CE 394K GIS in Water Resources – Term Project Report

Electricity generation from natural gas liquids in the Permian Basin in Texas

Qining Chen (UT EID: QC2242)

McKetta Department of Chemical Engineering

The University of Texas at Austin

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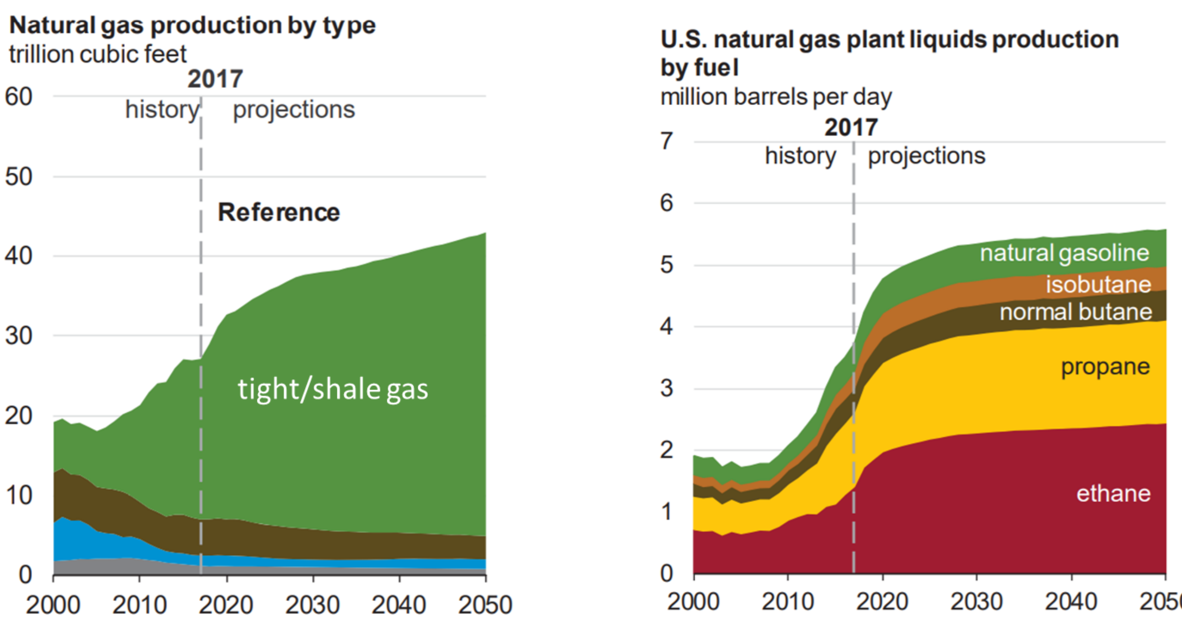
Introduction

Project background

Because of technology innovations in horizontal drilling and hydraulic fracturing, the production of natural gas, especially derived from shale resources, has expanded significantly in the United States in the past decade. According to U.S. Energy Information Administration (EIA), the production of natural gas is expected to increase by over 50% from 2017 to 2050 (EIA, 2018a). Together with the expanded production of natural gas, the production of natural gas plant liquids (NGPLs, or NGLs) has also increased rapidly during the same time period, from 650 million barrels (MMbbl) in 2007 to 1363 MMbbl in 2017 (EIA, 2018b). The expanded production of NGLs (primarily ethane and propane) has driven a widespread transformation in U.S. chemical manufacturing industry, from the use of petroleum-based hydrocarbon feedstocks to use of NGL derived feedstocks. However, this kind of substitution of NGLs for petroleum feedstocks in U.S. chemical manufacturing has reach its saturation, and ethane and propane are now being produced at rates that exceed their domestic demand (EIA, 2018c).



(a) (b)

Figure 1. Production history (from 2000 to 2017) and production projection (from 2017 to 2050) of (a) natural gas, (b) natural gas plant liquids (NGPLs, or NGLs) in the United States.

An alternative use for NGLs would be electricity generation at gas processing plants, where NGLs are separated from pipeline-quality natural gas (Allen et al. 2018). In this project, the Texas part of the Permian Basin (located in western Texas and southeastern New Mexico) is selected as a case study area, shown in Figure 2. The Permian Basin is one of the largest shale basins in the U.S. and could supply relatively large amounts of NGLs available for electricity generation. However, it is unclear whether the electric power generated at the gas processing plants in the Permian Basin could be integrated into the Texas electricity grid, which depends primarily on the spatial distributions of shale production wells, gas processing plants, and electricity transmission lines in the Permian Basin.

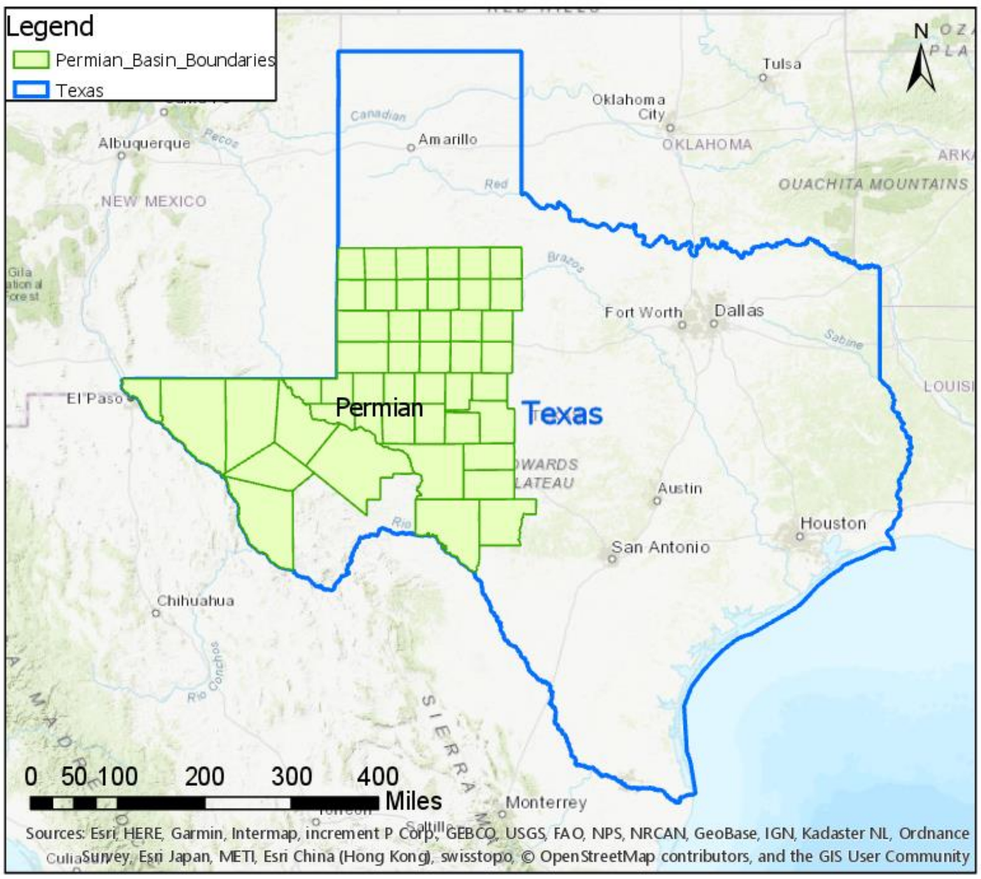


Figure 2. The Texas part of the Permian Basin and the inside county boundaries.

This project will evaluate the potential electricity generation from NGLs in the Permian Basin, based on the locations of shale production wells and gas processing plants, and evaluate the potential integration of the NGL-fired electricity production into Texas electric power transmission system.

Objectives

- Evaluate potential electricity generation at gas processing plants in the Permian Basin
- Integrate the NGL-based electricity production from the Permian Basin into Texas electric power transmission system

Significance

This project will provide an alternative transformation of expanded NGLs into electric power. The NGL-fired electricity production could displace part of conventional electricity production, such as coal-fired electricity, to reduce environmental burdens. Electricity produced at gas plants could also be used onsite to drive pneumatic systems to reduce methane (a potent greenhouse gas) leakage. In addition, this emerging use of NGLs could mitigate the need for expanded transport infrastructures for NGLs in the United States.

Data, data sources, and base maps

Data and data sources

- Texas boundary shapefile derived from course material (exercise 1); the county features inside the Permian Basin extracted from U.S. county feature shapefiles, available in *Living Atlas* in ArcGIS Pro.
- Coordinate information and production profiles of shale gas wells in the Permian Basin. Data available in research group (from Drilling Info: https://info.drillinginfo.com/, not open source)
- Coordinate information of gas processing plants in the Permian Basin. Data combined from U.S. Energy Information Administration: https://www.eia.gov/, and U.S. Environmental Protection Agency Greenhouse Gas Reporting Program (GHGRP): https://www.epa.gov/ghgreporting
- Shapefile of Texas electricity transmission lines. Data from Homeland Infrastructure Foundation-Level Data, available at: https://hifld-geoplatform.opendata.arcgis.com/datasets/electric-power-transmission-lines?geometry=-207.054%2C9.132%2C60.661%2C57.532

Base maps

This project estimates the potential electricity production from natural gas liquids (NGLs) in the Permian Basin and evaluates the potential integration of the NGL based electricity production into Texas electric power transmission system. 2 base maps for further analysis and calculations are created in GCS North American 1983 and are described below.

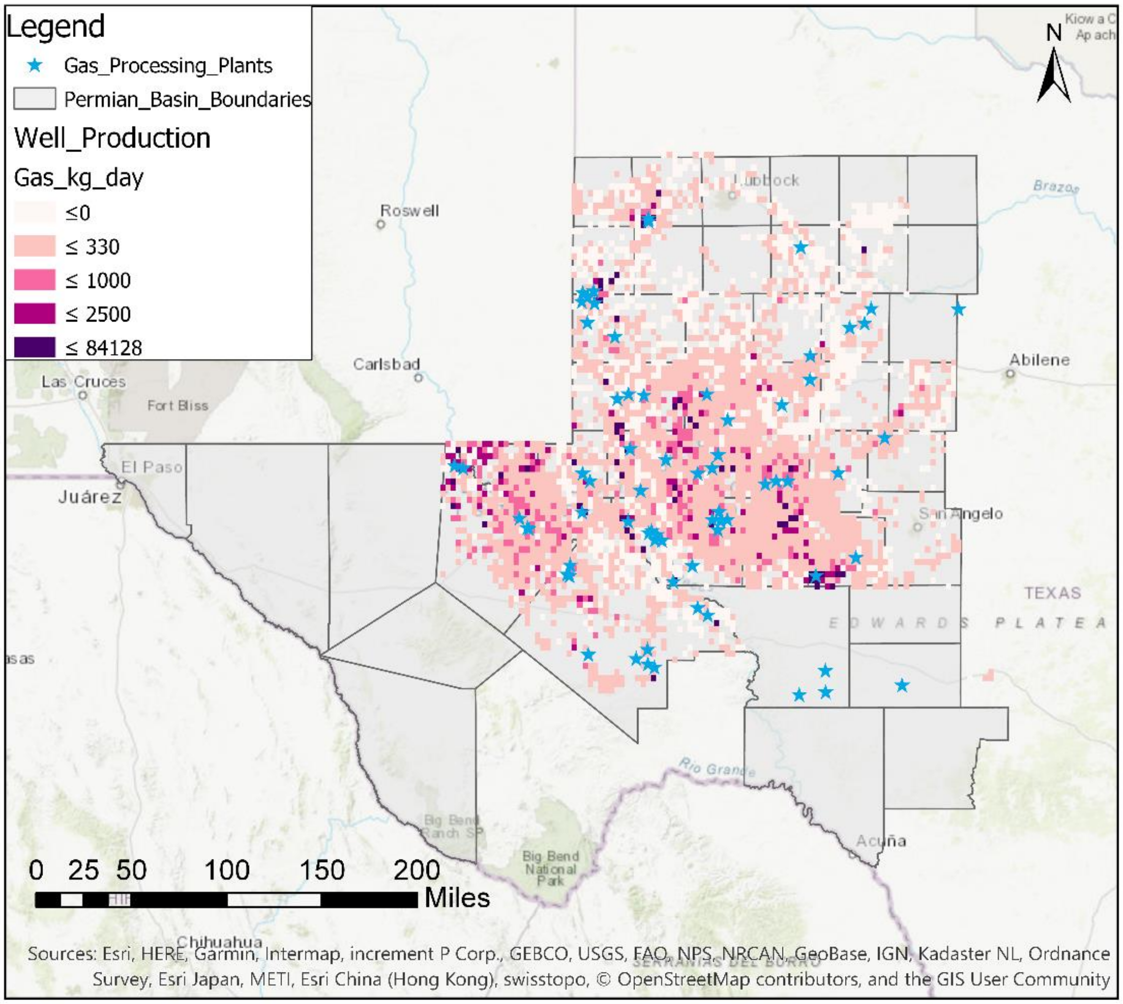


Figure 3. Distribution of shale production wells and gas processing plants in the Permian Basin.

Figure 3 shows the mapping of distribution of shale production wells, visualized by gas production magnitudes, and gas processing plants in the Permian Basin, and is further used to determine the NGL production and available electric power production at each plant. The counties and boundaries of the Permian Basin are first selected and exported from the U.S. county features. Shale production wells and gas processing plants are added to the map and displayed by their coordinate information. Wells and plants that intersect with the Permian Basin area are considered in this project, and others are removed from the map. Over 60,000 shale production wells and 68 gas processing plants are identified inside the basin boundary in this project. Since locations and production of wells are not available to public, these information are converted and expressed in raster data (cell size: 0.4 degrees) to lower the level of information details.

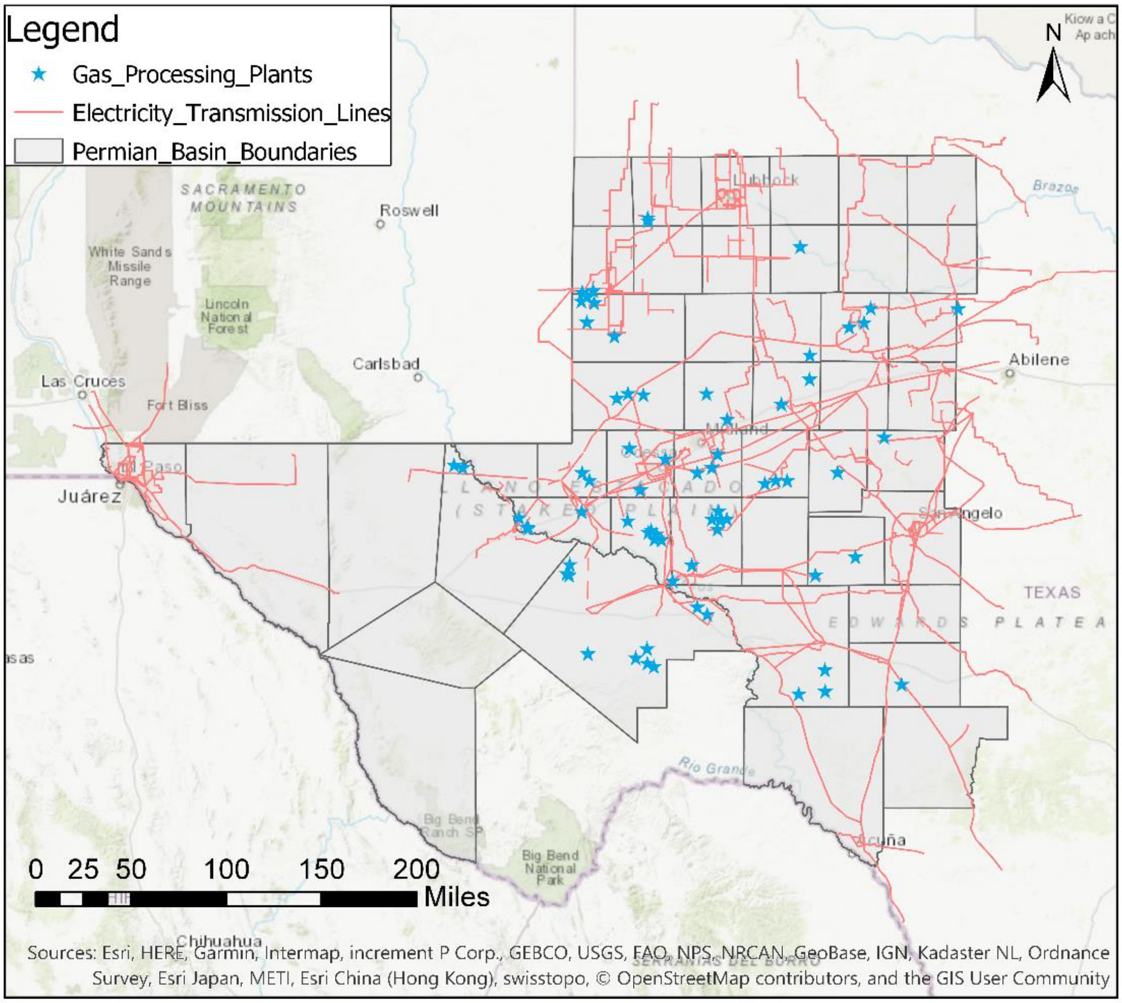


Figure 4. Gas processing plants and electricity transmission lines in the Permian Basin.

Figure 4 shows the mapping of locations of gas processing plants and the distribution of electricity transmission lines in the Permian Basin. It visualizes the connections between where the electric power could be produced and how the electric power could be delivered. The map is further applied to evaluate whether the electric power produced from the gas plants in the Permian Basin could be integrated into Texas electric power transmission system.

Spatial analysis, calculations, and preliminary results

Plant allocation

The first step is to identify the potential amounts of NGLs available for electricity generation at each gas processing plant. Shale gas produced at each well is assumed to be processed at the closest plant, where NGLs are separated from pipeline quality gas. 2 spatial analysis tools, Euclidean Allocation and Spatial Join in ArcGIS Pro, are applied to collectively determine the closest plant allocated to each well.

Figure 5 shows the allocation polygons created by Euclidean Allocation function. A specific allocation polygon is created for the gas processing plant determined as the closest gas plant for all possible locations inside the polygon. Each of the 68 gas plants in the study area of this project has a certain allocation polygon associated with. All the wells inside a certain allocation polygon should deliver their products to the gas plant associated with that polygon.

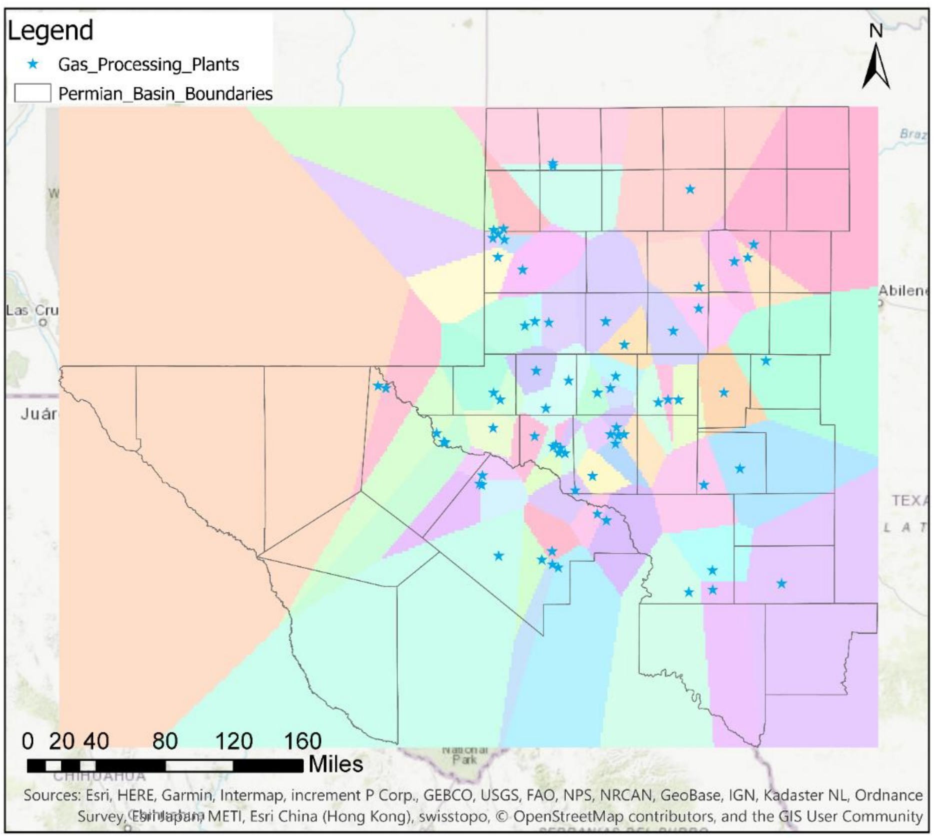


Figure 5. Allocation polygons for 68 gas processing plants in the Permian Basin calculated by Euclidean Allocation function.

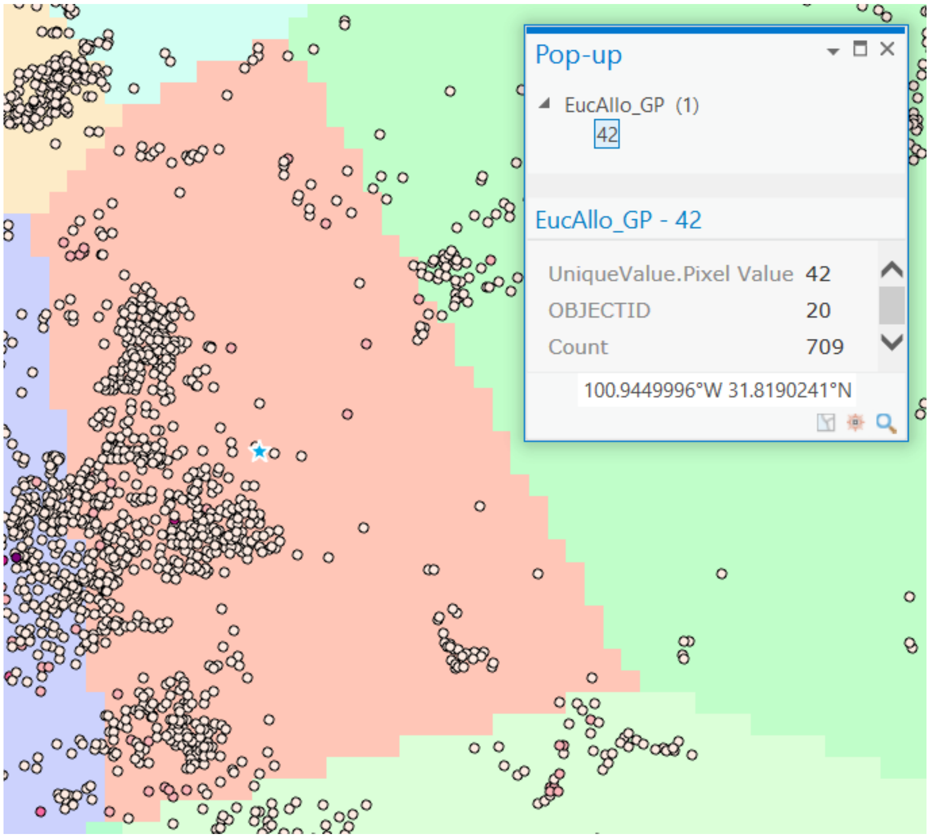
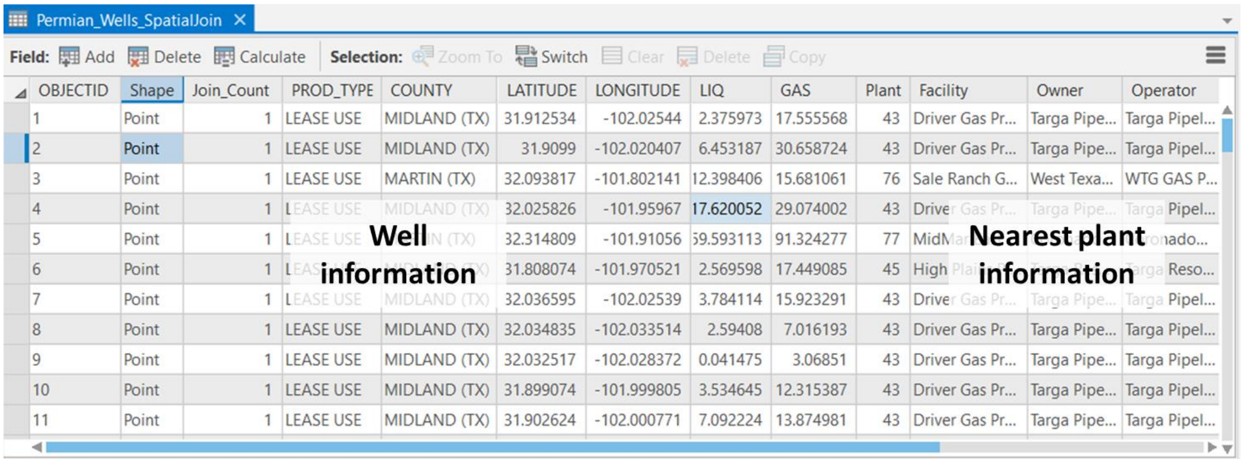


Figure 6. Relationship between shale production wells, gas processing plants, and allocation polygons calculated by Euclidean Allocation function for plants.

Figure 6 describes the relationship between shale production well, gas processing plants, and allocation polygons calculated by Euclidean Allocation function for the gas plants. For example, gas products produced from all the wells (symbolized by dots) inside the center polygon (the quadrilateral in orange) should be allocated to the gas plant with object ID 20 located inside the center polygon. Euclidean Allocation function visualizes the relationships between the wells and their closest gas processing plants by linking them within polygons. Production information of wells inside each polygon could be selected and extracted for estimating the production of each plant. This function, however, is not convenient for further calculations, especially in this project that aims to allocate the production from over 60000 wells to 68 gas processing plants.

An alternative spatial analysis tool, Spatial Join in ArcGIS Pro, is also applied. Spatial Join function joins attributes from one feature to another based on the spatial relationship. By choosing the closest match option, the closest plant information could be joined to each well in the attribute table of the well features, as shown in Figure 6. The joined attribute table is exported to excel for further calculations. Compared to Euclidean Allocation function, Spatial Join function is more convenient for result exportation and further calculations, however, is not visualized on the map.



OBJECTID	Shape	Join_Count	PROD_TYPE	COUNTY	LATITUDE	LONGITUDE	LIQ	GAS	Plant	Facility	Owner	Operator
1	Point	1	LEASE USE	MIDLAND (TX)	31.912534	-102.02544	2.375973	17.555568	43	Driver Gas Pr...	Targa Pipe...	Targa Pipel...
2	Point	1	LEASE USE	MIDLAND (TX)	31.9099	-102.020407	6.453187	30.658724	43	Driver Gas Pr...	Targa Pipe...	Targa Pipel...
3	Point	1	LEASE USE	MARTIN (TX)	32.093817	-101.802141	12.398406	15.681061	76	Sale Ranch G...	West Texa...	WTG GAS P...
4	Point	1	LEASE USE	MIDLAND (TX)	32.025826	-101.95967	17.620052	29.074002	43	Driver Gas Pr...	Targa Pipe...	Targa Pipel...
5	Point	1	LEASE USE	[illegible]	32.314809	-101.91056	59.593113	91.324277	77	MidMa[illegible]	[illegible]	[illegible]nado...
6	Point	1	[illegible]	[illegible]	31.808074	-101.970521	2.569598	17.449085	45	High Plai[illegible]	[illegible]	Targa Reso...
7	Point	1	LEASE USE	MIDLAND (TX)	32.036595	-102.02539	3.784114	15.923291	43	Driver Gas Pr...	Targa Pipe...	Targa Pipel...
8	Point	1	LEASE USE	MIDLAND (TX)	32.034835	-102.033514	2.59408	7.016193	43	Driver Gas Pr...	Targa Pipe...	Targa Pipel...
9	Point	1	LEASE USE	MIDLAND (TX)	32.032517	-102.028372	0.041475	3.06851	43	Driver Gas Pr...	Targa Pipe...	Targa Pipel...
10	Point	1	LEASE USE	MIDLAND (TX)	31.899074	-101.999805	3.534645	12.315387	43	Driver Gas Pr...	Targa Pipe...	Targa Pipel...
11	Point	1	LEASE USE	MIDLAND (TX)	31.902624	-102.000771	7.092224	13.874981	43	Driver Gas Pr...	Targa Pipe...	Targa Pipel...

Figure 7. Closest plant information joined to well attributes by Spatial Join with the closest match option in ArcGIS Pro.

Potential electricity production

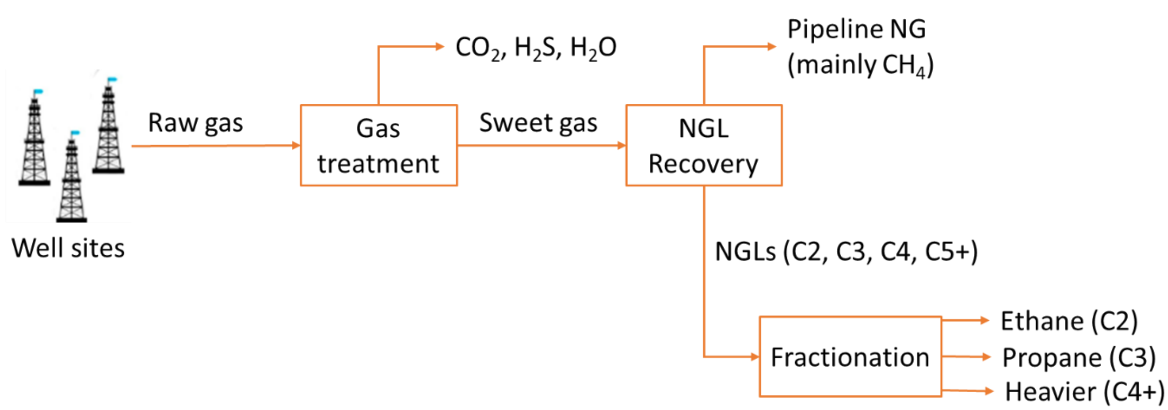


Figure 8. A typical flow in the gas processing plant

Figure 8 shows a typical flow in the gas processing plant. Raw produced gas stream (containing methane, ethane, propane, butane, other heavier hydrocarbon components, acid gases and water) from associated wells (determined by plant allocation discussed previously) first goes through gas treatment units to remove acid gases and water, then undergoes NGL recovery, during which NGLs are separated from pipeline quality natural gas. The pipeline quality natural gas stream contains all the methane and a small portion of ethane, with an ethane-to-methane molar ratio of

0.0337. The separated NGL stream will then be fractionated into ethane, propane and heavier hydrocarbons. All ethane and propane in the NGL stream are assumed to be available for electricity generation.

NGLs available for electricity generation at each gas processing plant in the Permian Basin are calculated based on the flow assumptions described above, and the total energy production are then estimated by combining the flow rates and lower heating values (LHVs) of the NGLs. A turbine efficiency of 34.7% is assumed to estimate potential electricity production as:

$$E_{\text{potential}} = \sum_{\text{C2, C3}} LHV \times 34.7\%$$

where $E_{\text{potential}}$ represents the potential electricity production. Calculation results are shown in Figure 9. Among the 68 gas processing plants in the Permian Basin, the total potential electricity production would be 9430 megawatts (MW), with nearly 40% contributed by only 5 gas plants with electricity production more than 400 MW, and only 4% contributed by 30 plants with electricity production less than 50 MW.

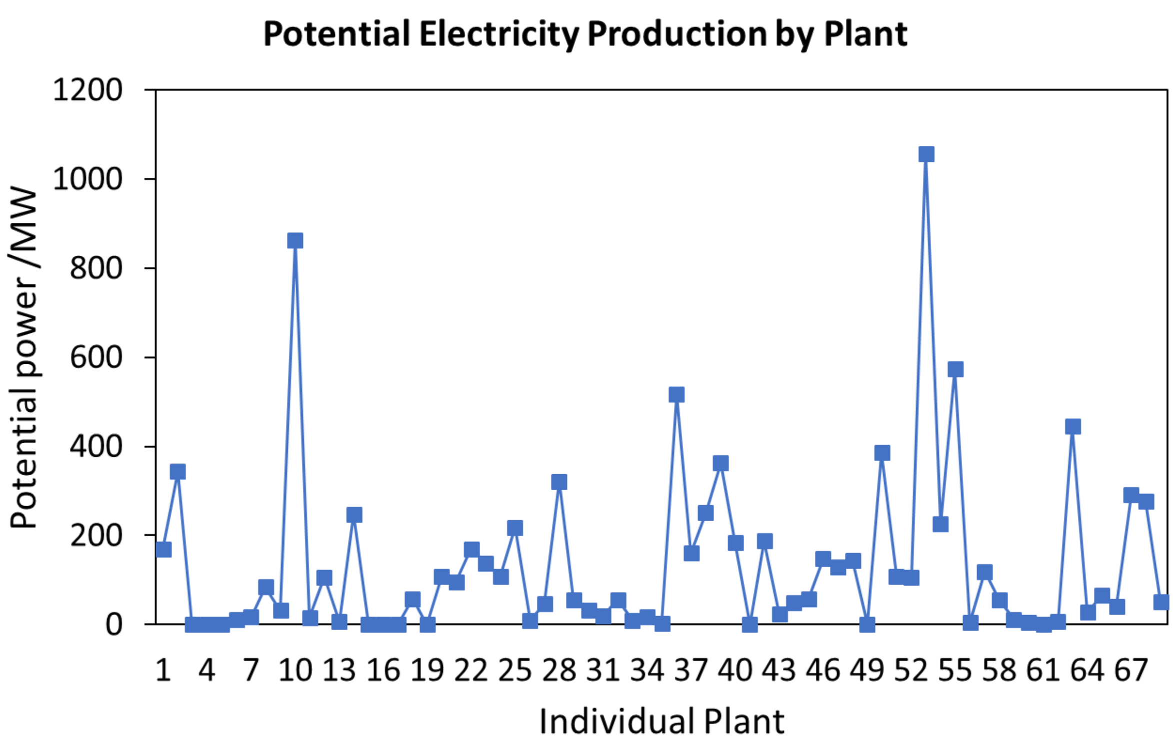


Figure 9. Potential electricity production by plant in the Permian Basin

Electricity grid integration

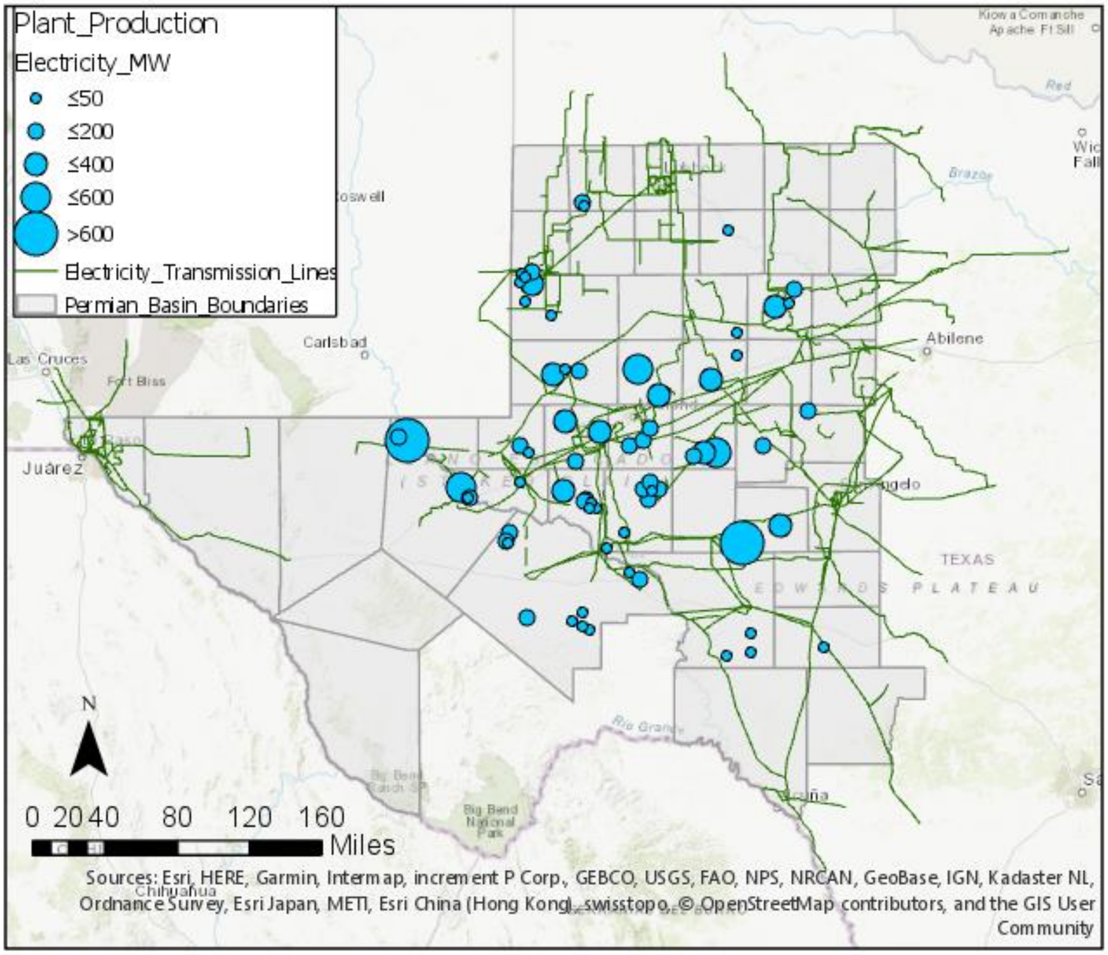


Figure 10. Distributions of electricity production at gas processing plants and electricity transmission lines in the Permian Basin

68 gas processing plants in the Permian Basin, symbolized by potential production of electricity, and the distributions of Texas electricity transmission lines in the Permian Basin are mapped to determine how the electricity produced from NGLs at gas processing plants could be connected and integrated into Texas electric power transmission system. As shown on the map, most of the gas processing plants are connected into the transmission system, which is expected because in most cases these gas processing plants need electricity for operations. However, there are also some plants, relatively far away from the electricity grid in the south part of the basin, where electricity transmission lines are not as concentrated as in the central part of the basin. To account

for these disconnections as well as other integration barriers, an integration factor of 0.9 is assumed, leading to the potential electricity integration of 8148 MW.

As reported by The Electric Reliability Council of Texas (ERCOT), Average electricity demand in Texas was 73000 MW in 2017. Therefore, the electricity produced from NGLs in the Permian Basin could probably provide over 10% of Texas electricity demand!

Suggestions for next steps

In this project, an integration factor of 0.9 is assumed for calculating potential integration of electricity produced at gas plants into Texas electricity grid, considering the disconnections between on-site production and electricity transmission lines as well as other integration barriers. To get a more accurate estimate of potential integration, more detailed information is needed. For example, it is also important to locate the electricity substations to identify the possible connections between the electricity produced onsite and electricity substations, and between the electricity substations and electricity transmission lines. Besides, other integration issues need to be considered, for example, it is unclear that whether electricity produced from gas plants could be adjusted to right voltages on the transmission lines that the electricity is potentially delivered to.

References

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