Built Green homes are even more efficient than you—and we—thought

As proven by hundreds of Seattle homes in first ever study of its kind

FULL REPORT

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Executive Summary

In cooperation with the City of Seattle and Seattle City Light, Built Green, a residential green building certification program of the Master Builders Association of King and Snohomish Counties, conducted research to determine how much electricity is saved by single-family homes and townhomes that are certified Built Green compared to non-certified homes.

In order for a home to achieve Built Green certification, it must meet minimum requirements and achieve a total point score that measures the four key areas in which homes impact the environment: site and water, energy efficiency, indoor air quality, and materials efficiency. In addressing energy use, a home must demonstrate that it exceeds the Washington State Energy Code through an energy model. However, energy models, though extensively researched and widely accepted, are simply an estimate of how much energy a home will use—much depends on occupant behavior and other factors.

This study determined the actual electricity savings of Built Green homes by examining how much electricity the homes used after being occupied for a at least one year. Built Green obtained electricity data for all single-family homes and townhomes that had been built in Seattle in the year 2014. 746 homes were examined in the final evaluation, making the study, to our knowledge, one of the largest of its kind.

By comparing the usage of homes that were not certified as Built Green to those certified at various star-levels according to Built Green's tiered rating system, we determined the actual savings that result from building to Built Green's certification standards. We found that, on average, Built Green homes perform far better than non-certified homes, as well as exceed the modeled savings required for certification at all star-levels. At the time these homes were certified in 2014, the 3-Star certification level had no energy modeling requirements, 4-Star homes had to demonstrate modeled savings at 15% above energy code, and 5-Star homes had to model at 30% more efficient than code. Comparing the average annual electricity consumption of all-electric non-Built Green homes to all-electric Built Green homes of different star-levels, we observed the following:

- **A 25% improvement in 3-Star homes** (or 2,900 kWh saved per home annually)
- **A 33% improvement for 4-Star homes** (or 3,806 kWh saved per home annually)
- **A 40% improvement for 5-Star homes** (or 4,708 kWh saved per home annually)

Based on these findings, it is clear that Built Green homes are far more efficient than non-certified homes. Further, these results demonstrate the efficacy of Built Green certification; the certification indicates significant electricity efficiency as compared to non-certified homes.

The electricity savings provided by Built Green homes benefit homeowners financially and give them more flexibility in their spending while simultaneously producing a positive environmental impact.
The gains in electricity efficiency resulting from Built Green certification standards present significant financial and environmental savings:

- Built Green 4-Star homes save about $450 each year on electricity costs when compared to non-certified homes; Built Green 5-Star homes save about $558 annually.
- The annual Built Green 4-Star electricity savings are equivalent to installing more than ten solar PV panels (a cost above $8,000) on a home.
- These yearly Built Green 4-Star savings are also equivalent to the amount of electricity it takes to provide electricity for 1.3 years' worth of typical Nissan Leaf driving habits; pairing a green home with an electric vehicle would not use more electricity than a non-certified home would on average, but the occupant's carbon footprint would be drastically reduced through use of an electric, rather than conventional gas-fueled, vehicle.

These proven electricity savings, determined from an unusually large number of homes, and their corresponding environmental, social, and financial impacts, provide local governments, utilities, and builders with the tools to better promote green construction and the Built Green program, which in turn contributes to sustainability and community health. This paper explains how analysis was conducted, details the results of the study, speculates as to why the results are what they are, provides environmental and monetary equivalencies, and elaborates on implications and next steps for the program, local governments and utilities, residents, and builders.

Introduction

Buildings have a large environmental footprint: they require materials for construction and land where they can be built, their construction and operation generates waste and greenhouse gas emissions, and their occupants, through the building's appliances, consume water and electricity. All these environmental impacts deserve attention. With the urgency of climate change becoming ever more pressing,[i] it is understood that carbon emissions need to be reduced across all sectors, including within the building industry. Apart from the carbon emitted through building materials manufacturing and the construction process, buildings contribute to climate change via their energy consumption. In fact, in 2016, about 40% of U.S. energy consumption was from the residential and commercial sectors, which account for almost all U.S. building energy consumption.[ii]

In the City of Seattle, which is the geographic focus of this study, buildings account for 33% of greenhouse gas emissions, with 14% coming from the residential building sector.[iii] As such, improving building energy efficiency has a significant impact on greenhouse gas emission reductions. As cities, states, and countries work to reduce their greenhouse gas emissions, the building sector's impact cannot be ignored. It is less clear what specific building strategies will have the most positive impact, and how these strategies can become more widespread. This study presents some answers by quantifying electricity savings stemming from Built Green certified homes and elaborating on their impact and how certified green home construction can be encouraged.

Background

Built Green

Built Green is a holistic green home certification program of the Master Builders Association of King and Snohomish Counties, established in partnership with King and Snohomish counties in 1999. In addition to certifying green homes, remodels, multifamily buildings, and communities, Built Green hosts a membership network of companies and individuals involved in the green building industry, conducts research, and markets the social and environmental benefits of green building. The program's mission is to serve as the driving force for environmentally sound design, construction, and development practices in the state of Washington's cities and communities.

Over the years, Built Green's underlying aim of fostering building practices that mitigate their environmental impact has not changed, though the program has been updated over time. Built Green certifies projects based on a star-level system, with the higher star-levels corresponding with greater environmental rigor of the projects. At program inception, certification was limited to 1-, 2-, and 3-Star levels. By 2005, the 4-Star and 5-Star levels had been added, as well as third-party verification of projects. Over time, the 1- and 2-Star levels were eliminated and an Emerald Star level added in addition to the 4- and 5-Star levels. Emerald Star certification, the highest current certification level, requires net zero energy use, a 70% reduction in per person water consumption below average, and the use of products with environmental attributes such as green labeling, recycled content, and salvaged material, among other traits. In addition to higher star-levels, remodel, refit, and community certifications were introduced, and third-party verification (where independent green building experts assure that projects have completed the action items claimed on their certification checklist) became a requirement for all projects at all star-levels.

Since its inception (as of March 2017), Built Green has certified more than 31,000 housing units and 17,000 buildings. The program has partnered with local governments and utilities to create green building incentive programs, which have helped spur uptake in the region. Additionally, Built Green has worked closely with entities such as King County and the City of Issaquah on demonstration projects, among them zHome, the United States' first net zero energy townhome complex.

Built Green certifications continue to increase in volume even as the program maintains rigor above code, which is increasingly stringent. In this way, Built Green helps prepare builders for code advances to come, allowing them to stay ahead of the curve and differentiate their work from homes built to code. The certification also provides governments and utilities with a voluntary mechanism that helps them meet environmental and efficiency goals.

Seattle Green Building Incentives

The City of Seattle's green building incentives have been a significant contributing factor to the growth of Built Green certification. In recent years, more than half of new single-family homes and townhomes built in the city have received Built Green certification.

Seattle began offering its priority green permitting program in the fall of 2009 for residential projects. Projects in Seattle that aim for and achieve Built Green 4-Star (other green building certifications are included in the program, but Built Green makes up the vast majority of projects going through the program) are eligible for expedited permitting—a significant benefit to builders in a place such as Seattle, where permitting volume is high and permit timelines are at times long. In addition to the Priority Green program, in January 2010, a zoning incentive became effective which provides additional FAR (floor area ratio) or density in exchange for meeting a building standard such as Built Green. Seattle's land use code stipulates that multi-unit projects that meet a minimum of Built Green 4-Star are eligible for these development bonuses. This is also a significant incentive for builders, who can maximize the land and make financial gains from larger projects. From 2010 through 2016, a total of 972 permit applications were sent through Priority Green.

Seattle City Light

In 2015, Seattle City Light finalized a townhome incentive based on projects achieving Built Green 4-Star or higher. Projects consisting of five or more homes are eligible for a $1,500 incentive per unit. In addition to Built Green certification, projects must use ductless heat pumps as their primary heat source, and any backup heat must be zonal. Gas heat is not accepted.

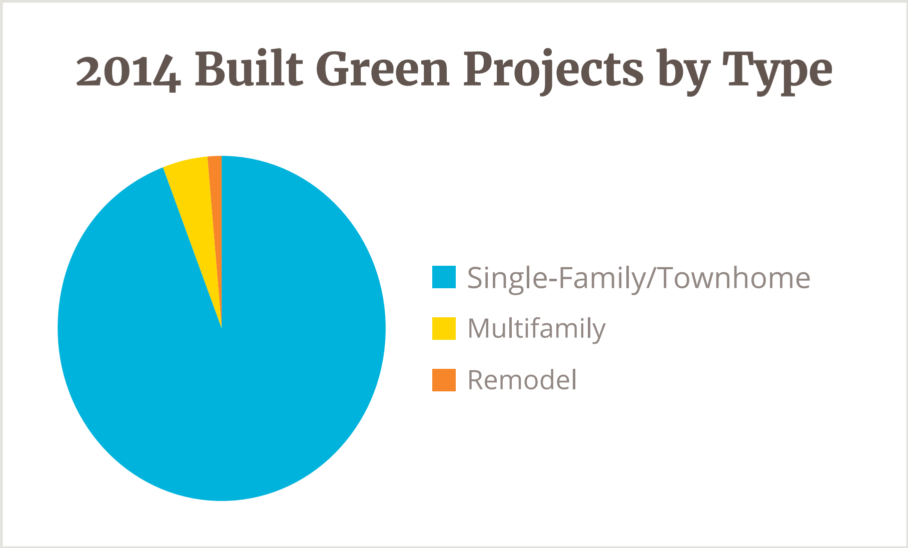
This incentive aligns with the City's and Seattle City Light's work to protect the environment. In 2005, City Light became the first utility to go carbon neutral by offsetting its emissions created by daily operations and power purchases. This supplements City Light's own hydroelectric production, which alone contributes to a relatively clean fuel mix. In 2014, hydro accounted for 89.6% of the fuel mix.[iv] Seattle City Light, as the electricity supplier within Seattle, provided the electricity use data for this report.

The Data

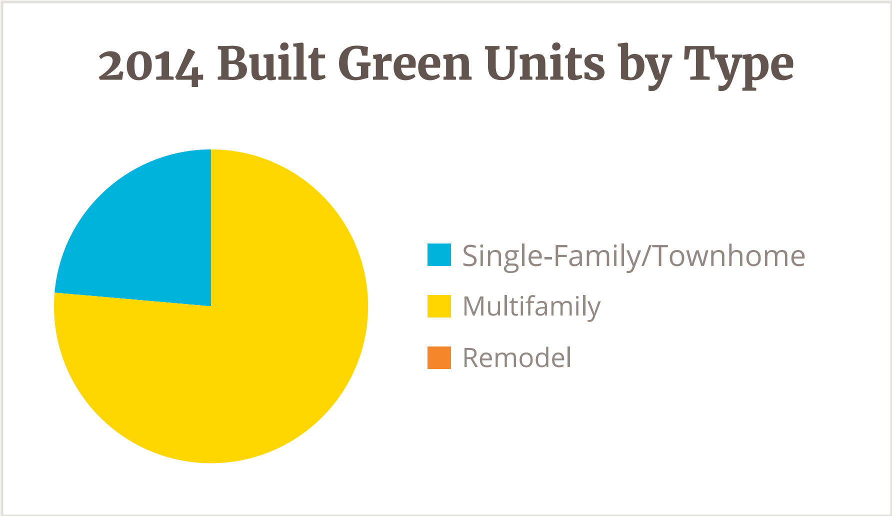
Overview

For this research, we examined new construction single-family homes (including townhomes) built in the City of Seattle in 2014. We settled on this population for a variety of reasons. First, using the most recent construction and certification available was necessary to best evaluate the most current housing stock and iteration of the Built Green program. Since the Built Green checklist and Washington State Energy Code are regularly updated and become more stringent as years pass, the more recently homes were built, the better they will represent current and future development. Second, we wanted to analyze at least a full calendar year of electricity use data. Because weather fluctuates over the seasons, having a timeline of less than a year would potentially not be representative of differences in electricity use or average monthly use per home. We also wanted to be able to observe seasonal fluctuations and to do so, at least a calendar year of data is necessary. Given these factors, the most recent calendar year we could evaluate at the time of data collection (spring 2016) was 2015. Thus, we chose homes that were either certified by Built Green or had their permit issued by the City of Seattle in 2014, shortly after which the homes would presumably be occupied.

Single-family homes were selected primarily because that is the most common type of Built Green project, both within Seattle and outside of the city limits. Townhomes, in particular, are a popular form of new construction in Seattle. Furthermore, in 2016, 58% of new single-family homes built in Seattle were Built Green certified. Given this information, we knew we would have a data set that had ample amounts of both Built Green and non-certified homes. Additionally, multifamily buildings vary significantly in size and because Built Green certifies fewer multifamily projects, we did not feel we would have an adequate population to make accurate projections regarding differences in certified and non-certified multifamily buildings.



Note: These numbers are by project rather than living unit (for example, an apartment building would be one project, but multiple living units).

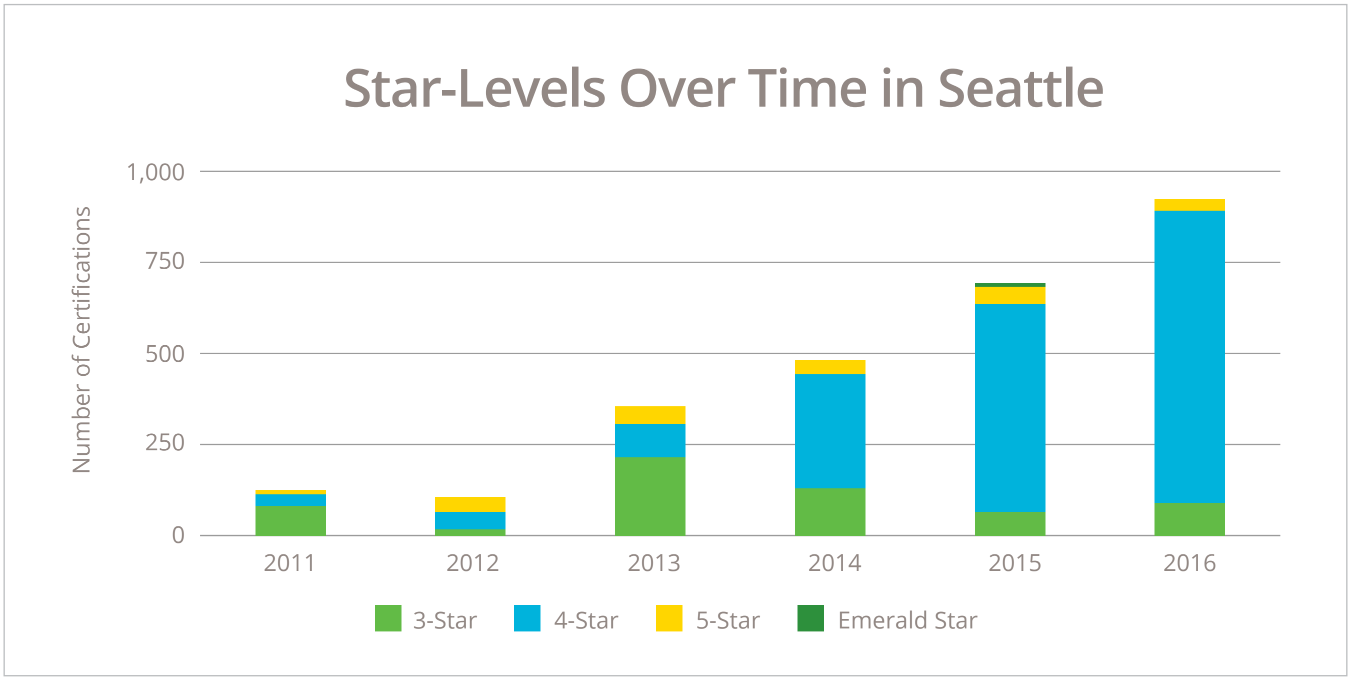


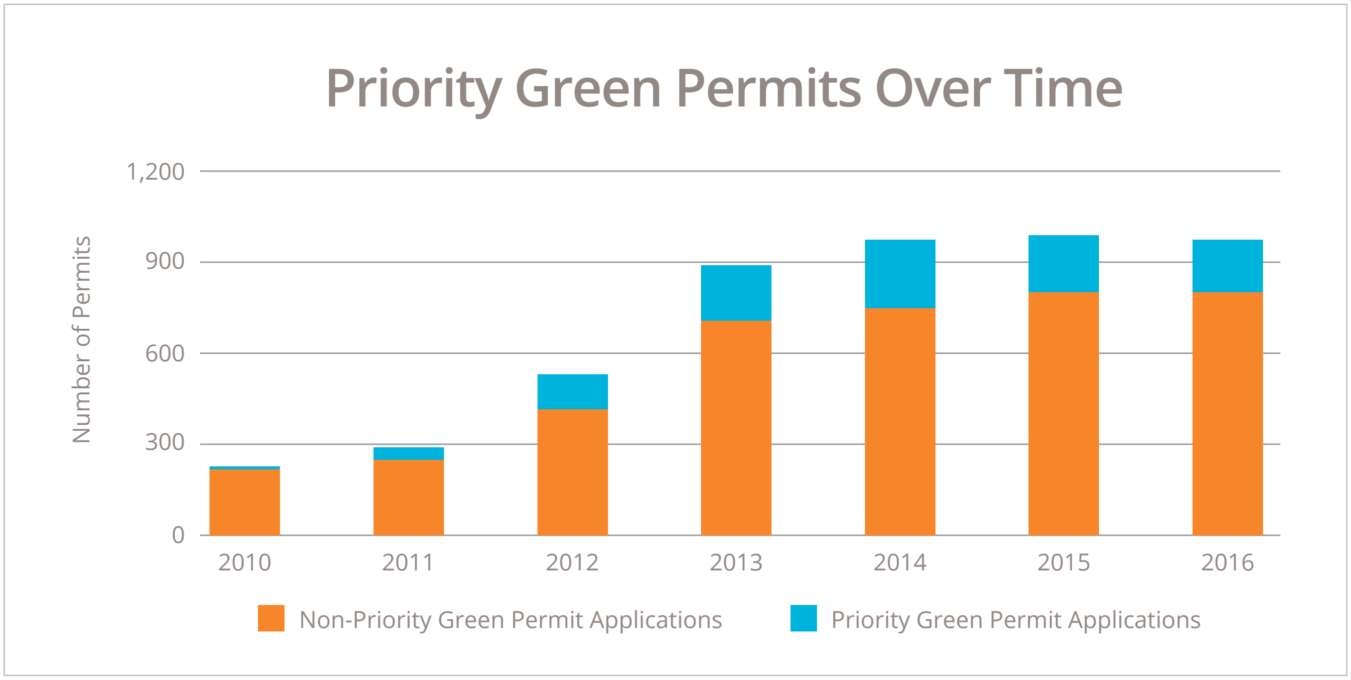
Note: This chart represents projects by units certified. A single-family home or townhome accounts for one unit, whereas an apartment building would be multiple units. Because of this, many people live in Built Green certified units, but single-family projects still make up the majority of buildings certified due to higher construction volume.

Finally, we settled on analyzing homes built in the City of Seattle due to project volume, meaning we would have a large data population to study, thanks to Built Green's relationship with both the City and Seattle City Light. This relationship made it possible to obtain data from Seattle City Light—data which is the foundation for the entire study. Additionally, thanks to the collaboration between the City and Built Green, and due to the existing incentives for Built Green homes, the volume of Built Green construction in the City provides a robust and statistically significant data set to study. Built Green's portfolio has clearly benefitted and shifted due to these incentives.

For example, in 2014, 4-Star, rather than the less stringent 3-Star, became Built Green's most common certification level. This is likely largely due to Seattle's Priority Green program requiring a minimum of Built Green 4-Star as an incentive basis, given that the shift in star-levels occurred following the post-recession increase in Priority Green enrollees (a time lag exists between enrolling in Priority Green, which occurs during permitting, and receiving Built Green certification, which occurs after the home is completed, and which accounts for the rise in 4-Star certifications happening slightly after Priority Green's popularity increased). Because of this important, mutually-beneficial relationship, there is a significant amount of data to examine as well as an imperative to examine it: Seattle invests resources into establishing and maintaining its incentives and thus, it is important for the City to know the exact impact of its work. Correspondingly, Built Green has an interest in understanding whether the time, energy, and resources it invests in its program result in actual environmental benefits.

Growth of Built Green and Priority Green





Obtaining Data

This analysis hinges upon post-occupancy electricity use data obtained from Seattle City Light. However, before making the data request, lists of addresses had to be compiled for the homes whose electricity use we would be analyzing.

For the set of addresses for non-certified homes, we used permit data provided by the City of Seattle. From this information, we created a list of addresses that had permits finalized in 2014 and were single-family residences or townhomes. These addresses were then cross-referenced against the Built Green database to remove any homes that had achieved certification. The remaining list of address constituted our control group: non-certified single-family homes and townhomes completed in 2014.

Built Green maintains a database of all homes the program has certified since its inception in 1999. Thus, it was a simple matter to create a list of single-family homes in Seattle that were certified by Built Green in 2014. These addresses were split out by certification level—3-Star, 4-Star, and 5-Star—so the performance of these different groups could be compared against each other and to the control group of homes.

These four lists—control (non-certified homes), 3-Star, 4-Star, and 5-Star—were all sent to Seattle City Light, where staff then provided electricity usage per billing period (roughly bimonthly) for each address. Inevitably, not all addresses matched up with information from Seattle City Light's database of addresses due to unit number discrepancies or a lack of an account. However, we were able to get electricity use data for the vast majority of addresses requested, a total of 932 homes.

Raw Data Count

Group	Number of Addresses
3-Star	118
4-Star	263
5-Star	44
Control	507

Cleaning the Data

Though we received electricity consumption data for 932 addresses, we were not able to use all of this information since some of the data points had clear errors or lacked adequate information for our analysis. These address, which would hinder accurate study, were scrubbed from the list.

First, we removed data with obvious problems. One example was readings of zero kWh, or negative kWh. These addresses, which likely indicated billing corrections or residents moving, were automatically removed from the analysis. Another example of errors we removed were duplicate readings, made on the same date but with different usage amounts. The likely reason is that Seattle City Light made reading corrections. However, because we were unable to know with certainty as to which reading was correct, we threw out addresses in which this occurred.

Duplicate Read Date Examples

Reading Date	Days Since Last Reading	kWh Usage	
6/3/2015	56	509	Address 1
4/8/2015	62	714	Address 1
4/8/2015	62	1880	Address 1
2/5/2015	63	1219	Address 1

Reading Date	Days Since Last Reading	kWh Usage	
12/12/2015	61	824	Address 2
12/12/2015	61	790	Address 2
10/12/2015	62	2264	Address 2
10/12/2015	62	-784	Address 2
7/2/2015	17	455	Address 2
8/11/2015	40	-1199	Address 2
8/11/2015	40	2164	Address 2

The other leading category of dismissed addresses were those addresses whose read dates contained an obvious error in the number of days since the last reading.

Incorrect Days Since Last Reading Example			
Reading Date	**Days Since Last Reading**	**kWh Usage**	
9/12/2015	59	691	Address 3
7/15/2015	182	4020	Address 3
5/15/2015	57	2127	Address 3

After removing addresses containing errors we were unable to correct for without making assumptions, the final step was to exclude addresses that didn't fit within the study's time-frame parameters. As discussed, the analysis spans a full calendar year to ensure that seasonal changes don't skew the conclusions. However, billing periods do not follow an exact calendar year; they are roughly bimonthly, and the read dates vary by address.

Because of this, not all addresses were able to be included in the final analysis. Due to read dates and billing period length variation, some addresses included electricity usage for well over a year and others well under a year. We decided to exclude addresses for which the usage reading time span could not be made to fit a span of 358 to 372 days, or one year, give or take a week. If billing periods led to greater than or less than this range of continuous usage data, they were removed. We were consistent with this rule across the data sets.

Too Long of a Usage Period Example			
Reading Date	**Days Since Last Reading**	**kWh Usage**	
4/5/2016	61	1051	Address 4
2/4/2016	63	2440	Address 4
12/3/2015	63	1814	Address 4
10/1/2015	59	948	Address 4
8/3/2015	60	987	Address 4
6/4/2015	112	2191	Address 4

Note: This is the total amount of data that we got for one address. It is not possible to get a range of days that adds up to within a week of a year. Additionally, the last entry listed/ the first reading date for "Days since last reading" is unusually high, given that readings are bimonthly.

Given the billing period inconsistencies, it was not possible for all addresses to have the same time range analyzed. Whenever possible, we used a start date between mid-December 2014 and mid-February 2015, but in some cases, this was not possible, and we had to include addresses whose earliest billing data began a couple of months later. However, the distribution of start dates between data groups does not vary tremendously outside of this December to February range, with outliers distributed between data groups, so we feel comparisons between these data groups are fair.

Outliers

As with nearly any large data set, there will be outliers, numbers that fall well outside of the standard range. In this case, a good example is homes that use far more electricity than any other address in the same group. The most extreme example of this within our data was a gas-connected control group address that used 64,884 kWh total during the analysis's year-long timeframe. This is far above the average usage of 8,787 kWh for this same group.

We decided to include outliers such as this address in our analysis. We tested how data groups compared to each other both when outliers were removed and kept in the analysis and there was not much difference in the improvement of Built Green star-levels compared to control group homes. For 4- and 5-Star homes, the percentage differences fluctuated by only a couple of percentage points. Also, since this data covers all single-family homes built in Seattle in 2014 and is not a sample but rather a complete population that reflects reality, we felt justified in including outliers. These are actual homes that are consuming large amounts of electricity and, as a result, they are having a correspondingly real environmental impact.

To better understand the reason why homes were outliers, we used Google Maps Street View to see what these high-consumption homes looked like. Those we were able to see on Google Maps appeared to be large, and one control group outlier appeared to have a pool. The above average size of control group homes with especially high consumption was proven by looking at building permit data. This would help explain the high electricity usage. It is also worth noting that a home consuming that much energy would likely not have been able to model to Built Green's requisite standards, and would have had a more difficult time meeting the higher points requirement imposed by the Built Green checklist on homes that are larger than average. Thus, not only is the inclusion of these outliers a reflection of reality, but it also points to the fact that not all homes can achieve Built Green certification—their size would make it much more difficult to reach the required modeled performance above code and meet point thresholds even if they chose more efficient appliances and design.

Gas Connections

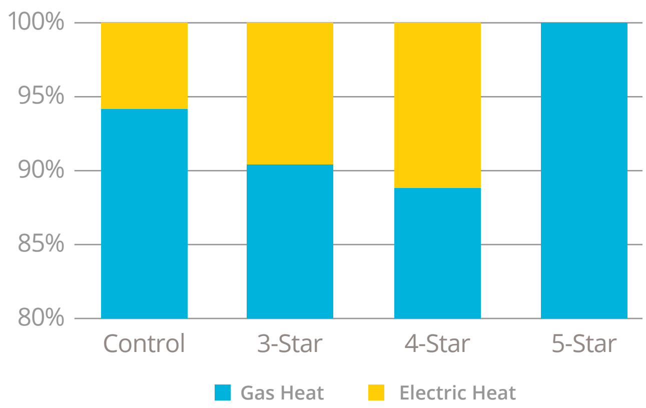
Seattle City Light is an electricity utility and thus, does not sell gas. Some homes in Seattle do have gas connections, and their gas supply is provided by the utility Puget Sound Energy. Unfortunately, we were unable to obtain gas consumption information by address from Puget Sound Energy, and our analysis therefore only examines electricity, rather than overall energy, consumption.

To accommodate the reality that some addresses in the study use gas for a percentage of their home energy needs and some don't, addresses were split by those with gas connections and those without. This information was found from public King County records as well as from City of Seattle permit information. First, we split addresses by whether or not they were listed as having a gas piping permit according to King County records. Then, after City of Seattle staff examined individual permit records, we did a double check for homes that showed they used gas heating but did not have their address listed as having a King County gas piping permit.
Usually, we were able to ascertain the reason for the discrepancy, most often a changed address or one address in a development being used for the permit of multiple townhomes rather than each individual address. We also double-checked against Built Green submittal records for certified projects to see if they contained gas appliances or equipment and, as a result, many homes were moved into the gas-connected group.

However, despite our diligence and best efforts, this separation mechanism is imperfect for a post-occupancy analysis consisting only of electricity data. An address may have a permit for gas connection, but it may not use any gas appliances.

Alternatively, a home that has a gas connection could heavily rely on gas for heating and more. There are a range of appliances that utilize gas and a range of the amount of gas used by those appliances. A home that only uses a gas connection for a gas cooking stove may be in the same data set—homes with gas connections—as a home with a gas connection that uses a gas furnace for home heating. The latter, relying more heavily on gas, would likely use less electricity—but not necessarily less total energy—than the former home. Based on the homes we have permit data for, however, we were able to get some idea of this distribution.

Distribution of Heat Types for Gas-Connected Homes

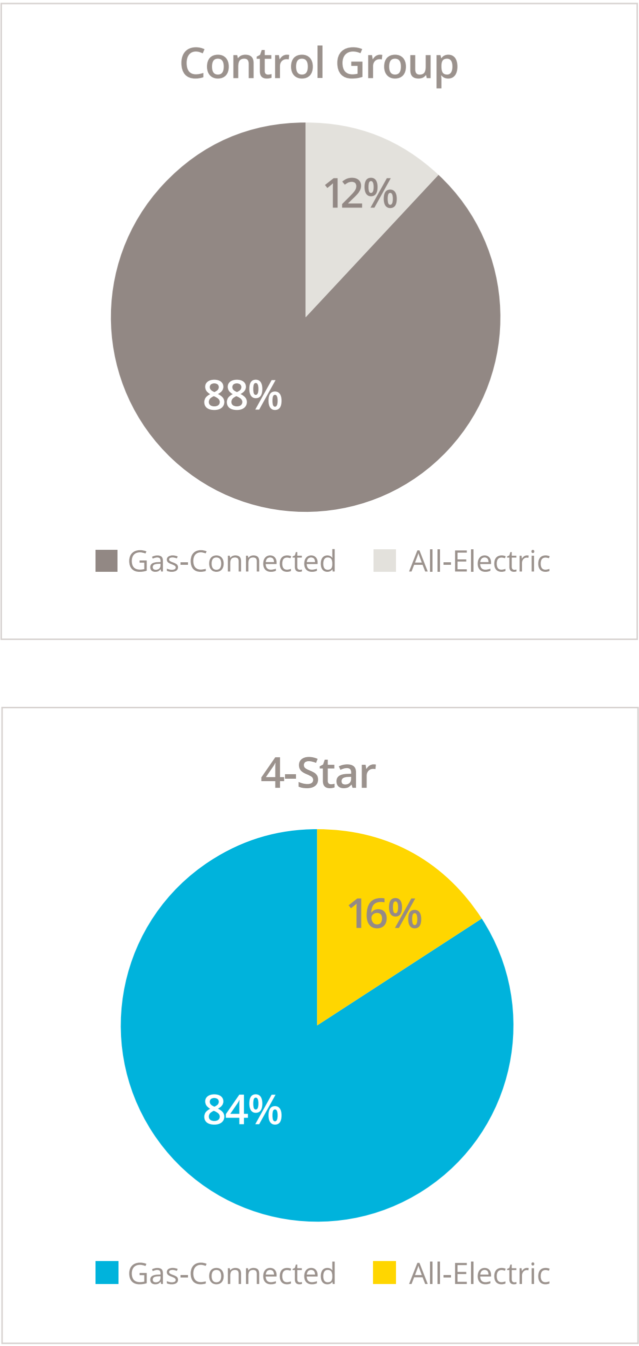


Both gas-connected 3- and 4-Star homes are more likely to have electric heating than control group homes. This indicates that 3- and 4-Star homes would have a higher electric load, making electricity savings over gas-connected control group homes on average all the more impressive. No gas-connected 5-Star homes had electric heating, however. In fact, only one 5-Star home out of 33 total was classified as all-electric based on our information. Based on Built Green certification data, we found that these gas-connected 5-Star homes were using high efficiency tankless water heaters and hydronic radiant heating, which is very efficient and at the time of certification one of the most cost-effective ways to meet the high-efficiency requirements for Built Green 5-Star certification. For consistency between data sets, we still focused on the comparison of all-electric homes to one another, even for 5-Star homes. It is worth noting that had we compared all 5-Star homes to all control group homes, Built Green savings would have been even greater.

Out of Built Green homes, 5-Star homes were most likely to have a gas connection, at 97% of addresses – all but one in the study. The percentage of 3-Star and 4-Star homes with a gas connection was 79% and 84%, respectively. Control homes were just slightly more likely to have a gas connection than 3- and 4-Star homes, with 88% of addresses. The overall percentage of homes with gas connections across Built Green star-levels is 84%, making Built Green homes slightly less likely than non-certified homes to be all-electric.

Due to not having gas consumption data, and to potential data-sorting shortfalls (especially given address changes during construction), we acknowledge that comparisons between the all-electric and gas-connected groups have their drawbacks and that assumptions based on these results are weaker. Nonetheless, the data set is large and given that control homes are slightly more likely to utilize gas than 3- and 4-Star, and out of those that do, are more likely to use it for heating, therefore underrepresenting their energy use, we feel our conclusions overall are well supported. For full disclosure on the data we received, we will provide information on homes in the gas-connected group briefly. Yet, the best comparison this study provides is all-electric homes against all-electric homes, as we are more certain we are accounting for the homes' total energy usage in the comparison. Therefore, we will heavily concentrate on comparisons of all-electric homes, though we will also mention outcomes for gas-connected homes.

Distribution Of Gas Connections Across Study Groups (After Data Cleaning)



Final Data Count

After taking the steps described above, we were still left with a significant amount of addresses to examine, 746 in total. During data cleaning, about 20% of addresses were removed for either having clear meter reading errors or for not fitting within the study timeline. The remaining addresses, after being separated by star level and whether or not they had a gas connection, resulted in the following counts.

Data Count by Group			
Group	All-Electric	Gas-Connected	Total
Control	46	353	399
3-Star	20	74	94
4-Star	35	185	220
5-Star	1	32	33

Analysis and Quality Assurance Process

The data was first procured from Seattle City Light by Built Green, with help from the City of Seattle, as described earlier. After obtaining the raw data, Built Green separated addresses with gas connections from those without and conducted the data cleaning, as also described earlier.

After the data was cleaned, Built Green analyzed it, finding the average total, monthly, and daily electricity use by data group, how those compare to each other, how usage fluctuates over time, the cost associated with different levels of usage, and associated environmental impacts generated by electricity savings. The methodology for all these layers of analysis will be described.

Once the preliminary round of analysis was completed, officials from the City of Seattle conducted a check on the methodology and discussed ideas and alternate paths to explore with Built Green. Next, the raw data and analysis was provided to a third-party firm, Rushing, for an in-depth data and methodology check. Rushing provided Built Green with recommendations for slight changes and with verification that the overall analysis methodology was sound.

After incorporating Rushing's suggestions, Built Green wrote the final research paper, which was then reviewed by both the City of Seattle and Rushing for content and accuracy.

Findings

Summary

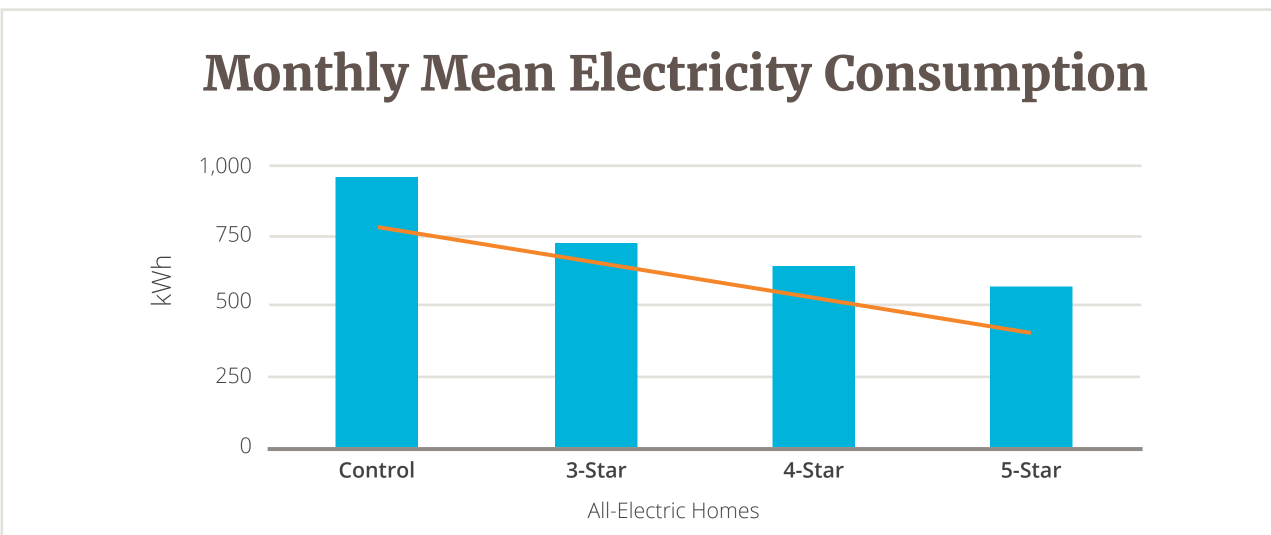
The results of the analysis not only demonstrate that Built Green certified homes on average are more energy efficient than non-certified homes, but that they exceeded our expectations and home energy models significantly. Assuming that non-certified homes were built to code at minimum, the results would then show that Built Green homes surpassed the energy requirements stipulated by Built Green's single-family/townhome checklist that was in place at the time these homes were built.

Homes that were certified Built Green in 2014 were certified under the 2011 version of Built Green's single-family/townhome checklist (in other words, the checklist iteration that had been finalized in 2011). Built Green's checklists are updated periodically to ensure that Built Green represents savings above current energy code at the time of construction, even as code becomes stricter. Under the checklist in place at the time, homes were required to demonstrate 15% improvement above 2012 Washington State Energy Code for 4-Star projects, and 30% improvement above 2012 Washington State Energy Code for 5-Star projects. There was not yet any energy modeling requirement for 3-Star certification.

When comparing the total electricity consumption of all-electric homes to each other, 3-Star, 4-Star, and 5-Star homes outperformed control group homes by 25%, 33%, and 40% respectively. This represents a significant increase in overall energy performance than was required by Built Green's modeling standards.

All-Electric Homes kWh Usage

Group	Average kWh usage per year	Average monthly kWh usage	Percent improvement over control group
Control *(Non-certified homes)*	11,632.40	962.38	N/A
3-Star	8,732.00	722.31	25%
4-Star	7,826.23	646.05	33%
5-Star *Note: Only one home in sample*	6,924.00	570.66	40%

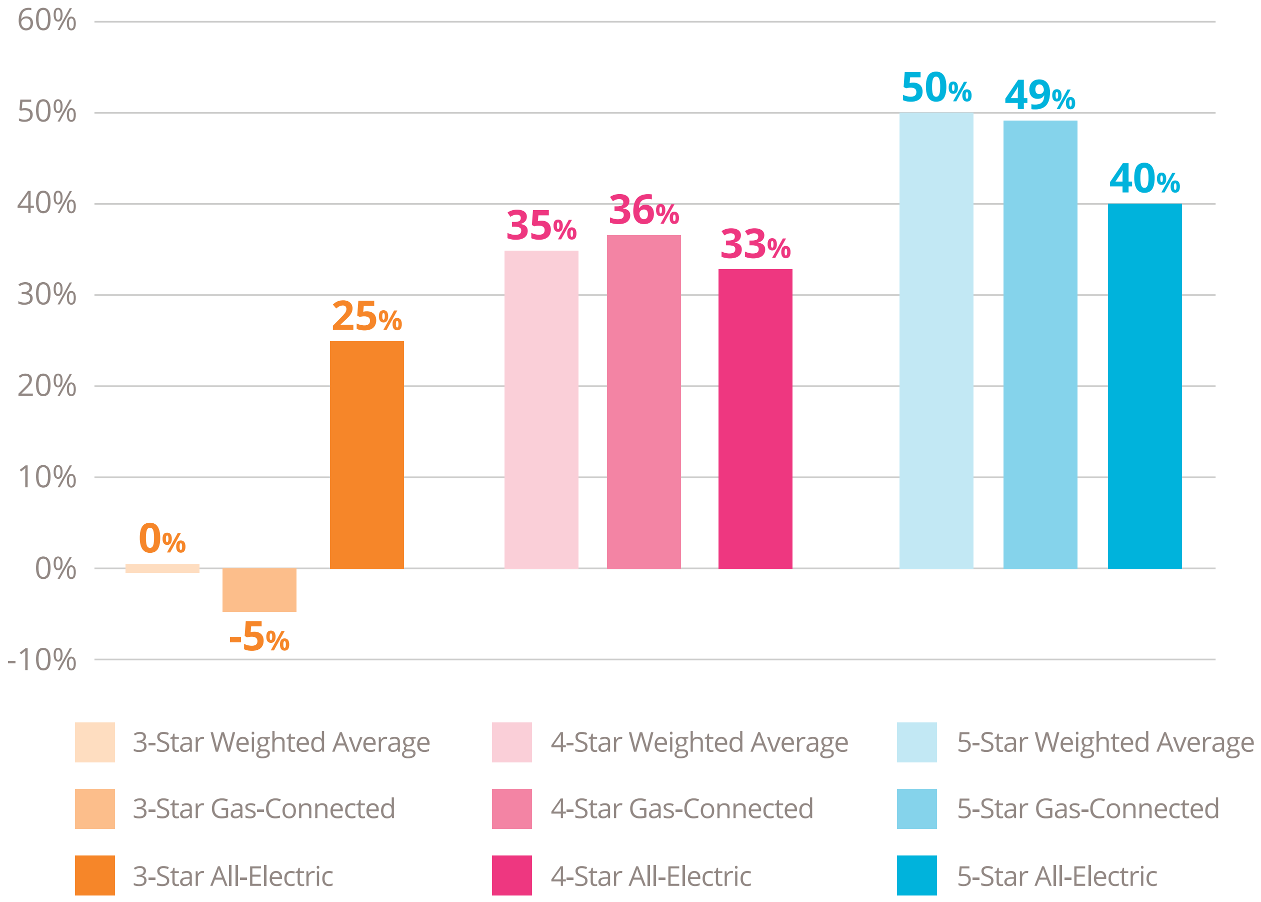


Gas-Connected Homes vs. All-Electric Homes

For reasons detailed earlier, comparing homes with gas connections to each other is not an entirely level analysis, whereas comparing all-electric homes to each other is. Homes may have a permitted gas connection, but it may not be in use, or the gas may only be used for a relatively low energy-consuming appliance (such as a stove) as opposed to being used for a high energy-consuming appliance (such as a furnace). The homes that are relying on gas connections more heavily to meet their energy needs would likely be using less electricity.

Even so, we will present all results for the information of the reader, including those pertaining to gas-connected homes, with the qualification that comparing these homes to each other is not a level comparison. We note that gas-connected 3- and 4-Star homes were less likely to utilize their gas connections for heating than control group homes (see chart "Distribution of Heat Types for Gas-Connected Homes"), and thus comparing the electricity use of 3- and 4-Star homes to that of control group homes is likely an overrepresentation of their overall energy use.

Electric Efficiency of Built Green Homes Compared to Non-Certified Homes of Same Category



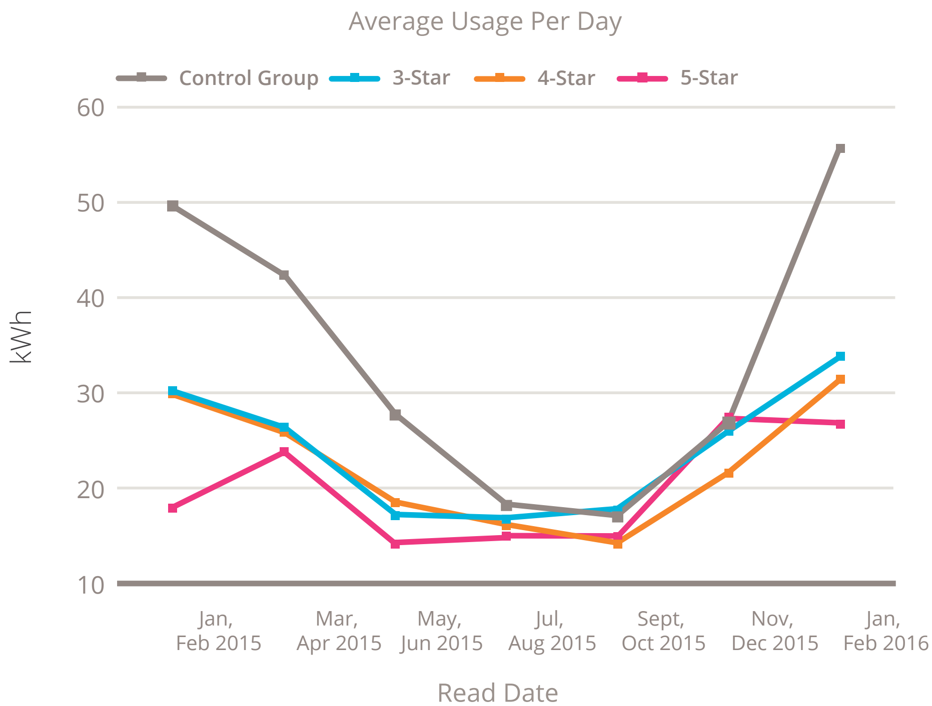
Despite the aforementioned caveat, it is interesting to see that the gains Built Green homes exhibit over the control group for all-electric homes are relatively even with the gas-connected group, with the significant exception of for 3-Star homes.
We can speculate that Built Green homes use electricity rather than gas, even when they have gas connections, to meet more of their energy needs. This assertion is supported by the fact that out of homes with gas connections, 3- and 4-Star Built Green homes are more likely than control group homes to use electricity for heating (see charts "Distribution Of Gas Connections Across Study Groups (After Data Cleaning)"). In view of this, Built Green gains are perhaps even more impressive.

It is also interesting to note that a weighted average (again, not an equalizing factor but which does account for proportionality of gas connections) shows that 3-Star homes consume about the same amount of electricity as control homes. At the time these homes were certified, the Built Green checklist did not require modeled energy gains for the 3-Star certification level. Moreover, not all of the 3-Star homes would have been third-party verified since the transition to require verification for Built Green projects at all levels was still underway. That 3-Star homes on average do not show any gains above control homes may speak to the importance of both third-party verification and energy modeling for efficiency results, especially given that 4- and 5-Star homes show significant gains for both gas-connected and all-electric homes. Indeed, gas-connected 3-Star homes performed 5% worse regarding electricity efficiency than gas-connected non-certified homes. Likely reasons for this not only include the lack of third-party verification and energy modeling requirements for certification at the time, but also the fact that gas-connected 3-Star homes were more likely to use electric heating than gas-connected control group homes, with almost 10% of gas-connected 3-Star homes using electricity for heat versus fewer than 6% of non-certified homes. Overall, this means 3-Star homes have a greater electricity load as a proportion of their energy use. However, since we do not have gas consumption information, we cannot determine whether these 3-Star homes performed better in terms of overall energy use. What is clear is the 20 all-electric 3-Star homes in the analysis far outperformed all-electric control group homes in terms of electricity efficiency, which accounts for the whole of their energy use.

Electricity Use Over Time

Over a year of use, electricity consumption varies. Points of high and low consumption are, in aggregate, largely dependent on the climate zone where homes are located. In the Pacific Northwest, which has a mild climate, particularly by the coast, electricity use can be expected to increase during the winter months when it is darker but also, more importantly, when the outside temperature is cold enough to warrant home heating. The summers are mild enough that, if included in the home, air conditioners are utilized less. As a result, over a year, one can expect electricity use to exhibit somewhat of a U-curve, with higher use during the winter months at the beginning and end of the year and lower use during the summer months.

Electricity Use Over Time For All-Electric Homes



Note: Since there was only one 5-Star all-electric home, this does not exhibit as smoothly of a curved line as the other graphs.

This curve is one we would expect to see in all our datasets and, indeed, we do. To look at change over time, we took the average use of every home in each data group for all electric homes (control, 3-Star, 4-Star, and 5-Star) and charted it over time. Since meter readings are taken roughly bimonthly but on different dates for different homes, we averaged every reading taken in January or February, then in March or April, and so on. Rarely, a reading for a home would not fit in this timeframe, falling just outside of it instead. We skipped the rare data point that did this. Do note that read dates reflect usage for the two months prior to this date, so for actual usage, these curves would be shifted slightly earlier in the year/to the left. The main takeaway is that the expected seasonal fluctuation is revealed.

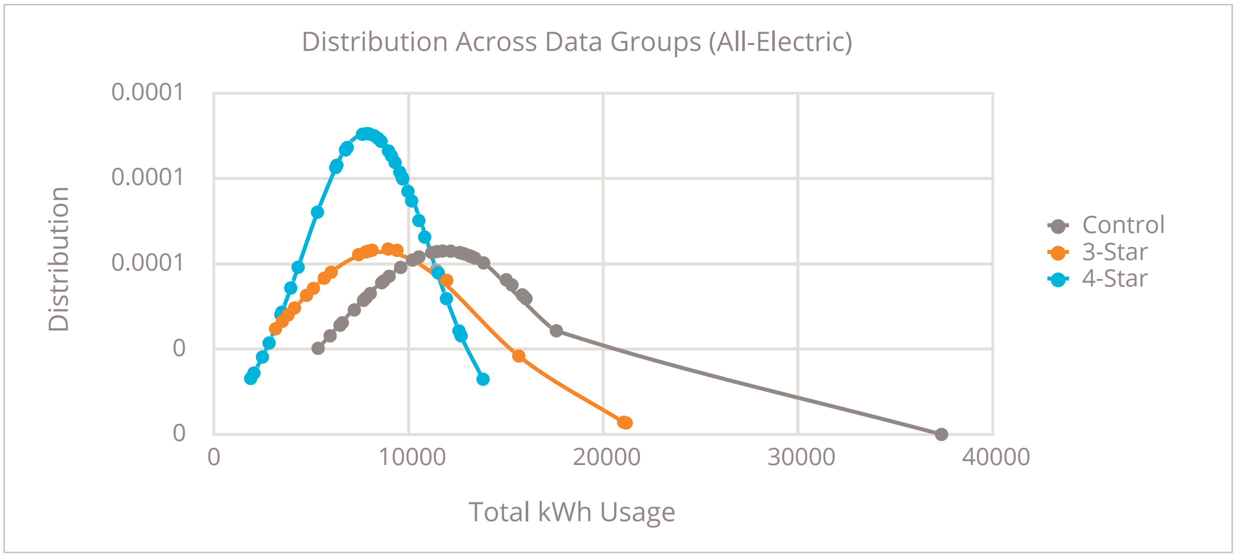
Electricity Use Results Distribution

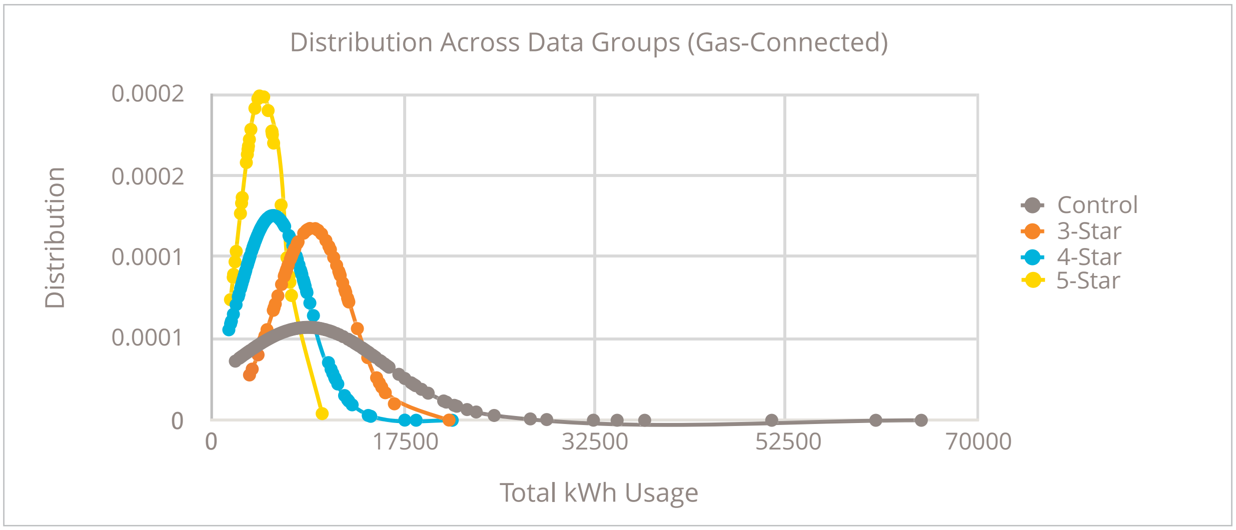
Based on the data from Seattle City Light, we were able to calculate total electricity use for each address over the course of a year (give or take a week, as explained earlier). All-electric Built Green homes performed substantially better than all-electric control group homes (see table "All-electric homes kWh usage"). Within the data sets for each Built Green star-level and for control homes, there was of course substantial variation. All data groups had outliers using a relatively large amount of electricity, causing most groups' distribution charts to have a tail on the right-side. The two groups that did not exhibit these high outliers were the all-electric 4-Star homes and gas-connected 5-Star homes.

Since, as mentioned earlier, removing outliers did not significantly impact results, and because we are examining a population rather than a sample (meaning the data, outliers included, is representative), outliers were included in the analysis.

Interestingly, the bell curves become wider as Built Green certification level decreases, and the control groups exhibit the widest curves. This could indicate that Built Green certification, as it is employed and then becomes more rigorous at higher star-levels, is indicative of higher quality: electricity use falls within a tighter range, and there are fewer high-consuming outliers as homes are certified at higher levels.

Electricity Use Results Distribution





Electricity Use Comparisons

Looking outside of Seattle, on average, Built Green homes use significantly less electricity than the Washington state and national averages. In 2015, according to the United States Energy Information Administration, the average monthly residential electricity consumption (including both new construction and older homes) in Washington was 964 kWh.[v] The national average at the time was 901 kWh per month.[vi] All-electric control group homes in Seattle, according to our data, used an average of 962 kWh—almost the same as the state average and 7% more than the national average; in other words, they are fairly aligned with average homes state- and nationwide. The one all-electric 5-Star Built Green home in the study, however, used far less electricity: 41% less than the average Washington home and 37% less than the nationwide average. The average use of the 35 4-Star all-electric homes in the study also compares favorably to the state and national average consumption, using 33% and 28% less respectively. Of course, the national average of electricity use includes all homes, not just homes built in a certain year. Interestingly, new construction homes in Seattle are using slightly more electricity than the average of all homes. It isn't possible to say exactly why, but it could be in part due to Seattle's relatively low electricity costs.[vii] However, the difference between a Built Green home and an average home is clear.

It is also informative to look at how the three Built Green star-levels compare to each other. Each star-level is supposed to signify a progression in how "green" a home is compared to the level before it. At the time these homes were certified, under the single-family checklist version in place, 3-Star did not have a modeling requirement, 4-Star required 15% improvement over Washington state energy code, and 5-Star required 30% improvement over code. Thus, each progressive star-level required a 15% modeled energy use reduction compared to the previous star -level. We know that all-electric homes performed better than expected, but looking at the differences between star-levels shows the difference between all-electric 4- and 5-Star homes is roughly what one would expect: a 7% difference between all-electric homes (acknowledging the small population of one for 5-Star in this category), and a 13% difference between those with gas connections. There is a leap, however, between 3- and 4-Star home performance: 8% between all-electric homes but a whopping 41% between homes with gas-connections, of which, 4-Star homes were more likely to use electric heat.

This wide range can perhaps be attributed to the fact that most 3-Star homes at this time did not have energy models completed since there was no modeling requirement on the version of the Built Green checklist at that time for 3-Star. Further, 3-Star certification at that time also did not necessitate a third-party verifier. Having a third-party verifier who completes a project energy model, of which the protocol erred on the conservative side, pushed 4- and 5-Star homes toward even greater efficiencies while still roughly maintaining the relative gains expected between these two levels.

Built Green Homes Comparison

Group	Percent Gain Over Control Group (All-Electric)	Percent Gain Over Previous Star-Level (All-Electric)	Percent Gain Over Control Group (Gas-Connected)	Percent Gain Over Previous Star-Level (Gas-Connected)
3-Star	25%	NA	-5%	N/A
4-Star	33%	8%	36%	41%
5-Star	40%	7%	49%	13%

Based on this information, it seems that completing an energy model for a building, using Built Green's protocol in place at the time, is effective in spurring greater efficiency gains, while also being a conservative estimate of those gains in comparison to code. The gains we see over control homes in this study are not gains over code, but we assume that control homes at least meet code requirements and thus are an adequate, even conservative, baseline.

Housing Size

One factor that we were able to account for, and one that can greatly impact the total electricity use of a home, is housing size. We gathered square footage for the vast majority of homes in our data set via their building permits, though we were unable to do so for every single home in our data set.

Dataset Size for Housing Size Information

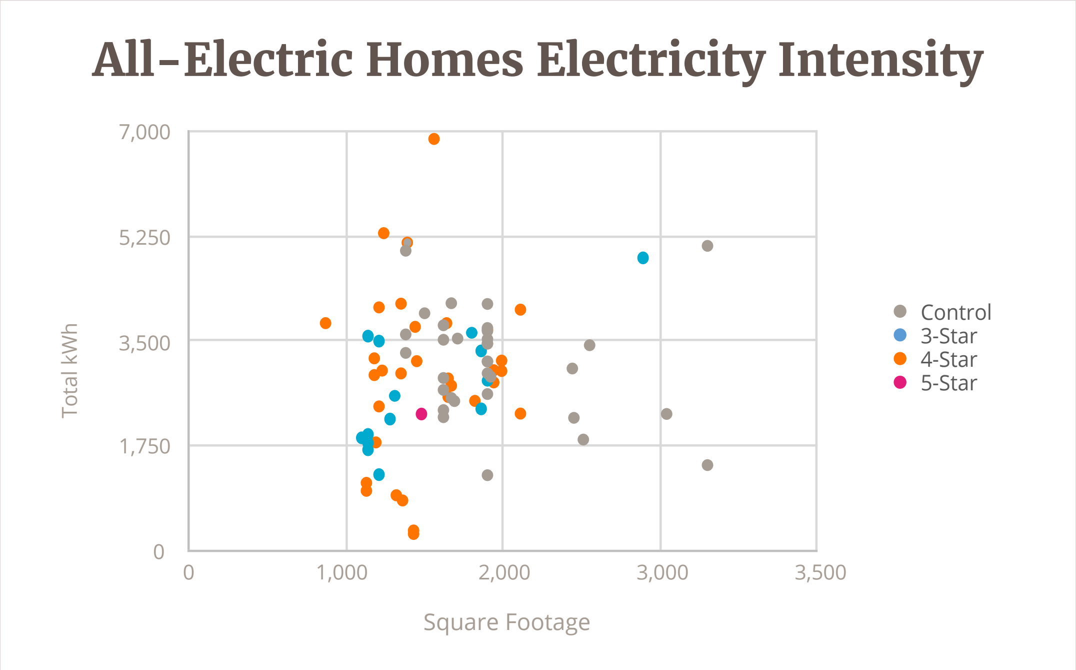
Data Group	Total Data Points in Study	Data Points for Housing Size
Control Gas-Connected	353	336
Control All-Electric	46	37
3-Star Gas-Connected	74	73
3-Star All-Electric	20	11
4-Star Gas-Connected	185	178
4-Star All-Electric	35	31
5-Star Gas-Connected	32	32
5-Star All-Electric	1	1

As you can see, we were able to obtain housing size information for 94% of our total, scrubbed data set for which we were analyzing home electricity use. The following table details the results of this information, and includes gas-connected homes for the following point of interest: these homes, on average, have a larger square footage. However, we remind the reader the impossibility of comparing all-electric to gas-connected homes, and of the complexity of separating these groups in the first place.

As anticipated, all-electric homes have a higher electricity intensity than gas-connected homes of the corresponding data group (Built Green star-level or control), since, for gas-connected homes, gas would be offsetting some of the electricity use.

Housing Size and Electricity Intensity

Data Group	Average Housing Size (Square Feet)	Average kWh Use/Square Foot
Control Gas-Connected	2,610	3.36
Control All-Electric	1,930	6.36
3-Star Gas-Connected	2,269	4.39
3-Star All-Electric	1,452	5.90
4-Star Gas-Connected	1,716	3.34
4-Star All-Electric	1,489	5.43
5-Star Gas-Connected	1,752	2.56
5-Star All-Electric	1,480	4.68



There are a couple of noteworthy conclusions that can be drawn from this data. One is that Built Green homes are, on average, smaller than non-Built Green homes. The "All-Electric Homes Electricity Intensity" scatter plot shows that, generally, control homes are larger, and each Built Green level is clustered at a slightly smaller size overall. This is unsurprising for a couple of reasons. First, the Built Green checklist is advantageous for smaller homes over larger homes because of its housing size matrix. Homes that, based on a combination of bedrooms and overall square footage, receive a points multiplier that increases the project's point total by a factor that increases the smaller the home is. Conversely, larger homes do not receive a multiplier that amplifies their point total—and large homes may also be subject to higher point thresholds that must be met in the energy and materials categories of the Built Green checklist. The intention here is to require the project to compensate, in a way, for higher energy and materials use inherent in a larger project.

Beyond the Built Green checklist, there is a push for smaller, more energy-, water- and resource-efficient homes within parts of the green building community and those interested in green living. This is a broader ideological trend rather than substantiated data, but the general ethos remains and likely has impact, even if just to a small degree.

Though smaller house sizes contribute to Built Green's electric savings for all-electric homes, Built Green homes tend to have a lower electricity intensity, which compounds these savings. All-electric control group homes have the highest electricity intensity at 6.36 kWh/square foot on average. All-electric 3-Star homes come in at an electricity intensity of 5.90 kWh/square foot, 4-Star at 5.43 kWh/square foot, and 5-Star at 4.68 kWh/square foot. Interestingly, both 4- and 5-Star all-electric homes are slightly larger, on average, than 3-Star all-electric homes. It is their lower electricity intensity, therefore, that causes them to still be 8% and 16% more efficient than 3-Star homes.

4-Star gas-connected homes, though more likely than both 3-Star and control gas-connected homes to use electricity for heat, are still less electricity intensive, at 3.34 kWh/square foot versus 4.38 and 3.36 kWh/square foot, respectively. Compared to these two groups, gas-connected 4-Star homes are tremendously more electrically efficient, by 40% and 36%. This reduction is achieved by combining the less electrically intensive 4-Star homes with a smaller size; the average square footage for a 4-Star home is 1,716. This is significantly smaller than the average 3-Star gas connected home (2,269 square feet) and the average control gas-connected home (2,610 square feet). The lower energy intensity in combination with a smaller housing size leads to significant electricity savings.

Gas-connected 5-Star homes are the least electrically intensive of all groups of homes, at 2.56 kWh/square foot. They also tend to be smaller than control homes, at 1,752 square feet on average. This accounts for the significant 49% reduction in electricity use of gas-connected 5-Star homes when compared to gas-connected control group homes. The one all-electric 5-Star home in this study had a smaller electric intensity than all-electric control group homes (4.68 kWh/square foot versus 6.36 kWh/square foot), and it was also smaller (1,480 square feet versus 1,930 square feet). These two factors in combination account for the 40% reduction the all-electric 5-Star home had compared to the all-electric control group average.

Overall, this analysis shows that although Built Green homes are generally smaller than non-Built Green homes, it is not only their size that accounts in full for their electricity reduction, but rather, most groups of Built Green homes are additionally more electrically efficient per square foot than the corresponding control group homes due to the energy efficiency measures that must be taken in order to achieve certification.

Reasons for Built Green Gains

The performance of Built Green homes compared to control homes begets the question: Why do Built Green homes use less electricity than non-Built Green homes? Moreover, why do they perform even better than the requirements for certification? This question cannot be answered definitively, but we can make educated guesses based on the data as to what the answers may be. Ultimately, it is almost certainly a combination of factors that have led to the better than required electricity efficiencies of Built Green homes. As described earlier, the average size of Built Green homes is a contributing factor, but it does not explain the difference in full.

Occupant Behavior

One factor that energy models cannot account for, but that nonetheless can have a significant impact on home energy use, is occupant behavior. However, it is impossible to control for this in the data so we can only speculate as to the impact behavior has on the electricity savings described in this research.

According to qualitative research, living in a Built Green home does change the behavior of some homeowners. In an earlier publication, zHome: Setting a National Net Zero Energy and Green Building Precedent (www.builtgreen.net/library/zhomewhitepaper.pdf), Built Green interviewed homeowners who bought and live in a Built Green net zero energy townhome. The couple interviewed, Karin Weekly and Bryan Bell, described how living in their home changed their behavior. Knowing their home was green, combined with feedback they got from home energy and water monitoring systems, spurred them to make changes that did not impact their comfort but which led to greater energy and water savings. Granted, the home Bryan and Karin live in, part of the zHome development, is a special case in that it was a pilot deep green development and, as such, is even more efficient in terms of energy, water, and materials than the typical Built Green home.

However, there is also quantitative data that could point to a homeowner learning curve that leads to less electricity use. Charting the electricity use of eight of the ten zHome townhomes (those for which data could be procured) show there is an overall slight downward trend in use.

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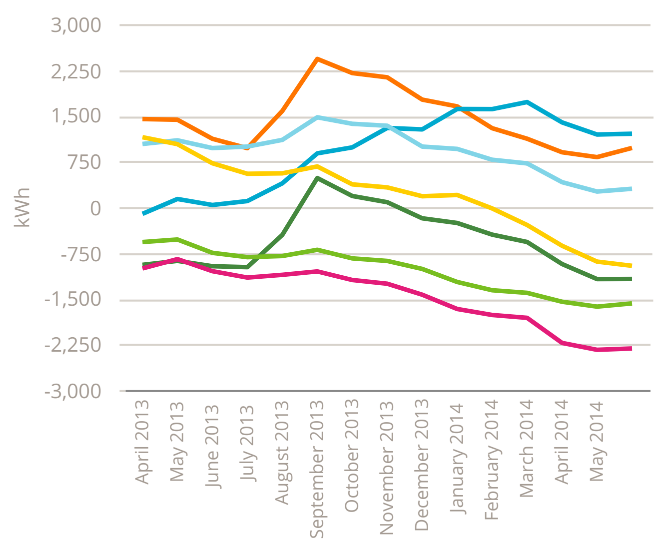
Rolling Annual Electricity Usage For zHome Units



The data in the above graph looks at the rolling annual electricity usage starting from the month indicated on the chart, meaning over two years of data is being shown. Rolling annual usage better demonstrates the downward trend by removing seasonal fluctuations. Overall, this graph demonstrates a trend of less electricity use over time in the zHome units.

One strong possibility for this decrease is that homeowners adjusted to their new homes and their systems and became more efficient in their behavior, and this assumption is backed up by the homeowner interviews described above.

Granted, zHome is not representative of all Built Green homes. They are certified at Built Green's highest certification level, Emerald Star, and as such were built to very stringent parameters, including an expectation of net zero energy usage. zHome was also a demonstration project, and received a lot of attention. Even so, there is both numerical and anecdotal evidence indicating that some homeowners live more efficiently in their green homes over time.

In addition to homeowners adopting more efficient behaviors over time as they adapt to their green home, homeowners who make the choice to live in a Built Green home are likely more environmentally conscious than average. Though whether or not a home is green is only one factor in the complex decision making that goes into purchasing a home, it certainly plays a role. In a 2014 survey of 147 Built Green homeowners, only 19% said that the fact the home was Built Green played no role in their purchasing decision. Almost 5% of homeowners said it was the biggest factor in their decision, and a substantial 23% said it was a "pretty big factor." Another 32% said it was somewhat of a factor or a small factor. 56% of respondents also indicated that they associated Built Green with "a greener lifestyle," and a tremendous 91% associated Built Green with energy efficiency. Clearly, environmental awareness is a motivating factor for many homebuyers who purchase Built Green. A logical conclusion is that they are more attentive to the environmental impact they have, and therefore take steps to save energy. This behavior would amplify the built-in efficiency of Built Green homes and further reduce the amount of electricity they consume.

Conservative Assumptions on the Part of Modeling Programs

Another factor that could explain why Built Green homes used even less electricity than expected compared to non-certified homes is Built Green's modeling protocol. Energy modeling is, by nature, an important but imperfect science. In essence, an energy model is a computer simulation of the energy consumption of a building. A model is built using one of the software options available by detailing the building and the equipment contained therein. The software then projects how much energy the home will use based on aggregated averages generated from observations of how certain equipment performs under specific situations. Since software is using generalized observations to make projections, it might not be entirely accurate for any one given building—especially because energy models cannot easily account for variations in occupant behavior. However, energy models are the best tool we have for projecting how much energy a given building will use, and they encompass much of the best knowledge building scientists have compiled about building energy use. At the time the homes in this study were certified by Built Green, the majority of projects were modeled in the software REM/Rate, and compared to the International Energy Conservation Code 2004. The result was then converted to a comparison against Washington state's code. The conversion was a conservative estimate of the percentage difference between the two codes, which could have resulted in underreporting of energy savings. Now, Built Green has a modeling protocol with parameters on how to model a "baseline" home built to the current Washington State Energy Code, to which homes aiming for certification are compared. Though this is a different method, it was also designed on the conservative side. In both modeling cases, a conservative protocol could be underestimating the energy usage of a code-built home, or it could be overestimating the usage of a Built Green home.

For example, many Built Green homes use all LED lighting, which is more efficient than using a combination of CFL and LED lighting, or all CFL lighting. However, REM/Rate does not allow for distinguishing between CFLs and LEDs, so a model for a home using all LED lighting might overestimate its energy use in this area.

Ultimately, it is impossible to know precisely why Built Green homes surpass the efficiency of non-certified homes by a greater amount than would be anticipated through energy modeling. However, these savings are real, as are their impacts.

Considerations

There are some elements to consider when evaluating these results that could impact the overall findings, but for which we were unable to control.

This study is a result of a snapshot of roughly one year in time. Factors that may impact electricity use, such as weather and electricity cost, differ from year to year. Since this study is comparing the electricity use of homes within the same year, this variation is significantly mitigated. However, influencing factors may cause different changes in usage depending on the efficiency of the home. In other words, these factors may not have uniform influence, and the results may have been different if we looked at usage from another year. Despite this, we feel our analysis is solid while acknowledging it hinges on one year of information.

Another factor that we could not account for in the data, but which would impact results, is that of solar, or potentially other renewable, installations. Given the information we had, there was no way for us to tell if solar photovoltaic panels, solar thermal, or other energy-saving additions had been installed on non-certified homes, or on Built Green homes by the homeowners post-certification. Of course, solar panels would greatly decrease a home's electricity use from Seattle City Light. A converse situation would be a homeowner who has an electric vehicle, which would consume a significant amount of electricity while averting fossil fuel use that is outside the scope of our study. However, given the size of our dataset, we do not think the results would be greatly modified if we could account for these factors. Moreover, the study only claims to compare actual electricity use of homes—for whatever it may be used.

We recognize that these factors are not accounted for in our results, but again, the results put forth represent consumption that actually occurred in the designated time period, and the electricity savings of Built Green homes are clear.

Impacts of Built Green Savings

Now that it has been established that Built Green homes use less electricity than non-Built Green homes, the ramifications of these electricity savings will be discussed. The two main categories we examined were the financial and environmental impacts generated by these savings each year.

Cost Analysis

Substantial electricity savings translates to lower electricity bills. However, these savings heavily depend on the utility and the rate it charges for a base connection charge and per kWh rates. The higher the base connection charge in relation to the per kWh usage charge, the fewer monetary savings in proportion to electricity savings there will be. This situation would thus perhaps disincentivize people from saving electricity since there would not be a large monetary impact.

Compared to the rest of the country, Washington state has a relatively low average electricity cost, partially due to its preponderance of hydroelectric power. According to the Energy Information Administration, in 2015, the average price per kWh in Washington was 9.09 cents.[viii] The nationwide average was 12.65 cents per kWh—a 28% increase over Washington's average price.

The rate for Seattle City Light customers is even a bit lower than the already low Washington average. These rates were calculated based on the 2016 rate and their increase over 2015.[ix] For residential customers, Seattle City Light levies a base charge for each day, then has first block and second block rates. The first block is the price per kWh for the first defined number of kWh used per day, and the second block is a higher rate per kWh for all kWh exceeding the first block's ceiling. The number of kWh per day considered first block is 10 in the summer (April through September) and 16 in the winter (October through March). Please note that all cost analysis is done in 2015 U.S. dollars.

Seattle City Light 2015 Rates
(Based on 2016 rates and increase over previous year)

First Block	$.0561
Second Block	$.1183
Base Charge Per Day	$.1396

From these rates, we were able to calculate the average bill per group, from which we determined the overall per kWh rate by dividing the average bill by the average kWh usage for each data group, then taking a weighted average of all of these rates to find the average cost per kWh across all groups. Since the rate is based on usage (low users who hardly reach second block rates pay much less), cost per kWh varies significantly between the different groups. For all-electric homes, the weighted average unit cost for electricity was 9.25 cents.

Average per kWh Electricity Price per Data Group

Control Group (all-electric)	$.0975
3-Star (all-electric)	$.0905
4-Star (all-electric)	$.0873
5-Star (all-electric)	$.0831

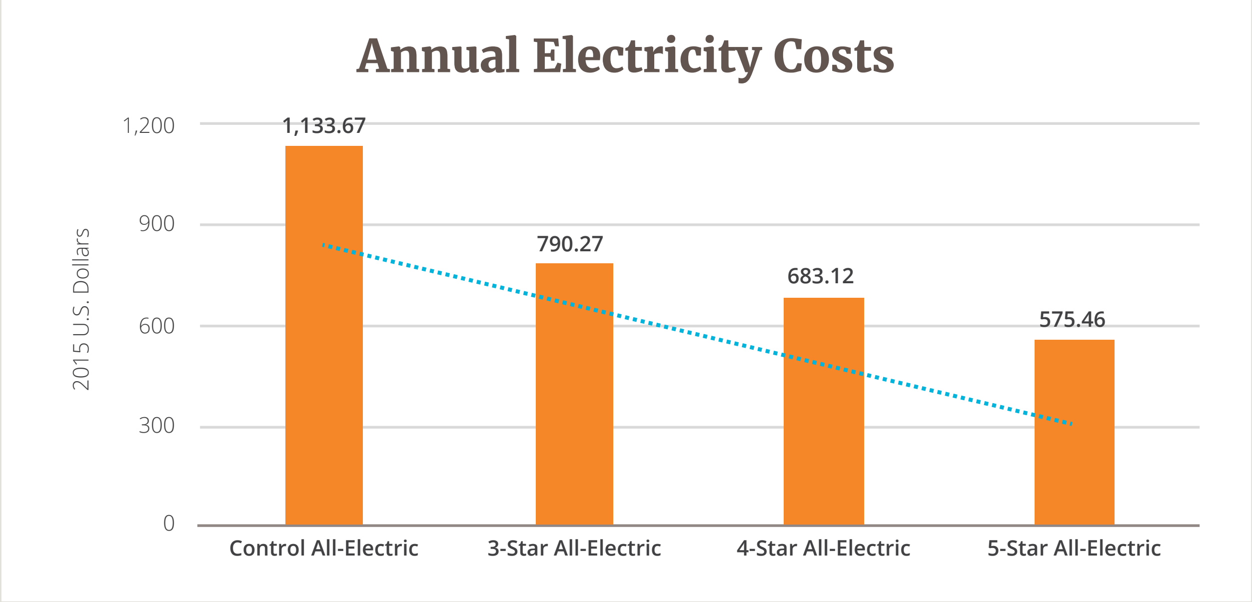
As you can see, 5-Star homes pay a rate that is more than a cent less than the rate paid for by non-certified control homes. A cent doesn't seem like much, but it adds up over time. The rate difference is caused by the fact that control homes pay at the second block rate for some of their usage, whereas the all-electric 5-Star home in the data set used less electricity in a day and was charged entirely at the lower first block rate, never exceeding its maximum and incurring second block rate charges.

Using the electricity use and cost data in our possession, we were able to simply calculate yearly and monthly electricity costs for the homes in our study. As expected, for all-electric homes in the study, the biggest difference in electricity bills was between control group homes and 5-Star homes. For all-electric control homes, the electricity monthly cost was an average of $93.80, whereas the all-electric 5-Star home's monthly costs were only $47.43 on average. That is a not insignificant difference of $46.37. For comparison, the monthly electricity costs for a gas-connected 5-Star home are, on average, $23.96—compared to $65.68 for gas-connected control homes (of course, these homes must also pay gas bills as a part of their energy usage). When viewed on the timescale of a year, the all-electric 5-Star home on average was only billed $575.46 for electricity, whereas all-electric control homes incurred a total annual electricity cost of $1,133.67. These monetary savings generated by Built Green homes would occur each year, compounding their financial impact over time.

These savings can translate into greater home purchasing power. Too rarely is total homeownership cost, which includes electricity bills, factored into the equation when a new home is purchased. However, the significant differences in electricity costs between non-certified and Built Green certified homes warrant this analysis. The electricity savings gleaned from a Built Green home as opposed to a non-certified home, if redirected toward mortgage payments, enable the purchaser to consider homes that have a more expensive up-front cost. Though the price of the home itself may be higher, the monthly payments made by the homeowner would not be any different, thanks to significant electricity savings leading to lower utility bills. In a market as rapidly growing and competitive as that of the Seattle region, this is very impactful.

How much purchasing price leverage does a Built Green home grant by way of its electricity savings? To determine this, we first calculated electricity savings based on 2016 Seattle City Light prices and on 2015 usage (assuming usage was similar in 2016). We did this since our housing price information was in 2016 U.S. dollars and we wanted to eliminate the impact of inflation. Monthly electricity costs were slightly higher in 2016 than in 2015. Then, we used an interest rate of 3.31% and a housing price of $588,000—the Washington state interest rate and the Seattle mean housing price at the end of August 2016, according to Zillow. Using these numbers as a base, we calculated loan amounts, assuming a down payment of 20% and monthly payments through a 30-year mortgage.

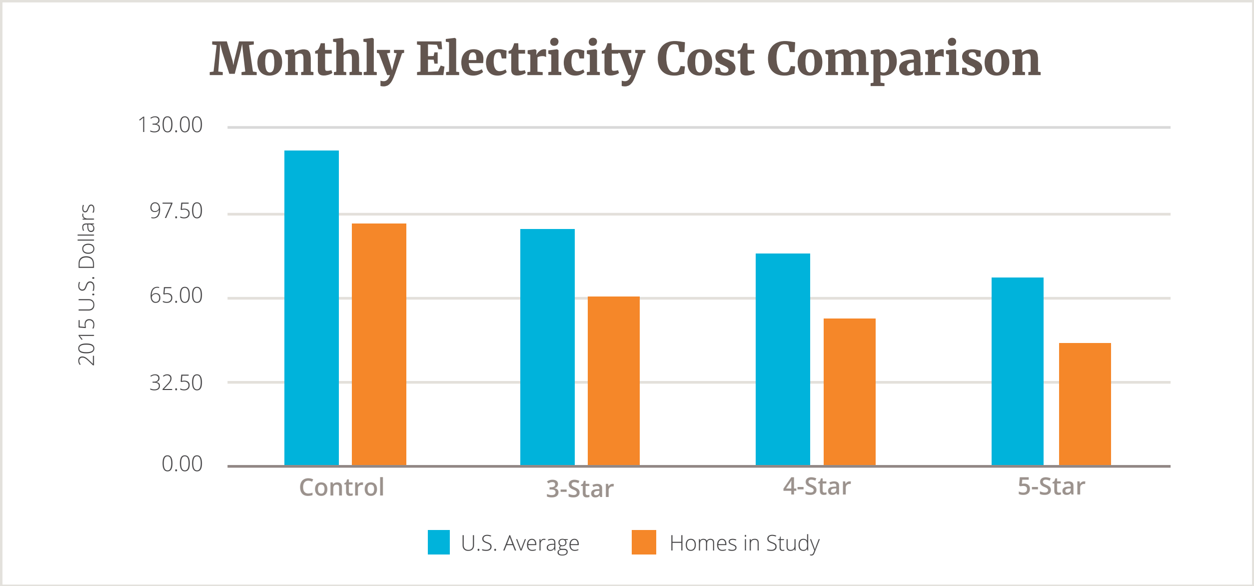
We then added the difference in monthly electricity costs between both 4- and 5-Star and non-certified homes to this standard monthly payment, and back-calculated to see how the home price would change based on these larger monthly mortgage payments. If the 2016 monthly electricity savings of an all-electric 4-Star home (compared to a non-Built Green home) were applied to a monthly mortgage payment, the buyer would be able to afford a loan of $9,077.64 more. If they still paid 20% down, they could afford a home with the sales price of $599,347.04, which is $11,347.04 more than the median housing price, while still spending the same amount per month on home ownership as someone purchasing a non-certified home at the median price would. The only difference is the purchaser would be spending more money on the mortgage payment, and that much less on electricity.



When the even bigger electricity savings of 5-Star homes, when compared to non-certified homes, are applied to the monthly mortgage payment, the sales price of a home could increase from the median price of $588,000 to $602,048.44—a difference of $14,048.44. Of course, this method does not factor in any other variables (and there are many) that could influence housing price, but it provides a base analysis demonstrating the impact lower bills could have on purchasing power. Factoring electricity, and indeed, other bill payments, into one's homeownership budget is important given the amount of money on the table.

Of course, this analysis could be flipped and applied instead to affordable housing: Built Green certified homes are more affordable since, given their lower electricity use, their bills will be that much lower. Compared to an all-electric non-certified home, a Built Green 5-Star home costs $558.21 less in a year to operate. All-electric 3-Star homes produced annual savings of $343.40, and 4-Star homes led to savings of $450.55 per year. For those with tight finances, this can make a big difference. The argument can be made that whether or not housing is affordable is not solely based on the house's price or its rent, but also on monthly expenditures associated with living in that space, such as electricity.

According to the Energy Information Administration, in 2015, Washington state had the lowest price per kWh of all states. This means that if Built Green electricity savings were applied to homes in other states, the resulting monetary savings would be even more significant. Of course, changes in cost would likely cause behavioral shifts, which would impact electricity usage. However, the potential for electricity-related cost savings outside of Washington as a result of building green is likely quite strong. For comparison, the average U.S. monthly electricity cost, based on average use and average price, was $114.03 in 2015.[x] Additionally, as electricity prices grow over time in Washington, the savings associated with Built Green homes in this study will increase as the years go on.



Average Built Green Home Yearly Electricity Savings

Environmental Analysis

At its root, Built Green's objective is to lessen the environmental impact of housing. Ultimately, Built Green's energy efficiency requirements for certification are in place to lessen the environmental impacts associated with energy, of which there are many, and which depend on the energy source. Energy from fossil fuel results in particulate matter and greenhouse gas pollution when generated, and the extraction of fossil fuels has tremendous impacts on land and water quality. Energy from hydropower has the detrimental environmental ramifications associated with damming up rivers, and the lakes created are actually sources of greenhouse gas emissions as time goes on.[xi] Because of Seattle City Light's fuel source composition, the homes in this study are primarily utilizing hydropower for their electricity, though if homes have gas connections then they, of course, would be using fossil fuel energy in addition to hydropower. Though the climate impacts of hydropower are less than those of fossil fuels, it is still important to reduce electricity use to prevent the need to build additional generation facilities. Additionally, even though the homes in this study are using electricity that is largely hydroelectric, if homes elsewhere that were connected to more fossil fuel-reliant electricity sources were built to Built Green standards, related greenhouse gas emission savings would ensue. Electricity efficiency in Seattle City Light territory can also spur greenhouse gas reductions elsewhere, as Seattle City Light can sell its less carbon intensive mix to other areas when supply outpaces local demand.

To better demonstrate the environmental impact of Built Green certification, we calculated various equivalencies that provide a more tangible representation of the electricity savings. We also calculated the difference between various Built Green star-levels and control group homes from the study, an average Washington home, and an average U.S. home. The latter two comparisons are based on data not gleaned from Seattle City Light in the context of this study (these numbers are based on information from the Energy Information Administration). However, they still provide interesting reference points and so they are included in the analysis, as they demonstrate the impact Built Green homes hypothetically could have outside of Seattle along with the actual savings inherent in living in a Built Green home in Seattle compared to an average Washington or U.S. home.

An important calculation is that of how many greenhouse gas emissions are averted by a Built Green home. This calculation, however, is entirely dependent on where the homes are theoretically located, and what electricity source they are using. We calculated emissions based on 1) national carbon equivalent emissions per kWh of electricity,[xii] 2) Washington state carbon emissions per kWh of residential electricity,[xiii] 3) Puget Sound Energy's emissions rate in order to provide comparisons against a typical U.S. home and a typical Washington home. Using these rates of carbon emissions per kWh, we are able to calculate a range of savings: various Built Green star-levels to control homes in the study, Built Green homes to an average Washington home or to homes in Puget Sound Energy's territory, and Built Green homes to an average U.S. home.[xiv] The electricity provided by Seattle City Light is claimed to be carbon neutral, so the below savings are not actual. Rather, they represent savings for Built Green homes outside of Seattle (the program covers all of King and Snohomish counties), or the averted emissions that could result from Seattle City Light selling its excess electricity to other utilities, thanks to the efficiencies stemming from Built Green homes.

According to the Energy Information Administration, the average emissions per kWh of residential electricity in Washington is .26 pounds of carbon dioxide. When this is applied to the difference in annual electricity consumption between a Built Green home and an average non-certified home, the following savings result each year.

Annual Carbon Dioxide Savings per Home Using WA Emissions Rates

Comparison	Resulting Savings
Built Green 4-Star v. Study Control	989.60 lbs CO_2
Built Green 5-Star v. Study Control	1,224.18 lbs CO_2
Built Green 4-Star v. Average WA Home	972.86 lbs CO_2
Built Green 5-Star v. Average WA Home	1,207.44 lbs CO_2

The above chart assumes Built Green homes are built outside of Seattle, since we are applying the average Washington emissions rate to their electricity consumption. However, in reality, since Seattle City Light's grid is carbon neutral, we would see even greater savings between a Built Green home built in Seattle and the emissions of an average Washington home, since a home built in Seattle's emissions are theoretically zero, and an average Washington home would produce 3,007.68 pounds of carbon dioxide annually.

Greenhouse gas emissions savings are far greater when the average U.S. emissions per kWh is used instead, since the Washington electricity grid is cleaner than the grids of many other states, and the U.S. grid on average. The carbon dioxide-equivalent emissions per kWh in the U.S. is 1.5 pounds.[xv]

Annual Carbon Dioxide-Equivalent Savings per Home Using U.S. Emissions Rates	
Comparison	Resulting Savings
Built Green 4-Star v. Study Control	5,709.25 lbs CO_2e
Built Green 5-Star v. Study Control	7,062.60 lbs CO_2e
Built Green 4-Star v. Average U.S. Home	4,478.66 lbs CO_2e
Built Green 5-Star v. Average U.S. Home	5,832.00 lbs CO_2e

Annual Carbon Dioxide-Equivalent Savings per Home Using Puget Sound Energy Emissions Rates	
Comparison	Resulting Savings
Built Green 4-Star v. Study Control	3,920.35 lbs CO_2e
Built Green 5-Star v. Study Control	4,849.65 lbs CO_2e
Built Green 4-Star v. Average WA Home	3,854.02 lbs CO_2e
Built Green 5-Star v. Average WA Home	4,783.32 lbs CO_2e

Again, the above chart assumes a Built Green home built not just outside of Seattle, but outside of Washington state. In reality, a Seattle Built Green home's electricity consumption would result in zero carbon dioxide emissions due to the carbon neutral grid, while an average U.S. home produces 16,218 pounds of carbon dioxide-equivalent every year.

Since Built Green is a program that operates around Washington state and certifies a significant number of homes outside of Seattle in King County (in 2014, Built Green certified 91 single-family homes in King County outside the City of Seattle), it is appropriate to look at the carbon dioxide savings of Built Green homes in this area, most of whose electricity would be served by Puget Sound Energy. In 2015, each kWh that went through its grid (both self-generated and purchased for end-use consumption) produced 1.03 pounds of carbon dioxide-equivalent.[xvi]

The above chart demonstrates that an all-electric 4-Star Built Green home built outside of Seattle but in King County would avert either 3,920.35 or 3,854.02 pounds of carbon dioxide-equivalent emissions annually, depending on whether or not the home is being compared to an average non-certified home built in 2014's usage as determined by this study, or to an average Washington home. Given that a not insignificant number of Built Green homes are built in Puget Sound Energy's electricity service territory, these results are important for quantifying Built Green's savings and for King County municipalities that are working to reduce their local greenhouse gas emissions. It is important to note that Seattle has a different energy code than Washington state, so buildings built in Seattle do not follow the same parameters as those built outside of the City. However, we would still expect to see emissions savings stemming from Built Green given the proven electricity savings demonstrated by homes built in the same place at the same time, and because these savings were also greater than required by modeling against the Washington State Energy Code.

Another comparison that can be made is that of electricity efficiency to solar photovoltaic electricity production. Though solar panels have decreased in cost tremendously,[xvii] it is often more cost-efficient to first ensure energy efficiencies in a home, and once that has been done, reduce reliance on utility-produced energy via onsite renewable energy production as the second step. So, what is the solar panel production equivalent of the electricity saved by Built Green homes?

Built Green electricity savings is equivalent to production of 13+ solar panels ($10,000+ cost)

A typical solar photovoltaic panel capacity for residential application is 250 W, and in Seattle, one of these panels would produce approximately 350.4 kWh per year.[xviii] Given this, it would take 11 individual panels to make up the difference in electricity consumption between an all-electric 4-Star and an all-electric control group home. To make up the gap between an all-electric 5-Star and a control group home would require 14 panels. The average cost of residential solar photovoltaic currently is approximately $3.00 per watt,[xix] meaning that a solar photovoltaic system that closes the electricity use gap between an all-electric control group home and a 4-Star home would cost $8,147, while making up the difference between an all-electric control home and a 5-Star home through solar would cost $10,078. Of course, the cost of purchasing solar photovoltaic is largely a one-time cost that is paid back over time. However, the upfront cost can sometimes be prohibitive. Additionally, these costs are well above the annual electric bill savings of all-electric 4- and 5-Star homes compared to control group homes ($451 and $558 respectively). This points to efficiency being a cost-effective way to lower utility electricity use. Solar photovoltaic technology is an important component of reducing our reliance on fossil fuels and other electricity sources that have negative impacts, of course, but efficiency is also a very important part of the equation.

Given that Seattle's electricity is relatively very clean, the transportation sector accounts for a large portion of the city's greenhouse gas emissions. Passenger road transport alone counts for 45% of the city's emissions.[xx] This means that in order to seriously tackle climate change from the local level, Seattle needs to take big steps to decarbonize its transportation sector. Increased public transit plays a significant role, but so does the decarbonization of individual vehicles. Electric vehicle infrastructure and ridership in the area are on the rise, and Seattle City Light estimates that there are currently 4,000 electric vehicles in its service territory.[xxi]

Built Green electricity savings could power an electric vehicle for over 15,000 miles

Knowing the average mileage a Nissan Leaf driver travels in a year (9,697),[xxii] and how many miles a Leaf can go per kWh (the EPA says estimates a Leaf can travel 100 miles per every 30 kWh),[xxiii] it is possible to ascertain how much electricity is needed to supply an average Leaf per year. The electricity savings from an all-electric Built Green 4-Star home as compared to a non-Built Green home are enough to power 1.3 typical Leafs under typical usage. 5-Star savings provide the same amount of electricity it would take to account for the electricity use of 1.6 average Leaf drivers in a year. These results are roughly the same if we look at a different electric vehicle, the Tesla Model S, since according to the EPA,[xxiv] it can travel 100 miles on 38 kWh, which means 4-Star Built Green savings compared to a non-certified home could provide electricity for just over one typical driver in a year. These numbers are important: an individual looking to greatly reduce their own carbon footprint in an area where the electricity grid is quite clean would need to shift their transit habits away from being fossil fuel-powered. On average, a typical passenger vehicle produces 10,362 pounds of CO_2 per year.[xxv] Living in a Built Green 4-Star home and driving an electric car (that is always charged at home, never elsewhere) still leads to less electricity consumption than the average home and averts these carbon emissions!

Of course, there is an upfront cost to purchasing a new vehicle, but given that electricity is cheaper than gas as a transport fuel (see Electric vehicle equivalency in appendices), and that one's electricity bill will still be lower than the average person's in a non-certified home built in the same year, living in a Built Green home and driving an electric vehicle is a compelling, cost-effective way to reduce one's carbon footprint.

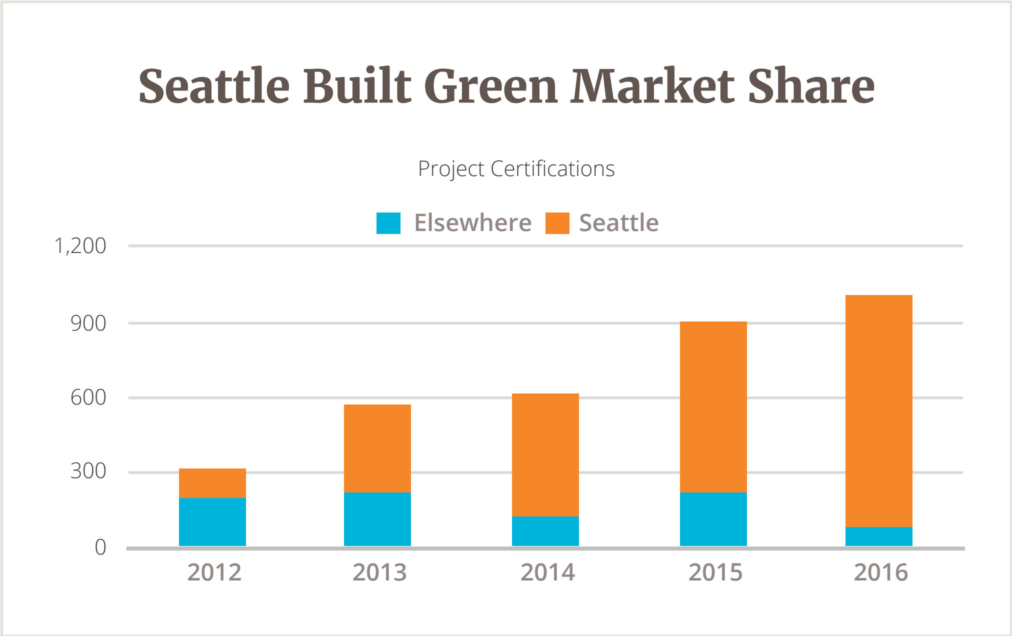
We calculated a few other environmental equivalencies for both demonstrative and comical purposes. One of these was how many times, using a year's savings from a Built Green home, an iPhone 6 could be fully charged up. Charging an iPhone 6—despite how frequently we use these devices!—takes a small amount of electricity, just .0105 kWh.[xxvi] Based on this, we can calculate that the annual savings of one all-electric Built Green 4-Star home compared to a non-certified home are enough to charge an iPhone 6 362,492 times. The yearly difference in electricity use between an all-electric Built Green 5-Star home and a control group home provides enough electricity to charge an iPhone 6 448,419 times; if you assume this phone is charged once a day, and that the battery is fully drained daily, this amount of electricity would be enough to charge the phone for more than 1,000 years—far longer than the phone, or the user, would last!

Another easily relatable equivalency is how long a LED light bulb can be kept on using Built Green electricity savings. LEDs are recognized for their energy efficiency and long lives and have become increasingly common.[xxvii] The electricity savings in one year between one all-electric Built Green 4-Star home and a control group home would be enough to continuously run a 12W LED for 36 years and 77 days. The difference in electricity use between an all-electric 5-Star home and a non-Built Green home could run such an LED for 44 years and 288 days. Of course, people utilize more than one light bulb in their homes, but these savings, when spread across many efficient light bulbs (which usually are not running continuously), could still provide a household's lighting needs for a significant amount of time.

Built Green electricity savings could run a 12W LED continuously for over 44 years

For fun, we calculated how many "movie nights" for which a year of Built Green savings could provide electricity. We estimated this based on the electricity it would take to: run a blender to make two margaritas or smoothies, run a DVD player for the duration of three movies, heat an electric blanket for the same amount of time, and heat an oven to bake a batch of cupcakes.[xxviii] Altogether, the electricity savings from one all-electric 4-Star Built Green home, compared to a control home, would be enough for 1,805 movie nights. All-electric 5-Star savings would cover the electricity needed for 2,233 movie nights. Comedy aside, the point here is that the savings generated by Built Green homes are ample and amount to the electricity needed for repeatedly doing household activities—a tangible representation of these savings.

Based on the above calculations, it is clear that not only do Built Green homes save electricity but that these savings have a tangible impact on the environment, and can also impact a homeowner's life by providing for greater financial flexibility and by allowing them to more easily make choices (such as switching from a traditional vehicle to an electric vehicle) that would be harder to justify in a non-certified home. Energy efficient, Built Green homes have the ability to support progress across sectors and on both an individual and a global scale.



Implications and Next Steps

For Built Green

The results of this study present significant, positive implications for Built Green as a program. Built Green exists to make a meaningful reduction in the environmental impact of the construction and operation of housing. Happily, this research proves that the effort and thought Built Green has put into program design and administration is translating into tangible results. In fact, certification represents even larger environmental savings than anticipated. Not only does this justify Built Green's modus operandi, but it provides material to help market and expand the program, as well as justifies government and utility incentives that are based on, or include, Built Green certification.

At present, Seattle dominates the Built Green certification market, hosting the majority of projects in recent years. Though Built Green's success within the City of Seattle, greatly aided by the City's green building incentives, is significant, expanding the program's popularity outside of the Seattle city limits is also important. Though there is currently less building volume in other King and Snohomish County cities compared to Seattle, and though some municipalities still boast a fair Built Green market share relative to the amount of building occurring, there are also areas where Built Green is highly underutilized. As Seattle grows and housing costs rise, the importance of diversifying Built Green's geographical distribution will only rise as people look for potentially more attainable housing outside of Seattle. Further, there are major transit expansion plans for light rail and rapid bus transit to and from Seattle and other job centers, and transit oriented developments will be built. If new residential development is not Built Green, an opportunity has been missed.

Armed with the results of this study, Built Green has a convincing case for its impact. The results provide solid evidence of the program's benefits not just to utilities and municipalities for incentive purposes but also to builders as a means of distinguishing their product in a highly saturated market. Using these results as a marketing tool will likely aid Built Green in not only increasing its overall certification numbers, but also its geographical spread.

Of course, as Washington's energy code—already one of the toughest in the nation—improves, housing stock inches closer to net zero energy use. As required by the state legislature, under increasingly stringent code updates, by 2031 buildings must achieve a 70% reduction in energy use compared to the 2006 energy code. The legislature has also set a goal of zero fossil fuel greenhouse gas emissions from building by 2031.[xxix] As this occurs, there will be less space for Built Green certification to spur energy savings, though the certification is effective in doing so at the moment. This not only demonstrates that the program is helping builders adjust to new, more stringent codes by providing a mechanism that keeps them ahead of the curve, rather than scrambling to meet new legal requirements at the last minute, but that Built Green must also, eventually, pivot toward other environmental savings as energy code catches up to net zero energy use in buildings.

Built Green presents an effective path for reducing home electricity use while planning for a future when more energy efficient buildings are the norm. Given this, Built Green will leverage its proven efficacy to increase program uptake both within and outside of Seattle, working with builders, local governments, and utilities, as a voluntary pathway that will help the building industry adapt to code changes ahead of time, while locking in electricity efficiency in buildings as they are constructed.

For Builders

Builders who have projects within Seattle, and in some places outside of Seattle, are already able to take advantage of green building incentive programs. As described, the incentives offered by the City of Seattle have played a significant role in spurring the uptake of Built Green and the shift of star-level distribution toward 4-Star. If structured well, these incentives are meaningful and will be utilized, as is demonstrated by the situation in Seattle. With the results of this offering proof of Built Green's efficacy, other municipalities and utilities may be convinced to offer new or expanded incentives which in turn will benefit builders who utilize Built Green.

For builders who have already been certifying projects with Built Green, and taking advantage of incentives, this study offers an additional marketing tool that will potentially add to these builders' successes. The study proves that Built Green certification, though based on modeling, is a strong indicator of electricity efficiency, even beyond the savings specified to achieve the 4- and 5-Star levels. Builders can use this evidence to distinguish their projects in a crowded market. Further, it would behoove builders to also discuss the monetary and environmental savings that are generated by these electricity savings to make the impacts visceral to potential home buyers.

For Homeowners or Renters

The cost savings that are accumulated by those who live in Built Green homes have been detailed in the cost analysis portion of this paper. These savings can be applied to a mortgage, used to justify the electricity use (and corresponding gas savings) of an electric vehicle, or simply pocketed.

Of course, for Built Green homeowners, there is the additional satisfaction of knowing that one's home is efficient and that its environmental impact has been significantly reduced. Sustainability is a strong value throughout the Pacific Northwest and Puget Sound residents generally care deeply about where they live, and want to see a healthy environment.

This study is based on the electricity savings of Built Green homes, where Built Green certification has been proven as an effective measure. However, energy is only one focus of the certification, others being site and water, indoor air quality, and materials efficiency. Though the savings of these other environmental categories have not been quantified through post-occupancy data as a course of this research, one can postulate that the certification, as intended, also results in water savings, less stormwater runoff, better indoor air quality, and the use of more environmentally-friendly, or fewer, materials.

For Governments and Utilities

Many local governments have directives to reduce their greenhouse gas emissions, and utilities are mandated to promote energy efficiency and reduce their load, which prevents new capacity from needing to be built. Thanks to Built Green's proven impacts in cutting electricity use and thereby greenhouse gas emissions, the certification is a proven, and quantified, mechanism to base incentives on that will meet utility and municipal goals.

The case of Seattle demonstrates that when incentives are well structured or, in other words, the effort needed to obtain them is outweighed by what is being offered, they can shift the new construction market towards greener building. Seattle's efforts in this area were based on incentivizing building that was, at minimum, modeled to perform 15% better than code (hence, Seattle's incentives begin at the Built Green 4-Star level). This study shows that Seattle's resources were well-directed in creating and maintaining their incentive program: not only did the number of Built Green certifications increase, but the outcome regarding electricity savings was even better than expected, and required, by the City.

These results strengthen the case for basing residential green building incentives on Built Green. They also provide evidence that could be used to even better align incentives with the outcomes: for example, 5-Star homes, with their average 40% savings (for all-electric homes) could be rewarded at a proportionally higher level than 4-Star homes and their 33% savings. Now that there are hard numbers based on post-occupancy data, incentives can be created or restructured in such a way that reward better aligns with impact.

Those who supported incentives based on Built Green as they were being developed and approved are also justified in their work. Not infrequently is the outcome of green building contested—which is understandable, given that many programs are in all or in part based on construction practices and modeling rather than post-occupancy monitoring. However, these challenges to incentives are now more easily rebuffed with evidence proving Built Green's impact when it comes to electricity savings and its associated environmental and monetary savings.

As a result of this study, it is hoped that governments and utilities will consider offering new or expanded incentives based on Built Green's proven results, which will also allow these entities to track their impact on the electricity and greenhouse gas reductions they must achieve. Such incentives are of benefit to all parties— governments and utilities, Built Green, builders, and residents.

Next Steps

With hard results demonstrating the electricity savings of Built Green homes and the associated environmental and cost savings, Built Green will continue its push to expand program uptake and for new and improved government and utility incentives related to green building. In addition, these results point to marketing strategies that will be utilized. Not only can cost savings be spoken about definitively, but they can be paired with environmental savings through the link of electric vehicles. As the study shows, electric vehicles are cheaper to operate, and the electricity savings that Built Green 4- and 5-Star homes provide more than compensate for the difference in electricity use when compared with a non-certified home. Marketing green homes in a pairing with electric vehicles is a strategy that may gain more traction.

This research points the way for further investigation about the benefits of green homes as well. Obtaining gas consumption data for Built Green and non-certified homes would allow for a more robust comparison and would provide valuable information regarding carbon-related environmental savings. Relatedly, it would be useful to see how the fuel intake of homes (whether or not they are gas-connected or all-electric) has changed over time, by municipality, and between certification levels.

Energy efficiency is only one aspect of green building that presents environmental and cost savings. Water is another one, and given recent droughts, is an aspect we should not ignore. Built Green is currently working on obtaining water use data for Built Green and non-certified homes for use in an analogous study. Given the current gaps in large-scale post-occupancy analysis research, it is important for Built Green to continue this research, and for other entities in other parts of the U.S. and the world to do so as well, to provide even more points of comparison.

Conclusion

Built Green offers proven benefits for the environment and for those who live in certified homes. This unprecedented research quantifies electricity savings and the corresponding environmental and monetary savings resulting from homes that are Built Green certified at different levels, and provides further insight into the traits, such as size and fuel sources, of both Built Green and non-certified homes. The fact that Built Green homes save significantly more electricity than was required for certification and was estimated through energy models solidly justifies its use as a basis for incentive programs offered by governments and utilities. Indeed, quantifying the environmental benefits that stem from Built Green help justify green building as a whole. As new buildings are inevitably built as populations grow, it is highly important to make this new infrastructure greener. The impact of more environmentally friendly building is magnified over time, as the environmental benefits accumulate during the life of a building. During this era of pressing climate change, energy efficient buildings are all the more necessary.

The findings of this study, proof of Built Green's electricity and environmental savings, present positive ramifications for Built Green as a program, local governments and utilities, those who live in Built Green buildings, and for the population as a whole, since everyone ultimately benefits from environmental savings. Built Green is committed to strengthening its program, increasing its utilization, and supporting the growth of green building in other locations to the same effect. In turn, the results of this study highlight the importance of supporting Built Green, and perhaps other, similar, green building certification programs due to their impact. Built Green certification represents proven environmental and monetary savings, and is a mechanism to ensure more sustainable development as our infrastructure develops and changes.

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Leah Missik
Built Green Program Manager

Appendices

Determining timeframe

Many addresses included in this study had more than a year's worth of electricity consumption data. First, we determined which time frame would allow us to examine a period of a year, plus or minus a week (358 to 372 days). If an address had more than one time frame that would meet this requirement, we selected the range closest to a start date in December 2014 or January 2015 (Seattle City Light bills bimonthly).

Grouping data

Whether or not a home was Built Green certified, and at what level, was determined by Built Green's certification records. To determine whether or not a home had a gas connection, its address was compared with King County records. We further confirmed using individual City of Seattle permit information.

Gas connection distribution

To compare the likelihood of homes at various certification levels having a gas connection, we divided the number of gas-connected homes in a group by the total number of homes in that group. We used Excel to graph this distribution (and for all other graphs).

Determining average kWh usages

Using the SUM function in Excel, we found the total kWh used for each address in the selected time frame. We calculated each address's usage per day by dividing this total by the number of days in the address's individual time frame. To calculate an address's monthly mean usage, we multiplied the daily usage by 30. We did this because SCL's billing periods are roughly—not exactly—bimonthly, and this maintained consistency across addresses.

The above calculations (total kWh usage, monthly mean usage, daily usage) were then grouped by certification level (or lack thereof) and then subdivided by whether or not a home had a gas connection. For these groups, we used the AVERAGE function across all addresses in a group to find the group's average total kWh usage, monthly mean usage, and daily usage.

Electricity use over time

For each group (i.e. the all-electric control homes group), we used the AVERAGE formula to calculate the mean daily usage for every address for each rate date within the bimonthly period charted. In only a few cases, an address did not have a data point within a given bimonthly period, so we skipped that address for that period. This bimonthly daily average usage was then plotted over time. We only plotted this information for all-electric homes since homes using gas would exhibit a different profile, depending on which appliances they used gas for.

Data Distribution

To plot distribution curves, we took the individual addresses' total electricity use within each data group and sorted them in Excel from high to low. We then calculated the mean using the AVERAGE function and the standard deviation using STDEV for these groups. Then, using the average, standard deviation, and total kWh usage for each address, we used the normal distribution function (=NORM.DIST(total kWh usage, average, standard deviation, false)) to determine the distribution of each address within its group. We then plotted the curve, using the distribution as the y-axis and the total kWh as the x-axis.

Housing size and electricity intensity

For most addresses, we were able to obtain housing size (square footage of living space) from individual permit records. Using this data, we were then able to look at average house size across data groups, as well as electricity intensity. To calculate, we simply divided the total kWh usage for an address (for our approximate year timeframe) by the number of square feet. We also plotted these points on a graph, using square footage as the x-axis and total kWh as the y-axis. This provides a visual representation for size and usage comparisons across groups.

Rolling yearly average usage for zHome

See zHome white paper (http://www.builtgreen.net/library/zhomewhitepaper.pdf). Average monthly usage from a start date for the subsequent twelve months was calculated using start dates for over a twelve-month period. This shows average electricity usage over time while somewhat equalizing for seasonal differences or abnormalities, for a focus on overall trends.

Seattle City Light average rate and average costs

2015 rates were calculated based on 2016 rates and their percent increase from the prior year (information downloaded from SCL's website). SCL charges a daily base rate, a first block rate (upper limit varies by season), and a second block rate. Since we were looking at yearly averages for groups, we used 13 kWh as the first block's upper limit, which is the average upper limit between the winter and summer seasons. We then used the following formula to calculate bills for each group: daily base charge + (13 kWh or lesser amount, if applicable) * first block rate + (daily usage – 13 kWh) * second block rate = daily electricity cost. This daily cost was then multiplied by the number of days in a month, billing period, or year to get the corresponding electricity costs. Average cost per kWh for each group was found by dividing the yearly cost by the total kWh used. The weighted average cost per kWh across all groups was found using a simple weighted average that looked at each group's kWh cost weighted by the number of data points in that group.

Home purchasing power

We used the Seattle median house price and interest rate in Washington listed by Zillow on August 25, 2016 (when we first did the calculation) to calculate the typical monthly payment for a Seattle home. We used Excel's PMT function to do so, using a 20% down payment and a loan period of 30 years (360 months) in addition to the median price and the interest rate described. We then added either the monthly electricity savings from a typical 4-Star or 5-Star all-electric home and back-calculated to the house price using this higher monthly payment but keeping all other factors the same. To back-calculate, we used the equation: loan amount = monthly payment * (((1+monthly interest rate)^360 – 1)/(monthly interest rate * (1+monthly interest rate)^360)). From this, we calculated the total house price by dividing by 0.8 (still assuming a 20% down payment would be made).

Carbon emissions

CO_2 or CO_2-equivalent emissions savings resulting from Built Green homes were calculated using 1) the national CO_2-equivalent emissions per kWh of electricity, obtained from the EPA, 2) the Washington state CO_2 emissions per kWh of residential electricity, obtained from the EIA, or 3) Puget Sound Energy's CO_2-equivalent emissions per kWh. Comparisons were made based on yearly differences in electricity consumption between different groups of homes: 4-Star all-electric Built Green, 5-Star all-electric Built Green, all-electric control homes, an average U.S. home (sourced from EIA data), and an average Washington state home (sourced from EIA data). The difference in kWh consumption between a group was simply multiplied by the resulting emissions per kWh (either based on national, Washington state, or Puget Sound Energy estimates described above). This resulted in the emissions reduction of one home between two comparison groups, which could be further multiplied out to see the emissions savings from a larger number of homes.

Residential solar PV equivalency

The electricity savings from Built Green homes compared to either control, average Washington state, or average U.S. homes was compared to the number of standard sized (65" by 39", 250 W) residential solar photovoltaic panels by first determining how much electricity one panel would produce in a year. A Seattle capacity factor of 0.16 was used in the equation based on information from Sunmetrix. To determine annual kWh production of a typical panel we used the equation: 250 W * 1/1000 * 8760 hours/year * .16 = 350.4 kWh. Savings between different groups of homes were simply divided by this annual production number to determine how many solar PV panels would make up the difference.

To determine cost estimates of purchasing that number of panels, we used a cost estimate of $3.00/W (obtained from Greentech Media), multiplying that by 250 W (per panel) and the number of panels.

We also made estimates of how much space these panels would take up lying side by side by converting square feet to acres, and multiplying by the number of panels.

Electric vehicle equivalency

To calculate the average number of Nissan Leafs the electricity savings of a Built Green home could power, we assumed typical usage (the Idaho National Laboratory published a paper which listed the average number of miles driven by a typical Leaf driver in a year) and used the EPA estimate of how many miles per kWh a Leaf can travel. We multiplied annual kWh savings by the number of miles per kWh a Leaf can drive and then divided this by the number of miles a typical Leaf driver drives in a year to estimate the average number of Leafs, with typical usage, Built Green savings could power. We did similar calculations for a Tesla Model S, also using EPA mileage estimates; however, we used typical Leaf usage for average number of miles driven since we could not find this information for Tesla drivers.

We affirmed that the cost of using electricity for transportation (with a Nissan Leaf) is cheaper than using a conventional gas-fueled vehicle, on a cost per mile basis. According to the EPA, the average fuel economy of model year 2015 vehicles was 28.8 miles per gallon.[xxx] The EPA also estimates the fuel economy of a Nissan Leaf as being equivalent to 114 miles per gallon, and a gallon as being equivalent to 33.7 kWh.[xxxi] Using a price of $2.93 per gallon for gas[xxxii], we see that an average vehicle would cost 12 cents per mile to drive.

Using Seattle's average (as of June 2017) residential electricity cost (11.2 cents)[xxiii] and multiplying that by 33.7 kWh/gallon and by one gallon/114 miles, we see that a Nissan Leaf costs just 3 cents per mile to drive.

iPhone 6 equivalency

We obtained an estimate from Opower of how much electricity (kWh) it takes to charge an iPhone 6 and then divided savings between data groups by this number to determine how many iPhone 6 charges to which these savings are equivalent.

LED equivalency

We used a 12 W LED as the basis of our calculations. Running continuously, such a light bulb would use 12 W * (1/1000 kW) * 8760 hours = 105.12 kWh in a year. Electricity savings between data groups were then divided by this number to determine how many years the savings could run a 12 W LED continuously.

Movie nights equivalency

We defined the electricity that would enable a "movie night" as the amount it would take to run a blender twice (for two smoothies), use a DVD player to watch three movies, heat an electric blanket for that amount of time, and use the oven to bake a batch of cupcakes. The Wego Wise blog[xxxiv] provided information on how many times you could do each activity with 1 kWh. We then estimated how many kWh it would take to power our definition of a "movie night" using these numbers by adding up the kWh usage for each activity. 1 kWh runs a blender 400 times, so 2 blender uses would require 2/400 kWh. A kWh will play 29 movies on a DVD player, so watching 3 movies would require 3/29 kWh. It takes 1 kWh each to run an electric blanket all night and bake a batch of cupcakes. Adding these together, we estimate a movie night requires 2.11 kWh. We then divided savings by this number to estimate the number of "movie nights" that these savings could power.

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