Energy Burden in Philadelphia: Challenges and Policy Solutions

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Abstract

Energy burden is a percentage of income a household pays for energy costs, and high energy burden can lead to negative health, housing, and safety outcomes for financially vulnerable households. Using three federal datasets, this paper assesses relationships between housing characteristics and energy burden across Philadelphia census tracts. Philadelphia provides a unique insight into energy burden as it faces the dual challenges of having one of the country's poorest big cities and having an exceptionally old housing stock. This research finds that low-income households in the city have lower incomes, higher energy bills, older housing, and more residents per household, which are all contributors to high energy burden. Specific opportunities to reduce energy burden may be found in households with high energy burden utilizing expensive heating fuels and low-income households with air-conditioning.

Policy recommendations for reducing energy burden from this paper include continuing investments in the city's numerous housing and energy efficiency programs, embracing simple, effective energy efficiency solutions, prioritizing electrification upgrades for residents reliant on the most expensive heating fuels, and providing cooling energy efficiency interventions to homes with especially high heat vulnerability.

Acknowledgements

I'd like to thank my capstone mentor, Dr. Amardeep Dhanju, for his insight, guidance, and direction, and for helping me navigate difficult research questions and roadblocks. Thank you to my capstone advisor, Dr. Michael Schwebel, for his thoughtful edits and feedback. Thank you to my family for their unconditional support and honest edits. And, thank you to the wonderful people of Philadelphia I have met and worked with over the course of my life, who made me fall in love with the city.

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Executive Summary

Energy services give us the ability to control space temperature, cook indoors, light darkened areas, and many other services that protect occupant health and safety. However, energy costs money, and for many households, it's a heavy cost.

Energy burden is a percentage of income a household pays for energy costs. High energy burden can lead to negative health, housing, and safety outcomes for financially vulnerable households, including the "heat, eat, or treat" dilemma, a situation in which residents may be forced to choose between heating or cooling their homes, food, and medicine (Drehobl 2020).

This paper explores the research question: how do housing characteristics relevant to energy usage trend across different energy burden levels in Philadelphia? Expected findings are that census tracts with higher energy burdens experience higher energy bills, lower incomes, older homes, more residents per home, less electrified space heating, and lower air-conditioning usage.

Methodology and Findings

This research uses quantitative analysis to assess how various housing characteristics trend across different energy burden levels. Census tract data on housing characteristics is retrieved from the Low-income Energy Affordability Data tool from the U.S. Department of Energy and the 2016 U.S. Census Bureau 5-year American Community Survey. The data points are matched to the 375 2016 census tracts in Philadelphia and then charted in scatterplots. A regression model is utilized to understand the relationship between the data.

The findings include:

1. Census tracts with higher energy burden have lower household incomes and pay higher energy bills.

2. Census tracts with high energy burden tend to have older homes with more people living in them.
3. There are highly energy burdened homes in Philadelphia utilizing expensive heating fuels.
4. While most households have air-conditioning, heavily energy-burdened households in heat vulnerable areas are at higher risk on hot days.

The suggested solutions for the city include:

1. Continue or expand investments to programs that reduce energy costs.
2. Ensure simple energy efficiency measures are available to residents in highly energy-burdened census tracts.
3. Prioritize fuel-switching for census tracts with high bottled gas and heating oil use to electrification.
4. Reduce air-conditioning costs for low-income and heat vulnerable households.

Introduction

Energy provides homes, and their residents, with the ability to control space temperature, to cook indoors, to light darkened areas, and many other services that protect occupant health and safety. However, energy costs money. For a significant portion of the American population, this financial burden is especially heavy, putting their ability to access energy services at risk.

The percentage of gross household income spent on energy services is called a household's energy burden, according to the U.S. Department of Energy (DOE). Energy burden is also used to illustrate the financial hardship caused by "disproportionate allocation of financial resources among low-income households on energy expenditures" (Hernandez, 2010). Energy burden is considered high at just 6% of income (Drehobl 2020). However, the DOE reports the national average energy burden for low-income households is higher, at 8.6%, while non-low income families pay about a third of that percent, with an average 3% of their income spent towards energy.

Energy efficiency intervention measures, which reduce a household's energy load and consumption, can reduce this energy burden gap and save low- and moderate-income (LMI) households money. One study found that energy efficiency measures, if applied nationally to households that qualify as low-income by the federal government, could save ratepayers $13 billion annually, equal to $670 per year per household on average (Wilson 2019).

It is well-established in academic literature that low-income, minority populations tend to live in housing that creates high energy burden and unfavorable health outcomes (Wang 2021). This housing inequity is due to generational poverty, historic redlining, and systematic discrimination (Lewis 2021). Poor housing conditions include: lead, pests, mold, poor indoor air quality and ventilation, and energy inefficient appliances (Krieger 2002). These conditions can reduce quality of life and can result in chronic medical conditions, infectious disease, financial distress, and injuries (Krieger 2002).

Research Questions

This research addresses the following questions: how do housing characteristics relevant to energy usage trend across different energy burden levels in Philadelphia? The hypothesis is that census tracts with higher energy burdens experience higher energy bills, lower incomes, older homes, more residents per home, less electrified space heating, and lower air-conditioning usage. The second research question will look toward solutions: based on the findings, what solutions are available and seem feasible in Philadelphia? The hypothesis is that the city has solutions in place capable of meeting energy burden needs, but these likely need more funding or support.

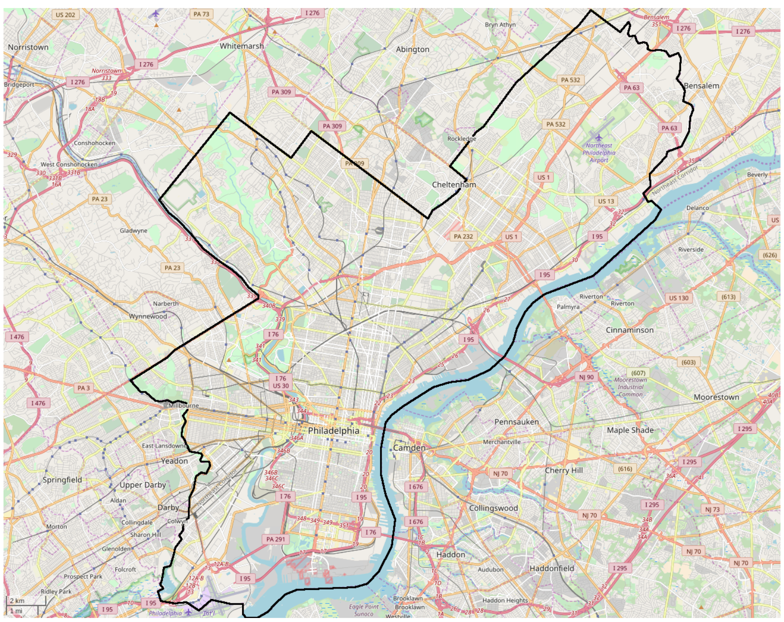
The Consequences of High Energy Burden

Low-income households have limited resources to put toward necessities, often leaving residents to choose between energy, food, and medicine, sometimes called the “heat, eat, or treat” dilemma (Drehobl 2020). Residents may be forced to ration medicine or go without food to heat or cool their homes. Vulnerable residents may also utilize unsafe measures to heat their homes, such as turning on their gas stoves to provide warmth, which is a fire hazard and can lead to poor air quality-related medical issues in vulnerable populations (Coker 2015). Being unable to cool one’s home also poses a dangerous problem: summers across the world are expected to be hotter and last longer due to climate change, and a growing number of people are at increased risk of heat-related illnesses (The Lancet Editorial 2021).

At a system-wide level, unaddressed energy burden can increase energy rates due to the costs of "shutoffs, debt collection, or debt cancellation" being socialized through the ratepayer base (Wilson 2019). These increased rates can, in turn, further exacerbate energy burden.

High energy burden poses public health concerns and economic injustices in communities across the United States. This research, however, will focus on Philadelphia, Pennsylvania, a city that provides unique insight into the many factors that can impact high energy burden.

Background on Philadelphia



Img 1. Map of Philadelphia City and Philadelphia County boundaries.
Source: commons.wikimedia.org

This research will utilize 2016 census and energy burden data. For that reason, this section will provide insight into the demographic, financial, and housing characteristics of the city in 2016 instead of more recent years. According to the U.S. Census Bureau's 2016 5-year American

Community Survey (ACS), Philadelphia County, which shares its boundaries with Philadelphia City, had a population of 1,567,872 people in 2016.

Financial Characteristics

The median household income of Philadelphia was $41,449 in 2016, about 30% lower than the national median income of $57,617, according to the Census Bureau. Philadelphia's lower median income may be due to the city having one of the consistently highest poverty rates for a major American city (Ozcan-Deniz 2021).

To determine a household's poverty threshold, the Census Bureau assesses the number of people living in a household and the household's annual income (Appendix A). For example, the poverty threshold income level in 2016 for a family of four nationally was $24,563 per year. About 47% of residents, or 709,070 people, in Philadelphia fell into 200% or less of the poverty threshold in 2016. Twelve percent of the city lived in especially deep poverty, at 50% or less of the threshold.

Federal poverty guidelines assess poverty at a national level and do not take into account factors that can impact poverty at a localized level. The Area Median Income is calculated annually for every metropolitan region by the U.S. Department of Housing and Urban Development (HUD) to determine affordable housing eligibility. This measure assesses local income levels and number of household residents. The AMI of Philadelphia County in 2016 was $80,300, more than three times the poverty threshold. A family of four in Philadelphia County making less than $64,250 was considered to have a low income under AMI and a family of four making less than $24,100 was considered to be extremely low income.

Housing Characteristics

According to the 2016 5-year ACS, the city had 671,125 registered units. The city's housing is 59% single-unit attached homes. In Philadelphia, these structures are primarily rowhomes, a historic part of Philadelphia's housing stock that were a space-efficient way to accommodate residents as the city grew rapidly throughout the 19th century (Schade 2019). Another 8% of homes are single-unit detached, free-standing homes, and 33% are apartments in structures with 2 or more units. The historic nature of Philadelphia's housing stock is a contributing factor to the city's high energy burden.

Philadelphia's Energy Burden

Philadelphia has consistently ranked as the country's poorest big city (Ozcan-Deniz 2021). At the same time, Philadelphia's housing stock is exceptionally old with a median age of 93 years in 2018 (Kramer 2021) and a quarter of the homes built before 1939 (Pew Charitable Trust 2020). According to Harvard University's State of Housing report, the median age of the national building stock is less than half the age of Philadelphia's at 41 years in 2019. A combination of these and other complex factors have made Philadelphia one of five metropolitan regions in the United States with more than quarter of its low-income households experiencing energy burden at 18%, three times higher than what is considered heavy (Drehobl 2020).

High energy burden in the city has contributed to utility shut-offs due to unpaid energy bills that have left residents without service. For example, in 2021, Philadelphia Gas Works disconnected over 4,000 residences from services in Philadelphia within months after COVID-19 moratorium on shut-offs was lifted (Maykuth 2021).

Methodology

This research uses quantitative analysis to assess how various housing characteristics trend across different energy burden levels. Data points were derived from multiple federal datasets and plotted on scatterplot. A regression model was then run on the plots to assess the relationships of the data points.

This research utilizes census-level data wherever possible. According to the U.S. Census Bureau, census tracts are "small, relatively permanent statistical subdivisions" of the county and average about 4,000 individuals. Energy efficiency potential, the extent to which efficiency measures can be put in place, has been difficult to calculate in the past due, in part, to a lack of granularity in the research (Wilson 2019). Localized climate, equipment, income level, and housing stock play a role in the efficacy of energy efficiency measures, and these unique data points cannot be extrapolated from national-level data (Wilson 2019).

Data Sources

The data used for this research is from the Department of Energy's Low-Income Energy Affordability Data (LEAD) tool, as well as from the U.S. Census Bureau's 2016 5-year American Community Survey (ACS). The 2016 5-year ACS dataset was selected over more recent ACS 5-year datasets to remain consistent with the LEAD tool, which utilizes the 2016 5-year ACS data in its analytics.

The following data was retrieved from the LEAD data tool:

- Average energy burden percent per census tract (%)
- Average annual energy costs per census tract ($)

The following additional household characteristics were retrieved from the 2016 5-year ACS survey. This survey collects demographic information from across the country over 60 months and is considered the most reliable of the Census Bureau's ACS datasets, which also come in 1-year and 3-year increments. This data is matched by census tract with the data from the LEAD data tool. These characteristics were selected due to being highlighted by the LEAD data tool as influential in determining energy burden:

- Average household income ($)
- Average household size (number of residents)
- Median year built (YYYY)
- Heating fuel type (Utility gas, electricity, bottled tanks and fuel oils, solar, other fuels, none)

Census Tract Level Data Selection

Census tracts are organized by counties by the Census Bureau, not by cities. However, Philadelphia City is co-extensive with Philadelphia County, meaning the city and county share the same boundaries. The energy burden data for all Pennsylvania census tracts was downloaded, and census tracts for Philadelphia County were identified and pulled out. For the purposes of this research, the 375 census tracts that fall under Philadelphia County in the 2016 ACS will be referred to as Philadelphia City census tracts.

Census tracts that have an average energy burden of 6% or higher are considered to experience high energy burden (Drehobl 2020). This definition of high energy burden will be utilized in this analysis. While an energy burden of 5% or below is considered lower energy burden in this research, it is possible some households may still experience financial constraints at lower energy burden. However, understanding financial constraints at lower energy burdens is beyond the scope of this research.

Data Analysis

The LEAD data tool determines the average energy burden percent for each one of Philadelphia County's 375 census tracts by calculating the average percentage of household income homes in each census tract pay toward energy costs. The resulting minimum average energy burden for census tracts in Philadelphia is 1% and the maximum is 10%.

ACS 2016 census data for each of these census tracts was retrieved for the following housing characteristics: average household income ($), average household size (number of residents), median year built (YYYY), and heating fuel type (utility gas, electricity, bottled tanks and fuel oils, solar, other fuels, none). All the data points were matched to the corresponding census tract in a spreadsheet.

To compare these data points and establish a baseline understanding of housing characteristic trends across energy burden levels, the data for energy burden and housing characteristics were graphed in scatterplots in Microsoft Excel. A regression model was then run on the resulting scatterplots to describe the relationship between energy burden and the various housing characteristics.

The two exceptions to this methodology are heating fuel types and air-conditioning use.

Heating Fuel Types

Analyzing the relationship between energy burden and heating fuel types in Philadelphia census tracts required a few extra steps in its methodology due to multiple fuel type data points per census tract. The data provided by the 2016 ACS includes the number of housing units using each type of heating fuel. To account for large differences in the total number of housing units per census tract, the percentage of homes utilizing each type of fuel was calculated. This was done by dividing the number of housing units using each fuel type by the total number of housing units per tract. The resulting graphs (Figs. 7, 8, and 9) illustrate the relationship between energy burden and the percent of heating oil type.

Air-Conditioning

The Census Bureau's ACS does not track air conditioning status of homes. However, another Census Bureau survey, the American Housing Survey (AHS), estimates air conditioning use in states and metropolitan areas, including the Philadelphia metropolitan area, using data from 2019. This data is not broken down by census tract, but can be cross-tabulated with other variables, including income level. The dataset provides the number of units in Philadelphia that have air-conditioning at all, centralized air-conditioning, and room air-conditioning by $10,000 income level increments. These unit numbers were converted to percentages by dividing the number of units per air-conditioning type by the total number of units per income level increment. The resulting percentages were charted (Fig. 10) to explore the connection between air-conditioning use and income levels in the city.

In the absence of census-level data on air-conditioning use, the Philadelphia Heat Vulnerability Index was utilized. It identifies census groups (one level of granularity deeper than census tracts) that get the hottest during the summer. Understanding where heat vulnerability is highest can focus air-conditioning upgrade efforts to those that are most vulnerable to heat-related risks.

Findings and Discussion

The analysis reinforced aspects of the original hypothesis, including that census tracts with higher energy burden tended to experience higher annual energy costs, lower average household income, larger household size, and older homes. Several findings differed from the original hypothesis. While lower income levels tend to use decentralized air-conditioning and higher incomes centralized, overall, most homes in Philadelphia have some form of cooling. There were no significant trends in heating fuel type in regards to electricity and natural gas, but there are highly energy-burdened census tracts with a significant number of residents using expensive heating oil and bottled gas fuels.

Energy Burden Distribution Across Census Tracts

There are 375 census tracts in Philadelphia, of which 27% are heavily energy-burdened at 6% energy burden or higher (Fig. 1, Appendix B).

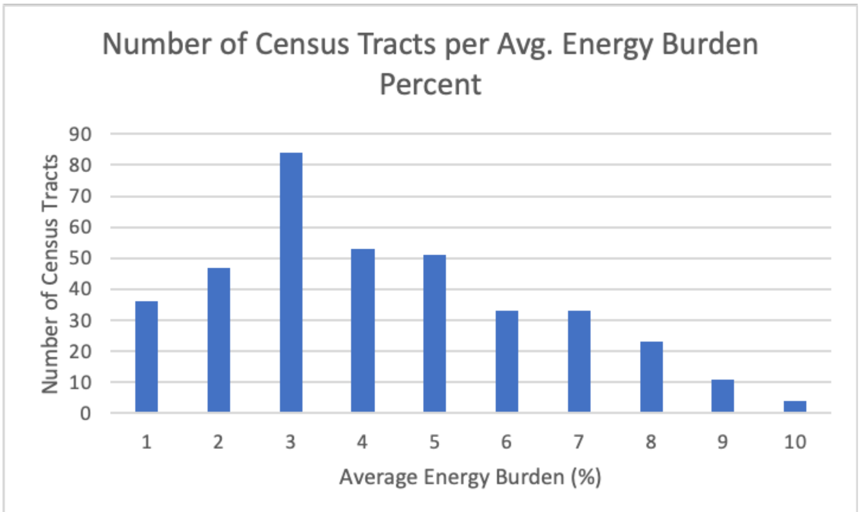


Figure 1. Number of census tracts per average energy burden percent.

Census tracts with higher energy burden have lower household incomes and pay higher energy bills.

Highly energy-burdened households are challenged with the dual burden of less income and higher energy bills than households with less energy burden. Census tracts in Philadelphia show a positive correlation (*P-value=2.84E-157*) between average energy burden and average energy costs. For each percent energy burden increase, census tracts pay approximately $93 more on average for energy annually.

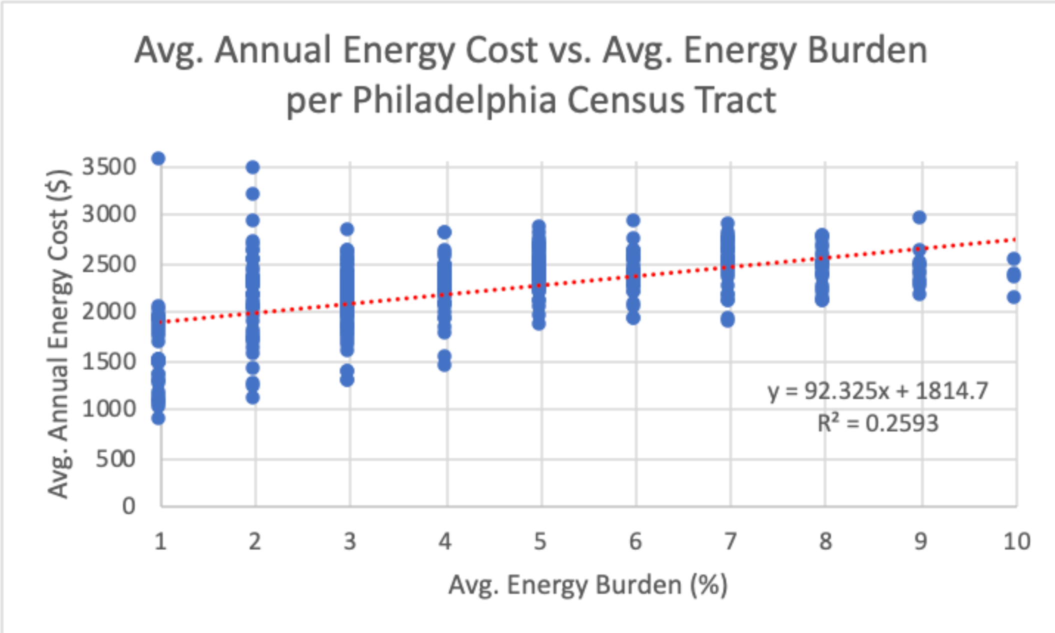


Figure 2. Scatterplot of average energy costs vs average energy burden percent per Philadelphia census tract

In addition to having higher energy costs, census tracts with higher energy burden tend to have lower household income. Census tracts in Philadelphia show a negative correlation (*P-value=5.267E-155*) between mean energy burden and mean household income (Fig. 3).

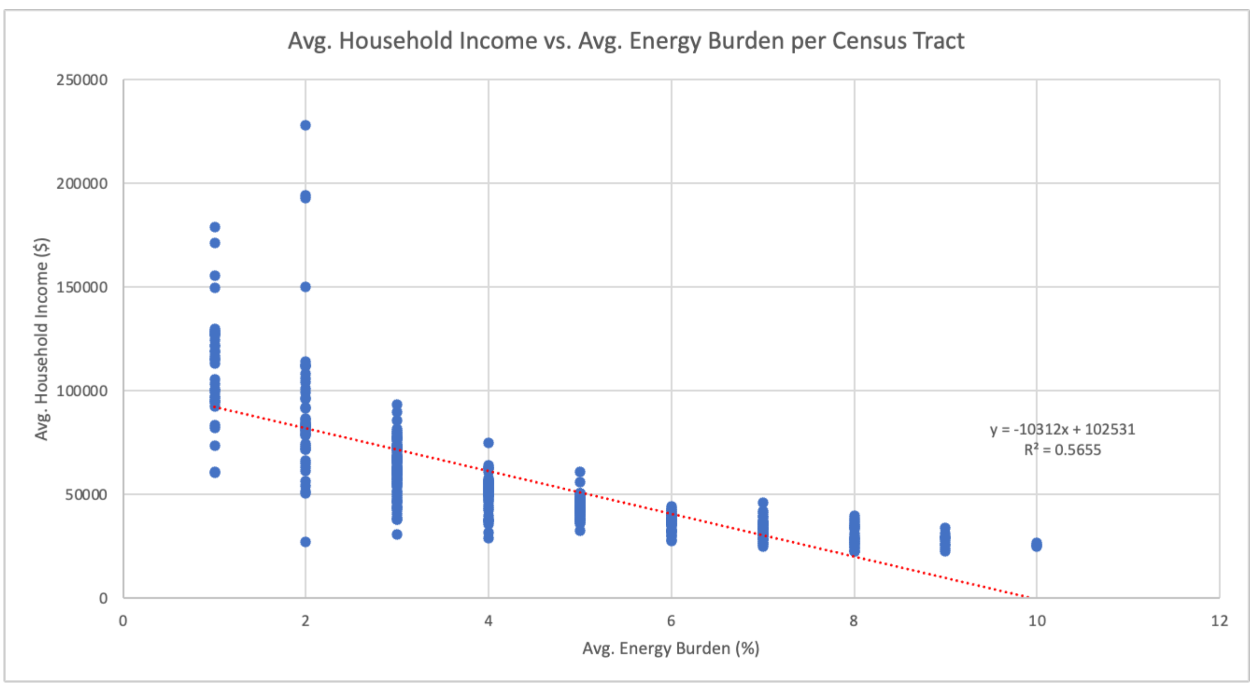


Figure 3. Scatterplot of average household income vs average energy burden per Philadelphia census tract.

Census tracts with high energy burden tend to have older homes with more people living in them.

Census tracts with high energy burden tend to have a higher average household size and older housing, both of which can increase energy costs and make it more difficult to lower energy costs.

Census tracts in Philadelphia show a positive correlation (*P-value=1.34E-162*) between average energy burden and average household size, or residents per household (Fig. 4). For census tracts that are considered high energy burdened (6% or more) the average household size is 2.48 residents, while the household size for lower energy burdened census tracts is 2.33.

According to estimates from the U.S. Energy Information Agency, Pennsylvania residents use about 69.7 million Btu per capita. More residents in a household could result in increased energy usage to accommodate the energy needs of more residents.

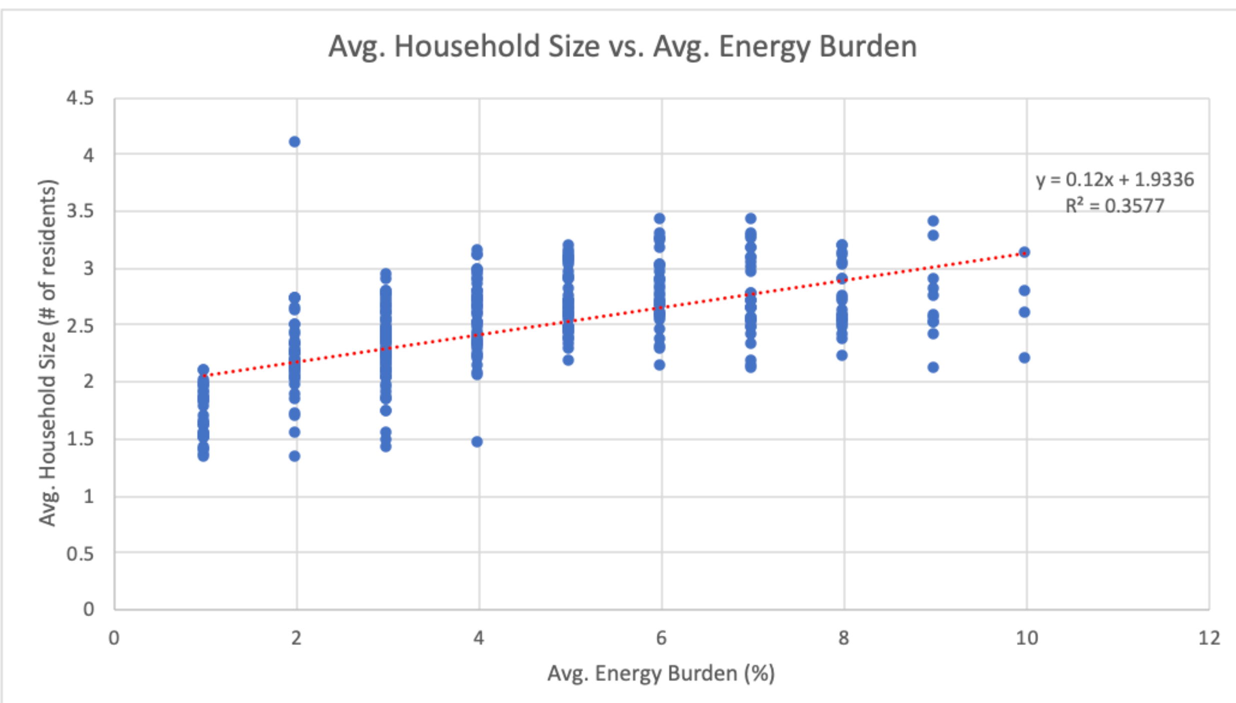


Figure 4. Scatterplot of average household size vs. average energy burden per Philadelphia census tract.

Older homes may lack proper insulation, have leaky windows, have cracks and holes in the structure that can cause high air filtration, and outdated appliances (La Jeunesse 2020). These factors can contribute to energy inefficiency and higher bills.

Census tracts in Philadelphia show a negative correlation (*P-value=0*) between average energy burden and the year the building was built (Fig. 5). Records for housing built before 1939 are not recorded by the Census Bureau. Therefore, census tracts with a median year built prior to 1939 are recorded as 1939. While these median years built should likely be earlier, for the purposes of this research we will assume 1939.

For census tracts with energy burden between 1-5% the average median year built is 1951, while the more heavily energy-burdened census tracts average a median year built of 1944, a 7-year difference. Due to the high number of outliers in the scatterplot (Fig. 5), a box-and-whisker plot was created to assess the distribution of the data points (Fig. 6). This chart demonstrates the same skewness as the scatterplot.

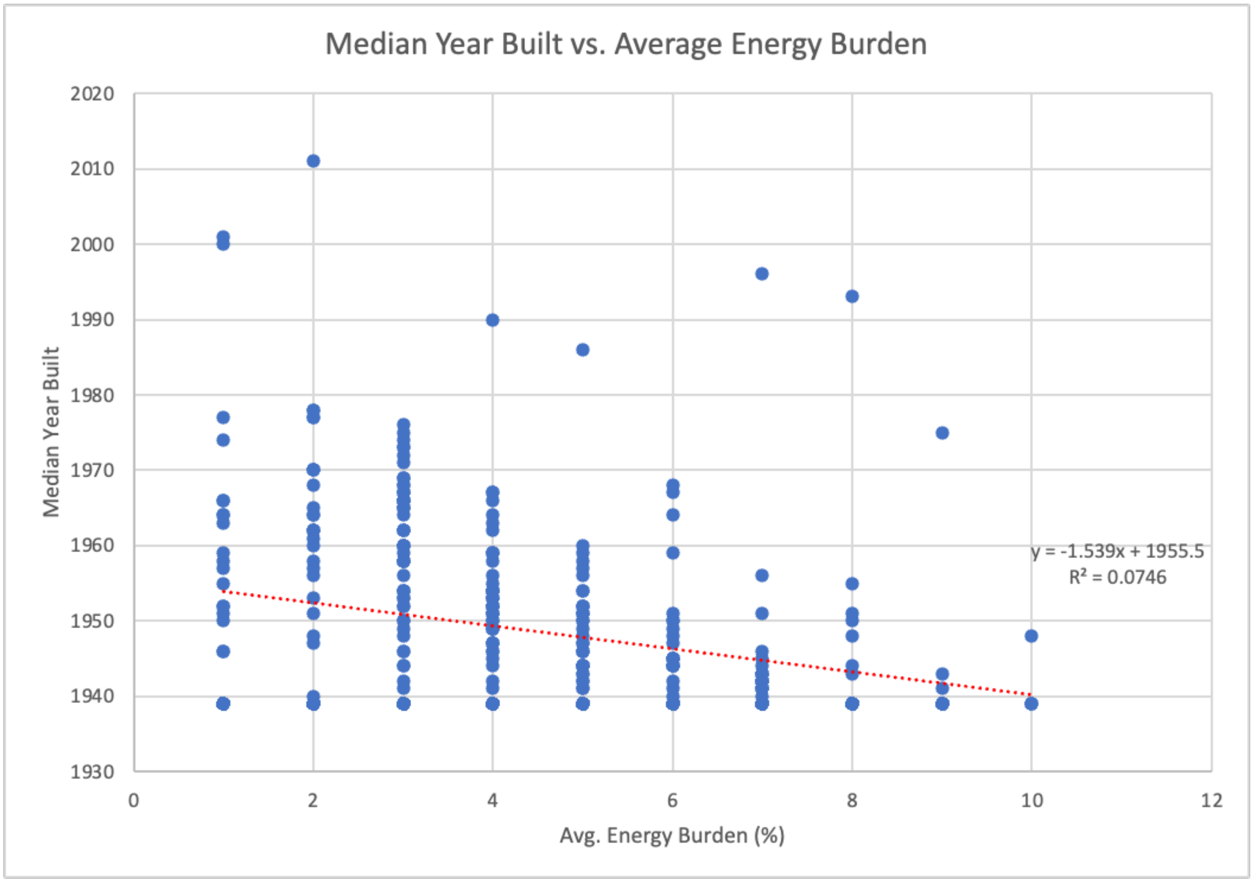


Figure 5. Scatterplot of median year built of residences vs. average energy burden per Philadelphia census tract.

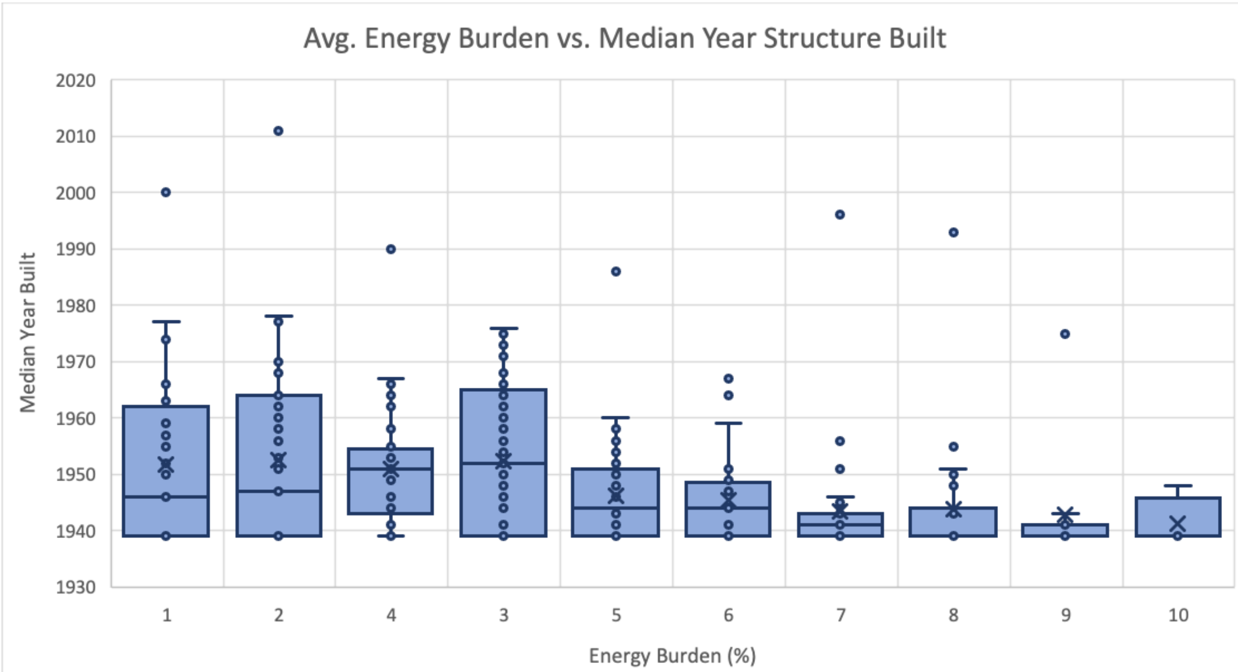


Figure 6. Box and whisker plot of median year residences built vs. average energy burden per Philadelphia census tract.

There are highly energy burdened homes in Philadelphia utilizing expensive heating fuels.

To calculate the percent of heating fuel type used in each census tract, the number of the number of units using each type of fuel was divided by the total number of units with heating fuel, both of which were retrieved from the ACS.

The relationship between utility gas and electricity as heating fuels is complicated. For the lesser energy burdened census tracts (1-5%), utility gas use increases as electricity use increases (Fig. 8). However, for the more heavily-burdened census tracts (6-10%) this trend reverses, with less households using gas and more using electricity to heat their homes (Fig. 9). A box-and whisker-plot demonstrates the non-linear relationship as well (Fig. 7). Understanding why this relationship exists is outside the scope of this research.

Bottled tank and heating fuel oils, like propane and kerosene, respectively, are more constant across energy burden levels, averaging between 4-10% of fuel use across energy burden levels. Other fuels, solar, and no fuels make up a small fraction of the total heating fuel use in Philadelphia.

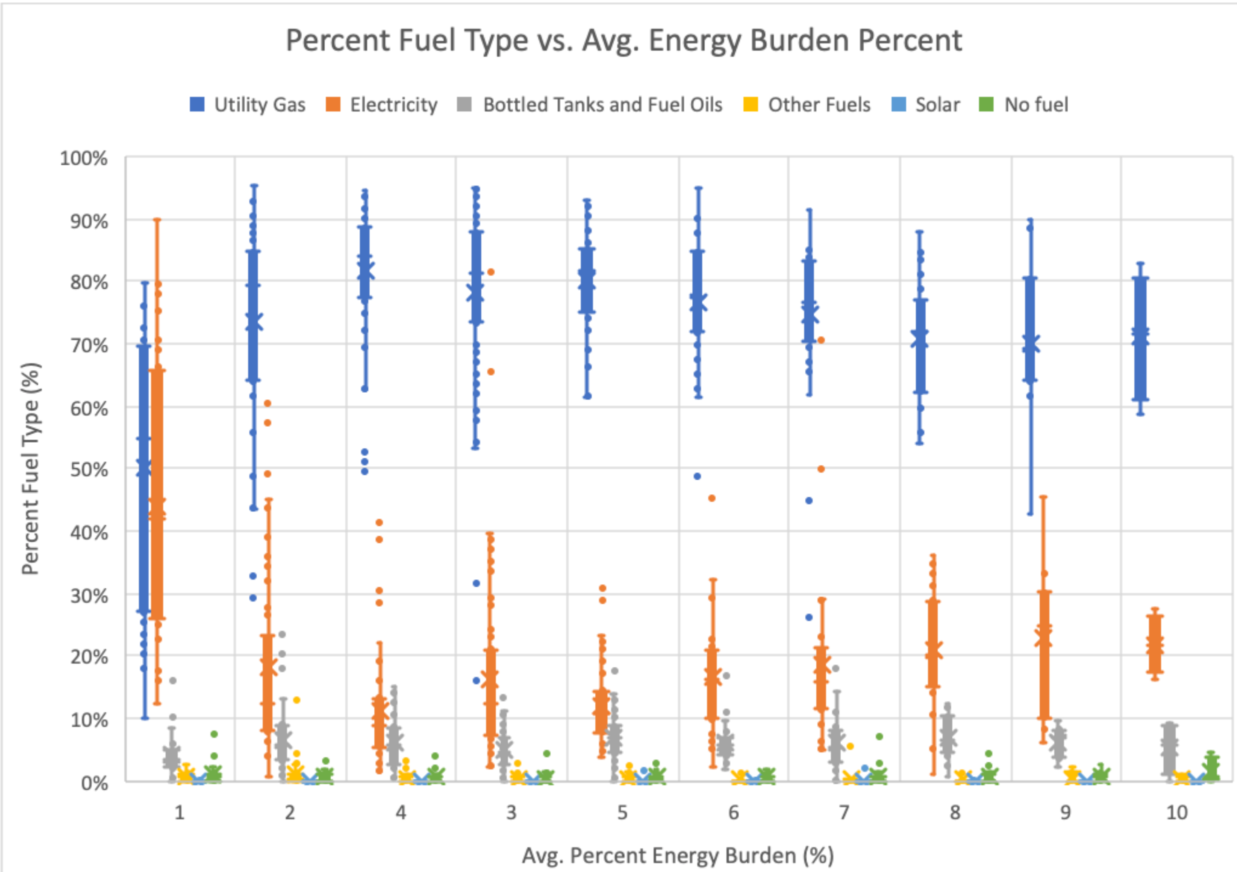


Figure 7. Box and whisker plot of percent heating fuel type vs. average percent energy burden per Philadelphia census tract.

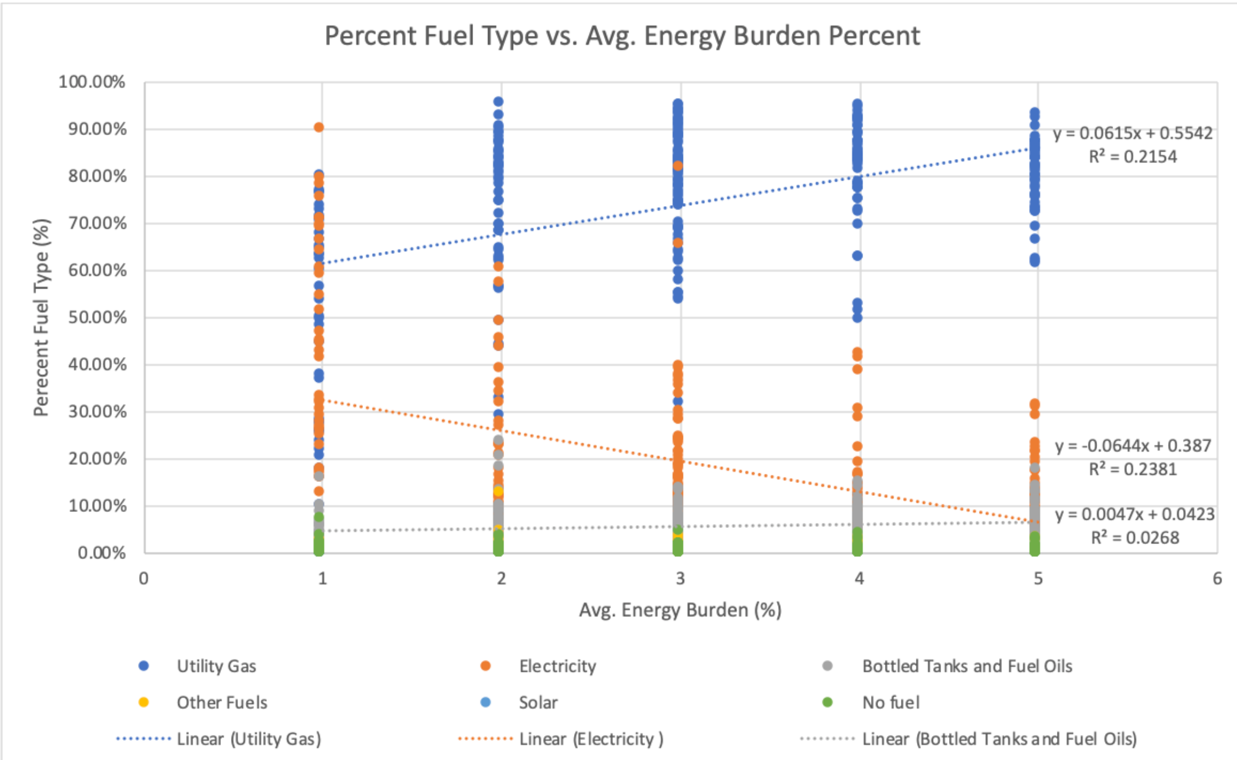


Figure 8. Scatterplot of percent fuel types for Philadelphia census tracts falling in 1-5% energy burden, categorized as lower energy burden.

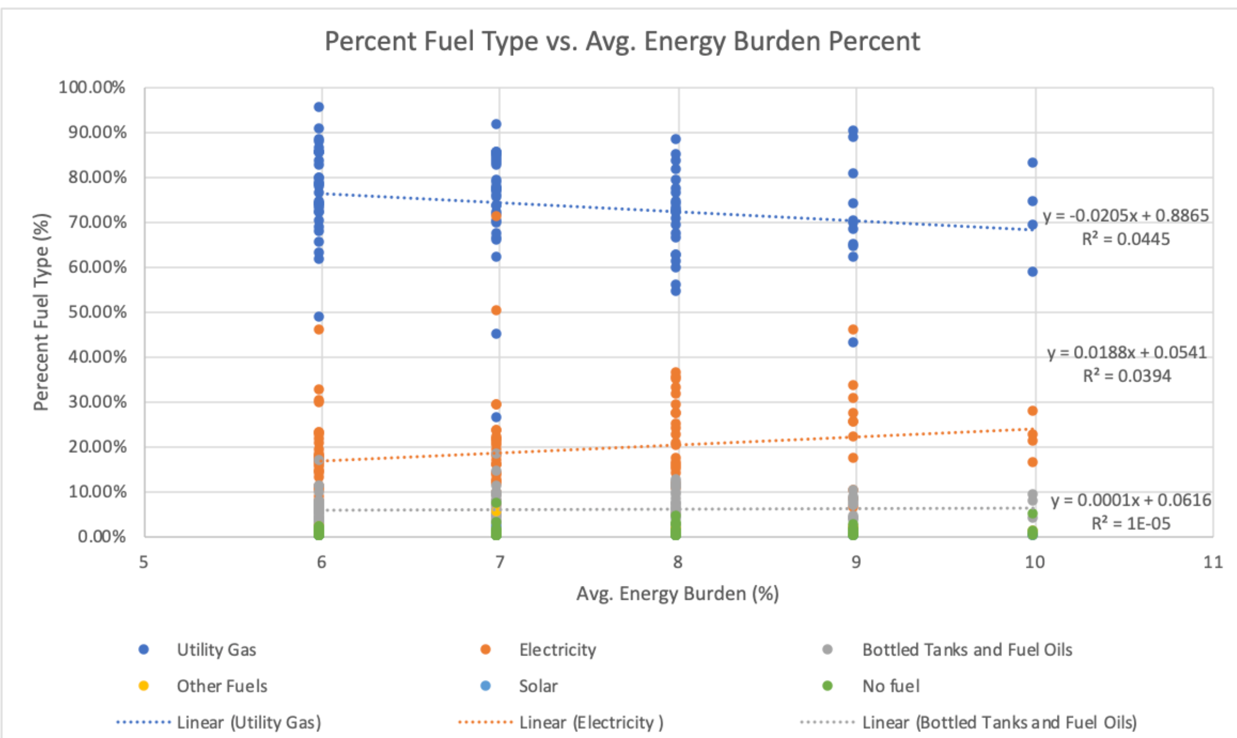


Figure 9. Scatterplot of percent fuel types for Philadelphia census tracts falling in 6-10% energy burden, categorized as higher energy burden.

Bottled Gas and Heating Fuels

Philadelphia's usage rate of bottled gas (ex. propane) and liquid heating fuels (ex. kerosene) is 5.86%. Typically, homes that rely on these fuels tend to pay higher energy bills than those that utilize natural gas or electricity. The U.S. Energy Information Administration's Winter Fuels Outlook for 2021-2022 estimated that propane users in the Northeast would pay $2,023, heating oil users $1,734, electricity users $1,538, and natural gas users $865. Propane and heating oil were projected to be the most expensive fuel options on an annual basis. Additionally, propane and heating oil usage prices have experienced sharp price increases in recent years. Nationally, households that rely on these fuels experienced propane price increases of $0.69/gal (23% increase) and heating oil by $2.26/gal (44% increase) between the winters of 2020-2021 and 2021-2022 (Bradbury 2022).

The potential financial impact of utilizing bottled gas and heating oil can be illustrated in Philadelphia County census tract 96. Located in West Philadelphia, census tract 96 has an especially high usage of bottled gas and heating oil at about 18% and has an average energy burden of 7%. Additionally, the census tract pays high energy costs at an average of $2,751 per year, compared to the city-wide census average of $2,029. Households in this census tract also tend to bring in a lower income than the city-wide census tract average ($58,543) at $33,784, putting the residents at higher risk for high energy burden—especially those that utilize bottled gas or heating oil.

While most households have air-conditioning, heavily energy-burdened households in heat vulnerable areas are at higher risk on hot days.

Only about 3% of Philadelphia homes don't have air-conditioning. For those that do have air-conditioning, the type of system differs across income levels. As seen in Figure 10, homes with higher annual income levels are more likely to have central air-conditioning than room air conditioning. Central air-conditioning utilizes ducts, pumps, and fans to cool multiple rooms (Zhou 2017). Room air conditioning is decentralized into units that operate in a single room (Zhou 2017). Examples include window units or split air conditioning units.

Both centralized and decentralized air conditioning have their drawbacks and benefits. Centralized air conditioning systems tend to have high capacity and are efficient, cooling more space with less energy than a decentralized air conditioning system, but they can be more expensive upfront and require additional energy to power the system's pumps and fans (Zhou 2017). With decentralized systems, users have more control over each unit and can reduce power consumption through efficient usage, but the systems have shorter lifespans and are more complex (Zhou 2017). Both these systems, when used properly, can be adequate and efficient.

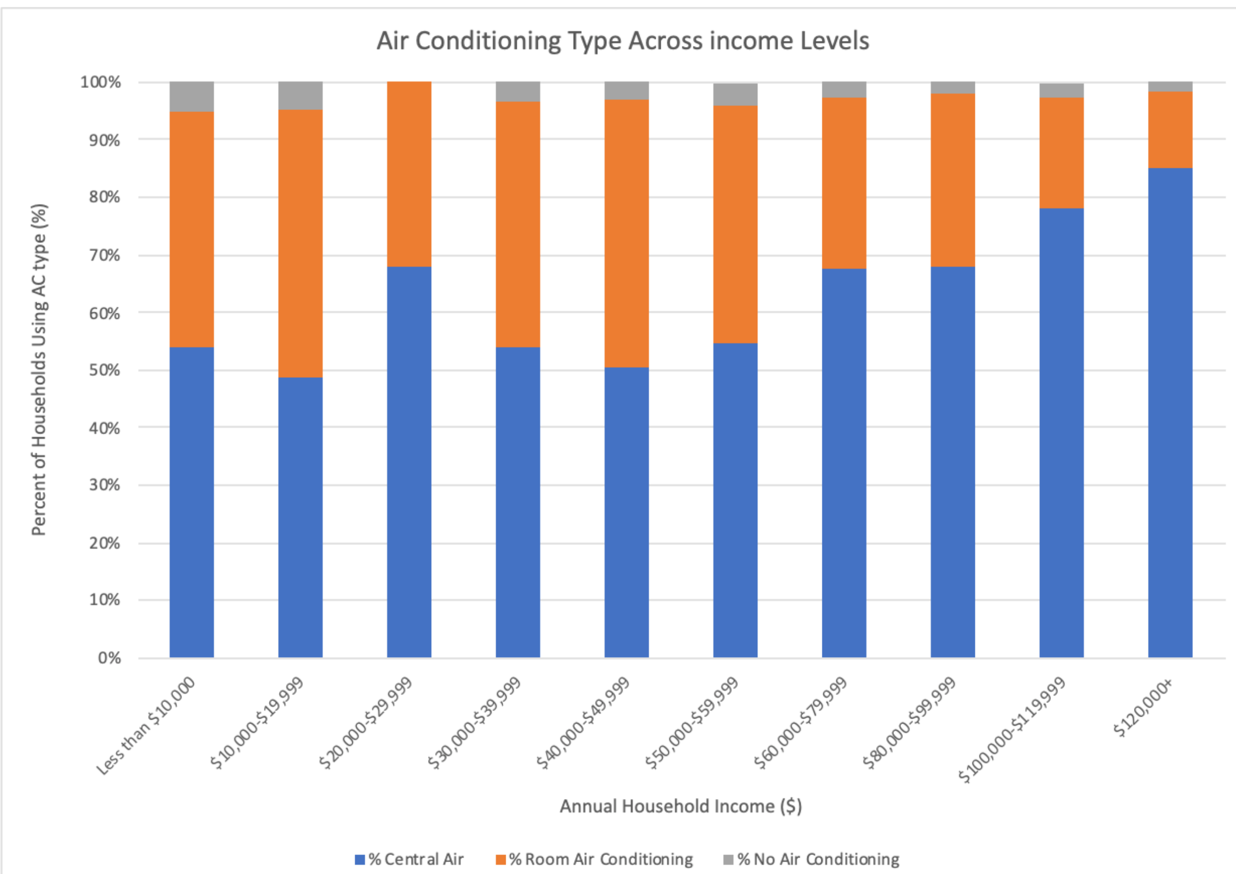
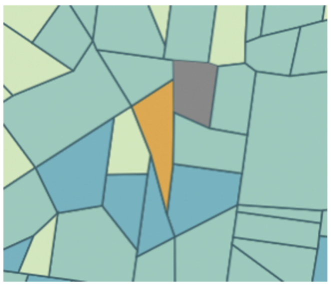


Figure 10. Bar chart with percentage of air conditioning type for different income levels across Philadelphia.

Although census tract-level data on where air-conditioning is located is not available, we do have census data on where air-conditioning services could be the most impactful. For example, located in the northern outskirts of central Philadelphia, census tract 203 (Img. 2) contains both first and third heat index priority areas according to Philadelphia Heat Vulnerability Index, indicating that heat vulnerability is of particular concern in this tract (Img. 3).

The index identifies these areas through surface temperatures, resident demographics, and resiliency measures in place. In census tract 203, these areas had especially high surface temperatures on seven days between 2013 to 2015. Additionally, these areas have high rates of vulnerable populations, including older residents, residents below the federal poverty rate, and residents with health conditions that can be exacerbated by heat exposure. Residents in these areas will need access to air conditioning to live comfortably and safely in Philadelphia's increasingly hot summers. However, these residents may also have more trouble being able to afford air-conditioning due to higher energy burden levels.



(Top image) Img. 2. Census tract 203, in orange, from the LEAD tool. (Bottom image): Img. 3. Census tract 203, in center, broken up into two census groups, one of which is a first priority heat vulnerability area, and the other, which is a third priority.

The energy burden in census tract 203 is considered heavy at 7% with higher than average energy costs at $2,454. Additionally, the mean household income of this census tract is $34,144. Assuming we can extrapolate income-level air-conditioning data to this census tract (Fig. 10), about 4% of households may not have access to air-conditioning, 54% of residents in this census tract will utilize central air-conditioning, and about 42% utilize decentralized air-conditioning.

Limitations

Housing unit size was not available at a census level for analysis. However, that data would be useful in future research to understand the relationship between energy usage and home size, as larger homes may require more energy for space heating and cooling, as well as more energy for lighting and appliances.

Additionally, this research did not explore the relationship between housing type and energy burden levels. But, in future research, it may be helpful to understand energy usage in the city's rowhomes, which make up a significant portion of the city's housing, as compared to the energy usage of other types of housing. This research can help inform what type of housing the city spends its weatherization and energy efficiency intervention monies.

The Philadelphia Heat Vulnerability Index identifies the city's hottest and most vulnerable census tracts in the summer. Future research would benefit from exploring the relationship between vulnerable census tracts and energy burden. Overlaying these datasets can help the city understand which census tracts may be at risk for heat vulnerability and an inability to afford adequate cooling. All these additional data points could help illustrate the types of challenges faced by highly energy-burdened census tracts and can inform potential solutions.

Recommendations

Continue or expand investments to programs that reduce energy costs.

Highly energy-burdened census tracts in Philadelphia tend to have both high energy bills and low incomes. Philadelphia should consider continued and expanded investments into several agencies and programs responsible for home upgrades and energy efficiency to reduce energy costs and alleviate financial stress for impacted census tracts.

Below are programs worth further investments, which descriptions from their respective websites:

- Heater Hotline: An emergency heating system repair and replace program that provides services for about 5,000 LMI homeowners annually, according to the Energy Coordinating Agency, the program administrator.
- Built to Last: Philadelphia Energy has started a whole home retrofit program that addresses a wide variety of housing services at one time, including energy efficiency services.
- Solarize Philly: A city-wide program that allows groups or homeowners or businesses to pool together for discounted solar installations.
- The Basic Systems Repair Program: Provides free repairs to correct electrical, plumbing, heating, as well as structural and carpentry services, and roofing emergencies in eligible owner-occupied homes in Philadelphia.

There are additional federal project and funding streams, including Weatherization Assistance Program (WAP) funding, which is granted by the DOE to local weatherization providers. However, federal funding and initiatives are outside the scope of this research.

Investments from these programs would be most useful in census tracts with exceptionally low incomes, as alleviating energy costs would reduce the magnitude of energy burden for some of the city's most financially vulnerable populations. For example, census tract 167.02, located in North Philadelphia, has an average household income of $25,486, less than half the average Philadelphia household income of about $58,500. The homes in this census tract also pay high energy costs. The average for the city is $2,209, but costs in tract 167.02 are 12% higher at $2,518. The resulting energy burden is 10%, among the most energy-burdened census tracts in the city. If energy costs in this tract were brought down to the city-wide average, the energy burden would likely fall below 9%.

Ensure simple energy efficiency measures are available to residents in highly energy-burdened census tracts.

The interventions in this section provide energy savings and are relatively easy to implement. Philadelphia should ensure that low-income census tracts that have high energy burden, large household sizes, and/or older homes have these options and services available.

Efficient Lighting

Lighting makes up about 20% of the average American household's energy bills (Reames 2018). And, despite new, highly efficient bulb options on the market, including light-emitting diodes (LEDs) and compact fluorescent lamps (CFLs), their use is not equitably distributed. A case study conducted in Wayne County, Michigan found that efficient lightbulb options were less available and more expensive in high-poverty areas and smaller stores, resulting in distribution disparities and lower adoption rates of efficient light bulbs in low-income neighborhoods (Reames 2018).

Those making a household income of $50,000 or less were less likely to have LED bulbs in their homes (Reames 2018). However, these technologies are some of the simplest ways to reduce energy consumption and costs in households (Reames 2018). For example, compared to traditional incandescent bulbs, LEDs last 25 times longer and use 75% less energy (Reames 2018).

Philadelphia should assess if its low-income populations' adoption of efficient bulbs is not at parity, the root causes of any disparities, and decide how and if to address resources accordingly.

Weatherization

Weatherization is an energy efficiency measure that tightens the packaging of the home through insulation, air sealing, repairing roof and wall leaks, window upgrades and appliance replacement, among other upgrades, according to the National Park Service. Significant energy efficiency improvements can be seen in older homes that are weatherized, with minimal impact to the building's envelope. One of its benefits is allowing space heating and cooling to operate more efficiently. The DOE estimates that weatherization can save residents $283 annually on energy bills and estimates that for every $1 spent on weatherization, $1.72 is generated in energy benefits and $2.78 in non-energy benefits.

Prioritize fuel-switching for census tracts with high bottled gas and heating oil use to electrification.

Both natural gas and electrification have less expensive annual costs than bottled gas and heating oils. However, given the price volatility and expected price increases of natural gas, it's recommended to fuel-switch homes that utilize bottled gas and heating oil to electrified heating appliances, rather than natural gas heating systems. A report published by energy research non-profit Rewiring America found that households using heat pumps for home heating over the last two decades have experienced 38% less price volatility than fossil fuels. And, natural gas prices have demonstrated price vulnerabilities due to global conflict. Recent conflicts in Ukraine and Russia have caused natural gas prices to increase from $4.69/MMBtu in February 2022 to $4.90/MMBtu in March 2022, according to the Henry Hub Natural Gas Spot Price Index. Last year, in March of 2021, the index reported that natural gas prices were about half that, at $2.62/MMBtu.

Reduce air-conditioning costs for low-income and heat vulnerable households.

Philadelphia's summers have begun to get hotter due to climate change, with the summer of 2020 ranking as the city's third hottest on record (Wood 2020). Without adequate air conditioning, vulnerable populations in census tracts like 203, including the elderly and those with pre-existing medical conditions, are at increased risk for heat-related illnesses and mortality. While most Philadelphia residents have access to air-conditioning, the city should consider targeting areas with both high energy burden and high heat vulnerability to 1) ensure access to cooling capabilities and 2) lower summertime electricity bills through cooling energy efficiency, including white roofs and heat pumps.

White Roofs

Philadelphia should prioritize low-income residents in single-family homes for white roof servicing. White roofs have been shown to help reduce indoor air temperatures. In 2004, Philadelphia published the results of a pilot program, called the Cool Homes Program, in which the city serviced homes of elderly participants with passive intervention methods, including white roof coatings and insulation (Blasnik 2004). "The white roof coating essentially eliminated the impact of solar heat gain through the roofs," the report finds (Blasnik 2004). In bedrooms without air conditioning units, room temperatures fell by 2.0-2.5°F on hot days (Blasnik 2004). Although the study lacked post-treatment electricity bill data, study authors anticipated that the cooling effect of the roof may have reduced average electrical usage by 5-10% (Blasnik 2004).

Heat Pumps for Cooling

Centralized and decentralized air-conditioning systems have their benefits and drawbacks, and it is outside the scope of this research to recommend one over the other. However, air source heat pumps are available for both systems and, in many cases, can increase efficiency for cooling. One study noted that cooling from heat pumps is efficient enough to possibly reduce residential peak energy demand if widely adopted in a region (Deetjen 2021).

The study also noted that for heating, houses that utilize heating oils and bottle gas fuels could see the most benefits from switching to heat pumps, as well as houses that tend to be older (Deetjen 2021). Specifically, they seem to offer the most benefits in three scenarios: 1) houses built between 1970-1989 that utilize natural-gas powered heating, 2) small (<1500 SF) houses built before the 1990s that utilize bottled gas and heating fuels, 3) and large (>2500) homes that utilize electric resistance heating and were built before the 1970s (Deetjen 2021). Therefore, homes that utilize expensive heating fuels, or that fit into these categories, and that experience high heat vulnerability should have highly prioritized for weatherization and heat pump servicing. For example, approximately 11% of residents in census tract 203, which has a high heat vulnerability, utilize bottled gas and liquid fuels, whereas the city-wide average is 5.86%. And houses there are older, with a median year built of 1939. These homes would likely see bill reductions in the winter and would have access to an efficient air-conditioning in the summer.

Conclusion

Through quantitative research, this paper analyzes the relationship between energy burden and housing characteristics in Philadelphia. It finds that census tracts with higher average energy burden rates tend to experience pressures that make it difficult to alleviate the energy burden, including: high energy bills, older homes, more residents per household, and lower incomes. Measures should be taken by the city to decrease energy bills and energy consumption in tracts of particular concern, including by expanding investments in housing and energy programs already developed by the city, utilizing simple, effective energy efficiency interventions, fuel-switching residents away from expensive heating fuels and making air-conditioning more affordable through energy efficiency interventions. Alleviating the health, safety, and financial costs of heavy energy burden may go beyond reducing energy expenditures for eligible households. By easing energy burden strategically, the city has the opportunity to improve, protect, and save the lives of its residents, and work toward safe home environments in which all Philadelphians can thrive.

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Appendix

Appendix A

National Poverty Thresholds for 2016 by Size of Family and Number of Related Children Under 18 years

Size of family unit	Weighted average thresholds	Related children under 18 years								
		None	One	Two	Three	Four	Five	Six	Seven	Eight or more
One person (unrelated individual):	12,228									
Under age 65................................	12,486	12,486								
Aged 65 and older..........................	11,511	11,511								
Two people:	15,569									
Householder under age 65..............	16,151	16,072	16,543							
Householder aged 65 and older.......	14,522	14,507	16,480							
Three people......................................	19,105	18,774	19,318	19,337						
Four people..	24,563	24,755	25,160	24,339	24,424					
Five people...	29,111	29,854	30,288	29,360	28,643	28,205				
Six people...	32,928	34,337	34,473	33,763	33,082	32,070	31,470			
Seven people......................................	37,458	39,509	39,756	38,905	38,313	37,208	35,920	34,507		
Eight people..	41,781	44,188	44,578	43,776	43,072	42,075	40,809	39,491	39,156	
Nine people or more............................	49,721	53,155	53,413	52,702	52,106	51,127	49,779	48,561	48,259	46,400
Source: U.S. Census Bureau.										

Appendix B

2016 5-year ACS and LEAD tool data

Census tract #	Avg. Energy Burden (%)	Avg. Annual Energy Cost($)	Avg household size (# of residents)	Household Mean Income ($)	Median Year Structure Built (Year)	Avg. Annual Energy Cost($)
1.00	1	1275	1.5	124525	1939	1275
2.00	2	1535	2.19	99337	1960	1535
3.00	1	1280	1.6	121867	1946	1280
4.01	1	1086	1.32	83354	1964	1086
4.02	1	1051	1.36	92625	1966	1051
5.00	1	1007	1.52	60813	1939	1007
6.00	1	1067	1.52	95177	1939	1067

7.00	1	1116	1.41	94942	1952	1116
8.01	1	1744	1.54	126632	1939	1744
8.03	1	1331	1.39	97095	1951	1331
8.04	1	1146	1.39	149413	1955	1146
9.01	2	1109	1.32	54331	1939	1109
9.02	1	1326	1.52	121644	1974	1326
10.01	1	1470	1.63	155665	1964	1470
10.02	1	1839	1.69	171273	1963	1839
11.01	1	1483	1.5	105356	1939	1483
11.02	1	1457	1.63	94419	1939	1457
12.01	1	1886	1.83	178699	1939	1886
12.02	1	1462	1.54	129882	1939	1462
13.00	1	1926	2	116790	1939	1926
14.00	1	1777	1.81	99217	1939	1777
15.00	1	1807	1.97	103212	1950	1807
16.00	1	1941	1.89	119221	1939	1941
17.00	1	2042	1.9	129056	1939	2042
18.00	1	1994	2.08	115595	1939	1994
19.00	1	1898	2.09	100724	1939	1898
20.00	4	2070	2.43	52580	1939	2070
21.00	3	2070	2.42	61770	1939	2070
22.00	2	1726	2.18	71923	1939	1726
23.00	2	1884	2.18	73347	1939	1884
24.00	2	1958	2.26	84101	1939	1958
25.00	2	2034	2.24	86091	1939	2034
27.01	3	2277	2.64	55498	1939	2277
27.02	2	2028	2.09	78959	1939	2028
28.01	3	2132	2.77	57727	1939	2132
28.02	2	2007	2.42	66166	1939	2007
29.00	3	2141	2.02	74082	1939	2141
30.01	3	2280	2.89	57276	1939	2280
30.02	3	2138	2.42	57085	1939	2138
31.00	3	2082	2.41	37938	1939	2082
32.00	5	2232	2.71	39146	1939	2232
33.00	4	2021	2.66	37427	1939	2021
36.00	5	1850	2.55	32743	1958	1850
37.01	5	2253	2.92	42456	1939	2253
37.02	4	2054	2.75	39928	1939	2054
38.00	3	2202	2.37	67233	1939	2202
39.01	3	1935	2.26	58939	1939	1935
39.02	3	2110	2.25	68378	1939	2110

40.01	3	1934	2.22	60265	1939	1934
40.02	3	2014	2.28	60406	1939	2014
41.01	4	2128	2.9	37632	1939	2128
41.02	5	2221	2.92	46264	1939	2221
42.01	3	2150	2.47	58435	1939	2150
42.02	4	2190	2.64	54092	1939	2190
54.00	3	1648	2.08	64812	1975	1648
55.00	4	2293	2.49	52526	1964	2293
56.00	4	1809	2.05	35481	1966	1809
60.00	5	2512	2.66	43032	1959	2512
61.00	6	2556	2.76	43530	1945	2556
62.00	7	2557	3.17	46257	1942	2557
63.00	7	2736	2.96	35607	1943	2736
64.00	7	2556	3.16	41838	1942	2556
65.00	6	2458	2.67	36703	1939	2458
66.00	8	2354	2.72	29730	1943	2354
67.00	6	2555	2.99	37108	1945	2555
69.00	8	2112	2.55	22414	1948	2112
70.00	7	2688	2.71	34912	1940	2688
71.01	9	2950	2.74	31121	1941	2950
71.02	7	2622	2.77	37062	1942	2622
72.00	7	2720	2.71	41191	1939	2720
73.00	7	2631	2.76	39374	1942	2631
74.00	6	2528	2.56	41619	1940	2528
77.00	3	1758	2.06	47095	1939	1758
78.00	3	1833	1.97	55021	1939	1833
79.00	3	2097	2.15	79298	1939	2097
80.00	4	2785	2.51	57750	1939	2785
81.01	7	2711	2.69	30489	1942	2711
81.02	8	2679	2.69	37585	1939	2679
82.00	5	2655	2.6	42754	1939	2655
83.01	6	2393	2.27	39015	1939	2393
83.02	7	2522	2.46	39215	1939	2522
84.00	6	2733	2.59	37906	1939	2733
85.00	7	2487	2.4	36903	1939	2487
86.01	2	1682	2.03	61509	1939	1682
86.02	3	1884	2.22	42346	1941	1884
87.01	3	1709	2.09	49114	1939	1709
87.02	2	1246	1.87	51247	1940	1246
88.01	2	1213	2.48	27148	1939	1213
88.02	4	1519	2.29	28835	1956	1519

90.00	4	1909	2.06	37878	1939	1909
91.00	3	1573	1.72	30929	1972	1573
92.00	6	2036	2.36	29946	1964	2036
93.00	7	2739	2.47	33230	1939	2739
94.00	8	2218	2.22	31068	1951	2218
95.00	7	2609	2.55	33932	1943	2609
96.00	7	2751	2.51	33784	1939	2751
98.01	4	2360	2.47	52209	1951	2360
98.02	4	2357	2.52	55525	1954	2357
100.00	5	2674	2.63	43950	1942	2674
101.00	5	2865	2.43	47988	1939	2865
102.00	8	2490	2.49	28744	1939	2490
103.00	7	2683	2.54	35720	1939	2683
104.00	8	2488	2.53	33374	1939	2488
105.00	6	1908	2.14	32557	1967	1908
106.00	7	2465	2.13	26890	1951	2465
107.00	7	2647	2.63	28467	1939	2647
108.00	7	2613	2.63	30803	1956	2613
109.00	6	2185	2.57	32871	1959	2185
110.00	7	2427	2.32	31217	1943	2427
111.00	7	2789	2.56	30363	1946	2789
112.00	7	2871	2.64	36197	1939	2871
113.00	8	2755	2.46	39774	1939	2755
114.00	4	2399	2.37	56155	1939	2399
115.00	4	2577	2.71	56789	1941	2577
117.00	3	2816	2.77	79638	1939	2816
118.00	5	2614	2.57	48070	1939	2614
119.00	5	2357	2.38	40075	1944	2357
120.00	3	2466	2.08	62679	1944	2466
121.00	3	1772	1.84	45861	1954	1772
122.01	3	1268	1.42	38885	1969	1268
122.03	3	1848	1.48	43685	1960	1848
122.04	3	1835	1.72	53891	1960	1835
125.00	1	1039	1.5	113169	1977	1039
131.00	2	1805	2.23	50616	1970	1805
132.00	4	1767	2.33	36808	1990	1767
133.00	1	1489	1.86	73648	1946	1489
134.01	1	1486	1.61	118921	1959	1486
134.02	1	1459	1.78	96967	1939	1459
135.00	2	2153	2.28	82678	1939	2153
136.01	1	1904	1.81	128427	1939	1904

136.02	1	1934	1.95	100328	1939	1934
137.00	3	2517	2.35	66013	1939	2517
138.00	5	2372	2.47	41352	1939	2372
139.00	6	1908	2.54	30200	1968	1908
140.00	5	2085	2.17	36123	1960	2085
141.00	3	1794	2.03	43450	1965	1794
142.00	1	1667	1.96	115164	1966	1667
143.00	2	2170	2.12	95890	1939	2170
144.00	3	2044	2.36	62740	1939	2044
145.00	5	1941	2.62	37043	1986	1941
146.00	4	1923	2.22	42431	1967	1923
147.00	9	2161	2.8	29392	1975	2161
148.00	7	2101	2.11	33571	1996	2101
149.00	8	2365	2.41	27099	1939	2365
151.01	8	2535	2.58	38542	1939	2535
151.02	8	2489	2.37	24313	1939	2489
152.00	8	2419	3.12	27146	1944	2419
153.00	8	2420	2.88	22727	1955	2420
156.00	6	2272	2.87	34591	1942	2272
157.00	4	2401	2.79	49039	1942	2401
158.00	2	2097	2.17	72414	1939	2097
160.00	3	2238	2.45	66410	1939	2238
161.00	3	2243	2.78	63725	1939	2243
162.00	6	2050	2.89	35579	1939	2050
163.00	8	2104	3.03	26288	1939	2104
164.00	7	2090	3.07	24961	1941	2090
165.00	10	2126	2.79	25915	1939	2126
166.00	7	1901	2.53	26521	1939	1901
167.01	8	2727	2.61	35218	1939	2727
167.02	10	2518	2.59	25486	1939	2518
168.00	9	2369	2.58	29206	1939	2369
169.01	8	2574	2.51	36635	1939	2574
169.02	9	2608	2.52	33938	1939	2608
170.00	3	1929	2.21	46630	1944	1929
171.00	6	2509	2.58	37791	1939	2509
172.01	5	2541	2.46	40928	1939	2541
172.02	9	2483	2.55	22536	1939	2483
173.00	7	2324	2.53	35115	1941	2324
174.00	8	2645	2.57	28559	1939	2645
175.00	7	2162	3.07	28274	1944	2162
176.01	8	2237	3.02	28367	1939	2237

176.02	8	2196	3.19	24329	1939	2196
177.01	9	2457	3.39	27392	1939	2457
177.02	9	2395	3.26	29497	1943	2395
178.00	8	2335	3.19	25975	1939	2335
179.00	6	2408	3.01	35021	1939	2408
180.01	3	2196	2.36	70446	1939	2196
180.02	4	2386	2.28	56011	1939	2386
183.00	3	2613	2.59	69097	1939	2613
184.00	4	2604	2.6	63838	1939	2604
188.00	7	2411	3.26	32194	1939	2411
190.00	5	2231	3.13	38531	1946	2231
191.00	5	2302	3.01	42736	1950	2302
192.00	7	2624	3.41	31739	1939	2624
195.01	8	2092	3.11	22672	1950	2092
195.02	6	2252	3.25	28132	1949	2252
197.00	7	2155	3.29	33164	1939	2155
198.00	6	2255	3.22	32289	1944	2255
199.00	10	2366	3.12	26471	1939	2366
200.00	9	2233	2.1	29037	1939	2233
201.01	10	2346	2.2	24887	1948	2346
201.02	5	2476	2.54	48361	1939	2476
202.00	9	2291	2.51	25882	1939	2291
203.00	7	2454	2.54	34144	1939	2454
204.00	6	2404	2.7	31677	1939	2404
205.00	7	1892	2.18	25802	1941	1892
206.00	3	1991	1.9	89556	1953	1991
207.00	2	2284	2.11	74372	1939	2284
208.00	2	1396	1.54	63235	1953	1396
209.00	2	2164	2.11	79360	1939	2164
210.00	2	2352	2.1	83128	1939	2352
211.00	3	2353	2.09	85726	1954	2353
212.00	3	2450	2.09	76702	1950	2450
213.00	3	2590	2.23	93289	1939	2590
214.00	3	2355	2.14	81517	1939	2355
215.00	2	2236	2.18	81371	1951	2236
216.00	2	2035	2.04	84563	1977	2035
217.00	2	2401	2.35	80777	1961	2401
218.00	2	1775	1.96	56556	1970	1775
219.00	2	2685	2.08	86560	1962	2685
220.00	2	2421	2.13	106020	1978	2421
231.00	2	3458	2.4	192982	1939	3458

235.00	2	2707	2.14	112193	1948	2707
236.00	2	2610	2.23	103980	1939	2610
237.00	2	2346	2	81030	1939	2346
238.00	3	2071	1.94	66246	1939	2071
239.00	3	1357	1.55	40731	1952	1357
240.00	3	2111	2.05	59816	1948	2111
241.00	4	1442	1.46	31730	1949	1442
242.00	5	2186	2.43	39915	1939	2186
243.00	5	2466	2.27	45391	1944	2466
244.00	6	2908	2.71	42415	1939	2908
245.00	6	2304	2.59	27792	1939	2304
246.00	9	2308	2.4	25826	1939	2308
247.00	7	2526	2.64	28691	1942	2526
248.00	4	2806	2.7	52146	1939	2806
249.00	8	2760	2.75	33749	1939	2760
252.00	5	2388	2.45	38536	1943	2388
253.00	5	2782	2.43	50043	1939	2782
254.00	3	2543	2.15	65425	1949	2543
255.00	3	2615	2.34	76990	1942	2615
256.00	2	2519	2.25	111781	1939	2519
257.00	2	1698	1.84	71604	1957	1698
258.00	4	2176	2.21	60822	1955	2176
259.00	3	2135	2.31	55606	1950	2135
260.00	4	2144	2.33	56308	1952	2144
261.00	4	2197	2.14	52456	1953	2197
262.00	4	2322	2.31	55156	1949	2322
263.01	5	2396	2.47	49186	1950	2396
263.02	5	2543	2.63	50425	1947	2543
264.00	5	2526	2.44	60690	1944	2526
265.00	5	2605	2.57	47098	1941	2605
266.00	5	2730	2.67	56099	1946	2730
267.00	5	2418	2.57	37631	1939	2418
268.00	4	2072	2.31	49442	1945	2072
269.00	3	2349	2.71	62632	1939	2349
270.00	3	2405	2.5	72783	1946	2405
271.00	4	2200	2.73	50831	1954	2200
272.00	4	2079	2.35	56212	1959	2079
273.00	4	2473	2.96	49435	1952	2473
274.01	6	2560	3.02	44234	1941	2560
274.02	5	2587	3.03	41834	1941	2587
275.00	5	2532	2.88	50357	1944	2532

276.00	5	2363	2.36	40873	1948	2363
277.00	6	2409	2.3	40707	1947	2409
278.00	5	2348	2.31	44797	1939	2348
279.01	5	2670	2.67	42215	1939	2670
279.02	6	2368	2.44	40000	1945	2368
280.00	6	2294	2.66	35625	1939	2294
281.00	5	2699	2.69	47758	1942	2699
282.00	5	2046	2.47	37860	1947	2046
283.00	6	2417	2.81	39349	1944	2417
284.00	5	2630	3.18	46465	1944	2630
285.00	6	2255	2.95	40340	1950	2255
286.00	7	2501	3.25	36898	1943	2501
287.00	6	2528	3.17	35736	1944	2528
288.00	6	2575	3.24	42220	1945	2575
289.01	6	2598	3.3	37806	1948	2598
289.02	6	2335	3.42	37901	1951	2335
290.00	5	2435	3.07	44054	1952	2435
291.00	5	2107	3.07	36339	1951	2107
292.00	4	2470	3.11	62641	1946	2470
293.00	6	2600	2.88	32643	1939	2600
294.00	9	2472	2.89	24190	1939	2472
298.00	6	2183	2.66	37981	1950	2183
299.00	7	2379	3.04	28443	1941	2379
300.00	6	2601	2.83	37142	1944	2601
301.00	5	2232	2.7	40052	1939	2232
302.00	3	2399	2.94	54143	1946	2399
305.01	5	2404	2.95	43068	1946	2404
305.02	4	2333	2.98	47744	1952	2333
306.00	3	2152	2.54	56317	1952	2152
307.00	3	1866	2.37	46776	1960	1866
308.00	4	2468	2.84	56391	1952	2468
309.00	4	2293	2.97	51671	1954	2293
310.00	4	2406	3.1	55907	1954	2406
311.01	5	2303	3.11	43381	1952	2303
311.02	4	2337	3.15	46505	1946	2337
312.00	4	2373	2.94	47496	1951	2373
313.00	5	2379	3.06	44711	1956	2379
314.01	5	2316	3.15	47015	1957	2316
314.02	5	2454	3.05	43366	1954	2454
315.01	4	2380	2.71	62801	1951	2380
315.02	5	2502	2.6	49035	1954	2502

316.00	4	2349	2.78	51740	1950	2349
317.00	4	2289	2.72	50978	1953	2289
318.00	4	2230	2.79	49816	1953	2230
319.00	4	2288	2.9	50977	1949	2288
320.00	4	2468	2.65	53280	1950	2468
321.00	5	2384	2.69	42473	1943	2384
323.00	5	2298	2.64	45204	1952	2298
325.00	4	2363	2.58	49329	1944	2363
326.00	4	2544	2.74	53148	1947	2544
329.00	5	2179	2.36	47527	1949	2179
330.00	5	2339	2.81	45892	1951	2339
331.01	4	2466	2.63	62902	1947	2466
331.02	4	2232	2.35	54836	1954	2232
332.00	3	2330	2.74	77121	1954	2330
333.00	3	2064	2.1	51524	1958	2064
334.00	3	2129	2.35	57381	1962	2129
335.00	4	2174	2.65	56081	1959	2174
336.00	4	2235	2.41	55652	1963	2235
337.01	4	2228	2.23	44651	1962	2228
337.02	4	2350	2.59	74787	1958	2350
338.00	4	2161	2.38	55528	1959	2161
339.00	3	2293	2.35	66683	1956	2293
340.00	3	2509	2.65	72386	1958	2509
341.00	3	2075	2.23	78370	1958	2075
342.00	3	1967	2.03	68323	1971	1967
344.00	2	2339	2.72	91940	1962	2339
345.01	3	1269	1.84	37768	1973	1269
345.02	3	1684	2.18	48145	1974	1684
346.00	3	1370	1.85	51434	1976	1370
347.01	3	2012	2.59	61809	1960	2012
347.02	2	2280	2.64	82496	1958	2280
348.01	3	1908	2.2	60299	1953	1908
348.02	3	2052	2.46	59813	1959	2052
348.03	3	2325	2.53	68092	1958	2325
349.00	3	2014	2.56	50227	1962	2014
351.00	2	1618	1.68	64798	1977	1618
352.00	3	2390	2.43	80728	1969	2390
353.01	3	2242	2.66	71990	1966	2242
353.02	3	1947	2.32	61924	1966	1947
355.00	3	2045	2.45	67726	1966	2045
356.01	3	2099	2.19	67019	1968	2099

356.02	2	2274	2.73	96319	1965	2274
357.01	3	1725	2.45	44118	1966	1725
357.02	4	1981	2.51	43488	1967	1981
358.00	3	2196	2.6	71478	1967	2196
359.00	3	2152	2.4	73449	1967	2152
360.00	3	2072	2.45	71617	1965	2072
361.00	3	2484	2.67	75578	1962	2484
362.01	3	2087	2.39	66171	1968	2087
362.02	3	2268	2.61	72928	1967	2268
362.03	2	2255	2.73	82995	1964	2255
363.01	3	2179	2.76	77397	1966	2179
363.02	3	2110	2.79	61477	1965	2110
363.03	3	2270	2.72	73766	1964	2270
364.00	2	2076	4.09	83441	2011	2076
365.01	3	1835	2.28	60163	1973	1835
365.02	2	2322	2.73	83363	1970	2322
366.00	1	1483	1.64	127011	2000	1483
367.00	1	1767	1.84	127755	1957	1767
369.00	1	896	1.51	82194	2001	896
372.00	3	2135	2.37	77555	1939	2135
373.00	2	2145	2.15	108267	1968	2145
375.00	2	2310	2.32	91576	1947	2310
376.00	1	1234	1.99	60513	1958	1234
377.00	8	2356	2.9	35155	1993	2356
378.00	3	2225	2.36	77115	1939	2225
379.00	3	2299	2.38	63071	1939	2299
380.00	5	2667	2.74	50357	1939	2667
381.00	6	2345	2.74	40189	1939	2345
382.00	5	2458	2.88	43037	1939	2458
383.00	7	2234	2.99	30403	1945	2234
384.00	2	2531	2.49	101170	1962	2531
385.00	2	2524	2.03	149994	1939	2524
386.00	2	2911	2.31	228178	1956	2911
387.00	2	3191	2.33	194093	1939	3191
388.00	2	2600	2.07	112356	1939	2600
389.00	4	2345	2.2	53873	1947	2345
390.00	5	2378	3.08	41917	1951	2378
9800.00	2	1695	1.7	78493	1978	1695
9801.00	1	3552	1.85	99554	1952	3552
9802.00	2	2233	2.62	114265	1964	2233