North Dakota Legislative Council

Prepared for Representative Brandenburg
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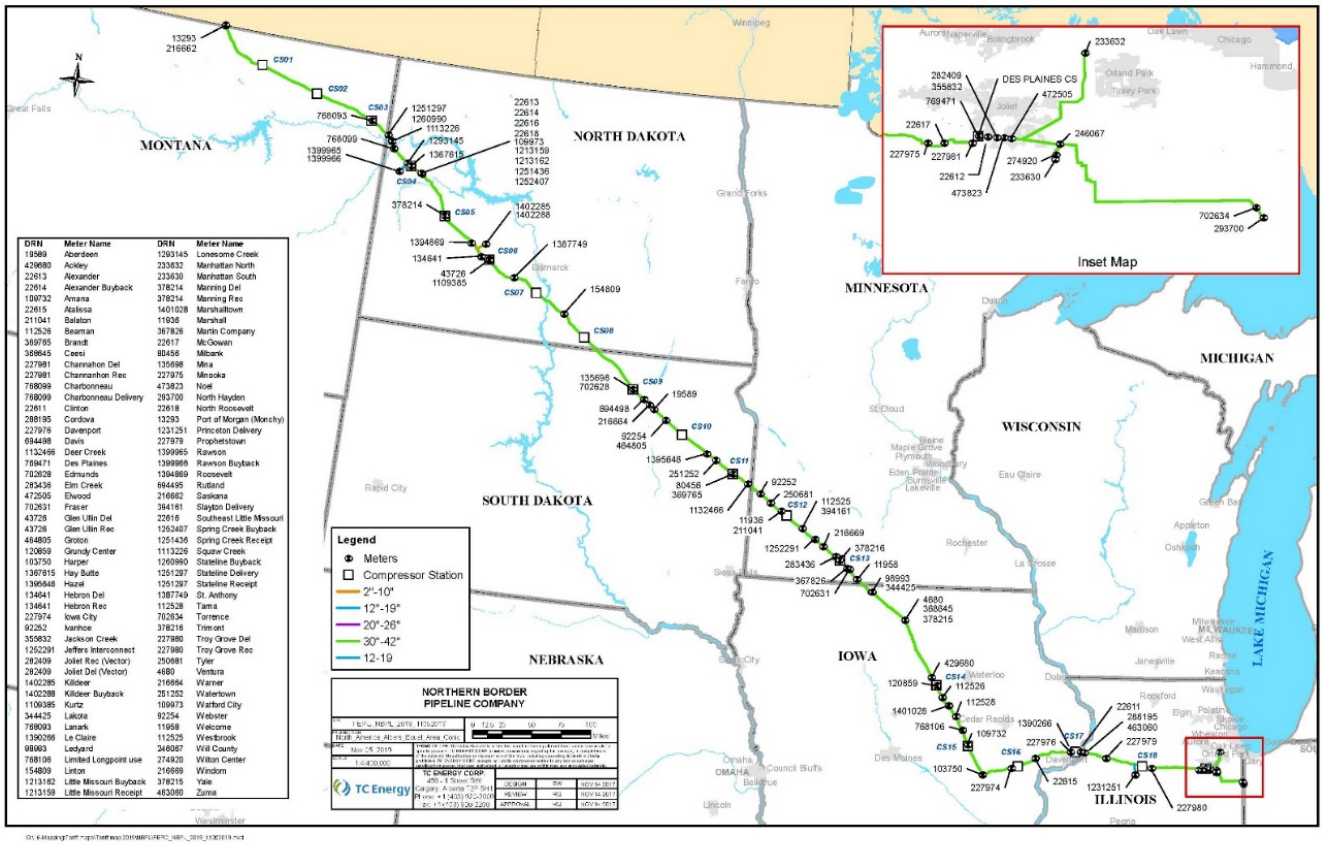
MEGAWATTS OF ELECTRICITY FROM THE NATURAL GAS PRODUCED IN NORTH DAKOTA

This memorandum provides information on megawatts of electricity from the natural gas produced in North Dakota and replacing or converting coal-fired plants to natural gas-fired combined-cycle (NGCC) plants.

MEGAWATTS OF ELECTRICITY

The Northern Border Pipeline (NBPL) is a joint venture owned by ONEOK, Inc. (50%) and TC PipeLines LP (50%) and is a 1,412 mile pipeline transporting Canadian, Bakken, and Rockies natural gas from connections with Foothills and Bison to United States Midwest markets including Chicago (see Figures 1.1 & 1.2). In addition to transporting Canadian sourced supply, the NBPL receives and transports natural gas produced in the Williston and Powder River Basins in the United States and synthetic natural gas produced at the Dakota Gasification plant in North Dakota.[1]

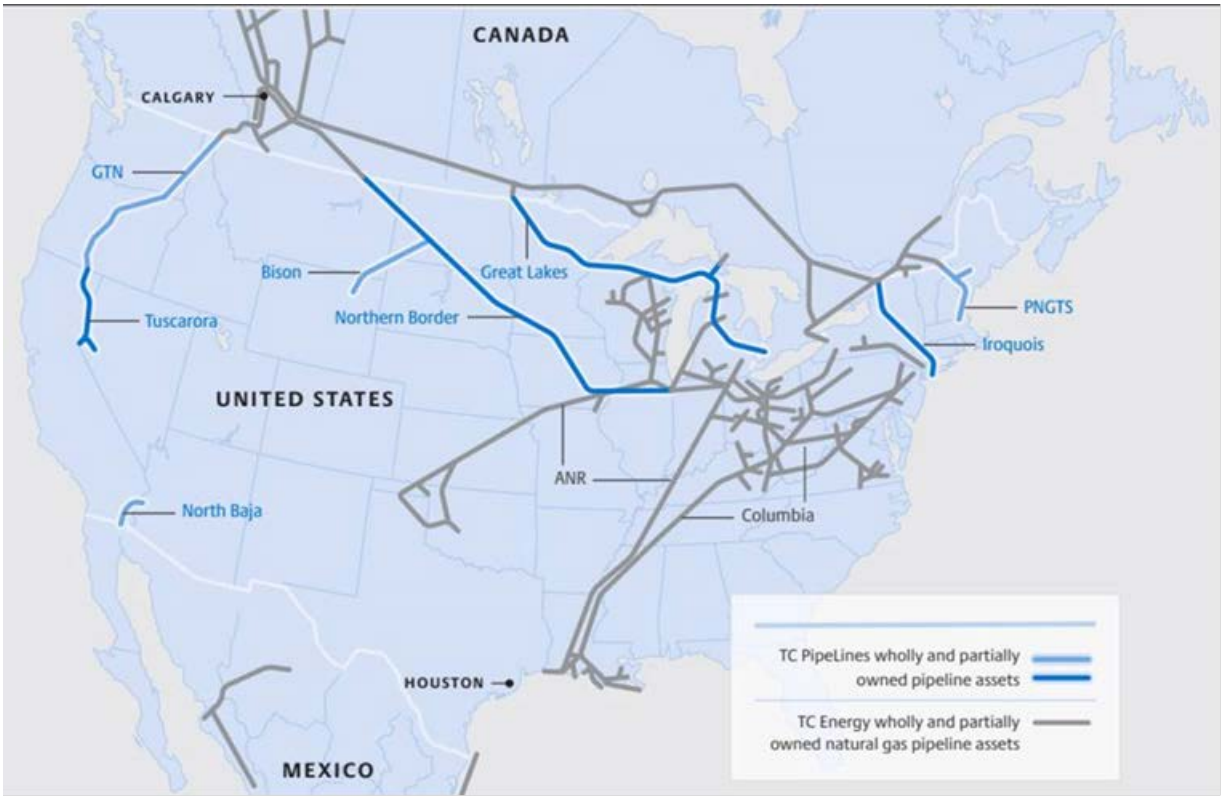
Figure 1.1



Source: Northern Border Pipeline Company, http://www.northernborder.com/docs/nbpl_sys_map.pdf

[1] Northern Border Pipeline Company; http://www.northernborder.com/.

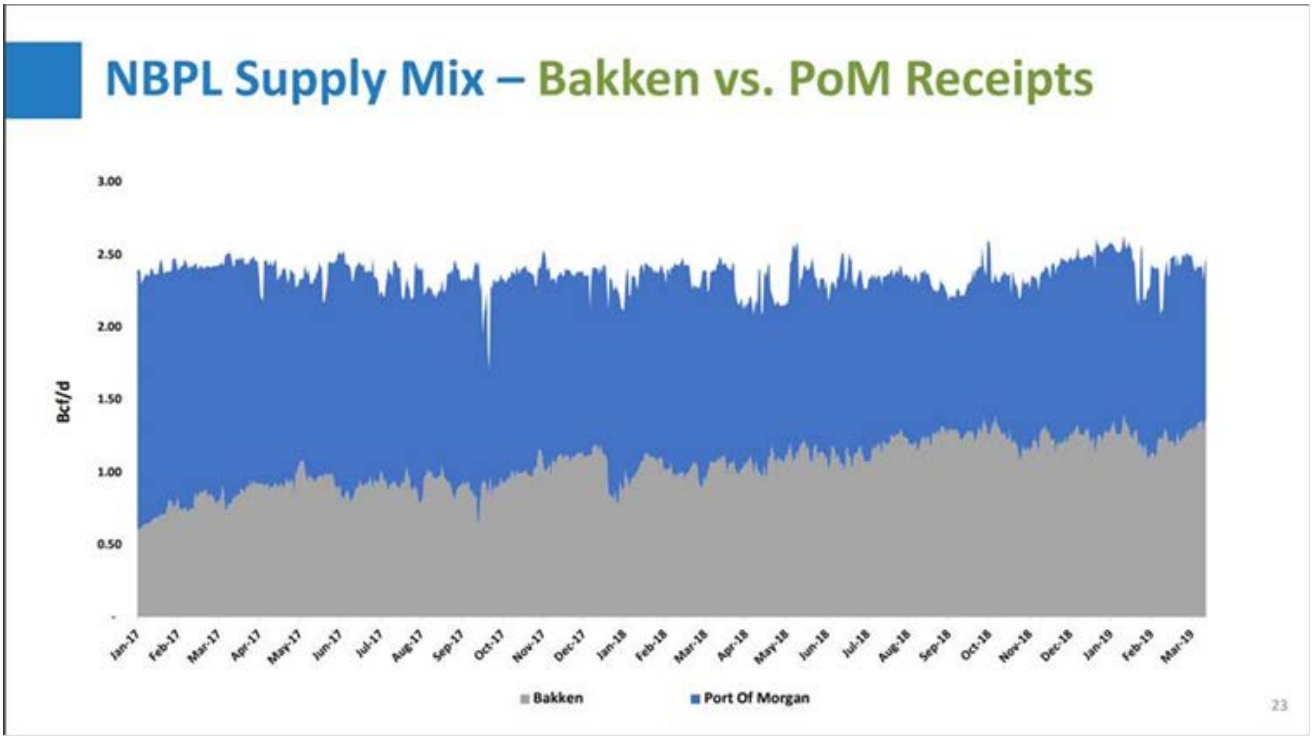
Figure 1.2



Source: TC Pipelines, LP., Gas Transmission Northwest LLP., http://www.tcpipelineslp.com/gtn.html

The Northern Border Pipeline has a capacity of approximately 2.5 billion cubic feet (Bcf) per day of natural gas with about fifty-five to sixty percent coming from the Bakken, or about 1.5 Bcf per day[2] (see Figure 2).

Figure 2



Source: http://www.northernborder.com/docs/CustomerMtgWEB.pdf

[2] Northern Border Pipeline Company; http://www.northernborder.com/docs/CustomerMtgWEB.pdf.

Northern Border Pipeline is fed by numerous gas processing plants in North Dakota (see Figure 3). Gas processing plants or "gas plants" take associated gas from the wellhead and separate it into natural gas liquids (NGL) and pipeline quality natural gas.[3] The pipeline quality natural gas is compressed and injected into interstate gas pipelines including Northern Border Pipeline, Bison and WBI Energy.[4] A map of ND gas pipelines and gas plants is shown below (see Figure 4). Some of the gas plants (north of the Missouri River) send rich gas stream to Alliance Pipeline.

A volume of 1.5 Bcf per day of Bakken natural gas could supply 15,000 to 16,000 megawatts (MW) of new modern efficient natural gas combined-cycle generation. This is about twice the electric generation capacity of North Dakota, and also is roughly equivalent to the coal generation that was replaced with natural gas combined-cycle plants between 2011 and 2019 (see Figure 5).

Figure 3

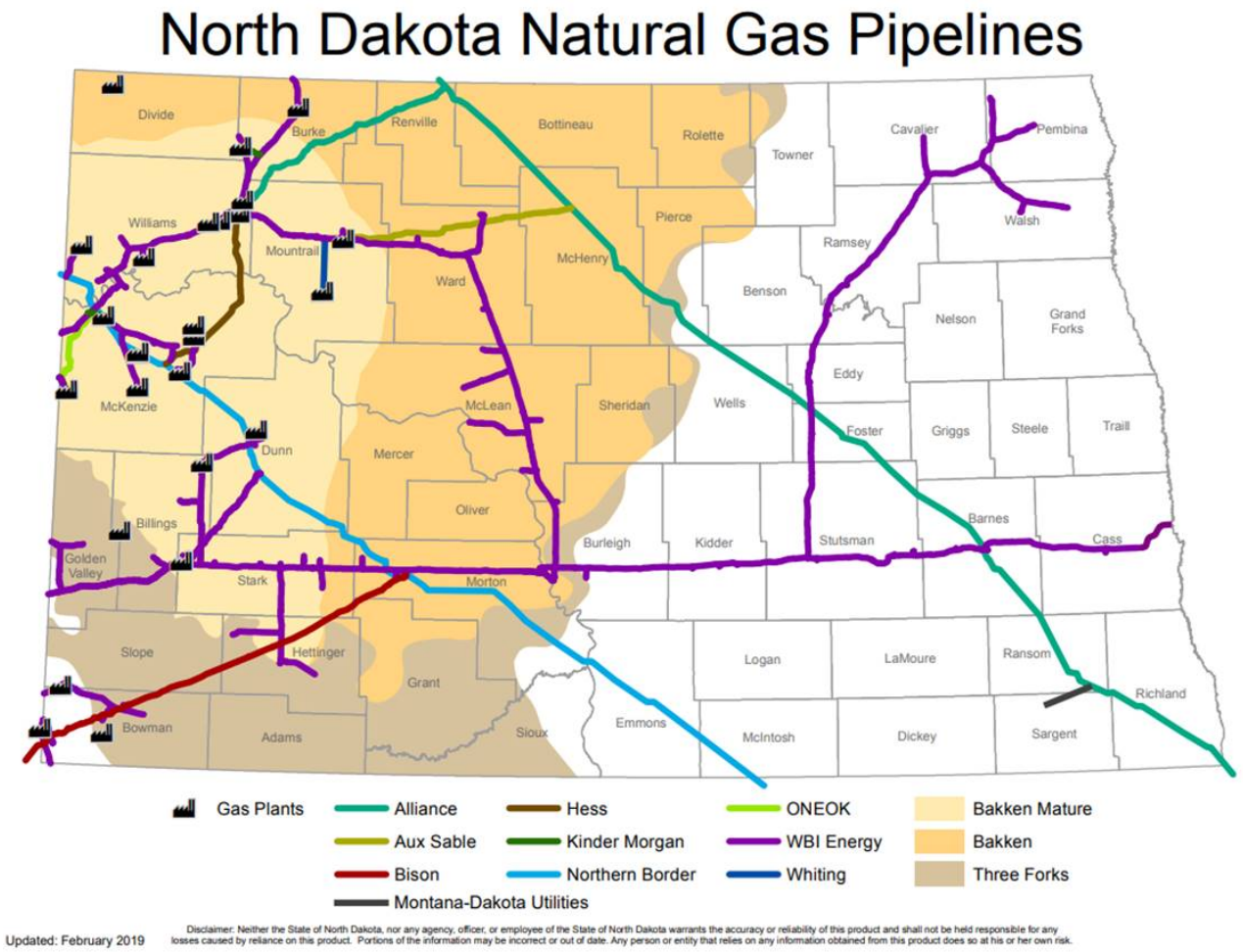
Natural Gas Processing Capacity, Million Cubic Feet Per Day

Owner Company	Facility	County	2006	2008	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
North Dakota																
Steel Reef	Lignite	Burke	6	6	6	6	6	6	6	6	6	6	6	6	6	6
ONEOK	Marmarth	Slope	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	NA	NA	NA	NA	NA
ONEOK	Grasslands	McKenzie	63	90	90	90	90	90	90	90	90	90	90	90	90	90
ONEOK	Stateline I	Williams	NA	NA	NA	NA	100	100	100	100	100	120	120	120	120	120
ONEOK	Stateline II	Williams	NA	NA	NA	NA	NA	100	100	120	120	120	120	120	120	120
ONEOK	Garden Creek I	McKenzie	NA	NA	NA	NA	100	100	120	120	120	120	120	120	120	120
ONEOK	Garden Creek II	McKenzie	NA	NA	NA	NA	NA	NA	120	120	120	120	120	120	120	120
ONEOK	Garden Creek III	McKenzie	NA	NA	NA	NA	NA	NA	120	120	120	120	120	120	120	120
ONEOK	Lonesome Creek	McKenzie	NA	NA	NA	NA	NA	NA	NA	NA	200	200	240	240	240	240
ONEOK	Demicks Lake	McKenzie	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	200	200	200
ONEOK	Demicks Lake II	McKenzie	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	200	200
ONEOK	Demicks Lake III	McKenzie	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Sus.
ONEOK	Bear Creek	Dunn	NA	NA	NA	NA	NA	NA	NA	NA	80	80	130	130	130	130
ONEOK	Bear Creek II	Dunn	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	200
Petro Hunt	Little Knife	Billings	27	27	27	27	27	27	27	27	27	27	27	27	27	27
True Oil	Red Wing Creek	McKenzie	4	4	4	4	4	10	10	10	10	10	15	15	15	15
Sterling Energy	Ambrose	Divide	0.5	0.5	0.5	0.5	0.5	0.5	NA	NA	NA	NA	NA	NA	NA	NA
EOG Resources	Stanley	Mountrail	NA	20	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*
Whiting Oil & Gas	Ray	Williams	NA	10	NA	NA	NA	NA	NA	10	10	10	15	25	25	25
Andeavor	Robinson Lake	Mountrail	NA	30	45	90	90	90	110	130	130	130	130	150	150	150
Andeavor	Belfield	Stark	NA	NA	NA	30	30	35	35	35	35	35	35	35	35	35
XTO - Nesson	Ray	Williams	NA	10	10	10	10	10	10	25	25	25	25	25	25	100
Hess	Tioga	Williams	110	110	110	110	110	110	250	250	250	250	265	265	265	415
Targa/Hess JV	LM4	McKenzie	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	200	200	200
Kinder Morgan	Badlands	Bowman	4	40	40	40	40	40	40	40	40	40	40	40	40	40
Kinder Morgan	Norse	Divide	NA	NA	25	25	25	25	25	25	25	25	25	25	25	25
Kinder Morgan	Watford City	McKenzie	NA	NA	NA	50	90	90	90	90	90	90	90	90	90	90
Kinder Morgan	Roosevelt	McKenzie	NA	NA	NA	NA	NA	NA	NA	NA	50	50	50	200	200	200
Liberty Midstream Solutions	County Line	Williams	NA	NA	NA	NA	NA	NA	NA	NA	20	20	30	30	30	30
Summit Resources	Knutson	Billings	NA**	NA**	NA**	NA**	NA**	NA**	NA**	NA**	NA**	NA**	NA**	NA**	NA**	NA**
Targa Resources	Badlands	McKenzie	NA	NA	NA	45	45	45	45	90	90	90	90	90	90	90
USG Midstream Bakken	DeWitt	Divide	NA	NA	NA	NA	NA	3	3	3	3	3	3	3	3	3
1804 Ltd	Spring Brook	Williams	NA	NA	NA	NA	NA	NA	NA	45	45	45	60	70	70	70
Oasis	Wild Basin	McKenzie	NA	NA	NA	NA	NA	NA	NA	NA	80	145	320	320	320	320
Arrow Field Services	Arrow	McKenzie	NA	NA	NA	NA	NA	NA	NA	NA	NA	30	30	150	150	150
Caliber Midstream	Hay Butte	McKenzie	NA	NA	NA	NA	NA	NA	10	10	10	10	10	10	10	10
Outrigger Energy II	N/A	Williams	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	250
Aux Sable - Chicago, IL																
Aux Sable	Prairie Rose	Mountrail	NA	NA	126	126	126	126	126	126	126	126	126	126	126	126
		Total, MMCFD	**222.0**	**355.0**	**491.0**	**661.0**	**901.0**	**1,015.0**	**1,444.5**	**1,599.5**	**2,029.5**	**2,137.0**	**2,452.0**	**3,162.0**	**3,362.0**	**4,037.0**

Source: *Infrastructure Constraints in the Bakken*, U.S. Department of Energy, August 2014.

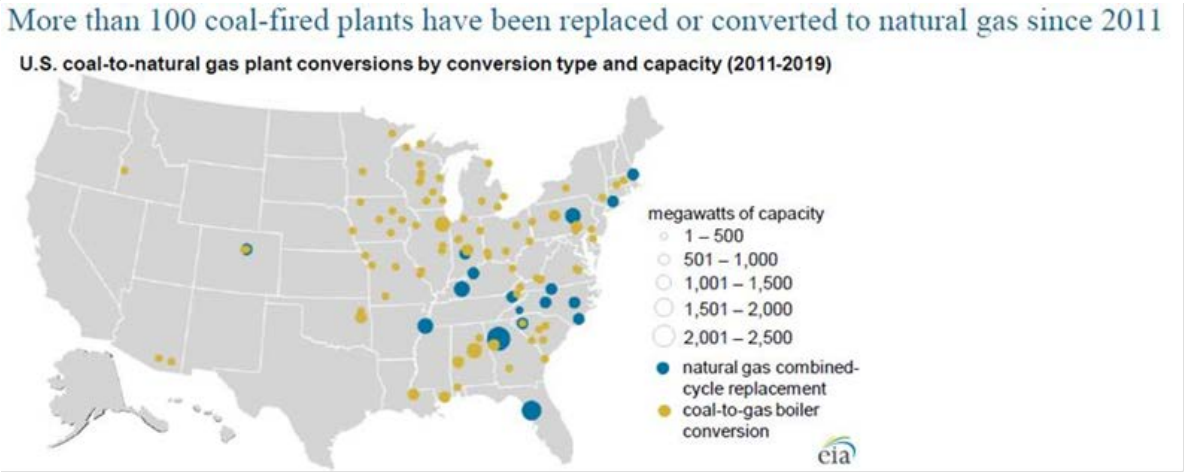
[3] Northern Border Pipeline Company; http://www.northernborder.com/.
[4] *Id.*

Figure 4



Source: https://www.ndstudies.gov/energy/level2/module-2-petroleum-natural-gas/transporting-and-processing

Figure 5



Source: U.S. Energy Information Administration, *Annual Electric Generator Report* and *Preliminary Monthly Electric Generator Inventory*.

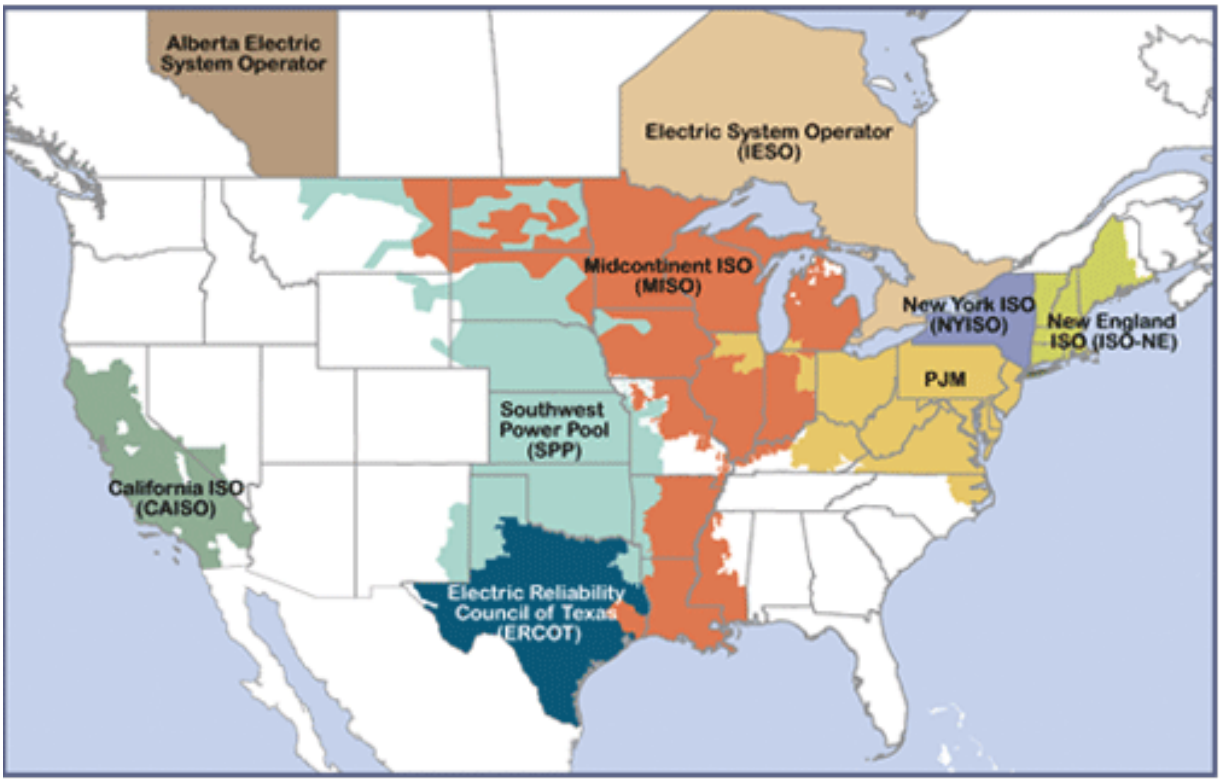
Between 2011 and 2019, 17 coal-fired plant owners replaced old coal-fired power plants with new NGCC plants with a total generating capacity of 15,300 MW, 94 percent more than the 7,900 MW capacity of the coal-fired power plants they replaced.[5]

[5] *More than 100 coal-fired plants have been replaced or converted to natural gas since 2011*, U.S. Energy Information Administration, August 2020.

Below are some statistics for North Dakota and several regional transmission organizations (see Figure 6) for comparison:

- North Dakota:
  - Installed capacity = 8,400 MW.
    - Natural gas combined cycle = 0 MW.
    - Natural gas simple cycle peaking = 520 MW.
  - Peak load = 3,900 MW.
- Southwest Power Pool (SPP) [6]:
  - Installed capacity = 89,500 MW.
    - Natural gas combined cycle = 13,500 MW.
    - Natural gas simple cycle peaking = 23,300 MW.
  - Peak load = 51,230 MW.
- Midcontinent Independent System Operator (MISO)[7]:
  - Installed capacity = 137,300 MW.
    - Natural gas combined cycle = 18,000 MW.
    - Natural gas simple cycle peaking = 27,100 MW.
  - Peak load = 124,200 MW.
- PJM[8]:
  - Installed capacity = 184,600 MW.
    - Natural gas combined cycle = 33,500 MW.
    - Natural gas simple cycle peaking = 44,100 MW.
  - Peak load = 148,200 MW.

Figure 6



Source: RTO map, Federal Energy Regulatory Commission, https://www.ferc.gov/sites/default/files/2020-05/elec-ovr-rto-map.pdf

[6] *Power Plant Summary; SPP Region*. S&P Global, 2019.
[7] *Power Plant Summary; MISO Region*. S&P Global, 2019.
[8] *Power Plant Summary; PJM Region*. S&P Global, 2019.

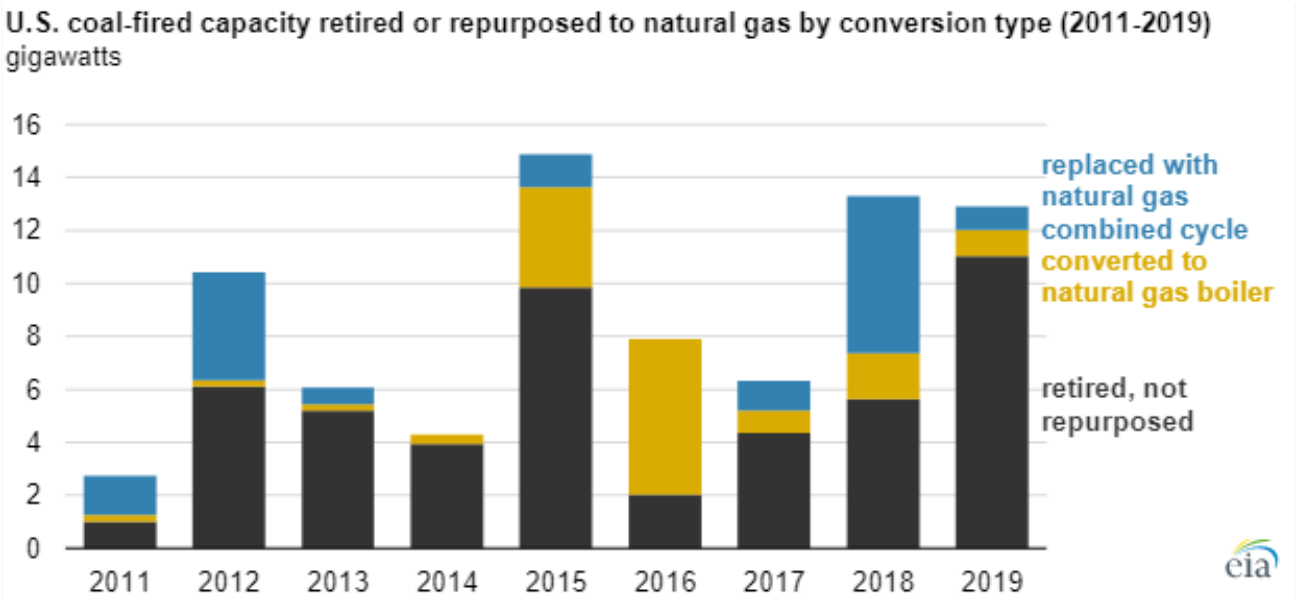
REPURPOSING COAL-FIRED POWER PLANTS

One hundred twenty-one United States coal-fired power plants were repurposed to burn other types of fuels between 2011 and 2019, 103 of which were converted to or replaced by natural gas-fired plants.[9] At the end of 2010, 316.8 gigawatts (GW) of coal-fired capacity existed in the United States, but by the end of 2019, 49.2 GW of that amount was retired, 14.3 GW had the boiler converted to burn natural gas, and 15.3 GW was replaced with natural gas combined cycle.[10] The decision for plants to switch from coal to natural gas was driven by stricter emission standards, low natural gas prices, and more efficient new natural gas turbine technology.[11]

Two different methods are used to switch coal-fired plants to natural gas.[12] The first method is to retire the coal-fired plant and replace it with a new NGCC plant.[13] The second method is to convert the boiler of a coal-fired steam plant to burn other types of fuel, such as natural gas.[14]

Between 2011 and 2019,17 coal-fired plant owners adopted the first method, replacing old coal-fired power plants with new NGCC plants.[15] The new NGCC plants have a total generating capacity of 15.3 GW, 94 percent more than the 7.9 GW capacity of the coal-fired power plants they replaced. The increase in capacity is largely a result of the advanced turbine technology installed in NGCC plants (see Figure 7).[16]

Figure 7



Source: U.S. Energy Information Administration, *Annual Electric Generator Report* and *Preliminary Monthly Electric Generator Inventory*, August 2020.

Between 2011 and 2019, 104 coal-fired plants adopted the second approach, converting the steam boiler to burn other fuels, most commonly natural gas, although some were configured to burn petroleum coke (a refinery by-product), waste materials from paper and pulp production, or wood waste solids.[17]

Coal-fired plants in the eastern half of the country have been good candidates for conversion because the plants tend to be smaller-capacity units and are mostly over 50 years old.[18] Of the 104 coal-fired plants in this age range, 86 have converted boilers to burn natural gas, representing 14.3 GW of capacity.[19] Although most plants

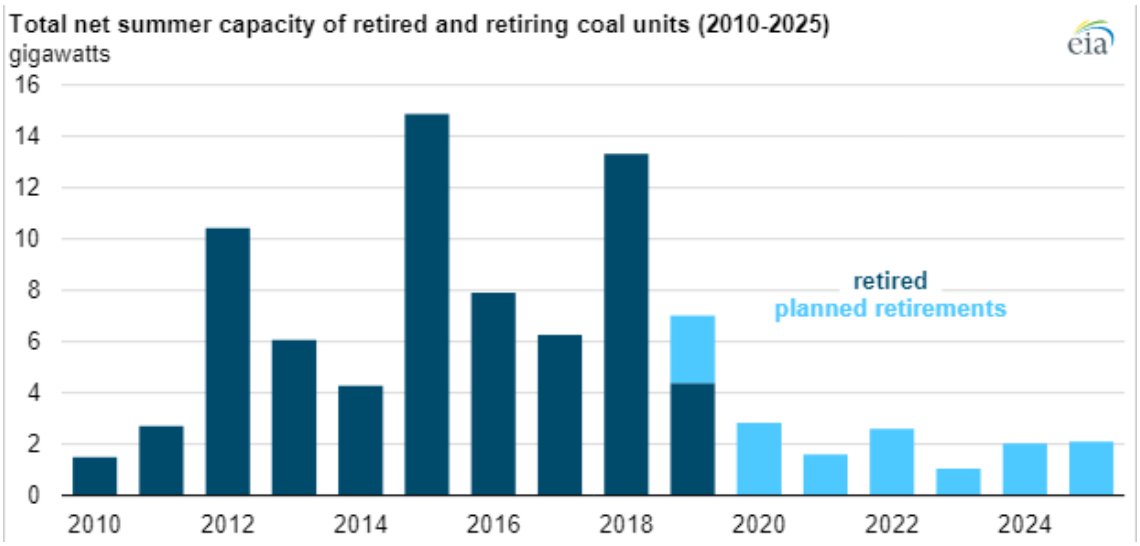
[9] *More than 100 coal-fired plants have been replaced or converted to natural gas since 2011*, U.S. Energy Information Administration, August 2020.
[10] *Id.*
[11] *Id.*
[12] *Id.*
[13] *Id.*
[14] *Id.*
[15] *Id.*
[16] *Id.*
[17] *Id.*
[18] *Id.*
[19] *Id.*

transitioned entirely to natural gas, a few maintained coal burning capabilities, allowing the plants to burn whichever fuel is most economically efficient.[20]

The utility with the most conversions between 2011 and 2019 was Alabama Power Co., which converted 10 generators located at four coal plants in Alabama, totaling 1.9 GW of capacity.[21] These conversions took place between 2015 and 2016, largely to comply with the Mercury and Air Toxics Standards required by the United States Environmental Protection Agency.[22]

Plant owners intend to retire another 17 GW of coal-fired capacity by 2025 (see Figure 8).[23] After a coal unit retires, the power plant site goes through a complex, multiyear process that includes decommissioning, remediation, and redevelopment.

Figure 8



Source: U.S. Energy Information Administration, *Annual Electric Generator Report* and *Preliminary Monthly Electric Generator Inventory,* July 2019.

Coal-fired power plants in the United States remain under significant economic pressure. Many plant owners have retired coal-fired units because of relatively flat electricity demand growth and increased competition from natural gas and renewables.[24] In 2018, plant owners retired more than 13 GW of coal-fired generation capacity, which is the second-highest annual total for United States coal retirements. The highest total for coal retirements, at 15 GW, occurred in 2015.[25]

CONCLUSION

Repowering a former coal-fired plant with natural gas-fired elements is a viable option for power providers because much of the critical infrastructure is in place, including transmission lines, substations, and water. As the United States coal-fired electric generation fleet continues to manage challenges from emission standards and low prices for natural gas, the expectation is that more of these conversions will take place, particularly in the Midwest and Southeast.

[20] *Id.*
[21] *Id.*
[22] *Id.*
[23] *Preliminary Monthly Electric Generator Inventory,* U.S. Energy Information Administration, August 2020.
[24] *More U.S. coal-fired power plants are decommissioning as retirements continue*, U.S. Energy Information Administration. July 2019.
[25] *Id.*

CONVERSION FORMULA

Converting the 1.5 Bcf/day of Bakken natural gas flowing on Northern Border Pipeline to megawatts (MW) is done by taking the energy value of the gas (Btu), the efficiency of the natural gas combined cycle (NGCC) and the capacity factor of the NGCC.

The base assumptions are:

- Energy value of natural gas is 1,050 Btu/cubic foot
- NGCC efficiency of 6,800-7,200 Btu/kWh (average of 7,000 Btu/kWh)
- NGCC capacity factor of 60%

$$\text{NGCC} = \frac{(1{,}500{,}000{,}000 \text{ cubic feet/day} \times 1{,}050 \text{ Btu/cubic foot})}{(24 \text{ hours/day} \times 0.60 \times 7{,}000 \text{ Btu/kWh} \times 1{,}000 \text{ kW/MW})}$$

$$= 15{,}625 \text{ MW}$$

To simplify, you can take the billions of cubic feet (Bcf) of natural gas flow on a daily basis and multiply by 10,400.

MW = Bcf x 10,400

For example;

- 1.5 Bcf = 15,600 MW or a range of (15,000-16,000 MW)
- 2.0 Bcf = 20,800 MW or a range of (20,000-21,000 MW)
- 2.5 Bcf = 26,000 MW or a range of (25,000-26,000 MW to be conservative).

The range of 15,000-16,000 MW that was initially provided takes into account the variability in the (1) **heat content of natural gas**, and (2) **efficiency of the natural gas combined cycle** (NGCC)

1. The heat content of natural gas, or the amount of energy released when a volume of gas is burned, varies according to the extent that gases with higher heat content than methane are included in delivered gas. The primary constituent of natural gas is methane, which has a heat content of 1,010 British thermal units per cubic foot (Btu/cf) at standard temperature and pressure (https://www.eia.gov/todayinenergy/detail.php?id=18371#:~:text=The%20primary%20constituent%20of%20natural,at%20standard%20temperature%20and%20pressure.). The higher ethane content of ND Bakken gas leads to a higher heat content.

2. The efficiency of a NGCC works somewhat like the efficiency of cars – newer car models have the latest technology and get higher gas mileage (more fuel efficient) just like new NGCC's have the latest technology and are more fuel efficient (requires fewer Btu of natural gas to make 1 kWh of electricity). Older cars work fine, and can cost less to buy than a new car, but the gas mileage for an older model is typically worse than for a new one.