Mapping US Residential Methane Usage

Prepared for the Environmental Defense Fund

By:

Zachary Merrin, Paul W. Francisco

Indoor Climate Research & Training

Applied Research Institute

University of Illinois, Champaign-Urbana

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Introduction

Natural gas is a popular fuel in the United States because of its low cost and high energy density. It is used in many applications, including electricity generation, industrial processes, transportation, and space/water heating. In the residential sector, natural gas is primarily used for space heating, water heating, and cooking; however, it is also used to a lesser extent for clothes dryers, indoor fireplaces, pool heaters, backup generators, air conditioners, and outdoor lighting.

Natural gas is primarily composed of methane (CH_4), with a typical concentration of ~95%, with the remaining constituents being other hydrocarbons, nitrogen, carbon dioxide, oxygen, and hydrogen. (1) Methane is a potent greenhouse gas with a carbon dioxide equivalency of ~25 (2), and as such, efforts should be made to minimized avoidable emissions.

In an effort to spatially understand residential natural gas metrics in the United States, publically available datasets with information on natural gas consumption and natural gas fueled appliance prevalence were identified and investigated. A summary of the databased analyzed is available in Table 1.

Databases analyzed

Energy Information Agency - Annual Report of Natural and Supplemental Gas Supply and Disposition

State level survey reporting quantity of natural gas delivered to consumers, separated by commercial and residential, over yearly and monthly periods. Annual data from most states is available through 1967, and from all states through 1980 when survey response requirements became mandatory. Monthly data is available for all states through 1989.

Energy Information Agency - Residential Energy Consumption Survey

The Residential Energy Consumption Survey (RECS) was first conducted in 1978, and is currently administered every 4-6 years. The most current available full dataset is from the 2009 survey; the summary data from the 2015 survey was recently released, and the full microdata set is scheduled for release in the spring of 2017.

RECS covers many aspects of residential building characteristics and energy consumption, and includes questions on if and how much natural gas is consumed for various end uses (e.g. cooking, space heating, water heating). RECS samples a subset of US households and assigns them a weighting factor approximating how many similar households exist, allowing it to extrapolate totals for the entire US housing stock. Since the survey collects personally identifiable information, the results are anonymized, and spatial quantization is limited to a set of 27 reportable domains consisting of states and groups of states. The 2009 data surveyed 12,083 households and weighted them to represent the 113.6 million occupied primary residents in the United States.

U.S. Census Bureau – American Housing Survey

The American Housing Survey (AHS) was first conducted in 1973, and was completed annually until 1981. In 1981 as part of a cost cutting measure, the survey frequency was reduced to biennially. The survey consists of both a nationally survey, and a metropolitan survey of a subset of the larger population centers. In the most recently investigated national survey (2013, the 2015 data was released

March 29th 2017, and is not included in this report), 84,400 units were surveyed. Starting in 2007, the national and metropolitan surveys schedule changed so that they would be completed concurrently.

The metropolitan survey samples 13-14 of the 41 largest metropolitan areas, with the six largest areas (Chicago, Detroit, Los Angeles, New York, Northern New Jersey, and Philadelphia) surveyed as an enhanced sample every other survey year (once every four calendar years). Table 8 in Appendix A summarizes the metropolitan areas sampled during recent surveys. Since U.S. Code Title 13 governs this survey, the identities of the respondents must remain confidential, and public use data is disclosed in a format that attempts to not attribute any data to a group smaller than 100,000 people. (3) For some metropolitan survey years, the data was quantized to individual zones, which the census defines as "a socio-economically homogeneous area of greater than 100,000 population." Since these zones are inconsistent between survey years, the Census stopped reporting them after 2011 based on the concern that groups smaller than 100,000 people could be identified by extrapolating sub-zone regions from combining multiple year's zone boundaries.

The AHS included information on whether or not the household uses natural gas, and the fuel most used for space heating, water heating, cooking, and clothes drying.

U.S. Census Bureau – American Community Survey

The American Community Survey (ACS) is part of the Census Bureau Decennial Census Program and is "designed to provide communities with reliable and timely demographic, social, economic, and housing data every year." (4) The survey assesses approximately 1 out of every 38 U.S. households, and releases the results annually with 1-year, 3-year, and 5-year estimates. Among other things, the ACS collects information on the primary fuel used for space heating, and reports spatially to a county level.

Local Datasets

Chicago, IL: Energy Usage 2010

The Chicago City Data Portal published data on the energy consumption of households, businesses, and industries during the 2010 calendar year. The local utilities provided data that encompassed 88% of the buildings, and 81% of all natural gas consumption at that time. (5) Data was spatially quantized down to the census block level, but for confidentiality reasons geographic data for census blocks with fewer than four accounts is omitted.

Gainesville, FL: Customer Natural Gas Consumption

The city of Gainesville, FL has generated a database containing service-address level data on energy consumption for all Gainesville Regional Utility customers. The dataset covers calendar years January 2012 – June 2015, and contains total annual consumption of natural gas measured in therms. The database does not identify or separate residential and non-residential customers.

Appliance Saturation Studies

Three residential appliance saturation studies were located including two state studies (California and Massachusetts) and one regional study (Midwest: Indiana, Kentucky, Michigan, Missouri, and Ohio). These studies collected data primarily via voluntary surveys about appliance prevalence and practices. The California survey also collected data on consumption.

Non-Exhaustive Datasets

There are several datasets available providing information about a specific subset of households (e.g. households that volunteered their data or participated in a particular utility program). Information from these datasets can be misleading because the scope of the data is limited, likely introducing selection bias. The most significant of these datasets is likely the Department of Energy's Building Performance Database (BPD), which contains information on buildings locations, use, and physical/operational characteristics, including the system and fuel used for space heating, as well as the energy use intensity (EUI). The BPD currently contains information from over 743,000 residential buildings, but nearly 87% of those are located in California.

Database Summary

Table 1 - Summary of Databases Analyzed

Database	Source	Space scope (quanta)	Time Scope (quanta)	Exhaustive	Nat Gas Consumption	Nat Gas Appliances
Annual Report of Natural and Supplemental Gas Supply and Disposition	Energy Information Agency (EIA)	USA (state)	1982-2016 (monthly)	True	True	False
Residential Energy Consumption Survey (RECS)	Energy Information Agency (EIA)	USA (state)	1978-2009 (~5 years)	True	True	False
American Housing Survey (AHS) - National	U.S. Census Bureau	USA (state)	1973-2015 (biennial)	True (representative sample)	False	True
American Housing Survey (AHS) - Metropolitan	U.S. Census Bureau	25 cities (zones/ city)	1974-2015 (biennial)	Representative sample in select cities	False	True
American Community Survey (ACS)	U.S. Census Bureau	USA	2000-2015 (annual)	True (representative sample)	True	False
California Energy Consumption Database	California Energy Commission	CA (county)	2006-2009	True	True	False
Customer Natural Gas Consumption	Gainesville Regional Utilities	Gainesville, FL (address)	2012-2015	True	True	False
Building Performance Database	Department of Energy	USA (CA centric)	NA	False	True (EUI only)	True
Chicago Energy Use 2010	City of Chicago Data Portal	Chicago, IL	2010	88% of buildings 81% of gas consumption	True	False

Massachusetts Residential Appliance Saturation Survey	Opinion Dynamics Corporation	MA (stratum)	2008	~3000 surveyed respondents extrapolated	False	True
Midwest Residential Market Assessment And DSM Potential Study	Summit Blue Consulting, LLC	IN, KY, MI, MO, OH (state)	2004	Surveyed 96 respondents in each of the 5 states	False	True
California Statewide Residential Appliance Saturation Study	California Energy Commission	CA (utility service area, and CA Building Climate Zones – 16)	2009	Sample of ~100,000 individually metered households	True	True

Results

Consumption

Total Consumption

Figure 1 and Figure 2 show the total (non-per capita) consumption of natural gas for residential end use as an annual average between 1/1989 and 9/2016, and during the 2015 calendar year respectively. Within a climate zone, natural gas consumption is highest in the states with larger populations. Natural gas use is also higher in the Midwest and Northeast – with the exception of New England where oil use is prevalent – than in most parts of the country other than California and Texas.

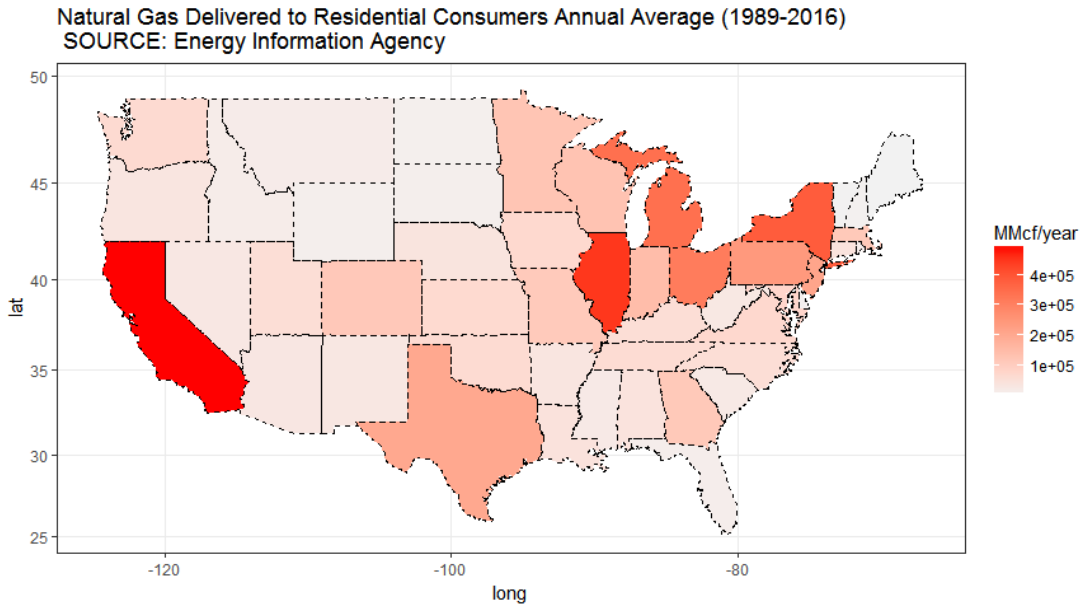


Figure 1 – Natural Gas Delivered to Residential Consumers (Annual Average 1989-2016)

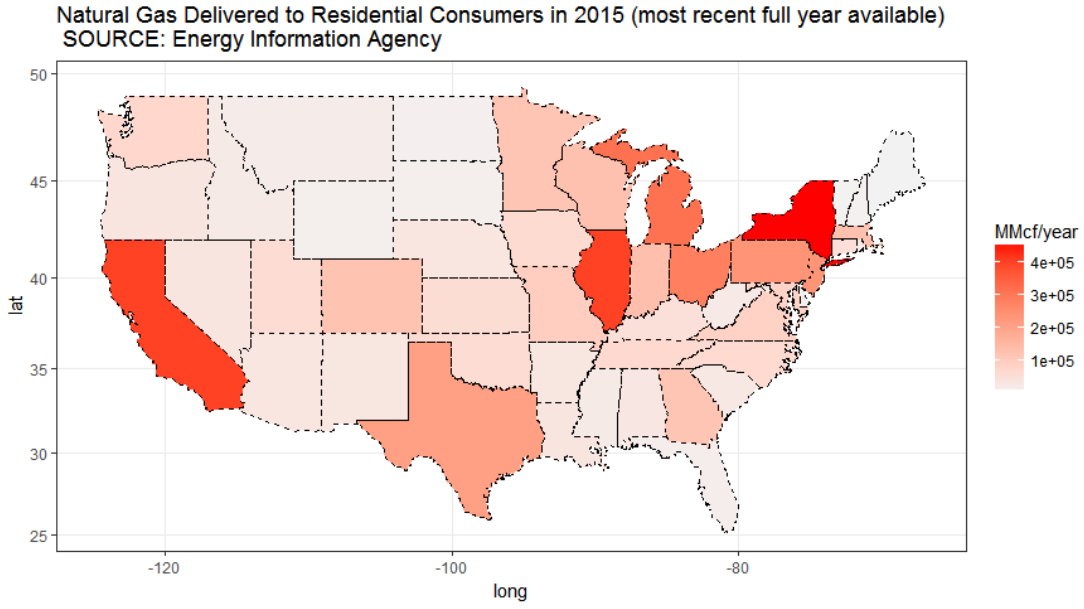


Figure 2 – Natural Gas Delivered to Residential Consumers in 2015

Figure 3, Figure 4, and Figure 5 show the monthly consumption of natural gas for each state in various levels of detail. As expected, natural gas consumption is at a maximum during the winter months, and a minimum during the summer months, corresponding with space heating demand.

These graphs also show that California has a much higher "floor" of usage, at about 25,000 MMcf/month, than any other state (Figure 3). Even for the four other states with the highest usage the monthly consumption in the summer is typically under 10,000 MMcf, as seen in Figure 4 and Figure 5. However, in winter, Illinois usually exceeds California's usage, and other states exceed California in some years. These findings reinforce the impact that California's large population can have on total natural gas consumption, despite its mild climate.

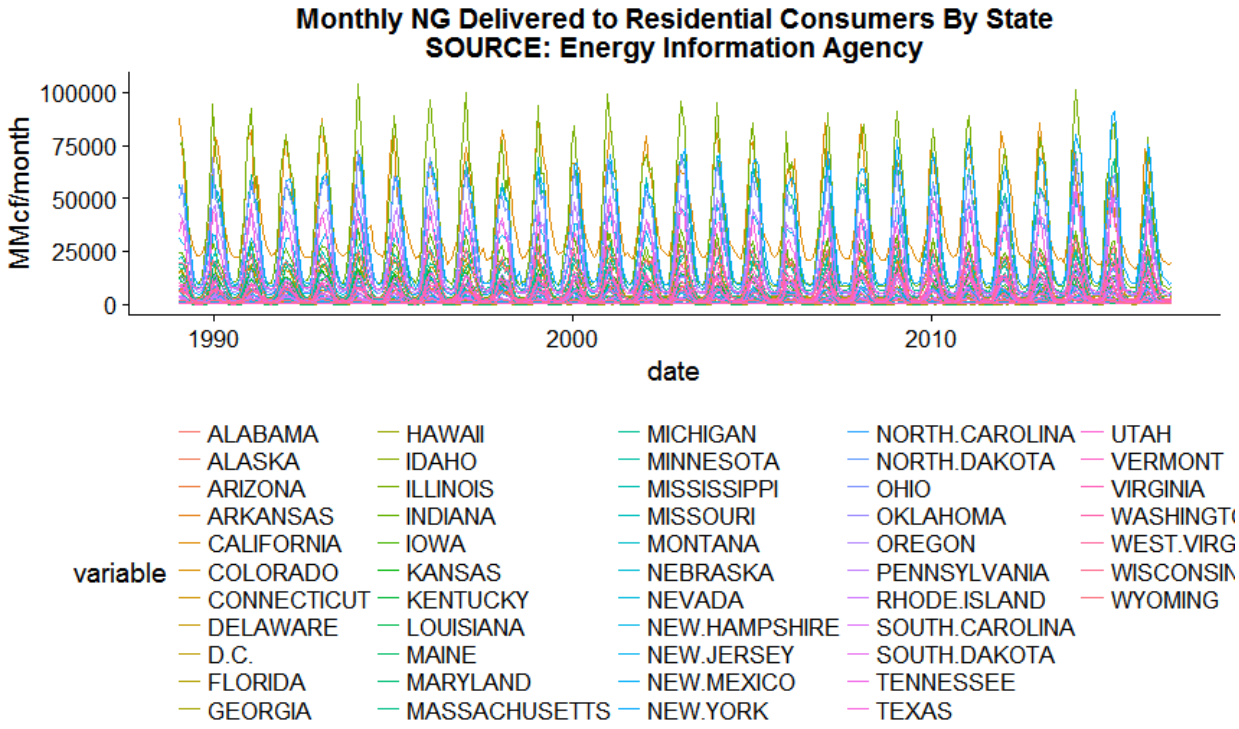


Figure 3 – Monthly Residential Natural Gas Deliveries (All States)

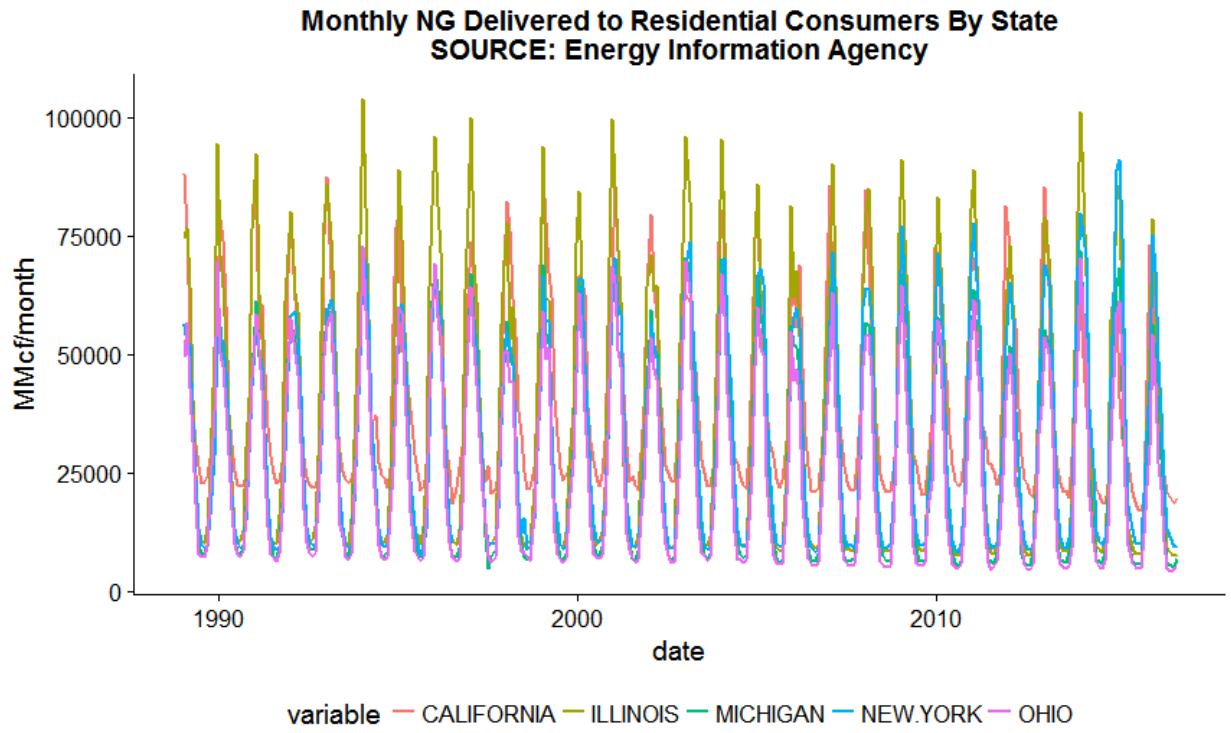


Figure 4 – Monthly Residential Natural Gas Deliveries (Highest Consuming States)

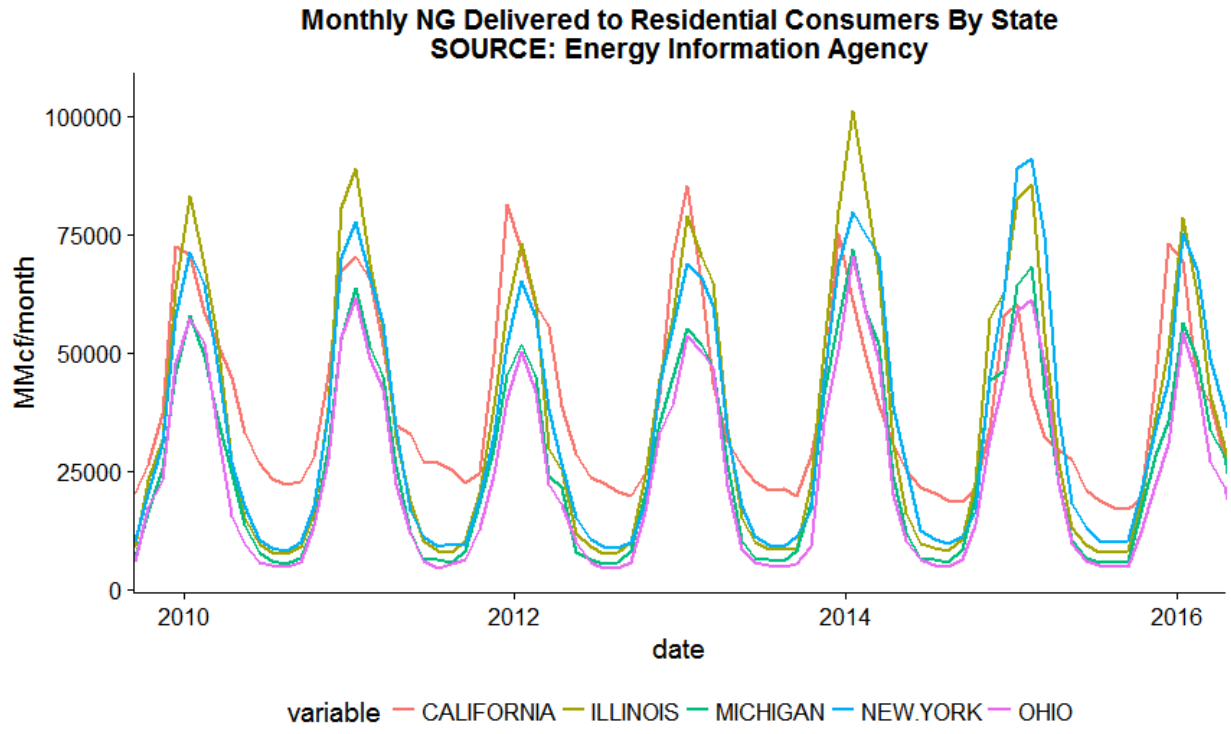


Figure 5 – Monthly Residential Natural Gas Deliveries (Highest Consuming States – 2010-2016 Detail)

Figure 6 shows the annual trend of natural gas consumption for each state between 1976 and 2015. This graph shows that changes in residential gas usage over the last 48 years have been modest. There is some evidence that states at the lower end of usage have experienced modest increases, likely as gas infrastructure has become more commonplace. California, the state with the highest historical usage, has experienced a reduction. Given the growth in the number and size (6) of homes and the increased demand for natural gas appliances, the overall trend of usage remaining approximately constant reflects the increasing efficiency of both homes and appliances.

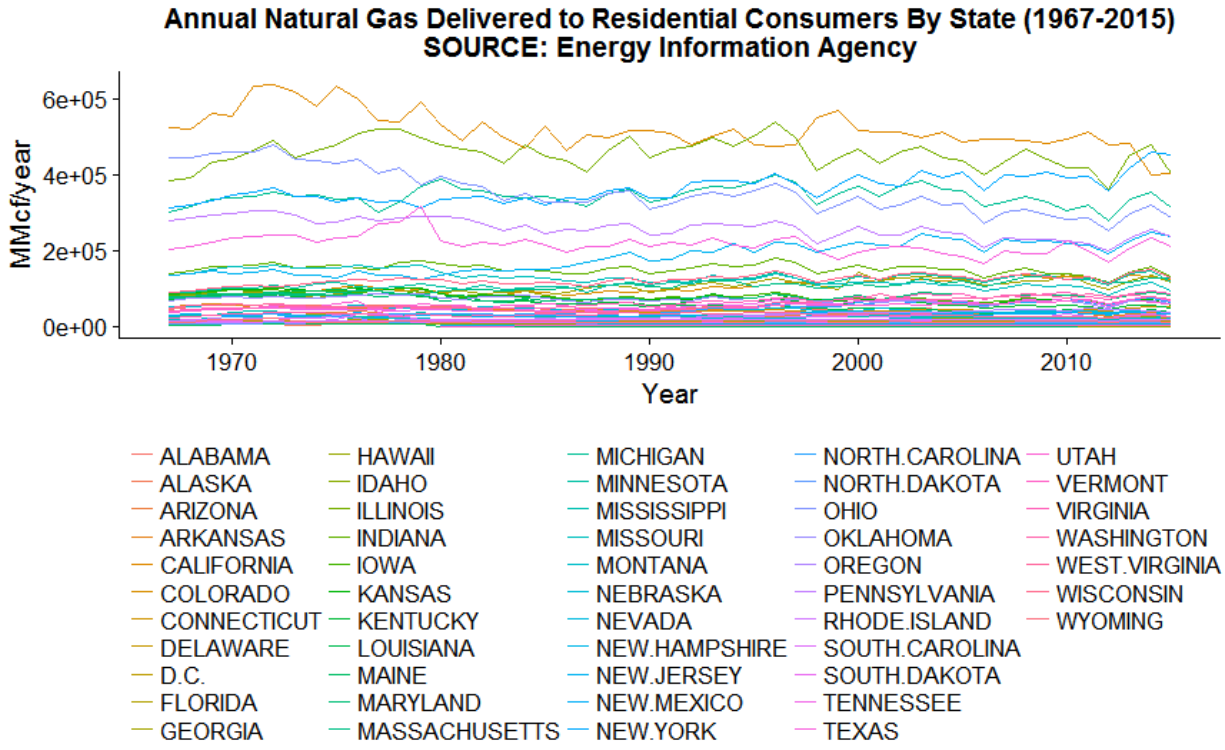


Figure 6 - Annual Residential Natural Gas Deliveries (All States)

Nationwide Per-Capita Natural Gas Consumption

Although the information about the absolute state level natural gas consumption can give insights into where natural gas is consumed, much of the data is determined by total population. State level per capita consumption data can give a better insight into trends in natural gas usage. Whereas states like California and Texas ranked highly in the absolute natural gas consumption (1 and 8, respectively), they rank much lower in per capita consumption (29 and 42, respectively), whereas states with colder climates like Illinois and Michigan rank 1 and 2, respectively (Figure 7 and Figure 8). Overall, per capita usage is highest in colder climates. New England has much lower per capita usage than other Northern states because of the prevalence of fuel oil. The Northwest has lower per capita usage than other Northern states because the climate is milder along the more densely-populated Pacific Coast and because hydroelectric power makes electricity much more inexpensive than most other locations within the U.S, leading to higher utilization of electricity for space and water heating.

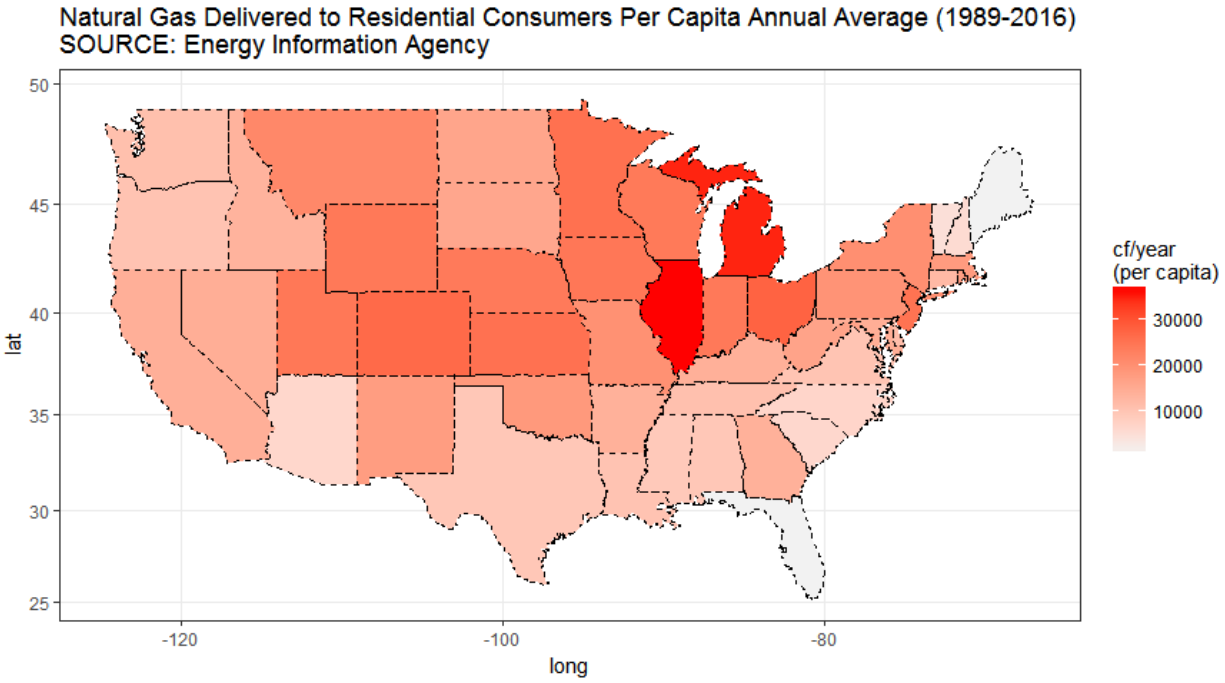


Figure 7 – Per-Capita Natural Gas Delivered to Residential Consumers (Annual Average 1989-2016)

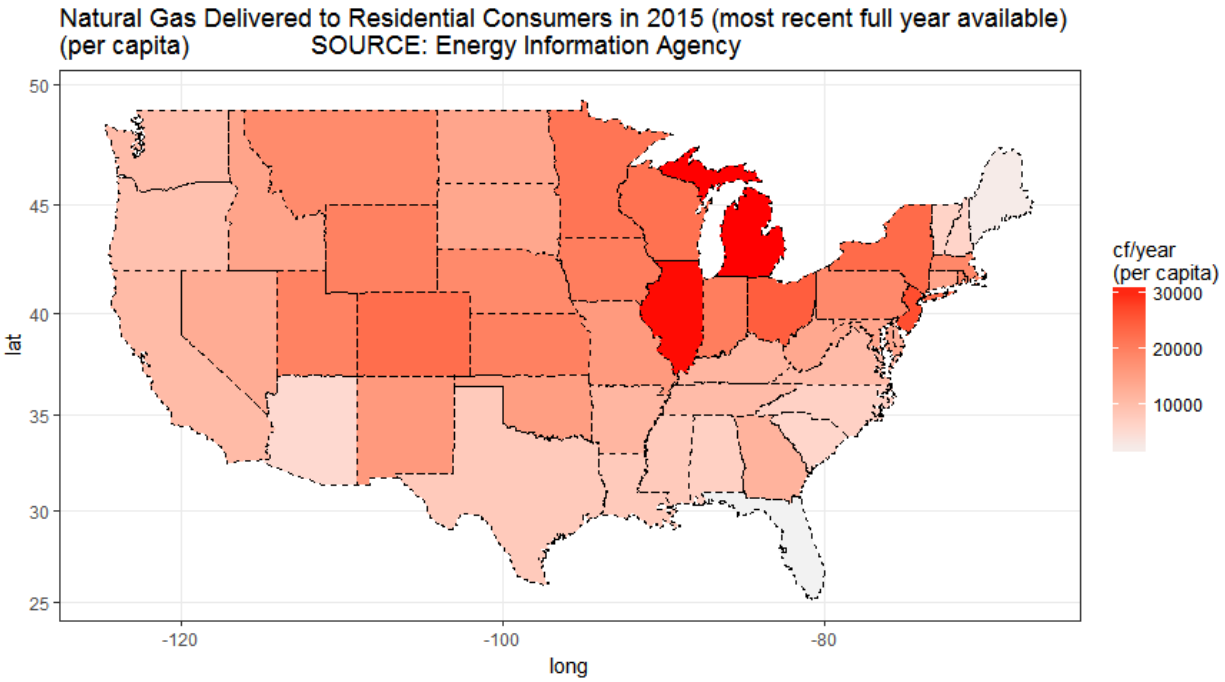


Figure 8 – Per-Capita Natural Gas Delivered to Residential Consumers in 2015

Figure 9 shows the distribution of total natural gas consumption for each of the reportable domains (RD) in the 2009 RECS database, sorted and colored by the weighted average heating degree day (HDD65) for the RD occupants. The graph shows a trend for more overall natural gas consumption in RD where there is a higher average HDD65. More detailed similar analysis for specific natural gas end uses are included in subsequent sections.

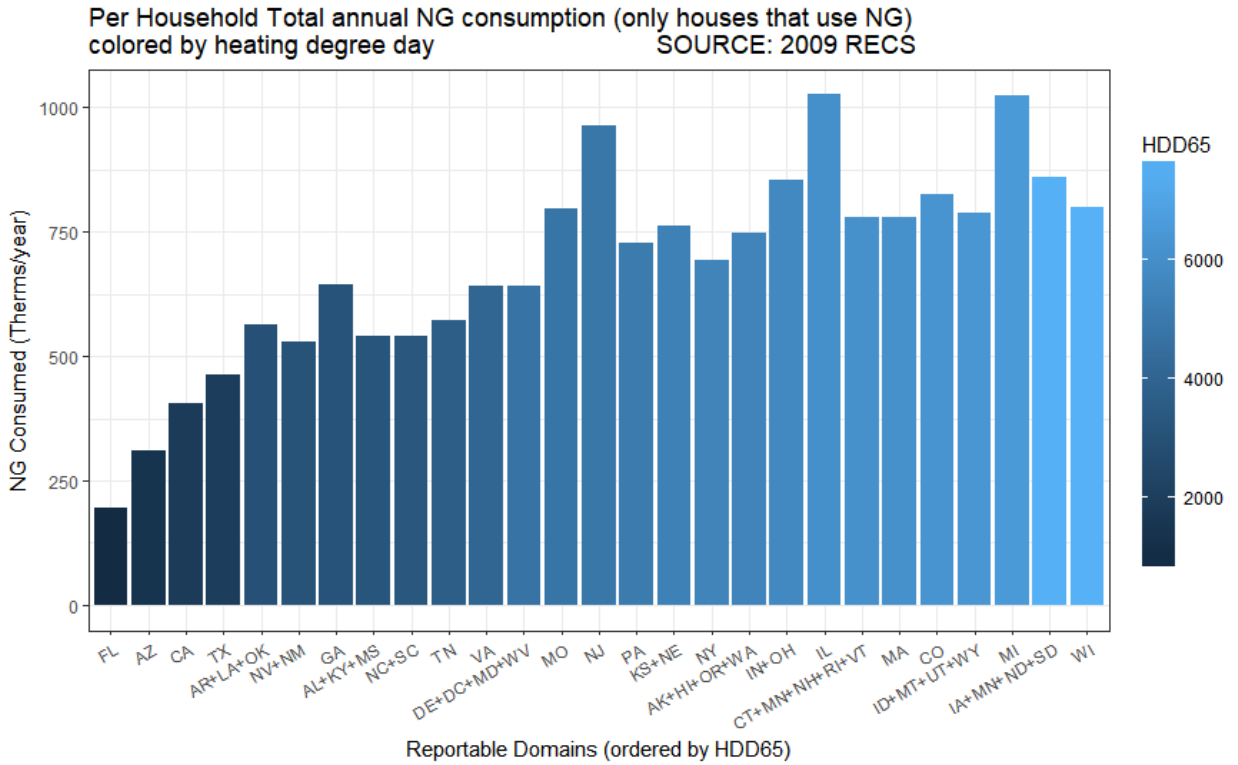


Figure 9 – Per Household Total Natural Gas Consumption Sorted by Heating Degree Day

Similar to the previous section, Figure 10, Figure 11, Figure 12, and Figure 13 show the patterns in per capita natural gas consumption over time. Figure 10 shows the trend for all states. Figure 11 shows the trend for the five states with the highest total consumption, and shows that California has a per capita use much lower than the other four states. In Figure 12 and Figure 13 (which show the per capita natural gas consumption for the highest and lowest overall consuming states, for years since 2010) it is clear that although the winter demand varies significantly based on the climate, the summer demand is relatively similar. This is predominantly because consumption for non-space heating uses (primarily, cooking and water heating) is minimally impacted by outdoor conditions. The relative stability of the summer time consumption between years makes sense since the combustion technology that cooking and water heating appliances utilize has not changed substantially in recent years (compared to space heating appliances, which are largely transitioning to higher efficiency sealed combustion).

For the three lowest per-capita usage states, Hawaii uses almost no natural gas, and its consumption pattern does not change seasonally. Florida's consumption does exhibit a winter increase that is related to winter severity (as based on seasonal HDD65), but does not show a clear trend in recent years. Maine is experiencing growth in per capita natural gas usage, suggesting that some people are switching from fuel oil to natural gas.

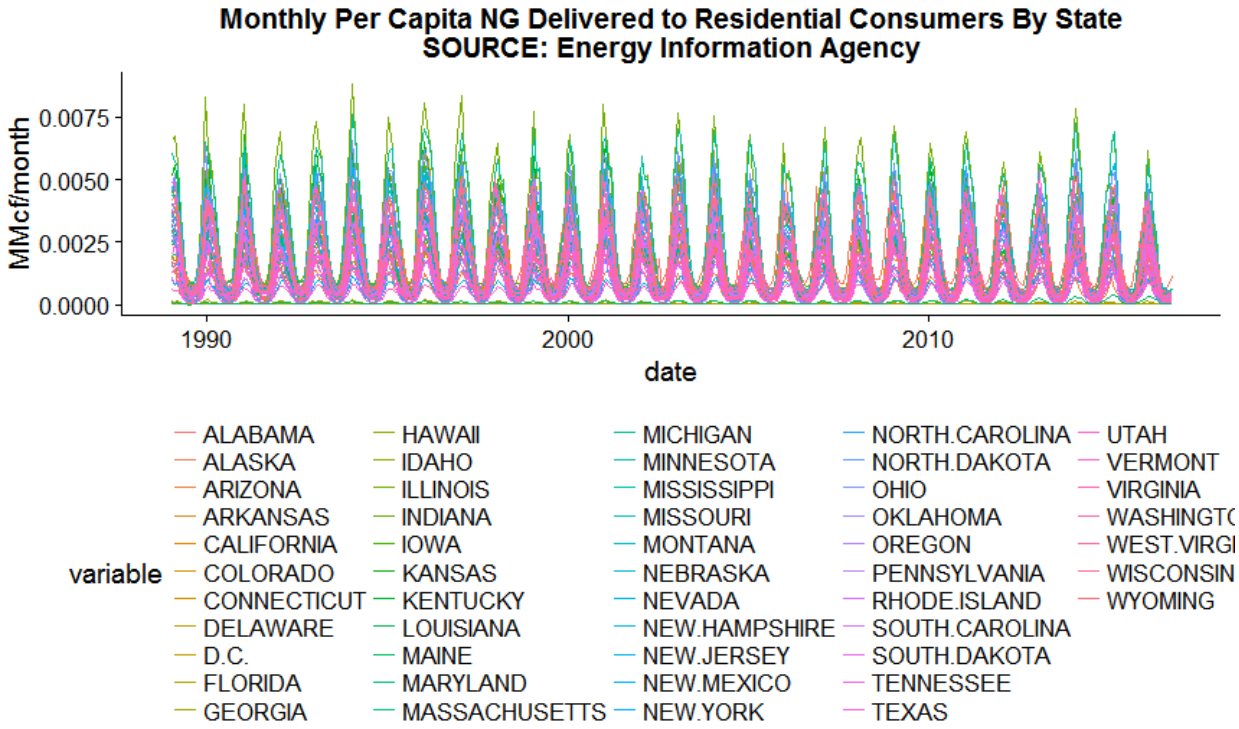


Figure 10 – Per-Capita Monthly Residential Natural Gas Deliveries (All States)

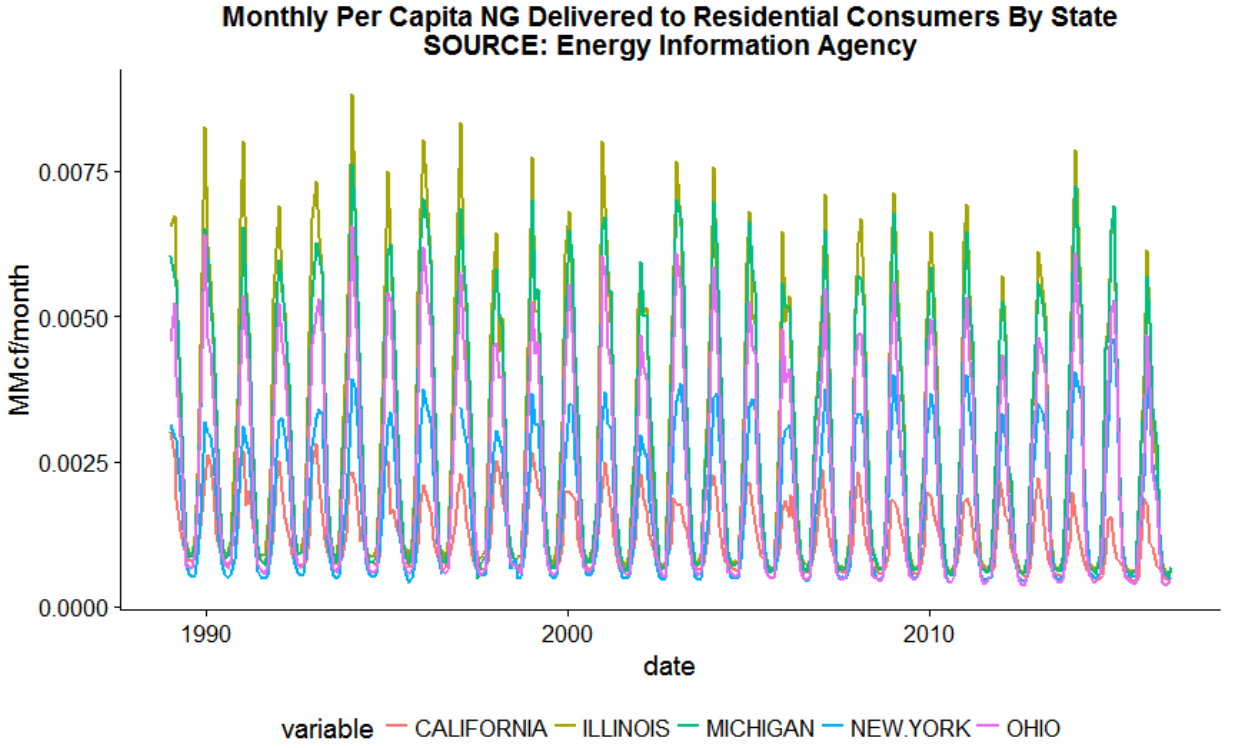


Figure 11 – Per-Capita Monthly Residential Natural Gas Deliveries (Highest Overall Consuming States)

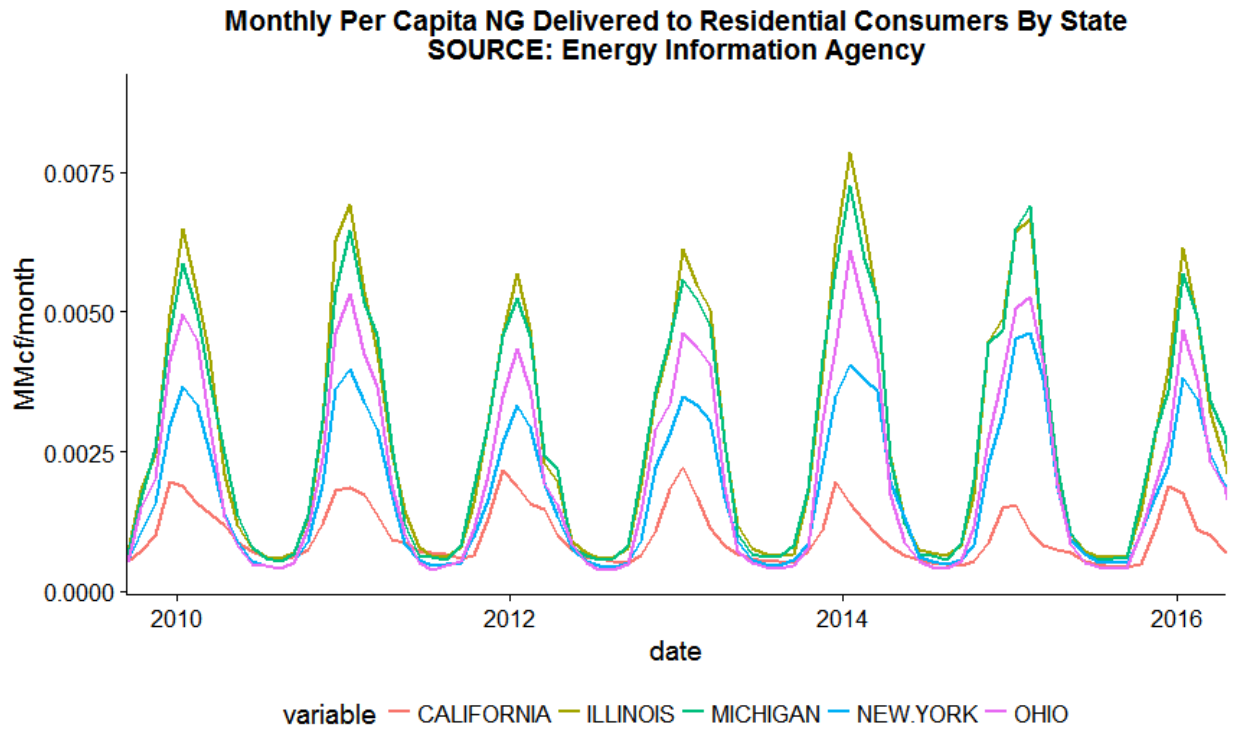


Figure 12 – Per-Capita Monthly Residential Natural Gas Deliveries (Highest Consuming States – 2010-2016 Detail)

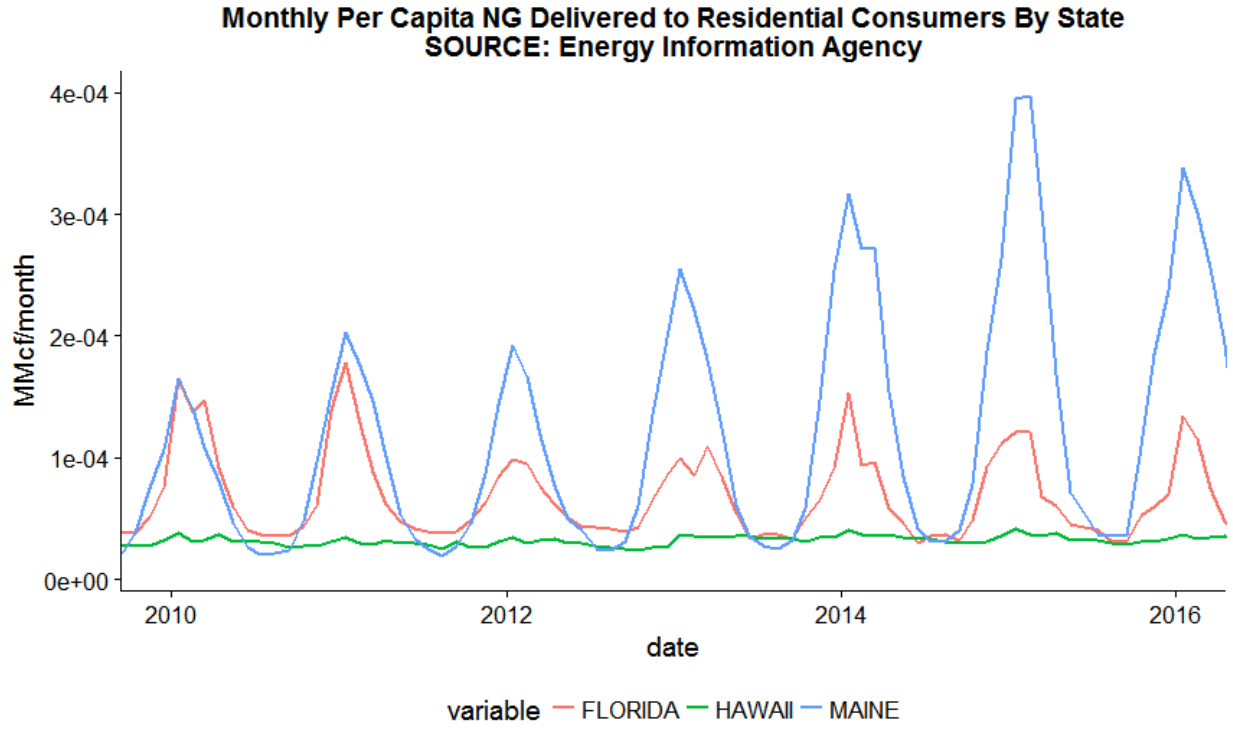


Figure 13 – Per-Capita Monthly Residential Natural Gas Deliveries (Lowest Consuming States – 2010-2016 Detail)

Figure 14 shows the trend of per capita natural gas consumption. Because this is per capita, it is not subject to more widespread demand for natural gas in the same way that total usage shown in Figure 6 is. In this case, there is a trend of reduced per capita natural gas consumption, reflecting the improved efficiency of homes and heating appliances. There is a trend for reduced consumption as buildings and appliances get more efficient, despite the increase in home size and per-person square footage. (6)

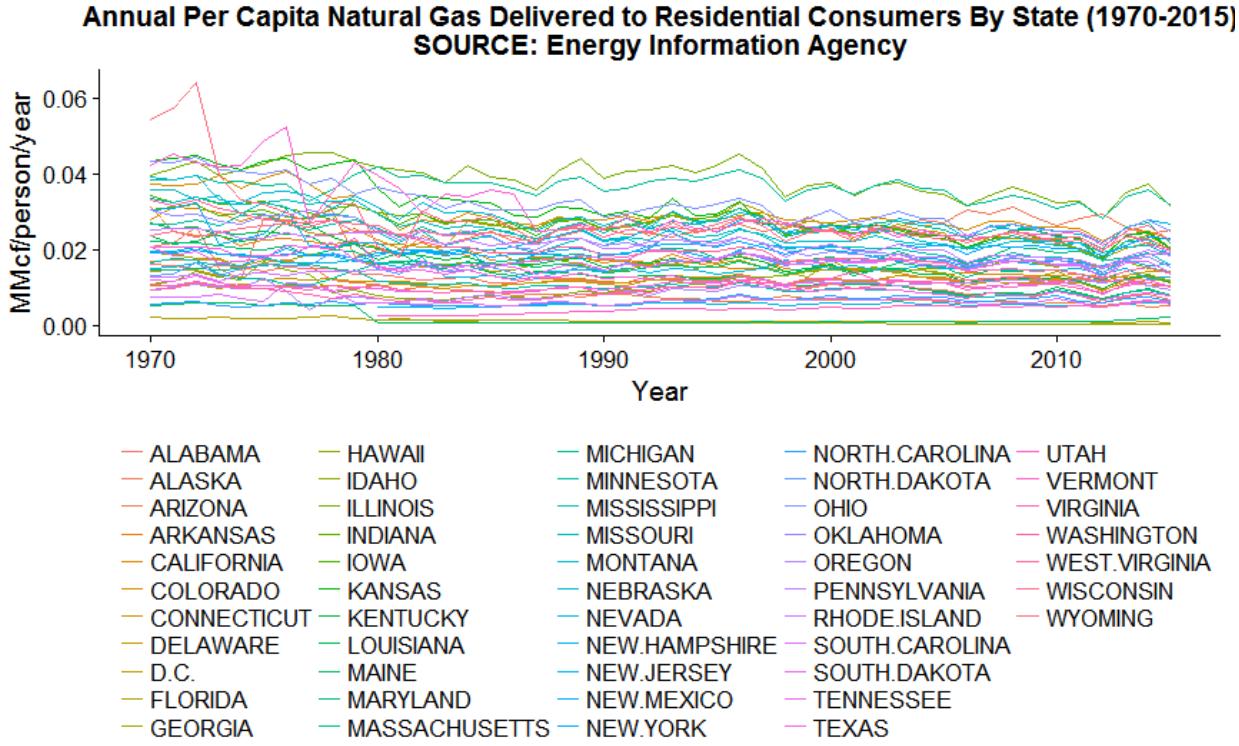


Figure 14 – Per-Capita Annual Residential Natural Gas Deliveries (All States)

Distribution of Consumption

Figure 15 - Figure 16 show the ratio of urban natural gas consumption compared to less urban areas. In all cases the trend is for urban areas to use vastly more natural gas than other areas. A map identifying urban and rural areas is presented in Figure 43. This allows usage estimates from urban areas to represent most of the natural gas consumption in many of the reportable domains.

Figure 15 – Ratio of natural gas consumed in urban relative to rural areas

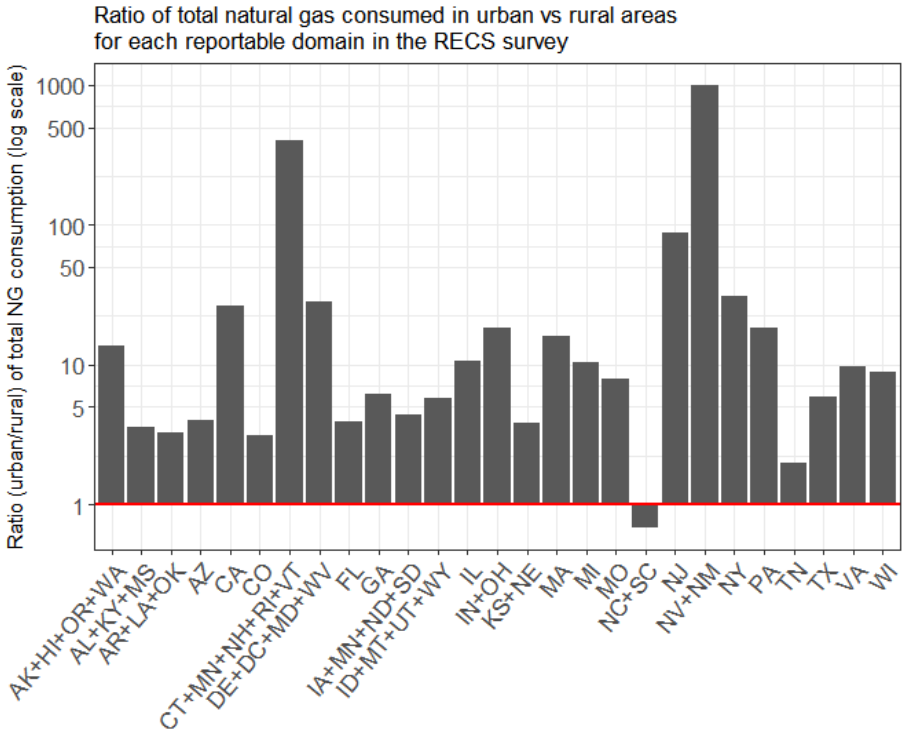


Figure 16 - Ratio of natural gas consumed in urban relative to rural areas (NM & NV excluded)

Figure 17 shows the ratio of natural gas consumed in metropolitan vs micropolitan areas. Similar to the urban vs rural ratios, much more gas is consumed in the metropolitan areas relative to the micropolitan areas. A map identifying metropolitan and micropolitan areas is presented in Figure 42.

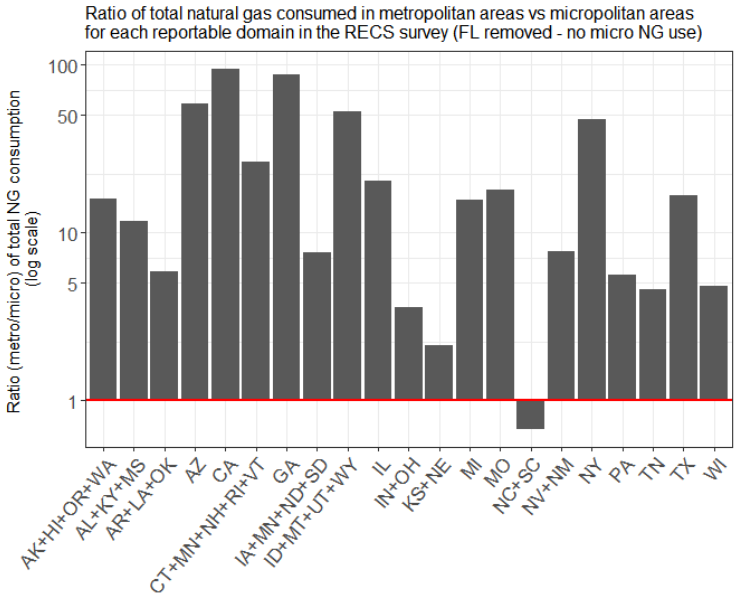


Figure 17 - Ratio of natural gas consumed in metropolitan relative to micropolitan areas

Individual State Natural Gas Consumption

California

The California Residential Appliance Saturation Survey (RASS) estimates the average natural gas usage per household and for each primary end use (Figure 18). Total consumption is estimated at 354 therms per household, with water heating, and space heating accounting for 86%. Water heating consumption is up 5% and space heating consumption is down 7% since the previous RASS in 2003. (7)

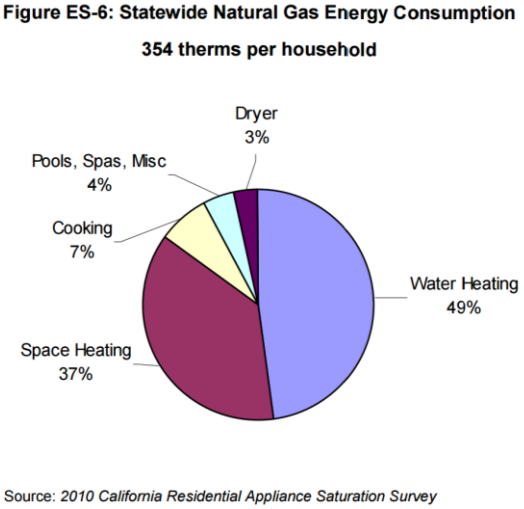


Figure 18 - California Residential Natural Gas Energy Consumption (SOURCE: 2010 California RASS)

The RASS also breaks down the Unit (Household) Energy Consumption (UEC), by utility provider (Figure 19 – left). There are three main natural gas utility providers in the state, and unsurprisingly the further north a utilities service area is, the more natural gas its customers consume overall, and for space heating specifically. The colored rectangles around the utility name in Figure 19 – left correspond to the service area's color in Figure 19 – right.

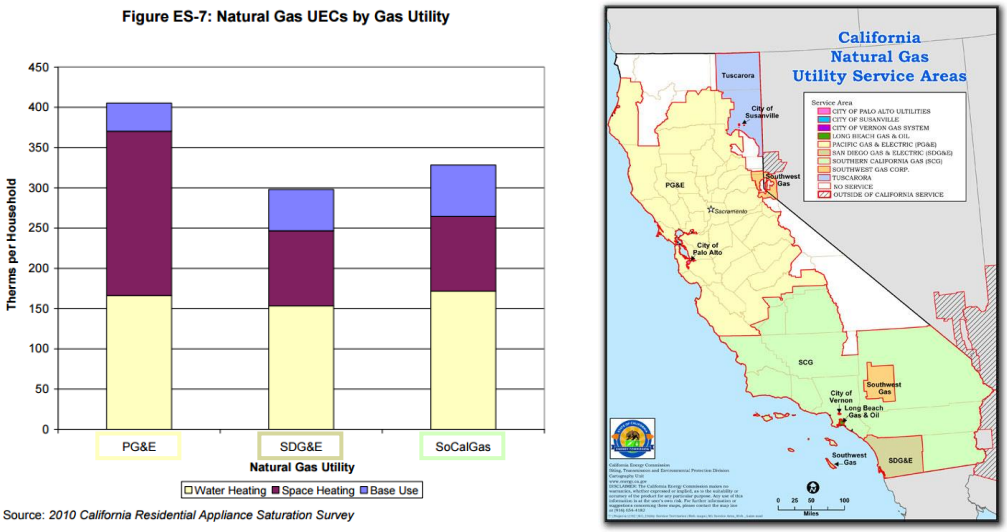


Figure 19 – Left: CA Natural Gas UEC by Utility (source 2010 RASS - modified); right: Natural Gas Utility Service Areas (SOURCE: California Energy Commission)

Additionally, California is the only state which tracks and releases its natural gas consumption by sector (residential and non-residential), at the county level. Figure 20 shows that Los Angeles county has by far the highest total natural gas consumption, but it is ranked 11th highest in per capita consumption (Figure 21).

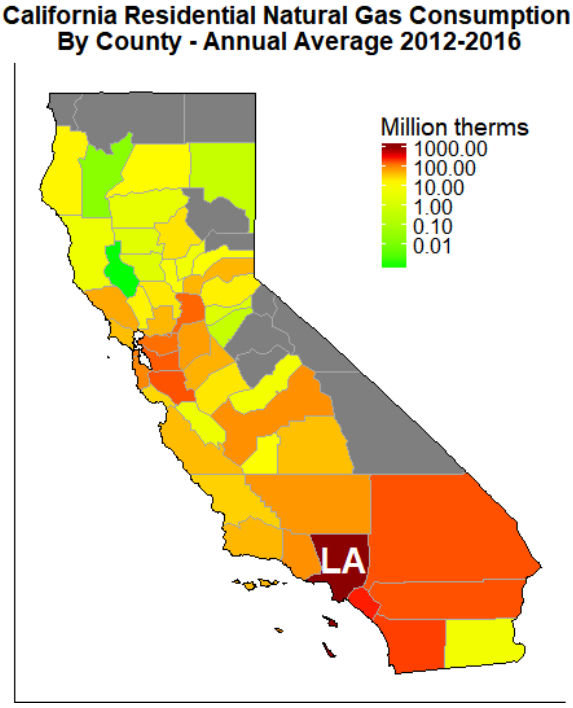


Figure 20 – California Residential Natural Gas Consumption Map by County (Annual Average 2012-2016) – gray indicates data not available

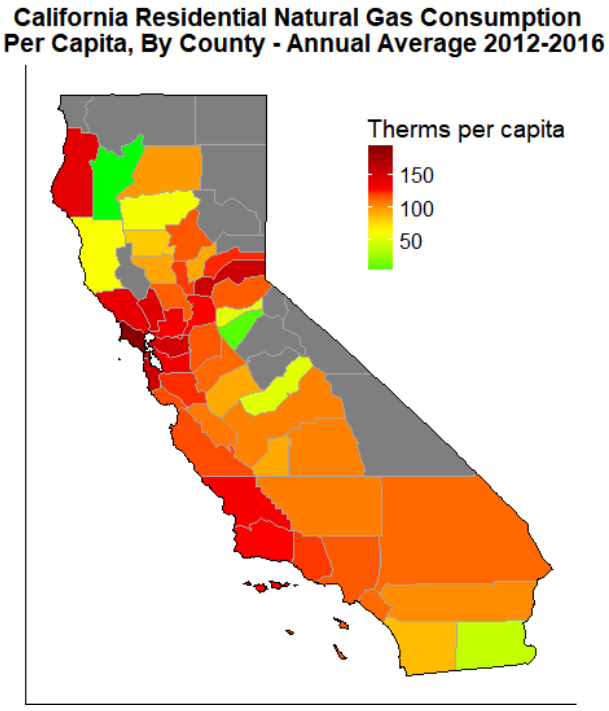
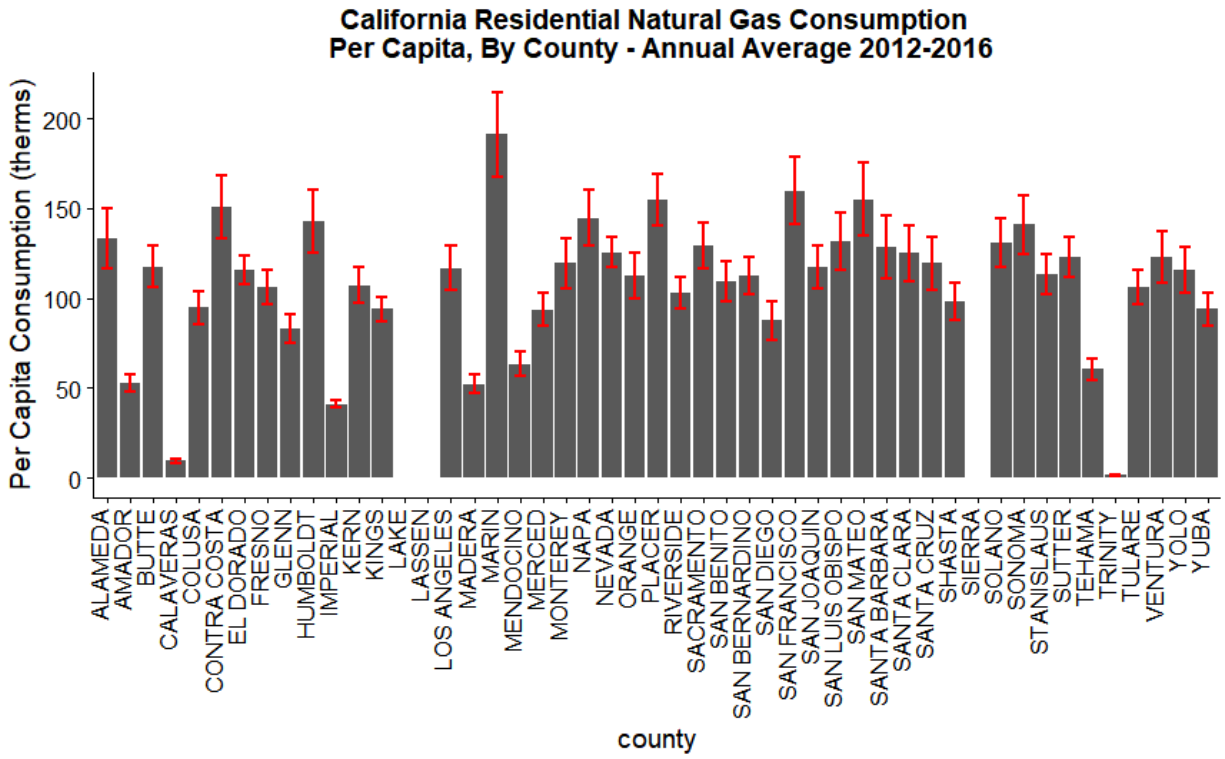
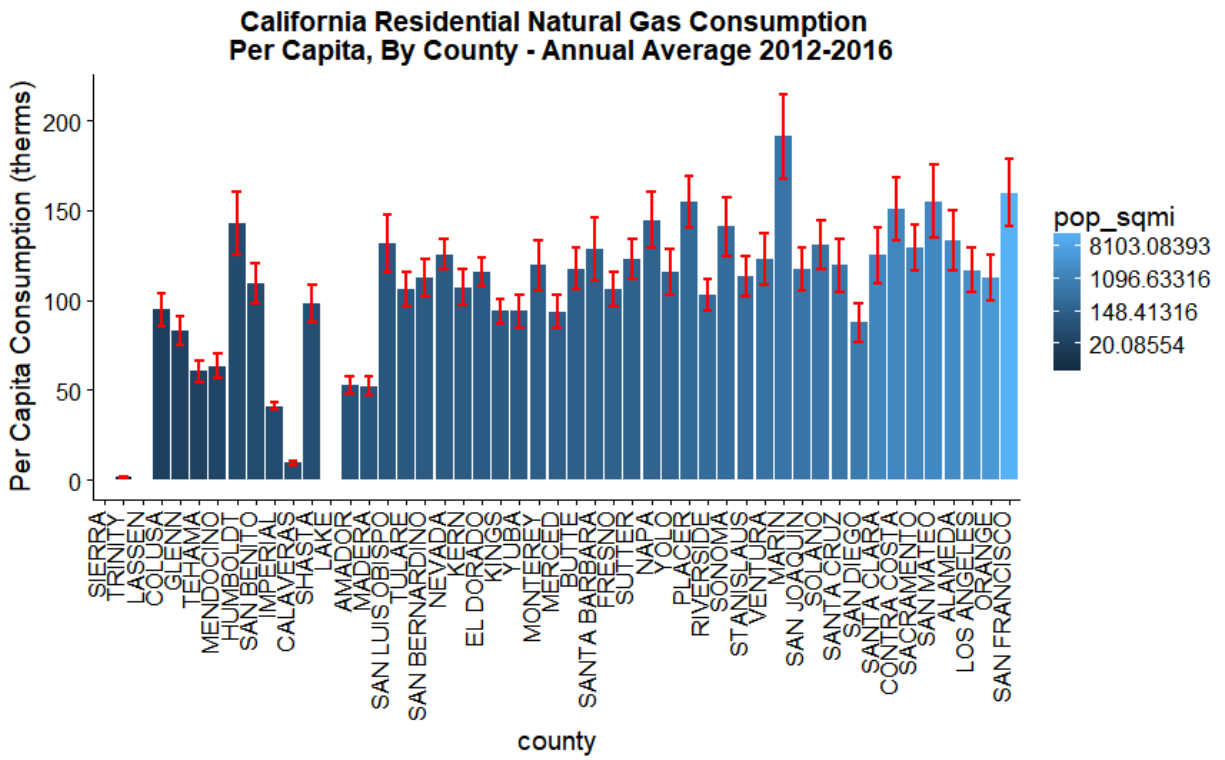


Figure 21 – California Per Capita Residential Natural Gas Consumption Map by County (Annual Average 2012-2016) – gray indicates data not available

Figure 22 and Figure 23 show the same information from Figure 20 and Figure 21 in graphical format. Note that the Y-axis in Figure 22 and Figure 23 is on a square root scale to include the high values without sacrificing detail on the lower consumption counties. Error bars correspond to standard deviation between annual consumption.


California Residential Natural Gas Consumption
Per Capita, By County - Annual Average 2012-2016
Per Capita Consumption (therms)
0
50
100
150
200
ALAMEDA
AMADOR
BUTTE
CALAVERAS
COLUSA
CONTRA COSTA
EL DORADO
FRESNO
GLENN
HUMBOLDT
IMPERIAL
KERN
KINGS
LAKE
LASSEN
LOS ANGELES
MADERA
MARIN
MENDOCINO
MERCED
MONTEREY
NAPA
NEVADA
ORANGE
PLACER
RIVERSIDE
SACRAMENTO
SAN BENITO
SAN BERNARDINO
SAN DIEGO
SAN FRANCISCO
SAN JOAQUIN
SAN LUIS OBISPO
SAN MATEO
SANTA BARBARA
SANTA CLARA
SANTA CRUZ
SHASTA
SIERRA
SOLANO
SONOMA
STANISLAUS
SUTTER
TEHAMA
TRINITY
TULARE
VENTURA
YOLO
YUBA
county


California Residential Natural Gas Consumption
Per Capita, By County - Annual Average 2012-2016
Per Capita Consumption (therms)
0
50
100
150
200
SIERRA
TRINITY
LASSEN
COLUSA
GLENN
TEHAMA
MENDOCINO
HUMBOLDT
SAN BENITO
IMPERIAL
CALAVERAS
SHASTA
LAKE
AMADOR
MADERA
SAN LUIS OBISPO
TULARE
SAN BERNARDINO
NEVADA
KERN
EL DORADO
KINGS
YUBA
MONTEREY
MERCED
BUTTE
SANTA BARBARA
FRESNO
SUTTER
NAPA
YOLO
PLACER
RIVERSIDE
SONOMA
STANISLAUS
VENTURA
MARIN
SAN JOAQUIN
SOLANO
SANTA CRUZ
SAN DIEGO
SANTA CLARA
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ALAMEDA
LOS ANGELES
ORANGE
SAN FRANCISCO
county
pop_sqmi
8103.08393
1096.63316
148.41316
20.08554

Figure 22 – California Residential Natural Gas Consumption Graph by County (Annual Average 2006-2009)

Figure 23 – California Per Capita Residential Natural Gas Consumption Graph by County (Annual Average 2006-2009)

Utah

Utah has tracked and released its total natural gas consumption for residential end uses every year since 1952 (Figure 24), which provides insight beyond the EIA dataset which only goes back to 1967. There was a steady and continuous rise in consumption until 1976, followed by a 46% reduction in 1977, likely due to the energy crisis of the decade. Following the reduction in the late 70s, consumption remained relatively level until the mid-90s when it began to increase again, and surpassed the previous 1976 record for the first time in 2011.

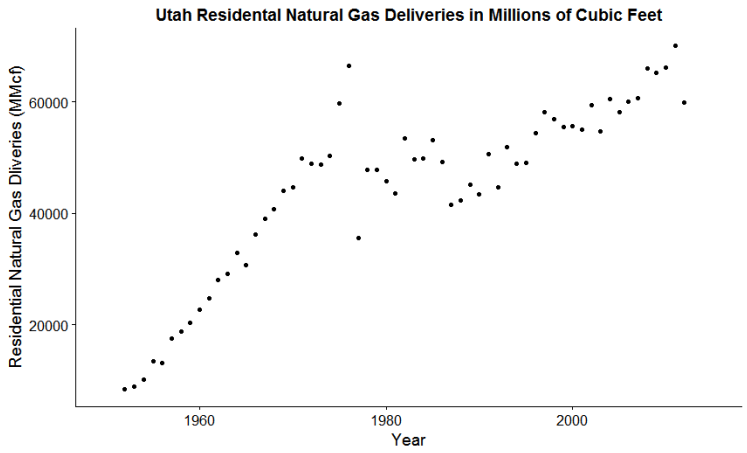

Figure 24 – Utah Residential Natural Gas Consumption vs Time

Individual Cities

Because of privacy concerns, and minimal push from the public or governing organizations for transparency, high-level spatial detail for residential energy consumption is difficult to access (8). A few notable exceptions to this trend are Madison, Wisconsin, and Gainesville, Florida, both of which provide service-address level energy consumption data, and Chicago, Illinois, which provides limited Census block level energy consumption data.

In Madison, the local utility provides a service aimed at prospective homebuyers and renters, allowing them to search for individual addresses within the utility's service area and see the historical energy consumption for that address. Unfortunately, individual address queries to the system were not feasible, and the database that the service is based on is not publically available, nor was the utility amicable to requests for access.

In Gainesville, the local natural gas supplier, Gainesville Regional Utilities (GRU), in partnership with EnergyIT created *Gainesville Green*, a resource that provides service-address level data on energy consumption. (9) While *Gainesville Green* is targeted at residential occupants and prospective buyers as a way to estimate and compare energy consumption and cost, the underlying database is available through the Open Data Network, a service from the company Socrata aiming to provide better access to government data. As is expected in a climate such as Gainesville's, most homes use little natural gas.

Figure 25, Figure 27, Figure 29, and Figure 31 show the available data on Gainesville natural gas consumption as an annual average during the calendar years 2012-2014, and the first half of 2015. The individual data points are not identified as residential vs non-residential, and even includes a cogeneration natural gas power plant, which skews the scale and obscures detail when plotting the map. For clarity purposes the scale was set to a maximum of 400 therms/year with anything at or above that value appearing identical. Accompanying those maps are Figure 26, Figure 28, Figure 30, and Figure 32, which show the histogram distribution of consumption giving a sense of how many values may appear truncated by the limitations of the color scale.

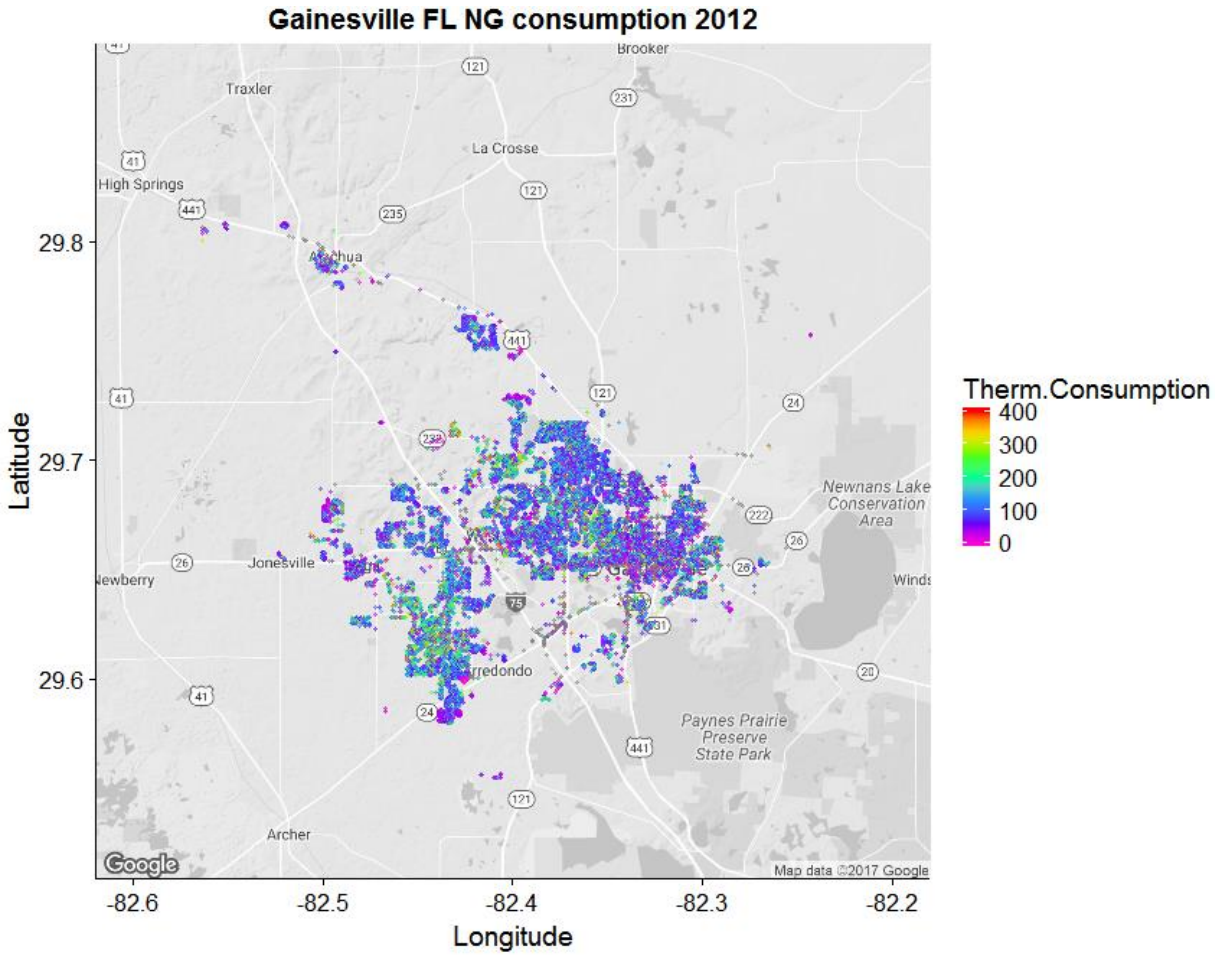

Figure 25 – Gainesville, Florida Natural Gas Consumption by Service-Address 2012

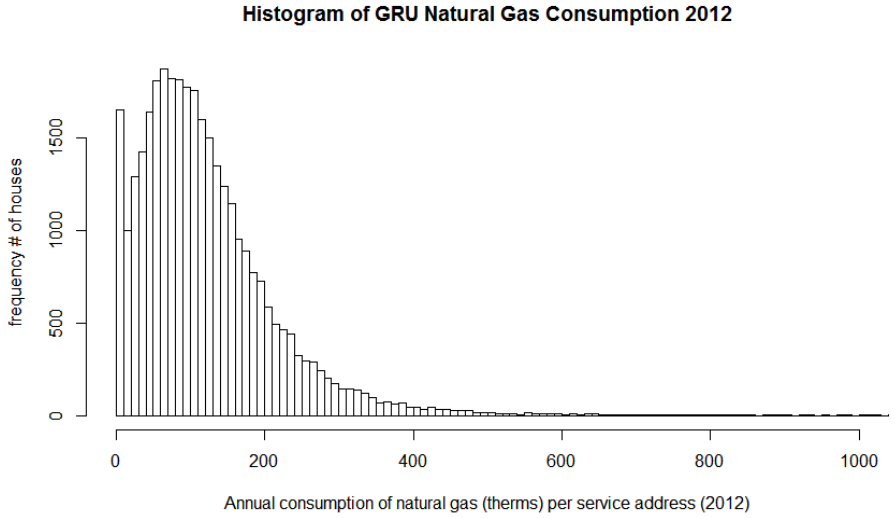

Figure 26 – Gainesville, Florida Annual Natural Gas Consumption distribution 2012

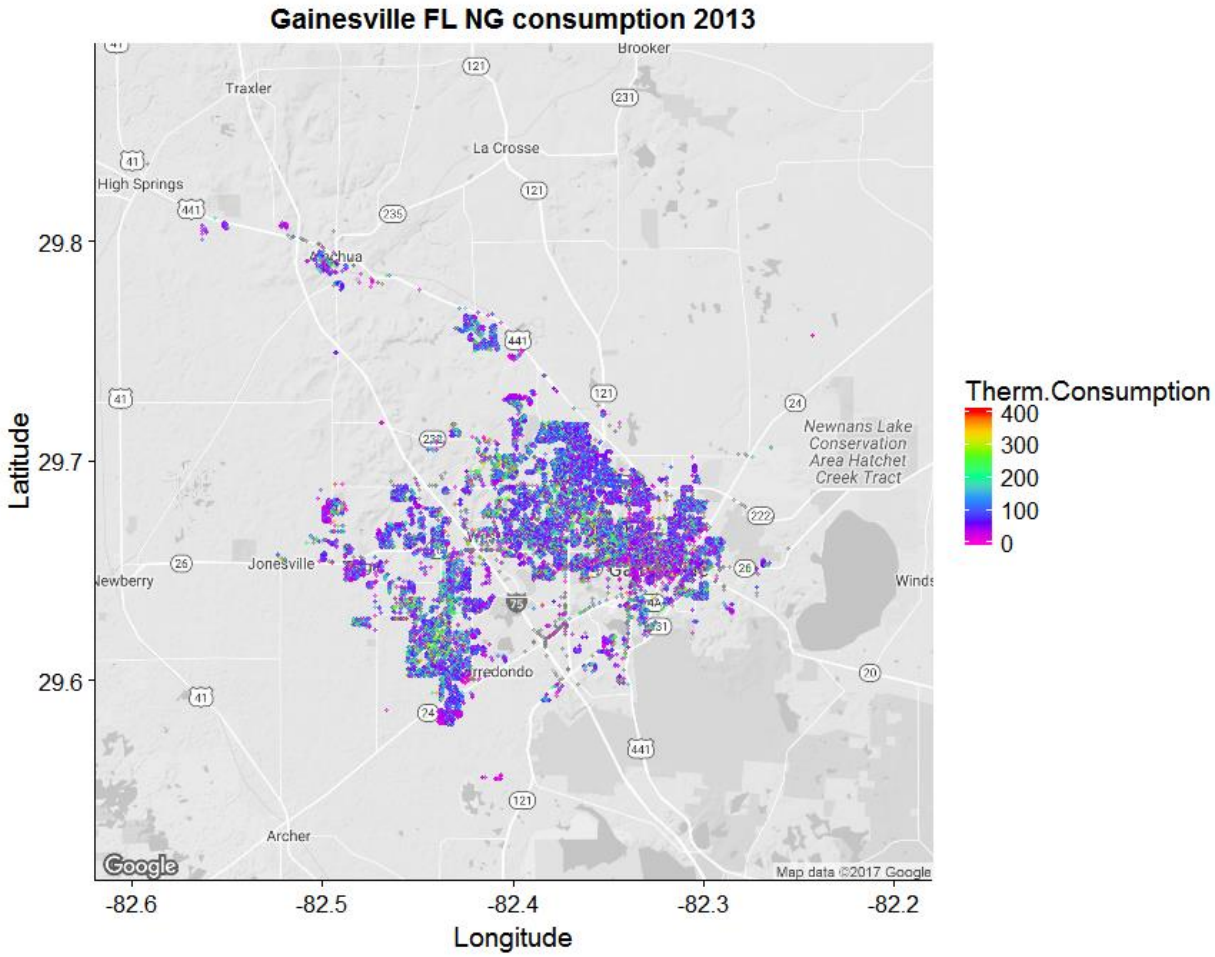

Figure 27 – Gainesville, Florida Natural Gas Consumption by Service-Address 2013

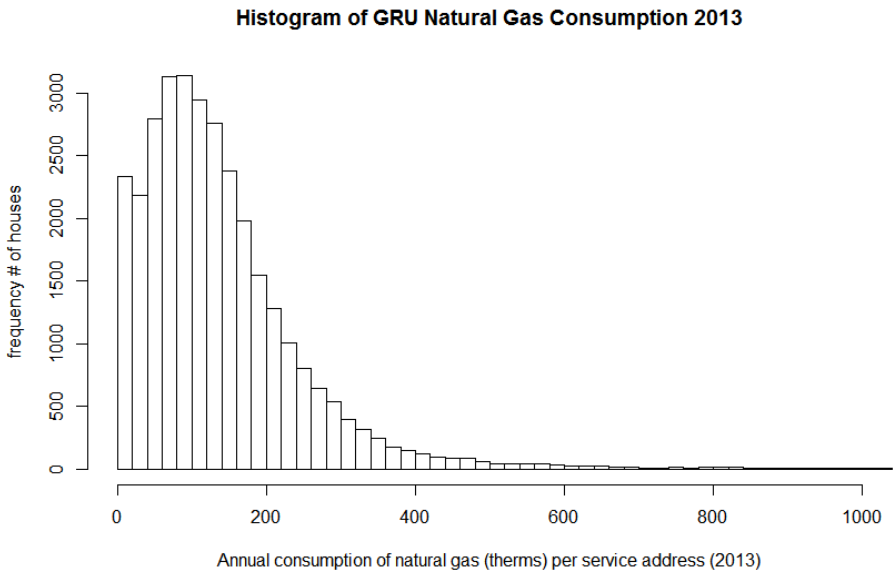

Figure 28 – Gainesville, Florida Annual Natural Gas Consumption distribution 2013

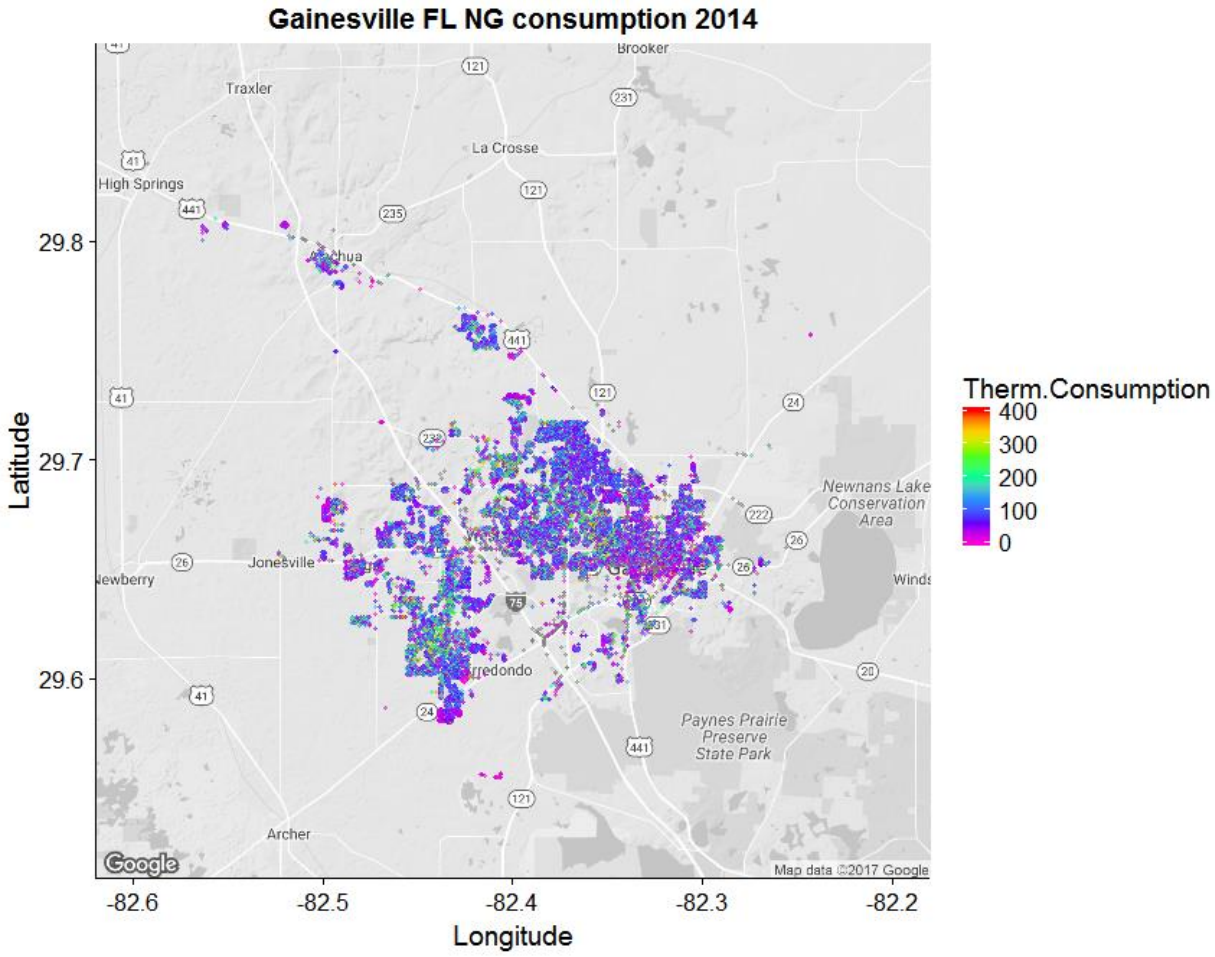

Figure 29 – Gainesville, Florida Natural Gas Consumption by Service-Address 2014

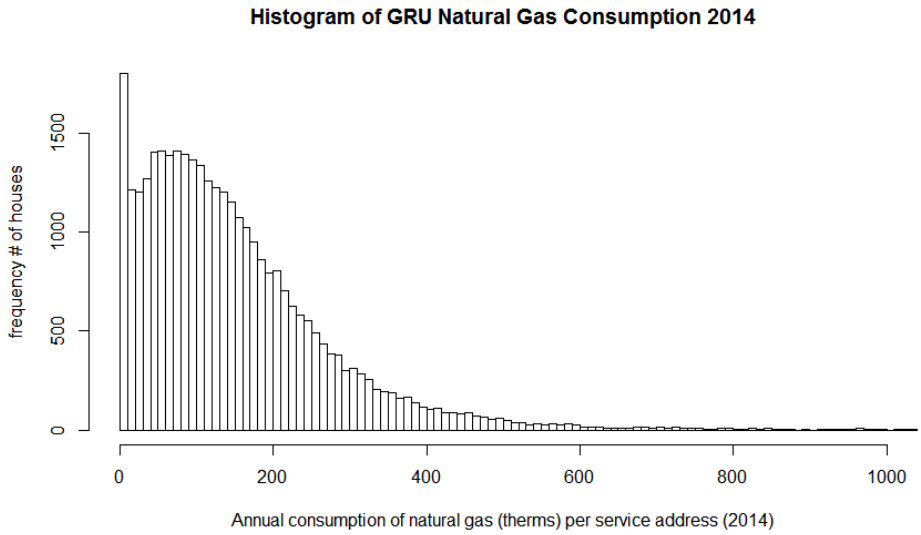

Figure 30 – Gainesville, Florida Annual Natural Gas Consumption distribution 2014

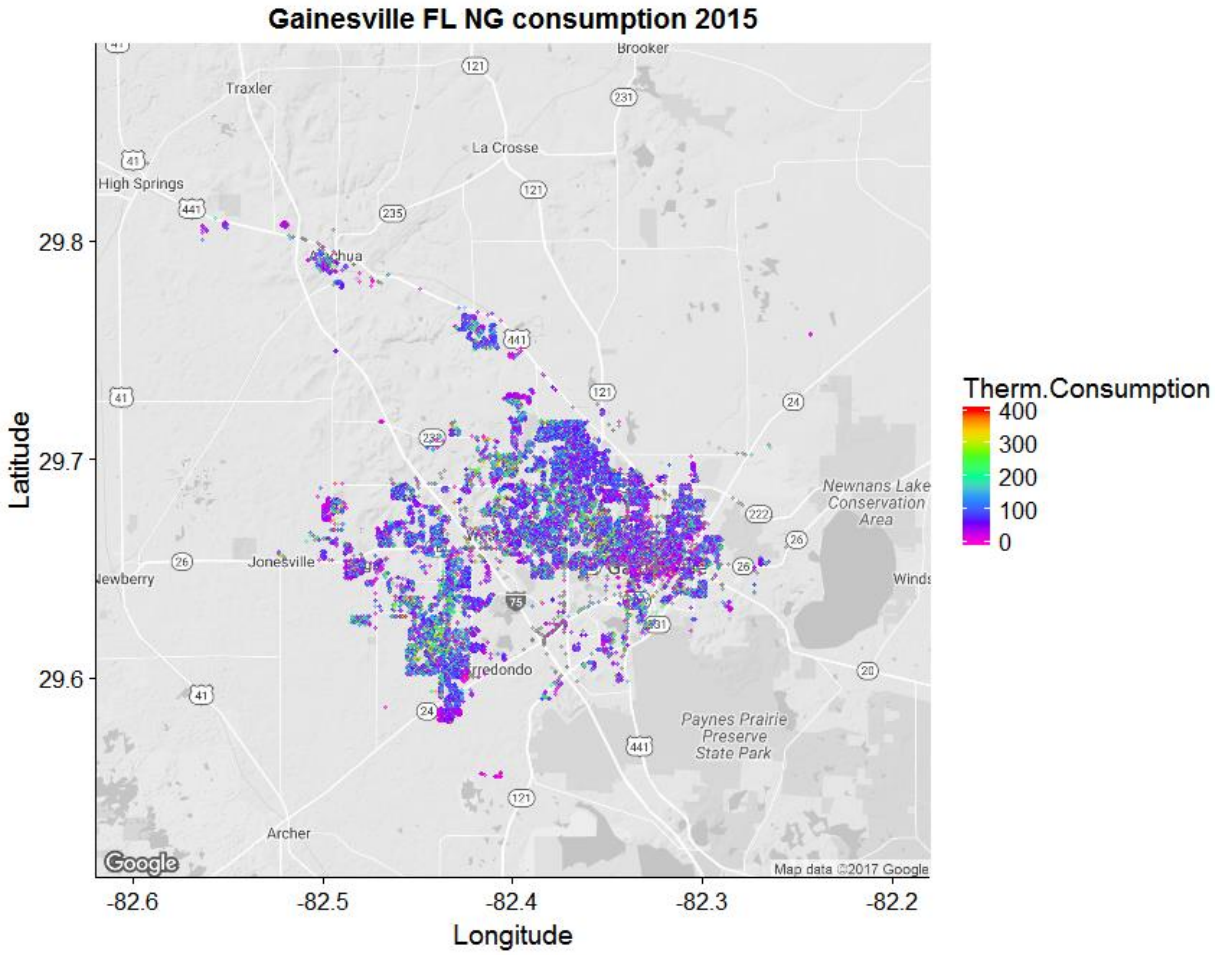

Figure 31 – Gainesville, Florida Natural Gas Consumption by Service-Address 2015

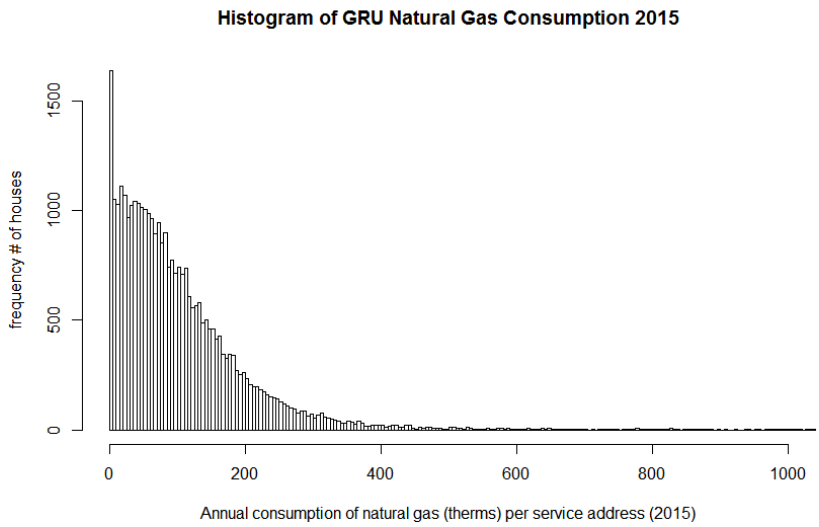

Figure 32 – Gainesville, Florida Annual Natural Gas Consumption distribution 2015

Figure 33 shows higher detailed zoomed views from the 2014 (the most recent complete year) Gainesville, FL natural gas consumption data. Figure 33 indicates that there are discrete clusters of areas whith either higher or lower natural gas consumption. Since the data contains both residential and non-residential addresses, a higher level view on two predominantly residential neighborhoods is included in Figure 34 and Figure 35.

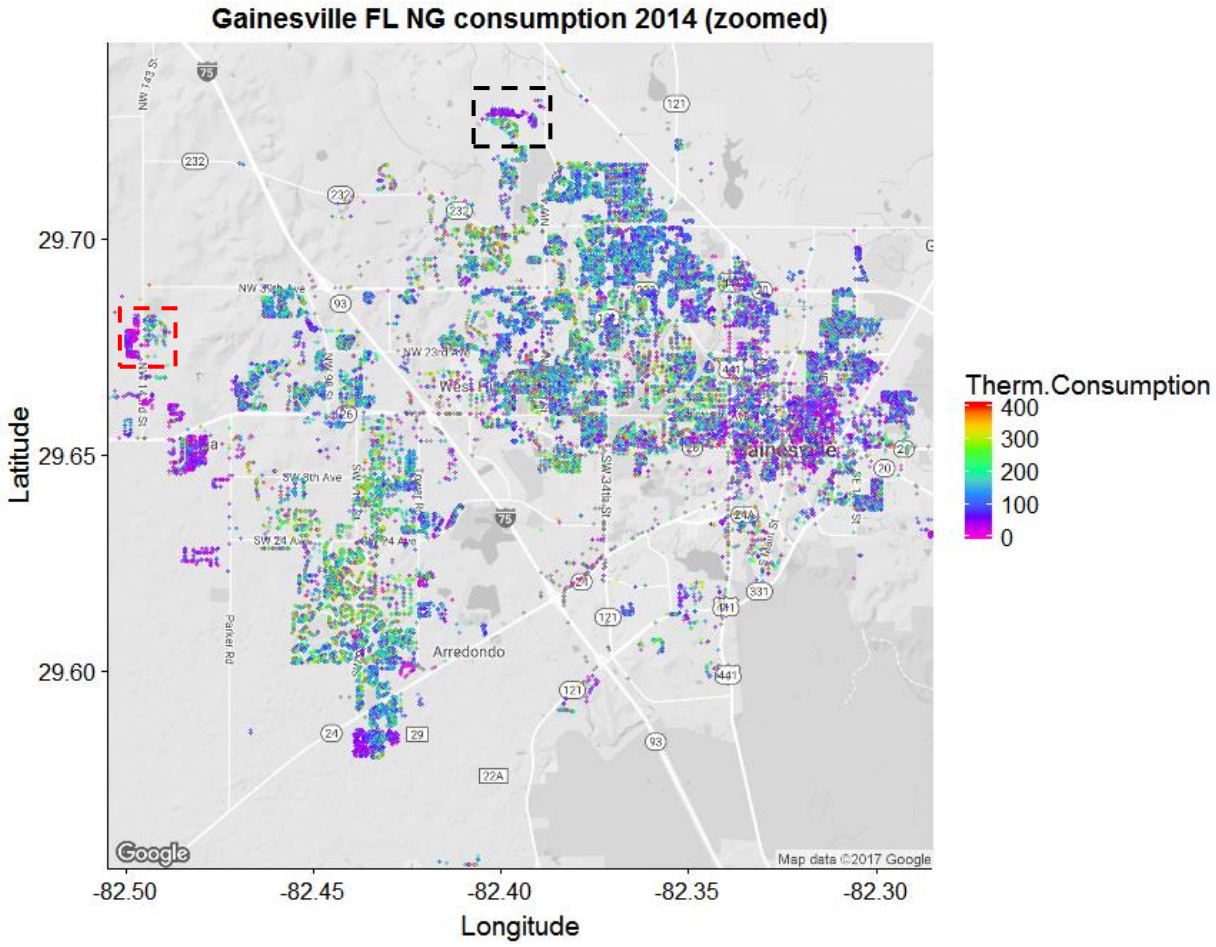

Figure 33 – Gainesville, Florida Natural Gas Consumption by Service-Address 2014 (Zoomed on population center detail. Black dashed line indicates callout area for Figure 34, red dashed line indicates callout area for Figure 35)

Figure 34 and Figure 35 take an even higher detailed look at two of the neighborhoods denoted by the dashed lines in Figure 33. Each image includes two different subdivisions with different size and configuration of houses. The top subdivision in Figure 34 and the left subdivision Figure 35 contain smaller and more tightly packed houses, which on average consume less natural gas. The bottom subdivision in Figure 34 and the right subdivision Figure 35 contain larger more spread out houses, with a higher prevalence of pools (and presumably pool heaters), and on average consume more natural gas.

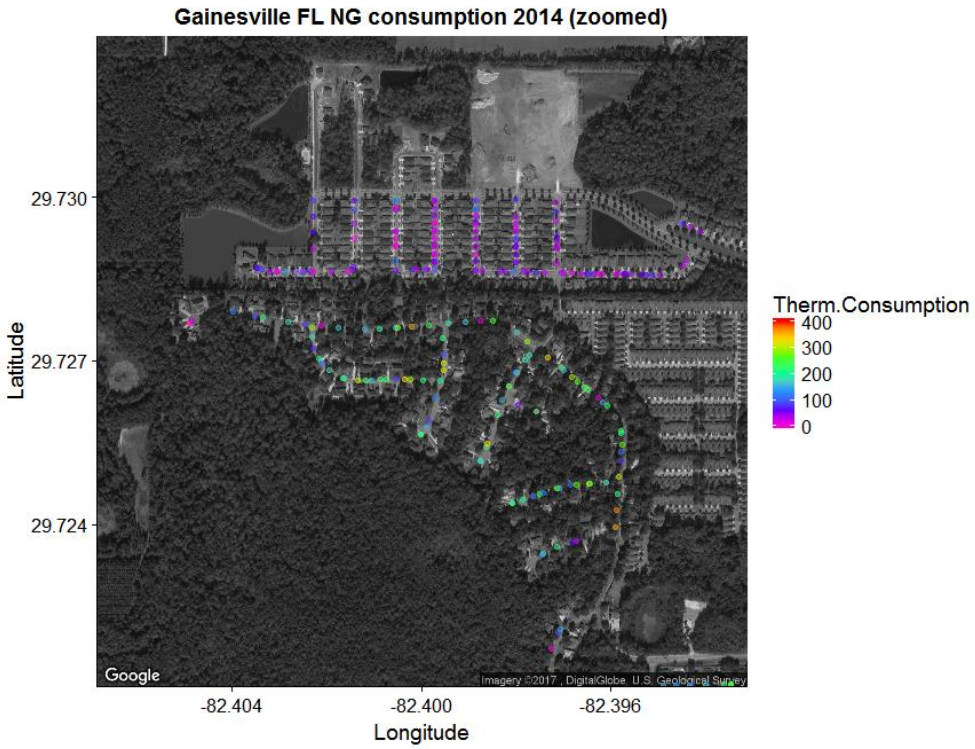

Figure 34 – Gainesville, Florida Natural Gas Consumption by Service-Address 2014 (higher detailed zoom callout from black dashed line section in Figure 33)

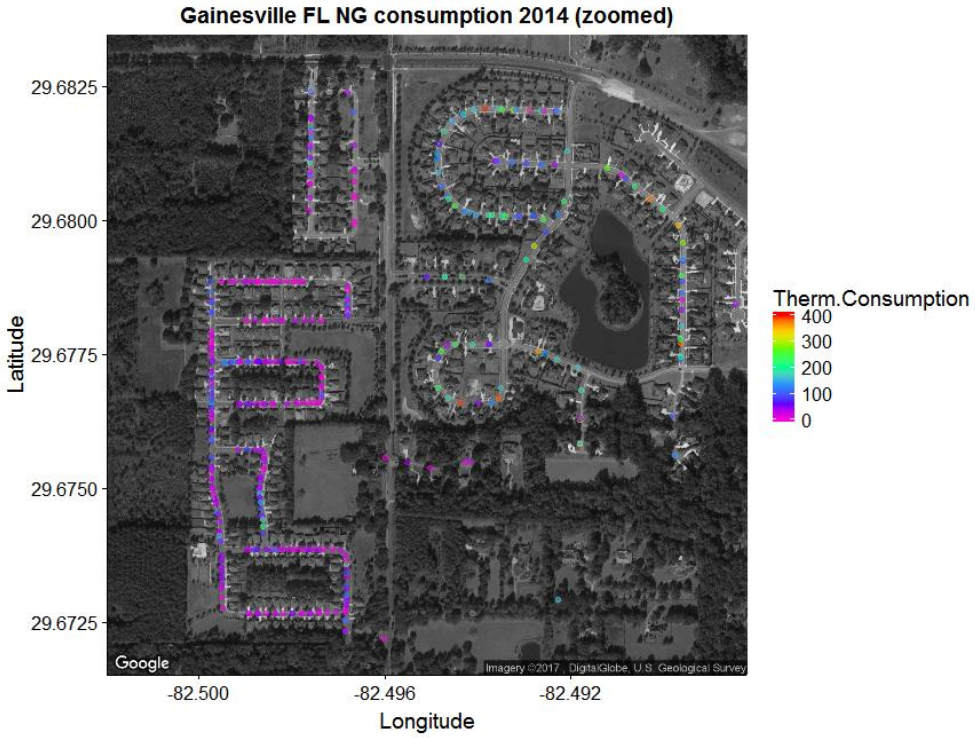

Figure 35 - Gainesville, Florida Natural Gas Consumption by Service-Address 2014 (higher detailed zoom callout from red dashed line section in Figure 33)

Table 2 summarizes the data from the Gainesville maps including quantitative summary metrics of the data for each year, as well as metrics about the outdoor weather conditions to qualify differences between years. As Figure 36 shows, there is a slight positive relationship between the total heating degree days, and total natural gas consumption for a year. This is expected in a climate like Florida where the majority of the natural gas consumption is used for non-space heating end uses. The partial year outlier from 2015 is also expected, as the total natural gas consumption will continue to increase as the year progresses, but the heating degree days will remain stable until the winter begins, at which point they will only increase modestly as a result of Florida's temperate climate.

Table 2 - Gainesville, FL Natural Gas Consumption Database Summary

	2012	2013	2014	2015 (1st half)
Months Covered	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Jun
Mean Consumption (therms/yr)	281.4	296.5	285.9	190*
Median Consumption (therms/yr)	105	117	125	81*
Cumulative Consumption (therms/yr)	9461326	9539894	9725581	6394402
HDD65 (degree F-days)[¤]	811	913	1312	734 (1/1-6/30)
Number of Service-Addresses	33626	32170	34021	33597
Number of Monthly Entries	246143	245345	232407	119219
				*therms/6-months
[¤]Degree day data from Midwestern Regional Climate Center, and based off of daily mean temperatures				

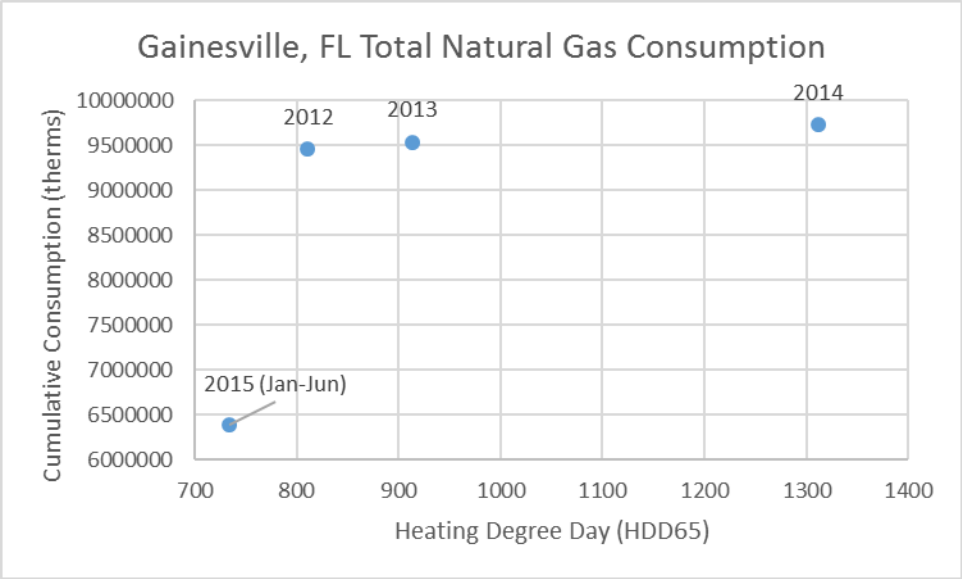

Figure 36 - Gainesville, FL relationship between natural gas consumption and outdoor temperature

The Chicago natural gas data is extremely limited in both scope and supporting documentation. The data is a single point snapshot about total natural gas consumption for a subset of buildings (encompassing 88% of buildings*, and 81% of natural gas consumption*) at the census block level; census blocks with fewer than four gas accounts are excluded for confidentiality. The data appears to show an increase in consumption further from the downtown city center (Figure 37 - left), this may be related to differences between population density near the city center (Figure 37 - right), and distribution of multifamily buildings (which are likely to generate and meter heat differently). Given the limited scope and multiple caveats of this data, it is difficult to draw conclusive findings.

*Including residential and non-residential.

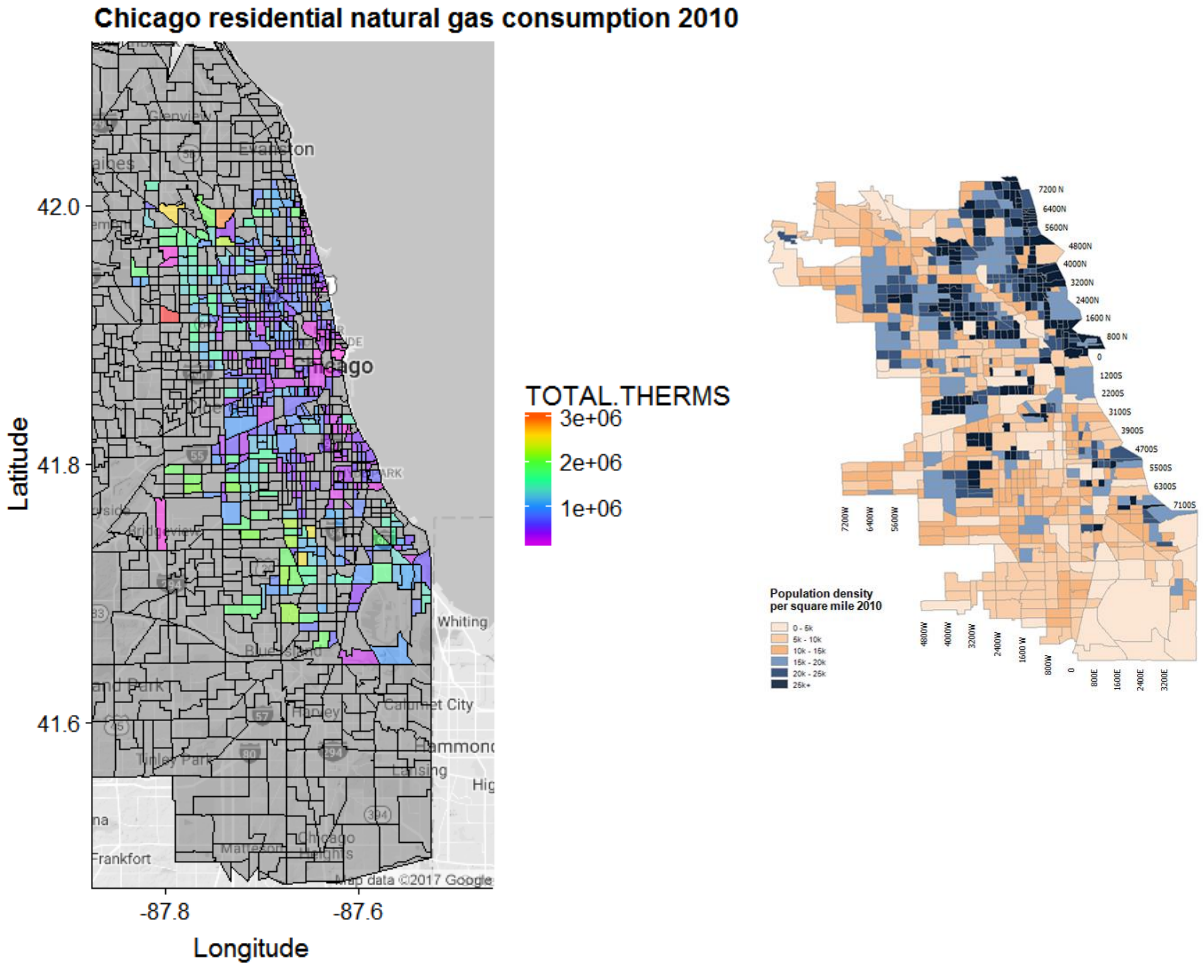

Figure 37 – (left) City of Chicago 2010 Natural Gas Consumption from Buildings classified as Residential; (right) Chicago Population Density from 2010 Census Data (10)

Space Heating Consumption

Figure 38 shows the distribution of natural gas consumption for space heating for each of the reportable domains (RD) in the 2009 RECS database, sorted and colored by the weighted average heating degree day (HDD65) for the RD occupants.

There is an obvious and easily explainable positive correlation between the HDD65, and the natural gas required to heat the dwellings, since the larger temperature difference between indoors and outdoors requires more energy to maintain.

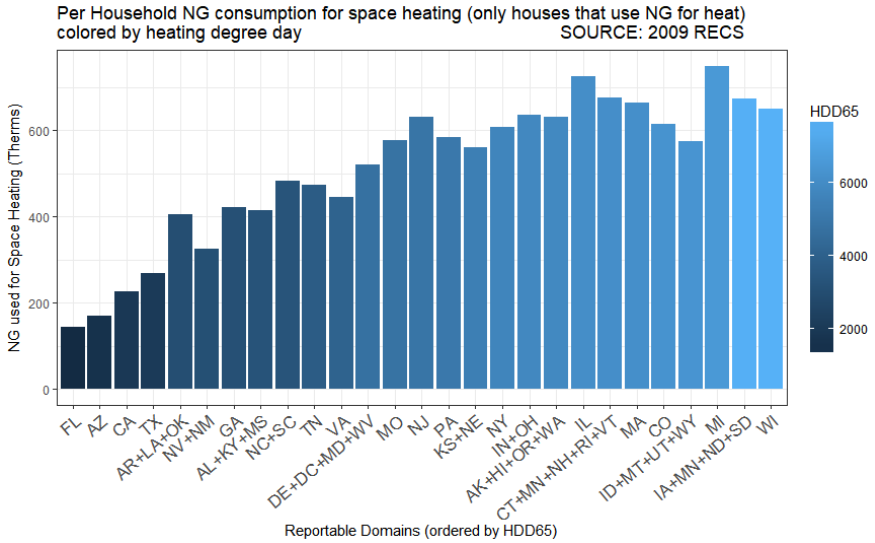

Figure 38 – Per Household Natural Gas Consumption for Space Heating Sorted by Heating Degree Day

Water Heating Consumption

Figure 39 shows the distribution of natural gas consumption for heating water for each of the RDs in the 2009 RECS database, sorted and colored by the weighted average heating degree day (HDD65) for the RD occupants.

Although the relationship between HDD65 and natural gas consumption is not as significant as with the space heating consumption (Figure 38), a positive correlation still exists. This makes sense since the delivered water temperature will be higher in states with lower HDD65, meaning that it takes less energy to heat it to the water heater set point. Additionally, in arid states like Arizona and California (which have the lowest per capita consumption of natural gas for water heating), consumption may be lower due to the behaviors of drought conscious residents who may make additional efforts to consume less water in general, thus reducing the energy needed to heat that water.

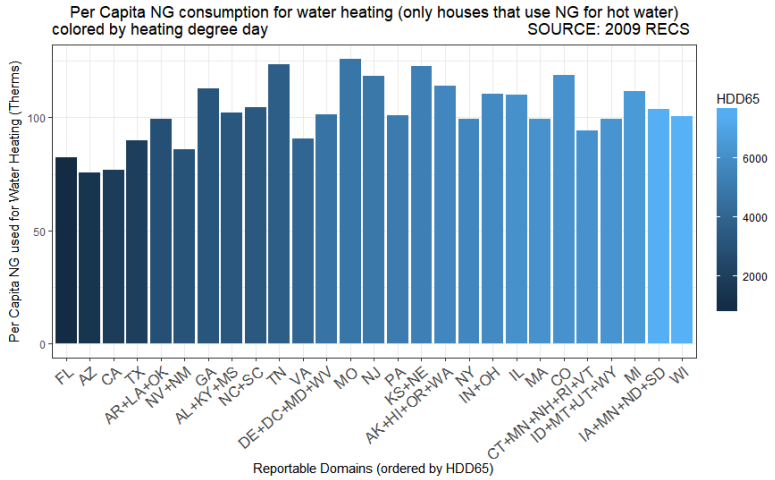

Figure 39 – Per Household Natural Gas Consumption for Water Heating Sorted by Heating Degree Day

Other Consumption

Figure 40 shows the distribution of natural gas consumption for end uses that are not space or water heating for each of the RDs in the 2009 RECS database, sorted and colored by the weighted average heating degree day (HDD65) for the RD occupants.

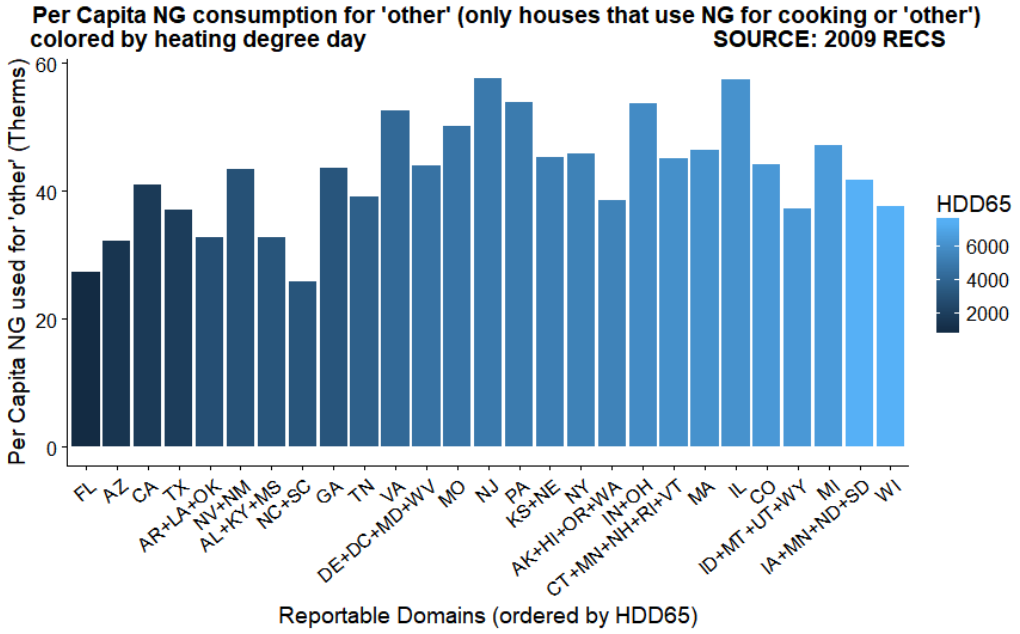

Figure 40 – Per Household Natural Gas Consumption for "Other" (non-space heating, and non-water heating) Sorted by Heating Degree Day

The magnitudes of these 'other' consumptions appears to be higher than expected, being more or less equivalent to the consumption for water heating; however this interpretation is skewed, because each graph only covers the units that use natural gas for the specific end use. Figure 41 shows the total natural gas consumed for each residential end use in the RECS reportable domains. It is clear that the total natural gas consumed for 'other' is the least significant end use in every reportable domain. According to the RECS data, California has the highest fraction of natural gas used for 'other' end uses; this is a result of California's high prevalence of gas ranges (Figure 48) and dryers (Figure 53), as well as a significant number of natural gas pool heaters (11).

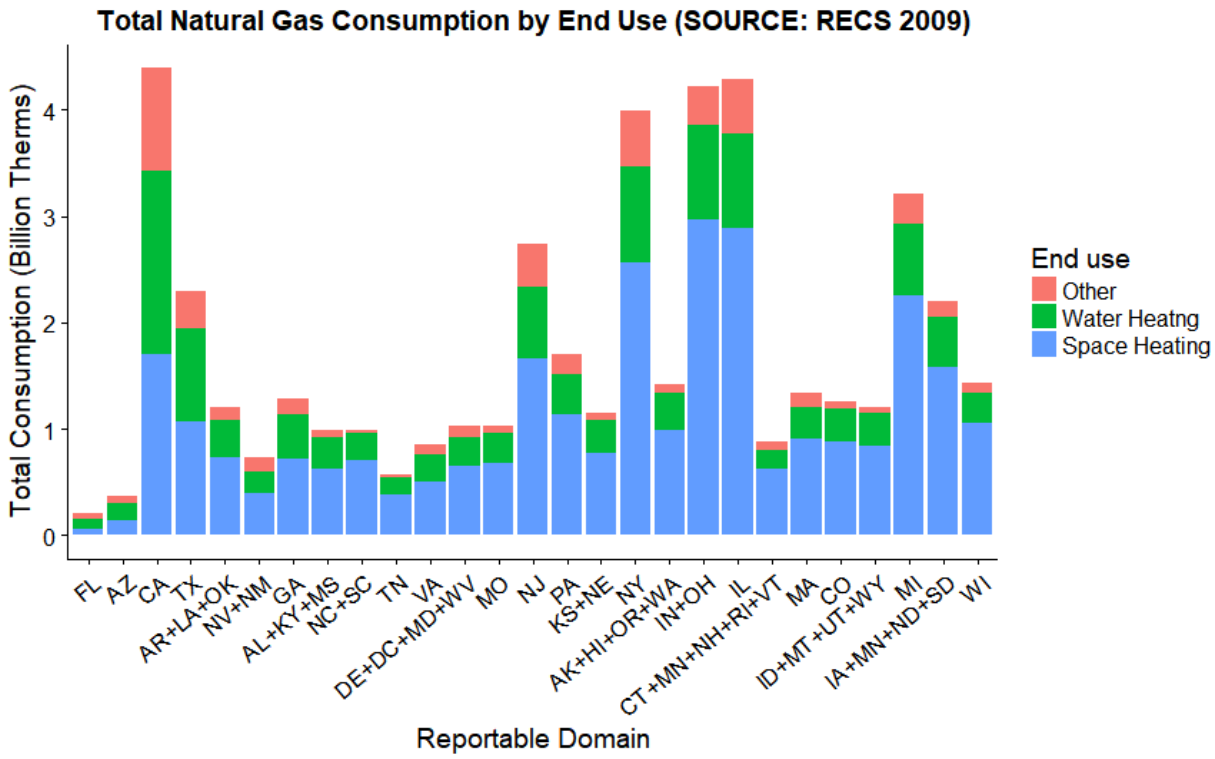

Figure 41- Total Natural Gas Consumption by End Use

There is a slight discrepancy between the RECS data and the California RASS (Figure 18), with RECS attributing a larger fraction of total natural gas consumption to other, and RASS attributing ~10% more consumption to water heating (Table 3).

Table 3 - Comparison of RECS and RASS Natural Gas End Use Consumption (California only)

Percentage of California's Residential Natural Gas Consumption for Various End Uses		
	RASS	RECS
Space Heating	37%	38.6%
Water Heating	49%	39.4%
Other	14%	21.9%

Prevalence

Distribution of Households with Natural Gas Service

The U.S. Office of Management and Budget (OMB) defines a metropolitan area as one or more counties having "a core urban area of 50,000 or more population," and a micropolitan area as one or more counties containing an urban core of 10,000 – 49,999 population. (https://www.census.gov/population/metro/)

Although the map changes based on population trends, the most recent version (7/2015, which is based on the data from the 2010 Census) is shown in Figure 42. The light green areas represent micropolitan areas, and the dark green sections represent metropolitan areas. Currently "there are 381 metro areas and 536 micro areas defined by OMB" and they "account for about 94 percent of the population…" Metropolitan and micropolitan areas account for ~47% of US land area, while the remaining ~53% if classified as non-metro (12).

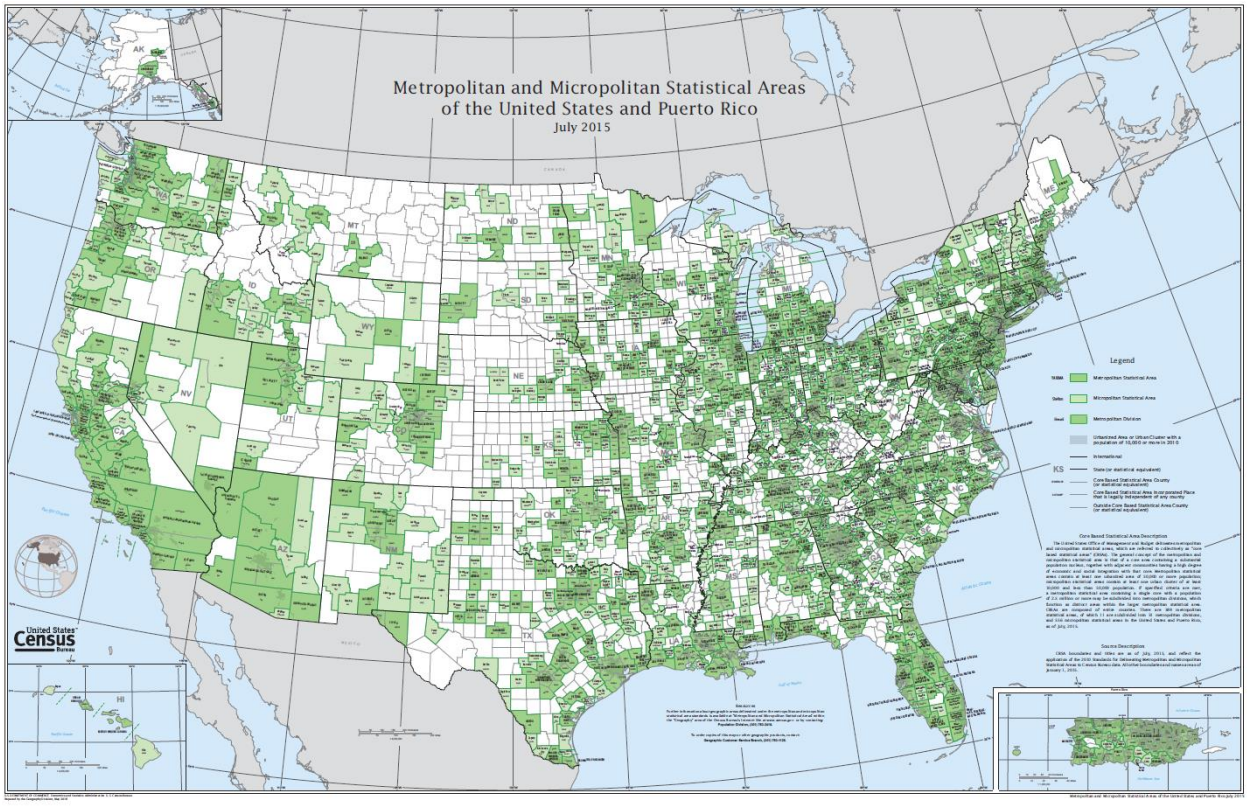

Figure 42 - Metropolitan and Micropolitan Statistical Areas (July 2015) (13)

The Census Bureau defines urbanized areas as those having at least 50,000 people, and urban clusters as those having between 2500 and 49,999 people. Rural areas are defined as the remainder of the areas not identified by either of the urban definitions. Figure 43 shows a map of the most recent (2010) urban definitions. (12)

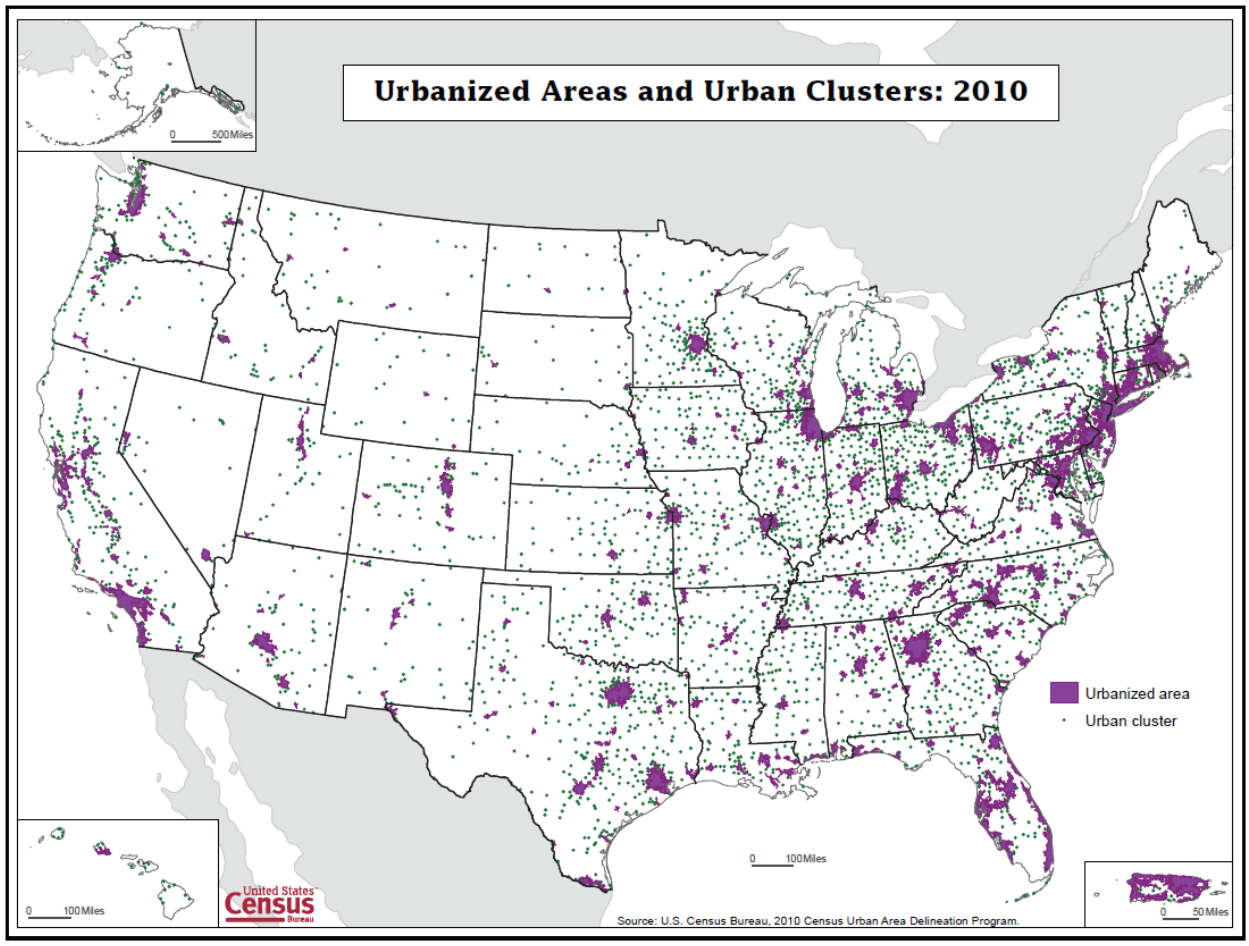

Figure 43 - Urbanized Areas and Urban Clusters (2010 Census)

Natural gas consumption is more common in urban areas than rural areas, and more common in metropolitan areas compared to micropolitan areas (Table 4). On the order of 90% of all gas use is in population centers. This means that analyses of gas use that focus on urban/metropolitan areas will capture the majority of the information.

Table 4 - Urban/Rural and Metropolitan/Metropolitan distribution of natural gas use

Metric	Urban/Rural Ratio	Metro/Micro Ratio
Number of houses that use NG	7.7	9.1
Quantity of NG consumed	8.3	9.1
Quantity of NG consumed for space heating	8.2	7.7
Quantity of NG consumed for water heating	8.6	11.0
Quantity of NG consumed for other	8.6	17.4
Calculated from RECS 2009 data		

Figure 44 shows a map of the United States natural gas piping infrastructure. Significant piping infrastructure exists in natural gas production regions, like Texas and Oklahoma, which combined produced over 35% of the U.S. marketed natural gas. (14) (15) The pipeline distribution network connects the gas producing regions to the densely populated gas consuming regions. In lieu of a pipeline servicing a population center, natural gas may be transported in its compressed form via an LNG carrier (16); transportation via rail is currently in the development and proof of concept stages. (17) Areas not directly serviced by a pipeline, or with port access will not have natural gas service.

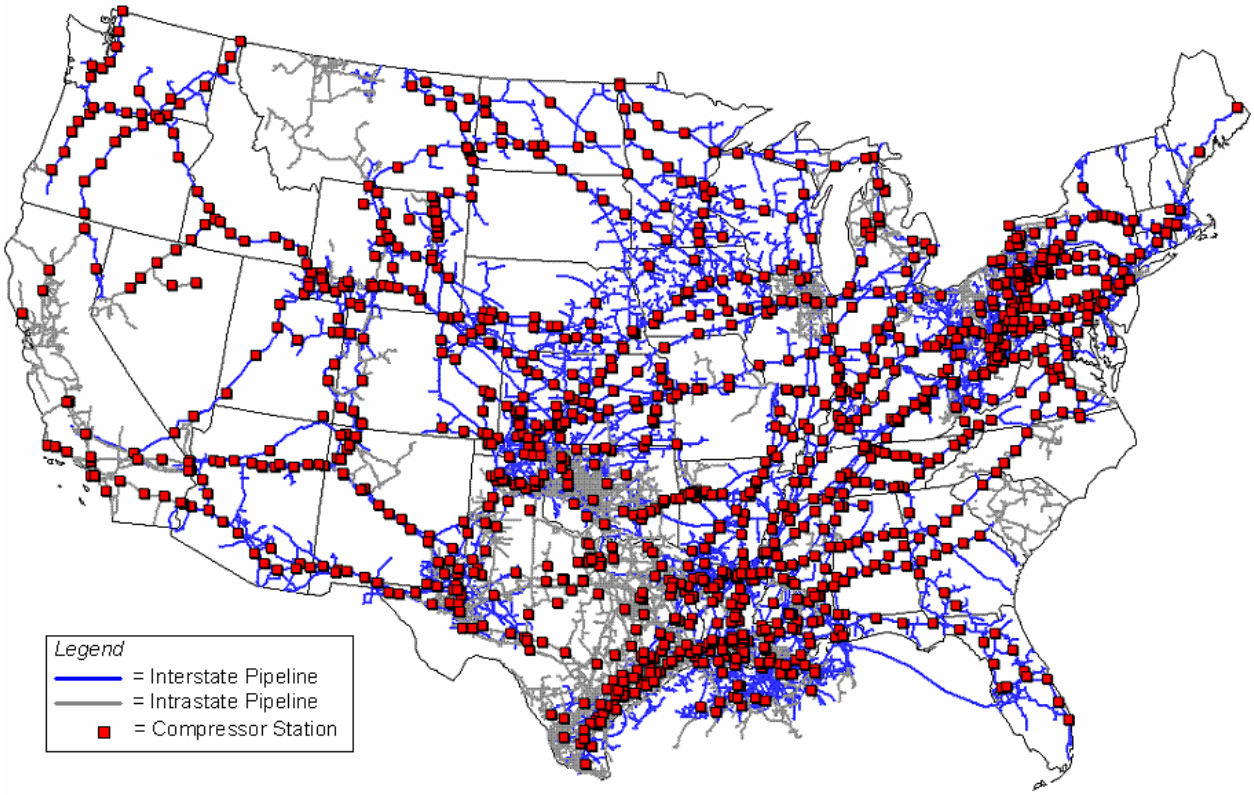

Figure 44 - US map showing natural gas distribution network (18)

Percent of Households Utilizing Natural Gas

Figure 45 shows the percentage of households in and around the various metropolitan areas surveyed in the 2011 AHS that use natural gas in some capacity. Detailed views of each metropolitan area are included in Appendix B (which is in a separate document due to its large size).

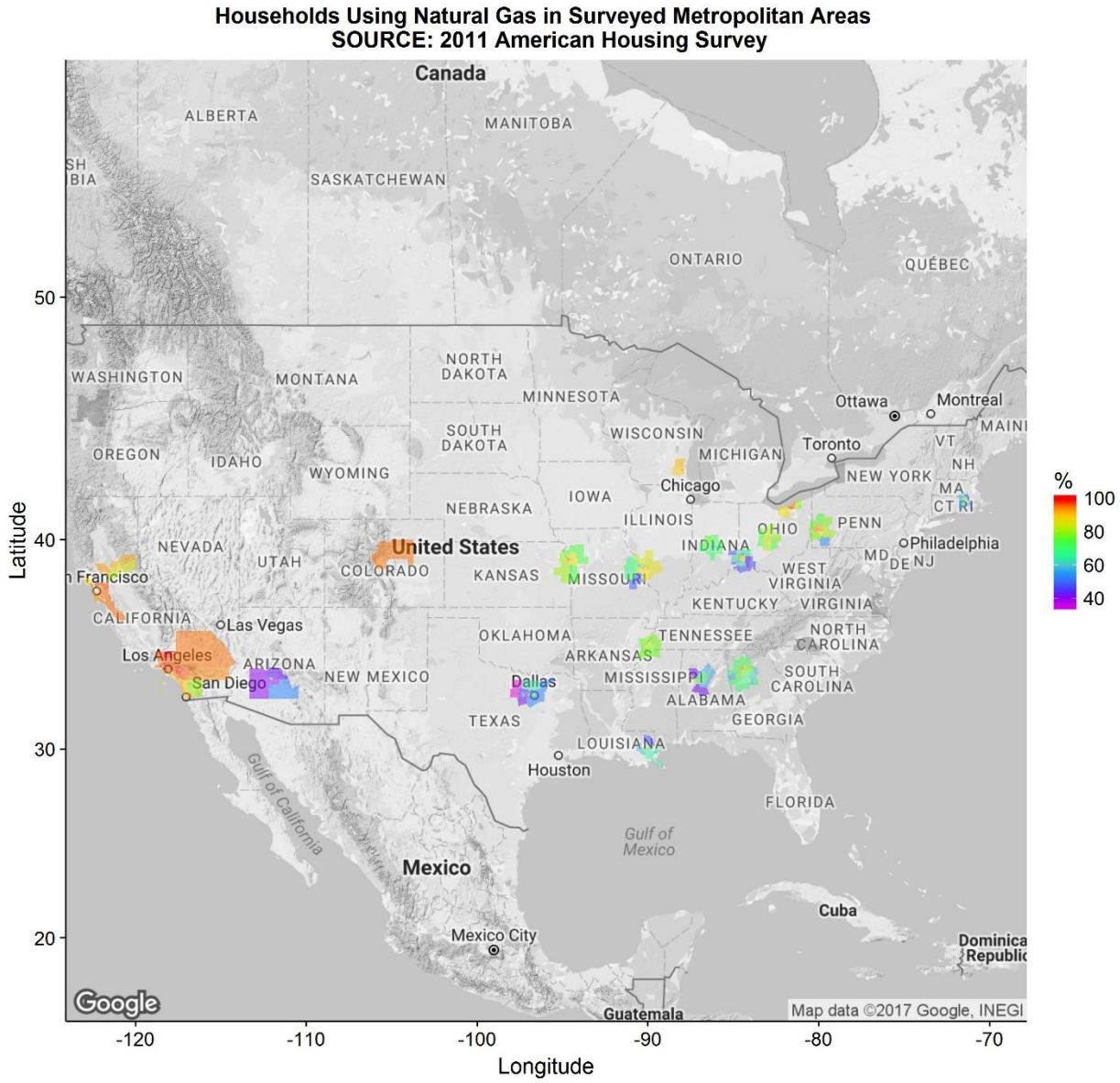

Figure 45 – Continental United States Percent of Households Using Natural Gas

The complete microdata from the updated 2015 RECS dataset is not yet available, and spatial information is limited to the census division level. Figure 46 and Figure 47, which show the percentage of households using natural gas by census division are included to show the most recent available information, with the equivalent from the more complete 2009 RECS for comparison. These two graphs show that there is an increase in the prevalence of gas, with the Pacific, the West North Central, and the Middle Atlantic Census Divisions all increasing. The West South Central Census Division, appear to have

experienced a drop in natural gas prevalence. The graphs also reinforce that, with the exception of New England where fuel oil is common, northern states have higher prevalence of natural gas use than other areas.

For each of these sets of figures, and the subsequent equivalents (Figure 54/Figure 55, Figure 56/Figure 57, Figure 58/Figure 59), the legend color scales are uniform to better highlight the changes between the survey years; while the color scales are different between different sets of maps (e.g. space heating and cooking) to better visually convey the extents of data. The color scales of Figure 60 and Figure 61, which are based on irrelevant metrics (outdoor grilling and other), are dissimilar from each other and from the other sets.

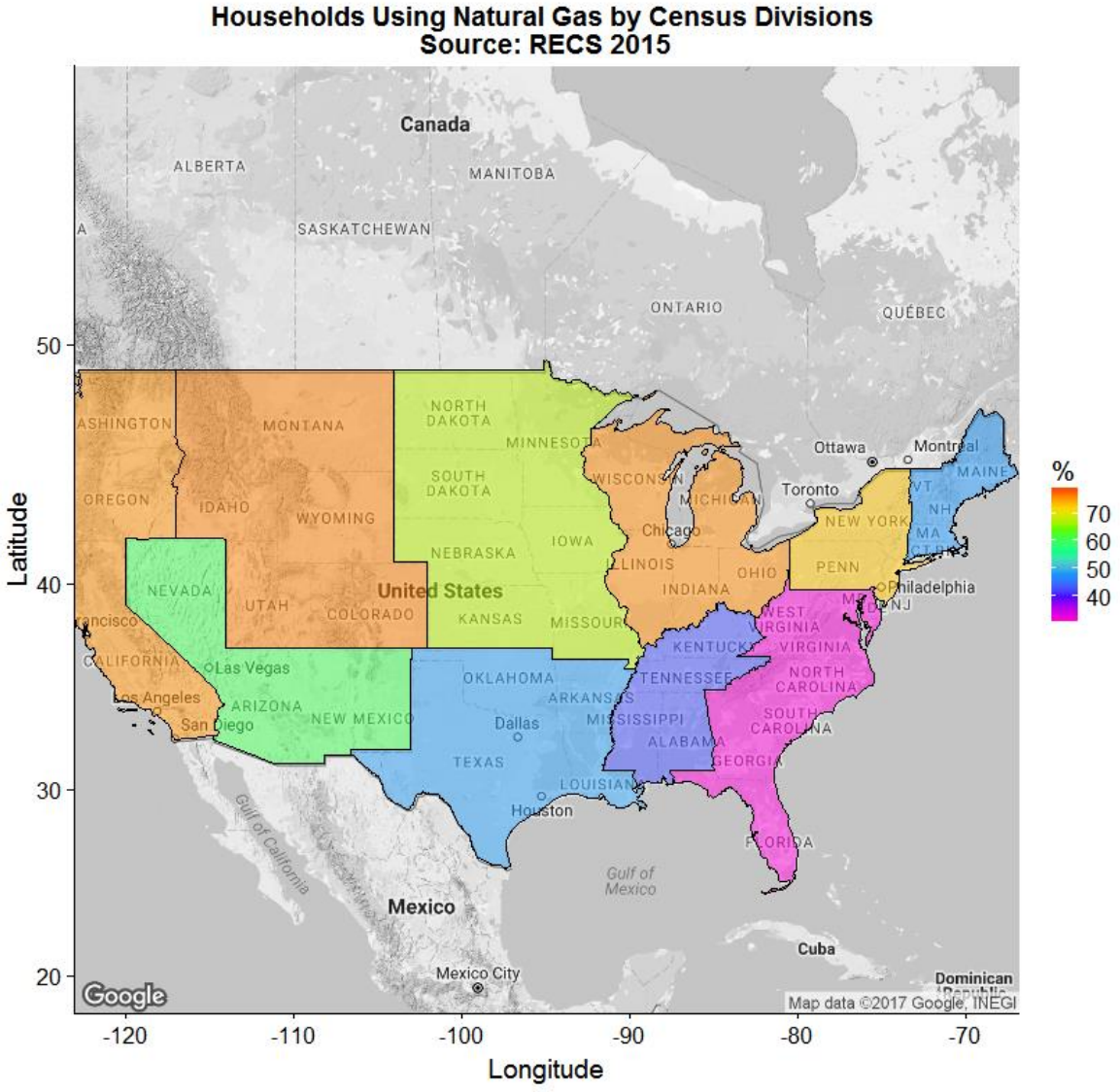

Figure 46 - Percent of Households that use Natural Gas (2015 - by Census Division)

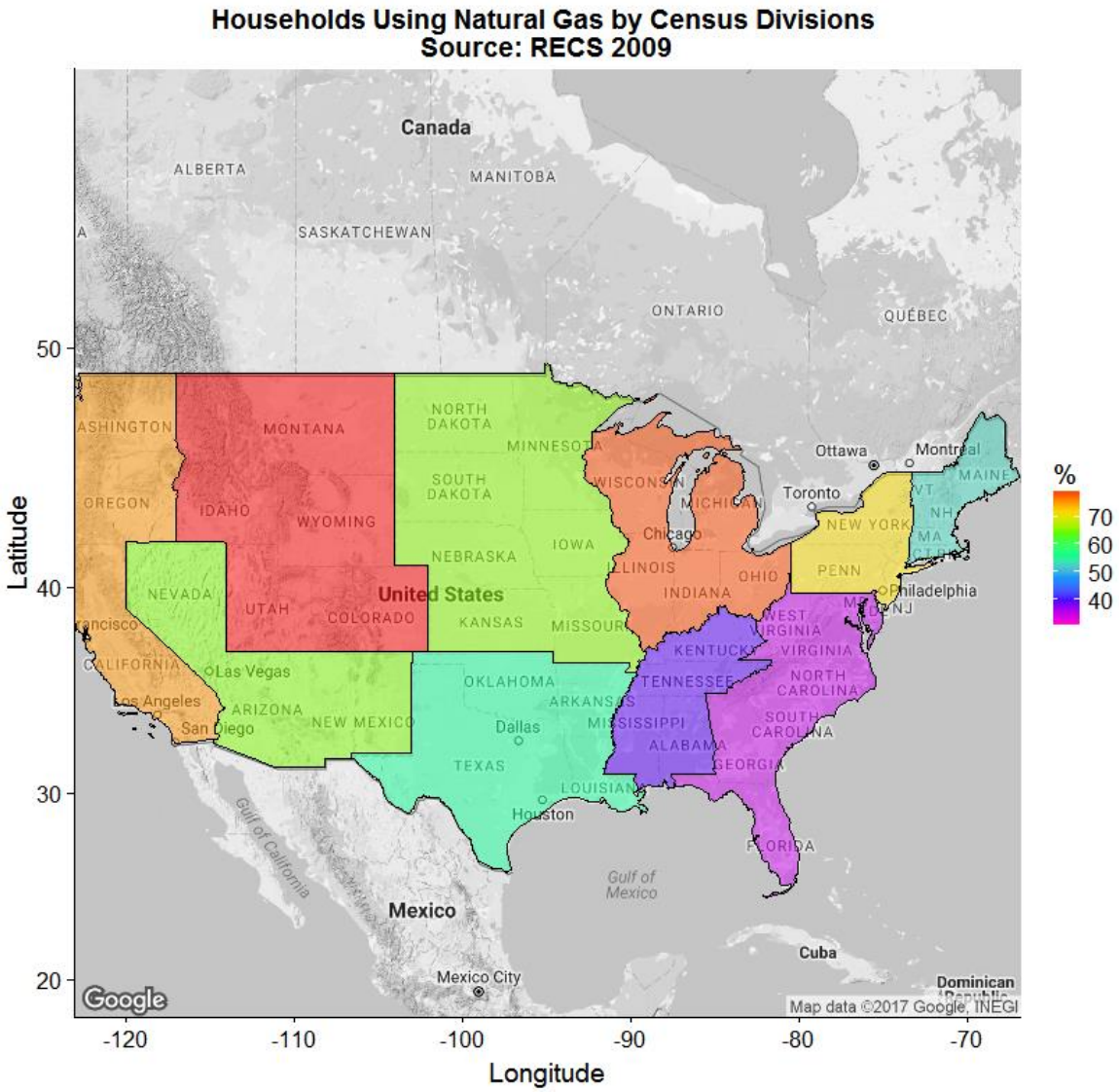

Figure 47 - Percent of Households that use Natural Gas (2009 - by Census Division)

Percent of Households Utilizing Natural Gas for Specific Purposes

Figure 48 and Figure 49 show the prevalence of naturally gas fired appliances for various end uses. Figure 48 includes all available data, whereas for increased visual clarity Figure 49 only includes data on the three predominant end uses (primary space heating, water heating, and cooking).

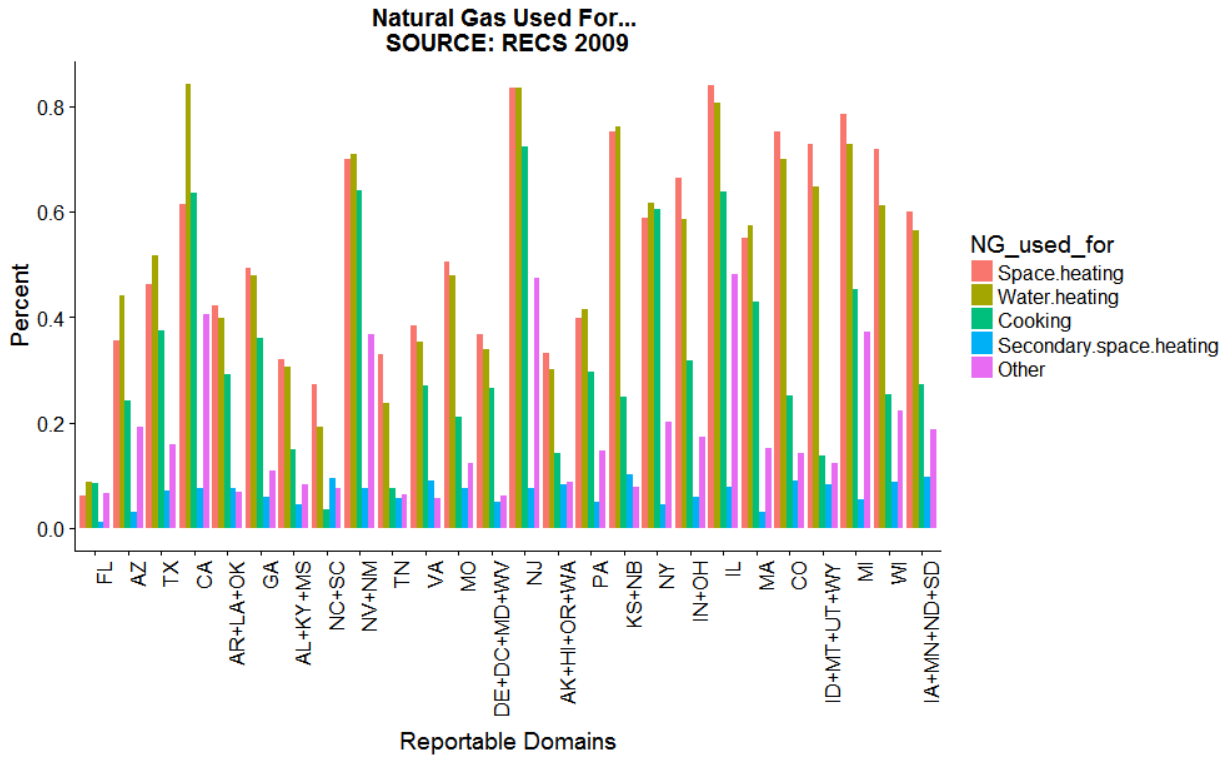

Figure 48 – Percent of Households Using Natural Gas for Various Activities

In warmer climates (e.g. Arizona, Texas & California), natural gas is utilized more for water heating than space heating, whereas in colder climates (e.g. Colorado, Michigan, Wisconsin), the opposite is true. In every reportable domain except Florida and New York, cooking is the least frequent end use (of the three predominant end uses) of natural gas. In Florida and New York, all three predominant end uses have similar percent utilization within each state, with a standard deviation of 1.47 and 1.43% respectively. It is clear from these graphs that most people choose natural gas water heating when they use natural gas for space heating. The data estimates that of the households that use some form of space heating, there are 49.6 million houses that use natural gas for both space heating and water heating, and only 6 million houses that use natural gas for water heating but not space heating.

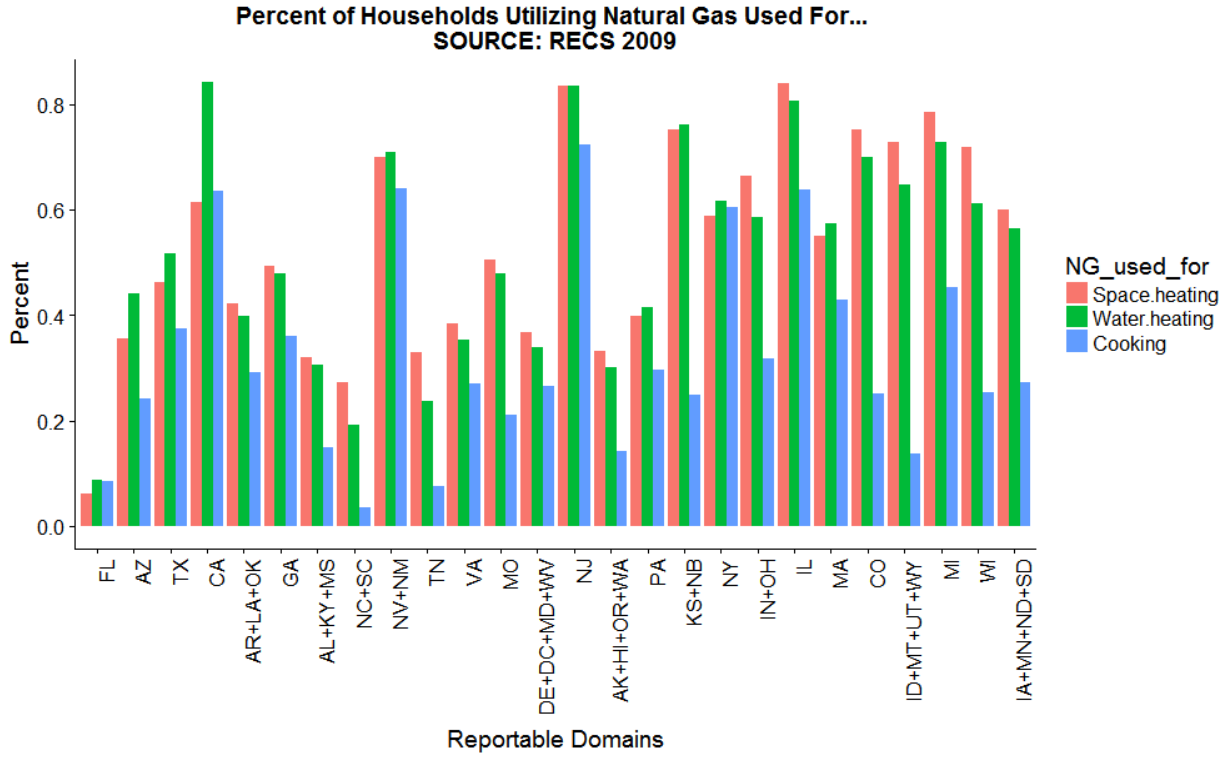

Figure 49 – Percent of Households Using Natural Gas for Space Heating, Water Heating, and Cooking

Figure 50 through Figure 53 show the percentage of households in and around various metropolitan areas that use natural gas for specific end uses. Gas is more commonly used for space and water heating compared to cooking and clothes drying. The surveyed metropolitan areas in California have the highest prevalence of natural gas fueled cooking appliances, and Los Angeles specifically, has the highest prevalence of natural gas fueled clothes dryers.

California has an estimated 438,974 (11) residential gas-fired pool heaters, of which 276,860 (11) are in the territory serviced by Southern California Edison, whose corresponding gas service area include the Los Angeles area. (19) A separate aerial imaging study estimated the number of pools in the LA basin as 43,123. (20) Pools heaters in California are estimated to run on high for 1100 hours per year, and low for 4300 hours per year (11) equating to a total consumption of 220 therms of natural gas annually. Spas are estimated to consume and additional 52 therms of natural gas annually. (7)

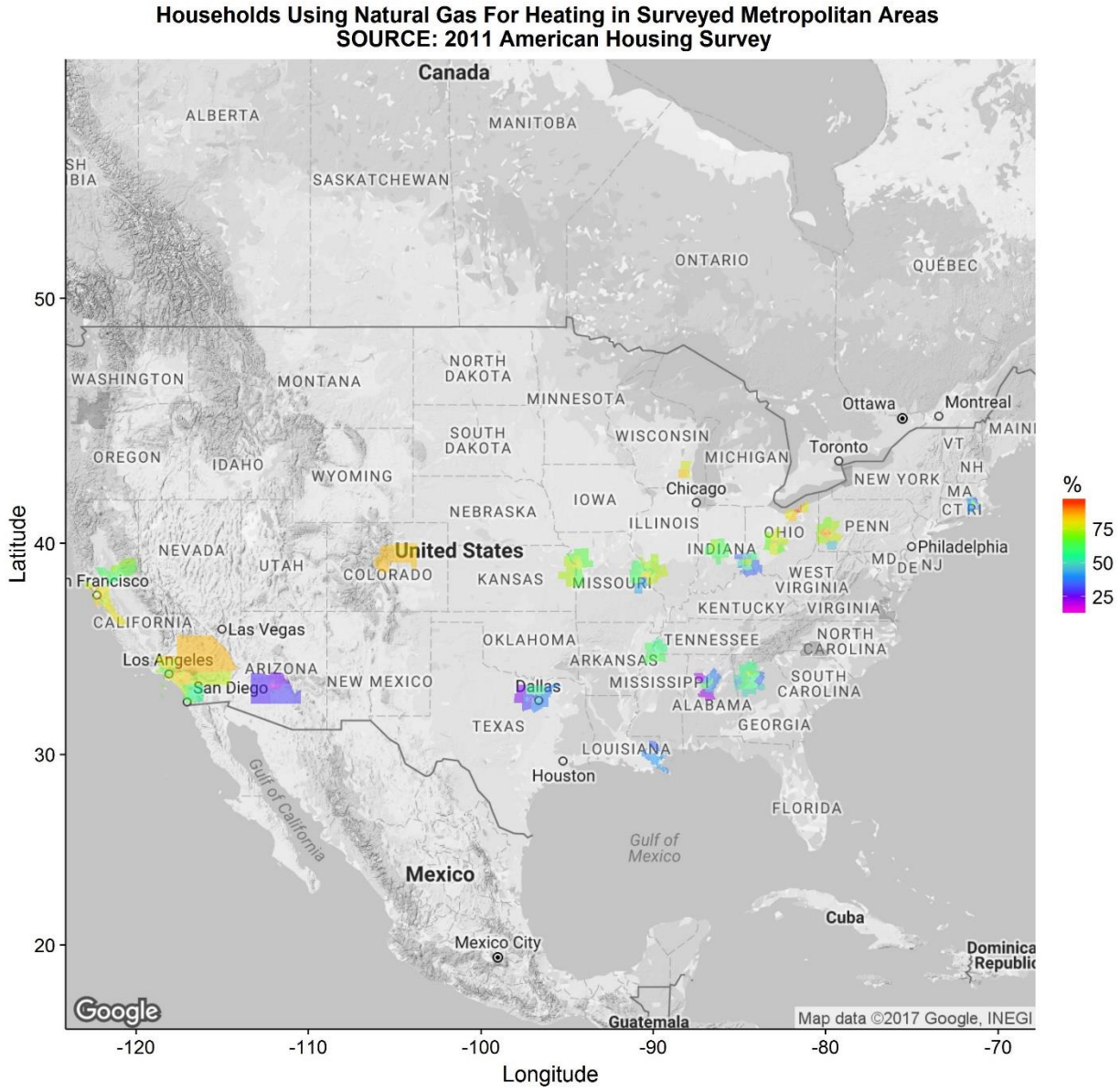

Figure 50 - Continental United States Percent of Households Using Natural Gas for Space Heating

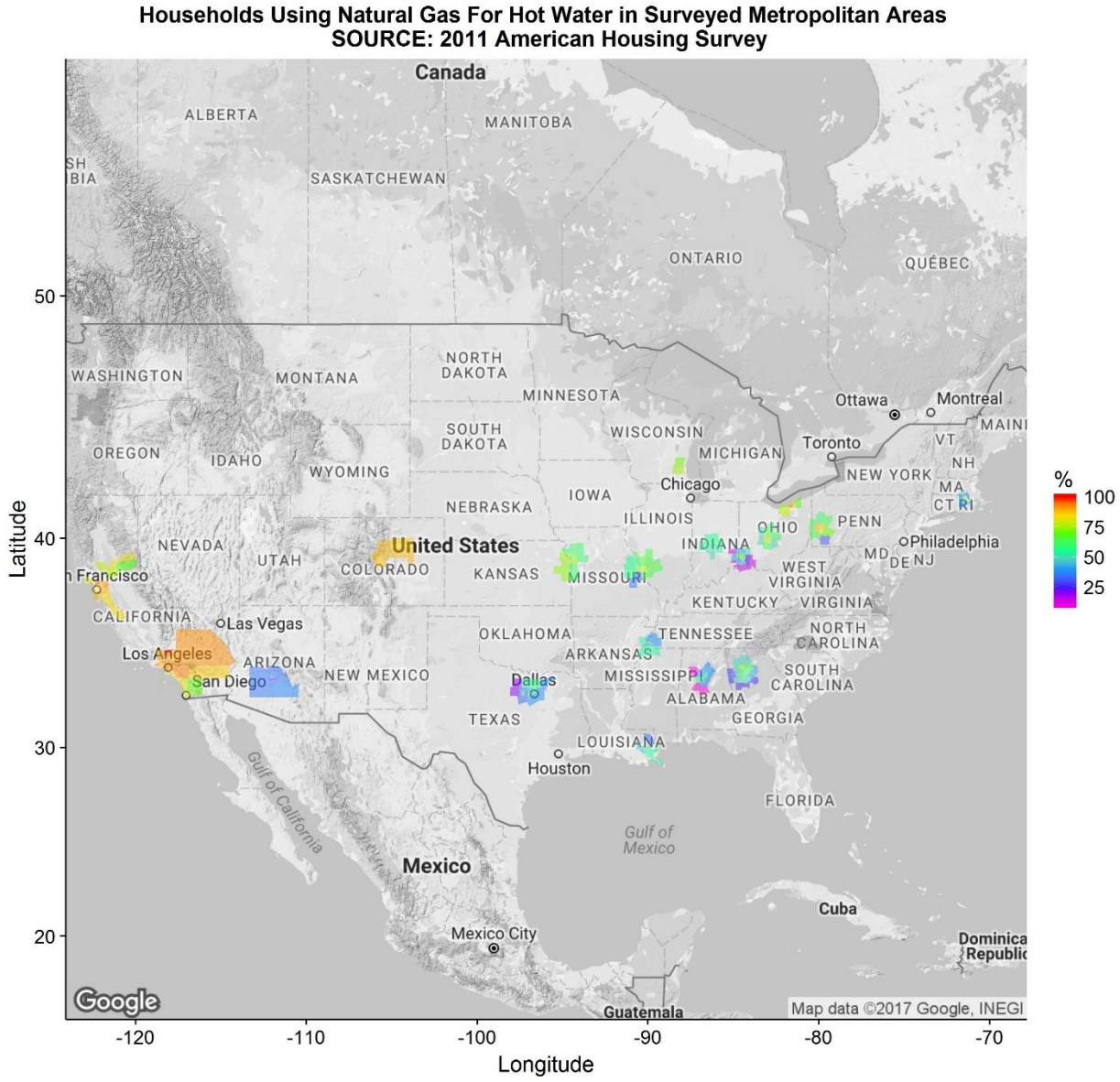

Figure 51 - Continental United States Percent of Households Using Natural Gas for Water Heating

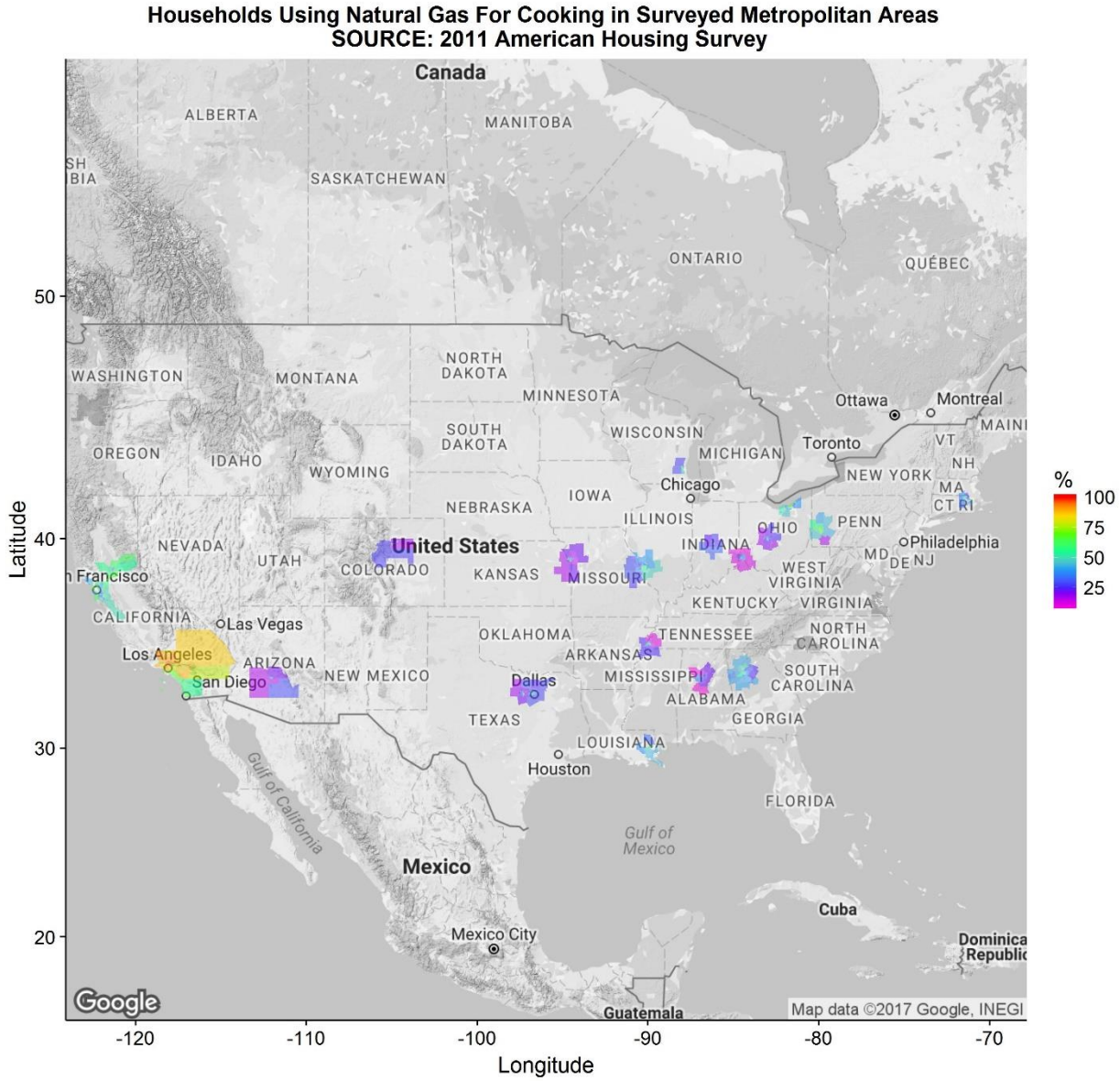

Figure 52 - Continental United States Percent of Households Using Natural Gas for Cooking

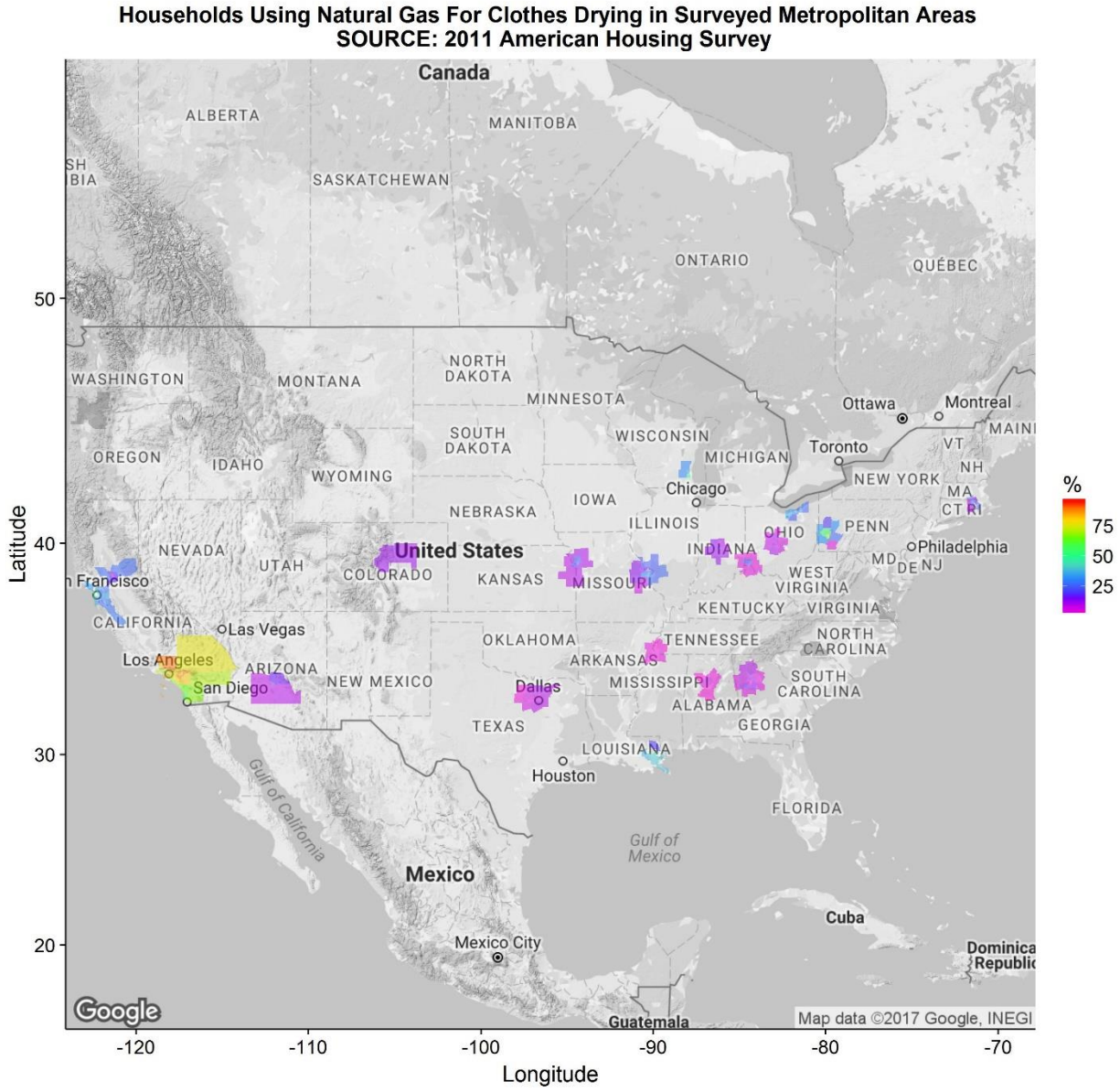

Figure 53 - Continental United States Percent of Households Using Natural Gas for Clothes Drying

Figure 54 - Figure 61 show the available information from the recently released most up to date RECS survey, and the equivalent data from the more detailed 2009 survey.

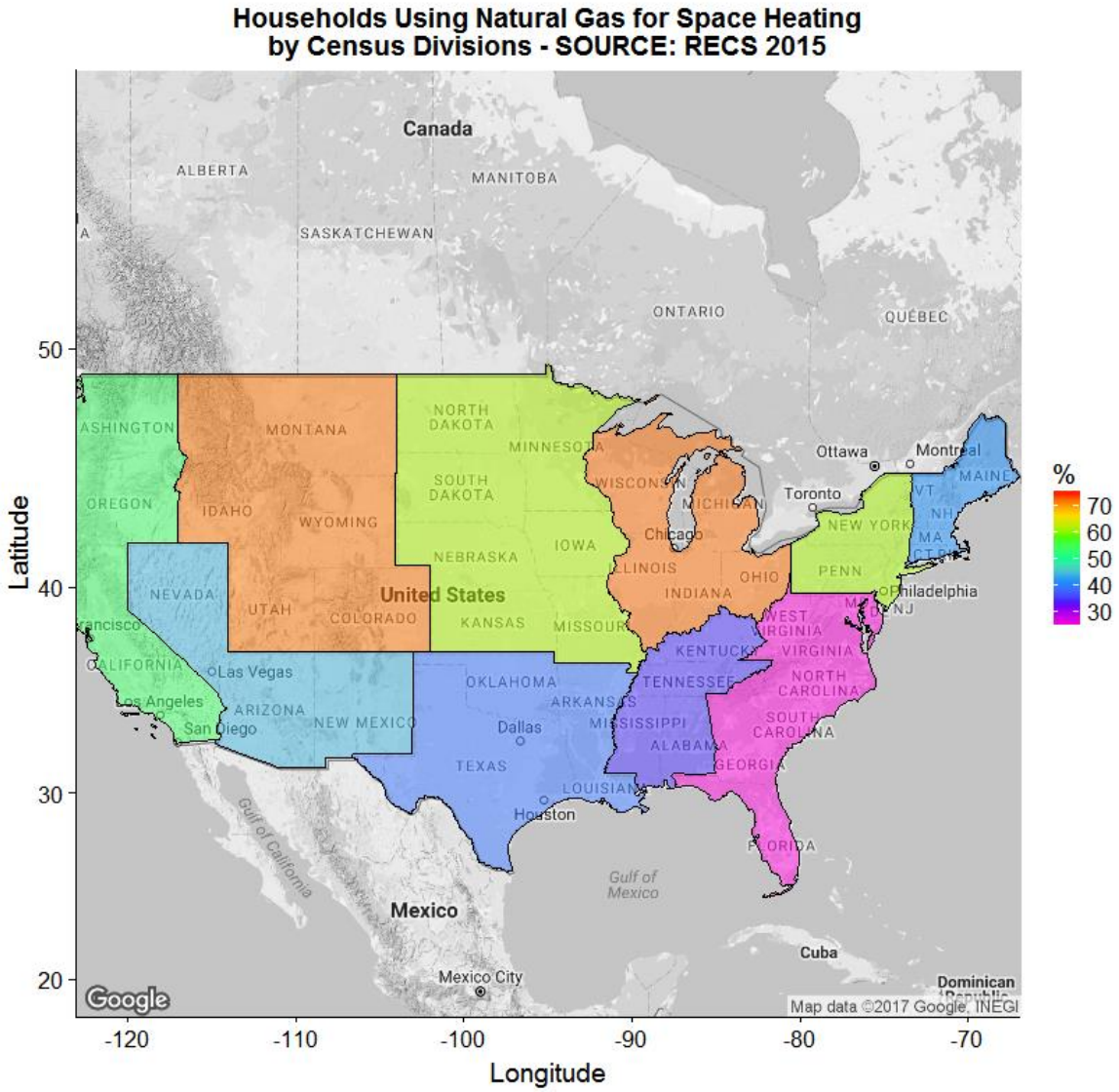

Figure 54 - Percent of Households that use Natural Gas for Space Heating (2015 - by Census Division)

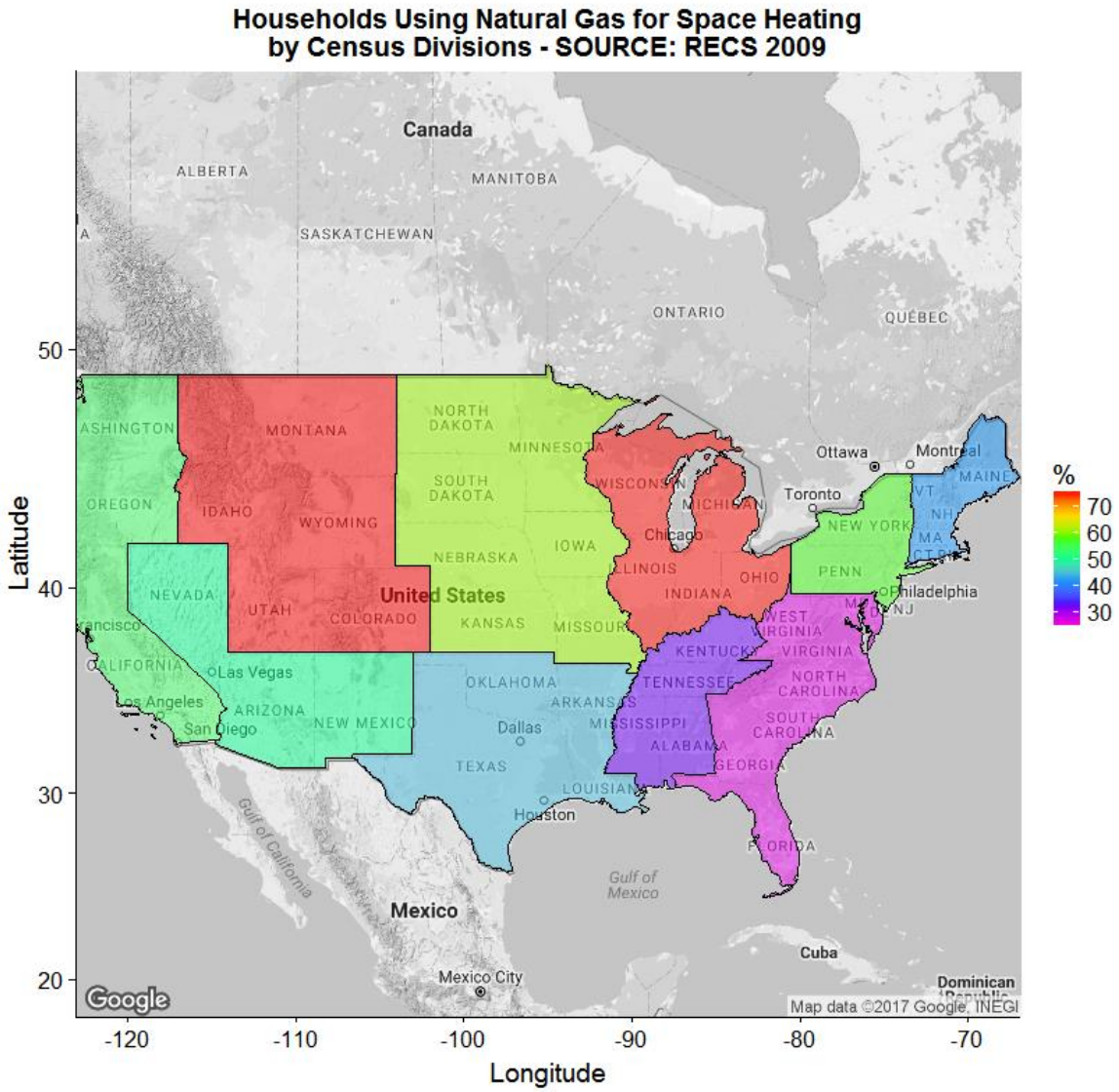

Figure 55 - Percent of Households that use Natural Gas for Space Heating (2009 - by Census Division)

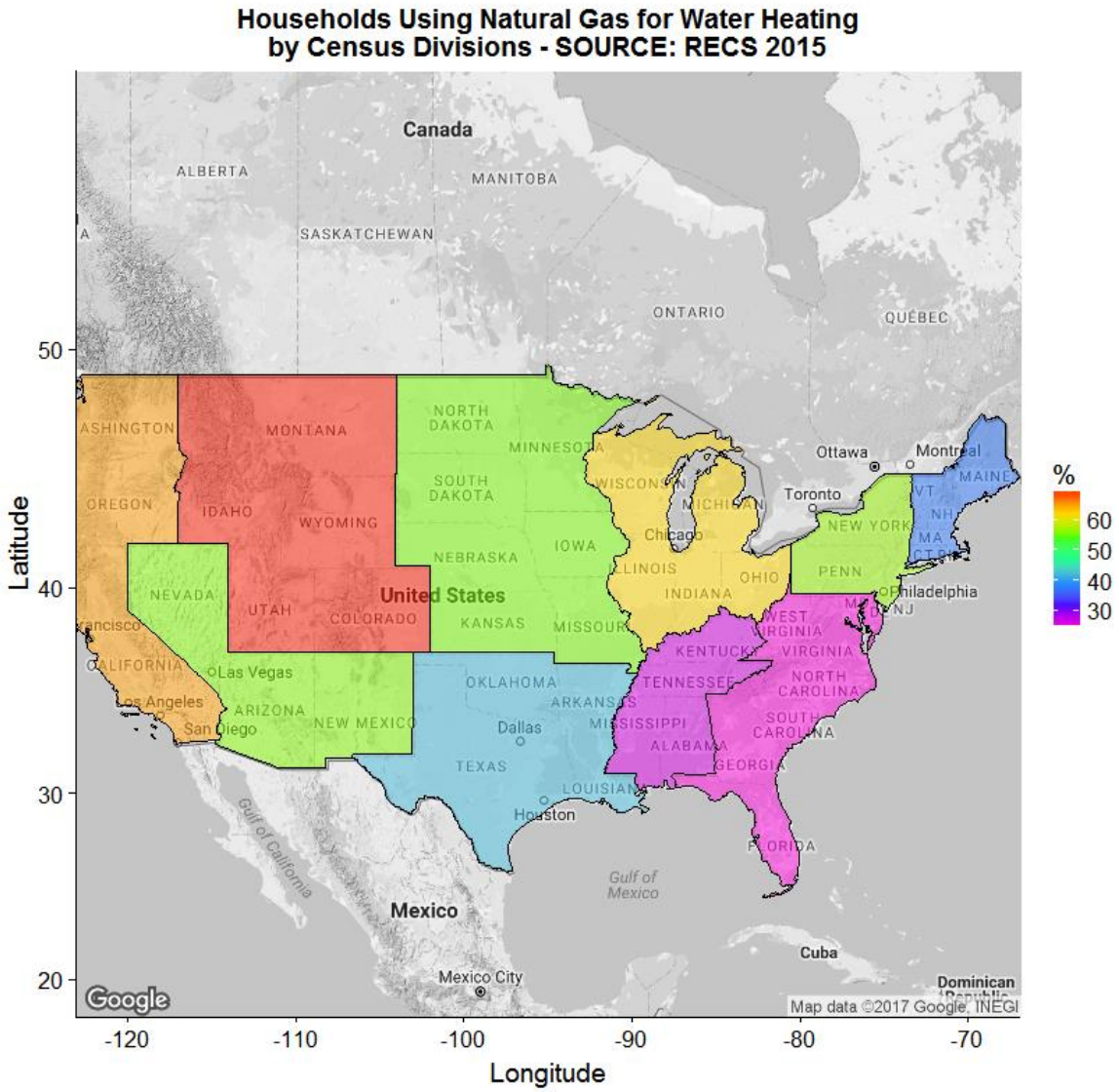

Figure 56 - Percent of Households that use Natural Gas for Water Heating (2015 - by Census Division)

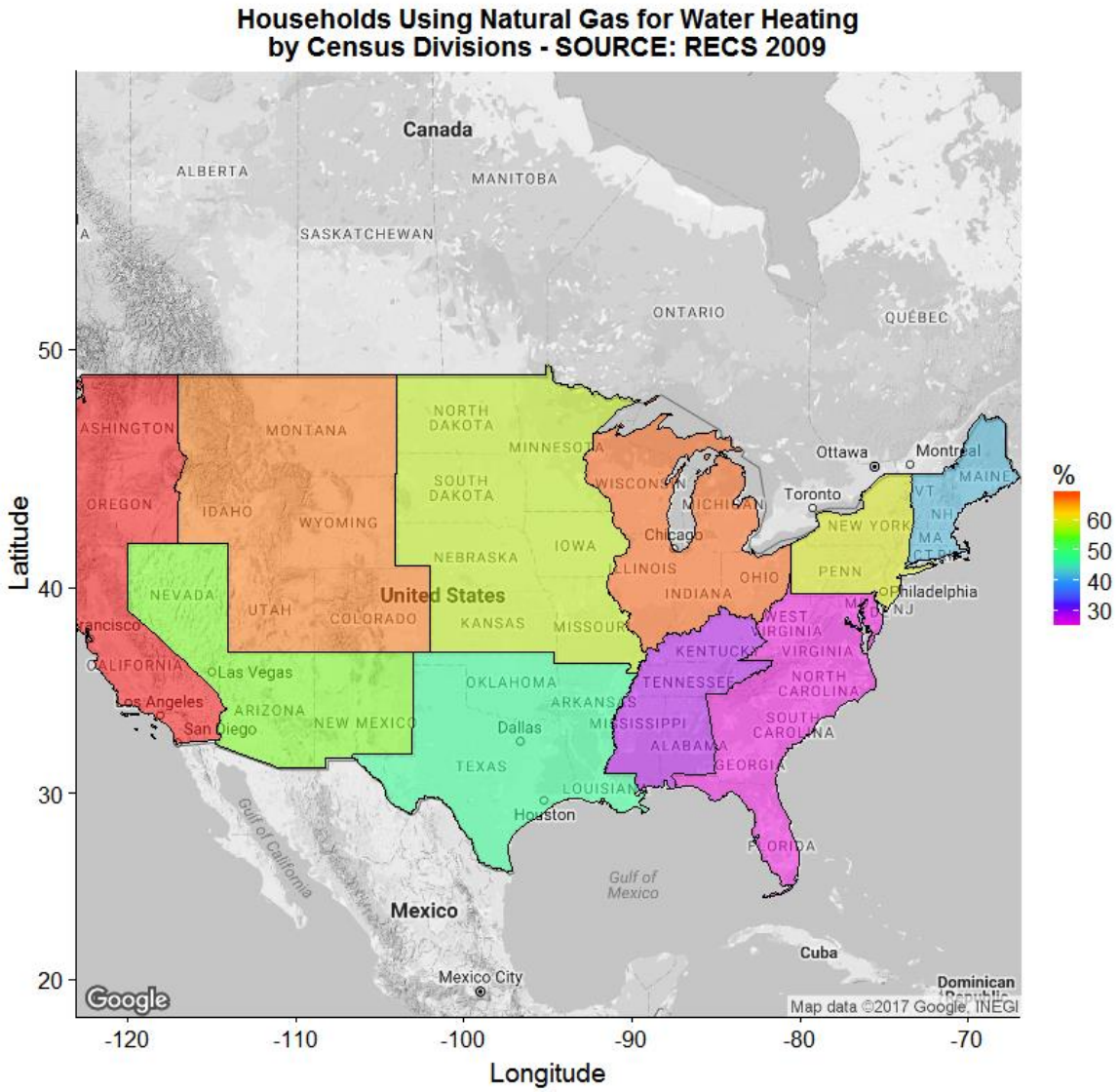

Figure 57 - Percent of Households that use Natural Gas for Water Heating (2009 - by Census Division)

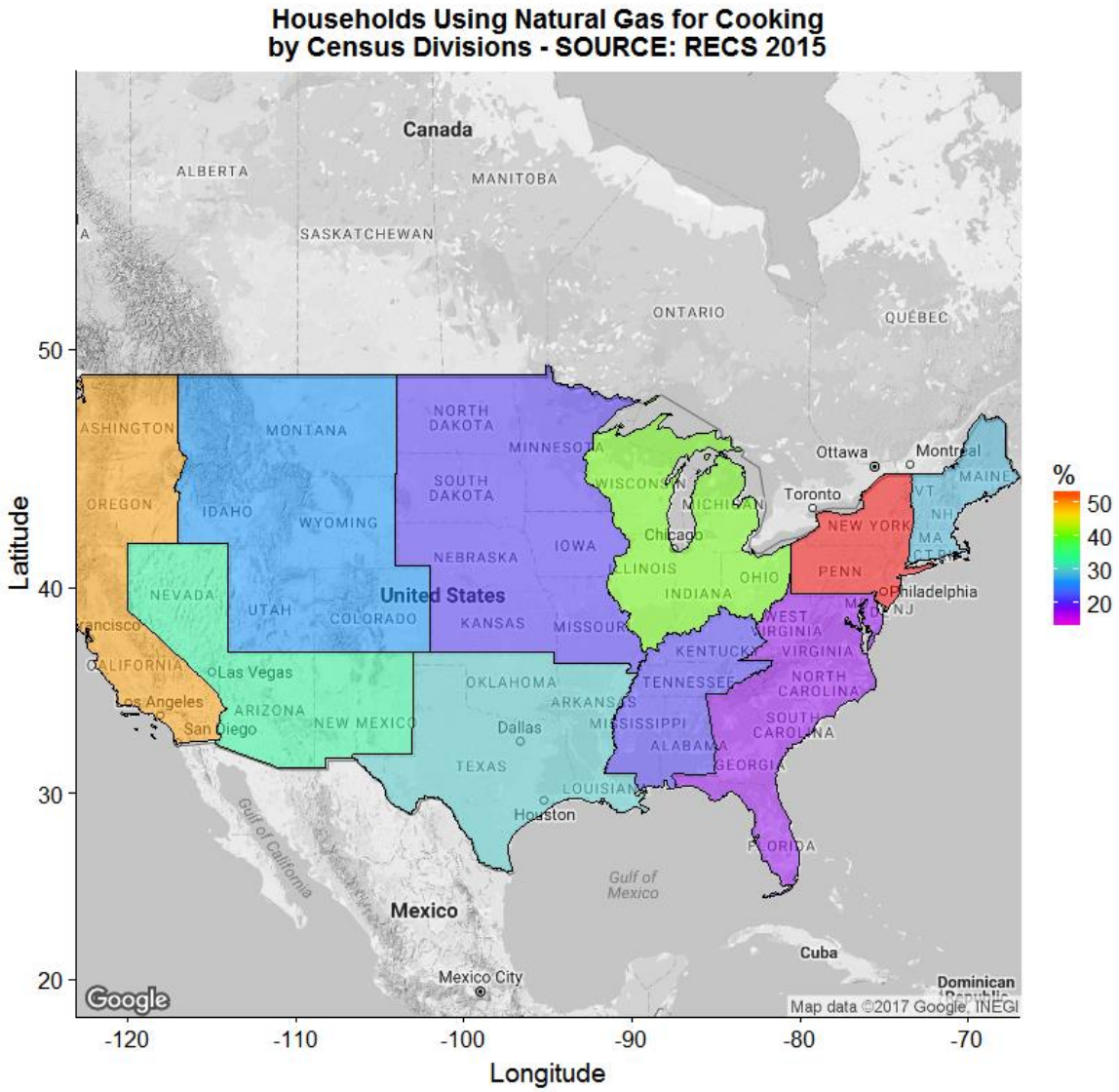

Figure 58 - Percent of Households that use Natural Gas for Cooking (2015 - by Census Division)

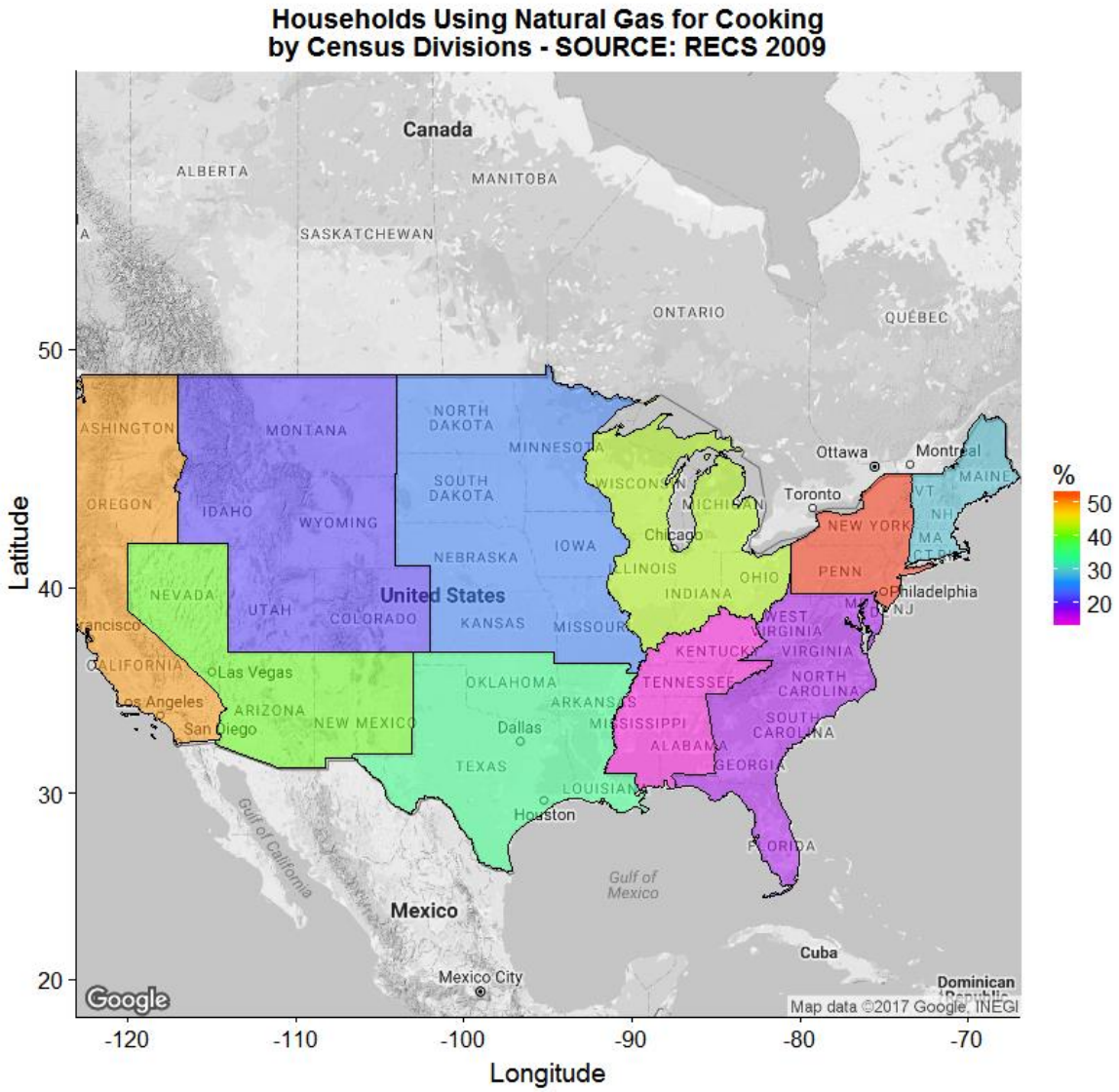

Figure 59 - Percent of Households that use Natural Gas for Cooking (2009 - by Census Division)

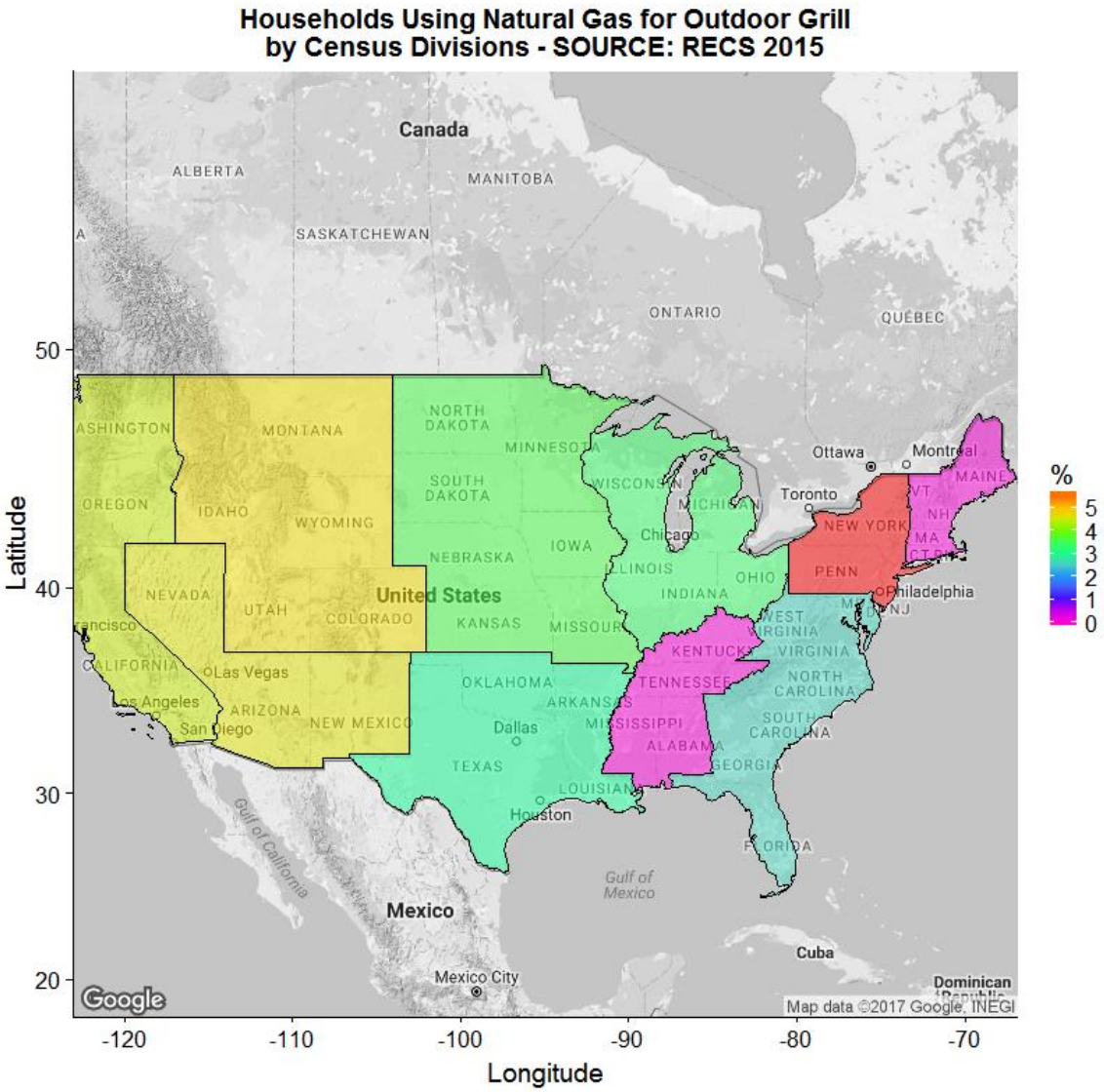

Figure 60 - Percent of Households that use Natural Gas for Outdoor Grill (2015 - by Census Division)

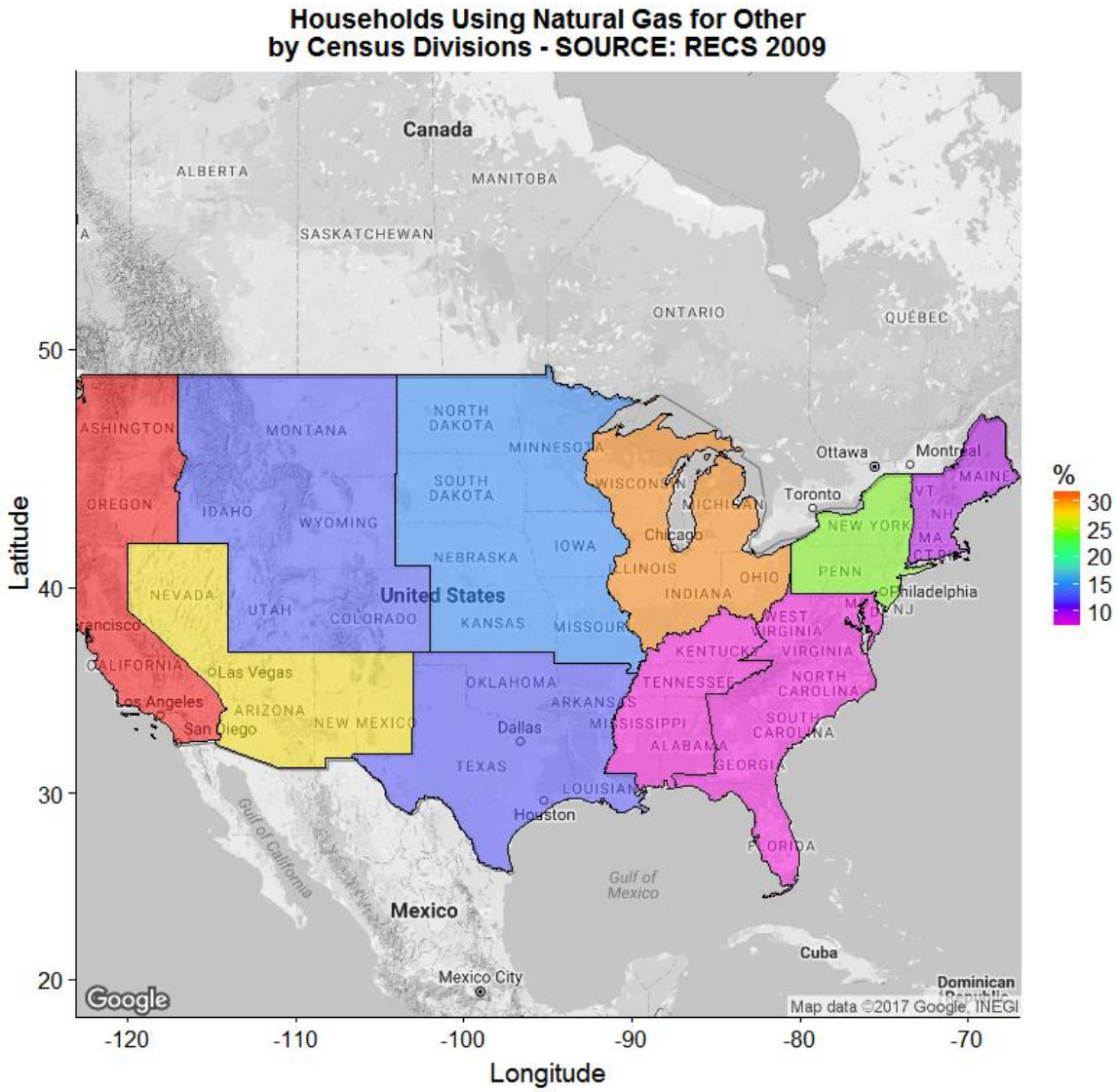

Figure 61 - Percent of Households that use Natural Gas for "Other" (2009 - by Census Division)

Table 5 and Table 6 show a numerical representation of the data displayed in Figure 46 - Figure 47 and Figure 54 - Figure 61 in both absolute units, and percentage change respectively. The data suggests that the popularity of natural gas water heaters is diminishing; from 2009-2015 there was a 1.5 million unit reduction in households using natural gas water heaters, despite a 4.6 million unit increase in total quantity of households. Water heaters were the only end use to experience a reduction in prevalence. The only regions to contradict the trend in gas-fired water heater prevalence were the Mountain region (which experienced a 400,000 unit and 0.4% overall increase in the number of households using natural gas water heaters), and to a much lesser extend the South Atlantic (which experienced a 200,000 unit increase, but a 0.5% overall decrease).

Table 5 – Quantity Change in Number of Households Using Natural Gas from 2009 to 2015 RECS (number of housing units in millions)

(All values in millions of housing units)	Total # of houses	Use Natural Gas	Use Natural Gas For…				
			Space Heating			Water Heating	Cooking
			Any	Main	Secondary space		
Total US	**4.6**	**0.5**	**0.8**	**0.3**	**0.3**	**-1.5**	**0.7**
Total South	**2.3**	**-0.4**	**-0.2**	**-0.5**	**0**	**-0.2**	**0.7**
South Atlantic	1.3	-0.3	-0.1	-0.2	0.1	0.2	0.4
East South Central	0.1	0.3	0.2	0.1	0.1	-0.1	0.6
West South Central	1	-0.4	-0.3	-0.5	-0.2	-0.3	-0.3
Total West	**1.6**	**1**	**0.5**	**0.5**	**-0.2**	**0.4**	**0.5**
Pacific	1	0.8	0.5	0.6	-0.3	-0.1	0.4
Total Mountain	0.6	0.2	0	0	0.1	0.4	0.1
Mountain North	0.3	0.1	0.1	0	0.1	0.3	0.3
Mountain South	0.3	0	-0.1	-0.1	0	0.2	-0.2
Total Northeast	**0.2**	**0.1**	**0.5**	**0.5**	**0.5**	**-0.6**	**0.2**
New England	0.1	-0.2	0	0	0.2	-0.2	0
Middle Atlantic	0.1	0.3	0.6	0.6	0.3	-0.4	0.1
Total Midwest	**0.5**	**-0.1**	**-0.1**	**-0.2**	**0.1**	**-0.9**	**-0.6**
East North Central	0.2	-0.3	-0.3	-0.3	0	-0.9	-0.3
West North Central	0.2	0.3	0.2	0.1	0.1	-0.1	-0.3

Space heating and cooking saw modest increases from 2009-2015 of 800,000 and 700,000 respectively, predominantly due to increases in the Pacific and Middle-Atlantic regions. However, when compared to the 4.6 million unit increase in the total number of housing units, it is clear that the popularity of natural gas is waning. One possible explanation for this is in the changing housing stock and more airtight and efficient new construction practices. With these new tighter and better-insulated houses, there is less of an overall heating demand, reducing the necessity of powerful gas-fired furnaces. Also in these tighter homes, conventional natural draft water heaters and unvented kitchen appliances can lead to indoor air quality issues. Additionally, the improvement in residential heat pump technology has made them an economical choice in many situations, especially within high performance buildings. (21) Without the need for a gas-fired furnace, it is an understandable choice to configure a house to run without natural gas, avoiding instillation and materials costs, as well as the fixed monthly costs of an additional utility.

Table 6 - Percentage Change in Number of Households Using Natural Gas from 2009 to 2015 RECS

	Total % of houses	Use Natural Gas	Use Natural Gas For…				
			Space Heating			Water Heating	Cooking
			Any	Main	Secondary Space		
Total US	**4.0%**	**-1.9%**	**-1.3%**	**-1.7%**	**0.0%**	**-3.3%**	**-0.8%**
Total South	**5.5%**	**-3.1%**	**-2.2%**	**-2.8%**	**-0.3%**	**-2.1%**	**0.5%**
South Atlantic	5.9%	-3.2%	-1.9%	-2.2%	0.1%	-0.5%	0.8%
East South Central	1.4%	3.6%	2.3%	1.0%	1.3%	-1.8%	8.2%
West South Central	7.8%	-6.9%	-5.4%	-6.8%	-2.0%	-5.6%	-4.7%
Total West	**6.5%**	**-0.7%**	**-1.5%**	**-1.4%**	**-1.2%**	**-2.5%**	**-0.7%**
Pacific	5.9%	0.3%	-0.2%	0.4%	-2.1%	-4.4%	-0.5%
Total Mountain	7.6%	-2.7%	-4.4%	-4.3%	0.7%	0.4%	-1.0%
Mountain North	7.7%	-3.3%	-2.9%	-5.3%	1.8%	2.4%	5.7%
Mountain South	7.5%	-4.5%	-5.8%	-5.8%	-0.3%	0.8%	-7.4%
Total Northeast	**1.0%**	**-0.2%**	**1.9%**	**1.9%**	**2.3%**	**-3.4%**	**0.5%**
New England	1.8%	-4.5%	-0.7%	-0.7%	3.5%	-4.3%	-0.5%
Middle Atlantic	0.7%	1.5%	3.5%	3.5%	1.9%	-3.0%	0.3%
Total Midwest	**1.9%**	**-1.8%**	**-1.7%**	**-2.1%**	**0.2%**	**-4.6%**	**-3.0%**
East North Central	1.1%	-2.5%	-2.5%	-2.5%	-0.1%	-5.7%	-2.1%
West North Central	2.5%	2.0%	1.0%	-0.2%	1.0%	-2.6%	-4.2%

Figure 62 shows the county level distribution of housing units using natural gas as the primary heating fuel. There is a lower prevalence of natural gas fueled heating in the South and Pacific Northwest, where the mild winters do not require significant heating energy, as well as in New England where fuel oil satisfies a large portion of the heating demand. There is a moderately high concentration in the more densely populated (where natural gas infrastructure is more likely to exist) portions of the south west, where moderate space heating and other end use demands combined with high electrical prices, make natural gas an economical choice

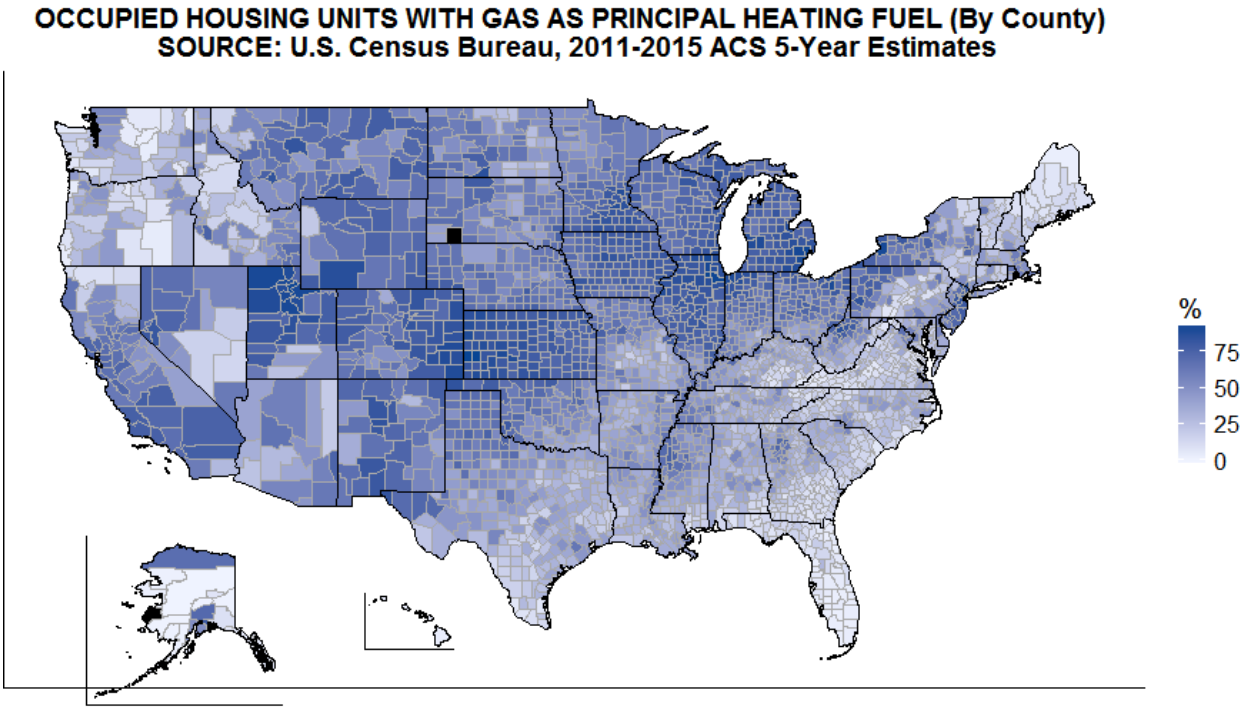

Figure 62 – County level distribution of households that use gas for space heating

Table 7 shows the percentage of the population using natural gas as the main space heating fuel in a variety of location types. Overall natural gas is significantly more likely to be used for heating in urban areas relative to rural areas, and in principal cities relative to outside of them.

Table 7 - Percent of Occupied Housing Units with Gas as Principal Heating Fuel

Geographic Area	Percent (%)
United States	53.4
Urban	56.8
Rural	39.3
In metropolitan or micropolitan statistical area	54.0
In metropolitan statistical area	54.7
In principal city	56.6
Not in principal city	53.5
In micropolitan statistical area	47.3
In principal city	57.2
Not in principal city	42.1
Not in metropolitan or micropolitan statistical area	44.7
Source: U.S. Census Bureau, 2011-2015 American Community Survey 5-Year Estimates	

Uncertainty

Most of the data sets utilized calculate an approximate value for a specific location by surveying a subset of the inhabitants, and then extrapolating based on population demographics data to represent the entire area. Some uncertainty data from the main databases used in this report (EIA Natural Gas Deliveries, RECS, AHS) are presented below.

The EIA Natural Gas Delivered To Residential Consumers data had a relative standard error (RSE) ranging from 0-6.1% depending on the state, with a total RSE of 0.3%. A complete list of the RSEs for each state is included in Appendix C, Table 9.

For the RECS data, the microdata that was used for the analysis in this report, error and uncertainty data is not provided. However, the summary estimates generated by the EIA does include RSEs for each metric. RSEs for relevant data to this report are included in Table 10 in Appendix C.

For the AHS, the bulk of the data used in this report is based off of yes or no question. In addition to the yes/no options, each question had options for not reported/blank, refused to answer, did not know, or not applicable. Each of the “percent yes” metrics calculated in the report are based on the weighted number of yes responses over the sum of the weighted number of yes or no responses. In addition, for each calculated metric a “percent other” value was calculated, from the weighted number of non-yes/no responses over the total weighted number of responses (yes, no, and other). Equivalent maps to the AHS based maps presented earlier showing the “percent other” values for each area are included in Appendix D (note, these maps have different color scales than their counterparts.

Conclusions

Not surprisingly, the majority of natural gas is consumed in urban and metropolitan areas, as this is where the population is concentrated, and where it makes economical and logistical sense to establish natural gas pipe distribution networks.

Areas with a more significant heating season will consume more natural gas than their warmer counterparts.

New England consumes less natural gas than areas with equivalent climates due to the high utilization of fuel oil, but natural gas is becoming more prevalent, and its consumption will continue to increase in the area.

The EIA predicts that residential natural gas consumption will not change significantly in the coming years, and may even decrease slightly (Figure 63). According to the EIA's Annual Energy Outlook 2017 "Natural gas consumption in the residential and commercial sectors remains largely flat [in the future] as a result of efficiency gains that balance increases in the number of housing units and commercial floor space." (22)

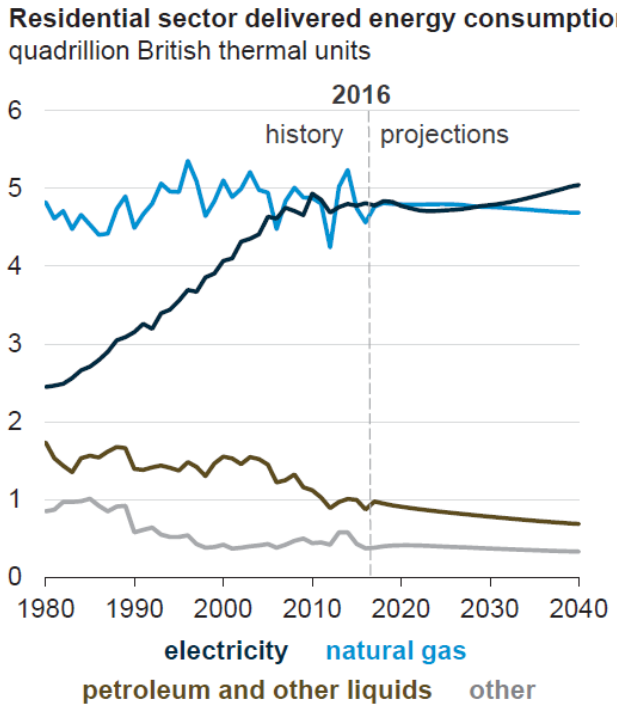

Figure 63 - Residential fuel consumption predictions

[SOURCE: EIA Annual Energy Outlook 2017 (22)]

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Appendices

Appendix A

Table 8 - American Housing Survey metropolitan location history

Recent American Housing Survey Metropolitan Locations										
	Metro	National	Metro	National	Metro	Concurrent National & Metro Survey				
	1998¤	1999	2002¤	2003	2004¤	2007	2009	2011¤	2013*	2015*
Anaheim, CA			Y					Y		
Atlanta, GA					Y			Y		
Austin, TX									Y	
Baltimore, MD	Y					Y			Y	
Birmingham, AL	Y							Y		
Boston, MA	Y					Y			Y	
Buffalo, NY			Y					Y		
Charlotte, NC			Y					Y		
Chicago, IL+		Y		Y			Y		Y	
Cincinnati, OH	Y							Y		
Cleveland, OH					Y			Y		
~~Colorado Springs, CO~~										
Columbus, OH			Y					Y		
Dallas, TX			Y					Y		
Denver, CO					Y			Y		
Detroit, MI+		Y		Y			Y		Y	
Fort Worth, TX			Y					Y		
~~Grand Rapids, MI~~										
Hartford, CT					Y				Y	
~~Honolulu, HI~~										
Houston, TX	Y					Y			Y	
Indianapolis, IN					Y			Y		
Jacksonville, FL									Y	
Kansas City, MO			Y					Y		
Las Vegas, NV									Y	
Louisville, KY									Y	
Los Angeles, CA+		Y		Y				Y		
~~Madison, WI~~										
Memphis, TN					Y			Y		
Miami, FL			Y			Y			Y	
Milwaukee, WI			Y					Y		
Minneapolis-St. Paul, MN	Y					Y			Y	
Nashville, TN									Y	

New Orleans, LA					Y		Y	Y		
New York, NY[+]		Y		Y			Y		Y	
Norfolk-Virginia Beach-Newport News, VA	Y							Y		
Northern New Jersey, NJ[+]		Y		Y			Y		Y	
Oakland, CA	Y							Y		
Oklahoma City, OK					Y				Y	
~~Omaha, NE~~										
Orlando, FL									Y	
Philadelphia, PA[+]		Y		Y			Y		Y	
Phoenix, AZ			Y					Y		
Pittsburgh, PA					Y			Y		
Portland, OR			Y					Y		
Providence, RI	Y							Y		
~~Raleigh, NC~~										
Richmond, VA									Y	
Riverside, CA			Y					Y		
Rochester, NY	Y								Y	
Sacramento, CA					Y			Y		
~~Saginaw, MI~~										
Salt Lake City, UT	Y									
San Diego, CA			Y					Y		
San Francisco, CA	Y							Y		
San Antonio, TX					Y				Y	
San Jose, CA	Y							Y		
Seattle, WA					Y		Y		Y	
~~Spokane, WA~~										
~~Springfield, MA~~										
St. Louis, MO					Y			Y		
Tampa, FL	Y					Y			Y	
Tucson, AZ									Y	
Washington, D.C.	Y					Y			Y	
* For data confidentiality reasons, zones were are no longer reported after 2011.										
[+]The six largest metro areas are surveyed as an enhanced sample during alternating national surveys										
[¤] Zone level detail available for this survey										
~~City, State~~: This city was not sampled during the 1998-2015 period										

Appendix B

See Separate file: EDF METHANE MAPS REPORT - Appendix B.docx

Appendix C

Table 9 - EIA Natural Gas Delivered to Consumers Standard Error

February 2017

Table C1

Table C1. Standard error for natural gas deliveries and price by consumers, by state, December 2016

State	Volume Relative Standard Error (Percent)				Price (Dollars per Thousand Cubic Feet)		
	Residential	Commercial	Industrial	Total	Residential	Commercial	Industrial
Alabama	2.1	2.5	1.9	1.3	0.11	0.10	NA
Alaska	0.0	0.0	0.0	0.0	0.00	0.00	0.00
Arizona	3.5	7.5	2.3	3.1	0.54	0.36	0.15
Arkansas	6.1	1.5	2.4	2.1	0.13	NA	0.34
California	2.7	2.7	0.6	1.2	0.38	0.48	0.51
Colorado	1.8	0.4	NA	NA	0.03	0.05	0.05
Connecticut	0.2	0.3	0.9	0.2	0.06	0.04	0.01
Delaware	0.0	0.0	0.0	0.0	0.00	0.00	0.00
District of Columbia	0.0	0.0	0.0	0.0	0.00	NA	0.00
Florida	1.7	0.8	NA	NA	0.16	0.20	0.24
Georgia	0.0	0.0	2.2	0.0	0.00	0.05	0.30
Hawaii	0.0	0.0	0.0	0.0	0.00	0.00	0.00
Idaho	0.6	0.6	0.0	0.3	0.00	0.01	0.00
Illinois	0.5	0.3	1.8	0.4	0.05	0.08	0.24
Indiana	1.0	0.6	1.6	0.9	0.08	0.10	0.38
Iowa	1.0	0.8	0.4	0.4	0.06	0.08	0.28
Kansas	2.4	0.6	2.2	1.4	NA	0.14	0.65
Kentucky	0.3	0.6	0.8	0.4	0.08	0.10	0.12
Louisiana	1.9	1.5	1.2	1.1	0.13	0.14	NA
Maine	3.2	4.6	6.6	NA	NA	0.79	0.41
Maryland	0.3	0.7	NA	NA	NA	0.12	0.37
Massachusetts	0.7	0.6	0.8	0.4	0.08	0.09	0.13
Michigan	0.5	0.6	1.0	0.4	0.08	0.04	0.03
Minnesota	1.1	1.2	0.9	0.6	0.02	0.06	0.08
Mississippi	4.4	3.6	1.4	1.4	0.26	0.26	0.12
Missouri	0.7	0.4	2.2	0.6	0.02	0.05	0.14
Montana	0.3	0.3	NA	NA	0.02	0.07	0.00
Nebraska	1.2	0.7	1.3	0.7	0.08	0.06	0.42
Nevada	0.0	0.0	NA	NA	0.00	0.00	0.02
New Hampshire	0.0	0.0	6.3	1.3	NA	0.00	0.00
New Jersey	0.0	0.0	0.8	0.1	0.00	0.00	0.14
New Mexico	2.9	0.6	5.4	1.6	0.30	0.10	0.61
New York	0.0	0.0	1.3	0.0	0.03	0.02	0.28
North Carolina	0.4	0.3	0.4	0.2	0.02	0.07	0.17
North Dakota	0.3	0.8	7.3	2.7	0.03	0.08	0.00
Ohio	0.0	0.0	1.2	0.0	0.07	0.03	0.62
Oklahoma	3.4	1.4	1.1	1.3	0.05	0.20	0.51
Oregon	0.0	0.0	1.5	0.4	0.00	NA	0.00
Pennsylvania	0.9	0.8	5.7	1.5	0.12	0.12	0.22
Rhode Island	0.0	0.0	0.0	0.0	0.00	0.00	0.00
South Carolina	1.1	1.8	1.6	0.9	0.24	0.11	0.10
South Dakota	0.6	0.8	1.0	0.5	0.04	0.10	0.23
Tennessee	1.0	0.7	1.4	0.7	0.07	0.06	0.11
Texas	3.3	1.4	1.2	1.0	0.25	0.14	0.03
Utah	0.3	0.2	0.0	0.2	0.00	0.00	0.01
Vermont	0.0	0.0	0.0	0.0	0.00	0.00	0.00
Virginia	3.1	2.9	2.4	1.7	NA	0.14	0.47
Washington	1.3	1.3	2.6	1.0	0.07	0.06	0.07
West Virginia	2.4	0.5	1.4	1.0	0.03	0.02	0.29
Wisconsin	0.5	0.5	0.4	0.3	0.03	0.02	0.02
Wyoming	1.1	2.4	1.0	NA	0.08	0.10	NA
Total	**0.3**	**0.2**	**0.4**	**0.2**	**0.03**	**0.03**	**0.02**

NA Not available.

Source: Energy Information Administration (EIA): Form EIA-857, "*Monthly Report of Natural Gas Purchases and Deliveries to Consumers.*"

Source: U.S. Energy Information Administration
https://www.eia.gov/naturalgas/monthly/pdf/table_c01.pdf

Table 10 - Relative Standard Errors for Select Metrics in 2009 RECS

		"Total U.S." [1]	Census Region			
			Northeast	Midwest	South	West
Natural Gas Used (any purpose)	Millions of units	69.2	13.8	19.4	17.7	18.3
	RSE (%)	0.5	1.5	0.7	1.3	1.0
Natural Gas used for Space Heating	Millions of units	57.2	11.1	18.2	14.0	14.0
	RSE (%)	0.4	1.0	0.4	0.7	0.8
Natural Gas used for Main Space Heating	Millions of units	55.6	10.8	17.9	13.3	13.6
	RSE (%)	0.2	0.6	0.2	0.4	0.6
Natural Gas used for Secondary Space Heating	Millions of units	7.2	0.9	1.9	2.5	1.9
	RSE (%)	4.8	11.7	9.6	9.6	7.0
Natural Gas used for Water Heating	Millions of units	58.4	11.4	16.8	13.6	16.5
	RSE (%)	0.7	1.9	1.2	1.7	1.3
Natural Gas used for Cooking	Millions of units	39.2	9.7	9.6	9.0	10.8
	RSE (%)	1.8	3.2	4.7	3.9	2.5
Natural Gas used for "other"	Millions of units	21.5	4.2	6.6	3.8	7.0
	RSE (%)	2.2	4.5	3.9	5.6	3.8
Natural Gas used by main water heater	Millions of units	58.3	11.4	16.8	13.6	16.5
	RSE (%)	0.7	1.9	1.2	1.7	1.3
Natural Gas used by Central Warm-Air Furnace	Millions of units	44.3	6.1	15.9	11.3	11.0
	RSE (%)	0.9	3.1	1.2	1.6	1.9
Natural Gas used by Steam or Hot Water System	Millions of units	6.9	4.3	1.7	0.4	0.4
	RSE (%)	4.6	4.7	10.3	24.4	31.9
Natural Gas used by Built-In Room Heater	Millions of units	2.3	0.2	0.1	0.9	1.1
	RSE (%)	6.9	22.9	37.2	11.8	9.5
Natural Gas used by Floor or Wall Pipeless Furnace	Millions of units	1.2	0.1	Q	0.2	0.9
	RSE (%)	8.2	39.5	43.0	25.6	8.3
Natural Gas used by Other Space Heating Equipment	Millions of units	0.9	Q	0.1	0.5	0.2
	RSE (%)	12.5	44.6	31.0	18.4	19.8
Natural Gas used by Secondary Space Heating Equipment	Millions of units	7.2	0.9	1.9	2.5	1.9
	RSE (%)	4.8	11.7	9.6	9.6	7.0
Natural Gas Consumed (total)	Quadrillion Btu	4.694	1.064	1.751	0.942	0.937
	RSE (%)	1.1	2.8	1.6	2.3	2.8
Natural Gas Consumed (average site)	Million Btu per household using the fuel	67.8	77.3	90.3	53.1	51.2
	RSE (%)	1.1	2.5	1.8	2.2	2.8
[1]Total U.S. includes all primary occupied housing units in the 50 States and the District of Columbia. Vacant housing units, seasonal units, second homes, military housing, and group quarters are excluded.						
Separate data for individual census divisions are available on the EIA website: https://www.eia.gov/consumption/residential/data/2009/						

Appendix D

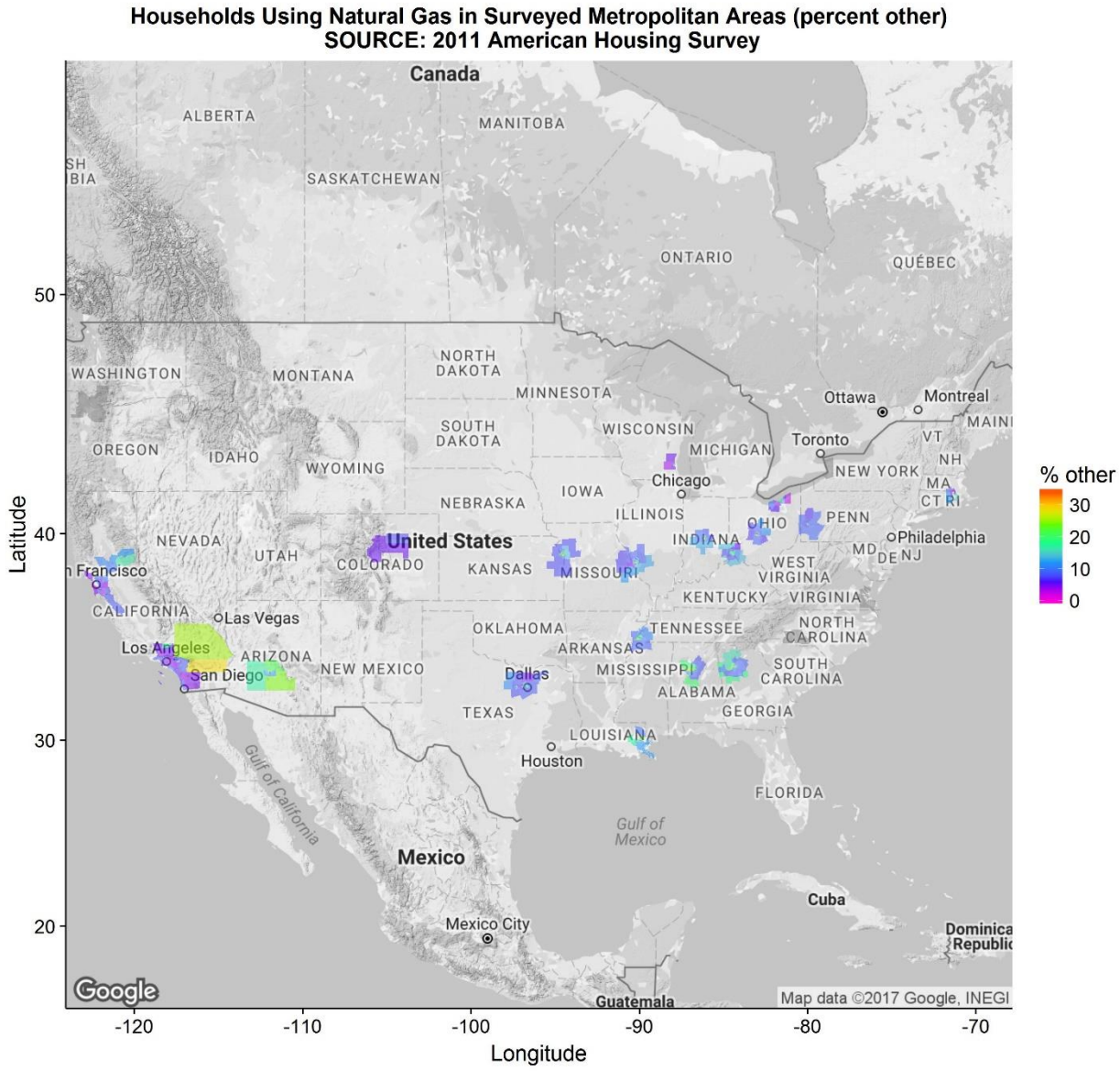

Figure 64 - Continental United States Percent of Households Using Natural Gas that Answered Other

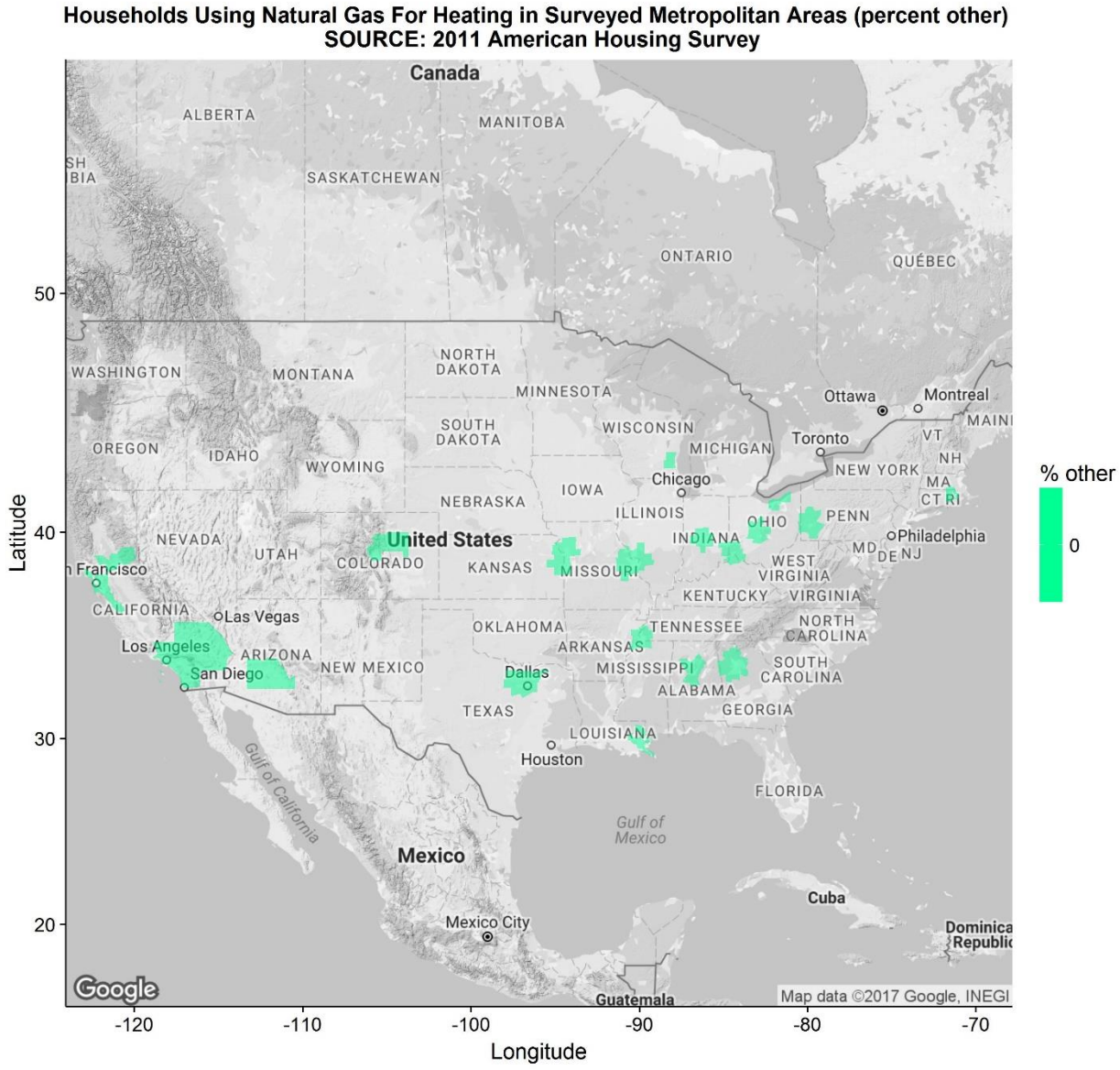

Figure 65 - Continental United States Percent of Households Using Natural Gas for Space Heating that Answered Other

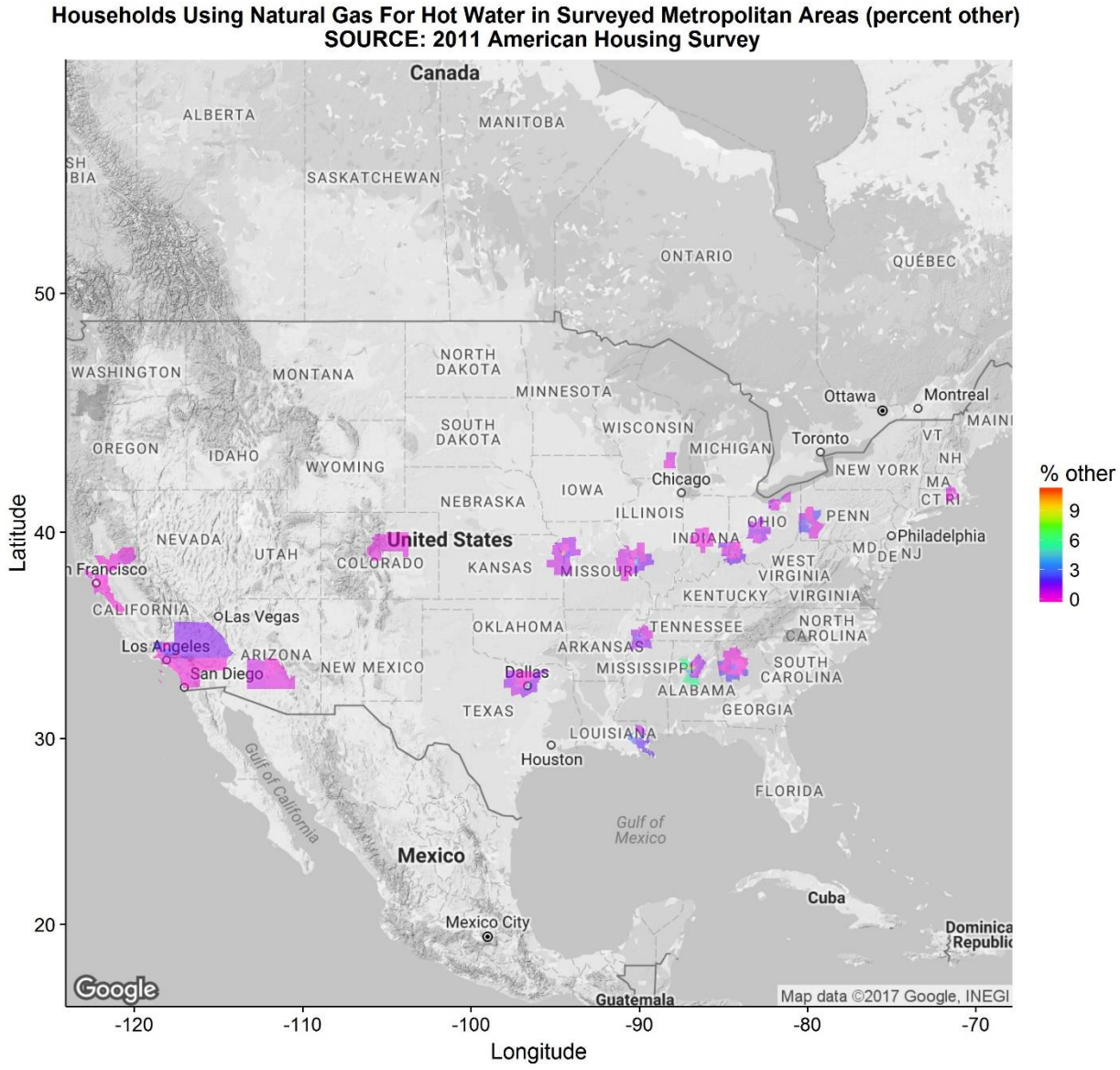

Figure 66 - Continental United States Percent of Households Using Natural Gas for Water Heating that Answered Other

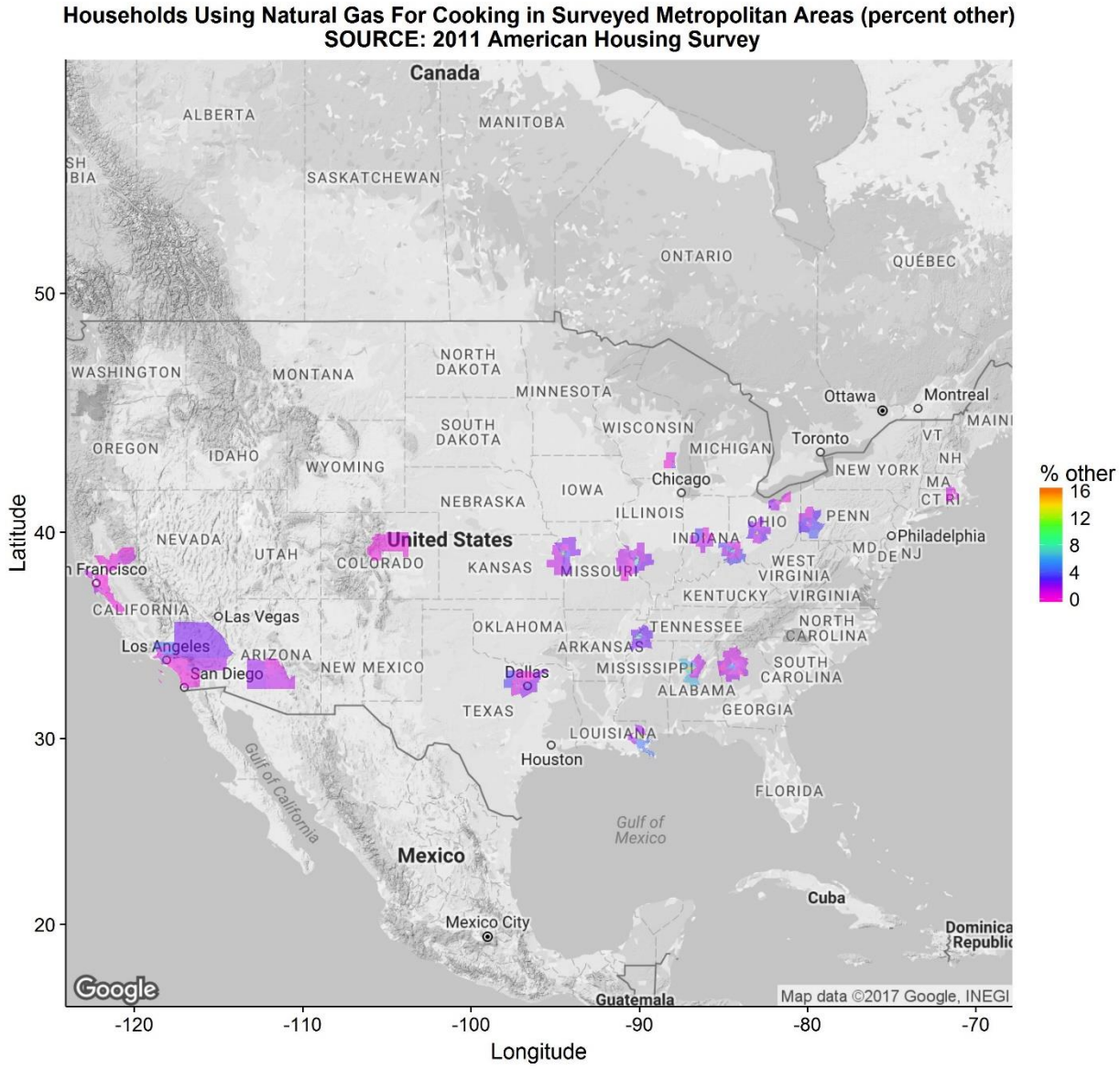

Figure 67 - Continental United States Percent of Households Using Natural Gas for Cooking that Answered Other

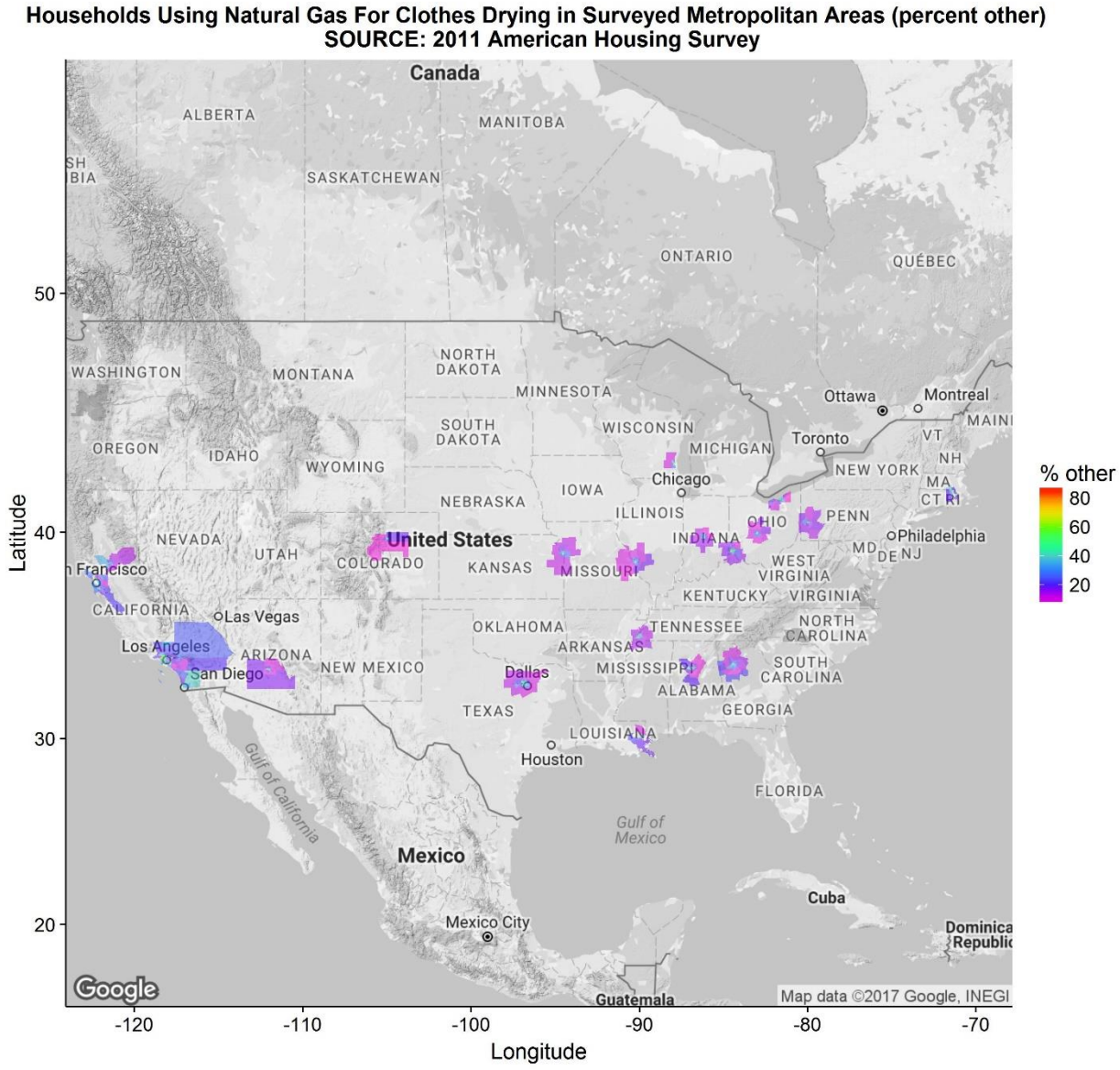

Figure 68 - Continental United States Percent of Households Using Natural Gas for Clothes Drying that Answered Other