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Article

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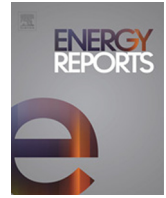
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The flame dilemma: A data analytics study of fireplace influence on winter energy consumption at the residential household level



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HIGHLIGHTS

- A big data model is proposed by layering energy and infrastructure information.
- Winter energy use of fireplaces is compared in size, vintage, and fuel type categories.
- Homes with fireplaces consume more winter energy disregarding size and vintage.
- San Antonio homes with fireplaces used 31% more winter energy than homes without.
- Big data analysis provides a “measure to manage” tool for utilities.

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ABSTRACT

This study investigates the effect of the presence of fireplaces at the household level independent of the function of ambiance and indoor air quality. The focus of this study is on the winter heating energy use of homes with and without fireplaces to promote energy conservation. Three years of winter energy usage (2011–2013) of 365,190 single-family homes are analyzed and compared. The data is further segmented by fuel type, all-electric versus dual-fuel homes as well as by size and vintage. On average, homes with fireplaces used 23,650 kBtu, source energy, for heating purposes during the winter months versus 18,055 kBtu ($p \leq 0.0001$) during the same time period, January, February, and December. There is a significant 31% increase in energy use in homes with fireplaces. In conclusion, policy prescriptions and retrofits are recommended during new home construction permits, renovations, and utility rebate outreach programs to encourage more efficient and cleaner fireplace technology applications.

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1. Introduction

The objective of this study is to quantitatively answer the question: are homes with fireplaces more or less energy efficient in the winter, and if so, by how much? A dataset of 365,190 single-family detached homes in San Antonio, Texas is used for this study.

Common knowledge since 1745 has indicated that fireplaces are not efficient, dating back to Benjamin Franklin's writing describing how heat “flies directly up the Chimney. Thus five sixth at least of the heat (and consequently of the fuel) is wasted, and contributes nothing towards warming the room” (Streever, 2013). The Department of Energy (DOE) estimates that “traditional fireplaces draw in as much as 300 cubic feet per minute of heated

room air for combustion, then send it straight up the chimney” (2013). Yet most of the recent literature and technology have focused on the indoor pollutant load of fireplaces, and there is a lack of literature on their true effectiveness as heating devices in the winter. More so, there is continuous interest in purchasing homes with fireplaces. According to the United States (US) Census Bureau data approximately half of the country's new single-family homes are built with a fireplace(s) in 2011. Similarly, in this case study, 46% of San Antonio, Texas single-family detached homes built as of December of 2013 and included in this study have fireplaces (Fig. 1).

Targeting the residential sector for energy savings opportunities remains a national priority, not only for energy security, but also for reduced impact on natural resources. The residential sector is not only considered more homogeneous than other areas of industry, manufacturing, and services but is also seen as more consistent in demand structures due to similarities in equipment and infrastructure (Haas, 1997; Pimentel et al., 2004; Hirst and Brown, 1990).

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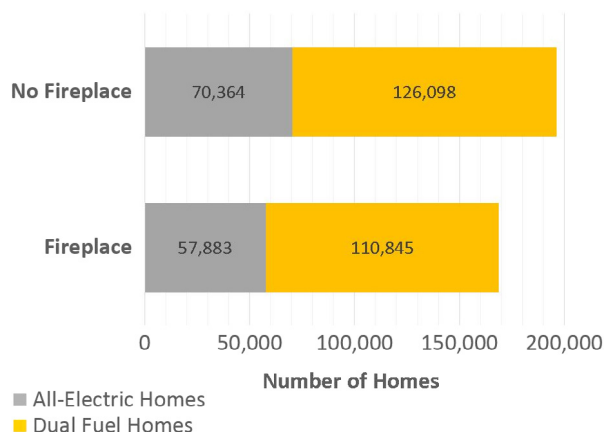


Fig. 1. Total number of homes in case study with and without a fireplace by fuel type.

Similar to retail and business industries (Manyika et al., 2011; Brynjolfsson et al., 2011), with the new age of data analytics, segmenting the various types of homes and appliances will provide a better approach to conservation. Data analytics can highlight individual impacts of building archetypes (Gomez et al., 2014), swimming pool presence (Elnakat et al., 2015), appliances and equipment, and why not fireplaces? Yet in the literature, there is a lack of comparative and segmented energy informatics on many energy-consuming systems, devices, and appliances such as swimming pool pumps (Elnakat et al., 2015), water heaters, fireplaces and many others. The lack of actionable information makes it challenging for homeowners to make informed decisions (Hirst and Brown, 1990) regarding home operation and performance.

Generally, and inaccurately, consumers correlate energy use to the magnitude of size and function of the appliance (Steg, 2008). Examining the 365,190 homes in this case study provides an unprecedented scaled look into the significance of variations in energy consumption patterns due to the fireplace effect.

2. Description of dataset and methodology

Utility billing data for the years 2011, 2012, and 2013 are obtained and merged with the residential building characteristics obtained from the county property tax assessor's office. Relevant building characteristics included vintage (year the home was built), size (living area or area of conditioned space), type of fuel used for space heating and cooling, the presence of swimming pools, and the presence of a fireplace. Swimming pools are also considered high energy consumers at the residential level as recently published in Elnakat et al. (2015); therefore, multivariate analysis coupled with a disciplined segmentation approach is performed to better assess the fireplace impact since in San Antonio, the swimming pool pumps usually operate year round. Data available to identify the presence of fireplaces did not include whether the fireplace was vented or unvented or the fuel consumed (e.g., electricity, natural gas, propane, or biomass).

Monthly billing records contained bill start and end dates, number of days on bill, and consumption information for electricity and natural gas in kilowatt hours (kWh) and one hundred cubic foot (ccf), respectively. Energy use for this study is converted to British thermal units (Btu), were both the electricity consumption and gas consumption are combined.

Historical weather data is obtained from Weather Data Depot (0000) and Weather Underground (0000). Parameters of interest are daily average temperature, cooling degree-days, heating degree-days, and total degree-days. The weather station chosen is located at the San Antonio International Airport. While

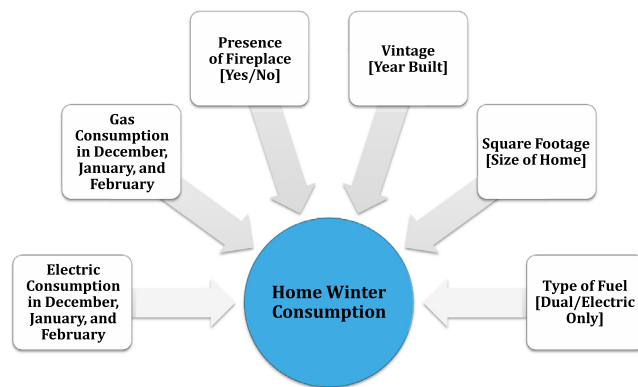


Fig. 2. Data analytics parameters set for each of the 365,190 homes in the dataset.

microclimates will vary slightly across the study area due to local effects such as wind, urban heat island, and other factors, for the purpose of this comparative analysis, a constant temperature across the city is assumed. Based on historical weather data, winter months, when space heating is required, are defined as the months exhibiting the highest number of heating degree-days, which for the San Antonio area are January, February, and December.

In addition, for each of the 365,190 homes the following parameters are identified to enable more accurate comparative data analytics (Fig. 2):

- Electric Consumption in January, February, and December
- Gas Consumption in January, February, and December
- Type of Fuel [Dual/Electric Only]
- Presence of Fireplace [Yes/No]
- Vintage [Year Built]
- Home Size [Living Area]
- Presence of Swimming Pools and spas [Yes/No].

The segmentation approach utilized for this study apportions single-family detached homes into one of 64 subcategories based on the vintage and size of each house ranging from old (built before 1950) to new (built on 2010 or later) and small (<1000 sf) to large (>4000 sf). Furthermore, homes are categorized based on the fuel utilized as all-electric or dual fuel homes. All-electric homes have access to only electricity for all end uses while dual fuel homes have access to natural gas. Natural gas may be used for space heating, water heating, cooking, and even drying clothes.

The final count of this large database reached over 30 million records of compiled and enriched data to be used for energy informatics, the database architecture included a validation process that removed null results, private records, duplicate records, homes with change of ownership and homes with interruptions of service during the time of the study. Structured query language software and python programming is used in a relational database management system. Data is encrypted and analyzed per security protocols administered to protect the privacy of the homeowners. Geolocation of each residential dwelling is the common attribute that is used to center the database and the data enrichment.

2.1. Energy estimates and end use disaggregation

To disaggregate energy consumption between the various end uses, energy utilized throughout the year is divided into two main groups: weather sensitive (cooling and/or heating) versus non-weather sensitive (baseload, minimum amount of energy necessary to operate the home year round). Each home's baseload consumption is estimated based on minimum monthly electricity and natural gas consumption, which may not occur during the same month or season. Lowest electricity consumption is generally

observed during the shoulder months, March, April, October and November. In some cases, homes with access to natural gas consume less electricity during the month of February. Similarly, lowest consumption of natural gas takes place during the summer and highest consumption is observed during the winter season. Eqs. (1)–(9) outline the disaggregation process:

$$\text{Annual Energy (kBtu)} = \Sigma(\text{Monthly}_{\text{Electricity}}) + \Sigma(\text{Monthly}_{\text{Natural Gas}}) \quad (1)$$

$$\text{Monthly Baseload Energy (kBtu)} = \text{Min}(\text{Monthly}_{\text{Electricity}}) + \text{Min}(\text{Monthly}_{\text{Natural Gas}}) \quad (2)$$

$$\text{Annual Baseload Energy (kBtu)} = 12 \times \text{Monthly Baseload Energy} \quad (3)$$

$$\text{Total Winter Energy (kBtu)} = \Sigma(\text{Monthly Energy}_{\text{Jan, Feb, Dec}}) \quad (4)$$

$$\text{Winter Baseload Energy (kBtu)} = 3 \times \text{Monthly Baseload Energy} \quad (5)$$

$$\text{Heating Energy (kBtu)} = \text{Total Winter Energy} - \text{Winter Baseload Energy} \quad (6)$$

$$\text{Total Summer Energy (kBtu)} = \Sigma(\text{Monthly Energy}_{\text{May–Sept}}) \quad (7)$$

$$\text{Summer Baseload Energy (kBtu)} = 5 \times \text{Monthly Baseload Energy} \quad (8)$$

$$\text{Cooling Energy (kBtu)} = \text{Total Summer Energy} - \text{Summer Baseload Energy} \quad (9)$$

2.2. Weather and home size normalization

To understand the impact of weather, heating energy consumption is also normalized based on total degree-days for each of the three years in question (2011–2013) based on Eq. (10), below.

$$\text{Weather Normalized Heating Energy (kBtu/TDD)} = \text{Heating Energy} / \text{Total Degree - Days} \quad (10)$$

To discern the effect of home size on energy consumption, heating energy intensity is calculated based on Eq. (11), below.

$$\text{Heating Energy Intensity (kBtu/sf)} = \text{Heating Energy} / \text{Home Size} \quad (11)$$

3. Results and discussion

3.1. Total consumption

On average homes with fireplaces consumed 23,650 kBtu, source energy, while homes without fireplaces consumed 18,055 kBtu in the heating seasons of 2011–2013 (Table 1). This is a 31% significant additional consumption in homes with fireplaces ($p \leq 0.001$, $df = 288,223$). The dataset is further disaggregated to better understand differences in usage patterns across house vintage, size, and fuel type categories. The objective of the segmentation approach utilized for this study is to compare homes that are similar (e.g., use the same fuels and have similar characteristics such as vintage and size). Heating energy at the individual household level is calculated for 2011, 2012 and 2013. Average heating energy values for each building category are calculated and presented in Table 2. Disaggregated results validate previous assertions introduced in Table 1 showing that in general homes with fireplaces use more energy during the heating season than homes without fireplaces, regardless of the fuel available. To remove the potential confounding effect of weather variations across multiple consecutive seasons, weather normalized heating energy consumption values are also included as an average of the 3-year period understanding that 2011 had the highest number of total degree-days during the winter, followed by 2013 and 2012.

3.2. Consumption by vintage

Fig. 3 displays the 3-year average heating energy consumption for each home by the year the house is built and fuel type (all-electric versus dual fuel). In general, homes with fireplaces consume more than homes without, more so in the newer homes. The reason for this trend is highly related to house size (Gomez et al., 2014; Elnakat et al., 2015). In the San Antonio area homes built in the 1990s are significantly larger than older homes as aligned with national trends.

3.3. Consumption by size

Previously published results indicate that in general, larger homes in the San Antonio area consume more energy than smaller ones, even though most newer homes are more efficient per square foot (lower energy intensity) due to a better building envelope, more efficient systems and smarter appliances. Increase in energy consumption in newer homes is simply due to larger areas to cool and heat in addition to sociodemographic and behavioral trends that likely influence customer usage patterns (Elnakat et al., 2015; Elnakat and Gomez, 2015). A similar trend can be observed in Fig. 4 when comparing 3-year average heating energy consumption of homes with and without fireplaces by house size and fuel type. Homes with fireplaces consume more energy for heating purposes in the winter months; the larger the house size the more energy is consumed. Similarly, homes with fireplaces tend to be larger and newer than homes without.

Additional multivariate analysis is conducted by creating a “Reference” home subcategory. Reference homes are homes that do not have swimming pools, spas, fireplaces, solar photovoltaic or any additional infrastructure improvements. When comparing these reference homes with homes with swimming pools, homes with swimming pools use on average 26% more heating energy (Table 2). Significantly as well, homes with fireplaces use 22% ($p \leq 0.001$) more heating energy as well. Combining these two subcategories (e.g., homes with pools and fireplaces) resulted in 92% more heating energy consumption than reference homes during the same time period. The impact of swimming pools on energy consumption at the residential level is well documented and published (see Elnakat et al., 2015 for a recent publication and extensive literature index). The literature agrees on the influence of swimming pools on energy consumption within the residential sector; however, the influence of fireplaces on energy utilization patterns has not been actively investigated.

This manuscript aims to start the dialog and serve as the launching platform for follow up studies focusing on quantifying the impact of fireplaces on energy consumption at the individual household level. The subject of this research has potential significant implications on the building industry, public policy, utility rebates, and ultimately homeowners and their ability to understand the functionality and the role fireplaces play in today’s households.

3.4. Consumption by fuel type

The objective of the segmentation approach utilized for this study is to compare homes that are similar (e.g., use the same fuels and have similar characteristics such as vintage and size). Homes with fireplaces that are dual fuel use 53% more heating energy than all-electric homes with fireplaces (Fig. 5 and Table 1). This is expected since dual fuel homes with no fireplaces also used more energy than their all-electric counterparts (45% more). However, the difference was more significant in the homes with fireplaces. To verify this assertion, a comparison of source energy consumption

Table 1
Summary of results based on 3-year average heating energy consumption (2011–2013).

| Home type | Heating energy consumption—homes with fireplace (kBtu) | Heating energy consumption—homes without fireplace (kBtu) | % Difference | p-value |
|-------------------|--|---|------------------|--------------------------|
| All homes | 15,653 (23,650) | 10,839 (18,055) | 44.4% (31.0%) | <0.001 (df = 288,223) |
| All-electric only | 5707 (17,517) | 4579 (13,999) | 24.6% (25.1%) | <0.001 (df = 96,579) |
| Dual fuel | 20,847 (26,853) | 14,332 (20,318) | 45.5% (32.2%) | <0.001 (df = 191,405) |

Note: equivalent source energy values shown in parenthesis for every category.

Table 2
Heating energy of various home categories.

| Category | Counts | Average vintage | Average size (sf) | 3-yr weather normalized average heating energy (kBtu/TDD) | 2011 heating energy (kBtu) | 2012 Heating energy (kBtu) | 2013 heating energy (kBtu) |
|--|---------|-----------------|-------------------|---|----------------------------|----------------------------|----------------------------|
| All homes | 365,190 | 1978 | 1855 | 12.57 | 14,793 (23,016) | 10,576 (16,590) | 13,820 (22,314) |
| All homes with fireplace | 168,728 | 1983 | 2242 | 15.05 | 17,819 (26,486) | 12,486 (18,872) | 16,655 (25,592) |
| All Homes with fireplace and pool | 23,431 | 1984 | 3022 | 21.82 | 25,721 (38,257) | 18,044 (27,740) | 24,291 (37,668) |
| All Homes with fireplace no pool | 145,297 | 1983 | 2116 | 13.96 | 16,545 (24,588) | 11,589 (17,441) | 15,423 (23,645) |
| All homes no fireplace | 196,462 | 1974 | 1523 | 10.44 | 12,195 (20,036) | 8936 (14,631) | 11,385 (19,498) |
| All Homes with pool no fireplace | 3,832 | 1976 | 2040 | 13.80 | 16,145 (24,483) | 11,654 (18,564) | 15,196 (24,546) |
| All reference homes | 192,630 | 1974 | 1512 | 10.38 | 12,116 (19,940) | 8882 (14,553) | 11,309 (19,398) |
| All-electric homes | 128,247 | 1995 | 2076 | 4.88 | 5864 (17,952) | 3919 (11,978) | 5481 (16,830) |
| All-Electric homes with fireplace | 57,883 | 1992 | 2310 | 5.48 | 6607 (20,275) | 4351 (13,333) | 6163 (18,942) |
| All-Electric homes with fireplace and pool | 6,665 | 1991 | 3161 | 7.91 | 9505 (29,084) | 6332 (19,344) | 8878 (27,172) |
| All-electric homes with fireplace no pool | 51,218 | 1992 | 2200 | 5.16 | 6230 (19,129) | 4093 (12,551) | 5809 (17,871) |
| All-electric homes no fireplace | 70,364 | 1997 | 1883 | 4.40 | 5252 (16,041) | 3564 (10,863) | 4920 (15,092) |
| All-electric homes no fireplace with pool | 1,179 | 1993 | 2424 | 5.49 | 6459 (19,574) | 4498 (13,644) | 6177 (18,762) |
| All-electric homes no fireplace no pool | 69,185 | 1997 | 1874 | 4.38 | 5232 (15,981) | 3548 (10,816) | 4899 (15,030) |
| Dual-fuel homes | 236,943 | 1969 | 1735 | 16.74 | 19,627 (25,757) | 14,179 (19,087) | 18,333 (25,282) |
| Dual-fuel homes with fireplace | 110,845 | 1979 | 2206 | 20.06 | 23,674 (29,730) | 16,733 (21,764) | 22,134 (29,064) |
| Dual-fuel homes with fireplace and pool | 16,766 | 1981 | 2967 | 27.35 | 32,167 (41,903) | 22,700 (31,077) | 30,418 (41,840) |
| Dual-fuel homes with fireplace no pool | 94,079 | 1979 | 2071 | 18.76 | 22,160 (27,560) | 15,670 (20,104) | 20,657 (26,788) |
| Dual-fuel homes no fireplace | 126,098 | 1961 | 1321 | 13.82 | 16,069 (22,265) | 11,934 (16,734) | 14,992 (21,956) |
| Dual-Fuel homes no fireplace with pool | 2,653 | 1968 | 1869 | 17.49 | 20,450 (27,185) | 14,834 (20,751) | 19,205 (27,117) |
| Dual-fuel homes no fireplace no pool | 123,445 | 1961 | 1310 | 13.74 | 15,975 (22,159) | 11,871 (16,647) | 14,902 (21,846) |

Note: equivalent source energy values shown in parenthesis for every category.

was conducted and the results validated and presented in Table 2 for all home categories.

Table 2 includes a summary of key characteristics of the housing subgroups developed as part of this study. The average home size for single-family detached homes included in this study is 1855 square foot (sf). Average vintage is 1978. In general, all-

electric homes in the San Antonio area tend to be larger (average size of 2076 sf) and built more recently (average vintage 1995). Conversely, dual fuel homes tend to be smaller in size (average of 1735 sf) and older (average vintage 1969). The stark difference between the two groups is a reflection of building trends across the area and the fact that about 80% of the all-electric homes in

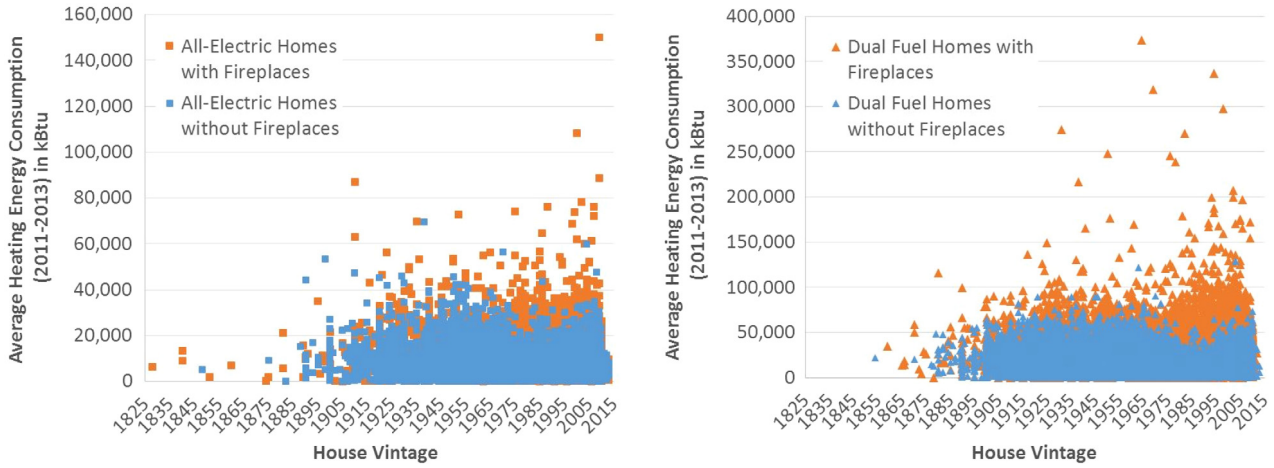


Fig. 3. Average heating energy consumption for homes with fireplaces versus without fireplaces by vintage.

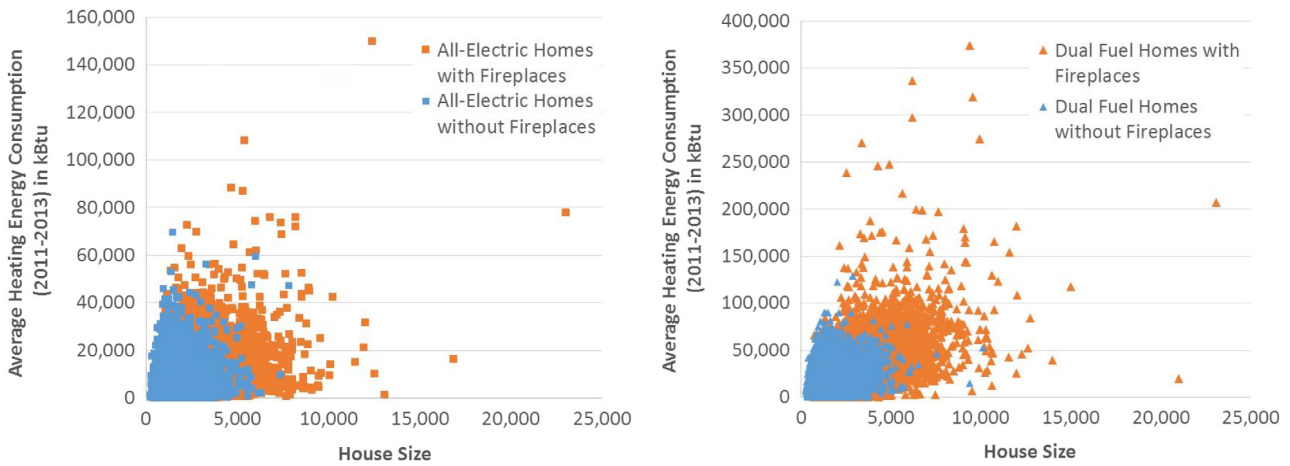


Fig. 4. Average heating energy consumption for homes with fireplaces versus without fireplaces by size.

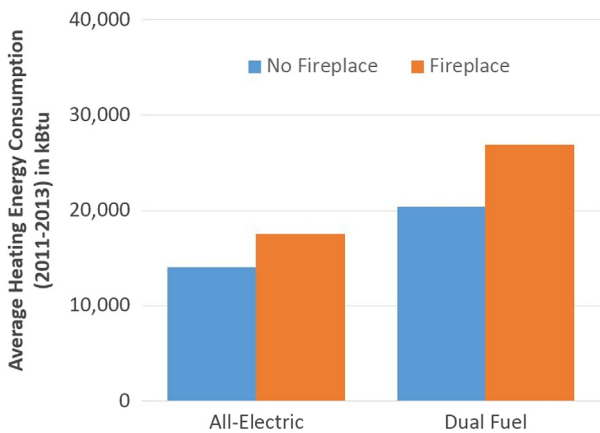


Fig. 5. Average heating energy consumption for homes with fireplaces versus without fireplaces categorized by fuel type over three years.

San Antonio have been built after 1980. All-electric homes with fireplaces are even larger in size (2200 sf) and relatively new (average vintage 1992) while their counterparts without fireplaces are smaller (1874 sf) and built more recently (1997). Dual fuel homes with fireplaces are smaller than similar all-electric homes (average size 2071 sf) but much older (average vintage 1979). Dual fuel homes without fireplaces represent the smallest homes in this study (average size 1310 sf) and the oldest (average vintage 1961).

When comparing heating energy consumption in dual fuel homes with and without fireplaces, homes with fireplaces had higher levels of consumption than their counterparts in 58 out of 63 (about 92%) vintage/size subcategories. The remaining two subcategories had no applicable records. Results of such comparison in all-electric homes are less definitive pre-1980s. However, in general all-electric homes with fireplaces use more heating energy than their counterparts 33 out of 62 vintage/size subcategories, about 53% of the time.

3.5. Further discussion

Fireplaces, often a forgotten component of energy efficiency studies, can be a significant energy user and their potential impact is obfuscated by aggregated energy usage information available at the individual household level. This study focuses on quantifying the potential impact of the presence of fireplaces and resulting energy use through data analytics. Through the proposed segmentation methodology, it is possible to quantify how much additional energy is consumed by homes with fireplaces versus comparable homes without fireplaces, with a surprising conclusion that homes with fireplaces actually use more energy in the winter for heating purposes, approximately 31% more! A replication of research on various other residential energy hogs, such as dryers, swimming pool pumps, gaming consoles and other devices can provide more insight into overlooked opportunities for energy efficiency and conservation within the residential sector.

As population increases in cities experiencing rapid growth such as San Antonio, a corresponding increase in supply of both energy and water is required if consumption is not curtailed. This trend is magnified in the residential sector due to the boom in development and construction of single-family detached homes across Texas. Schipper and Meyers indicate that single-family detached homes use significantly more energy than multi-family homes (1992). Hernandez and colleagues concur and specify that conventional single-family detached homes consumed an average of 108 million Btu per year, while single family attached homes consumed an average of 89 million Btu per year, and multi-family homes consumed an average of 54 million Btu per year (2011). Focusing on improved energy efficiency and promotion of energy conservation within the residential sector becomes increasingly important if trends observed over the past decade persist across metropolitan cities.

Municipal utilities continue to balance demand and supply of energy to ensure safe, reliable, cost effective, and secure service. As more legislation and tighter goals for reducing carbon emissions become effective, reducing demand in a growing population requires creative and innovative opportunities in which every kilowatt counts.

When looking at strategies to target homes with rebate incentives for potential participation in energy efficiency programs, it is important to provide the educational tools and energy consumption data that enable utility customers to make informed decisions and promote a culture of efficiency and conservation. Many customers are unaware of the impact of various household components and appliances on their monthly utility bills. Disaggregated end use energy consumption data is simply not available, although advanced metering infrastructure and automated meter reading deployment and adoption continue to gain ground. When it comes to fireplaces, the homeowner usually assumes that using the fireplace in the winter will save energy! This is not the case in San Antonio, Texas as established in this research.

4. Conclusions and policy implications

Major findings indicate that:

- As of recent years (2011–2013) approximately 46% of homes in this case study are constructed with a fireplace. This mimics national trends.
- Homes with fireplaces consume approximately 31% more heating energy than homes without, regardless of fuel type. More specifically, an average of 23,650 kBtu per year, source energy, versus 18,055 kBtu per year ($p \leq 0.001$).
- The majority of the homes with fireplaces in this study are dual fuel homes (110,845 dual fuel versus 57,883 all-electric). When comparing fuel type, dual fuel homes with fireplaces consume 53% more heating energy than all-electric homes with fireplaces ($p \leq 0.001$) indicating that it is not only the “chimney” or vented type fireplaces that are potential energy wasters.
- Home size and vintage play a role in how much energy is consumed. Larger – that also happen to be newer – homes with fireplaces consumed more winter energy than their counterparts without fireplaces.
- When comparing heating energy consumed by homes in each of the vintage/size subcategories, regardless of fuel type, homes with fireplaces use more energy in 97% of the subgroups. Similarly, dual fuel homes with fireplaces use more heating energy than their counterparts in 92% of the vintage/size subcategories. Results for all-electric homes are less definitive. Higher heating energy consumption in homes with fireplaces is observed in 53% of the all-electric subgroups.
- This study has disrupted the way one may think about fireplaces at the individual household level. Even if the homeowners and city development services are aware of the fireplace’s potential for resulting in higher levels of energy consumption, the literature has not quantified that usage. The results of this research can help quantify the additional amount of energy used by homes with fireplaces when compared to equivalent vintage and size homes without fireplaces, even when normalized by weather.

Ample opportunities are available to use fireplaces as an entry point to managing energy consumption at the household level and promote energy efficiency and conservation. Most of these opportunities are promoted by federal level outreach and private industry. Minimal efforts are witnessed at the utility and city development planning efforts. Encouraging fireplace efficiency in building development services provided by city municipalities is important. Rebates from utilities can also promote awareness and provide incentives to retrofit existing fireplace structures. Some examples to better promote fireplace efficiency include:

Better siting of fireplaces in new construction (DOE, 2013) where fireplaces are placed in a busier (more used) area of the house in addition to implementing a fan or blower assembly to help distribute the heat. This will encourage utilizing the fireplace instead of other energy consuming space heating devices, similar to the old times when fireplaces and stoves played a central role in the home. They served as the heart of the home.

In homes where new installations or retrofits are applicable, a certified professional install will not only maximize the efficiency but also provide protection for health and safety of the structure and its occupants. Institutes, such as the National Fireplace Institute, have an updated database registry of certified professionals (NFI, 2015).

The DOE also recommends utilizing fireplace designs that include dedicated air supplies, glass doors, and heat recovery systems (DOE, 2013). In addition, fitting a high efficiency fireplace insert can convert an existing chimney into a pseudo higher efficiency wood stove. This retrofit sits in the masonry on the fireplace hearth and should be installed to be air tight for maximum performance. Another measure geared towards improving the efficiency of fireplaces is to seal unused fireplace flues that act as an escape duct for warm air out of the home using an inflatable stopper to temporary seal chimneys when not in use to prevent heated air from leaving the home (DOE, 2013).

From the consumer perspective, when it comes to fireplaces, most consumers are not aware of the impact of the draft produced by vented fireplaces or the actual amount of energy used by the fireplace. This study points to the need for increased development and implementation of educational programs, building codes, and utility rebate programs targeting homeowners, fireplace sellers and installers, and homebuilders to promote not just fireplace safety but also efficiency. Studies like this also suggest the benefit of appliance and end-use based comparative utility billing, as many homeowners are not aware of how much specific appliances, swimming pools, and fireplaces actually contribute to their overall household energy consumption (Elnakat et al., 2015; Homes, 2012; Easley, 2010). More research is required to better isolate the impact of fuel type and other multivariables on the energy consumption of fireplaces within a residential setting by for example identifying electric, natural gas biomass fireplaces. This study has introduced the topic of fireplaces within the realm of the literature outside indoor air quality and heating devices. The objective is to continue to examine the impact of various types of fireplaces on residential energy consumption and disrupt traditional building practices to better utilize this asset.

In conclusion, traditional open masonry fireplaces can still be used for their ambiance by retrofitting, and should be discouraged

as heating devices due to their impact on lost indoor heat and bearing on indoor air quality. Family photos on the mantle, and LED type oversized block candles clustered in the fireplace can still produce a homey ambiance while maintaining heat efficiency and a clean indoor air quality. After all, energy efficiency can still be cozy!

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