Discussion Paper No. 2 for the Energy Infrastructure of the Future study, January, 2019

Local Distribution Companies: Relationship between Pipeline Miles and Number of Customers, and Different Pipeline Diameter Sizes

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Abstract

This white paper investigates the relationship between the miles of natural gas pipelines and number of natural gas customers in the U.S. To do this we constructed a data set by merging data from the U.S. Energy Information Administration (EIA) and the Pipeline and Hazardous Materials Safety Administration (PHSMA). We find that the number of miles of distribution pipelines has increased in the United States, but with significant heterogeneity across regions. Additionally, we compute the share of customers by region that use natural gas as an energy source. The percentage of residential customers with natural gas access ranges from 8% in Florida to 81% in California. Moreover, by investigating pipeline mileage by diameter, we quantify the branching topology of the natural gas local distribution network. Finally, our linear regression estimates suggest that, on average, serving an additional natural gas residential customer is related with the expansion of the local gas distribution network by 0.0074 miles, and serving an additional commercial customer is associated with a distribution network expansion of 0.11 miles.

Introduction

The goal of the Energy Infrastructure of the Future project is to understand the current state of domestic energy infrastructure. Moreover, it seeks to inform the public and policy makers about those relationships between current infrastructure and demographic, economic, climatic, technological and other social variables that are relevant for understanding the drivers of future infrastructure needs. In the present white paper, we focus on local natural gas distribution pipelines. We investigate the relationship between the number of miles of distribution pipelines and customers in each of the regions in which the United States (U.S.) has been divided for analysis (see Figure 1). We also explore the relationship between the number of miles of distribution pipelines of different diameter lengths.

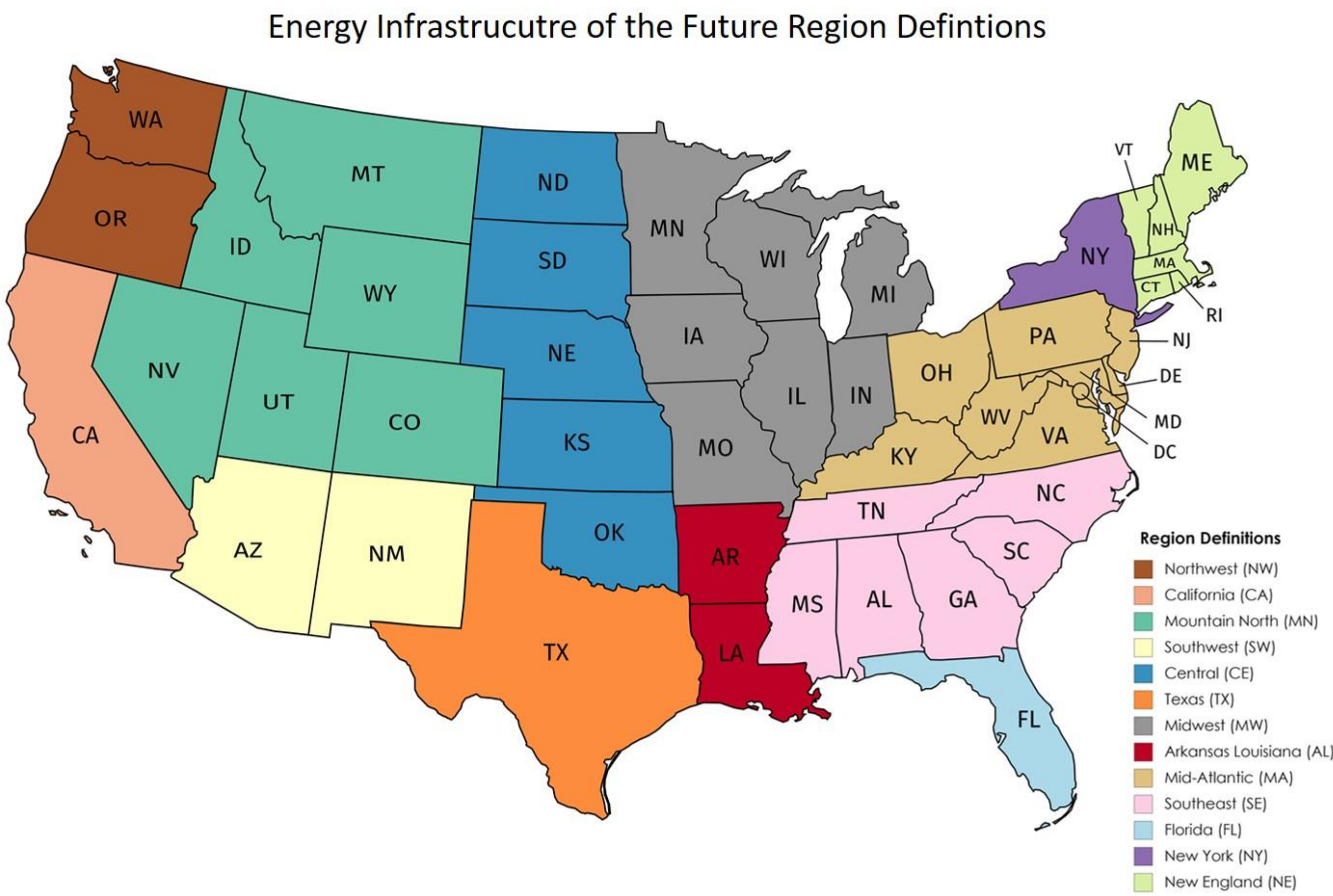

Figure 1: Energy Infrastructure of the Future Region Definitions

The natural gas industry's midstream sector provides the link between producers and consumers. As can be observed in Figure 2, it comprises gathering, processing, transportation and storage of natural gas. In the current paper our focus is on the "last mile" of the midstream sector: distribution pipelines. These pipelines bring natural gas to the final consumers, i.e. homes and business, after it has been received at the city gate by a local distribution company (LDC).

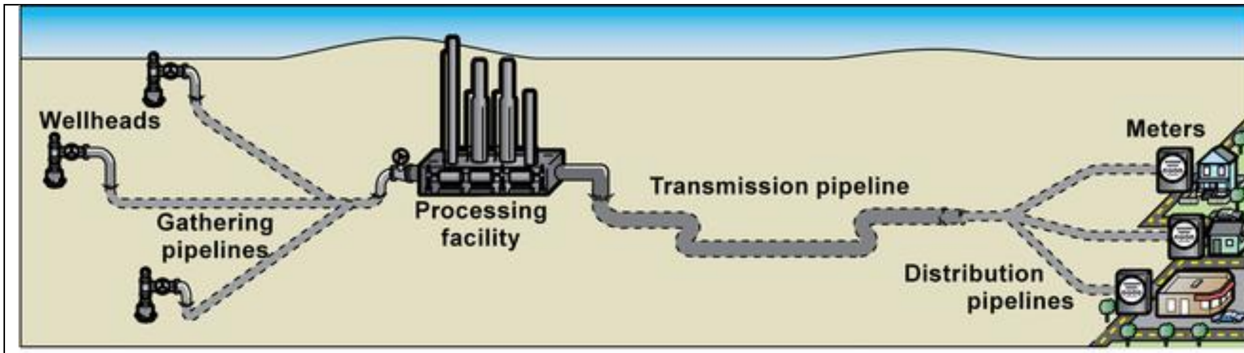

Figure 2: The Natural Gas Midstream [U.S. Government Accountability Office, 2015]

Summary of Methods

To investigate the relationship between pipeline miles and number of customers, we have merged data from two sources: the U.S. Energy Information Administration (EIA) and the Pipeline and Hazardous Materials Safety Administration (PHMSA). From the EIA we use the "Annual Report of Natural and Supplemental Gas Supply and Disposition", Form EIA-176, which collects data on the origin of natural gas and its disposition [EIA, 2018a]. Respondents include producers, processors, storage, and distributors. However, the focus of the present analysis is local distribution companies (LDCs). Therefore, we only use data corresponding to companies in at least one of the following five categories: "Investor Owned", "Municipally Owned", "Privately Owned", "Cooperative", and "Other Ownership".

In practice, we do not need to explicitly drop observations in different categories. This is "automatically" taken care of when merging EIA-176 data with PHMSA's "Gas Distribution Annual Report Data"[1] [PHMSA, 2018]. The Code of Federal Regulations requires gas distribution companies to submit an annual report to PHMSA. Through these surveys, companies disclose information about each of the systems they operate in each state: the total miles of pipelines they control, installation dates, characteristics of the pipelines such as diameter and material, number of services, and leaks.

[1] This is true because for the analysis we only keep those observations for which we could match a LDC in EIA-176 to one in PHMSA. Since all the observations in the PHMSA dataset that we use in the present paper correspond to LDCs, successful matching also implies that the company in question is a LDC.

Merging both datasets is not trivial. Although natural gas distribution companies must file both reports, each dataset assigns a different unique identification number to respondents. Therefore, to merge the EIA-176 dataset with PHMSA data on LDCs we must match observations by company name, state and year. This is challenging because names are inconsistent across years in the PHMSA data and across datasets. Consider Bay City Municipal Gas System as an example. In different years this company appears in the PHMSA data with two different names: "BAY CITY MUNICIPAL GAS SYSTEM" or "BAY CITY GAS COMPANY". On the other hand, the same company appears in EIA-176 as "BAY CITY GAS CO". Therefore, in merging the two data sets we spent considerable effort into homogenizing names across years in the PHMSA dataset and across the EIA-176 and PHMSA datasets.

The resulting dataset contains 174 variables, and 14,575 observations spanning thirteen years: 2004-2016. The goal of this paper is to take a first look at patterns in the data suggesting interesting relationships between pipeline miles and costumers. Therefore, we only make partial use of the information we have gathered. In the analysis below, we use annual total miles per region, average[2] number of miles of a given diameter size by region, miles of pipelines of diameter less than two inches by LDC, and number of residential customers by LDC.

[2] The average is taken over the sample 2004-2016 sample period.

Results and Analysis

Total Miles of Pipeline per Region

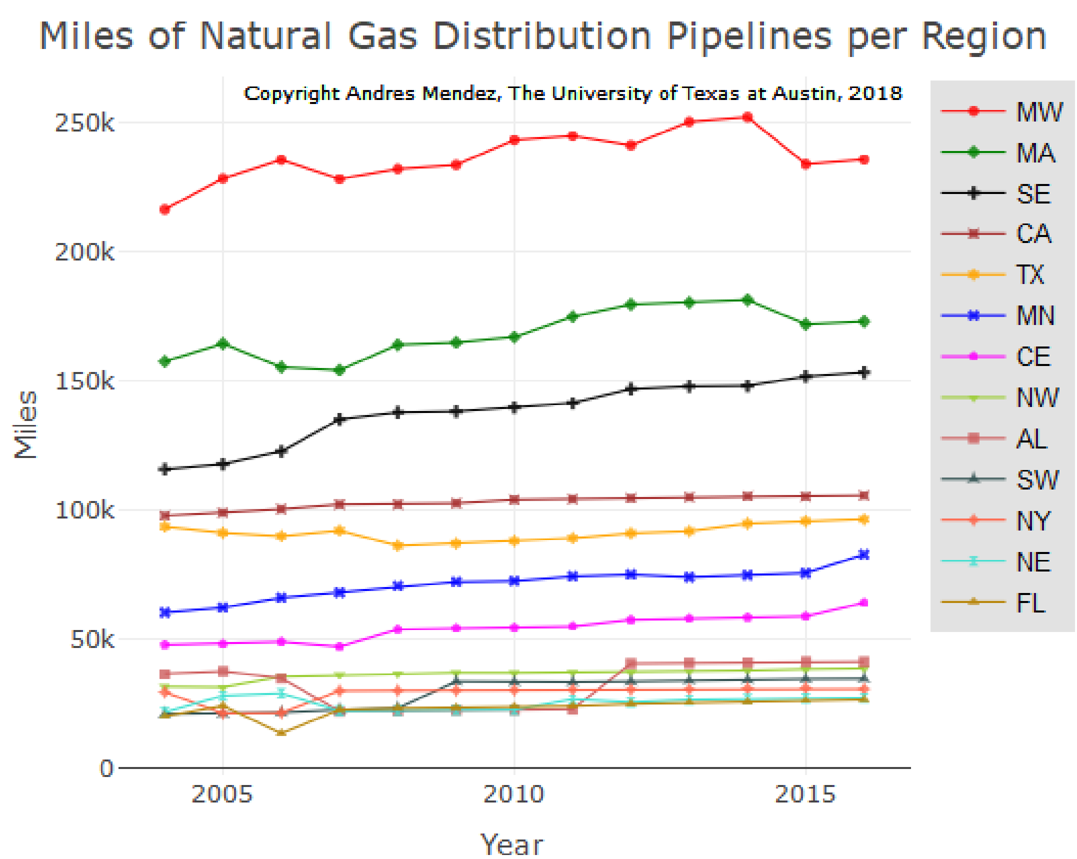

Figure 3: Miles of Natural Gas Distribution Pipelines per Region [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

Figure 3 presents a graph of the time series of total miles[3] of pipeline used for local distribution of natural gas, and **Error! Reference source not found.** summarizes the data. Total miles of pipeline increased in all regions in the period 2004-2016. The largest increase in percentage terms was experienced in the Southwest region, which includes Arizona and New Mexico. In this region the total number of miles more than doubled, increasing 65%. On the other

[3] This total number of miles includes miles of all diameter sizes.

hand, Texas experienced only a 3% growth in the number of pipeline miles, making it the region with the slowest expanding local distribution pipeline network in percentage terms. In absolute terms matters look slightly different. Although Texas' distribution network is also the slowest growing in levels, the Southeast (SE) region expanded its pipeline network the most in absolute terms. The pipeline network increased by around 38,000 miles in the SE region which comprises Mississippi, Alabama, Georgia, Tennessee, North Carolina and South Carolina.

Table 1: Summary Statistics - Miles of Natural Gas Distribution Pipelines per Region

Thousands of Miles of Pipeline per Region - Total

EIoF Region	Mean	Median	Min	Max	2004	2016	2004-2016 Percentage Change
MW	237	236	216	252	216	236	9%
MA	168	167	154	181	158	173	10%
SE	138	140	116	153	116	153	32%
CA	103	104	98	106	98	106	8%
TX	91	91	86	96	93	96	3%
MN	71	72	60	83	60	83	37%
CE	54	54	47	64	48	64	34%
NW	36	37	31	39	32	39	22%
AL	33	36	22	41	36	41	13%
SW	29	33	21	35	21	35	65%
NY	29	30	21	31	29	31	4%
NE	25	26	22	29	22	27	26%
FL	23	24	13	26	20	26	32%

Note: Data from PHMSA (Local NG Distribution Companies) and EIA Form 176

Number of Customers

To further understand future natural gas distribution infrastructure needs, we briefly investigate how the current use of natural gas by residential, commercial, and industrial customers varies across EIoF regions. This is relevant to our analysis, because the expansion of the natural gas distribution network would slow down as a higher percentage of regional customers become connected to the natural gas network. In other words, our goal is to investigate what regions have the largest reserve of potential new customers of natural gas.

For thinking about possible U.S. energy infrastructure investments, it is important to consider how many customers already have natural gas access. To calculate the share of natural gas customers by region, we need a measure of the total number of customers, i.e. the market size. We use information on the number of electricity customers from the EIA´s Form EIA-861M to calculate the number of potential natural gas customers in each EIoF region [EIA, 2018b]. Our working assumption is that all households, shops, and firms are connected to the electric grid, but not necessarily to the natural gas distribution network. This seems to be a reasonable assumption, because electricity access is practically universal in the U.S., but natural gas connectivity is not.

In Table 2 we present the number of natural gas customers, the number of electricity customers, and the ratio of natural gas to electricity customers by region. Assuming that the number of electricity customers equals the total number of potential customers for natural gas, we can interpret the ratio of natural gas to electricity customers as the market share of natural gas customers. The region with the largest share of residential natural gas customers is California (CA), with around 81% of the residential energy customers connected to a natural gas distribution network. The region with the smallest share of natural gas customers is Florida (FL), with only 8%. On the other hand, the region with the largest share of commercial customers is the Midwest (MW), with 41%, while the region with the smallest share of commercial customers is Florida (FL). Finally, the region with the largest share, 79%, of natural gas industrial customers is New York (NY), while Florida is the region with the lowest share of customers, 2%, that use natural gas. It is reasonable to expect a low percentage of industrial facilities to be customers of natural gas LDCs. Many industrial natural gas users defected from LDCs starting the mid-1990s after FERC passed open access regulations.

Table 2: Number of U.S. Natural Gas and Electricity Customers, by Region

Thousands of Customers of Natural Gas and Electricity in 2016 by EIoF Region

	Natural Gas			Electricity			Natural Gas to Electricity Ratio		
EIoF Region	Residential	Commercial	Industrial	Residential	Commercial	Industrial	Residential	Commercial	Industrial
AL	1298.3	109.6	1.0	3428.6	480.0	55.7	0.38	0.23	0.02
CA	10916.4	445.0	37.2	13445.1	1692.3	148.5	0.81	0.26	0.25
CE	2325.4	247.3	10.9	4593.6	805.1	116.9	0.51	0.31	0.09
FL	687.1	64.1	0.4	9149.2	1199.9	21.2	0.08	0.05	0.02
MA	10531.6	905.2	19.3	22904.8	3040.2	86.8	0.46	0.30	0.22
MN	3994.5	324.5	9.4	5926.7	924.1	77.8	0.67	0.35	0.12
MW	12996.8	1131.2	46.0	21515.4	2749.7	62.8	0.60	0.41	0.73
NE	1937.2	205.1	14.6	6290.4	874.5	26.4	0.31	0.23	0.55
NW	1881.1	185.0	4.6	4692.4	599.5	53.6	0.40	0.31	0.09
NY	3448.1	303.2	6.0	7118.9	1072.9	7.6	0.48	0.28	0.79
SE	4959.6	439.8	9.8	17165.2	2689.4	55.6	0.29	0.16	0.18
SW	1646.0	93.6	0.4	3602.4	459.9	17.5	0.46	0.20	0.02
TX	4442.2	355.2	7.0	10521.7	1447.2	105.6	0.42	0.25	0.07

Note: Data from PHMSA (Local NG Distribution Companies) and EIA Form 176 and Form 861M

Average Total Miles by Diameter

Local distribution companies also report the number of miles by diameter length to PHMSA. In the annual report, firms submit information for the following five pipeline diameter categories: “Less than Two Inches”, “2-4 Inches”, “4-8 Inches”, “8-12 Inches”, and “Greater than Twelve Inches”. Figure 4 presents the 2004-2016 average total miles by diameter category. The picture shows that the number of miles generally decreases as the diameter size increases. The NE and NY regions show a different pattern. The NE and NY regions have much fewer miles of NG pipe of smaller than 4-inch diameter. This could be explained by the higher population densities served by NG pipelines in these regions. For example, high-rise buildings in New York City must be served by larger diameter LDC pipelines as opposed to pipelines less than 2 inches in diameter that serve single family residential dwellings in less dense urban and rural areas. Further, the NE region has a lower percentage of residential NG customers compared to other regions (see Table 2).

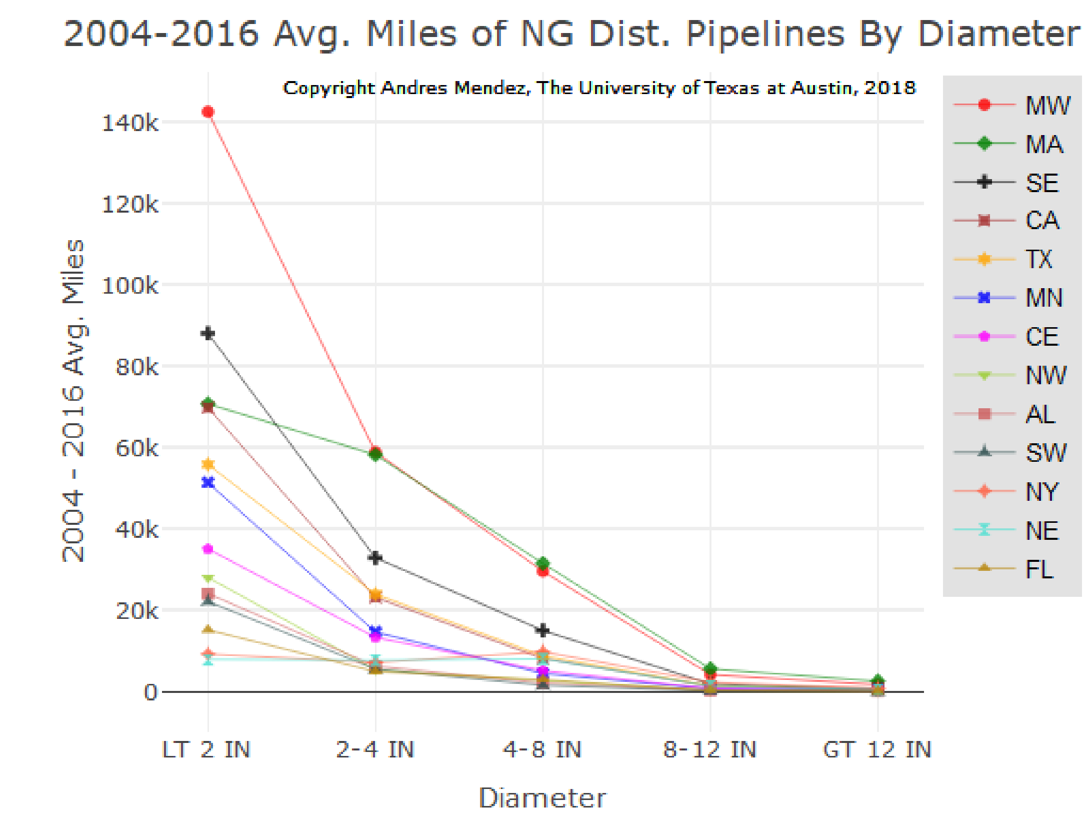

Figure 4: Natural Gas Distribution Pipeline Miles by Diameter [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

Overall, Figure 4 indicates that the NG LDC pipeline network exhibits a branching topology, just as exists in the human body circulatory system [Banavar *et al.*, 2010]. A small number of large diameter pipelines feed an increasing number of smaller diameter pipelines. Because energy distribution infrastructure also exhibits a branching topology, but is designed by more processes than biological evolution in animals, it has been proposed that the power grid and pipeline networks might exhibit similar scaling laws relating energy consumption, flow rate, and structure [Dalgaard and Strulick, 2011]. This remains an area for future research. It is important to recall that in the present analysis we are dealing only with local distribution pipelines, not long-distance interstate or intrastate pipelines. In Figure 5, we present a stylized sketch of the branching topology suggested by the decreasing relationship between diameter size.

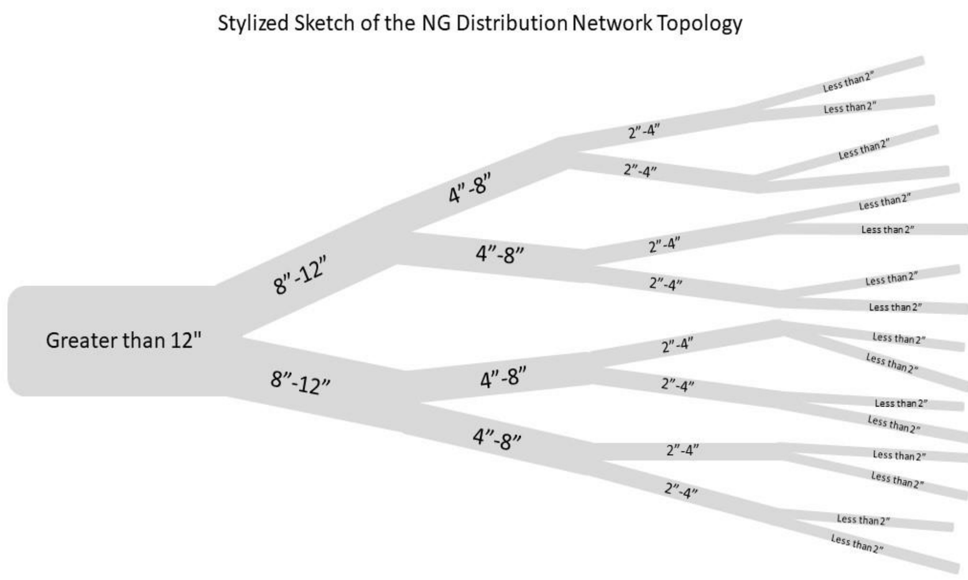

Figure 5: Stylized Sketch of the Distribution Network Topology

Pipeline Diameter and Customer Types

One of the reasons that we have merged PHMSA data and EIA-176 data is to enable analysis of the relationship between the number of consumers of each type and the number of miles of pipeline that are needed in each region to meet their natural gas demand. We have mentioned already that PHMSA classifies pipelines according to their diameter size. However, we have yet to discuss the EIA's consumer categories. The EIA classifies consumers into the following five categories: "Residential Customers", "Commercial Customers", "Industrial Customers", "Electric Customers", and "Vehicle Customers".

In order to analyze the number of miles needed to service a consumer of a given category, we need to match consumer types and pipeline diameter categories. For example, it is highly unlikely that pipelines in the local gas distribution network connect directly to residential customers using a diameter greater than 12 inches. Single-family dwelling residential customers are usually served using pipelines of less than 2-inch diameter. Additionally, commercial customers could also be supplied using less than 2-inch diameter pipelines. Table 3 shows the different pipeline diameter and consumer categories in our data. Because matching each diameter category to corresponding customer categories is not straightforward, in our analysis we describe only the relationship between less than 2-inch diameter pipelines and residential and commercial customers.

Table 3: Pipeline Diameter and Customer Types

Pipeline Diameter and Costumer Types					
Pipeline Diameter	Less than 2”	2”-4”	4”-8”	8”-12”	Greater than 12”
Customer Types	• Residential Customers • Commercial Customers	--	--	--	--

Less than Two-inch Diameter Pipelines and Residential Customers

Figure 6 shows the time series of the number of miles of local distribution pipelines with a diameter less than two-inches for each region. Overall, the ranking by region in terms of the number of miles of less than two-inch diameter pipelines is very similar to the ranking obtained when all diameter categories are included (see Figure 3).

The Southeast (SE) and the Mid-Atlantic (MA) constitute an exception. These two regions switch their respective position with respect to the ranking which includes all the pipeline categories. If we look at Figure 4, which contains information on the number of miles by pipeline diameter category for each of the regions, we can see that although the SE region has more pipelines with a diameter of less than two-inches than the MA region, the MA region more than makes up for this difference when it come to larger diameter pipelines, i.e. the MA region has more miles of larger diameter pipelines than the SE. A possible explanation could be that the MA region has more cities with high-rises than the SE region. Moreover, it is likely that vertical condos and other type of vertical constructions connect to the local distribution through larger diameter pipelines than stand-alone houses and businesses. This would create the type of patterns we see in our data.

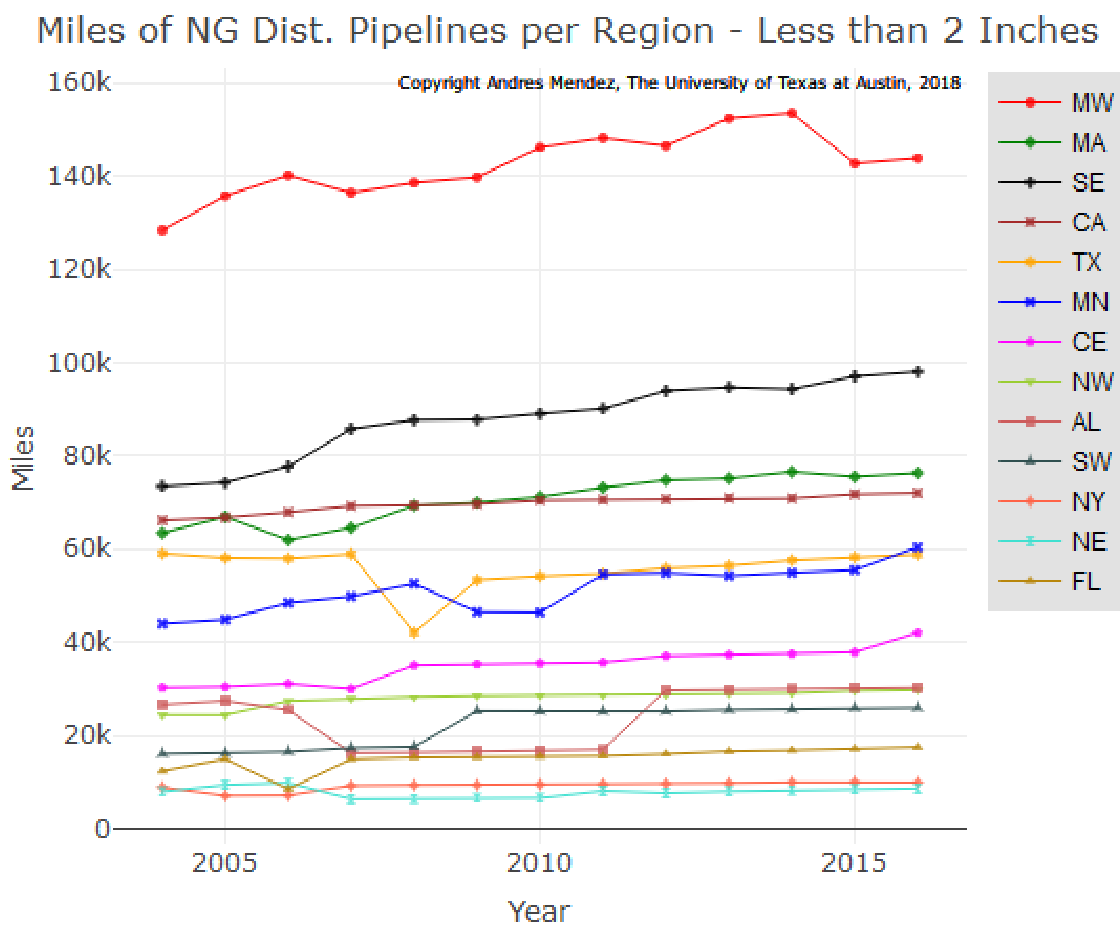

Figure 6: Miles of Less than 2" Natural Gas Distribution Pipelines per Region [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

In Figure 7, we present a scatter plot showing the relationship between miles of local distribution pipelines and number of residential customers. Each point corresponds to a firm in our dataset, and the color represents the region in which the local distribution company operates. We have also fitted a linear model to the data, which corresponds to the black line in Figure 7. We find that, on average, serving an additional natural gas residential customer is associated with an expansion of the local gas distribution network of 0.0074 miles. The Appendix shows corresponding charts using only data for each individual region.

At least two groups of observations in Figure 7 stand out from the rest. The first group is the fuchsia colored cluster in the upper-left corner of the graph within the Texas region. These observations with less than 15,000 residential customers and more than 20,000 miles of less than two-inch diameter distribution pipelines correspond to CENTERPOINT ENERGY ARKLA. A potential explanation for the large number of per-costumer miles of these observations that the geographic area in which this company operates is sparsely populated. Alternatively the data might be incorrect.

The second group that stands out is the green colored cluster of observations that have more than 900,000 residential customers but less than 1,000 miles of less than two-inch diameter pipelines. These observations correspond to the following two companies operating in the NY region: CONSOLIDATED EDISON NEW YORK INC and THE BROOKLYN UNION GAS CO. We have hypothesized that this could be explained by the large number of high-rises in the New York City and Brooklyn area.

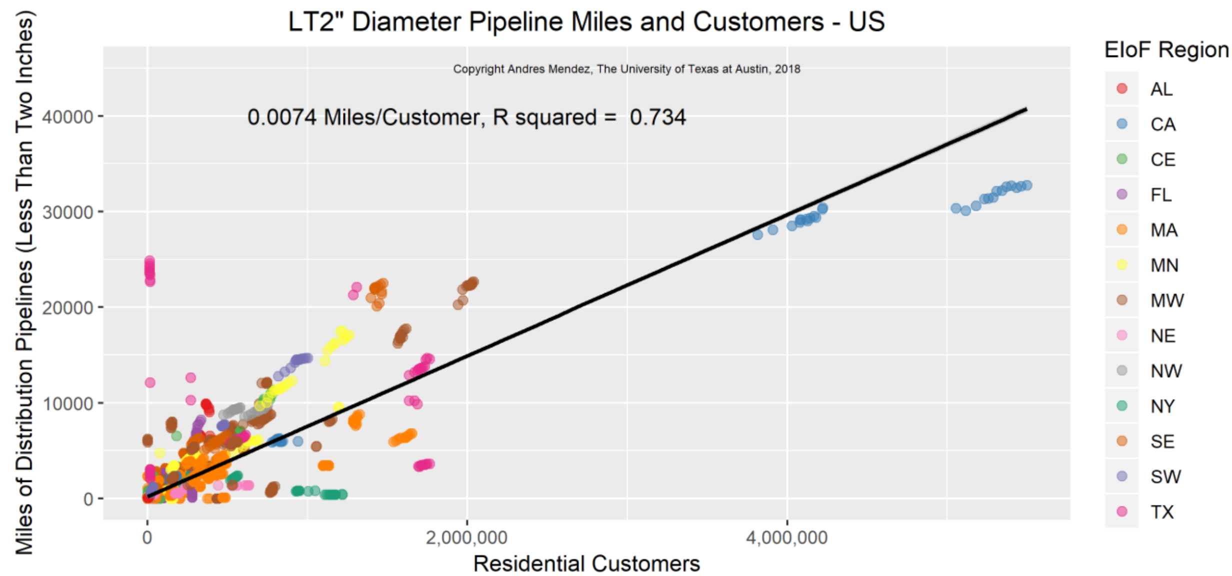

Figure 7: Distribution Pipeline Miles and Residential Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

Less than Two-inch Diameter Pipelines and Commercial Customers

In Figure 8, we present a scatter plot showing the relationship between the number of commercial customers a local distribution company supplies and the number of miles of less than two-inch pipelines in that company's distribution network. We find that, on average, serving an additional natural gas commercial customer is associated with an expansion of the local gas distribution network of 0.11 miles. The Appendix shows corresponding charts using only data for each individual region.

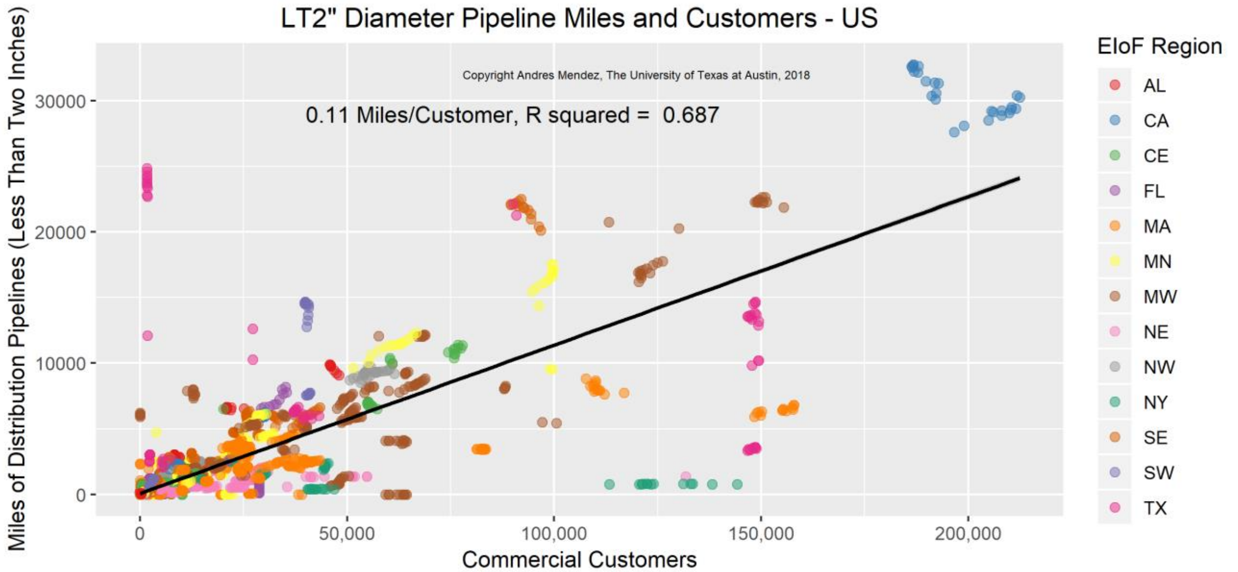

Figure 8: Distribution Pipeline Miles and Commercial Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

Conclusion

In this paper we have explored patterns regarding the local distribution pipeline networks across different regions in the US. We find that the number of miles of distribution pipelines has increased in the United States, but with a lot of heterogeneity across regions. Additionally, our data reveals that the share of customers by region that use natural gas as an energy source is low. This suggests that in most regions there is a reserve of customers that could eventually substitute consumption of other energy sources with natural gas. We also present evidence suggesting that the natural gas local distribution network exhibits a branching topology. Finally, our linear regression estimates suggest that serving an additional natural gas residential customer is related with the expansion of the local gas distribution network by 0.0074 miles, and serving an additional commercial customer is associated with a distribution network expansion of 0.11 miles.

References

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Appendix 1: NG Pipeline miles vs. Number of Residential Customers (per study region)

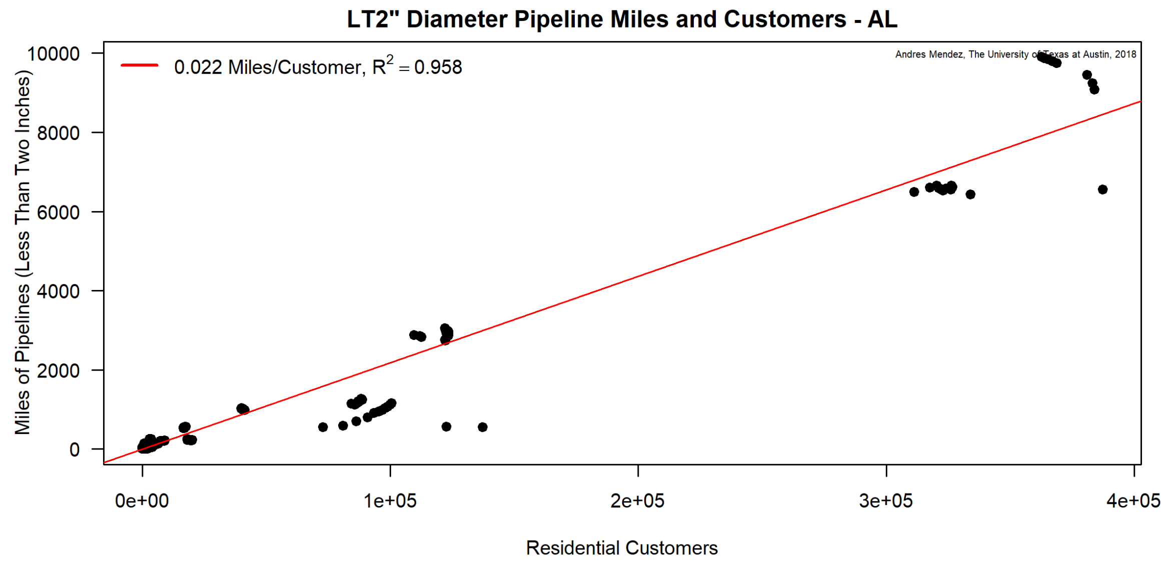

Figure A1: Distribution Pipeline Miles and Residential Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

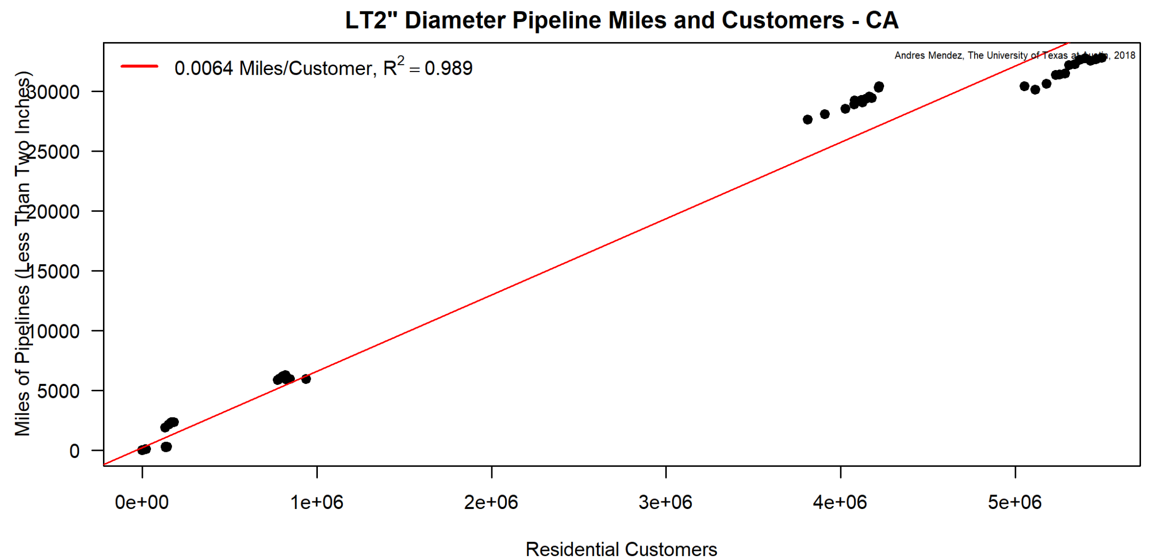

Figure A2: Distribution Pipeline Miles and Residential Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

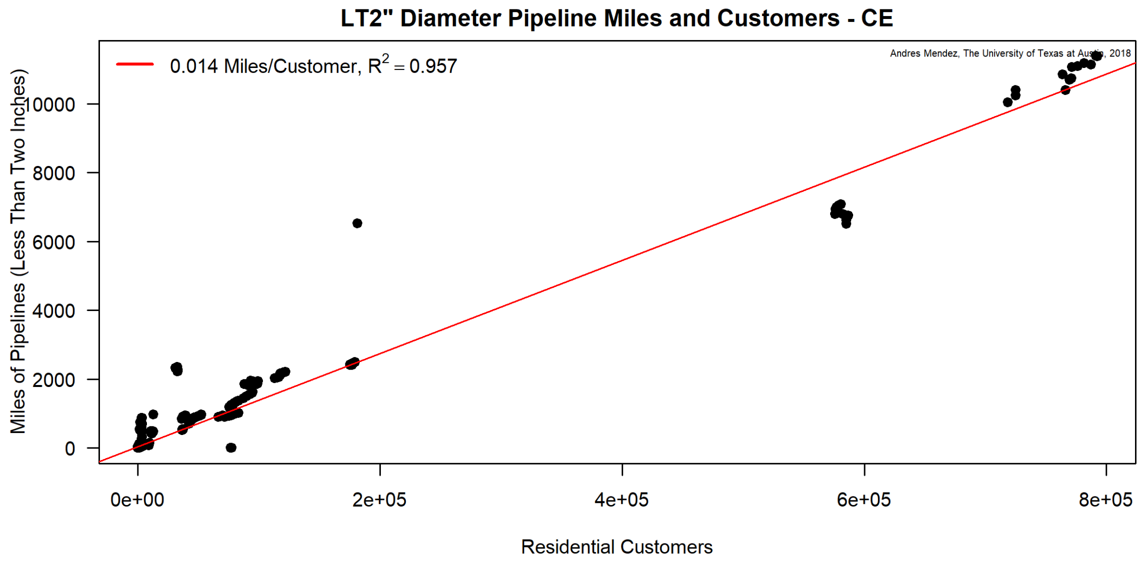

Figure A3: Distribution Pipeline Miles and Residential Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

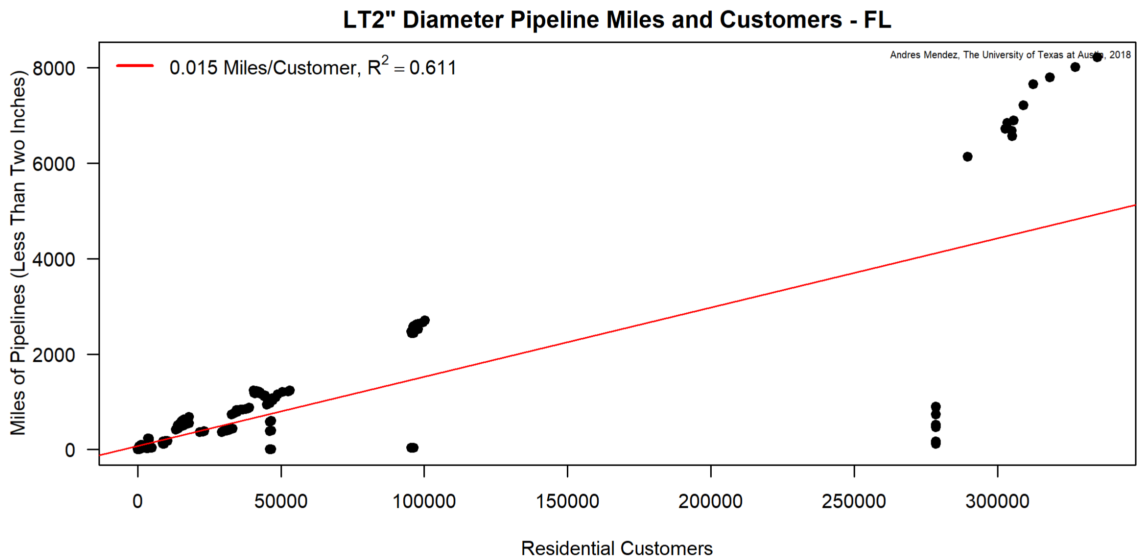

Figure A9: Distribution Pipeline Miles and Residential Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

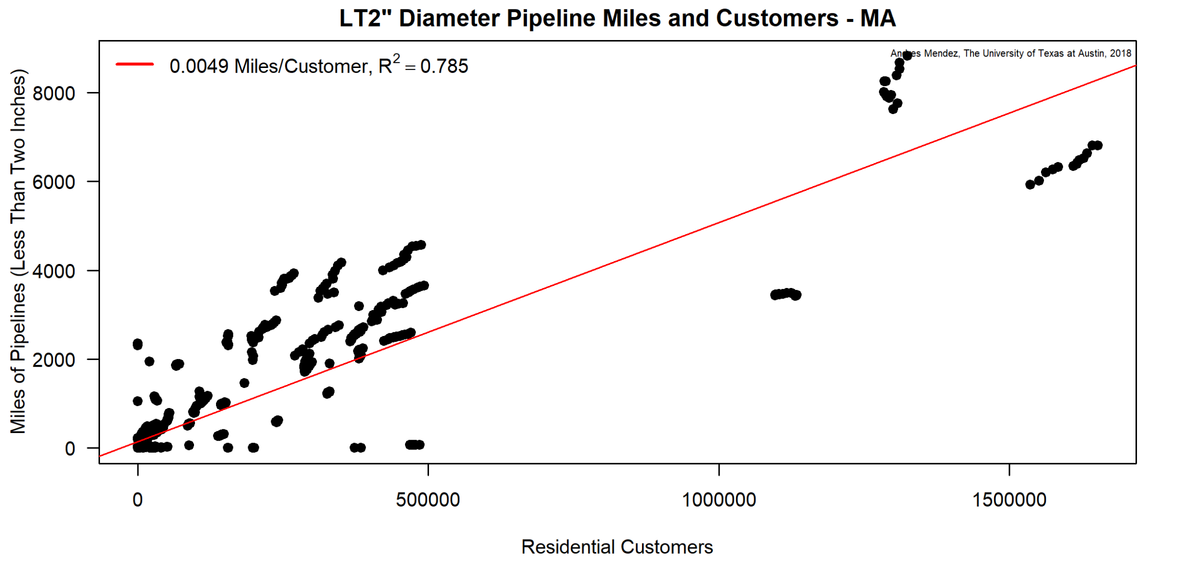

Figure A5: Distribution Pipeline Miles and Residential Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

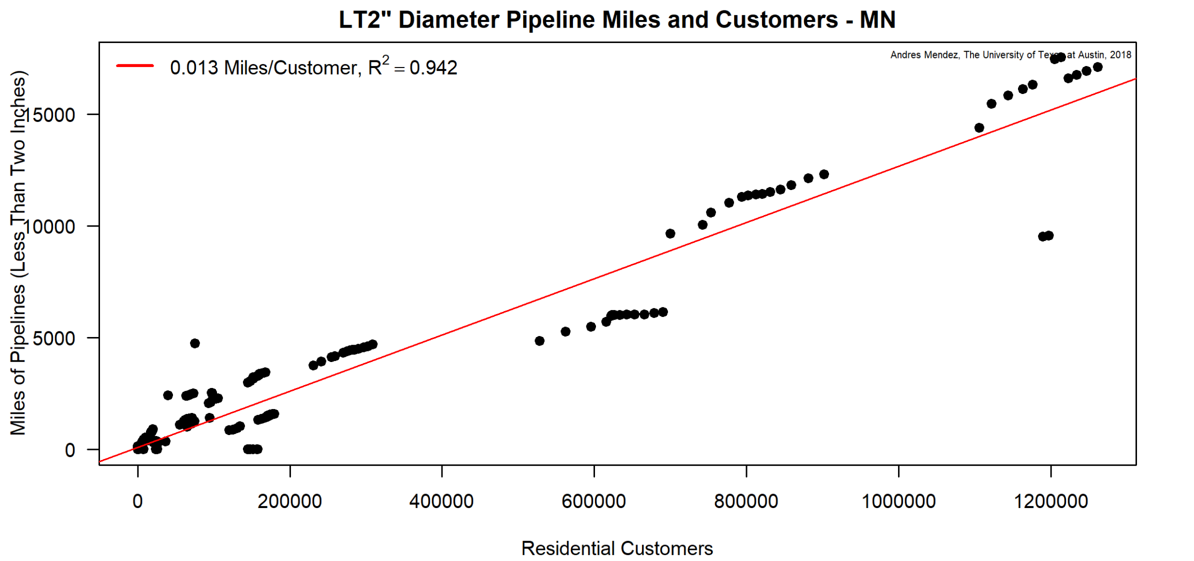

Figure A6: Distribution Pipeline Miles and Residential Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

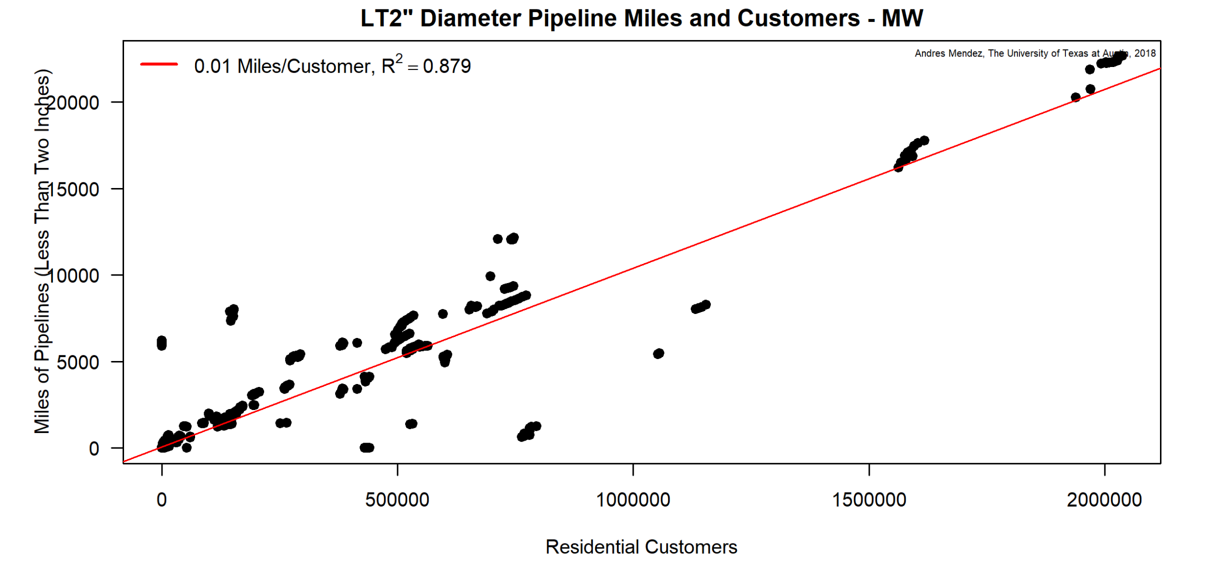

Figure A7: Distribution Pipeline Miles and Residential Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

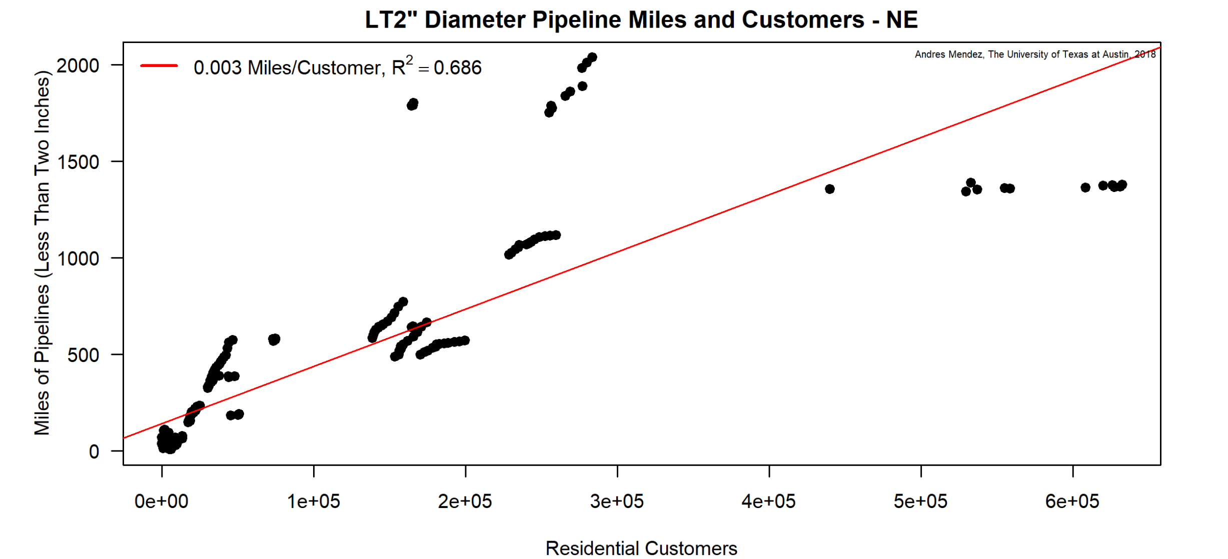

Figure A8: Distribution Pipeline Miles and Residential Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

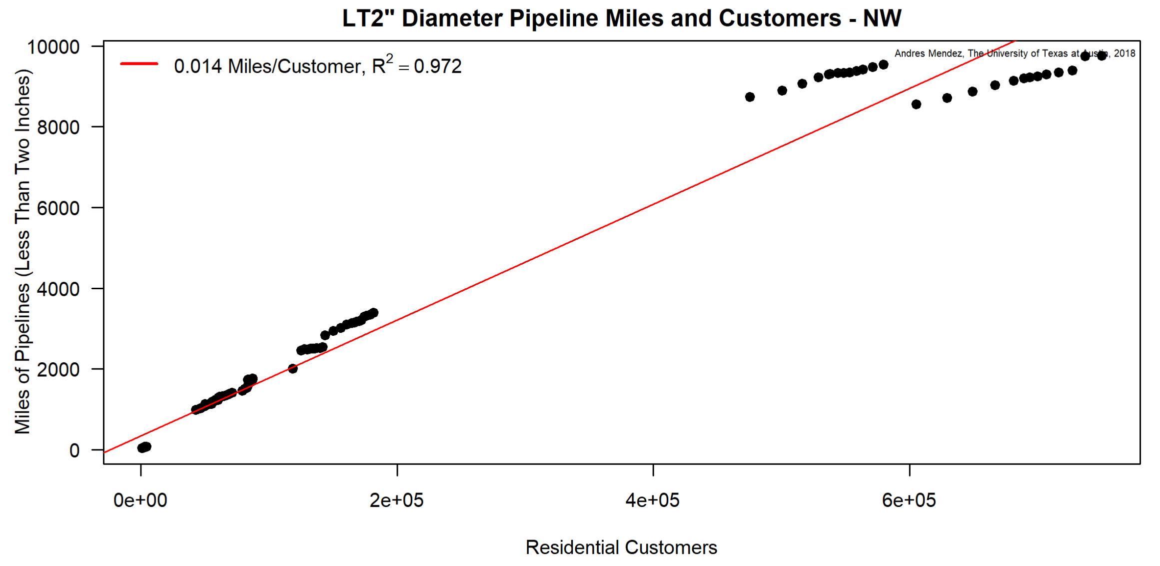

Figure A9: Distribution Pipeline Miles and Residential Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

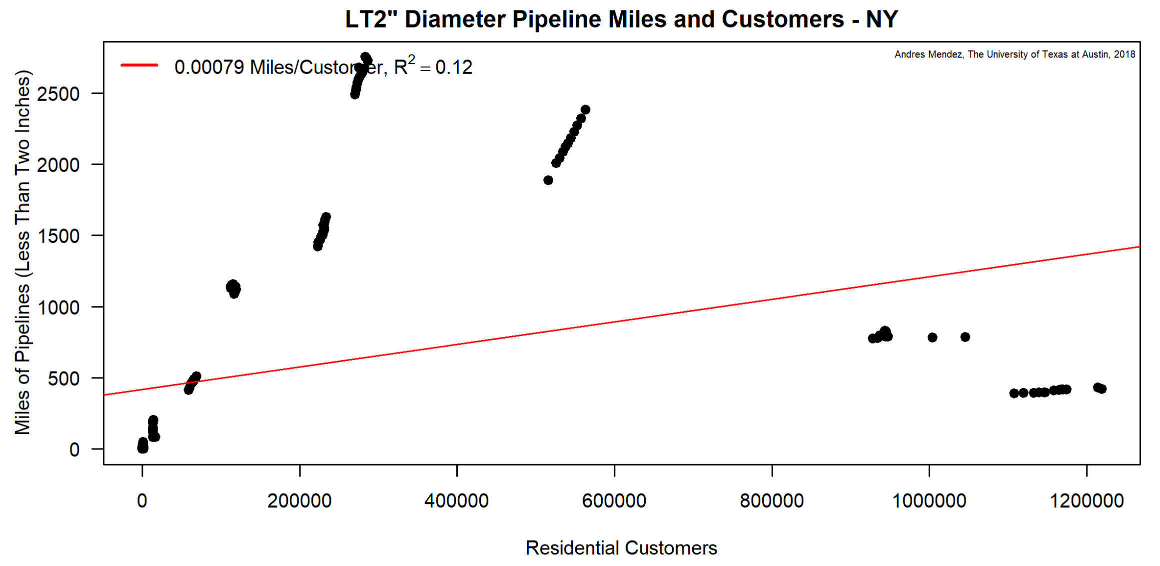

Figure A10: Distribution Pipeline Miles and Residential Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

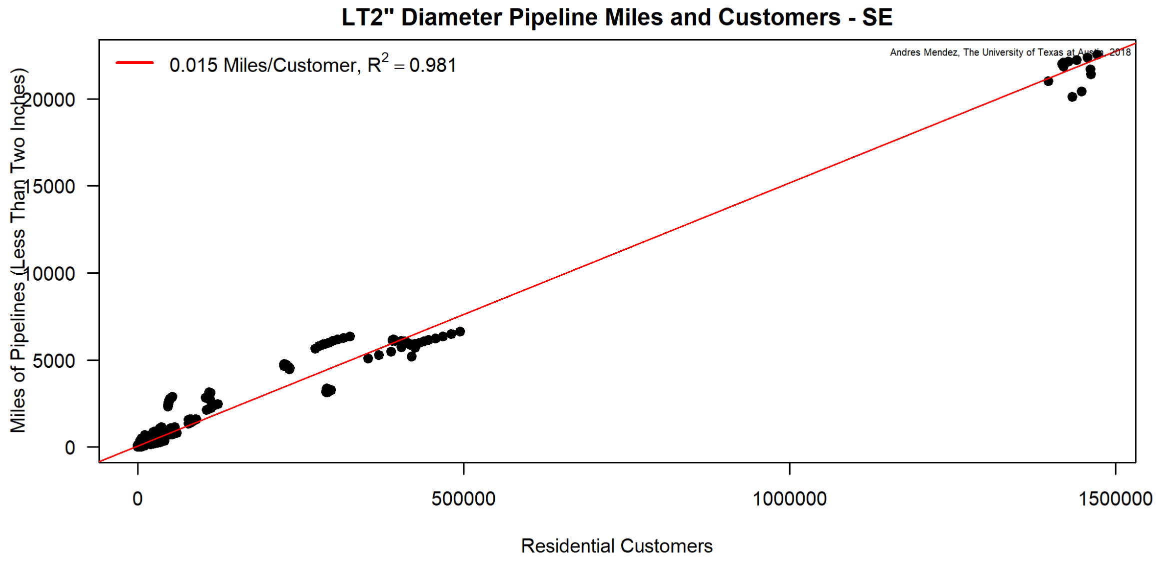

Figure A11: Distribution Pipeline Miles and Residential Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

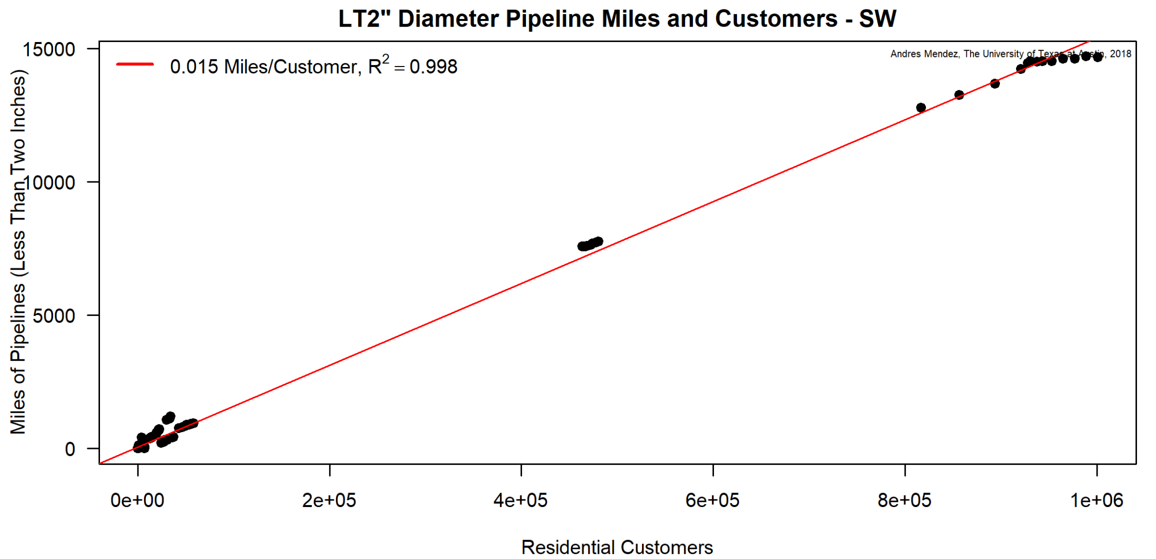

Figure A12: Distribution Pipeline Miles and Residential Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

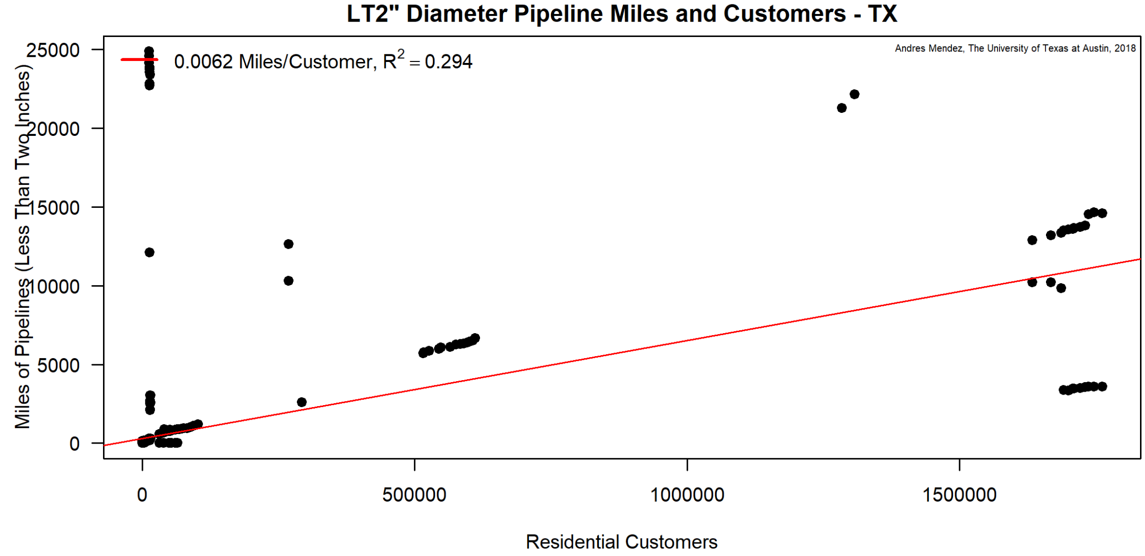

Figure A13: Distribution Pipeline Miles and Residential Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

Appendix 2: NG Pipeline miles vs. Number of Commercial Customers (per study region)

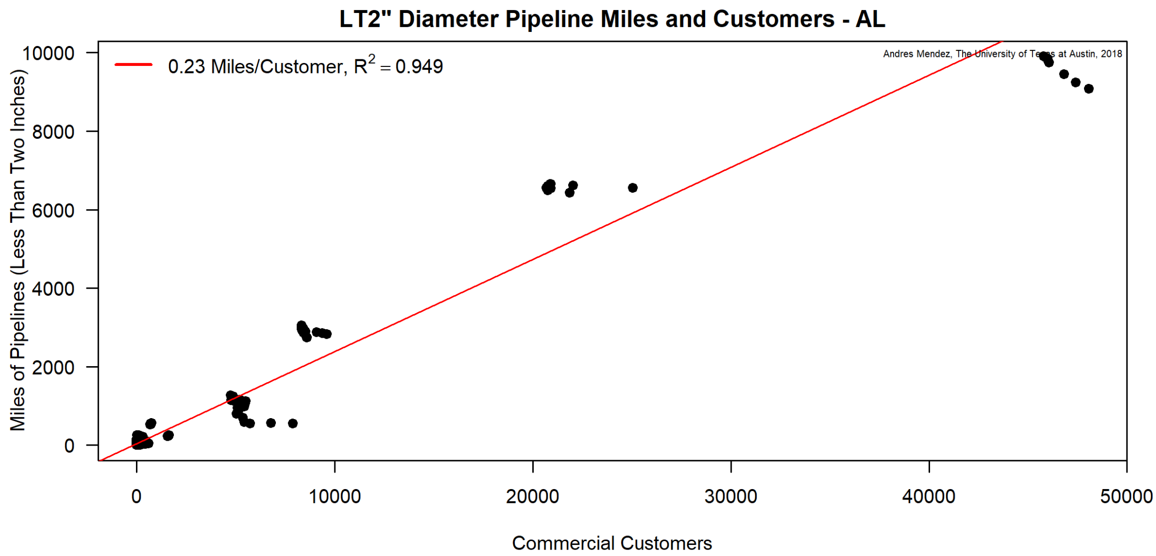

Figure A14: Distribution Pipeline Miles and Commercial Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

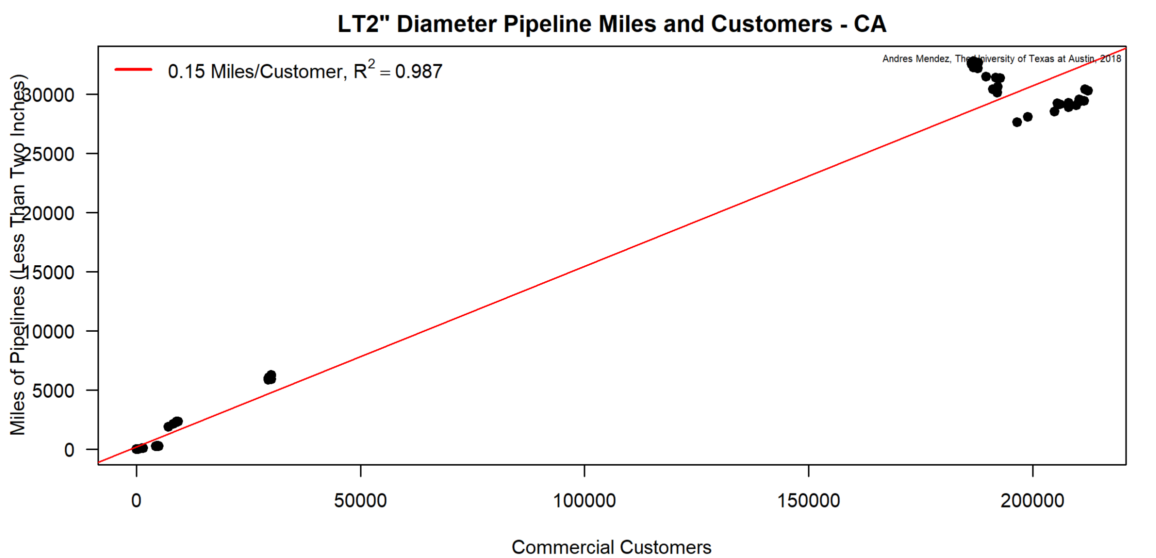

Figure A15: Distribution Pipeline Miles and Commercial Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

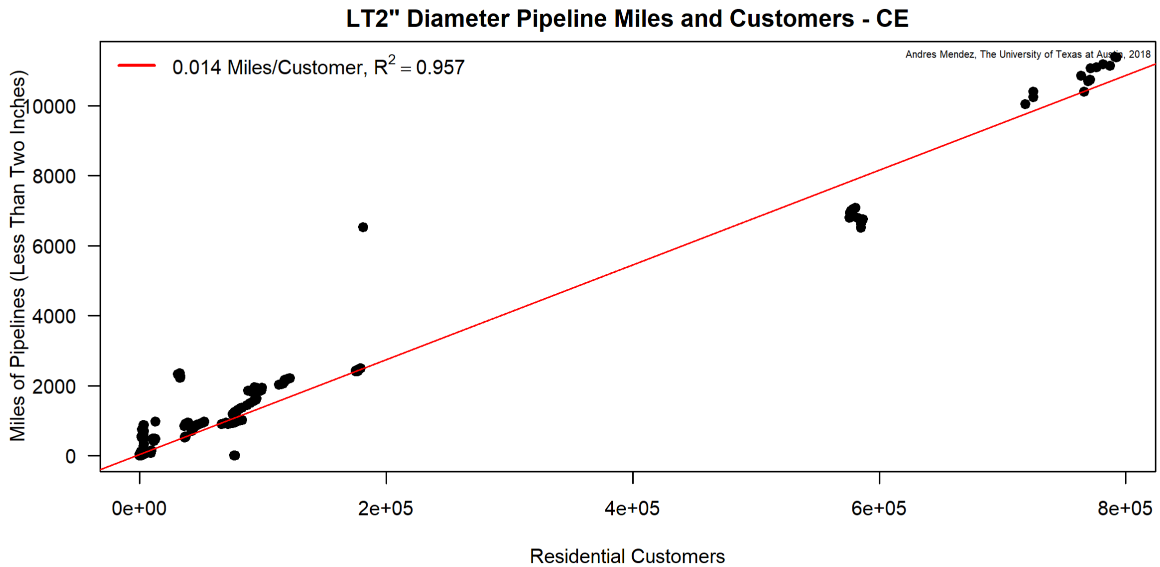

Figure A16: Distribution Pipeline Miles and Commercial Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

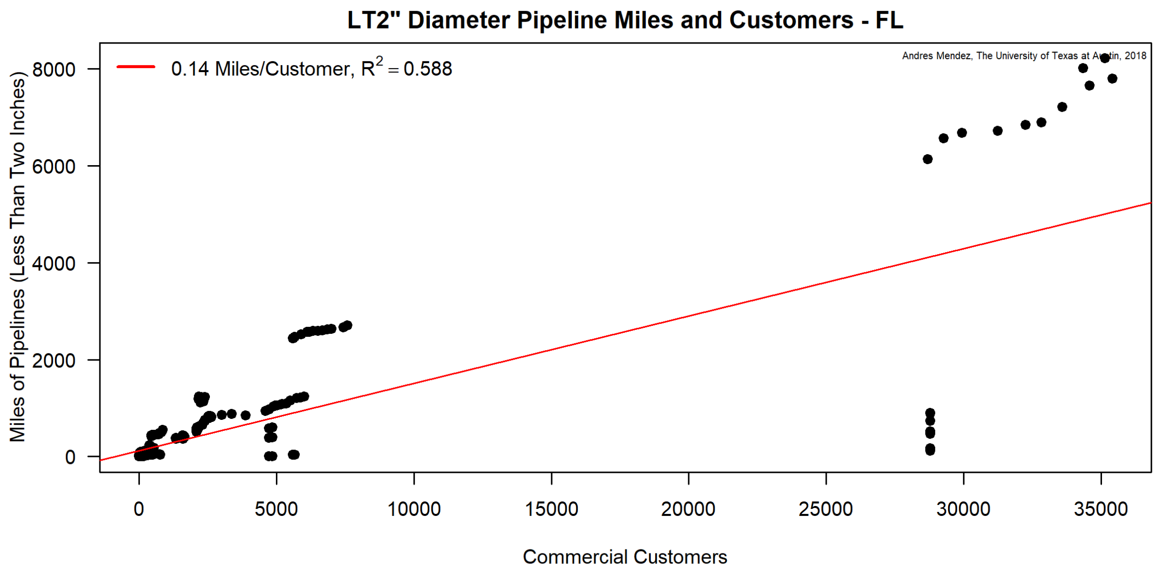

Figure A17: Distribution Pipeline Miles and Commercial Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

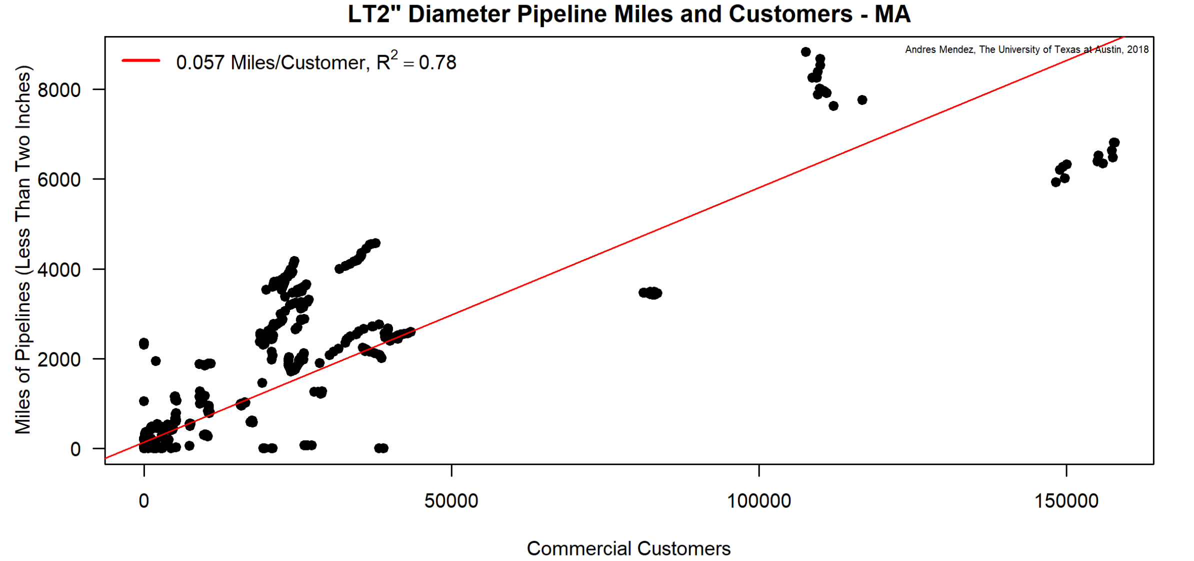

Figure A18: Distribution Pipeline Miles and Commercial Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

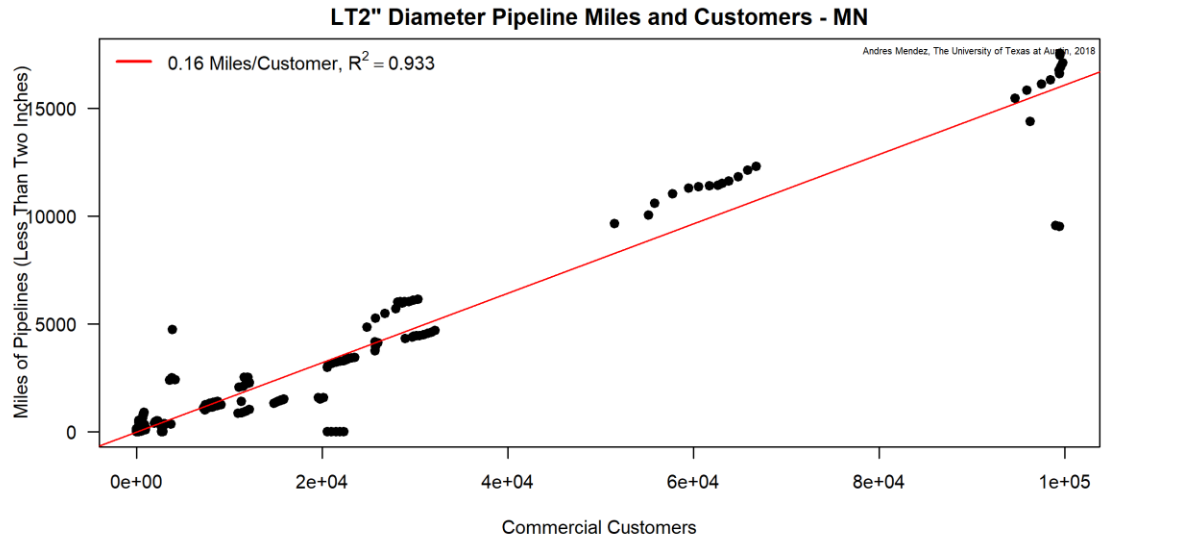

Figure A19: Distribution Pipeline Miles and Commercial Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

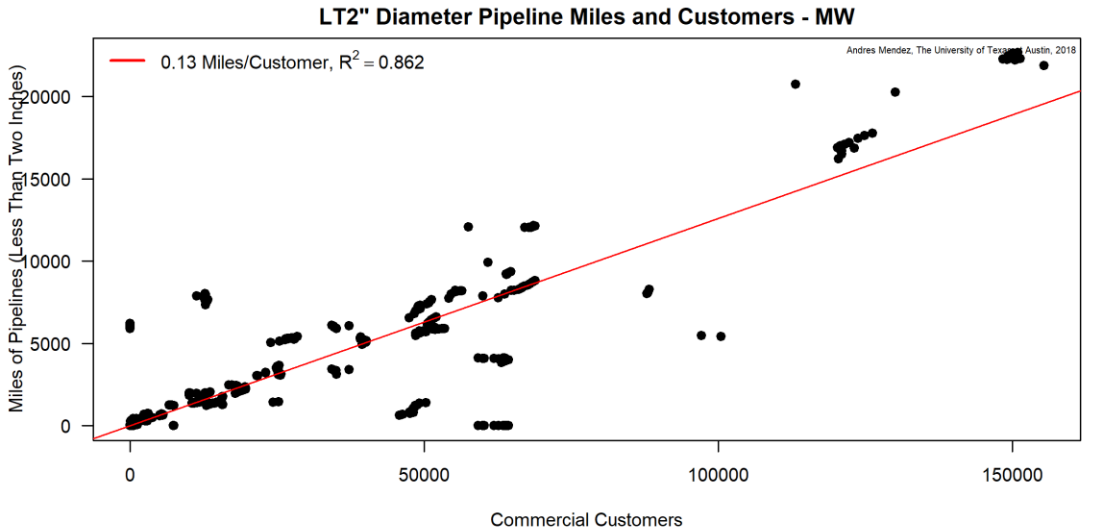

Figure A20: Distribution Pipeline Miles and Commercial Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

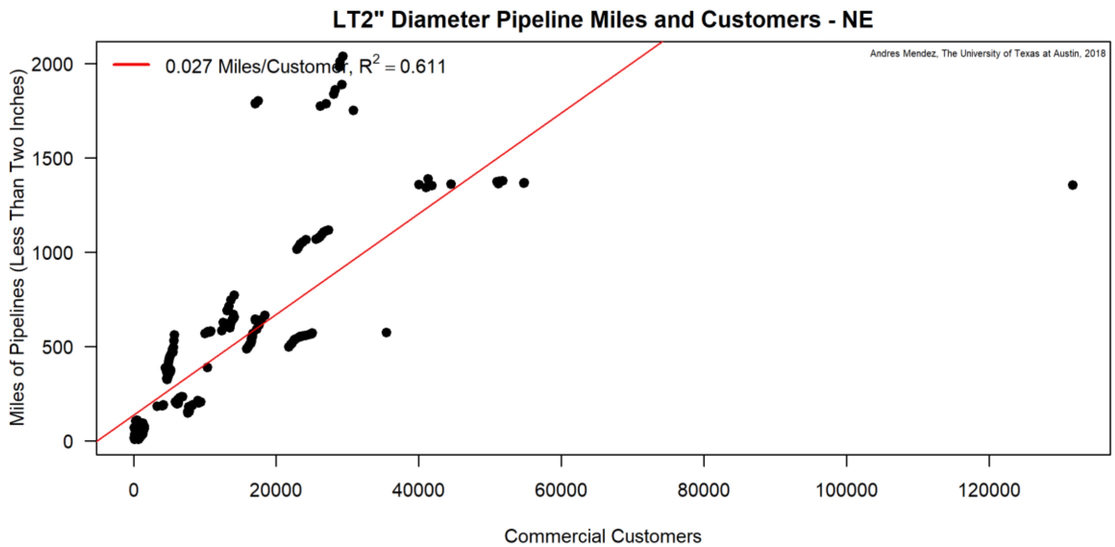

Figure A21: Distribution Pipeline Miles and Commercial Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

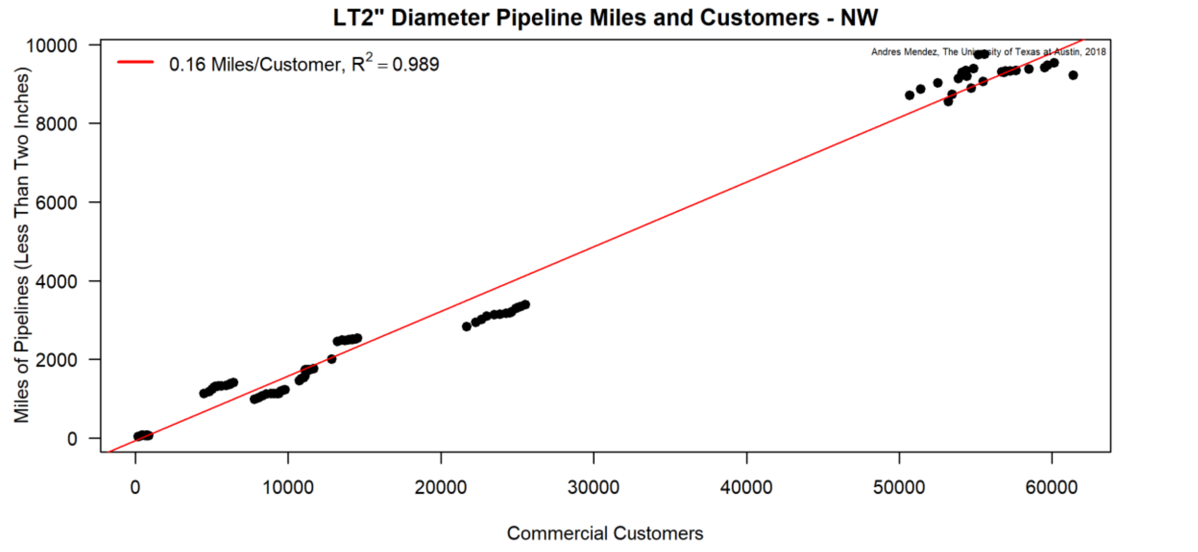

Figure A22: Distribution Pipeline Miles and Commercial Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

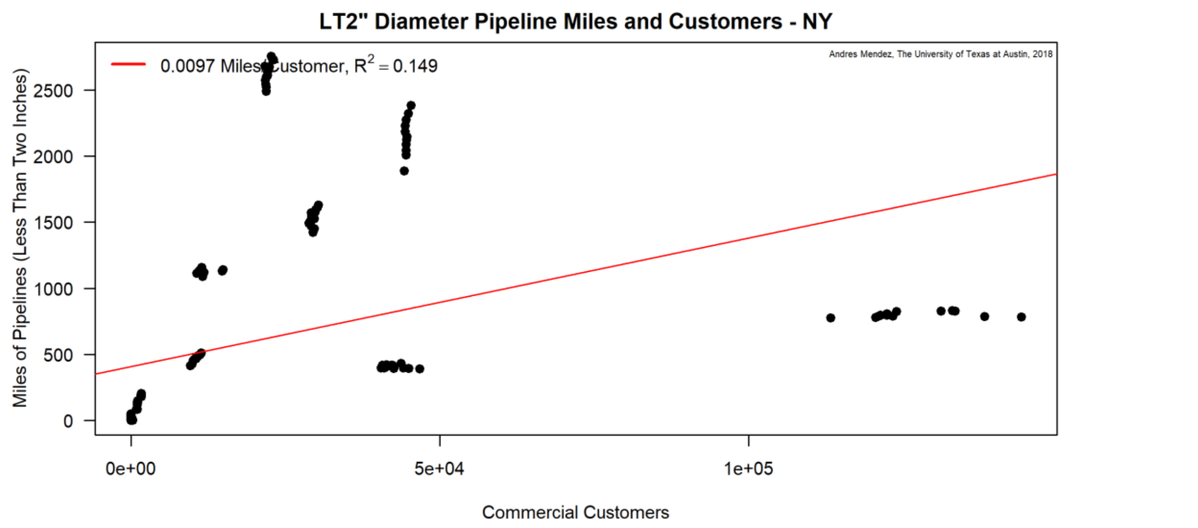

Figure A23: Distribution Pipeline Miles and Commercial Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

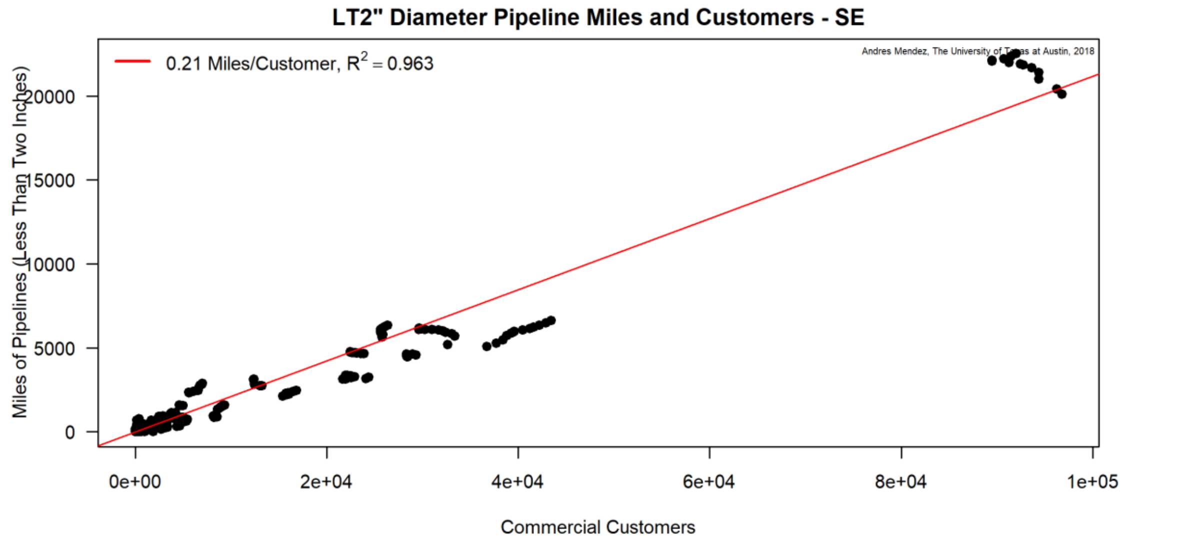

Figure A24: Distribution Pipeline Miles and Commercial Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

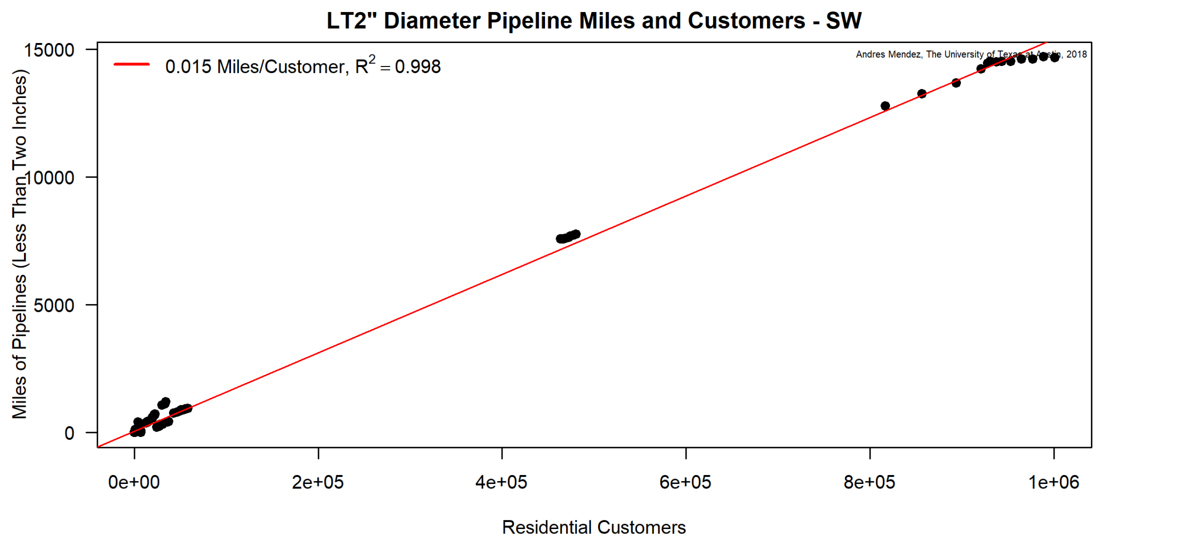

Figure A25: Distribution Pipeline Miles and Commercial Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]

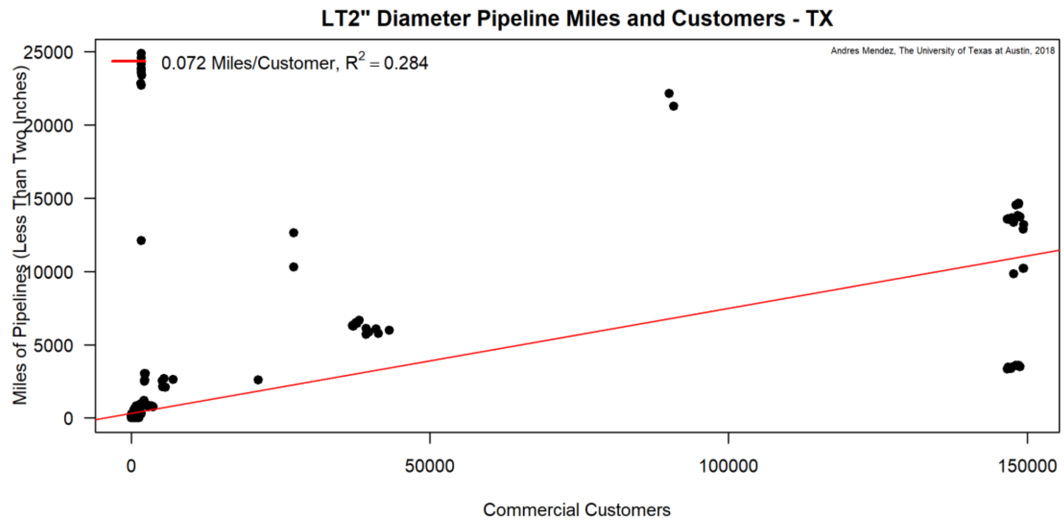

Figure A26: Distribution Pipeline Miles and Commercial Customers [Data from PHMSA (Local NG Distribution Companies) and EIA Form 176]