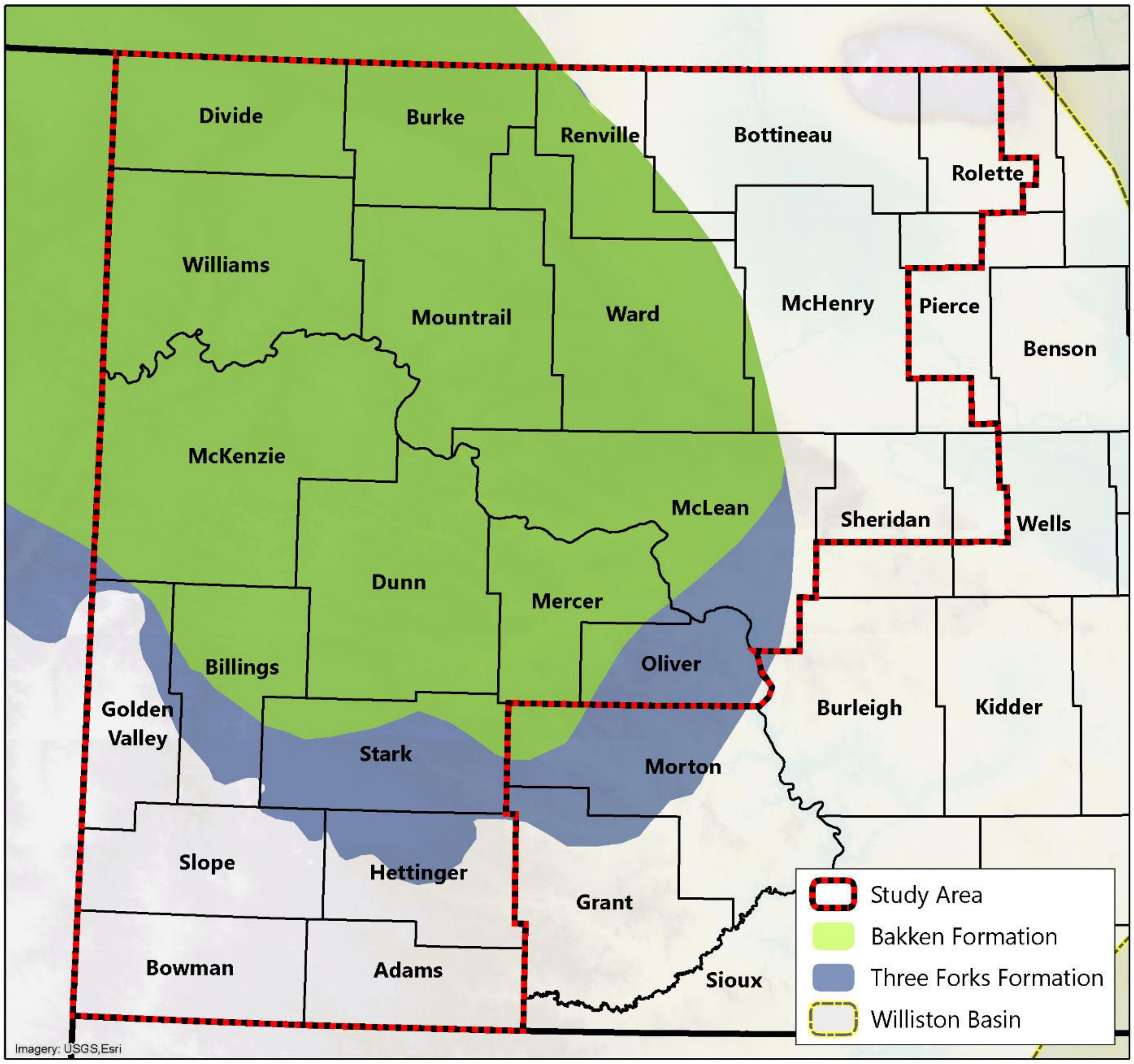


Figure 1-1 Study Area and Associated Williston Basin Formations

1.2.1 Williston Basin

The Williston Basin is a large geological feature centered in Williston, North Dakota; the full basin area compromises nearly 300,000 square miles including portions of North Dakota, South Dakota, Montana, Saskatchewan, and Manitoba (reference [3]). The formation of oil and gas within the Williston Basin was the result of many geologic events occurring over millions of years.

The Oil and Gas Division of the North Dakota Industrial Council (NDIC) combines production statistics within the Williston Basin for the Bakken and Three Forks formations. Over 90% of the oil and gas production in North Dakota comes from these two formations. This report follows the NDIC convention of combining production data for the Bakken and Three Forks. Descriptions of the Bakken formation and the Three Forks formation are provided in the following subsections.

1.2.1.1 Bakken Formation

The Bakken Formation (Bakken) lies within the subsurface formation of the Williston Basin; the portion of the Bakken formation within North Dakota is illustrated in Figure 1-1. The Bakken has been the main oil-producing formation (outside of conventional oil drilling) within the Williston Basin since its discovery. The maximum thickness of the Bakken is 150 feet and consists of three distinct layers. The top and bottom layers are known to have black, organic-rich shales, and the middle layer is largely composed of siltstones and sandstones (reference [4]). This middle layer is the primary oil-producing layer of the Bakken Formation and the focus of most current oil production efforts in North Dakota.

1.2.1.2 Three Forks Formation

Additional oil production beyond the middle stratum of the Bakken Formation within North Dakota has largely focused on extraction from the underlying Three Forks Formation. The portion of the Three Forks formation within North Dakota is illustrated in Figure 1-1. Throughout a large majority of the Williston Basin, the Three Forks Formation maintains a maximum thickness of 270 feet (reference [5]). Most oil and natural gas production has targeted the upper Three Forks Formation (first bench) consisting of layers of carbonates and evaporates, mudstone, dolomite, and peritidal sediments (reference [6]). The middle (second bench) and lower (third bench) Three Forks Formation are currently being assessed for future oil- and water-saturation capacities and future development (reference [7]).

2 Electrical Consumption Forecast Methodology

The study area's electrical energy consumption growth is predominately influenced by the oil and gas sector and is expected to be in the future unless certain significant developments occur. As such, the PF19 estimates future electrical consumption growth as a function of projected oil and gas production volumes available from NDPA. This approach is based on the premise that a particular amount of energy is required to produce a barrel of oil and an understanding that there is a correlation between oil and gas production rates and electrical consumption. The PF19 approach also assumes that increased demands for large industrial/commercial energy users such as gas processing plants, refineries, and oil pipelines are correlated to increased oil and gas production. Other loads such as commercial, retail, and municipal energy use are presumed to be more closely correlated to population growth. Additionally, while population growth may be driven by the need for labor in the oil and gas industry, there are other factors which may limit population growth rate. Consequently, the electrical energy consumption is divided into three broad load categories and calculated based on data sets provided by reliable authorities which estimate the underlying variables directly. It is recognized that other factors may also impact overall electric load growth; however, the focus of the PF19 is on impacts to electrical energy consumption growth associated with increased oil and gas production within the Bakken and Three Forks Formations of the Williston Basin.

An Environmental Systems Research Institute (Esri)-based geographic information system (GIS) database model was developed to store model inputs, parameters, and results for the PF19 study. Information regarding the total electrical consumption in 2018 was provided by MDU and BEPC to serve as the baseline electrical consumption totals. The 2018 electrical energy consumed (in kWh) was allocated to the three broad energy load categories used to organize consumption within the PF19 model and to spatially distribute the total consumption. Forecasted estimates were completed using GIS tools and Python scripting within the Esri ArcMap© software and organized into the same three broad energy load categories as the baseline. The following three broad load categories comprise the GIS database model as illustrated in Figure 2-1:

1. Oil and gas production
2. Large industrial/commercial (includes gas processing plants, oil refineries, and transmission pipeline pumps)
3. Population

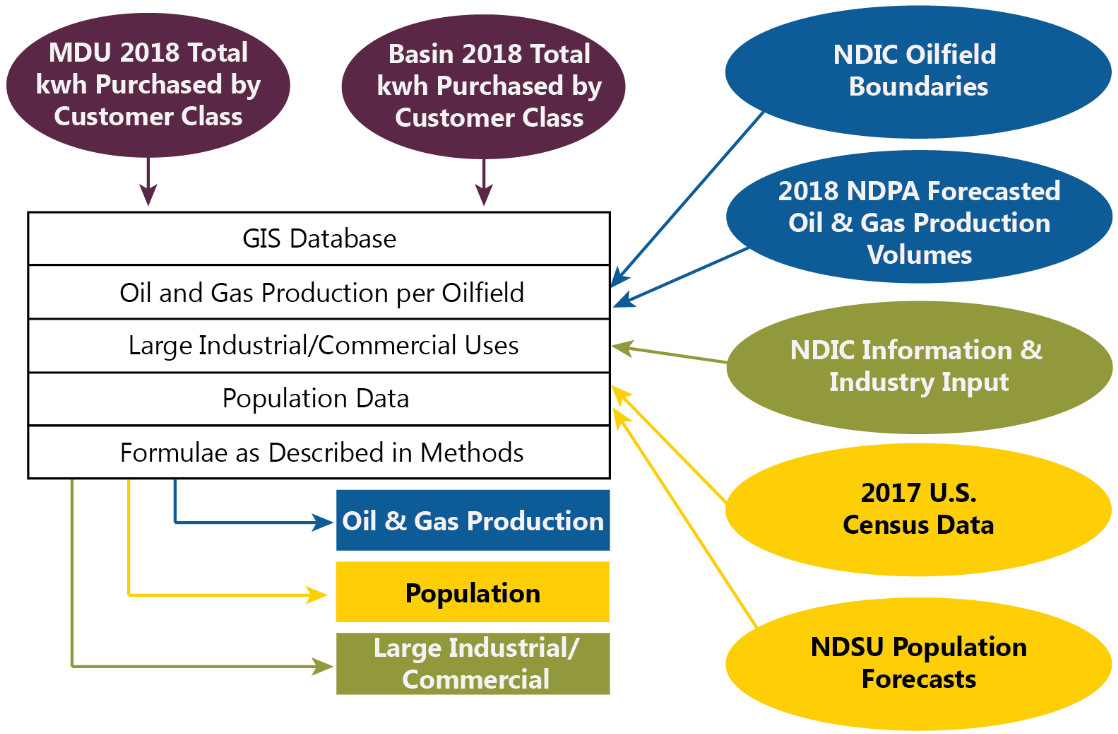


Figure 2-1 GIS Database Model Inputs

Data from various sources were used to determine how to allocate the baseline data within the three broad energy load categories (e.g., NDIC oil field boundaries, 2018 NDPA oil and gas production volumes, 2017 U.S. Census data, and NDIC information and industry input). Several data sources were also used to inform the forecast data and methods (e.g., NDPA forecasted oil and gas production volumes, formulae as described throughout this report, and NDSU population forecasts). Stakeholder outreach and industry input was gathered by NDTA and provided to Barr. Information input into the database model was organized so that parameters with impacts on the forecasted estimates are distinctly identified and can be easily updated and reloaded into the database model as new information becomes available.

The method used in this study forecasted total anticipated electrical energy (MWh or GWh) to be consumed on an annual basis; electric power demand in MW or gigawatt (GW) is not reported. While electric demand capacity is not reported, it is considered in hypothetical terms within the results section of the report (Section 4). The PF19 estimated two scenarios for total electrical energy consumption: the low scenario and the consensus scenario. For the oil and gas production broad load category, the PF19's consensus scenario corresponds with NDPA's Case 1 Scenario for oil and gas production and the low scenario corresponds with NDPA's Case 2 Scenario for oil and gas production. The NDPA scenarios are updated regularly and published to the NDPA public website and raw data was emailed to Barr [8]. Descriptions of the Case 1 and Case 2 scenarios are provided below.

- Case 1 Scenario – The expected oil production scenario based on current technology and the U.S. Department of Energy (DOE) oil price forecast. Refer to Figure 2-2 for estimated oil production totals. The expected gas production scenario is based on the gas oil ratio which increases as the well ages (causing the growth rate of the gas forecast to accelerate faster than the oil forecast). Refer to Figure 2-3 for estimated gas production totals.

- Case 2 Scenario – The expected oil production scenario is based on the same DOE price forecast as Case 1, but assumes lower industry activity in North Dakota at the forecast prices. For example, at $75 per barrel forecast price, more activity is concentrated in Texas or other plays around the U.S. and less oil and gas production would be expected in North Dakota. Refer to Figure 2-3 for estimated oil production totals. The expected gas production scenario is forecasted in the same way as it is described for the Case 1 scenario but included the modified oil production volumes. Refer to Figure 2-3 for estimated gas production totals.

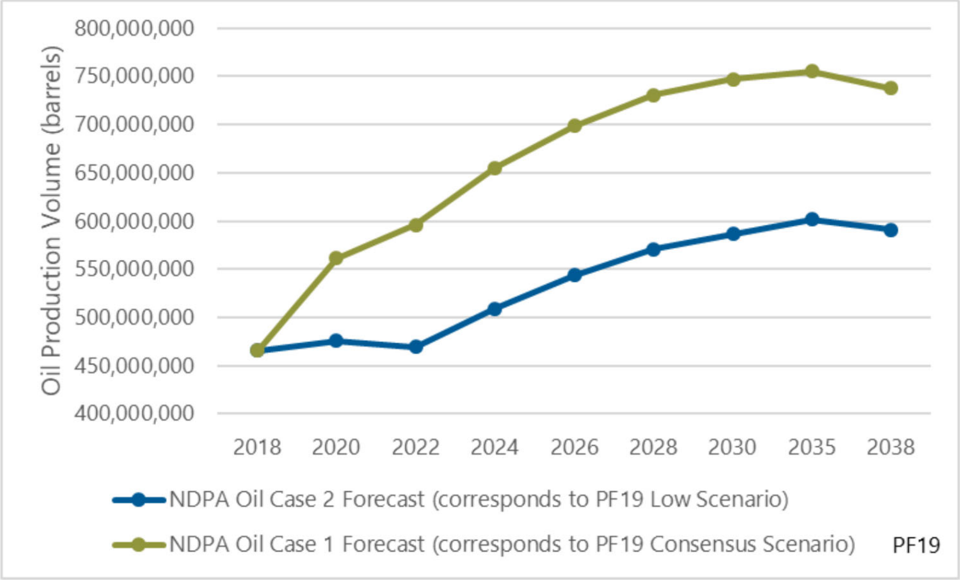


Figure 2-2 NDPA Forecast: Oil Production Volumes

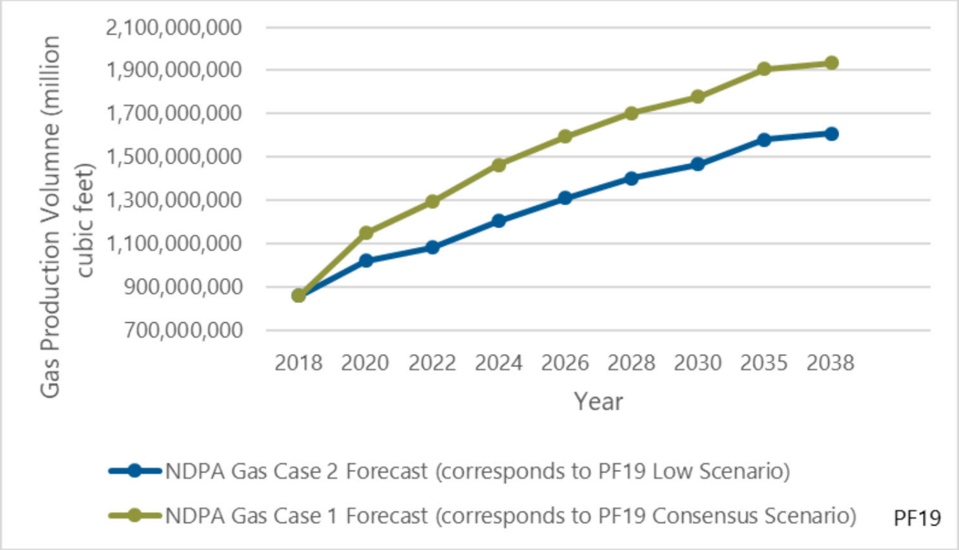


Figure 2-3 NDPA Forecast: Gas Production Volumes

The large industrial/commercial consumptive broad load category accounted for within the PF19 are also directly related to oil and gas production as described in Section 2.4.

For the population broad load category, the PF19 assumed population growth rates included in NDSU's Williston Basin 2016 forecast estimates which also incorporated estimated oil and gas production volumes into various scenarios as described in Section 2.5.

The remaining sections of the electrical consumption forecast methodology provide the following additional details regarding methodologies used to complete the PF19:

- Section 2.1 describes how the baseline MDU and BEPC 2018 electrical energy consumed (in MWh) was distributed across the three broad energy load categories
- Section 2.2 describes how baseline and forecasted data were distributed spatially
- Section 2.3 provides additional details on the oil and gas production forecast method
- Section 2.4 provides additional details on the large industrial/commercial forecast method
- Section 2.5 provides additional details on the population forecast method

2.1 Baseline Data

BEPC and MDU provided baseline electrical consumption data (in kWh) to Barr in a format organized by rate class; Barr allocated the rate classes to each of the three broad energy load categories used to estimate future electrical consumption. To distribute the data across the broad load categories, Barr first calculated the total energy consumption required to produce the volume of oil and gas produced in 2018 (Section 2.3). Barr then allocated the sources of large industrial/commercial energy consumers known to be related to the production of oil and gas, including natural gas processing plants, oil transmission pipeline pump stations, and oil refineries (Section 2.4). Finally, Barr allocated the remaining energy consumed in 2018 to the population load category (Section 2.5). As such, MDU and BEPC's rate class categories do not directly correlate to the PF19's three load categories. Furthermore, the PF19 study's distribution also results in almost half of MDU and BEPC's 2018 commercial or industrial electric usage being allocated to the PF19's population load category.

The organization of the baseline data was used to confirm, calibrate, or validate the forecast methods (Section 2.3). The baseline electrical consumption was approximately 10,500 GWh. The distribution of the total electrical energy consumption for the three broad energy load categories is shown in Figure 2-4. The breakdown of how the total electrical energy consumption was allocated per category is provided in Table 2-1 and is illustrated in Large Figure 1 in Appendix A.

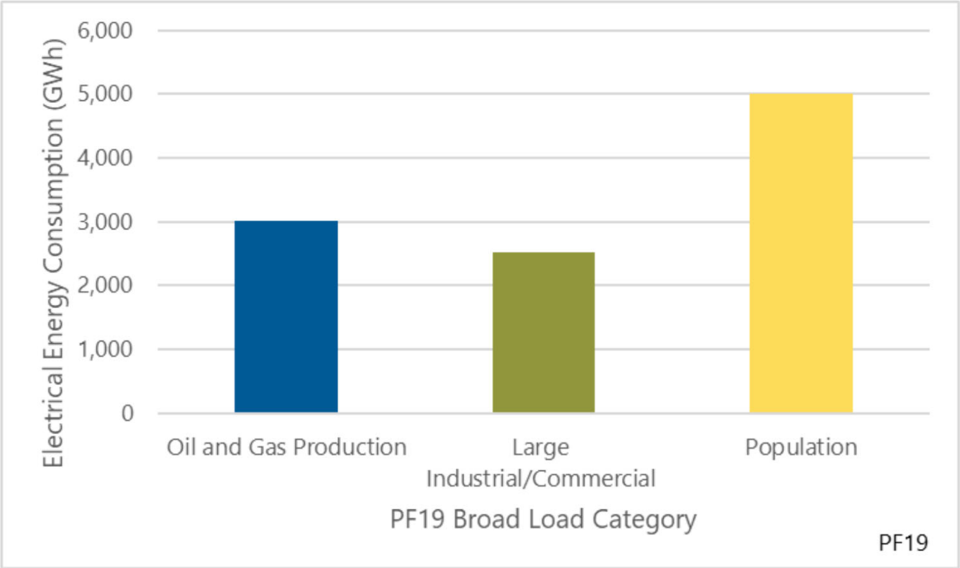


Figure 2-4 **Baseline (2018) Electrical Energy Consumption Distribution by Broad Load Category**

Table 2-1 **Baseline (2018) Energy Consumption Per-County**

County	Oil and Gas Production Broad Load Category (GWh)	Large Industrial/Commercial Usage Broad Load Category (GWh)	Population Broad Load Category (GWh)
Adams	0	0	43
Billings	76	28	68
Bottineau	41	0	98
Bowman	154	0	20
Burke	42	0	52
Divide	66	0	26
Dunn	460	42	585
Golden Valley	8	6	145
Hettinger	0	29	126
McHenry	1	135	227
McKenzie	1065	8	357
McLean	13	0	120
Mercer	0	0	165
Mountrail	434	63	1009
Oliver	0	0	109
Pierce	0	1306	38
Renville	19	0	84

County	Oil and Gas Production Broad Load Category (GWh)	Large Industrial/Commercial Usage Broad Load Category (GWh)	Population Broad Load Category (GWh)
Rolette	0	0	50
Sheridan	0	0	84
Slope	12	0	101
Stark	39	0	343
Ward	1	0	276
Wells	0	0	37
Williams	581	912	836
Total	3012	2530	5000

2.2 Spatial Distribution of Baseline and Forecast Data

Spatial distribution of the baseline and forecast data was completed for each broad energy load category used in the database model. The distribution approach for each of the three broad energy load categories is described in the following subsections.

2.2.1 Oil and Gas Production

To establish baseline conditions, oil and gas production was attributed to each oil field within the Williston Basin based on oil field production data for 2018 provided by NDIC. The total sum of production for all oil fields provided by the NDIC was slightly less than the total production provided for the Williston Basin. The differences in production totals were attributed to production in confidential wells. In some cases, oil wells may be considered “confidential” (which are typically exploratory in nature or in early stages of development) and the NDIC data set does not identify status (oil field well or otherwise). The difference between the total basin production and reported oil field totals were distributed proportionally across the oil fields based on the number of confidential wells reported in each oil field at the end of 2018.

To establish forecast conditions, increases of forecasted oil and gas production provided by NDPA were allocated to oil fields under an assumption that the areas with the highest historic production rates within the Bakken and Three Forks Formations will see a proportionate distribution of future production. This represents the drilling of in-fill wells in the most productive and profitable parts of the formation. In later years, the distribution was changed so that production was more broadly distributed across the Three Forks Tier I and Three Forks Tier II regions by increasing the amount of new production allocated to the lower production rate areas from the baseline year by a small percentage (approximately 1% per year). The distribution of forecasted volumes and the shift in how those forecasted volumes were distributed assumes that the highest production rate areas will not sustain the forecasted growth throughout the entirety of the study period. In other words, it is assumed that new production within the Williston will geographically shift in the later years of the study period.

The distribution was based in part on data provided by the NDPA and was also based in part on industry input. The geographic extents of where forecasted oil and gas production will occur is unknown and difficult to accurately estimate. However, the locations of future production impact the forecasted estimated energy use reported by county within the PF19. To inform the oil and gas production broad load category's estimated electrical energy consumption forecast by county, figures illustrating the model's distribution of oil production are provided for 2023 (Figure 2-5), 2028 (Figure 2-6), and 2033 (Figure 2-7). The gas production distribution mirrors that of oil production.

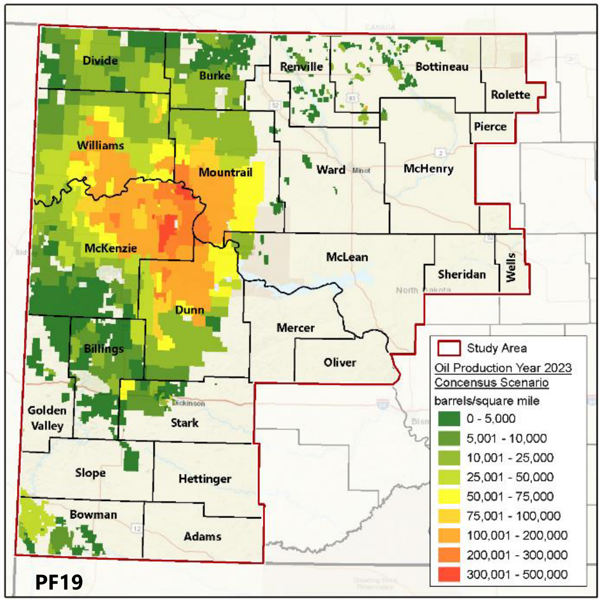


Figure 2-5 **Oil Production (barrels/square mile) Spatial Distribution, 2023**

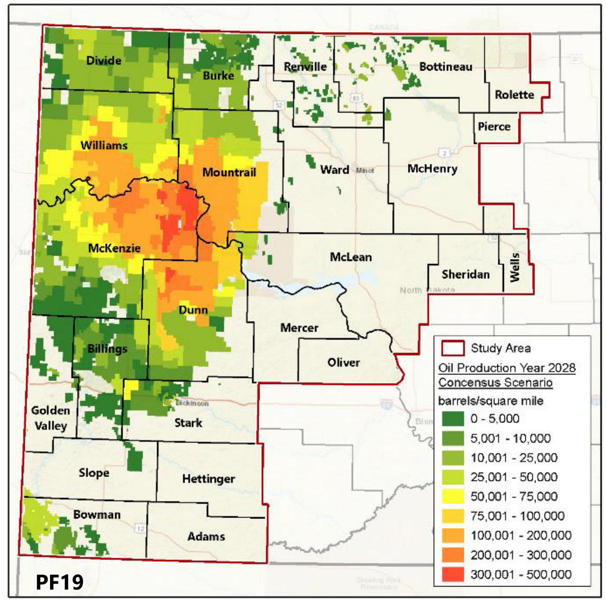


Figure 2-6 **Oil Production (barrels/square mile) Spatial Distribution, 2028**

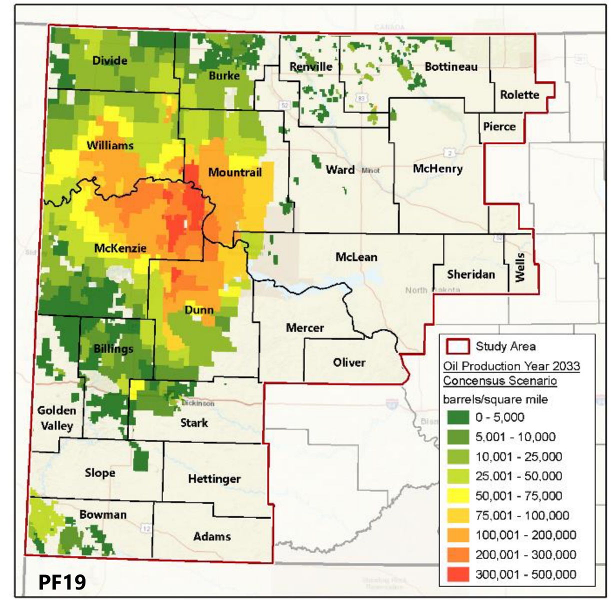


Figure 2-7 **Oil Production (barrels/square mile) Spatial Distribution, 2033**

2.2.2 Large Industrial and Commercial

Existing large industrial/commercial uses with distinct geographic locations (natural gas processing plants and oil refineries) were mapped in accordance with their actual locations. Baseline oil transmission pipeline pump station loads were calculated as a total and distributed evenly across the pipeline corridor.

Future large industrial/commercial consumers with distinct geographic locations (natural gas processing plants and oil refineries) were placed in accordance with their planned locations if known, or were placed based on professional judgment of likely locations. The PF19 incorporates new gas processing capacity as a function of the requirement to meet the regulated gas capture goals and per the increased production rates. In both the low growth scenario and the consensus scenario multiple new gas processing plants will be required.

Barr compared the gas production volumes for four different geographic regions to the gas processing capability in those regions to determine where new gas plants might be needed. Existing gas plant capacity includes all plants currently operating, under construction or announced expansions as of April 30, 2019. Table 2-2 shows the timing of new gas processing capacity which will be required for each region, in addition to the existing capacity.

Table 2-2 New Gas Processing Capacity by Year

Region [1]	Scenario	2019 or 2020	2021 or 2022	2023 or 2024	2025 or 2026	2027 or 2028	2029 or 2030	2031 or 2032	2033 or 2034	2035 or 2036	2037 or 2038
A	low	0	80	0	50	0	40	0	0	0	0
A	consensus	0	100	0	0	0	0	0	0	0	0
B	low	0	240	0	0	120	120	60	0	60	0
B	consensus	0	390	150	1500	150	150	0	150	0	0
C	low	200	0	0	50	0	0	0	0	0	0
C	consensus	0	0	0	0	200	0	200	0	0	0
E	low	0	0	0	0	0	0	0	0	0	0
E	consensus	0	20	20	20	0	20	0	0	0	0

Notes: units of gas plant capacity are in MMscf per day

[1] The regions were selected to represent specific co-op territories according to the list below.

A: Burke-Divide Electric Cooperative, north Central Electric Cooperative, Sheridan Electric Cooperative

B: Lower Yellowstone Electric Cooperative, McLean Electric Cooperative, Mountrail-Williams Electric Cooperative, Verendrye Electric Cooperative

C: McKenzie Electric Cooperative

E: Goldenwest Electric Cooperative, Roughrider Electric Cooperative, Slope Electric Cooperative

One future oil transmission pipeline was assumed (Liberty Pipeline) and a potential alignment was based on professional judgment and understanding of the pipeline's anticipated terminus. Estimated forecasted electrical energy consumption for the pump stations associated to this potential future pipeline were then distributed across the estimated pipeline corridor.

2.2.3 Population

Population was distributed according to the U.S. Census county and incorporated areas breakdown. Projections of future population were distributed proportionate to the baseline distribution of the population in 2018.

2.3 Oil and Gas Production Forecast Methods

Monthly oil and gas production for each oil field in 2018 was annualized and distributed amongst NDIC-defined oil fields. Key characteristics such as reservoir depth, formation initial pressure, and pump efficiency were allocated or assigned to each oil field (Figure 2-8). Total electrical energy consumption for oil and gas production was compiled by applying formulae described below to estimate the energy required to pump products (i.e., oil, gas, and water) to the ground surface and to estimate the energy required to process the oil and gas and dispose of the waste products (i.e., the energy to pump the fluids through the gathering network to a processing, transload, or disposal site). Annual electrical energy consumption totals for the oil and gas load category was estimated on a per-oil-field basis using the total volumes of oil, gas, and water production estimated by NDPA.

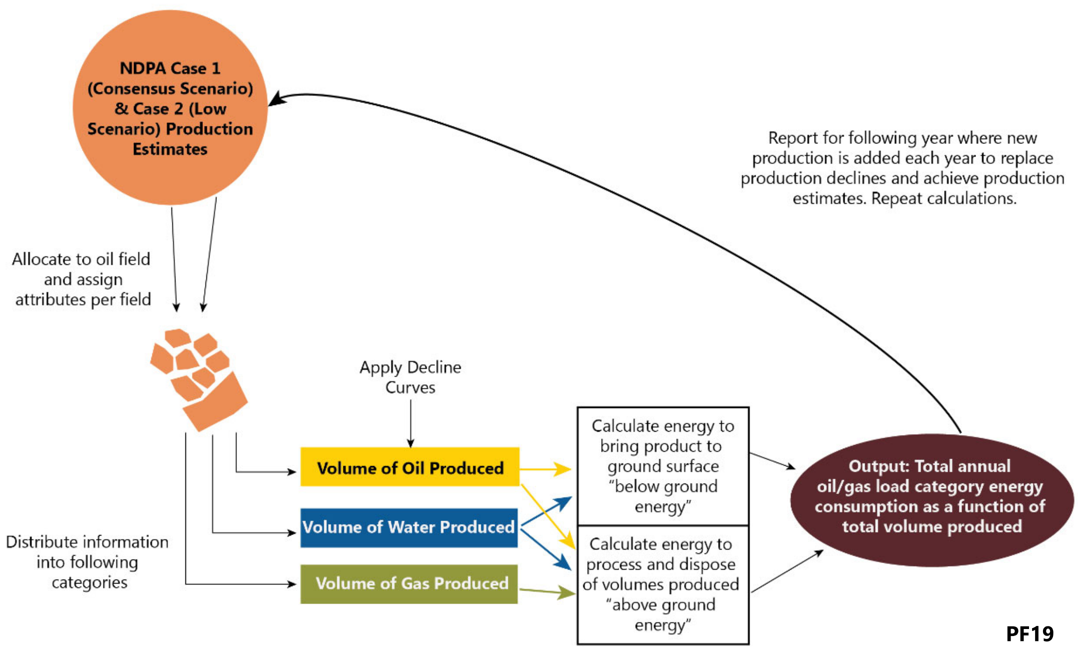


Figure 2-8 Annual Oil and Gas Energy Consumption Forecast Process

The basic calculation process is described within the following subsections; equations applied but not described in this report are provided in Appendix B. These forecast methods and algorithms were run for 2018 data so that the formulae results could be compared with recorded data.

The details of the calculation were implemented in Python™ scripting within Barr's GIS database model. The process to forecast annual oil and gas electrical consumption is illustrated in Figure 2-8. The process accounts for upstream production demand for well creation and maintaining production (Section 2.3.1) and moving liquids for the purpose of processing, transloading, or disposal (Section 2.3.2).

Oil and gas production methods within the Williston Basin also produce water brine that must be transported and disposed. Reported monthly oil, gas, and (brine) water production for each oil field was downloaded from NDPA and entered into the GIS database model. Values of oil (as provided by NDPA), gas (as provided by NDPA), and water production (as calculated as function of total oil production volumes) for each oil field for the years 2014 through 2018 were analyzed in the model for calibration.

2.3.1 Below-Ground Electrical Consumption

The "below-ground" electrical consumption (or the energy required to bring the liquids and gas to the surface) was estimated on a per-oil-field basis. The work required to pump the oil and water from the well to the surface is the product of the weight of water and the height it is lifted. However, an oil well may have a high initial reservoir pressure, which helps to reduce the pumping work required in the early phase of production. The weight of the liquid pumped and well pressure (both of which change over time) and the depth of the well (which is constant) are required to compute the pumping work.

The calculations used to estimate below-ground electrical consumption, therefore, considered well age, depth to reservoir, formation initial pressure, and pump efficiency; these attributes were assigned to each oil field on an annual basis. The reservoir depth was calculated using GIS surfaces that represented depths to the Bakken Formation and modified to account for ground elevations (reference [9]).

For all wells, Barr used the estimated formation initial pressure for of 5500 pounds per square inch gage (psig) as further described in Appendix C. The actual formation initial pressure can vary from a little over 8000 psi to about 3700 psi depending on the location. Using this initial pressure, the age dependent actual pressure was estimated using the same decline curve as for production rate (Section 2.3.1.1) and computed at mid-year.

A pump jack or Electrical Submersible Pump (ESP) is used to raise the liquid to the surface, where the gas, oil, and water are separated. The specific power required for this operation is dependent on the depth of the well, the pressure in the well, and the type of pump used. The last two variables change with the age of the well. When a well is first placed in operation, its pressure and production rate are high and an ESP is often used. Later in its life, the pressure and production rate decline and a pump jack will typically replace the ESP. This decline is accounted for by applying the pump efficiency calculation and pressure decline calculation (Appendix A) when computing the specific power for each age class of production volume. The pump efficiency calculation begins at 45% in Year 1 and increases to 75% over 6 years to represent the gradual replacement of ESPs with pump jacks over the early life of the well. The well pressure is calculated to decline at the same rate as oil production using the same decline formula from Energy Information Administration (EIA).

A Python™ script was run on the production volume data to estimate oil production per oil field, taking into consideration the factors discussed above. The estimated electrical consumption required to lift the projected volume of liquid from each age class of well for each oil field was calculated on an annual basis as illustrated in Figure 2-8. The formula used for calculating the specific production energy was:

$$ENERGY = [(h * 62.4) - (p\{age\} * 144)] / 473300 / \eta\{age\}$$

where the units are:

- ENERGY (kWh/barrel)
- age (years since completion or last workover)
- h (feet)
- p (pounds force/square inch)
- η (unitless pump efficiency)

After computing the estimated ENERGY, the volume of oil and water are estimated and the total electrical energy associated with oil and gas production was estimated using the production energy formula provided in Appendix B. The work to lift the oil is calculated based on specific gravity of 0.85 and the work to lift the produced water is based on specific gravity 1.2. The estimated energy is a function of the well age; therefore, the volume of production resulting from each age of well (associated to oil field) was estimated on an annual basis. This age of well power algorithm is also provided in Appendix B.

2.3.1.1 Decline Curve

After the projections for total oil production were estimated and added to the database model, decline curves were used to compute the new production estimated for the following year. Wells experience higher production rates at the beginning of the well's life, declining with age as shown in the example production decline curve provided for Dunn County below (Figure 2-9). The production decline curve of wells was developed by the EIA and coefficients for this curve were provided for key counties in the US with a shale or tight oil play. The data for North Dakota was used and applied to the individual fields being analyzed in this report.

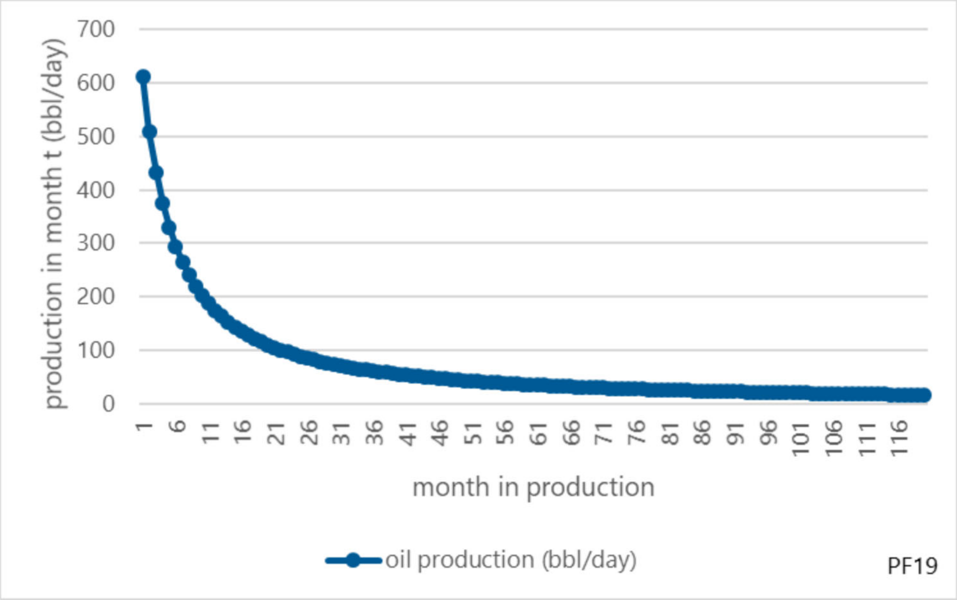


Figure 2-9 Production Decline Curve for Dunn County

The curve shown was plotted using the coefficients for Dunn County, which is near the heart of the play and is representative of decline curves for the Bakken. The actual calculations use the specific coefficients supplied by EIA for each county. The decline of production is computed for each year, and then used to compute the new production that must be brought on to achieve the forecasted production rate.

Sources of information required to estimate the below-ground electrical consumption totals are summarized in Table 2-3.

Table 2-3 Data Used to Estimate Below-Ground Energy Consumption for Oil and Gas Production

Variable	Data source
Oil production by year	North Dakota Pipeline Authority
Gas production by year	North Dakota Pipeline Authority
Water production by year	Calculated using oil production and water-oil ratio
Depth to formation	North Dakota Geological Survey (reference [9])
Formation initial pressure	Set at 5500 psig with input from Kringstad and Sonnenberg, based on map developed by C. Theoloy, Colorado School of Mines
Oil production by well age	U.S. Energy Information Administration: Decline Curve Analysis (reference [10])
Well pressure by age	U.S. Energy Information Administration: Decline Curve Analysis (reference [10])
Decline curve	U.S. Energy Information Administration: Decline Curve Analysis (reference [10])

2.3.2 Above-Ground Energy Consumption

After the liquid is raised to the surface, electrical energy is used to pump the fluids through the gathering network to a processing, transload, or disposal site; this is considered the "above-ground" electrical consumption. The above-ground electrical consumption includes the energy used by compressor stations, oil gathering line booster pumps, produced water gathering line booster pumps, saltwater disposal (SWD) injection facilities, and treatment plants.

The energy use was calculated based on the annual oil, gas, and water production values for each oil field, and the model calculated the electrical consumption for the production and gathering of oil, gas, and water. An estimation was made of the length and size of the gathering networks to compute the necessary pumping and compression power. SWD power is based on injection into the Dakota Formation at 1,500 psig. The electrical consumption predicted by this method was compared to historic production and energy-use data to test the soundness of this approach.

Above-ground pumping energy is a function of volume production, length of gathering network, and fraction of volume transported by truck. All of these parameters will be different in different oil fields and have the potential to change over time. The formulae used to compute the electrical consumption by the gathering pumps and compressor work are provided in Appendix B.

Sources of information required to estimate the below-ground electrical consumption totals are summarized in Table 2-4.

Table 2-4 Data Used to Estimate Above-Ground Energy Consumption for Oil and Gas Production

Variable	Data source
Oil fraction not moved by truck	NDPA
Average oil gathering line length	Estimation by Barr using GIS
Water fraction not moved by truck	NDPA
Average water gathering line length	Estimation by Barr using GIS
Gas fraction not flared	NDPA
Average gas gathering line length	Estimation by Barr using GIS
Average SWD injection pressure	Estimation by Barr from historic project data

2.4 Large Industrial/Commercial Forecast Methods

The PF19's large industrial/commercial load category includes gas processing plants, oil refineries, and oil transmission pipeline pumps. Locations of energy consumers in this category have specific geographic locations (i.e., they are not distributed throughout the production area) and typically have discrete quanta of electrical energy consumption. Other large industrial/commercial consumers such as arc furnaces, a recycling operation, and coal gasification facilities were not included in this category as their rate of growth is not directly correlated to increased oil and gas production volumes which is the focus of this study. The large industrial/commercial uses accounted for in terms of processing capacity within the PF19 are illustrated in Large Figure 2 in Appendix B.

Central processing facilities, or natural gas processing plants, employ a number of large compressors, pumps, and other energy-consuming equipment to process extracted gas to its end use. Locations and capacities of natural gas processing plants were obtained from NDIC. The specific energy consumption applied for gas processing plants within the PF19 was calculated using the specific power value of 13.2 MW for every 100 MMscf/d of processing capability (this specific power value of 13.2 MW for every 100 MMscf/d was estimated with industry input). It is unknown at what percentage natural gas processing plants are powered by electrical energy versus other energy sources (e.g., gas-powered); however it is assumed (with industry input) that the natural gas processing plants will continue to be powered by electrical energy at the same ratio as they are within the baseline year (2018). That is, the relationship of this processing capacity to future electrical energy consumption is implied.

The study area's natural gas processing plants' capacity was a bottleneck in 2018, and will continue to be a bottleneck in future years. Thus, to meet the requirements for gas capture new gas processing capacity must be installed. Data provided by NDPA identify locations for some of the planned new capacity, but additional new capacity will be required which at present is not announced and for which geographic locations have not been identified. We have evaluated the spatial distribution of projected new gas production to identify locations where future bottlenecks will be most acute and assumed new capacity will be located in areas where there is a shortage of gas processing capacity compared to gas production (refer to Section 2.2.2).

Oil refineries were the second class of energy users treated as large industrial/commercial users within the PF19. There are two Marathon oil refineries in North Dakota, one located in Dickinson and the other in Mandan. The Dickinson Refinery is located within the study area, and its electrical consumption was included within this category. The refinery located in Mandan is outside of the study area and therefore was not included.

The final class of electrical energy users included in the large industrial/commercial load category was pump stations along oil transmission pipeline corridors. The total horsepower required to move the product through a pipeline was estimated based on capacity and diameter of the pipeline. Specific geographic locations could not be assigned for the pump stations because the information is confidential; therefore the load was allocated uniformly along the known pipeline alignments.

Future large industrial/commercial uses related to oil and gas production and included with the estimated forecasted total electrical energy consumption for this load category included:

- The Davis Refinery project which is anticipated to come online in 2021 near Belfield, North Dakota with a capacity of 49,000 barrels (bbl)/day. For purposes of the PF19, a total of 66,150 MWh were estimated for total annual electrical energy consumption.

    - Note: An electrical energy consumption rate per bbl/day was calculated using the Dickinson Refinery's current electrical energy consumption amount and was applied to the Davis Refinery's anticipated capacity to estimate its electrical energy consumption total.

- The Trenton refinery which is a potential project but not yet fully planned or permitting. For purposes of the PF19, a total of 37,800 MWh were assumed to come online for this potential project starting in 2023.
    - Note: An electrical energy consumption rate per bbl/day was calculated using the Dickinson Refinery's current electrical energy consumption amount and was applied to the Davis Refinery's anticipated capacity to estimate its electrical energy consumption total.

- The Liberty Pipeline which is a potential oil transmission pipeline project that would transport oil from the Williston Basin to Corpus Christi, Texas. The capacity of the pipeline is anticipated to be 350,000 bbl/day. For purposes of the PF19, it was assumed that 175 miles of the proposed pipeline would be located within the study area with a diameter equal to other pipelines with similar capacities.

Enhanced oil recovery was considered but is not yet reflected in the estimated totals (see Section 3 for additional information). Additional potential sources of electrical energy consumption recognized but not included within the study includes a second tier industry such as use of produced water (brine) to produce chlorine or other chemical manufacturing.

Sources of information required to estimate the large industrial/commercial electrical consumption totals are summarized in Table 2-5.

Table 2-5 Data Used to Estimate Large Industrial/Commercial Energy Consumption

Variable	Data source
Gas processing plants in the state	North Dakota Industrial Commission
Gas processing specific electrical consumption	Estimated using 2018 MDU/BEPC electric usage data applied to gas processing facilities.
Oil refineries in the study area	U.S. Energy Information Administration
Future oil refineries in the study area	various online sources
Oil transmission pipeline alignment	U.S. Energy Information Administration
Oil transmission pipeline diameter and capacity	North Dakota Public Service Commission, newspaper resources, and professional judgment based on existing knowledge of pipelines in North Dakota

2.5 Population Forecast Methods

Population data was obtained from the U.S. Census Bureau for incorporated areas and unincorporated rural areas by county. This data was used to calculate the ratio of each incorporated area compared to the county's total population counts. In limited cases, populations for incorporated areas not reported within the U.S. Census were calculated by Barr based on estimated urban versus rural population ratios where estimates mirrored neighboring and demographically similar counties, as provided by the U.S. Census. Total baseline population included within the PF19 is described further below.

The forecasted electrical energy consumption totals for the population load category were determined based on the anticipated growth rates provided in the "Williston Basin 2016: Employment, Population, and Housing Forecasts" study completed by NDSU (reference [11]). The study estimated population growth as a function of employment needs. Employment forecasts were developed for a 20-year period to reflect potential changes driven by the pace and size of shale oil development in North Dakota. NDSU completed population forecasts for low, mid, and high oil price scenarios.

The method used by NDSU incorporated links between employment levels, migration rates, workforce commuting behavior, and local populations. Population forecasts included both permanent populations and temporary workforces. The PF19 used NDSU's estimated populations for each county's low and mid oil price economic scenario. The estimated population by county was downloaded from the Vision West ND website (reference [12]) and is provided in Appendix D.

The 2018 NDSU population estimates by county were used to establish the baseline population counts because the NDSU estimates included temporary population as well as permanent populations. The urban versus rural population ratios were used to distribute the forecasted data because NDSU reported population estimates by county and did not include estimates specific to incorporated areas. The baseline population data is illustrated in Figure 2-10 by county.

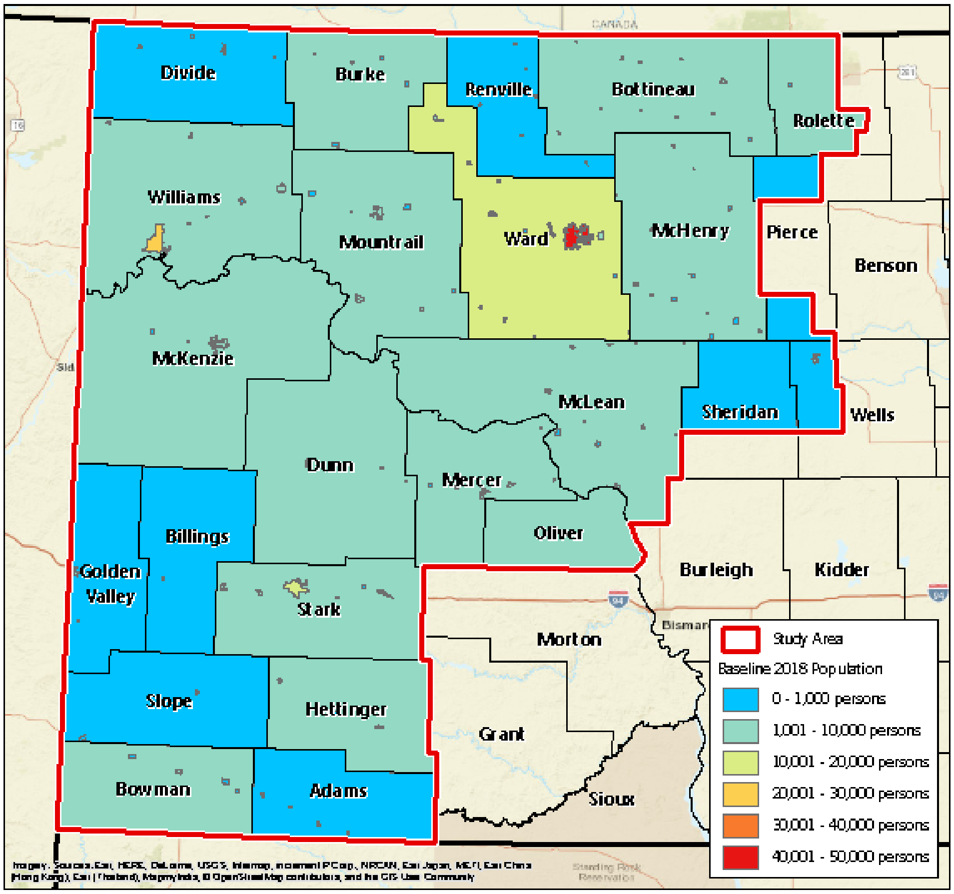


Figure 2-10 Baseline Population by County

Barr calculated a per capita electrical consumption for each county using data provided by Basin and MDU and applied the electrical consumption to the forecasted population numbers provided in the NDSU data (Appendix D). Because the population load category includes baseline electrical energy consumption from classes beyond the residential rate classes (i.e., this load category included electrical energy consumption MWh not accounted for within the oil and gas production estimates and the large industrial/commercial electrical energy consumption MWh estimated for oil and gas production related consumers), the per capita number is higher than what a per capita number that would reflect only residential uses/residential rate classes.

Sources of information required to estimate the population-based energy consumption totals are summarized in Table 2-6.

Table 2-6 Data Used to Estimate Population-Based Energy Consumption

Variable	Data source
Baseline population urban to rural ratios and baseline population counts for counties not included in NDSU's study	U.S. Census
Population baseline population counts and growth rates	North Dakota State University: 2018 Population Forecasts (reference [11])

3 Key Considerations and Drivers

This section includes background information on the oil and gas market within North Dakota. The purpose of providing the following discussion is to provide contextual background information relevant at the time of the PF19. Current oil and gas industry practices in North Dakota are affected by global market forces, technological advancements, and state and federal rules and regulations. These factors will influence oil and gas production, population growth rates, and growth of other industries in North Dakota. The various factors may have opposing effects on the ultimate growth, so accurately quantifying their net result is not possible. Additionally, other unknown factors may also impact the results of the study such as the potential for increasing gas drive versus electrical motors. The discussion below is meant to provide the current best understanding of the important factors as understood at the time of the study, and not necessarily to predict their influence on the calculated results. Significant sensitivities of the modeling methods acknowledged within the PF19 are described in Appendix C.

3.1 Drilling and Drilling Rigs

Advancements in well drilling technologies that reduce time from well spud to completion and increase production rates have financial benefits effects for producers. The current overall rig count in North Dakota is 62, up slightly from 48 two years ago (reference [13]). In 2016, the rig count was as low as 29; on the high end, the rig count was 84 in 2015 (reference [13]). At the beginning of the Bakken play, 2012 had the highest amount of active rigs at 214 rigs (reference [14]). The current availability of rigs seems to keep pace with demand for new wells; it does not currently appear to be a factor impacting power consumption rates for operating wells.

Technological advancements that increase efficiency and enhance oil recovery at wells may also have future effects on electrical energy consumption. The PF19 assumes that current practices are expected to largely carry forward into the future as the unknown potential changes cannot be accurately quantified.

3.2 Flaring and Gas Production

Regulatory limits on flaring of natural gas (i.e., raw, condensate, produced, associated, etc.) largely drive trends to capture and process gas produced at the wellhead. Within the last 10 years, oil production has increased from 308,000 barrels per day (bpd) in 2010 to nearly 1.27 million bpd in July of 2018, with gas production rates sextupling in the same time frame (reference [15]).

Flaring occurs to some extent in most oil and gas production and is a key driver for expansion in gas gathering and processing. North Dakota is working on reducing natural gas flaring and has set natural gas capture goals. By October of 2020 the goal is to capture 88% of natural gas and thereafter aim for 91% capture (reference [16]). The challenge to control and minimize gas flaring is mainly dependent on oil and gas production volumes and the ability for gathering and processing capacity to keep pace. Gathering and processing plants are largely powered by electricity, so as gathering and processing increases so, too, will power consumption.

Oil and gas production sites across the Williston Basin primarily rely on flaring as a means for managing raw or produced natural gas when offsite transportation methods (e.g., pipe or truck) are unavailable or when a new well is in its beginning life stages. The volume of gas being flared steadily increased in North Dakota between 2011 and 2014 as production outpaced gathering and processing capacity. Plans are currently underway for more additional new processing facilities and gathering lines (reference [17]; reference [18]). There has since been a steady decrease in the volume of natural gas flaring as gathering and processing capacity has increased significantly.

Lack of gas plant processing capacity creates bottlenecking that can, however, result in flaring at wells that are tied into gathering systems simply because there is no place for the gas to go for processing. According to the North Dakota Department of Mineral Resources, North Dakota producers flared roughly 17% of the natural gas that was produced in 2017—the highest percentage since 2015 (reference [16]). Lack of processing capacity is largely the cause.

North Dakota is looking at other long-term solutions to manage the volume of gas being produced. Studies are being conducted to determine the advantages of developing large storage facilities for natural gas that could limit flaring and facilitate storage for a period up to 5 years (reference [15]). This would help North Dakota oil producers meet increasingly more stringent flaring restrictions. Further investments to continue pace with increasing production and gas capture will be needed post 2020 (reference [18]).

3.2.1 Enhanced Oil Recovery

Potential technological advances including Enhanced Oil Recovery (EOR) and produced gas storage could result in increased power requirements for oil and gas production within the Williston Basin. However where injecting natural gas, the injected natural gas could decrease the total amount of natural gas necessary to process (thereby also reducing total electrical energy consumption).

The Energy & Environment Research Center (EERC) has initiated early efforts to estimate electrical load required to handle forecasted volumes of gas for incremental oil recovery and gas storage operations in North Dakota over the next 20 years. The initial work assumes early within the 20-year study period that storage of produced gas could serve as a means of flare mitigation. A rate in kWh was calculated to handle 1 MMscf of CO_2 (2200 kWh/MMscf) and applied to a total volume of gas assumed to be handled by prospective projects. The EERC estimated that as much as 9,500,000 kWh of base electrical usage could be required during the 20 year study period for four major gas usage categories: 1) conventional CO_2 EOR fields, 2) Bakken rich gas/CO_2 EOR (enhanced oil recovery), 3) produced gas storage, and 4) CO_2 EOR along a portion of the Cedar Creek Anticline. This would increase electricity usage by less than 1% from the total electrical consumption estimated in the study. Because the estimated usage is small and preliminary, it is not included in the model at this time.

3.3 Salt Water Disposal

At the time of this study, nearly all produced water is disposed of by deep well injection into the Dakota formation. The calculated energy consumption in this study is based on this practice continuing. However, efforts are underway to find better methods of disposal or to find re-use options for either the water or the dissolved solids in the water. These efforts range from on-site evaporation using gas which otherwise would be flared or processed, to producing hydrochloric acid and caustic soda in a chlor-alklai process. Depending on the outcome of these efforts, gas gathering and processing power, and/or produced water gathering and disposal power could vary significantly from the projection.

3.4 Pipelines

Pipelines are the dominant form of transport for oil and gas produced in North Dakota. Currently an estimated 77% of crude oil is transported from the Williston Basin via pipeline exportation, 9% from rail car, 6% is refined locally, and 8% is trucked to other pipelines (reference [18]; reference [19]). Transportation methods since 2012 have seen a shift from shipping by rail to more interstate pipelines for transport of crude oil and natural gas. Nearly 30,000 miles of gathering pipelines and transmission lines transporting oil, various forms of natural-gas-related products, produced water, and other products are located within North Dakota. Large-scale pipeline projects continue to be developed for transportation of NGLs and oil.

3.5 Plastic and chemicals production

At the time of this study, nearly all ethane produced in the state is transported out via pipeline. There has been some interest expressed in the possibility of making either PVC or PE from the ethane to increase the value received by the state. Additionally, industrial chemicals such as acetic acid, methanol, sodium methylate, ammonia, etc. could be produced to improve the value chain. These projects have strong potential for profitability due to the large quantity of natural gas and North Dakota's low electric prices. However, there are no publicly announced projects at this time, so this potential has not been included in PF19.

4 Results

The PF19's estimated total amount of additional electrical energy consumption required to support the projected oil and gas production volumes and the correlated anticipated secondary growth (i.e., including all three PF19 broad load categories) reflects an overall study period (2018-2038) growth rate of approximately 44% for the low scenario and a 71% growth rate for the consensus scenario. The total estimated energy in GWh for the low scenario and the consensus scenario is illustrated in Figure 4-1.

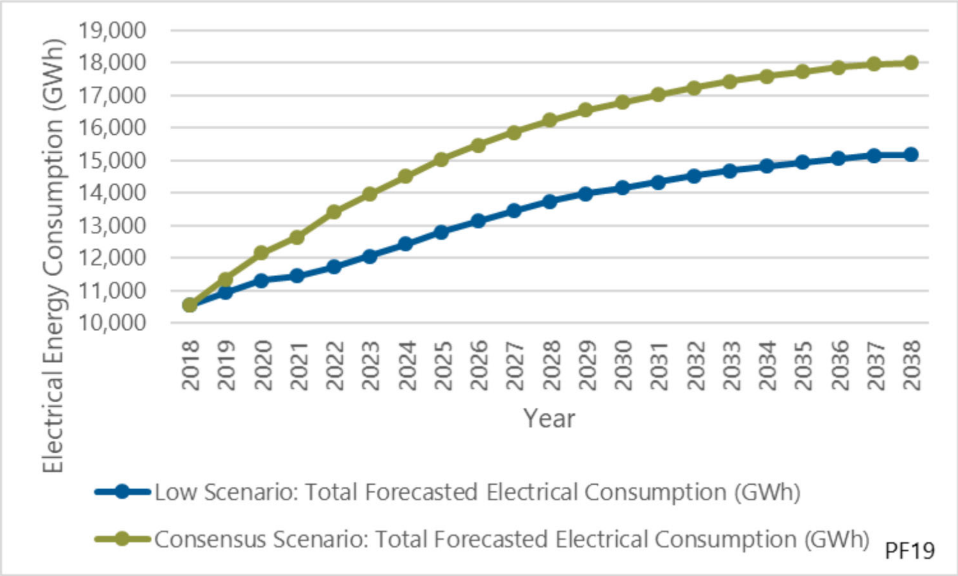


Figure 4-1 Study Area Forecasted Electrical Energy Consumption

At the end of the study period (2038), the low scenario forecasts a total need of 15,000 GWh and the consensus forecasts a total need of 18,000 GWh of electrical energy consumption. Compared to the baseline, this represents an increase of 4,600 GWh for the low scenario and 7,500 GWh for the consensus scenario. Consistent with the needs to meet margin requirements, this implies an increase in generation capacity of 670 MW to 1,000 MW (calculated using a 92% load factor and an 86% capacity factor) above the capacity demand.

The majority of the growth is in load categories which have nearly flat demand curves (i.e., oil and gas production and large industrial/commercial sources related to oil and gas production), and do not readily lend themselves to interruptible power supply. Therefore the estimated new demand will typically be supplied by base load capacity or mid-load capacity with fast dispatch rates.

The state's base load generating capacity, not including Heskett Station, is 4,380 MW. Since existing base load resources in North Dakota are operating well above industry averages, new base load or equivalent will likely be selected by utilities that need to meet this increased demand.

There are several options. Capacity that is currently committed to other markets could be shifted to the appropriated market to meet the North Dakota demand. New base load capacity could also be supplied by a new 2x1 combined cycle plant based on the GE 7F.05 rated 756 MW, with annual capacity factor of between 61% (low scenario) to 86% (consensus scenario). An alternative mid-load capacity solution with fast dispatch rates would allow for maximum use of base loaded lignite fueled generation, and intermittent wind power. Typical power plants of this type are the GE LMS-100 and the Wartsila 20V34SG natural gas fueled engines. Multiple installations of these engines would be required, but could be distributed throughout the system. The mid-load option would be attractive in the scenario where a large amount of new wind generation is expected to be added to the system. A 200 MW wind farm site would add approximately 75 MW of intermittent annual capacity at the average 2018 capacity of 37.4% cited in EIA's April Power Monthly Report (reference [20]). Mid-load power plants would then be used to quickly start when needed, and shut down again to keep the lignite fueled plants at a steadier load point.

Additional study-wide findings are discussed below and additional detail regarding each base load category's results are provided in the following subsections.

The highest growth rates for total estimated electrical consumption by year occur within the first eight years of the study period, from 2019 through 2025. Within this timeframe, the projected range of annual growth is approximately 2.5% to 3% under the low scenario and approximately 3.6% to 7.7% the consensus scenario. Figures illustrating the estimated distribution of total electrical energy consumption for the reported years listed below are provided in Appendix A:

- Large Figure 3 Estimated Electrical Energy Consumption: 2022
- Large Figure 4 Estimated Electrical Energy Consumption: 2028
- Large Figure 5 Estimated Electrical Energy Consumption: 2038

4.1 Specific Results per Broad Load Category

The total forecasted electrical consumption by broad load category is shown in Figure 4-2 and Table 4-1 for the low scenario and Figure 4-3 and Table 4-2 for the consensus scenario. In both scenarios, as the study period progresses, the population broad load category (which makes up approximately half of the baseline year) comprises less of a percentage of the total forecasted electrical energy consumption. The anticipated growth rate of the oil and gas production broad load category flattens toward the end of the study period, and the anticipated large industrial/commercial load category continues to grow, surpassing the total population broad load category in the consensus scenario (Figure 4-3). Details regarding the estimated power consumption forecast totals for each broad load category and by county are provided in the following subsections.

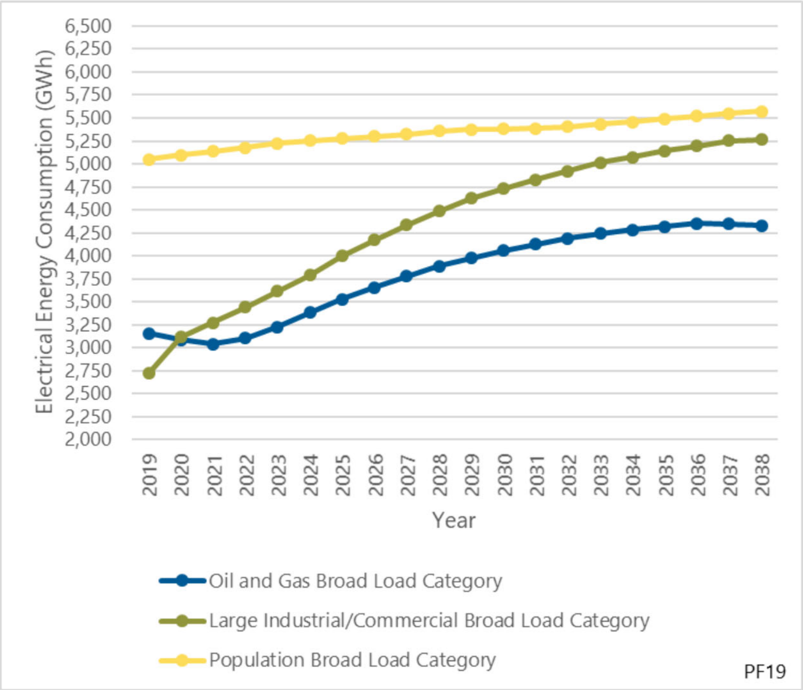


Figure 4-2 **Low Scenario: Study Area Forecasted Electrical Energy Consumption by Broad Load Category**

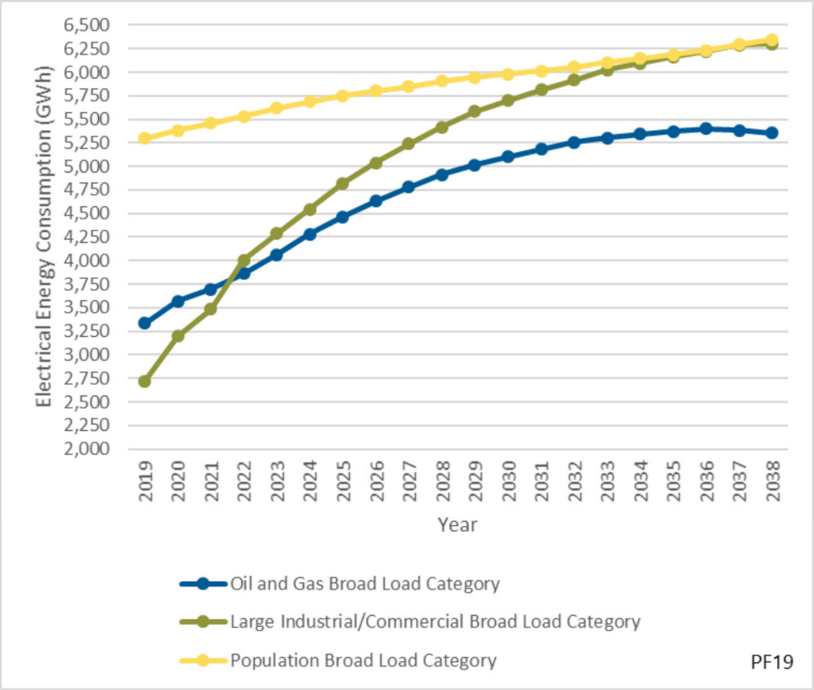


Figure 4-3 **Consensus Scenario: Study Area Forecasted Electrical Energy Consumption by Broad Load Category**

Table 4-1 Study Area Forecasted Electrical Energy Consumption by Broad Load Category

Broad Base Load Category	2020 (GWh)	2022 (GWh)	2024 (GWh)	2026 (GWh)	2028 (GWh)	2033 (GWh)	2038 (GWh)
Oil and Gas Production	3,100	3,100	3,400	3,700	3,900	4,200	4,300
Large Industrial/Commercial	3,100	3,400	3,800	4,200	4,500	5,000	5,300
Population	5,100	5,200	5,300	5,300	5,400	5,400	5,600
Total	11,300	11,700	12,500	13,200	13,800	14,600	15,200

Table 4-2 Consensus Scenario: Study Area Forecasted Electrical Energy Consumption by Broad Load Category

Broad Base Load Category	2020 (MWh)	2022 (MWh)	2024 (MWh)	2026 (MWh)	2028 (MWh)	2033 (MWh)	2038 (MWh)
Oil and Gas Production	3,600	3,900	4,300	4,600	4,900	5,300	5,400
Large Industrial/Commercial	3,200	4,000	4,500	5,000	5,400	6,000	6,300
Population	5,400	5,500	5,700	5,800	5,900	6,100	6,300
Total	12,200	13,400	14,500	15,400	16,200	17,400	18,000

4.1.1 Oil and Gas Production

The forecasted oil and gas production load category’s total electrical energy consumption is shown in Figure 4-4. For the consensus scenario, this load category is estimated to see continuous growth throughout the study period, corresponding with the NDPA’s oil and gas production volume estimates, illustrated in Figure 2-2 and Figure 2-3.

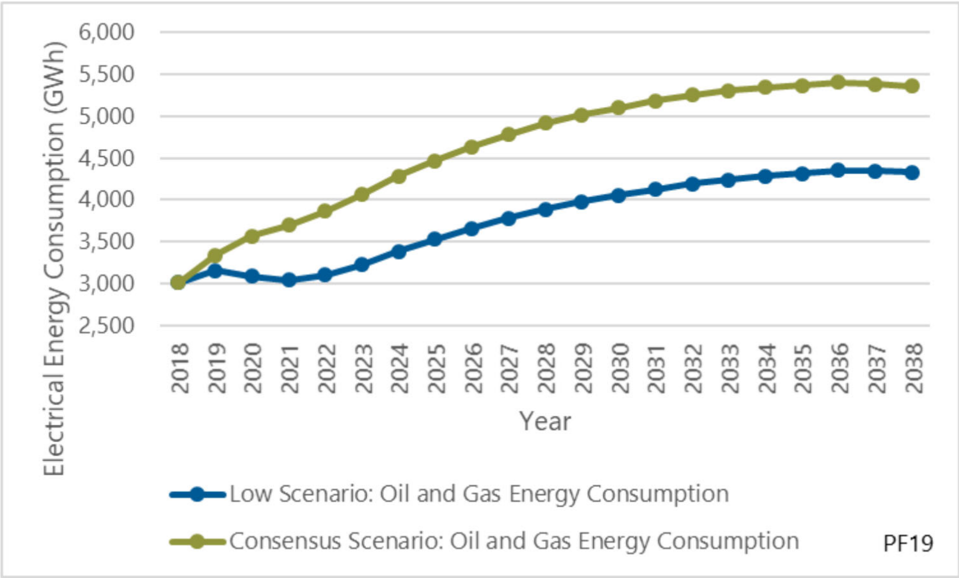


Figure 4-4 Oil and Gas Production Forecasted Electrical Energy Consumption

The forecasted oil and gas production load category's total electrical energy consumption by county for the low scenario is provided in Table 4-3.

Table 4-3 Low Scenario: Relative Per-County Forecasted Electrical Energy Use Associated with Oil and Gas Production

County	2020 (MWh)	2022 (MWh)	2024 (MWh)	2026 (MWh)	2028 (MWh)	2033 (MWh)	2038 (MWh)
Billings	77,000	78,000	82,000	86,000	90,000	95,000	97,000
Bottineau	41,000	42,000	43,000	44,000	46,000	48,000	51,000
Bowman	140,000	142,000	143,000	145,000	146,000	150,000	154,000
Burke	45,000	45,000	54,000	63,000	71,000	82,000	84,000
Divide	69,000	68,000	83,000	96,000	107,000	122,000	124,000
Dunn	476,000	480,000	523,000	566,000	602,000	658,000	675,000
Golden Valley	8,000	8,000	8,000	9,000	9,000	9,000	10,000
McHenry	1,000	1,000	1,000	1,000	1,000	1,000	1,000
McKenzie	1,094,000	1,100,000	1,192,000	1,280,000	1,354,000	1,463,000	1,492,000
McLean	14,000	14,000	16,000	18,000	19,000	21,000	22,000
Mountrail	450,000	453,000	499,000	545,000	583,000	643,000	659,000
Renville	18,000	18,000	19,000	19,000	19,000	20,000	21,000
Slope	11,000	11,000	11,000	11,000	11,000	11,000	12,000
Stark	40,000	40,000	41,000	42,000	43,000	44,000	45,000
Ward	500	600	600	600	600	600	600
Williams	603,000	603,000	668,000	731,000	787,000	872,000	886,000
Grand Total	3,087,500	3,103,600	3,383,600	3,656,600	3,888,600	4,239,600	4,333,600

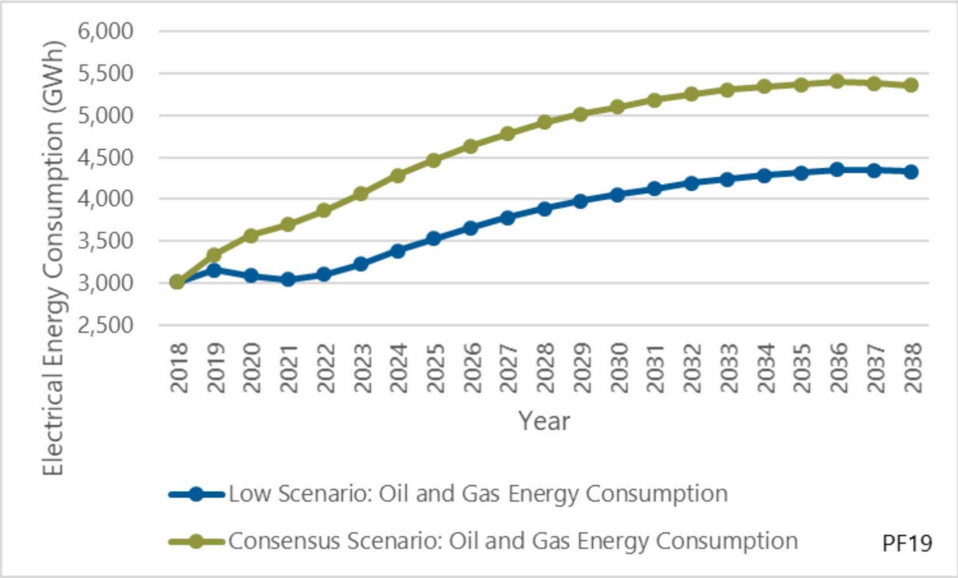
The forecasted oil and gas production load category's total electrical energy consumption by county for the consensus scenario is provided in Table 4-4.

Table 4-4 Consensus Scenario: Relative Per-County Forecasted Electrical Energy Use Associated with Oil and Gas Production

County	2020 (MWh)	2022 (MWh)	2024 (MWh)	2026 (MWh)	2028 (MWh)	2033 (MWh)	2038 (MWh)
Billings	84,000	89,000	95,000	100,000	104,000	110,000	111,000
Bottineau	41,000	42,000	43,000	44,000	46,000	48,000	51,000
Bowman	140,000	142,000	143,000	145,000	146,000	150,000	154,000
Burke	62,000	73,000	87,000	99,000	109,000	122,000	123,000
Divide	96,000	110,000	132,000	150,000	164,000	180,000	181,000
Dunn	547,000	595,000	659,000	715,000	759,000	820,000	833,000
Golden Valley	8,000	9,000	9,000	9,000	10,000	10,000	10,000
McHenry	1,000	1,000	1,000	1,000	1,000	1,000	1,000
McKenzie	1,251,000	1,347,000	1,484,000	1,596,000	1,686,000	1,805,000	1,821,000
McLean	17,000	19,000	22,000	24,000	26,000	28,000	29,000
Mountrail	529,000	579,000	648,000	707,000	755,000	821,000	832,000
Renville	18,000	18,000	19,000	19,000	19,000	20,000	21,000
Slope	11,000	11,000	11,000	11,000	11,000	11,000	12,000
Stark	41,000	41,000	43,000	44,000	45,000	46,000	47,000
Ward	500	600	600	600	600	600	600
Williams	720,000	787,000	886,000	967,000	1,035,000	1,127,000	1,128,000
Grand Total	3,566,500	3,863,600	4,282,600	4,631,600	4,916,600	5,299,600	5,354,600

4.1.2 Large Industrial and Commercial

The forecasted large industrial and commercial load category's total electrical energy consumption is shown in Figure 4-5. Because the energy consumption within the large industrial and commercial load category is comprised primarily of natural gas processing plants, the total forecasted electrical energy consumption for electrical energy follows a similar trajectory as the projected gas production values (Figure 2-3).



(natural gas processing plants, refineries, and oil transmission pump stations)

Figure 4-5 Large Industrial and Commercial Sources Forecasted Electrical Energy Consumption

The forecast estimates that an additional 2,735 GWh (low scenario) to 3,771 GWh (consensus) will be consumed by natural gas processing plants, refineries, and oil transmission pipeline pump stations by the end of the study period. Total consumption for this load category at the end of the study period is estimated to more than double (or approximately a 200% increase for the low scenario and an approximately 250% increase for the consensus scenario).

The forecasted results are reported by county in Table 4-5 and Table 4-6, however the locations of future consumption for this category will be dependent upon where new infrastructure is constructed as described in Section 2.2.2. Locations of potential future natural gas processing plants and refineries assumed within the study are shown in Large Figure 2; as described in Section 2.2.2, one potential future oil transmission pipeline was assumed within Williams, McKenzie, Dunn, Stark, Hettinger, and Adam Counties.

Table 4-5 Low Scenario: Relative Per-County Forecasted Electrical Energy Use Associated with Large Industrial and Commercial Sources

County	2020 (MWh)	2022 (MWh)	2024 (MWh)	2026 (MWh)	2028 (MWh)	2033 (MWh)	2038 (MWh)
Adams	-	-	-	-	40	40	40
Billings	25,000	93,000	96,000	89,000	92,000	95,000	96,000
Bowman	37,000	39,000	44,000	78,000	85,000	96,000	101,000
Burke	7,000	6,000	7,000	6,000	7,000	6,000	7,000
Divide	34,000	103,000	121,000	147,000	166,000	195,000	209,000
Dunn	123,000	143,000	154,000	167,000	179,000	197,000	206,000
Golden Valley	20	20	20	20	20	20	20
Hettinger	-	-	-	-	70	70	70
McHenry	60	60	60	60	60	60	60
McKenzie	1,721,000	1,765,000	1,901,000	2,070,000	2,207,000	2,433,000	2,541,000
Mercer	20	20	20	20	20	20	20
Mountrail	335,000	298,000	284,000	291,000	292,000	299,000	307,000
Slope	7,000	7,000	8,000	6,000	7,000	8,000	8,000
Stark	60,000	116,000	120,000	111,000	114,000	118,000	120,000
Ward	100	100	100	100	100	100	100
Williams	765,000	874,000	1,055,000	1,208,000	1,337,000	1,565,000	1,670,000
Grand Total	3,114,200	3,444,200	3,790,200	4,173,200	4,486,310	5,012,310	5,265,310

Notes: Natural gas processing plants, refineries, and oil transmission pump stations only.
Where total MWh's by county decrease from one reported year to another, this is due to the method used to estimate the locations of potential future natural gas processing plants. In some cases when a new or expanded gas plant is introduced into the calculations, the result is that capacity from another geographic area is decreased, thereby lowering the total estimated electrical energy consumption in a neighboring county.

Table 4-6 Consensus Scenario: Relative Per-County Forecasted Electrical Energy Use Associated with Large Industrial and Commercial Sources

County	2020 (MWh)	2022 (MWh)	2024 (MWh)	2026 (MWh)	2028 (MWh)	2033 (MWh)	2038 (MWh)
Adams	-	-	-	-	40	40	40
Billings	27,000	94,000	98,000	98,000	97,000	96,000	98,000
Bowman	40,000	61,000	71,000	93,000	112,000	134,000	141,000
Burke	7,000	6,000	6,000	7,000	6,000	7,000	7,000
Divide	34,000	138,000	170,000	201,000	226,000	258,000	273,000
Dunn	128,000	163,000	181,000	198,000	195,000	199,000	207,000
Golden Valley	20	20	20	20	20	20	20
Hettinger	-	-	-	-	70	70	70
McHenry	60	60	60	60	60	60	60
McKenzie	1,791,000	2,013,000	2,235,000	2,452,000	2,635,000	2,914,000	3,033,000
Mercer	20	20	20	20	20	20	20
Mountrail	335,000	314,000	285,000	293,000	293,000	308,000	302,000
Slope	7,000	8,000	9,000	9,000	8,000	8,000	9,000
Stark	62,000	117,000	122,000	122,000	120,000	120,000	122,000
Ward	100	100	100	100	100	100	100
Williams	765,000	1,092,000	1,369,000	1,565,000	1,723,000	1,979,000	2,108,000
Grand Total	3,196,200	4,006,200	4,546,200	5,038,200	5,415,310	6,023,310	6,300,310

Notes: Natural gas processing plants, refineries, and oil transmission pump stations only.
Where total MWh's by county decrease from one reported year to another, this is due to the method used to estimate the locations of potential future natural gas processing plants. In some cases when a new or expanded gas plant is introduced into the calculations, the result is that capacity from another geographic area is decreased, thereby lowering the total estimated electrical energy consumption in a neighboring county.

4.1.3 Population

The forecasted population load category's total electrical energy consumption is shown in Figure 4-6.

The relative per-county energy use associated with population grows steadily throughout the study period for both the low scenario and the consensus scenario. Population growth rates within the NDSU study included relatively continuous rates of growth and therefore the population load category followed.

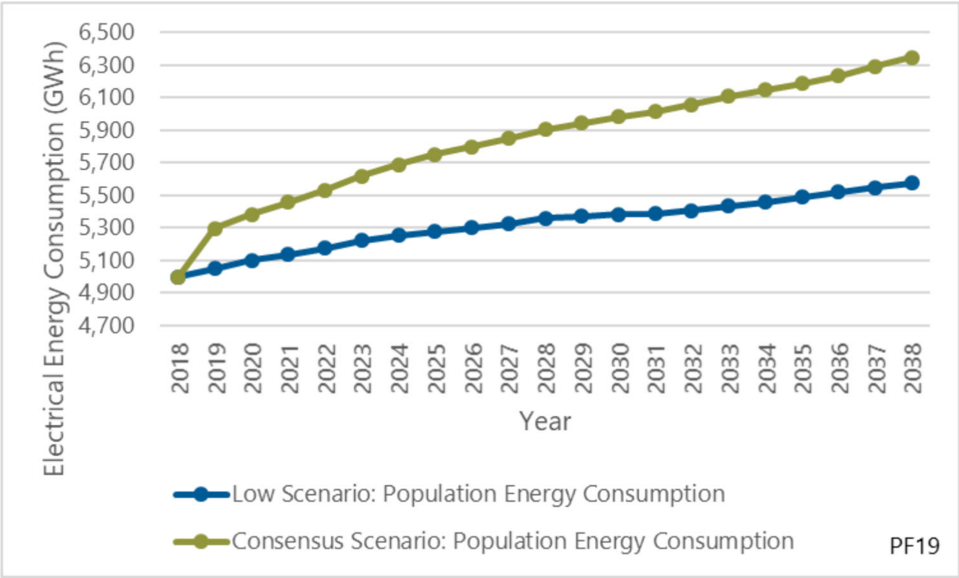


Figure 4-6 Population Forecasted Electrical Energy Consumption

The forecasted population load category's total electrical energy consumption by county for the low scenario is provided in Table 4-7.

Table 4-7 Low Scenario: Relative Per-County Forecasted Electrical Energy Use Associated with Population

County	2020 (MWh)	2022 (MWh)	2024 (MWh)	2026 (MWh)	2028 (MWh)	2033 (MWh)	2038 (MWh)
Adams	44,000	45,000	45,000	45,000	45,000	45,000	46,000
Billings	69,000	70,000	70,000	70,000	70,000	69,000	70,000
Bottineau	99,000	100,000	101,000	101,000	101,000	102,000	104,000
Bowman	21,000	21,000	22,000	22,000	22,000	22,000	22,000
Burke	54,000	55,000	55,000	56,000	55,000	55,000	55,000
Divide	26,000	25,000	25,000	25,000	25,000	25,000	25,000
Dunn	588,000	590,000	594,000	595,000	595,000	599,000	616,000
Golden Valley	151,000	154,000	157,000	159,000	160,000	161,000	161,000
Hettinger	128,000	129,000	129,000	129,000	129,000	127,000	129,000
McHenry	235,000	240,000	239,000	240,000	240,000	241,000	241,000
McKenzie	365,000	373,000	384,000	394,000	405,000	419,000	435,000
McLean	120,000	120,000	120,000	120,000	120,000	120,000	121,000
Mercer	165,000	165,000	165,000	165,000	164,000	163,000	163,000
Mountrail	1,032,000	1,056,000	1,108,000	1,141,000	1,175,000	1,215,000	1,259,000
Oliver	109,000	109,000	109,000	109,000	109,000	109,000	109,000
Pierce	38,000	38,000	38,000	38,000	38,000	38,000	38,000
Renville	85,000	85,000	85,000	85,000	85,000	85,000	86,000
Rolette	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Sheridan	84,000	84,000	84,000	84,000	84,000	84,000	84,000
Slope	101,000	101,000	102,000	101,000	101,000	100,000	99,000
Stark	360,000	368,000	374,000	376,000	376,000	375,000	389,000
Ward	280,000	286,000	288,000	290,000	292,000	298,000	306,000
Wells	37,000	37,000	37,000	37,000	37,000	37,000	37,000
Williams	856,000	874,000	872,000	869,000	879,000	892,000	929,000
Grand Total	5,097,000	5,175,000	5,253,000	5,301,000	5,357,000	5,431,000	5,574,000

The forecasted population load category's total electrical energy consumption by county for the consensus scenario is provided in Table 4-8.

Table 4-8 Consensus Scenario: Relative Per-County Forecasted Electrical Energy Use Associated with Population

County	2020 (MWh)	2022 (MWh)	2024 (MWh)	2026 (MWh)	2028 (MWh)	2033 (MWh)	2038 (MWh)
Adams	45,000	47,000	48,000	48,000	48,000	48,000	49,000
Billings	72,000	72,000	73,000	73,000	72,000	73,000	74,000
Bottineau	102,000	104,000	106,000	107,000	107,000	108,000	112,000
Bowman	22,000	23,000	23,000	23,000	24,000	24,000	24,000
Burke	56,000	57,000	58,000	58,000	58,000	59,000	60,000
Divide	27,000	27,000	26,000	26,000	27,000	28,000	28,000
Dunn	639,000	657,000	676,000	690,000	702,000	720,000	750,000
Golden Valley	154,000	160,000	162,000	164,000	166,000	167,000	170,000
Hettinger	130,000	131,000	131,000	131,000	131,000	131,000	134,000
McHenry	240,000	247,000	250,000	253,000	253,000	255,000	256,000
McKenzie	392,000	409,000	426,000	440,000	456,000	488,000	522,000
McLean	124,000	124,000	125,000	126,000	126,000	128,000	129,000
Mercer	168,000	169,000	170,000	171,000	171,000	172,000	173,000
Mountrail	1,104,000	1,136,000	1,196,000	1,238,000	1,282,000	1,343,000	1,408,000
Oliver	109,000	109,000	109,000	109,000	109,000	109,000	109,000
Pierce	38,000	38,000	38,000	38,000	38,000	38,000	38,000
Renville	89,000	90,000	90,000	90,000	91,000	91,000	92,000
Rolette	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Sheridan	84,000	84,000	84,000	84,000	84,000	84,000	84,000
Slope	104,000	105,000	105,000	105,000	105,000	104,000	104,000
Stark	391,000	407,000	419,000	423,000	425,000	432,000	453,000
Ward	297,000	304,000	307,000	309,000	311,000	318,000	331,000
Wells	37,000	37,000	37,000	37,000	37,000	37,000	37,000
Williams	906,000	946,000	977,000	1,005,000	1,030,000	1,101,000	1,162,000
Grand Total	5,380,000	5,533,000	5,686,000	5,798,000	5,903,000	6,108,000	6,349,000

5 References

[1] North Dakota Transmission Authority, *Annual Report (July 1, 2015 - June 30, 2016),* 2016.

[2] Kadrmas, Lee & Jackson, Inc., *Power Forecast 2012: Williston Basin Oil and Gas Related Electrical Load Growth Forecast,* 2012.

[3] State Historical Society of North Dakota, "Section 2: The Williston Basin," 2019. [Online]. Available: https://www.ndstudies.gov/gr8/content/unit-i-paleocene-1200-ad/lesson-1-changing-landscapes/topic-2-geology/section-2-williston-basin. [Accessed 4 March 2019].

[4] Energy & Environmental Research Center, "Geology," [Online]. Available: http://www.undeerc.org/Bakken/geology.aspx. [Accessed 4 March 2019].

[5] J. A. LeFever and S. H. Nordeng, "Three Forks Formation," *North Dakota Department of DMR Mineral Resources Newsletter,* vol. 35, no. 2, pp. 4-5, June 2008.

[6] S. A. Sonnenberg, *Sequence Stratigraphy of the Bakken and Three Forks Formations, Williston Basin, USA,* 2017.

[7] T. O. Nesheim, *Examination of Middle Three Forks (2nd Bench) Hydrocarbon Charge and Production,* vol. 45, 2018.

[8] North Dakota Pipeline Authority, "March 2019 NDPA Raw Forecast Data," 15 March 2019. [Online]. Available: Emailed to Barr from Justin Kringstad.

[9] North Dakota Geological Survey, *Geologic Investigations No. 59: Bakken Formation Map Series: Sheet 1-3, 5,* 2008.

[10] U.S. Energy Information Administration, "Appendix 2.C: Decline Curve Analysis," in *Oil and Gas Supply Module of the National Energy Modeling System: Model Documentation 2018*, 2018.

[11] North Dakota State University, *Williston Basin 2016: Employment, Population, and Housing Forecasts,* 2017.

[12] Vision West ND, "Research & Reports," [Online]. Available: https://www.visionwestnd.com/research-resources/?category=Webinar. [Accessed Aprl 2019].

[13] North Dakota, "Current Active Drilling Rig List," [Online]. Available: https://www.dmr.nd.gov/oilgas/riglist.asp. [Accessed 24 April 2019].

[14] Industrial Commission of North Dakota - North Dakota Pipeline Authority, *The Pipeline Publication,* vol. V, 2012.

[15] B. Barnes, "North Dakota's gas flaring challenge lingers on," *Petroleum Economist,* 13 November 2018.

[16] U.S. Energy Information Administration, *Natural Gas Weekly Update,* 2017.

[17] A. Dalrymple, "North Dakota natural gas flaring hits record high; improvement expected in 2019," *Bismarck Tribune,* 25 December 2018.

[18] Industrial Commission of North Dakota Pipeline Authority, "Pipeline Industry Update," *The Pipeline Publication,* vol. 10, no. 1, January 2019.

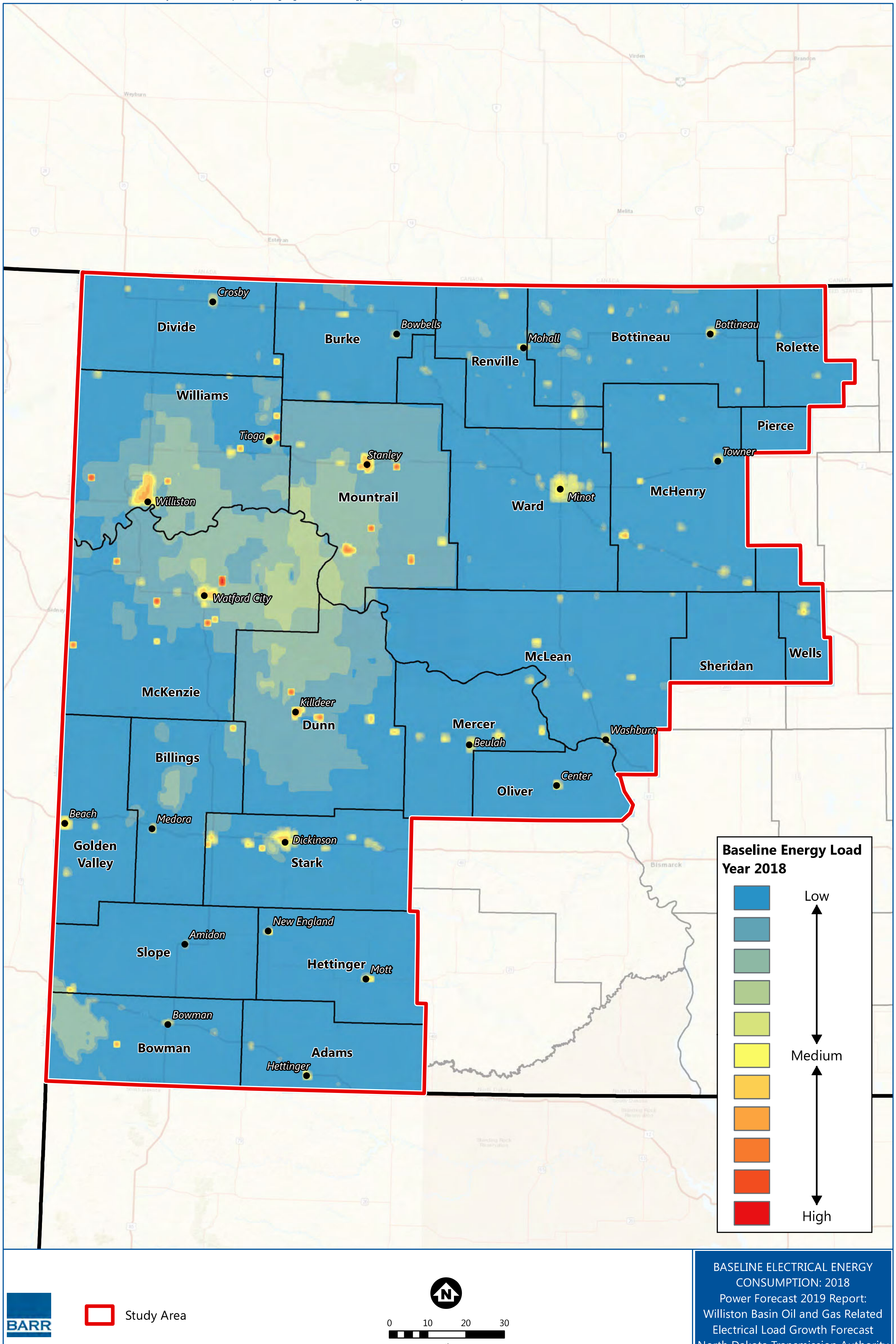
[19] Great Plains Energy Corridor; Bismarck State College, "Spotlight on North Dakota Energy 2017 Annual Report," 2017. [Online].

[20] U.S. Energy Information Administration, *Electric Power Monthly with Data for February 2019,* 2019.

Appendices

Appendix A

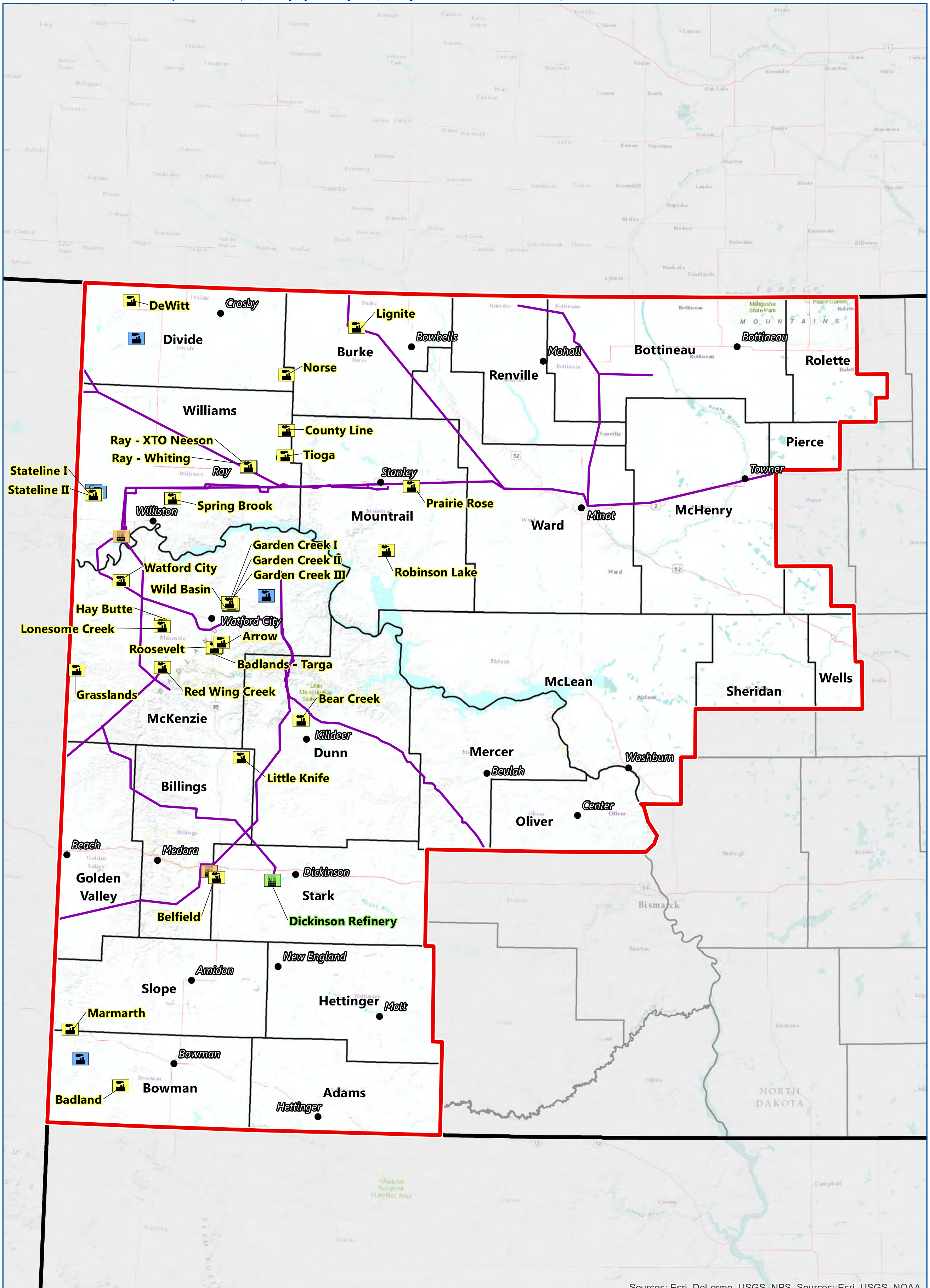
Large Figures



BASELINE ELECTRICAL ENERGY CONSUMPTION: 2018
Power Forecast 2019 Report:
Williston Basin Oil and Gas Related Electrical Load Growth Forecast
North Dakota Transmission Authority

LARGE FIGURE 1

Barr Footer: ArcGIS 10.6, 2019-05-09 11:17 File: I:\Projects\34\53\1076\Maps\Reports\Large Figure 2 Existing and Proposed Large Industrial Commercial Users.mxd User: MRQ



Study Area
Existing Refinery
Existing Gas Plant
Proposed Refinery
Proposed or Hypothetical Gas Plant
Crude Oil Pipelines

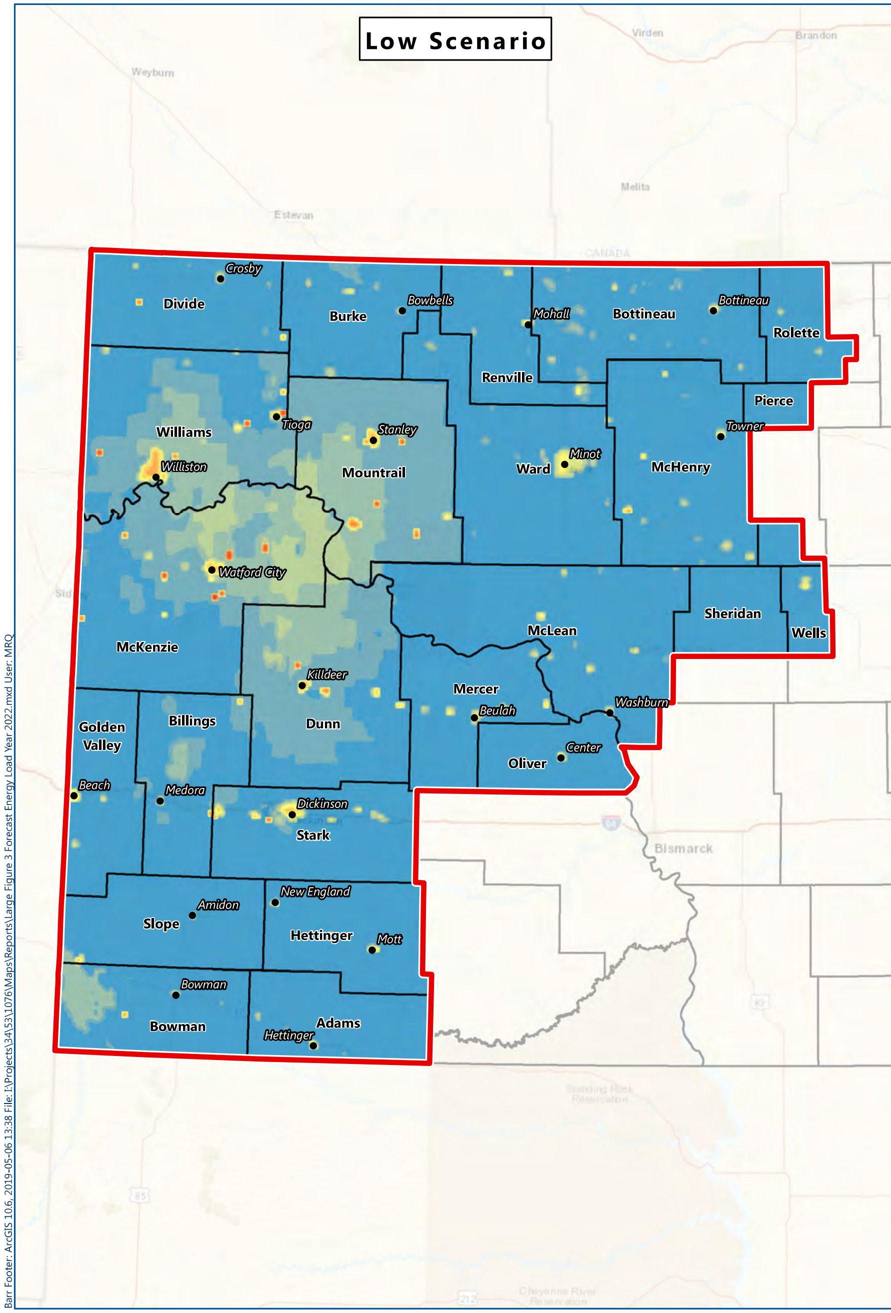
Note: Liberty Pipeline is a proposed pipeline of approximately 175 miles within our study area. The location of the proposed pipeline is unknown.

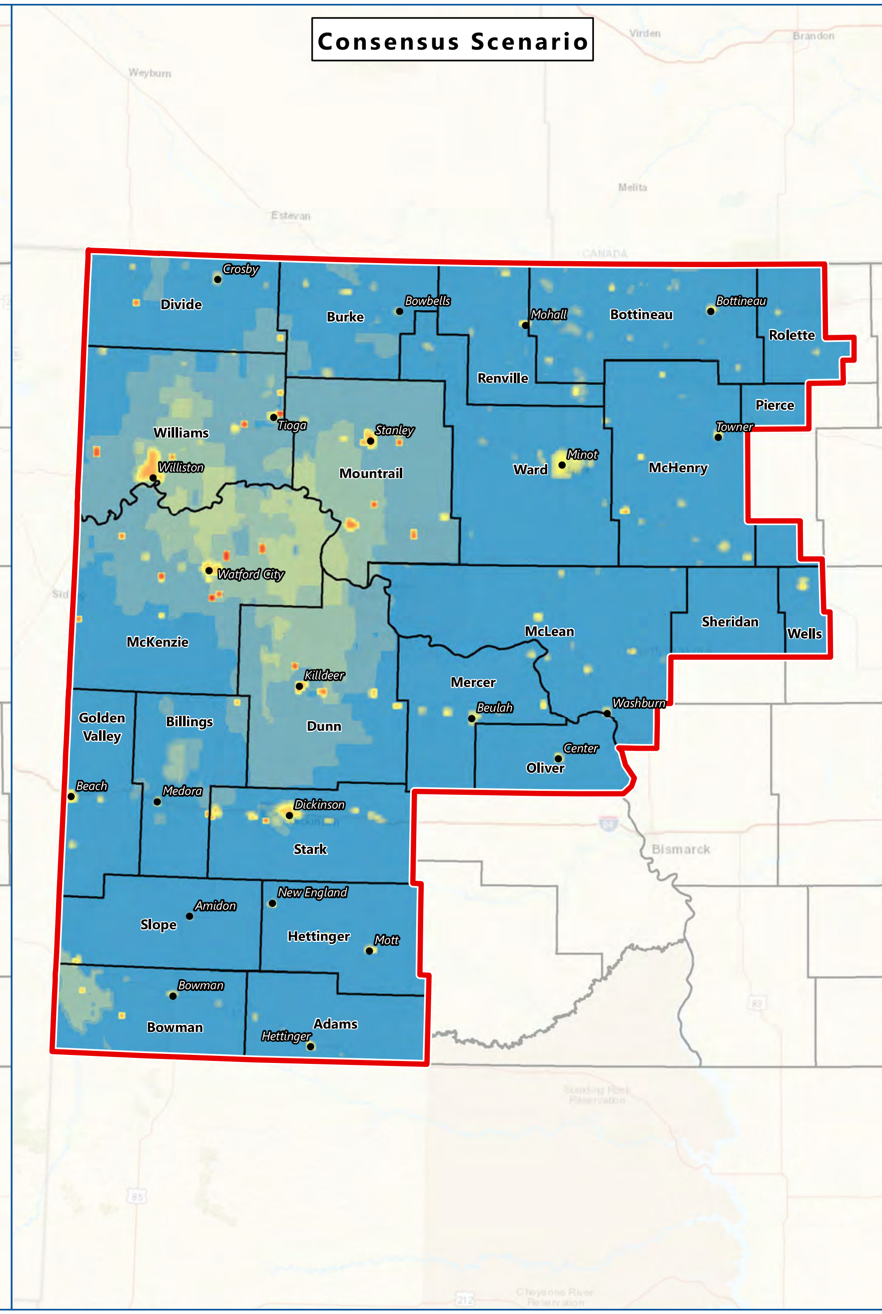
0 10 20 30
Miles

BARR

LARGE INDUSTRIAL/COMMERCIAL SOURCES ASSUMED WITHIN PF19
Power Forecast 2019 Report: Williston Basin Oil and Gas Related Electrical Load Growth Forecast
North Dakota Transmission Authority

LARGE FIGURE 2





Study Area

Estimated Energy Load

Year 2022

Low

Medium

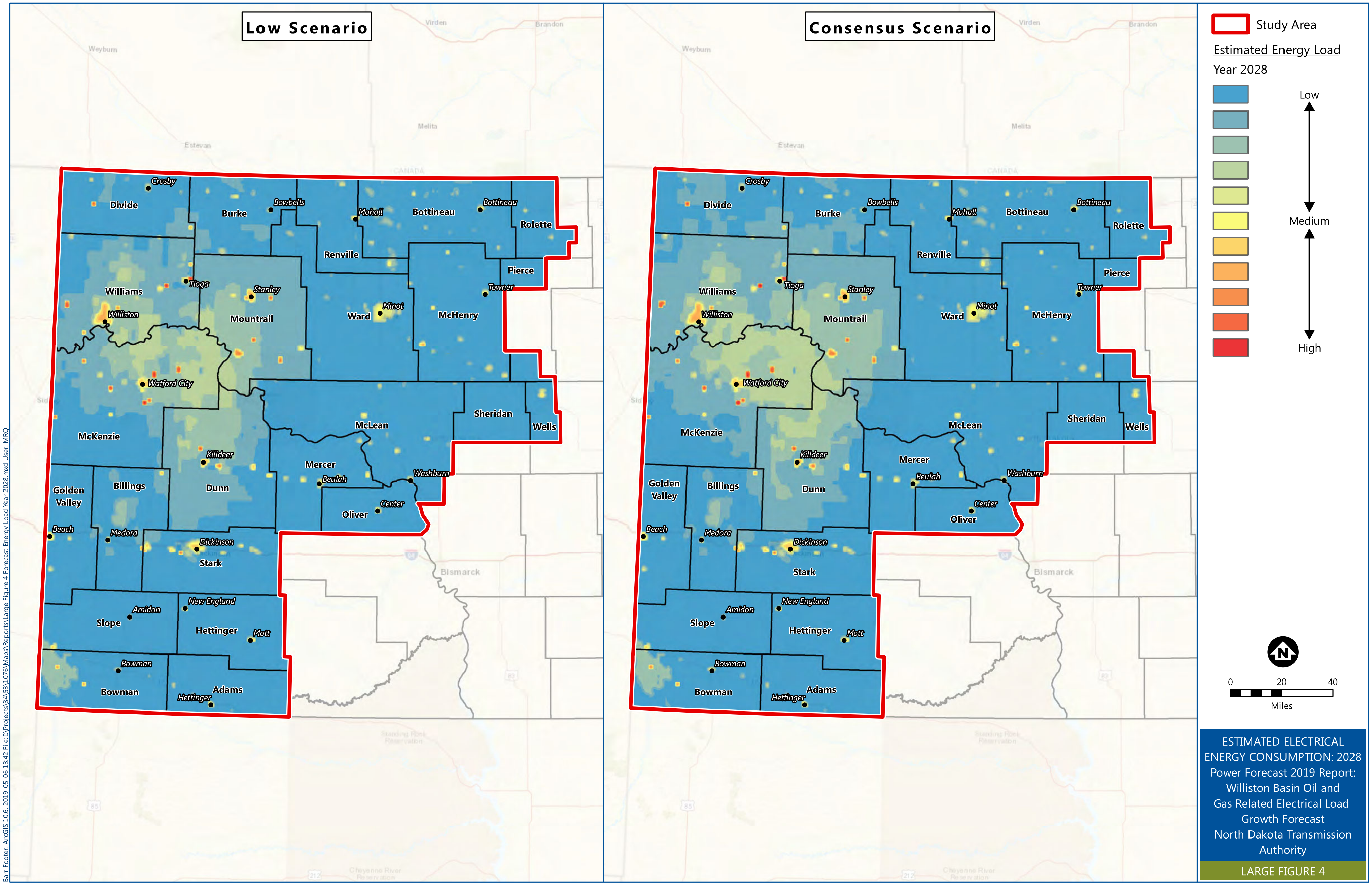
High

0 20 40

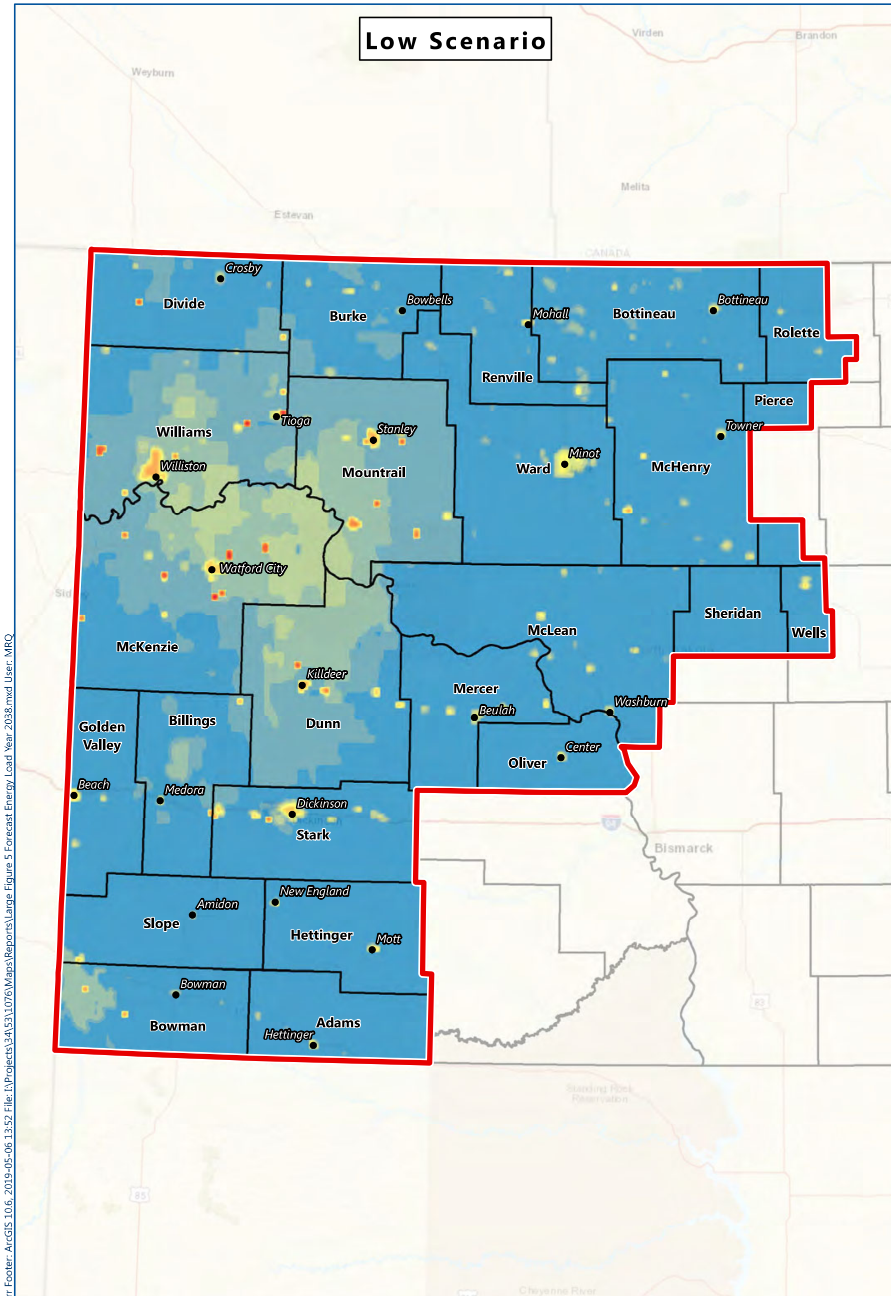
Miles

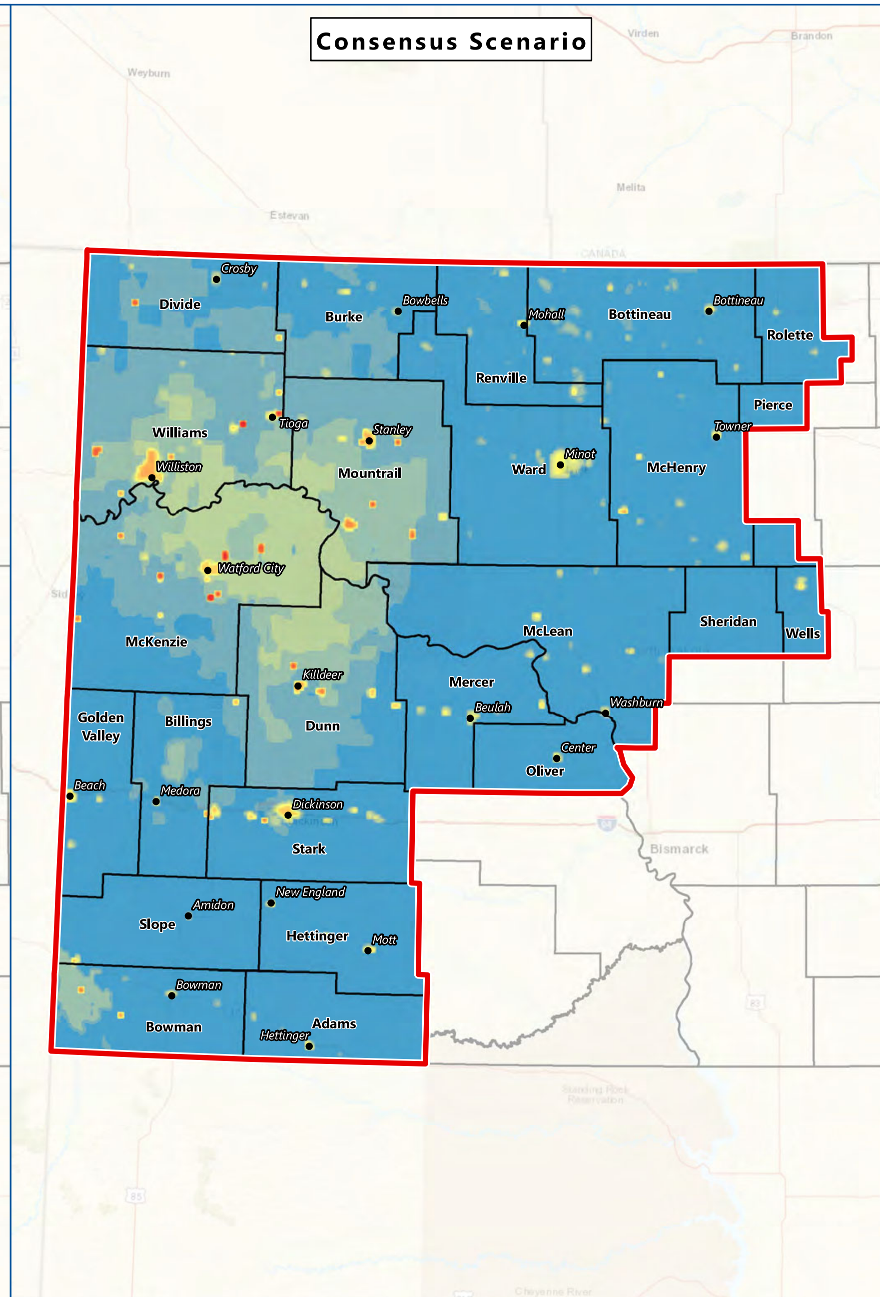
ESTIMATED ELECTRICAL ENERGY CONSUMPTION: 2022
Power Forecast 2019 Report: Williston Basin Oil and Gas Related Electrical Load Growth Forecast
North Dakota Transmission Authority

LARGE FIGURE 3



Barr Footer: ArcGIS 10.6, 2019-05-06 13:42 File: I:\Projects\34\53\1076\Maps\Reports\Large Figure 4 Forecast Energy Load Year 2028.mxd User: MRQ





Study Area

Estimated Energy Load
Year 2038

Low
Medium
High

0 20 40
Miles

ESTIMATED ELECTRICAL ENERGY CONSUMPTION: 2038
Power Forecast 2019 Report: Williston Basin Oil and Gas Related Electrical Load Growth Forecast
North Dakota Transmission Authority

LARGE FIGURE 5

Appendix B

Formulae used in Calculations

Equations Used but not provided in Report

1) Pump Efficiency

The pump efficiency can change from a minimum value of about 0.3 for a smaller sized ESP to a maximum of about 0.8 for a pump jack. But the average pump efficiency in a field for a specific age class of wells is a value dependent on the fraction of each type pump deployed. So for this work the pump efficiency as a function of age is approximated as:

$$n\{age\} = \text{minimum}\ [\ 0.4 + .05*age,\ 0.8\ ]$$

It can be seen that after age = 8 years the value of n will be a constant value of 0.8.

2) Pressure as Function of Age

$pressure\{age\} = a_0 * e^{-(age/t_p)} + a_1*age + a_2*age^2 + a_3*age^3$

where *age* is the age of the well, and a0, a1, a2, a3 and *t* are coefficients specific to the geology of the well. In principle the coefficients could be different for each well. However, for a geographic region at a particular interval of history, the completion methods and geology are similar enough that a composite curve can be used.

3) Production Energy

production_energy = ENERGY * (oil_production * 0.85 + water_production * 1.2)

the specific gravity of crude oil from the Bakken is about 0.85, and the produced water is 1.2

4) Age of Well Algorithm

An algorithm for computing the power is shown below.

```
For FIELD = aaa to zzz;
    For YEAR = 2014 to 2040;
            For AGE = 0 to 15;  'decide whether 15 years is good enough
            Select {a0, a1, a2, a3, tp, new_production} From FIELD.(YEAR-AGE)];
            new_water = new_production * w_o_r;  'decide whether to use a constant for water/oil ratio
            energy_production = ENERGY{age}*(new_production*0.85+new_water *1.2);
            cumulative_energy = cumulative_energy + energy_production;
            Next AGE
    Select {oil_production, water_production} From [FIELD.(YEAR-16)]
    cumulative_energy = ENERGY{16}*(oil_production*0.85+water_production *1.2)*volume{16};
```

Next YEAR

5) Energy Information Administration (EIA) of the US Department of Energy (DOE) Decline Curve

New oil production is calculated using an algorithm described in pseudocode below:

```
:volume{age} = 1/(1+b*Di*age*12)^(1/b)

For FIELD = aaa To zzz;
    For Year = 2020 To 2040;
        For AGE = 1 to 20;
        Select {b, Di, oil_production} From FIELD.(YEAR-AGE);
        Declination = FIELD.(YEAR-AGE).new_production * (1-volume{age});
        new_oil = new_oil + Declination;
        Next AGE;
    FIELD.YEAR.new_production = new_oil + FIELD.YEAR.oil_production-FIELD.(YEAR-1).oil_production;
    Next YEAR;
Next FIELD;
```

This algorithm ignores declining production volumes of wells more than 20 years old. This is believed to not be significant because either a) the wells have by then declined to a small and irrelevant level; or b) they have been reworked and will be counted as new production.

6) Energy Consumed by the Gathering Pumps and Compressor Work

pump_work = oil_production*length *(1-trucked_oil)* 0.15 + water_production*length*(1-trucked_water)* 0.15 + water_production *SWD_pressure /55000

Where the units for production is in barrels/day and the gathering network segment length is in miles.

Gas gathering power consumption is also a function of volume production, length of gathering pipelines, and fraction of gas flared. The formula is:

compressor_work = gas_production * length *(1-flare_fraction) * 27

Where the units for production is in million standard cubic feet per day and the gathering network segment length is in miles.

NOTE: in this context “oilfield” means a geographic region in North Dakota which produces hydrocarbons; “FIELD” means a piece of data stored in a RECORD of a data base.

Appendix C

PF19 Sensitivities Analysis Memorandum

Memorandum

To: File
From: Sarah Johnson and Don Kopecky
Subject: PF19 Sensitivities Analysis
Date: May 8, 2019

1.0 Introduction

The purpose of this memo is to summarize what we think are the most impactful sensitivities surrounding methodologies used within the PF19. As described in the PF19, a number of formulae and information sources were used to compile the electrical energy consumption forecast. Sensitivities surrounding how those forecasts were completed with the greatest potential for impact include:

- production-based forecasting and continuation of existing technologies/similar production areas (Section 2.0),
- population forecast growth rate application (Section 3.0),
- length of gathering lines (Section 4.0), and
- initial well pressure (Section 5.0).

This memo does not address or confirm sensitivities included within NDPA's oil and gas production estimates or NDSU's population forecast estimates, as those were not validated by Barr and instead used as the best publicly available datasets.

We recognize unknown factors may also impact the results of the study. Therefore, the PF19 was designed so it may be readily updated to account for changes.

2.0 Production-Based Forecasting and Continuation of Existing Technologies/Similar Production Areas

The PF19's approach was to estimate future electric energy consumption growth as a function of projected oil and gas production volumes available from NDPA. The PF12 also forecasted future electrical energy consumption growth as a result of increased oil and gas production but instead forecasted it as a function of specific well counts and rig counts (which are incorporated into the PF19 as a function of the NDPA and NDSU forecasts which use many of those same factors as the PF12 for their forecasts).

In both cases, the forecasts are limited by the unknown which includes future oil prices, regulations, North Dakota policy, and potentially most important – future technological advances that would increase efficiency and enhance oil recovery at wells as well at the geographic extents of where new development will occur. Because the PF19 assumes that current practices are expected to largely carry forward into the future, the calculations used to estimate future production of oil and gas are not altered throughout the study period for new technologies, but are modified to reflect decline curves. The PF19 also assumes that most of the new production of oil and gas will occur where the currently highest producing areas are located. As described in the FP19, production is extended outward from this focal area however the distribution outward is projected out very gradually.

To better understand the potential sensitivities around forecasting as a means of well and rig counts (PF12) versus forecasted volumes (PF19), Barr compared the rate of growth for reported years between the two studies. Generally speaking, the FP12 estimate continue "boom" like growth for the first half of the study period, and the PF19's year-to-year growth rates appear to be steadier than the PF12. It is unknown however, whether the changes in the rates of growth are attributable to the different methods used to forecast (as a function of volumes versus a function of counts), different assumptions used for future oil and gas productions, or is attributable to more efficient means of extraction and production. Table 2-1 compares the PF12's first and second halves' growth rates of their respective study periods, as well as compares the overall growth rate from the beginning to the end of the respective 20-year study periods.

Table 2-1 Comparing PF12 to PF19 Growth Rates

Study and Point of Comparison	First Half of Study Period	Second Half of Study Period	Full Study Period
PF12: total demand (MW) [1]	From 2012 – 2022, the PF12 forecasted in increase of **247%** in total MW.	From 2023 – 2032, the PF12 forecasted an increase of **126%** in total KWh.	Overall, the PF12 forecasted an increase of **312%** from the study period's beginning to end.
PF12: total KWh [2]	From 2012 – 2022, the PF12 forecasted in increase of **278%** in total KWh.	From 2023 – 2032, the PF12 forecasted an increase of **128%** in total KWh.	Overall, the PF12 forecasted an increase of **357%** from the study period's beginning to end.
PF19 Low Scenario: total KWh	From 2018 – 2028, the PF19 forecasted an increase of **130%** in total KWh.	From 2029 – 2038, the PF19 forecasted an increase of **109%** in total KWh.	Overall, the PF19 forecasted an increase of **144%** from the study period's beginning to end.
PF19 Consensus Scenario: total KWh	From 2018 – 2028, the PF19 forecasted an increase of **154%** in total KWh.	From 2029 – 2038, the PF19 forecasted an increase of **109%** in total KWh.	Overall, the PF19 forecasted an increase of **171%** from the study period's beginning to end.

[1] Per numbers provided in Table 1 of the PF12 Summary
[2] Per numbers provided in Table 3 of the PF12.

The PF12's study area was more inclusive than the PF19's and extended into the states of South Dakota, Montana, and Wyoming. The PF12 results were organized by regions whereas the PF19 results were organized by county. Barr compared the 2027 and 2032 reporting years to identify potential sensitivities around the geographic extents of forecasted growth. The PF12's reported numbers for this year had high agreement (i.e., where the PF12's forecasted numbers were within 10% of the PF19's forecasted numbers) in the higher oil and gas producing counties of Williams, Mountrail, and Dunn. The biggest difference between the PF12 and PF19's compared reporting year's results is that the PF12 forecasted significantly more growth across the PF12's Region 1 counties further outside of the highest producing areas. Specifically, the PF12 estimated more growth in Divide, Burke, Ward, McLean, Bottineau, and Rollete Counties. The PF12 seemed more optimistic in future production growth in these areas; and the PF19 forecasts less geographic expansion of future production.

The PF19's greatest sensitivity around its methodology would be a change in the gas forecast (similar to the PF12), but it would also be sensitive to significant changes in extraction and processing methodologies and a potential geographic difference in what was assumed for future areas of oil and gas production.

3.0 Population Broad Load Category Growth-Rate Forecasting Method

Approximately half of the baseline electrical energy consumption in the PF19 was allocated to the population broad load category. Specifically, approximately 3,000 GWh were allocated to oil and gas, approximately 2,500 GWh were allocated to large industrial/commercial, and approximately 5,000 GWh were allocated to population. This load category was forecasted as a function of NDSU's population forecast growth rates.

Because commercial users not directly related to oil and gas production (i.e., commercial and industrial users that are not natural gas processing plants, oil transmission pump stations, or terminals) are included within the population base load category, these commercial and industrial users are subject to the estimated population forecast rate growths established in the NDSU study. The overall growth rates from the beginning of the study period to the end of the study period in the population category are provided in Table 3-1 and more specific information regarding annual growth rates are provided in Appendix B of the PF19.

Table 3-1 Population Base Load Category Growth Rates by County

County	2018 - 2038 Population Growth [1]	2018 - 2038 O&G Growth [1]
Adam	11%	0%
Billings	7%	47%
Bottineau	11%	26%
Bowman	15%	0%
Burke	10%	193%
Divide	5%	175%
Dunn	22%	81%
Golden Valley	15%	31%
Hettinger	6%	0%
McHenry	10%	31%
McKenzie	41%	71%

County	2018 - 2038 Population Growth [1]	2018 - 2038 O&G Growth [1]
McLean	5%	126%
Mercer	3%	0%
Mountrail	33%	92%
Oliver	6%	0%
Pierce	2%	0%
Renville	25%	12%
Rolette	15%	0%
Sheridan	34%	0%
Slope	11%	0%
Stark	7%	21%
Ward	11%	3%
Wells	15%	0%
Williams	10%	94%

[1] Reported rates pertain to the consensus scenario of the NDSU population study.

4.0 Gathering Line Length

The pumping work necessary to gather the liquid and gas and transport it to their respective destinations is directly related to the length and diameter of pipes in the gathering network. These values are impossible to define precisely across the entire study area, and will change over time. Consequently the PF19 estimates are based on reasonable values for fluid velocity, pressure drop, and locations of well fields and processing facilities. Variation in specific gathering energy of oil or water for a range of conditions is given in the Table 4-1.

Table 4-1 Variation in Specific Gathering Energy of Oil or Water

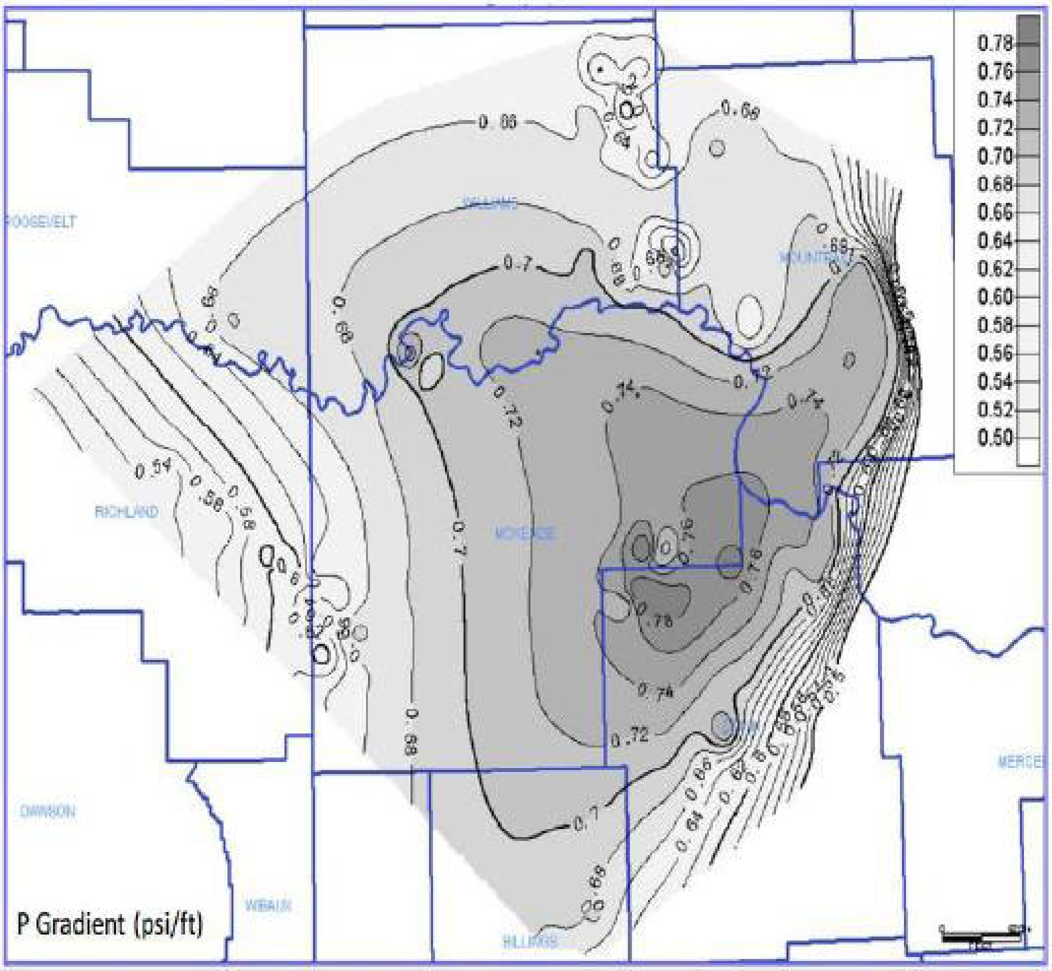
Condition	Pipeline length (miles)	Pressure drop (psid/mile)	Pumping work kwh/bbl
MODEL BASIS	12	170	1.8
Long pipeline and high pressure	20	250	4.4
Short pipeline and low pressure	5	80	.35

The pumping work in the table spans an order of magnitude, which implies that there could be a considerable error introduced by using the wrong values. This underscores the importance of calibrating the model to the 2018 baseline data. Using actual data for a representative cooperative the computed gathering energy agreed within about 7% of reported energy sales. Consequently, the parameters used in the model basis are most likely within 10% of the actual field average values. Gathering line energy use at the baseline is approximately 1,314 GWh or 12 % of the total energy consumption.

5.0 Initial Well Pressure

Initial well pressure is known to vary throughout the basin. Tim Nesheim (ND Geologic Survey) provided the following information to Barr about pressure in the Bakken Formation:

> *Typically, most reservoirs in North Dakota are at a normal pressure gradient during initial production, which is around ~0.46 psi/ft. However, the fluid system in the Bakken Formation is overpressured due to a combination of very low rock permeability and the large amount of oil pressure. So without going into too much detail, the initial reservoir pressure of the Bakken is going to be a combination of depth and fluid pressure gradient. Below is a fluid pressure map for the Bakken presented at a meeting in 2013 by a Colorado School of Mines student.*
>
> *Based on the map below, the highest fluid pressure gradients for the Bakken Formation are in and around northwestern Dunn County, which includes the Lost Bridge Field. In the Lost Bridge Field, the Bakken Formation is at a TVD (true vertical depth) of around ~10,600 ft., and with a fluid pressure gradient of ~0.76 psi/ft, the Bakken fluid pressure would be a little over 8,000 psi. Conversely, in northern Divide County in the Colgan Field, the Bakken is probably close to normal pressure (~0.46 psi/ft.) at a depth of ~8,000 ft. and probably has/had an initial reservoir pressure of ~3,700 psi. So your rule of thumb ~5,500 psi initial reservoir pressure is a middle of the road value, and the 3,000 psi is an underestimate.*



The highest overpressures in the Middle Bakken are correlated to peak hydrocarbon generation (after Theloy and Sonnenberg, 2013). [1]

Figure 5-1 Middle Bakken Pressure Gradient

Our calculation uses 5500 psig initial reservoir pressure for all fields, rather than following the pressure distribution shown in the map. We then calculate actual reservoir pressure at the time of production using the same decline curve as developed by EIA for production volume.

To get an idea of how the below ground energy will be affected by reservoir initial pressure we evaluated a few bounding cases. The pump work A was calculated first using an initial pressure of 5500, and the pressure decline was based on a mid-year convention. The pump work B was then compared using an initial pressure based on the pressure gradient and a monthly pressure decline. Using the parameters for Lost Bridge Field, the specific power computed using the two different pressures is shown below.

[1] Source: Email dated April 17, 2019 from Tim Nesheim (UND) to Justin Kringstad (NDPA).

Year	0	1	2	3	4
work A =	10.55	13.05	13.17	13.18	13.18
work B =	7.05	12.89	13.16	13.18	13.18

Repeating this procedure for the Colgan Field gives:

Year	0	1	2	3	4
work A=	11.58	13.14	13.18	13.18	13.18
work B =	10.39	13.13	13.18	13.18	13.18

Therefore, using an initial pressure of 5500 psig across the entire basin with a mid-year decline calculation, tends to overestimate the pump work required as compared to using field specific pressure gradients and a monthly decline calculation. This difference is a maximum of 33% higher in Lost Bridge Field at Year 0 but quickly declines to insignificance by Year 2. For Colgan Field the difference at Year 0 is only about 10%. The below ground energy use affected by this estimate accounted for approximately 112 GWh in the baseline or 1 % of the total energy consumption.

Appendix D

NDSU Population Forecasts

Historical and Projected Service Populations, by Economic Scenario, Adams County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low[1]	Mid	High[2]	Low[2]	Mid	High[2]	Low[2]	Mid	High[1]
2002	2,683									
2003	2,666									
2004	2,619									
2005	2,572									
2006	2,540									
2007	2,534									
2008	2,543									
2009	2,504									
2010	2,508									
2011	2,469									
2012	2,458									
2013	2,582									
2014	2,582									
2015	2,555									
2016		2,516	2,516	2,516	2,502	2,502	2,502	2,502	2,502	2,502
2017		2,500	2,504	2,508	2,536	2,540	2,540	2,570	2,570	2,570
2018		2,535	2,541	2,546	2,599	2,615	2,619	2,658	2,661	2,669
2019		2,561	2,569	2,578	2,630	2,648	2,663	2,707	2,728	2,738
2020		2,593	2,604	2,617	2,667	2,688	2,714	2,763	2,803	2,815
2021		2,632	2,645	2,662	2,737	2,762	2,783	2,837	2,861	2,884
2022		2,627	2,642	2,661	2,747	2,774	2,797	2,875	2,901	2,926
2023		2,647	2,663	2,685	2,772	2,801	2,827	2,875	2,904	2,931
2024		2,650	2,668	2,693	2,798	2,829	2,857	2,892	2,923	2,952
2025		2,650	2,670	2,697	2,806	2,838	2,869	2,907	2,940	2,971
2026		2,640	2,660	2,689	2,802	2,835	2,868	2,912	2,947	2,980
2027		2,632	2,652	2,682	2,800	2,835	2,869	2,917	2,955	2,989
2028		2,624	2,646	2,677	2,799	2,836	2,872	2,924	2,964	3,000
2029		2,647	2,668	2,699	2,805	2,842	2,880	2,929	2,970	3,008
2030		2,646	2,668	2,698	2,802	2,841	2,879	2,933	2,976	3,015
2031		2,669	2,691	2,721	2,799	2,839	2,878	2,937	2,982	3,022
2032		2,664	2,687	2,718	2,800	2,841	2,883	2,945	2,992	3,034
2033		2,663	2,687	2,721	2,805	2,848	2,892	2,957	3,006	3,051
2034		2,662	2,687	2,723	2,809	2,855	2,901	2,969	3,020	3,067
2035		2,663	2,690	2,730	2,817	2,865	2,914	2,984	3,038	3,087
2036		2,660	2,689	2,733	2,822	2,872	2,923	2,996	3,051	3,102
2037		2,659	2,689	2,737	2,828	2,880	2,934	3,010	3,066	3,120
2038		2,660	2,693	2,743	2,836	2,890	2,946	3,025	3,083	3,139
2039		2,663	2,698	2,752	2,846	2,903	2,961	3,043	3,103	3,160
2040		2,671	2,707	2,765	2,860	2,919	2,980	3,065	3,126	3,186

[1]Developed from extrapolation of main forecasts. [2]Developed from interpolation between main forecasts.

Historical and Projected Service Populations, by Economic Scenario, Billings County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Actual	Low[1]	Mid	High[2]	Low[2]	Mid	High[2]	Low[2]	Mid	High[1]
2002	933									
2003	921									
2004	929									
2005	869									
2006	851									
2007	831									
2008	827									
2009	824									
2010	847									
2011	921									
2012	1,038									
2013	1,047									
2014	1,069									
2015	1,051									
2016		1,018	1,018	1,018	1,018	1,018	1,018	1,018	1,018	1,018
2017		1,015	1,016	1,017	1,021	1,027	1,032	1,037	1,040	1,045
2018		1,011	1,014	1,016	1,027	1,036	1,046	1,054	1,061	1,071
2019		1,015	1,019	1,024	1,045	1,055	1,070	1,085	1,095	1,108
2020		1,028	1,030	1,037	1,061	1,073	1,085	1,098	1,113	1,127
2021		1,036	1,040	1,049	1,069	1,083	1,094	1,109	1,124	1,138
2022		1,041	1,048	1,057	1,073	1,084	1,098	1,110	1,128	1,146
2023		1,040	1,051	1,062	1,075	1,087	1,101	1,114	1,132	1,150
2024		1,044	1,053	1,064	1,078	1,090	1,105	1,117	1,138	1,159
2025		1,045	1,055	1,065	1,078	1,090	1,106	1,120	1,141	1,163
2026		1,043	1,053	1,065	1,080	1,089	1,104	1,122	1,145	1,169
2027		1,036	1,047	1,062	1,079	1,085	1,101	1,122	1,146	1,171
2028		1,031	1,042	1,058	1,077	1,084	1,099	1,123	1,149	1,175
2029		1,026	1,037	1,055	1,075	1,082	1,098	1,124	1,151	1,177
2030		1,022	1,033	1,049	1,072	1,081	1,096	1,124	1,151	1,179
2031		1,017	1,031	1,047	1,070	1,080	1,097	1,122	1,151	1,179
2032		1,015	1,032	1,047	1,067	1,081	1,098	1,124	1,153	1,183
2033		1,015	1,032	1,050	1,067	1,085	1,102	1,127	1,158	1,189
2034		1,015	1,033	1,053	1,070	1,090	1,108	1,131	1,163	1,196
2035		1,015	1,035	1,058	1,077	1,097	1,109	1,137	1,171	1,205
2036		1,015	1,036	1,061	1,079	1,100	1,115	1,141	1,176	1,211
2037		1,014	1,038	1,063	1,082	1,103	1,118	1,146	1,183	1,219
2038		1,014	1,042	1,067	1,089	1,108	1,123	1,153	1,190	1,228
2039		1,015	1,044	1,073	1,094	1,114	1,131	1,160	1,199	1,238
2040		1,017	1,046	1,079	1,100	1,122	1,139	1,169	1,210	1,250

[1]Developed from extrapolation of main forecasts. [2]Developed from interpolation between main forecasts.

Historical and Projected Service Populations, by Economic Scenario, Bottineau County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low[1]	Mid	High[2]	Low[2]	Mid	High[2]	Low[2]	Mid	High[1]
2002	7,150									
2003	6,990									
2004	6,954									
2005	6,813									
2006	6,776									
2007	6,712									
2008	6,624									
2009	6,579									
2010	6,608									
2011	6,743									
2012	6,885									
2013	7,013									
2014	6,931									
2015	6,922									
2016		6,899	6,899	6,899	6,899	6,899	6,899	6,899	6,899	6,899
2017		6,831	6,837	6,841	6,921	6,961	6,989	7,052	7,052	7,052
2018		6,868	6,882	6,889	6,978	7,022	7,069	7,167	7,168	7,167
2019		6,892	6,912	6,932	7,050	7,102	7,176	7,296	7,308	7,322
2020		6,942	6,962	6,986	7,103	7,168	7,232	7,365	7,383	7,398
2021		6,984	6,993	7,014	7,172	7,240	7,308	7,462	7,481	7,500
2022		7,009	7,025	7,043	7,227	7,297	7,368	7,551	7,572	7,593
2023		7,030	7,047	7,067	7,270	7,344	7,417	7,628	7,651	7,674
2024		7,047	7,066	7,089	7,318	7,394	7,470	7,708	7,733	7,757
2025		7,060	7,080	7,105	7,348	7,427	7,505	7,768	7,799	7,833
2026		7,060	7,081	7,107	7,400	7,481	7,562	7,839	7,867	7,895
2027		7,058	7,080	7,106	7,407	7,490	7,574	7,860	7,890	7,919
2028		7,054	7,076	7,103	7,418	7,503	7,589	7,898	7,930	7,961
2029		7,042	7,064	7,091	7,417	7,504	7,591	7,912	7,945	7,978
2030		7,032	7,053	7,080	7,415	7,504	7,592	7,922	7,957	7,990
2031		7,044	7,066	7,092	7,416	7,505	7,604	7,921	7,957	7,992
2032		7,068	7,090	7,118	7,433	7,538	7,642	7,960	7,998	8,035
2033		7,089	7,113	7,143	7,464	7,570	7,677	8,006	8,046	8,084
2034		7,104	7,129	7,161	7,488	7,597	7,707	8,033	8,075	8,115
2035		7,126	7,152	7,187	7,516	7,630	7,743	8,075	8,118	8,161
2036		7,177	7,206	7,244	7,577	7,692	7,807	8,141	8,185	8,229
2037		7,227	7,258	7,298	7,642	7,759	7,876	8,218	8,264	8,309
2038		7,269	7,301	7,345	7,700	7,819	7,937	8,283	8,331	8,378
2039		7,308	7,342	7,389	7,752	7,873	7,994	8,346	8,395	8,444
2040		7,349	7,384	7,434	7,803	7,927	8,050	8,410	8,461	8,511

[1]Developed from extrapolation of main forecasts. [2]Developed from interpolation between main forecasts.

Historical and Projected Service Populations, by Economic Scenario, Bowman County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low[1]	Mid	High[2]	Low[2]	Mid	High[2]	Low[2]	Mid	High[1]
2002	3,271									
2003	3,235									
2004	3,229									
2005	3,249									
2006	3,177									
2007	3,198									
2008	3,261									
2009	3,272									
2010	3,316									
2011	3,363									
2012	3,534									
2013	3,588									
2014	3,552									
2015	3,553									
2016		3,565	3,565	3,565	3,565	3,565	3,565	3,565	3,565	3,565
2017		3,327	3,332	3,334	3,497	3,508	3,530	3,628	3,649	3,672
2018		3,370	3,382	3,399	3,546	3,565	3,598	3,736	3,762	3,785
2019		3,447	3,464	3,481	3,642	3,662	3,686	3,844	3,874	3,894
2020		3,528	3,538	3,551	3,720	3,745	3,768	3,944	3,962	3,990
2021		3,569	3,581	3,596	3,801	3,825	3,850	4,033	4,058	4,082
2022		3,619	3,632	3,649	3,850	3,873	3,894	4,098	4,120	4,141
2023		3,644	3,659	3,679	3,883	3,908	3,931	4,142	4,166	4,190
2024		3,667	3,684	3,706	3,916	3,942	3,967	4,186	4,212	4,237
2025		3,687	3,705	3,730	3,945	3,974	4,000	4,226	4,254	4,282
2026		3,694	3,713	3,739	3,961	3,991	4,019	4,254	4,284	4,313
2027		3,701	3,721	3,748	3,977	4,009	4,039	4,281	4,313	4,344
2028		3,708	3,728	3,757	3,993	4,026	4,058	4,293	4,326	4,359
2029		3,712	3,732	3,760	4,004	4,038	4,070	4,296	4,330	4,364
2030		3,715	3,735	3,763	4,002	4,037	4,069	4,296	4,333	4,368
2031		3,722	3,743	3,771	4,000	4,036	4,070	4,309	4,352	4,379
2032		3,730	3,752	3,781	4,017	4,054	4,090	4,324	4,364	4,402
2033		3,742	3,765	3,796	4,037	4,076	4,115	4,356	4,397	4,438
2034		3,744	3,768	3,801	4,050	4,091	4,132	4,375	4,418	4,461
2035		3,743	3,768	3,805	4,059	4,102	4,145	4,394	4,438	4,483
2036		3,728	3,755	3,794	4,056	4,101	4,145	4,401	4,447	4,493
2037		3,713	3,742	3,785	4,052	4,099	4,145	4,408	4,456	4,503
2038		3,701	3,731	3,776	4,051	4,099	4,147	4,416	4,465	4,514
2039		3,688	3,720	3,768	4,048	4,098	4,149	4,423	4,474	4,525
2040		3,680	3,714	3,764	4,051	4,102	4,154	4,435	4,488	4,540

[1]Developed from extrapolation of main forecasts. [2]Developed from interpolation between main forecasts.

Historical and Projected Service Populations, by Economic Scenario, Burke County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low[1]	Mid	High[2]	Low[2]	Mid	High[2]	Low[2]	Mid	High[1]
2002	2,240									
2003	2,208									
2004	2,190									
2005	2,129									
2006	2,097									
2007	2,025									
2008	1,952									
2009	1,932									
2010	1,993									
2011	2,093									
2012	2,250									
2013	2,362									
2014	2,368									
2015	2,350									
2016		2,339	2,339	2,339	2,339	2,339	2,339	2,339	2,339	2,339
2017		2,269	2,276	2,280	2,316	2,319	2,322	2,349	2,348	2,349
2018		2,298	2,307	2,316	2,384	2,393	2,403	2,442	2,452	2,466
2019		2,330	2,342	2,355	2,426	2,441	2,452	2,506	2,517	2,533
2020		2,366	2,382	2,398	2,468	2,483	2,500	2,559	2,577	2,595
2021		2,390	2,408	2,426	2,497	2,514	2,533	2,598	2,617	2,639
2022		2,398	2,417	2,435	2,508	2,526	2,547	2,613	2,638	2,659
2023		2,404	2,425	2,447	2,519	2,539	2,560	2,628	2,652	2,677
2024		2,420	2,442	2,466	2,537	2,560	2,583	2,642	2,669	2,696
2025		2,425	2,448	2,472	2,544	2,570	2,596	2,658	2,684	2,715
2026		2,428	2,453	2,478	2,554	2,579	2,605	2,668	2,695	2,721
2027		2,428	2,453	2,479	2,554	2,578	2,608	2,668	2,697	2,724
2028		2,423	2,449	2,476	2,555	2,578	2,611	2,677	2,708	2,736
2029		2,422	2,448	2,474	2,559	2,579	2,617	2,687	2,719	2,749
2030		2,410	2,437	2,465	2,556	2,585	2,615	2,696	2,729	2,759
2031		2,402	2,427	2,454	2,553	2,582	2,614	2,696	2,735	2,769
2032		2,397	2,423	2,450	2,558	2,585	2,620	2,709	2,744	2,778
2033		2,402	2,429	2,458	2,567	2,597	2,630	2,724	2,761	2,796
2034		2,395	2,424	2,454	2,574	2,598	2,637	2,737	2,770	2,811
2035		2,395	2,425	2,457	2,575	2,605	2,646	2,743	2,783	2,821
2036		2,387	2,419	2,453	2,579	2,608	2,653	2,757	2,798	2,838
2037		2,383	2,417	2,453	2,586	2,618	2,663	2,772	2,814	2,855
2038		2,385	2,421	2,459	2,595	2,629	2,676	2,786	2,830	2,872
2039		2,392	2,429	2,469	2,606	2,643	2,690	2,799	2,843	2,887
2040		2,404	2,443	2,485	2,622	2,662	2,709	2,819	2,865	2,910

[1]Developed from extrapolation of main forecasts. [2]Developed from interpolation between main forecasts.

Historical and Projected Service Populations, by Economic Scenario, Divide County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low[1]	Mid	High[2]	Low[2]	Mid	High[2]	Low[2]	Mid	High[1]
2002	2,231									
2003	2,245									
2004	2,227									
2005	2,199									
2006	2,156									
2007	2,139									
2008	2,094									
2009	2,052									
2010	2,104									
2011	2,199									
2012	2,373									
2013	2,463									
2014	2,652									
2015	2,638									
2016		2,681	2,681	2,681	2,681	2,681	2,681	2,681	2,681	2,681
2017		2,648	2,652	2,657	2,698	2,707	2,715	2,763	2,780	2,794
2018		2,635	2,644	2,651	2,713	2,729	2,740	2,816	2,833	2,853
2019		2,619	2,629	2,639	2,733	2,746	2,760	2,839	2,866	2,886
2020		2,608	2,621	2,635	2,741	2,755	2,768	2,853	2,878	2,898
2021		2,587	2,603	2,618	2,728	2,743	2,758	2,853	2,879	2,899
2022		2,562	2,579	2,597	2,706	2,723	2,740	2,839	2,863	2,884
2023		2,535	2,554	2,573	2,688	2,706	2,724	2,820	2,842	2,861
2024		2,523	2,543	2,563	2,677	2,697	2,716	2,814	2,834	2,852
2025		2,510	2,531	2,553	2,670	2,691	2,712	2,805	2,827	2,846
2026		2,488	2,510	2,532	2,654	2,676	2,698	2,789	2,812	2,834
2027		2,484	2,506	2,530	2,658	2,681	2,704	2,794	2,819	2,841
2028		2,497	2,520	2,544	2,680	2,704	2,728	2,821	2,847	2,871
2029		2,509	2,531	2,555	2,702	2,727	2,751	2,846	2,873	2,898
2030		2,522	2,545	2,569	2,723	2,749	2,774	2,874	2,902	2,928
2031		2,528	2,551	2,574	2,739	2,765	2,791	2,895	2,924	2,952
2032		2,535	2,559	2,583	2,757	2,784	2,811	2,918	2,949	2,977
2033		2,549	2,574	2,599	2,778	2,807	2,835	2,947	2,979	3,009
2034		2,564	2,590	2,617	2,802	2,832	2,862	2,978	3,011	3,043
2035		2,576	2,605	2,633	2,816	2,848	2,880	3,007	3,035	3,068
2036		2,577	2,606	2,636	2,830	2,863	2,896	3,024	3,059	3,093
2037		2,571	2,601	2,633	2,831	2,865	2,899	3,034	3,071	3,106
2038		2,565	2,597	2,631	2,833	2,868	2,903	3,042	3,080	3,117
2039		2,565	2,598	2,633	2,839	2,875	2,912	3,056	3,095	3,133
2040		2,569	2,604	2,640	2,846	2,884	2,922	3,075	3,115	3,154

[1]Developed from extrapolation of main forecasts. [2]Developed from interpolation between main forecasts.

Historical and Projected Service Populations, by Economic Scenario, Dunn County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low	Mid	High	Low	Mid	High	Low	Mid	High
2002	3,678									
2003	3,657									
2004	3,609									
2005	3,538									
2006	3,508									
2007	3,512									
2008	3,532									
2009	3,549									
2010	3,648									
2011	4,023									
2012	4,665									
2013	4,887									
2014	5,327									
2015	5,214									
2016		4,917	4,917	4,917	4,917	4,917	4,917	4,917	4,917	4,917
2017		4,913	4,958	5,004	5,053	5,087	5,121	5,152	5,196	5,212
2018		4,909	4,969	5,030	5,159	5,215	5,261	5,339	5,429	5,470
2019		4,905	4,980	5,055	5,270	5,342	5,412	5,501	5,632	5,728
2020		4,901	4,991	5,081	5,335	5,424	5,511	5,625	5,783	5,941
2021		4,894	4,999	5,104	5,397	5,503	5,608	5,794	5,970	6,146
2022		4,887	5,007	5,126	5,458	5,582	5,704	5,908	6,100	6,291
2023		4,897	5,022	5,148	5,520	5,660	5,800	6,030	6,236	6,441
2024		4,909	5,041	5,172	5,581	5,739	5,895	6,099	6,316	6,533
2025		4,922	5,061	5,199	5,642	5,817	5,991	6,173	6,403	6,632
2026		4,903	5,049	5,194	5,694	5,859	6,055	6,224	6,469	6,712
2027		4,898	5,051	5,204	5,714	5,916	6,103	6,288	6,546	6,803
2028		4,895	5,056	5,216	5,747	5,958	6,167	6,353	6,626	6,898
2029		4,880	5,050	5,218	5,757	5,978	6,197	6,405	6,693	6,979
2030		4,869	5,046	5,221	5,769	5,999	6,227	6,458	6,760	7,060
2031		4,858	5,043	5,227	5,783	6,023	6,262	6,516	6,833	7,147
2032		4,865	5,060	5,252	5,814	6,064	6,312	6,593	6,924	7,254
2033		4,886	5,088	5,288	5,855	6,115	6,373	6,682	7,028	7,371
2034		4,908	5,116	5,322	5,895	6,162	6,428	6,770	7,130	7,486
2035		4,937	5,153	5,366	5,943	6,220	6,495	6,867	7,240	7,609
2036		4,953	5,177	5,398	5,980	6,269	6,555	6,953	7,338	7,722
2037		4,971	5,204	5,434	6,018	6,318	6,615	7,039	7,438	7,835
2038		4,992	5,232	5,471	6,058	6,368	6,676	7,125	7,537	7,947
2039		5,014	5,262	5,509	6,099	6,420	6,738	7,211	7,637	8,060
2040		5,040	5,297	5,551	6,146	6,477	6,807	7,303	7,742	8,179

Historical and Projected Service Populations, by Economic Scenario, Golden Valley County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low[1]	Mid	High[2]	Low[2]	Mid	High[2]	Low[2]	Mid	High[1]
2002	2,014									
2003	1,981									
2004	1,979									
2005	1,839									
2006	1,777									
2007	1,820									
2008	1,837									
2009	1,752									
2010	1,789									
2011	1,840									
2012	1,948									
2013	1,957									
2014	1,994									
2015	1,988									
2016		1,998	1,998	1,998	1,998	1,998	1,998	1,998	1,998	1,998
2017		1,952	1,965	1,978	1,982	1,986	1,994	2,024	2,040	2,056
2018		1,999	2,004	2,010	2,030	2,040	2,052	2,102	2,133	2,148
2019		2,041	2,053	2,065	2,088	2,101	2,120	2,173	2,209	2,237
2020		2,071	2,087	2,103	2,123	2,138	2,163	2,219	2,256	2,289
2021		2,090	2,114	2,138	2,165	2,185	2,211	2,259	2,284	2,321
2022		2,111	2,135	2,159	2,195	2,213	2,238	2,272	2,302	2,332
2023		2,128	2,159	2,189	2,213	2,230	2,261	2,290	2,318	2,346
2024		2,151	2,178	2,205	2,230	2,250	2,276	2,303	2,325	2,355
2025		2,169	2,188	2,213	2,246	2,269	2,297	2,315	2,336	2,366
2026		2,182	2,203	2,224	2,253	2,278	2,309	2,325	2,352	2,381
2027		2,190	2,212	2,234	2,262	2,289	2,320	2,339	2,360	2,388
2028		2,197	2,220	2,243	2,273	2,300	2,332	2,353	2,377	2,409
2029		2,201	2,224	2,247	2,277	2,306	2,339	2,361	2,388	2,417
2030		2,202	2,224	2,247	2,281	2,310	2,344	2,369	2,397	2,429
2031		2,199	2,221	2,244	2,280	2,311	2,346	2,371	2,398	2,430
2032		2,199	2,223	2,247	2,284	2,317	2,348	2,379	2,403	2,441
2033		2,201	2,226	2,252	2,285	2,316	2,350	2,384	2,409	2,441
2034		2,200	2,227	2,255	2,285	2,315	2,351	2,388	2,420	2,453
2035		2,199	2,229	2,258	2,288	2,323	2,361	2,395	2,432	2,464
2036		2,197	2,228	2,260	2,296	2,331	2,369	2,406	2,439	2,477
2037		2,198	2,231	2,265	2,303	2,343	2,382	2,412	2,446	2,487
2038		2,200	2,235	2,271	2,313	2,355	2,395	2,421	2,456	2,498
2039		2,200	2,238	2,276	2,325	2,366	2,406	2,431	2,470	2,507
2040		2,200	2,240	2,280	2,330	2,377	2,416	2,441	2,491	2,520

[1]Developed from extrapolation of main forecasts. [2]Developed from interpolation between main forecasts.

Historical and Projected Service Populations, by Economic Scenario, Hettinger County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low[1]	Mid	High[2]	Low[2]	Mid	High[2]	Low[2]	Mid	High[1]
2002	2,731									
2003	2,714									
2004	2,667									
2005	2,689									
2006	2,670									
2007	2,688									
2008	2,622									
2009	2,539									
2010	2,554									
2011	2,610									
2012	2,634									
2013	2,759									
2014	2,769									
2015	2,769									
2016		2,854	2,854	2,854	2,854	2,854	2,854	2,854	2,854	2,854
2017		2,831	2,835	2,836	2,859	2,865	2,872	2,880	2,889	2,898
2018		2,875	2,879	2,881	2,890	2,901	2,912	2,923	2,932	2,946
2019		2,916	2,922	2,929	2,940	2,949	2,964	2,978	2,996	3,014
2020		2,931	2,939	2,953	2,963	2,971	2,991	3,010	3,035	3,060
2021		2,934	2,946	2,959	2,977	2,985	3,000	3,034	3,064	3,095
2022		2,937	2,948	2,963	2,978	2,989	3,005	3,049	3,082	3,116
2023		2,932	2,945	2,963	2,978	2,992	3,008	3,053	3,089	3,125
2024		2,935	2,949	2,964	2,980	2,996	3,018	3,057	3,092	3,135
2025		2,937	2,953	2,969	2,985	3,004	3,023	3,062	3,103	3,145
2026		2,937	2,954	2,971	2,988	3,009	3,030	3,073	3,112	3,150
2027		2,931	2,949	2,967	2,986	3,010	3,034	3,075	3,111	3,148
2028		2,928	2,946	2,965	2,986	3,010	3,035	3,079	3,114	3,149
2029		2,915	2,933	2,951	2,977	3,005	3,032	3,077	3,117	3,157
2030		2,903	2,921	2,939	2,969	2,998	3,028	3,076	3,120	3,164
2031		2,900	2,918	2,937	2,971	3,002	3,033	3,077	3,120	3,162
2032		2,894	2,913	2,932	2,970	3,004	3,037	3,078	3,124	3,169
2033		2,891	2,912	2,932	2,971	3,008	3,045	3,087	3,132	3,176
2034		2,892	2,914	2,936	2,977	3,016	3,056	3,099	3,146	3,192
2035		2,894	2,918	2,942	2,983	3,025	3,068	3,112	3,157	3,202
2036		2,897	2,923	2,949	2,990	3,036	3,081	3,120	3,164	3,208
2037		2,898	2,926	2,954	2,998	3,047	3,095	3,130	3,178	3,226
2038		2,916	2,946	2,976	3,010	3,062	3,113	3,149	3,201	3,252
2039		2,922	2,954	2,986	3,021	3,075	3,129	3,166	3,221	3,276
2040		2,933	2,968	3,002	3,036	3,093	3,150	3,188	3,239	3,290

[1]Developed from extrapolation of main forecasts. [2]Developed from interpolation between main forecasts.

Historical and Projected Service Populations, by Economic Scenario, McHenry County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low[1]	Mid	High[2]	Low[2]	Mid	High[2]	Low[2]	Mid	High[1]
2002	6,091									
2003	5,986									
2004	5,925									
2005	5,830									
2006	5,779									
2007	5,791									
2008	5,615									
2009	5,604									
2010	5,610									
2011	5,702									
2012	6,016									
2013	6,184									
2014	6,225									
2015	6,219									
2016		6,386	6,386	6,386	6,386	6,386	6,386	6,386	6,386	6,386
2017		6,289	6,301	6,315	6,387	6,414	6,458	6,524	6,546	6,584
2018		6,349	6,369	6,388	6,490	6,537	6,572	6,629	6,669	6,709
2019		6,464	6,491	6,506	6,612	6,644	6,682	6,761	6,802	6,831
2020		6,575	6,602	6,632	6,709	6,748	6,787	6,883	6,927	6,958
2021		6,655	6,678	6,703	6,811	6,844	6,879	7,021	7,070	7,099
2022		6,711	6,736	6,764	6,908	6,941	6,980	7,108	7,140	7,171
2023		6,706	6,733	6,764	6,974	7,011	7,044	7,200	7,234	7,267
2024		6,701	6,730	6,765	7,002	7,037	7,081	7,289	7,325	7,362
2025		6,723	6,755	6,792	7,051	7,092	7,130	7,315	7,361	7,406
2026		6,719	6,752	6,790	7,082	7,125	7,164	7,347	7,388	7,429
2027		6,726	6,759	6,799	7,093	7,137	7,179	7,374	7,417	7,460
2028		6,707	6,741	6,781	7,073	7,118	7,162	7,386	7,432	7,477
2029		6,716	6,749	6,788	7,093	7,139	7,184	7,426	7,473	7,519
2030		6,729	6,761	6,800	7,098	7,145	7,191	7,498	7,556	7,614
2031		6,719	6,751	6,790	7,124	7,172	7,219	7,552	7,602	7,652
2032		6,732	6,765	6,805	7,130	7,179	7,229	7,553	7,605	7,658
2033		6,726	6,761	6,803	7,112	7,163	7,215	7,564	7,619	7,674
2034		6,707	6,744	6,790	7,097	7,151	7,206	7,566	7,624	7,681
2035		6,709	6,748	6,798	7,095	7,151	7,209	7,560	7,620	7,681
2036		6,705	6,747	6,800	7,097	7,156	7,216	7,580	7,643	7,705
2037		6,711	6,756	6,813	7,125	7,186	7,250	7,595	7,659	7,724
2038		6,718	6,766	6,827	7,137	7,201	7,267	7,580	7,646	7,713
2039		6,738	6,788	6,853	7,177	7,244	7,312	7,615	7,684	7,753
2040		6,768	6,821	6,890	7,219	7,289	7,360	7,664	7,736	7,807

[1]Developed from extrapolation of main forecasts. [2]Developed from interpolation between main forecasts.

Historical and Projected Service Populations, by Economic Scenario, McKenzie County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low	Mid	High	Low	Mid	High	Low	Mid	High
2002	5,836									
2003	5,892									
2004	5,752									
2005	5,790									
2006	5,937									
2007	6,142									
2008	6,228									
2009	6,256									
2010	6,849									
2011	7,923									
2012	9,892									
2013	12,385									
2014	15,471									
2015	15,276									
2016		13,638	13,638	13,638	13,638	13,638	13,638	13,638	13,638	13,638
2017		13,612	13,777	13,794	13,941	14,010	14,196	14,326	14,464	14,718
2018		13,645	13,870	14,007	14,213	14,410	14,613	14,828	15,109	15,465
2019		13,784	14,011	14,199	14,578	14,858	15,127	15,407	15,727	16,255
2020		13,932	14,195	14,356	14,868	15,232	15,527	15,875	16,342	16,877
2021		14,077	14,315	14,556	15,126	15,589	16,018	16,377	16,916	17,517
2022		14,252	14,488	14,757	15,439	15,883	16,328	16,806	17,347	18,008
2023		14,308	14,681	15,096	15,749	16,208	16,669	17,177	17,840	18,641
2024		14,498	14,944	15,389	16,074	16,553	17,036	17,590	18,311	19,161
2025		14,624	15,097	15,566	16,276	16,778	17,284	18,088	18,873	19,780
2026		14,802	15,311	15,816	16,557	17,085	17,621	18,601	19,470	20,448
2027		15,026	15,575	16,119	16,896	17,465	18,047	19,022	19,961	21,004
2028		15,145	15,729	16,308	17,116	17,723	18,344	19,567	20,585	21,703
2029		15,275	15,972	16,593	17,508	18,162	18,833	19,982	21,077	22,267
2030		15,370	16,030	16,683	17,716	18,409	19,122	20,233	21,395	22,642
2031		15,402	16,179	16,788	17,943	18,680	19,438	20,533	21,768	23,082
2032		15,410	16,235	16,852	18,044	18,809	19,599	20,868	22,175	23,552
2033		15,465	16,304	16,955	18,184	18,981	19,805	21,174	22,542	23,971
2034		15,597	16,450	17,135	18,433	19,258	20,121	21,503	22,927	24,405
2035		15,720	16,586	17,305	18,657	19,507	20,396	21,739	23,213	24,730
2036		15,820	16,704	17,462	18,886	19,768	20,687	21,992	23,527	25,098
2037		15,904	16,806	17,600	19,112	20,025	20,974	22,210	23,803	25,422
2038		15,981	16,898	17,728	19,338	20,284	21,262	22,418	24,067	25,735
2039		16,066	16,999	17,867	19,587	20,565	21,574	22,732	24,446	26,166
2040		16,087	17,032	17,935	19,763	20,770	21,806	23,029	24,815	26,588

Historical and Projected Service Populations, by Economic Scenario, McLean County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low[1]	Mid	High[2]	Low[2]	Mid	High[2]	Low[2]	Mid	High[1]
2002	9,933									
2003	9,735									
2004	9,822									
2005	9,644									
2006	9,554									
2007	9,703									
2008	9,826									
2009	9,820									
2010	9,994									
2011	10,384									
2012	10,569									
2013	10,786									
2014	10,847									
2015	10,842									
2016		11,017	11,017	11,017	11,017	11,017	11,017	11,017	11,017	11,017
2017		10,922	10,934	10,946	11,024	11,054	11,087	11,134	11,191	11,221
2018		10,944	10,967	10,998	11,121	11,169	11,228	11,300	11,345	11,388
2019		10,939	10,975	11,010	11,206	11,255	11,302	11,408	11,462	11,509
2020		10,939	10,966	10,997	11,254	11,313	11,347	11,507	11,558	11,596
2021		10,942	10,984	11,022	11,270	11,318	11,358	11,577	11,622	11,666
2022		10,944	10,981	11,019	11,294	11,345	11,390	11,625	11,674	11,722
2023		10,924	10,961	11,004	11,310	11,365	11,415	11,686	11,740	11,792
2024		10,899	10,942	10,986	11,346	11,412	11,462	11,725	11,782	11,847
2025		10,870	10,914	10,967	11,374	11,436	11,495	11,783	11,836	11,906
2026		10,855	10,900	10,956	11,402	11,466	11,529	11,831	11,898	11,963
2027		10,856	10,903	10,961	11,437	11,505	11,571	11,889	11,960	12,029
2028		10,864	10,913	10,973	11,453	11,524	11,594	11,955	12,030	12,104
2029		10,870	10,919	10,979	11,479	11,551	11,624	11,998	12,077	12,153
2030		10,887	10,936	10,996	11,496	11,571	11,645	12,047	12,129	12,208
2031		10,896	10,945	11,004	11,505	11,582	11,659	12,091	12,176	12,258
2032		10,916	10,967	11,029	11,535	11,614	11,695	12,144	12,233	12,319
2033		10,935	10,989	11,056	11,576	11,659	11,745	12,186	12,280	12,371
2034		10,964	11,021	11,092	11,575	11,661	11,752	12,198	12,296	12,392
2035		10,965	11,034	11,108	11,622	11,713	11,808	12,266	12,368	12,467
2036		10,956	11,023	11,107	11,610	11,705	11,805	12,268	12,373	12,476
2037		10,933	11,003	11,094	11,616	11,714	11,819	12,290	12,399	12,506
2038		10,943	11,018	11,114	11,634	11,737	11,845	12,311	12,423	12,534
2039		10,912	10,991	11,094	11,611	11,718	11,831	12,296	12,412	12,526
2040		10,927	11,011	11,119	11,634	11,745	11,862	12,322	12,441	12,558

[1]Developed from extrapolation of main forecasts. [2]Developed from interpolation between main forecasts.

Historical and Projected Service Populations, by Economic Scenario, Mercer County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low[1]	Mid	High[2]	Low[2]	Mid	High[2]	Low[2]	Mid	High[1]
2002	9,218									
2003	9,210									
2004	9,281									
2005	9,220									
2006	9,290									
2007	9,317									
2008	9,398									
2009	9,631									
2010	9,518									
2011	9,724									
2012	9,769									
2013	10,054									
2014	10,136									
2015	10,171									
2016		9,932	9,932	9,932	9,932	9,932	9,932	9,932	9,932	9,932
2017		9,869	9,893	9,905	9,930	9,959	9,974	10,010	10,040	10,053
2018		9,878	9,915	9,948	9,992	10,014	10,044	10,101	10,122	10,146
2019		9,887	9,929	9,964	10,027	10,058	10,087	10,162	10,189	10,217
2020		9,886	9,921	9,951	10,055	10,092	10,128	10,209	10,249	10,285
2021		9,867	9,899	9,934	10,063	10,110	10,150	10,247	10,291	10,335
2022		9,853	9,888	9,928	10,083	10,133	10,179	10,302	10,352	10,400
2023		9,846	9,884	9,929	10,103	10,157	10,207	10,354	10,408	10,461
2024		9,843	9,885	9,935	10,131	10,188	10,243	10,413	10,472	10,529
2025		9,839	9,885	9,939	10,147	10,208	10,268	10,446	10,510	10,572
2026		9,848	9,895	9,952	10,177	10,241	10,305	10,502	10,570	10,637
2027		9,831	9,881	9,940	10,185	10,253	10,321	10,538	10,610	10,682
2028		9,787	9,838	9,901	10,163	10,234	10,307	10,543	10,620	10,696
2029		9,773	9,825	9,888	10,173	10,246	10,322	10,580	10,661	10,740
2030		9,738	9,790	9,854	10,158	10,233	10,312	10,589	10,674	10,757
2031		9,732	9,785	9,848	10,179	10,257	10,339	10,630	10,719	10,806
2032		9,718	9,774	9,840	10,177	10,257	10,343	10,650	10,743	10,834
2033		9,721	9,780	9,851	10,201	10,286	10,377	10,655	10,753	10,850
2034		9,703	9,765	9,841	10,209	10,297	10,394	10,694	10,796	10,898
2035		9,686	9,752	9,834	10,222	10,314	10,418	10,702	10,808	10,914
2036		9,703	9,773	9,861	10,233	10,331	10,437	10,752	10,867	10,972
2037		9,706	9,781	9,875	10,259	10,361	10,472	10,773	10,888	11,002
2038		9,697	9,776	9,876	10,249	10,354	10,470	10,794	10,913	11,031
2039		9,690	9,773	9,880	10,240	10,350	10,471	10,795	10,918	11,040
2040		9,677	9,765	9,877	10,207	10,321	10,447	10,784	10,911	11,036

[1]Developed from extrapolation of main forecasts. [2]Developed from interpolation between main forecasts.

Historical and Projected Service Populations, by Economic Scenario, McKenzie County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low	Mid	High	Low	Mid	High	Low	Mid	High
2002	6,763									
2003	6,769									
2004	6,873									
2005	6,901									
2006	6,938									
2007	7,031									
2008	7,223									
2009	7,344									
2010	8,060									
2011	8,777									
2012	10,214									
2013	11,099									
2014	12,118									
2015	11,792									
2016		11,044	11,045	11,045	11,045	11,045	11,045	11,045	11,045	11,045
2017		10,752	11,031	11,081	11,243	11,358	11,435	11,538	11,646	11,749
2018		10,917	11,116	11,211	11,496	11,626	11,755	11,967	12,102	12,240
2019		11,101	11,223	11,347	11,789	11,971	12,094	12,322	12,506	12,608
2020		11,226	11,370	11,519	11,962	12,165	12,317	12,612	12,805	12,972
2021		11,294	11,451	11,612	12,070	12,289	12,466	12,768	12,975	13,172
2022		11,458	11,627	11,802	12,280	12,515	12,717	13,010	13,238	13,455
2023		11,800	11,993	12,193	12,672	12,929	13,160	13,476	13,733	13,980
2024		11,989	12,202	12,426	12,901	13,176	13,433	13,762	14,045	14,317
2025		12,143	12,377	12,624	13,096	13,390	13,673	14,008	14,316	14,613
2026		12,323	12,573	12,837	13,321	13,632	13,938	14,311	14,647	14,971
2027		12,446	12,711	12,990	13,491	13,819	14,149	14,545	14,907	15,256
2028		12,663	12,947	13,245	13,767	14,116	14,474	14,901	15,292	15,671
2029		12,732	13,020	13,322	13,876	14,236	14,610	15,073	15,484	15,882
2030		12,821	13,116	13,425	14,008	14,381	14,772	15,266	15,698	16,118
2031		12,868	13,168	13,481	14,097	14,481	14,887	15,417	15,868	16,307
2032		12,958	13,273	13,602	14,232	14,633	15,063	15,613	16,089	16,551
2033		13,048	13,386	13,740	14,368	14,789	15,248	15,808	16,312	16,802
2034		13,099	13,459	13,838	14,459	14,896	15,382	15,946	16,472	16,984
2035		13,157	13,545	13,955	14,562	15,021	15,533	16,093	16,637	17,175
2036		13,232	13,651	14,096	14,698	15,183	15,722	16,273	16,839	17,400
2037		13,310	13,761	14,240	14,837	15,347	15,914	16,458	17,047	17,631
2038		13,387	13,869	14,382	14,972	15,507	16,102	16,635	17,248	17,855
2039		13,490	14,006	14,555	15,137	15,699	16,323	16,850	17,487	18,119
2040		13,534	14,079	14,660	15,232	15,817	16,467	16,986	17,644	18,297

Historical and Projected Service Populations, by Economic Scenario, Renville County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low[1]	Mid	High[2]	Low[2]	Mid	High[2]	Low[2]	Mid	High[1]
2002	2,593									
2003	2,603									
2004	2,559									
2005	2,532									
2006	2,539									
2007	2,535									
2008	2,447									
2009	2,439									
2010	2,550									
2011	2,555									
2012	2,667									
2013	2,683									
2014	2,657									
2015	2,648									
2016		2,643	2,643	2,643	2,643	2,643	2,643	2,643	2,643	2,643
2017		2,594	2,605	2,612	2,635	2,636	2,645	2,668	2,685	2,708
2018		2,583	2,595	2,609	2,653	2,673	2,690	2,725	2,746	2,764
2019		2,596	2,614	2,628	2,684	2,701	2,723	2,788	2,812	2,833
2020		2,599	2,618	2,634	2,711	2,731	2,749	2,832	2,853	2,870
2021		2,608	2,620	2,638	2,739	2,754	2,773	2,850	2,879	2,901
2022		2,609	2,623	2,643	2,744	2,765	2,783	2,871	2,896	2,918
2023		2,605	2,620	2,643	2,749	2,769	2,792	2,876	2,902	2,920
2024		2,609	2,625	2,650	2,759	2,772	2,794	2,889	2,914	2,939
2025		2,613	2,629	2,656	2,762	2,778	2,797	2,898	2,922	2,941
2026		2,608	2,625	2,654	2,765	2,780	2,798	2,905	2,927	2,949
2027		2,608	2,627	2,656	2,765	2,785	2,804	2,910	2,935	2,960
2028		2,606	2,626	2,651	2,763	2,786	2,806	2,916	2,945	2,970
2029		2,610	2,623	2,648	2,765	2,787	2,807	2,921	2,951	2,981
2030		2,604	2,624	2,647	2,770	2,792	2,808	2,931	2,960	2,988
2031		2,599	2,620	2,642	2,773	2,795	2,809	2,942	2,970	2,997
2032		2,598	2,620	2,642	2,777	2,799	2,814	2,951	2,978	3,004
2033		2,597	2,621	2,645	2,780	2,802	2,819	2,961	2,986	3,012
2034		2,596	2,619	2,647	2,782	2,806	2,824	2,966	2,991	3,015
2035		2,601	2,624	2,649	2,794	2,815	2,837	2,986	3,007	3,028
2036		2,602	2,625	2,650	2,799	2,822	2,845	2,996	3,018	3,039
2037		2,601	2,624	2,650	2,802	2,827	2,849	3,004	3,026	3,049
2038		2,604	2,628	2,651	2,810	2,836	2,860	3,014	3,037	3,059
2039		2,608	2,631	2,653	2,817	2,845	2,869	3,026	3,049	3,072
2040		2,613	2,636	2,657	2,824	2,853	2,877	3,038	3,062	3,086

[1]Developed from extrapolation of main forecasts. [2]Developed from interpolation between main forecasts.

Historical and Projected Service Populations, by Economic Scenario, Slope County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low[1]	Mid	High[2]	Low[2]	Mid	High[2]	Low[2]	Mid	High[1]
2002	759									
2003	760									
2004	758									
2005	748									
2006	758									
2007	786									
2008	771									
2009	745									
2010	752									
2011	756									
2012	819									
2013	830									
2014	826									
2015	809									
2016		816	816	816	816	816	816	816	816	816
2017		819	820	821	824	826	827	829	832	836
2018		822	824	826	832	835	837	843	846	850
2019		825	827	830	838	843	847	854	859	865
2020		827	831	835	844	851	856	863	870	879
2021		826	830	835	845	855	859	867	874	885
2022		825	831	836	846	857	861	869	879	891
2023		824	831	838	847	858	863	872	883	895
2024		823	832	839	848	860	866	876	886	897
2025		824	832	838	848	861	868	880	889	900
2026		823	831	838	847	861	869	881	890	905
2027		820	829	836	848	860	869	882	891	908
2028		818	828	836	848	859	868	882	893	909
2029		817	825	834	847	859	868	882	893	909
2030		813	823	832	847	858	868	882	893	909
2031		811	820	832	845	857	866	881	894	910
2032		810	818	830	845	857	866	881	895	911
2033		808	816	828	843	855	865	881	894	912
2034		805	814	826	842	854	865	881	895	913
2035		803	814	825	841	855	866	883	895	915
2036		802	813	823	839	854	865	882	895	916
2037		800	811	822	837	854	865	882	896	916
2038		797	809	822	836	853	865	882	896	917
2039		796	808	821	834	852	864	881	895	917
2040		795	807	819	832	851	863	881	894	917

[1]Developed from extrapolation of main forecasts. [2]Developed from interpolation between main forecasts.

Historical and Projected Service Populations, by Economic Scenario, Stark County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low	Mid	High	Low	Mid	High	Low	Mid	High
2002	23,393									
2003	23,341									
2004	23,582									
2005	23,586									
2006	23,773									
2007	24,269									
2008	24,831									
2009	25,135									
2010	26,282									
2011	27,828									
2012	31,089									
2013	33,268									
2014	35,998									
2015	35,554									
2016		33,946	33,946	33,946	33,946	33,946	33,946	33,946	33,946	33,946
2017		33,911	33,995	34,079	34,206	34,569	35,199	35,388	35,738	36,253
2018		33,993	34,385	34,777	35,396	36,436	37,410	38,588	38,997	39,656
2019		34,780	35,306	35,833	36,900	37,790	39,227	40,924	41,707	42,739
2020		35,536	36,051	36,613	37,777	39,140	40,840	42,430	43,688	44,665
2021		36,036	36,631	37,228	38,858	39,966	42,161	43,755	44,804	46,362
2022		36,331	36,901	37,621	39,391	40,786	42,804	44,361	45,877	47,268
2023		36,464	37,176	37,891	39,741	41,426	43,153	44,804	46,400	47,939
2024		36,581	37,425	38,272	40,191	41,959	43,546	45,263	46,948	48,632
2025		36,685	37,655	38,628	40,352	42,245	43,955	45,726	47,530	49,331
2026		36,649	37,668	38,690	40,360	42,336	44,129	46,069	47,979	49,887
2027		36,617	37,682	38,752	40,403	42,477	44,367	46,416	48,432	50,446
2028		36,585	37,699	38,817	40,453	42,625	44,612	46,777	48,898	51,018
2029		36,466	37,540	38,618	40,420	42,644	44,683	47,013	49,214	51,414
2030		36,380	37,437	38,499	40,423	42,709	44,811	47,286	49,571	51,857
2031		36,297	37,326	38,357	40,441	42,782	44,939	47,561	49,923	52,285
2032		36,317	37,397	38,482	40,555	42,988	45,233	47,948	50,405	52,863
2033		36,406	37,605	38,808	40,873	43,311	45,684	48,438	51,013	53,589
2034		36,498	37,818	39,142	41,132	43,623	46,123	48,919	51,613	54,300
2035		36,643	38,125	39,613	41,512	44,042	46,675	49,478	52,284	55,089
2036		36,773	38,410	40,052	42,022	44,477	47,234	50,025	52,934	55,844
2037		36,916	38,710	40,509	42,460	44,925	47,807	50,591	53,605	56,622
2038		37,066	39,016	40,973	42,786	45,377	48,388	51,156	54,279	57,404
2039		37,221	39,331	41,447	43,260	45,824	48,964	51,726	54,958	58,192
2040		37,428	39,698	41,976	43,856	46,332	49,605	52,360	55,705	59,051

Historical and Projected Service Populations, by Economic Scenario, Ward County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low[1]	Mid	High[2]	Low[2]	Mid	High[2]	Low[2]	Mid	High[1]
2002	60,282									
2003	59,896									
2004	59,689									
2005	60,097									
2006	60,109									
2007	61,023									
2008	61,511									
2009	62,179									
2010	65,505									
2011	68,413									
2012	70,568									
2013	73,714									
2014	75,252									
2015	75,166									
2016		74,894	74,894	74,894	74,894	74,894	74,894	74,894	74,894	74,894
2017		74,480	74,622	74,764	76,018	76,163	76,308	77,014	77,169	77,323
2018		73,870	74,240	74,612	77,041	77,428	77,816	79,221	79,628	80,035
2019		74,045	74,599	75,157	78,104	78,692	79,281	81,084	81,704	82,323
2020		74,759	75,288	75,820	79,201	79,766	80,330	82,663	83,261	83,858
2021		75,415	76,088	76,766	79,995	80,714	81,434	83,833	84,596	85,359
2022		76,154	76,732	77,313	80,872	81,558	82,176	84,726	85,382	86,038
2023		76,439	77,062	77,685	81,231	81,893	82,555	85,571	86,277	86,983
2024		76,725	77,389	78,053	81,634	82,341	83,048	86,109	86,864	87,618
2025		77,009	77,715	78,421	82,080	82,832	83,584	86,323	87,123	87,923
2026		77,233	77,981	78,728	82,267	83,063	83,859	86,555	87,401	88,247
2027		77,469	78,259	79,048	82,458	83,298	84,138	86,804	87,697	88,590
2028		77,695	78,526	79,357	82,569	83,453	84,336	87,363	88,306	89,250
2029		77,855	78,728	79,600	82,843	83,772	84,700	87,772	88,764	89,757
2030		78,031	78,945	79,860	83,042	84,016	84,989	88,024	89,064	90,105
2031		78,247	79,204	80,161	83,482	84,503	85,524	88,737	89,832	90,926
2032		78,573	79,574	80,575	83,869	84,938	86,006	89,252	90,398	91,545
2033		78,911	79,957	81,004	84,207	85,323	86,440	89,836	91,036	92,236
2034		79,209	80,300	81,391	84,810	85,977	87,145	90,345	91,598	92,852
2035		79,582	80,719	81,856	85,322	86,541	87,760	91,226	92,538	93,851
2036		80,042	81,227	82,411	86,087	87,361	88,635	92,071	93,443	94,815
2037		80,500	81,733	82,965	86,840	88,170	89,500	93,027	94,461	95,896
2038		80,937	82,218	83,499	87,595	88,981	90,368	93,728	95,222	96,715
2039		81,349	82,678	84,008	88,292	89,736	91,179	94,567	96,123	97,679
2040		81,767	83,146	84,525	88,856	90,355	91,853	95,435	97,055	98,674

[1]Developed from extrapolation of main forecasts. [2]Developed from interpolation between main forecasts.

Historical and Projected Service Populations, by Economic Scenario, Williams County, North Dakota 2002 - 2040

		Low Scenarios			Moderate Scenarios			High Scenarios		
Year	Estimated	Low	Mid	High	Low	Mid	High	Low	Mid	High
2002	20,180									
2003	20,265									
2004	20,208									
2005	20,102									
2006	20,319									
2007	21,109									
2008	21,839									
2009	22,388									
2010	24,814									
2011	29,760									
2012	37,467									
2013	42,148									
2014	47,231									
2015	45,312									
2016		38,276	38,276	38,276	38,276	38,276	38,276	38,276	38,276	38,276
2017		38,622	38,949	39,351	39,625	39,858	40,224	41,691	42,388	43,194
2018		38,862	39,412	39,955	40,361	40,858	41,759	43,544	44,666	45,778
2019		39,101	39,974	40,557	41,104	41,888	42,856	44,964	46,591	48,697
2020		39,338	40,371	41,157	41,927	42,707	44,006	46,222	48,174	50,679
2021		39,541	40,831	42,001	42,853	43,773	45,357	47,808	50,293	52,823
2022		39,521	41,215	42,457	43,692	44,610	46,727	49,685	52,338	55,124
2023		39,414	41,301	43,104	44,292	45,308	47,609	51,689	54,528	57,567
2024		39,186	41,111	43,211	44,570	46,081	49,279	53,201	56,338	59,431
2025		38,962	40,934	43,502	44,927	46,996	50,405	54,809	58,138	61,417
2026		38,924	40,955	43,503	45,013	47,389	51,004	56,517	60,097	63,616
2027		38,875	41,086	43,686	45,475	47,937	51,783	57,586	61,369	65,078
2028		39,093	41,453	44,207	45,622	48,554	52,404	58,322	62,284	66,160
2029		39,081	41,606	44,517	46,073	49,160	53,039	58,836	62,974	67,020
2030		38,954	41,619	44,664	46,605	49,854	53,771	59,660	63,851	68,212
2031		38,722	41,540	44,730	46,867	50,269	54,212	59,943	64,446	68,841
2032		38,820	41,681	45,007	47,378	50,933	54,899	60,444	65,095	69,636
2033		39,175	42,053	45,502	48,221	51,926	55,454	61,118	65,911	70,584
2034		39,421	42,413	45,964	48,565	52,346	55,948	61,799	66,719	71,511
2035		39,822	42,953	46,635	48,808	52,661	56,343	62,601	67,647	72,563
2036		40,222	43,308	47,142	49,140	53,131	56,953	62,816	67,968	72,995
2037		40,377	43,708	47,693	49,887	54,060	58,066	63,336	68,620	73,777
2038		41,001	43,803	47,891	50,443	54,766	58,929	64,030	69,455	74,765
2039		41,201	44,149	48,363	50,999	55,467	59,780	64,705	70,274	75,725
2040		41,204	44,214	48,521	51,121	55,685	60,097	65,373	71,078	76,669