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Research article

A measure to manage approach to characterizing the energy impact of residential building stocks

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Abstract: The city of San Antonio is the seventh largest in the United States by population and the second in the state of Texas, with a population of over 1.3 million people. As one of the fastest growing cities, the San Antonio residential real estate market has expanded to meet the demands of the growing population. Managing the energy footprint of single-family houses can be enhanced by big data analysis of combined metered energy consumption and building infrastructure characteristics. This study analyzes the energy intensity of 389,160 single family detached homes and identifies energy utilization trends across various residential building stock size and vintage categories. Supported by the "measure to manage" premise, this study highlights the value of this characterization as a forecasting and planning tool for sustainable growth and a more engaged consumer.

Keywords: Energy efficiency; energy intensity; residential energy consumption; measure to manage; residential building characterization; forecasting energy demand

1. Introduction

The objective of this study is to demonstrate how data analytics applied to the energy sector, highlights trends in the residential building stock that can influence energy consumption and conservation. The study creates and examines an enriched database of 389,160 homes that totals to over 15 million datapoints. In addition, this paper builds on insight from previous work published by the authors that used specific data layering within the same database. The previous and published work examined 1) the influence of energy use intensity and total consumption in newer larger homes when compared to smaller older homes as a benchmarking indicator of potential energy savings [1],

2) the significant impact of swimming pools [2], and fireplaces [3] on energy consumption in the residential sector across all size and vintage category comparisons, and 3) energy engenderment [4] and the influence of socioeconomic, demographic, and household gendered energy decisions that can lead to opportunities for conservation [5] and better targeted utility programs at the zip code level [6].

Residential energy consumption accounts for nearly 22% of total primary annual energy consumption in the United States [7]. Energy efficiency, often driven by financial benefits, is critical to the nation’s future and a key component towards achieving goals of energy security, energy independence, and reduced environmental impacts [8]. To accomplish these goals towards sustainable energy security and independence, it is important to be able to measure to manage.

1.1. Measure to manage

The “measure to manage” concept provides a framework to define and quantify variables of interest in order to track and direct change [9]. “In order to manage something, one needs to define and quantify it first. However, the measure needs to be effective and simple” [9]. To avoid overwhelming users with the sheer volume of data acquired, thoughtful consideration must be placed on “what data to collect, how often to collect it, and how to present the data collected” [10]. Before designing any energy information system, the “key performance indicators” need to be established to support the main goals [10]. According to Karamjeet “a management process requires three sound components to work effectively: 1) definition and quantification criteria, 2) judgment on limits and targets, and 3) management controls” [9]. Measure to manage approaches allow realistic goals to be set and then measure performance against those goals [10]. Edwards Deming has been attributed to the “if you can’t measure something, you can’t manage it” concept, however one of his seven deadly sins of management relates to being able to measure the right variables, which often are the variables that are immeasurable or qualitative in nature [11]. Measuring energy is often a function of utility operations. More needs to be achieved in understanding the influence of the residential infrastructure that drives the consumption.

1.2. Managing energy

Measure to manage is an important concept in the area of energy efficiency because it provides baseline numbers, “benchmarks” [12-14], or “yardsticks” [10] for energy use and factors affecting energy use [14]. These benchmarks are often lacking or are difficult to acquire in the commercial [12] and residential sectors [14]. Benchmarking energy use numbers can be used in a number of ways in both sectors in the interest of tracking, understanding and targeting buildings for efficient, cost-effective, and energy saving retrofits and interventions.

Instability in oil and gas markets coupled with rising concerns over greenhouse gases and pollution have led to a renewed emphasis on energy use and an analysis of the efficiency of techniques designed to reduce energy consumption through programs such as stricter building codes [15]. Improved understanding of factors that influence energy consumption will help guide future policies that drive sustainability [15]. The U.S. Energy Information Administration estimates that energy consumption in the United States will increase 40% in the next two decades [16]. In the residential sector, the examination of more easily understood energy data, such as comparative billing, would lead to significant gains in energy efficiency [14].

The measure to manage approach has emerged from business and finance, yet this study is one example of how the principle transposes to other sectors. This paper applies measure to manage to a large database to provide a better understanding of energy utilization for more informed decisions in the energy sector. Studies of energy efficiency in the residential sector often focus on the physical characteristics and technical factors of energy consumption [15]. However, residential energy consumption is dependent on many factors, including building characteristics (vintage, size, number and distribution of rooms, building type, and materials) [1-3] and demographic characteristics (household income, educational attainment, and family composition) [4-6]. Unfortunately that detailed and granular data is not always available and addressed geographically to the individual household level. This study is unique in its data layering approach to provide a massive 15 million datapoints georeferenced database by combining the data from various sources. This is where the measure to manage approach can help with understanding big data by highlighting outliers and clusters of data that lead to decisions that can influence energy consumption and promote future policies driving sustainability [15].

1.3. The case study

The State of Texas is one of the fastest growing states in the nation [17]. From 2000 to 2010 the population of the country grew by 9%, the Texas population grew by 21% and San Antonio grew by 16%, making it the second most populated city in Texas [18]. The population growth in San Antonio is being fueled by domestic migration as well as increased number of births by residents [17]. Examples of this migration can be attributed to a number of factors including the military base expansions, healthcare and biosciences growth, the renewed investment in oil, gas and non-traditional energy sources as well as production at the local Toyota plant [19].

Sustainability is about integrating humans and the environment in a way that preserves both; it is about integrated decision-making involving systemic thinking, and recognizing the co-dynamic influence of human and natural systems [20]. Like other large metropolitan cities, sustainable growth is key for the progress of San Antonio, Texas. Managing energy and water resources is integral to the sustainable growth in both an economic and an environmental sense. A study on cohort effects states that electricity sales per residential housing unit increased 58%, nationwide, from 1970 to 2007 [21]. The current price of electricity at the time the home is constructed often plays an important role in the efficiency of the home thus, inefficient homes often remain inefficient at later points in time due to the durability of homes [21]. In this study, learning the energy trends of the various stocks of housing (past and present) will better allow for managed growth in the future and provide a good reference point for planning in other metropolitan areas facing growth opportunities.

2. Description of data and methods

2.1. Data sources

Multiple layers of information are compiled, validated and segmented to develop the database utilized in this study including over 15 million records encompassing building attributes and monthly energy consumption data at the individual household level dating back to 2010 thru 2013. The database architecture includes:

- Utility Bills: Segmented into electric and gas usage at the individual household building level for the year 2013.
- Tax Assessor Data: Georeferenced to the utility bills and segmented to isolate single-family detached homes and their conditioned space square footage (size), year built (vintage), presence of a swimming pool, fireplace, solar photovoltaic (PV) panels, participation in rebate programs (to include HVAC, lighting, windows, and water heater upgrades, weatherization, etc.), and energy efficiency certification from a local initiative - Build San Antonio Green (BSAG).
- Weather Data: Historical weather data was retrieved from weather data depot using the location of the San Antonio International Airport and degree days were set to a reference temperature of 65 deg. F (18.3 deg. C).

Segmenting the database to better manage the data was critical for the analysis. The resulting segmentation approach resulted in 389,160 single-family detached homes that are validated and used for the purpose of this study. During the validation process, homes with incomplete data records for the year 2013 are removed, so are homes with change of ownership, interruption of service, private records, duplicate records, and null records. Single-family detached homes represent the majority of residential building stock in San Antonio, Texas.

Figure 1 demonstrates the database architecture for this study. Combined, the layers create a big data analysis opportunity for the dynamic trending of residential energy use in San Antonio, Texas separated by vintage and size, and enriched with an overlay of infrastructure properties.

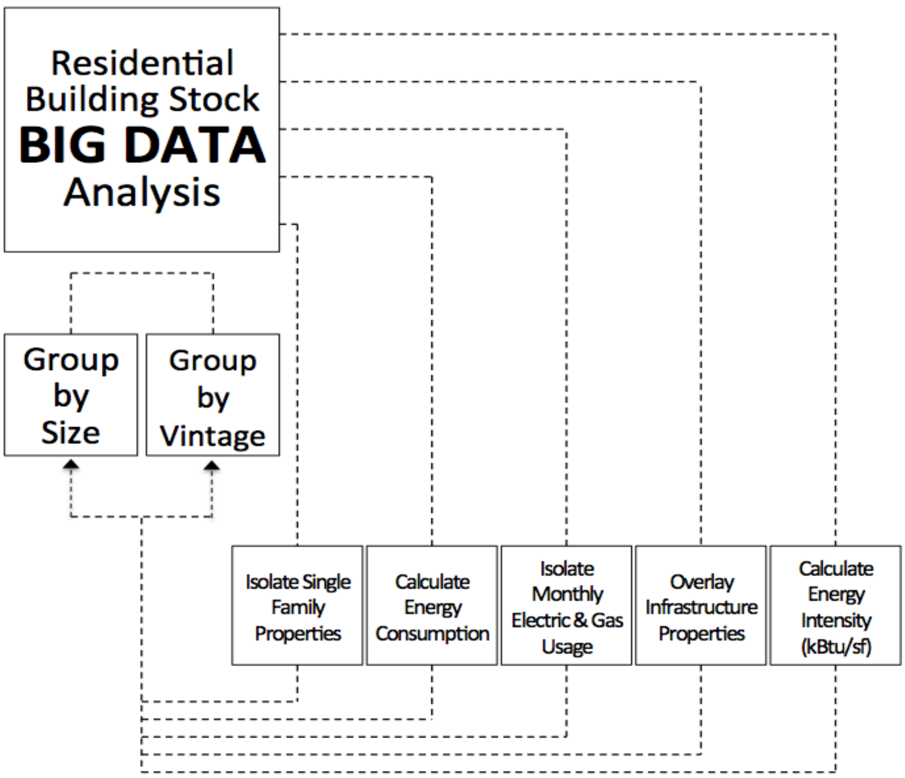

Figure 1. Database architecture.

2.2. Data architecture

A relational database management system is implemented and data is encrypted and analyzed though structured query language (SQL) software and python programing. The database is queried using a set of aggregation and filtering functions provided by SQL. The architecture of the database is centered on one common attribute, the geolocation of each residential building. After encryption, an SQL serial number (an auto increment key) is used as the primary key for summary output tables containing desired estimated monthly energy consumption and all other infrastructure characteristics. The final output tables are exported in .csv format and include electricity and natural gas consumption data and building characteristics organized by size and vintage groups. Data challenges include common issues associated with processing and attribute extraction to include the use of nonstandard building codes and addresses, that require extensive validation through a programming framework (python, awk, ruby).

2.3. Methods

In an effort to characterize the energy impact of similar residential units, it is necessary to categorize the homes by vintage (year built) and size category, of which there are 8 of each, and fuel type. Homes built prior to 1950 are vintage 1, and each decade after that is categorized as a new vintage (i.e., homes built 1980–1989 are vintage 5). Homes sizes are broken into 500-sf (46.5 m^2) ranges; with homes under 1000 sf (92.9 m^2) being size category 1 and homes larger than 4000 sf (371.6 m^2) are size category 8. The fuel types of homes are generally described as homes with access to gas and all-electric homes. Homes without additional features defined in the dataset such as pools or fireplaces are considered reference homes, and are used in comparative analyses.

Site and source energy are also used when comparing across fuel types. Site energy is defined as the amount of energy, as billed by the utility, used by a building. It is often used when comparing buildings of similar fuel type. Source energy is defined as the amount of raw fuel needed to produce the site energy that is then consumed by the building, which incorporates the inefficiencies of different fuel types, expressed in kBtu (Eq. 1) or kWh (Eq. 2). The source-site ratios used, as published by the Energy Star Portfolio Manager, are 3.14 for electricity (grid purchase) and 1.05 for natural gas [22]. Data in this paper are in terms of site energy, unless otherwise specified.

$$\text{Source Energy (kBtu)} = (\text{Electricity (kBtu)} * 3.14) + (\text{Gas (kBtu)} * 1.05) \quad \text{(Eq. 1)}$$

$$\text{Source Energy (kWh)} = \text{Source Energy (kBtu)} * \left(\frac{1000 \text{ Btu}}{1 \text{ kBtu}}\right) * \left(\frac{1 \text{ kWh}}{3413 \text{ Btu}}\right) \quad \text{(Eq. 2)}$$

To compare homes across vintage and size categories, the energy use intensity (also known as energy index, EI) is calculated as energy per area of conditioned floor space expressed in kBtu/sf (Eq. 3) or kWh/m^2 (Eq. 4), utilizing the site energy of homes, as shown below.

$$\text{Energy Index (kBtu/sf)} = \frac{(\text{Annual Electricity Use (kWh)} * 3.413) + (\text{Annual Gas Use (CCF)} * 100)}{\text{Conditioned Floor Area (sf)}} \quad \text{(Eq. 3)}$$

$$\text{Energy Index (kWh/m}^2\text{)} = \text{Energy Index}\left(\frac{\text{kBtu}}{\text{sf}}\right) * \left(\frac{1000 \text{ Btu}}{1 \text{ kBtu}}\right) * \left(\frac{1 \text{ kWh}}{3413 \text{ Btu}}\right) * \left(\frac{10.7639 \text{ sf}}{1 \text{ m}^2}\right) \quad \text{(Eq. 4)}$$

3. Results and discussions

The objective of this paper is to identify trends in the residential building stock that can influence energy consumption and conservation through the use of data analytics. The following sections highlight the findings from analyses performed on almost 389,160 single-family detached homes in accordance to the proposed segmentation methodology. Results are presented for the year 2013, mainly, but similar trends are observed across the 4 years for which energy consumption information is available. Results presented here are representative of longer-term trends and patterns observed across the local geography.

3.1. Long-term energy utilization within the residential building stock

To better understand energy utilization across the study area, seasonal energy patterns over a 3-year period (2011–2013) are analyzed. When looking at the way single-family detached homes utilize energy throughout the year, it is evident, as shown in Figure 2, that on average about half (51–54% based on size category and 49–53% based on vintage category) of the energy is used to satisfy baseload purposes, about a third is used to satisfy cooling demands during the summer months (27–30% based on size category and 28–31% based on vintage category), about 12% is used for heating demands during the winter months (9–12% based on size category and 10–12% based on vintage category), and the balance is used during the shoulder months to offset heating and cooling needs during cooler and warmer days (7–9% based on size category and 8–9% based on vintage category).

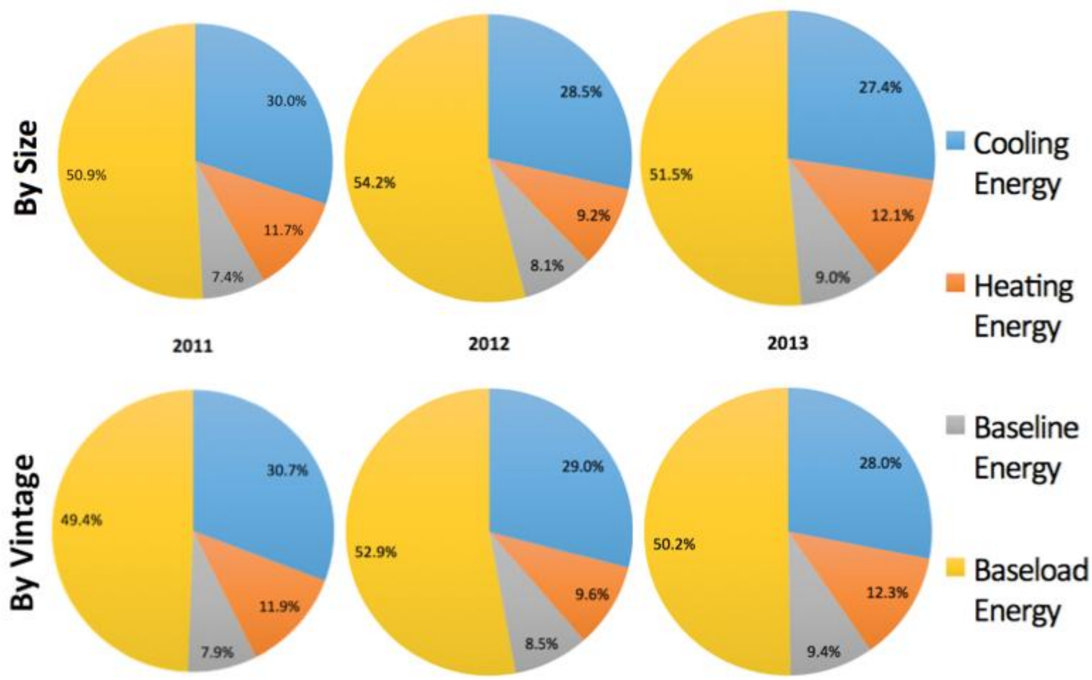

Figure 2. Seasonal energy utilization (2011–2013).

Weather records indicate that 2012 was the mildest of the three years as evidenced by the lowest number of total degree-days across all seasons, Table 1. In contrast, 2011 was the warmest and coldest year and had the highest number of total degree-days. Abnormally hot summers (e.g., 2011) or cold winters (e.g., 2011) resulted in higher energy consumption driven by increased cooling and heating demands.

Table 1. Total Degree-Days 2011–2013.

Year	TDD during Cooling Season	TDD during Heating Season	TDD during Baseline Months	Total TDD
2011	3100	1208	1042	5350
2012	2673	902	939	4514
2013	2906	1005	1001	4912

Furthermore, when looking at weather normalized baseload energy consumption (kBtu/TDD or kWh/TDD) by size category, as shown by Figure 3, it can be seen that larger homes tend to consume more energy to fulfill their basic needs. Large homes (Size 8, >4000 sf (>371.6 m^2)) consume 5 times more energy than small homes (Size 1, <1000 sf (<92.9 m^2)). The pattern is very consistent across the 3-year period of analysis.

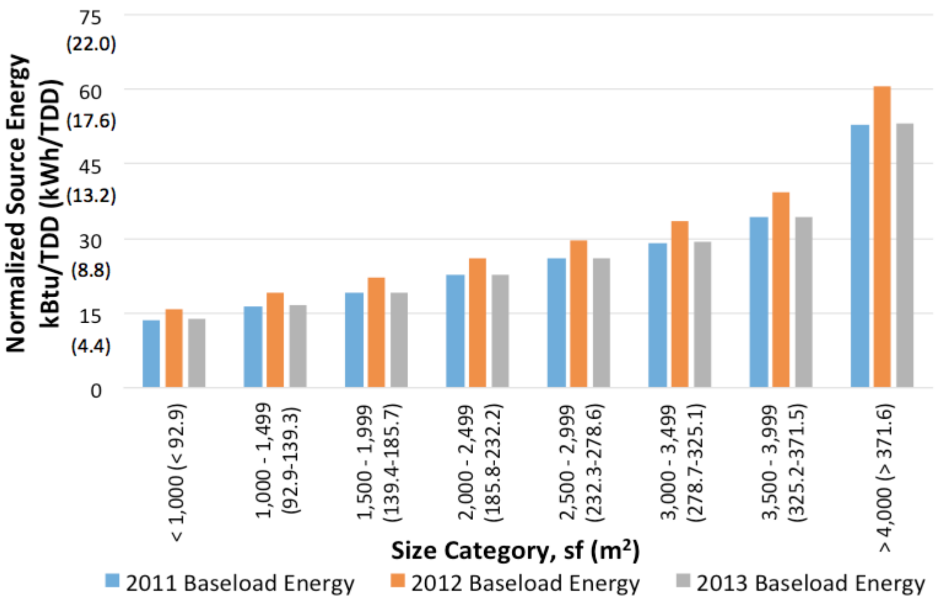

Figure 3. Weather-normalized baseload energy utilization (2011–2013).

3.2. Energy utilization by vintage and size

The distribution of the number of single-family detached houses built in each decade and the corresponding average house size is shown in Table 2. The distribution and associated values are shown in Table 3 by size category. Also shown is the percent of total electric and gas consumption of all homes built in each vintage and size category. The majority of homes (70%) in this study are between 1000–2500 sf (92.9–232.3 m^2) in size. Over 53% of all single-family detached houses in

San Antonio were built after 1980. The number of new houses built increased by approximately 76% from the 1990s to the 2000s. However, the highest increase in house size in San Antonio is seen between the 1980s and 1990s when the average house size increased by approximately 29%, from 1787 sf (166 m^2) to 2302 sf (213.9 m^2). Nationwide, average house size has also increased over the past decades; however, at a much lower rate than San Antonio (16% increase nationwide between the 1980s and the 1990s) [3]. As building size increases, energy use increases due to the greater number of rooms, lighting, heating, and cooling demands [23]. Natural sunlight, ventilation, and shading can be utilized to supplement artificial light and reduce heating and cooling loads, reducing overall energy consumption and increasing sustainability of the building stock [23].

Table 2. Summary of results: energy use and intensity by vintage.

Vintage Category	Number of Homes Built	Average Size sf (m^2)	Avg EI kBtu/sf (kWh/m^2)	Total Electricity Consumption	Total Gas Consumption
<1950	45,902	1309 (121.6)	64.6 (203.9)	10.1%	17.1%
1950–1959	42,909	1318 (122.4)	60.4 (190.5)	9.1%	14.8%
1960–1969	40,587	1516 (140.8)	54.3 (171.2)	9.0%	14.0%
1970–1979	51,323	1649 (153.2)	51.5 (162.4)	12.0%	18.2%
1980–1989	53,224	1787 (166.0)	44.3 (139.7)	14.2%	11.6%
1990–1999	50,777	2302 (213.9)	34.8 (109.7)	15.6%	7.8%
2000–2009	89,362	2352 (218.5)	32.4 (102.1)	26.3%	13.4%
2010–2013	15,076	2410 (223.9)	28.4 (89.6)	3.6%	3.1%

Table 3. Summary of results: energy use and intensity by size.

Size Category sf (m^2)	Number of Homes Built	Average Vintage	Avg EI kBtu/sf (kWh/m^2)	Total Electricity Consumption	Total Gas Consumption
<1000 (<92.9)	42,840	1956	72.2 (227.6)	7.5%	11.3%
1000–1499 (92.9–139.3)	114,239	1969	54.4 (171.5)	24.1%	30.0%
1500–1999 (139.4–185.7)	94,482	1982	41.0 (129.3)	22.8%	21.0%
2000–2499 (185.8–232.2)	61,928	1990	34.9 (110.0)	17.5%	13.1%
2500–2999 (232.3–278.6)	38,876	1995	32.6 (102.9)	12.5%	9.5%
3000–3499 (278.7–325.1)	21,117	1996	32.3 (101.9)	7.6%	6.8%
3500–3999 (325.2–371.5)	8,194	1996	34.1 (107.7)	3.4%	3.6%
>4000 (>371.6)	7484	1993	38.0 (119.9)	4.6%	4.8%

Appropriate orientation of windows and rooms within the building can have a significant impact on the ability to utilize natural lighting and ventilation [23]. Energy use is also impacted by the presence of appliances in and around the home. Televisions and multimedia set-top boxes, found in most homes, contribute 6% of a home's electricity consumption [16]. Homes with multiple televisions or set-top boxes will, therefore, consume an even greater amount of electricity.

3.3. Other building attributes affecting energy utilization

It is well documented in the literature and supported by previous results published by the authors that certain building features such as the size of the home (area of conditioned space) strongly influence the amount of energy consumed. The presence of other building features such as swimming pools, hot tubs, and fireplaces, as well as the number of stories, or the fuel type of the home, can also influence energy utilization patterns across vintage and size categories within the residential building sector. Homes with access to gas use, on average, 192,090 kBtu (56,282 kWh) of source energy on an annual basis while all-electric homes utilize, on average, 195,383 kBtu (57,247 kWh) of source energy. The number of stories also shows an increasing trend related to energy consumption; however, square footage increases at a greater rate between one- and two-story homes. On average, one-story homes use 175,289 kBtu (51,359 kWh), and two-story homes use 232,645 kBtu (68,164 kWh) of source energy, equivalent to a 32.7% increase. Two-story homes are, in average, 70.6% larger than one-story homes meaning the relative increase in energy consumption is notably less than the increase in conditioned floor area of the home. Furthermore, the average energy index of two-story homes is 34.0 kBtu/sf (107.2 kWh/m^2) while the average energy index of one-story homes is 51.2 kBtu/sf (161.5 kWh/m^2).

A notable shift in building practices, and perhaps homebuyer preferences, is represented in Figure 4 where the 1980s symbolize the transition from single-story homes (about 85%) with access to natural gas (about 90%) to two-story (about 60% of new homes) and all-electric homes (about 70% of all homes built thereafter). Over 90% of the all-electric homes built in the county have been built since 1980. New homes built after 1980 were also bigger. Larger homes coupled with advances in technology and better building envelopes result in lower energy index values (EI < 50 kBtu/sf (157.7 kWh/m^2)) as shown in Table 2.

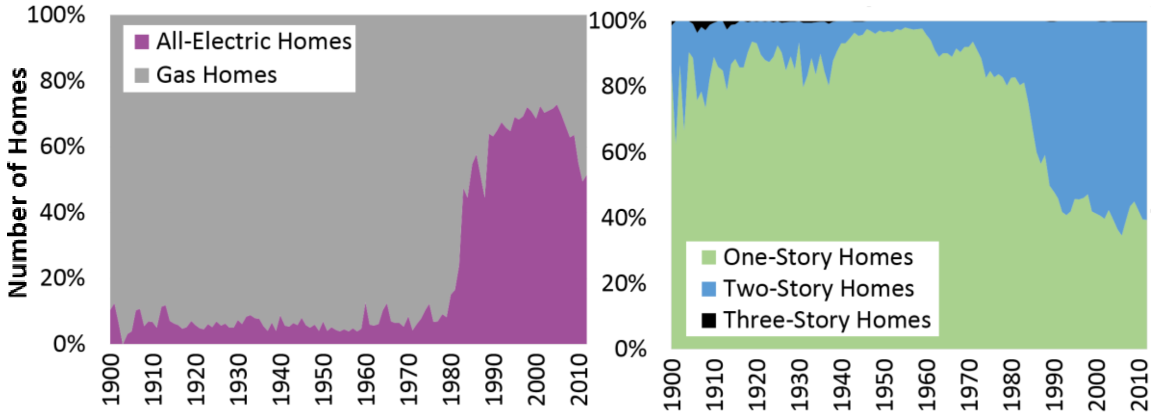

Figure 4. Change of building stock by vintage (1900–2013) by fuel type and number of stories.

Homes built after 2010 have the lowest energy index values across all vintage categories, average EI of 28.44 kBtu/sf (89.69 kWh/m^2). However, despite being more efficient -i.e. using less energy per area of conditioned space- the newer houses tend to be larger (average size 2410 sf (223.9 m^2)) and currently account for a large percentage of total electricity consumed. Over 155,000 homes have been built in the area since 1990 (equivalent to about 40% of the homes being analyzed) and represent over 45% of the electricity and 24% of the natural gas consumed by all homes included in the study. In contrast, smaller houses (<1500 sf (<139.4 m^2) in size) have higher EI values, a well-documented fact, and represent a relatively small percentage of total consumption.

In addition to size and vintage, dwelling additions are known to affect energy consumption of homes. Figure 5 highlights the differences across various building stock categories and compares them to reference homes that do not have any dwelling additions such as swimming pools, fireplaces, etc. Three main drivers are shown alongside an increase in energy consumption: size of the home, presence of a swimming pool, and presence of a fireplace. The presence of solar photovoltaic (PV) installations, participation in rebate programs, and certification through the BSAG program result in reduced energy consumption. There is an offset of energy savings in homes that present a multitude of both energy consuming and energy saving features, as is shown in the various permutations of building features displayed in Figure 5. Homes with a swimming pool are 35% larger than reference homes and use 49% more source energy on an annual basis. Homes with a fireplace, swimming pool, and certified thru the BSAG program have the highest average home size and highest average annual source energy, using 145% more energy than reference homes. The energy consumption of the fireplace and the pool outweigh the savings seen from BSAG certification in this case. The same can be seen in homes with a pool and BSAG certification, but is not seen in homes with a fireplace and BSAG certification.

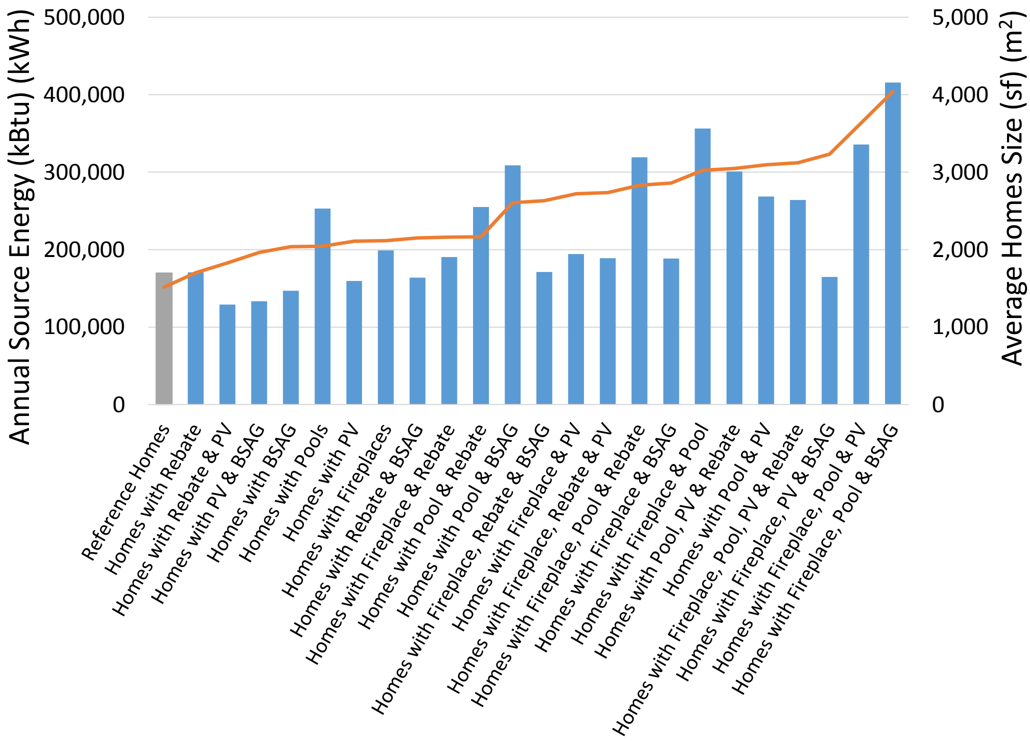

Figure 5. Summary of results: average source energy consumption in kBtu (kWh) and average home size in sf (m^2) per house category for 2013.

To complement the information presented in Figure 5, average site energy and energy index values are presented in Figure 6. Homes with fireplaces and swimming pools exhibit the highest average site energy consumption. The average energy index of these homes is slightly lower than that of reference homes, mainly driven by the fact that homes with pools and fireplaces are almost twice as big as reference homes. Swimming pools and fireplaces remain a top user category even when energy-saving features (e.g., BSAG—green building certification) and participation in rebate programs are present highlighting the influence of the relationship that exists between the dwelling profile and energy consumption, as well as between the socioeconomic characteristics of a household and its resulting energy consumption [2].

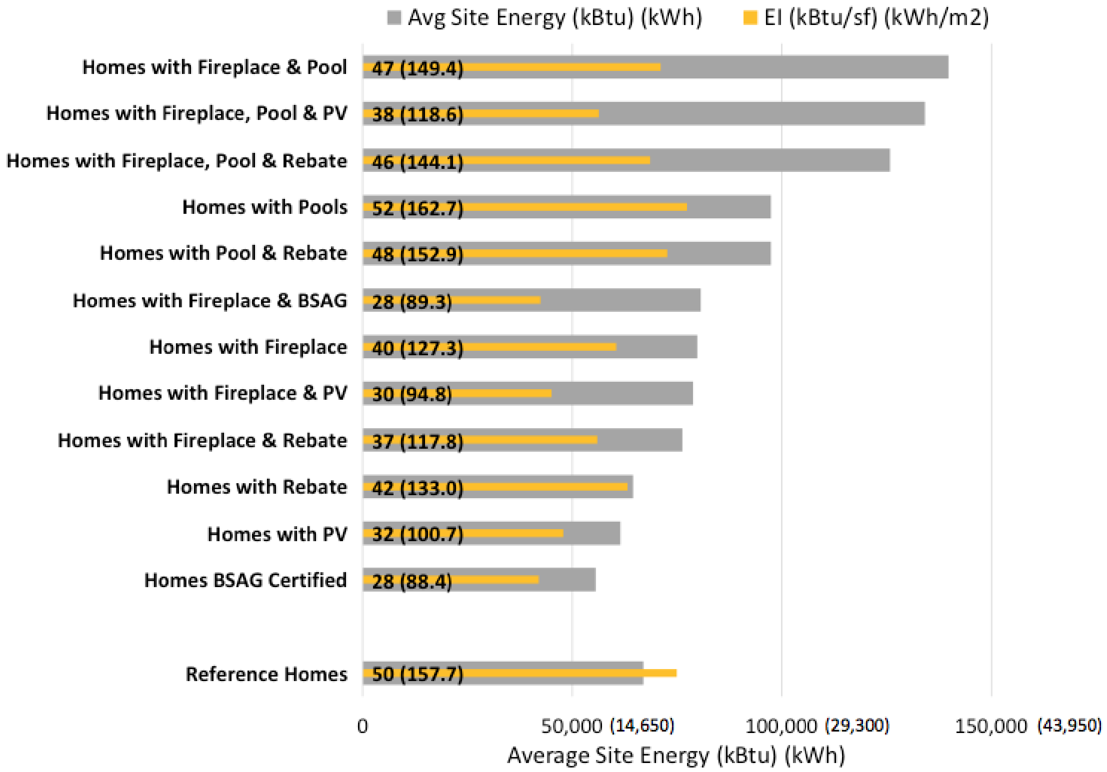

Figure 6. Summary of results: average site energy consumption in kBtu (kWh) and energy index in kBtu/sf (kWh/m^2) per house category for 2013.

For example, houses with the lowest EI values are clustered in North San Antonio, and are newer and larger houses that tend to be more efficient (low EI values) yet consume more total energy and tend to have higher concentration of homes with PV and BSAG certified. In contrast, the southern portion of the city comprises houses with the highest EI values yet account for lower total energy consumption per household due to older and smaller homes [6]. The southern portion of the study area also has a higher percentage of older and smaller houses built pre-1970. A relatively consistent energy consumption pattern for homes built prior to 1970 is observed. Houses in the first three vintage groups (1900–1949, 1950–1959, 1960–1969) represent the smallest brackets of energy consumption across the study area.

Table 4 lists the 2013 average energy consumption of the various dwelling types profiled in this study in comparison to the reference homes. The table also lists the p-values for the t-tests performed comparing the means of the various groups to reference homes. Alpha is set at 0.05 for all tests, thus showing that the mean energy consumption from all groups is significantly different from the mean energy consumption of reference homes. Statistical analyses are conducted to ensure an "apples to apples" comparison among categories. Reference homes are used as a baseline to facilitate highlighting the additional energy usage of various categories added such as swimming pools, fireplaces, solar photovoltaic systems, and homes that participated in a rebate program. This statistical method provides evidence of representative trends based on true variance in energy usage across groups as opposed to casual correlations that do not indicate causation.

Efficiency measures and rebate upgrades including the use of efficient HVAC systems, water heating, windows, lighting, weatherization, and proper use of programmable thermostats can improve the performance of a house and can provide cost effective upgrades for homeowners. As portrayed in Figure 6, homes with pools have lower energy index and site energy only when they have participated in a rebate program. The same can be seen when comparing homes with a fireplace and pool as well as homes with a fireplace, showing that rebate programs are effective at reducing energy consumption. Policies and incentives by local utilities and governments are key in influencing behaviors and promoting resource utilization efficiency. Better understanding of the socioeconomic characteristics and homeowners' behaviors can improve the effectiveness of proposed efficiency and conservation measures and aid in developing programs tailored to the communities in which they will be implemented.

Table 4. 2013 Site energy consumption differences based on average energy consumption across home categories in comparison to reference homes.

Category	Average 2013 Consumption kBtu (kWh)	Comparison with Reference Homes (*p*-value)
Reference Homes	66,978 (19,624)	--
Homes with Fireplace & Pool	139,813 (40,965)	<0.001
Homes with Fireplace, Pool & PV	134,121 (39,297)	<0.001
Homes with Fireplace, Pool & Rebate	125,857 (36,876)	<0.001
Homes with Pools	97,451 (28,553)	<0.001
Homes with Pool & Rebate	97,449 (28,552)	<0.001
Homes with Fireplace & BSAG	80,679 (23,639)	<0.001
Homes with Fireplace	79,887 (23,407)	<0.001
Homes with Fireplace & PV	78,869 (23,108)	<0.001
Homes with Fireplace & Rebate	76,321 (22,362)	<0.001
Homes with Rebate	64,515 (18,903)	<0.001
Homes with PV	61,545 (18,032)	0.003
Homes with BSAG	55,666 (16,310)	<0.001

4. Conclusions and implications

This study increases awareness of energy consumption and energy use intensity patterns across vintage and size categories of single-family detached houses in San Antonio, Texas. Newer construction (homes built since 1990) not only accounts for the highest percentage of all building stock but it also accounts for the highest proportion of total energy consumption in the entire city. Data analyzed correlates the energy efficiency improvements brought about by the relatively recent implementation of building codes to improvements in intensity trends in these larger residential units. Meanwhile, data analytics through the implementation of a sound segmentation methodology has allowed the researchers to measure impacts from homestead additions such as swimming pools, fireplaces, and other building features.

This study shows higher consumption brackets based on the presence of building features such as swimming pools, fireplaces, and larger home sizes, while lower consumption brackets are based on the presence of photovoltaic panels, participation in rebate programs, and BSAG certification. Homes with a pool, fireplace, and BSAG certification have the highest source energy consumption and the highest average size of all the categories, showing that home size along with energy consuming additions offset green measures (e.g., PV, BSAG certification, and rebates).

As utilities aim to provide better, smarter, and more secure services, energy efficiency will impact their bottom line. However, as the behavioral and education adjustments of homeowners switch to more connected and smarter devices, the consumer will target energy efficiency not just from a virtue, but also from a cost cutting and environmental protection perspective. The study also shows that homes that participate in programs aimed at reducing energy consumption, including BSAG certification and rebate programs, are effective at lowering both the energy index and site energy consumption. Further studies in delineating rebate program types will provide insight into the effectiveness of specific rebates.

As the city of San Antonio, Texas continues to experience rapid population growth patterns over the next decade the local utility continues to proactively develop energy saving opportunities. As "population and affluence rise" the potential effect on the environment can be the "business-as-usual and policy-induced efficiency gains" of the locality [24]. The analyses in this study verify the importance of creating a varied portfolio of energy management and targeted programs, more so, highlighting the significance of utilizing benchmarking and measuring to manage methodologies across utilities' service territories. In all, old versus new houses, small versus large houses, efficient versus less efficient houses, houses with or without swimming pools, all these characteristics and performance indicators constitute opportunities for developing targeted energy conservation plans and programs that can be prioritized for cost effectiveness and applicability based on customers' needs and preferences while keeping municipalities secure, service oriented, and environmentally compliant.

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Conflicts of interest

All authors declare no conflicts of interest in this paper.

About the authors

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