Reducing Home Energy Usage

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Abstract

This project sets out to focus on how residential owners can reduce overall energy use in their own home. Utilizing research to highlight high level categories of energy use and what drives that use, the focus is then shifted to using a Six Sigma approach via the DMAIC process to confirm potential root causes. Initial research drove the study towards electrical use specifically. By analyzing data, the project team was able to confirm major sources of electrical use and developed solutions to demonstrate how to effectively reduce that consumption. The study also highlights other recommendations that could be implemented to further reduce or control energy consumption and highlights overall benefits to the end user.

Keywords

Residential Electrical Use, Six Sigma DMAIC, Lighting Benefits, Thermostat/Temperature settings, Energy Reduction

1. Introduction

Americans use a lot of energy in their day to day lives. Whether they are driving to a job, sitting at work or relaxing at home after a hard day, energy is constantly being consumed. With that in mind, it is important to understand energy use and how it can affect the day to day lives of every person. For homeowners or renters, this can be a huge expense and headache. Many homeowners stress over energy use as it can drive higher bills, impacting a person's life, personal cash flow and overall well-being. Higher energy use also affects the overall environment and greenhouse gas emissions. The objective of this paper is to understand what type of items or behaviors drive higher energy use. While large purchases of energy efficient appliances or major upgrades to a home may drive a more efficient footprint; there are other ways for an average homeowner to reduce overall usage without large capital investment, yet instead with minor changes in their day to day schedule.

2. Literature Review

2.1 General Energy Use

Energy is used in many different sectors and drives much of the world today for day to day needs. In the United States, there are 5 energy use sectors as noted below (EIA 2019):

Industrial. This type of energy is used to power facilities or equipment used in manufacturing, agriculture, mining and construction. This is the type of energy used to produce crops for food or energy used to build automobiles across the globe.

Transportation. This type of energy is used in day to day travel and is produced by boats, cars, airplanes, etc.

Residential. Energy used for homes, condos and apartments.

Commercial. This energy usage includes office spaces, schools, hotels, restaurants, hospitals, etc.

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Electric Power. This sector consumes primary energy to generate the energy necessary to deliver it to the other 4 sectors. Primary energy is the energy that is harvested from natural resources and has not yet been converted. This primary energy must be converted to supply to the Industrial, Transportation, Residential and Commercial sectors.

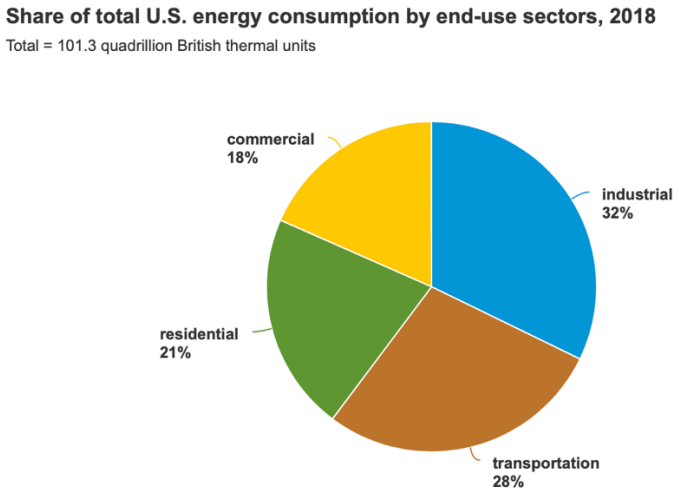

Figure 1. Energy usage by Sector (EIA)

2.2 Residential Energy Use

Residential or household energy use makes up 21% of the secondary end use sectors as shown in Figure 1 above. Energy use in the home comes from many different outlets and is used for many different purposes. Heating, cooling, lighting, water heating and electronics/appliances are some of the major categories that make up a typical household use. As seen in Figure 2, more than 50% of the average energy use in residential is for heating and cooling alone. For heating and cooling, they are often seasonal and will vary depending on location, size of the home and equipment used. Water heating, lighting and refrigeration make up over another quarter of the usage, while the remainder is made up of items such as televisions, appliances, washer/dryer and an ever-growing list of power needed to recharge tablets, phones, etc. (EIA 2019). The percentages vary depending on type of home, but overall, they are consistently similar in regard to what drives energy usage in residential areas.

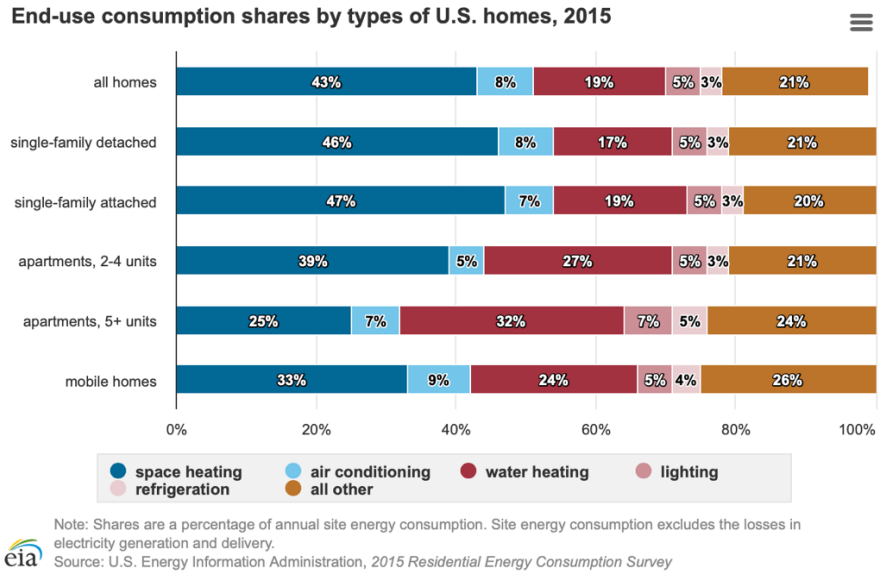

Figure 2. Energy usage by type (EIA)

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Energy use can come from multiple sources such as electricity, petroleum fuels and natural gas. In regard to electricity, the average household uses approximately 11,000 kilowatt-hours (kWh) per year (EIA 2019). The amount of electricity use will vary by region and by type of home. Using data collected from 2015, a single-family detached home uses the most energy and while most regions are similar, the South is typically higher on average due to high air conditioning use and electric heaters.

While the other resources such as natural gas can only typically be used for heating and cooking, electricity is used for almost everything else in the home, including heating/cooking. The top energy uses in residential homes in today's society are dominated by air conditioning, heating and water heating. Lighting, refrigerators and television are the next biggest users as highlighted in Figure 3. Interestingly, many residential homes now have more than 1 refrigerator, which will further increase the electrical load. Smaller appliances all add up as well, which include items such ceiling fans, microwaves, washers, etc.

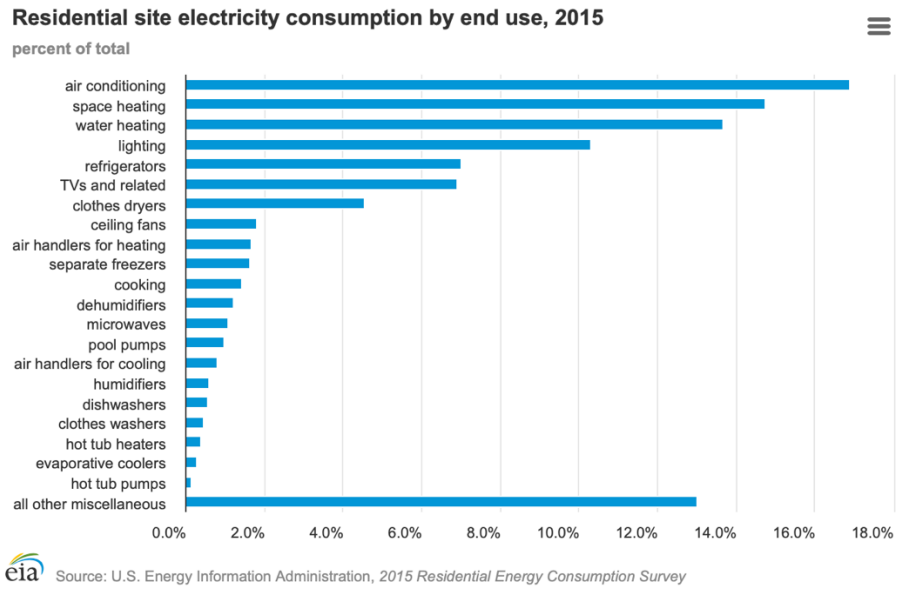

Figure 3. Energy usage by category (EIA)

When looking for ways to reduce home energy use, a good start would be to focus on the pareto chart above and for a user to evaluate how they use this energy. As Energysage points out, it doesn't mean you need to go out and buy energy efficient products to reduce electrical usage. The easiest way to do this is by adjusting your day to day behavior. The behavior adjustments that have the highest potential for utility savings are turning down the heat on your thermostat in the winter and using your air conditioner less in the summer (Energysage 2020). As Charles Wing points out in his book, setting back your thermostat from 70 to 69 can average a 3% cost reduction regardless of region. Setting it back 5 degrees jumps the average to 15% and if you move even more drastically to a 15 degree difference, it is above 33 to 34% savings (Wing 2013). In addition to setting back a thermostat, a residential owner could also look at more drastic changes such as upgrading home insulation or windows. They could even go as far as investing into solar panels for their home (Yogeswaran et al 2019).

Other ways to reduce energy use can include turning off lights when you leave the room or doing more dishes by hand rather than using a dishwasher. Another easy way to reduce energy consumption is to switch to more efficient light bulbs such as LEDs. LED bulbs for example can drastically reduce wattage for the same amount of lumen output. For example, an incandescent bulb will take 60W of energy to output ~750 lumens, while an LED bulb will require only 7 to 10 W for the same output. LED bulbs also have a much longer life span at an average of approximately 25,000 hours vs 1200 hours for incandescent (Viribright). Therefore, even if LED bulbs cost more, they can be more cost effective in the long run and continue to go down in price. A good example of how LEDs can save money is shown below in Figure 4.

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LED vs CFL vs Incandescent Cost	Incandescent	CFL	LED (Viribright)
Watts used	60W	14W	7W
Average cost per bulb	$1	$2	$4 or less
Average lifespan	1,200 hours	8,000 hours	25,000 hours
Bulbs needed for 25,000 hours	21	3	1
Total purchase price of bulbs over 20 years	$21	$6	$4
Cost of electricity (25,000 hours at $0.15 per kWh)	$169	$52	$30
Total estimated cost over 20 years	**$211**	**$54**	**$34**

Figure 4. Bulb type power usage (Viribright)

In addition to using historical data to look for areas of improvement, there is also a lot of research and movement towards Smart Grids, which allow two-way communication and integration between the grid and generation sources. This allows for higher quality and more reliable electrical energy to the users. One key application of the Smart Grid in regard to home energy use is HEMS or Home Energy Management System. HEMS is a technology platform that combines both hardware and software and allows the customer to monitor home energy usage. It also can allow them to manually control and automate the usage of energy within a house (Qayyum et al 2019). This ties closely to other research that indicates that 20 to 30 percent reduction in electrical use can be achieved without any type of structural changes to the building by optimizing home operation and management (Khani 2017). In the future, smart technology can continue to help drive lower energy consumption and can even work with smart appliances to utilize energy at optimal, non-peak times.

As noted above, there are many ways to reduce energy use, but why do it? Obviously cost savings is a huge reason why users look to reduce energy consumption. However, there are many other reasons to reduce energy consumption including reducing greenhouse gas emissions and creating a more efficient electric grid which can help reduce price for everyone. As noted earlier, energy for residents is really a secondary source and therefore must come from a primary source. Over 60% of the current U.S. mix of energy sources comes from fossil fuels. Less energy means burning less fossil fuels which in turn reduces greenhouse gas emissions. As Beadle points out, in 2016 alone, ratepayer-funded electric EE programs saved over 30,000 GWh of electricity and 522 million therms of gas in the U.S. and Canada. Using the EPA's GHG Equivalencies Calculator, this is equivalent to the annual energy use of over 2.8 million U.S. homes, and avoids over 24 million metric tons of CO2 from being released into the atmosphere. This is enough energy to provide for the annual needs of every home in Washington State (Beadle 2019).

It can also have health benefits and even boost local economic development (Beadle 2019). By taking on energy efficient practices, you can create a drier home with more consistent temperatures, fewer air pollutants and allergens and lower risk of asthma triggers such as mold and fluctuating temperatures. However, most research assess a bundling of multiple energy efficient tactics and not just a single action. (Cowell et al 2016). In addition to physical health, lower bills and a more comfortable environment can also increase mental health as well (Cowell et al 2016). When people are saving more money using energy efficient techniques, they often use that new disposable income to spend on other items locally. This can help the local economy by supporting existing jobs. Equally important, a company that uses energy efficient techniques can become more profitable by bringing down overall operating cost (Beadle 2019).

3. Project Charter

Referenced in Figure 5, the project charter identifies the current plan for the project and the overall problem statement. It highlights the objective, what is in and out of scope and overall timing for the project.

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Project Charter

Problem Statement

User is currently using ~50% more electric energy than efficient homes in winter months and ~100% more electric energy than efficient homes in summer months. In the summer months, the user also uses ~30% more electric energy than non efficient similar homes. The user is consistently spending more money than users of similar homes.

Business Case & Benefits

Reduced energy usage will result in a lower monthly bill for the user and can also increase property value by being an energy efficient home. Energy efficient homes can also help enhance a user's quality of life and may provide health benefits. Finally, energy efficient users can help protect the environment.

Goal Statement

Decrease gap of electric energy usage between users home and similar efficient homes by 10% for winter months.

Timeline

Phase	Planned Completion Date	Actual
Define:	Feb 24th, 2020	
Measure:	March 9th, 2020	
Analyze:	March 30th, 2020	
Improve:	April 13th, 2020	
Control:	May 4th, 2020	

Scope - First/Last and In/Out

In Scope: Small budget purchase or user usage changes

Out of Scope: Large budget purchases, other users behaviors, natural gas usage

Team Members

Position	Person	Title	% of Time
Team Lead	Nick Egli	Project Leader	100

Figure 5. Project Charter

4. Six Sigma Tools

The project utilized the DMAIC framework and six sigma tools. The DMAIC approach was instrumental into finding potential root causes and then using data to verify and move forward with solutions. In the Define phase, the pareto chart was used to help narrow down potential causes and is a common six sigma tool to identify highest failure modes or problem areas. Using a data collection plan and the SIPOC tool helped to streamline what baseline data to take, while the graphical analysis in the analyze phase was key to confirm root causes. Hypothesis testing is also a very useful data driven six sigma tool used to confirm that the root cause is truly significant. The following tools or six sigma methodologies were used in the project as highlighted below.

D – Project Charter, Project scope, Project timeline, Customer Data Analysis (Line Graph), Pareto Chart
M – Data Collection Plan, SIPOC, Research Data, Gather Variable Baseline Data
A – Fishbone diagram, Graphical Analysis, Comparative Analysis, Hypothesis Testing
I – Identify and Pilot Solutions (Implementation Plan), Validate Solutions, Future Recommendations
C – Process Control Charts, Lessons Learned

5. DMAIC Process

5.1. Define

Utilizing the DMAIC process, the team begins with the define phase. The define phase involves the project charter shown in figure 5 and determining what issue needs to be resolved. As shown in Figures 6 and 7, the problem for the current homeowner is electrical energy use and efficiency of that energy use compared to similar homes. Similar homes as defined by DTE energy is energy use patterns of a group of approximately 100 homes in the owner's area that also have characteristics that lead to similar energy needs, such as heating sources. It is also important to note that DTE only compares homes that appear to be occupied at the time. Efficient homes are defined as the most efficient 20% of energy usage in the group (DTE Energy). In a small window from Nov 21, 2019 through December 19th, 2019, the user used nearly 50% more energy than efficient homes.

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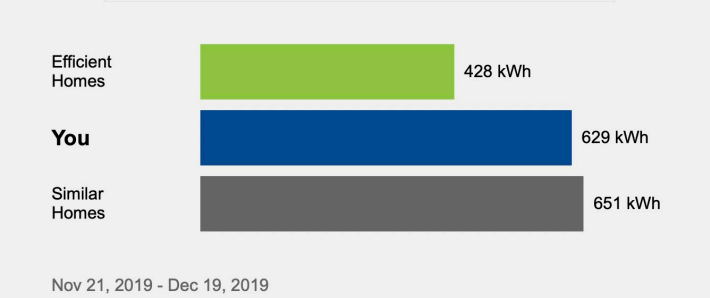

Figure 6. Energy Usage for user over 1 month

If you step back and look at the broader picture over the last 6 months, the trend and gap to efficient homes increases greatly in the summer months. As seen in Figure 7 below, the users home utilizes 100% more energy than efficient homes and approximately 30% more than similar, non-efficient homes.

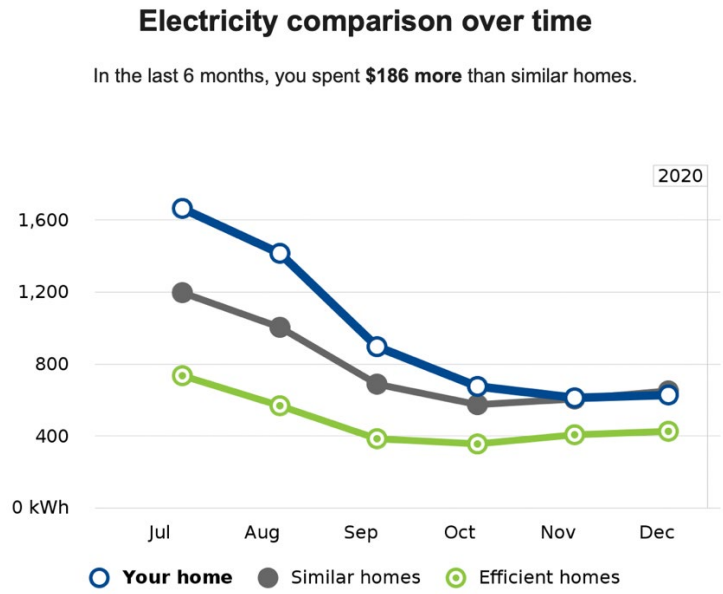

Figure 7. User energy consumption over 6-month period

Reviewing the data, a clear energy usage issue is the problem and the user wants to use the DMAIC process to help resolve.

Problem Statement: User is currently using ~50% more electric energy than efficient homes in winter months and ~100% more electric energy than efficient homes in summer months. In the summer months, the user also uses ~30% more electric energy than non-efficient similar homes. The user is consistently spending more money than users of similar homes.

Project Objective/Goal: Decrease gap of electric energy usage between users' home and similar efficient homes by 10% for winter months.

Scope (In/Out): For this project, small budget items or user behaviors regarding usage are in scope. While in the long run, it may be considered, large budget purchases, other user's behaviors and natural gas usage are out of scope.

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Expected Benefits: Reduced energy usage will result in a lower monthly bill for the user and can also increase property value by being an energy efficient home. Energy efficient homes can also help enhance a user's quality of life and may provide health benefits. Finally, energy efficient users can help protect the environment.

5.2. Measure

In the measure phase, data will be collected to later analyze. For this phase, a SIPOC chart was used as shown in Figure 8 to layout the data collection thought process. This helps to identify a data collection plan that will be needed to summarize the data for analysis later in the process. SIPOC is a high-level overview of the measurement process and a short definition of each part of the process is broken out below (Go Lean Six Sigma 2020). In this case, the process in question is homeowner's energy use.

S – Supplier: This is the person/organization that provides input to a process.
I – Input: Resource(s) added to the process by a supplier(s)
P – Process: The series of steps used to convert input into output
O – Output: Resource/Result of the process
C – Customer: The person/organization receiving a service or product

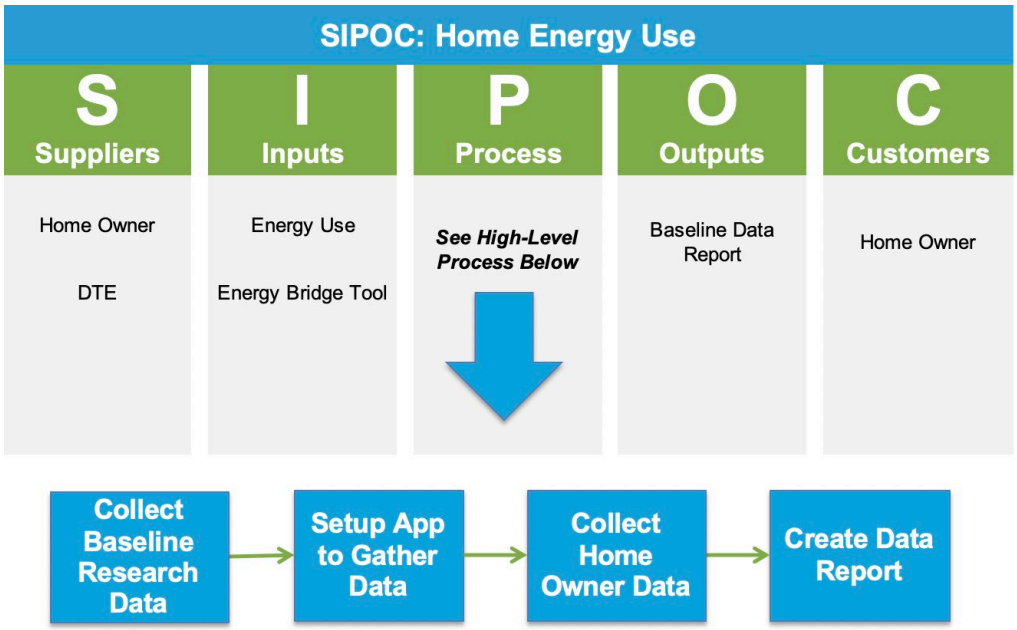

Figure 8. SIPOC chart for Home Energy Use

5.2.1 Data Collection: To get detailed data, the project utilized DTE's Smart Meter and energy usage reports from the DTE website. This allows for detailed analysis of energy use by hour and day and can be exported for further analysis. To be able to further analyze the detailed data, the homeowner installed a DTE Energy Bridge. This device can work with the user's Smart Meter to gather live energy use data. This allows the user to be able to see energy usage as it is happening and can allow instant feedback into what changes are occurring to drive higher usage.

The data collection plan for obtaining baseline data will start on March 15th and run through March 28th. The concept behind the plan is to see how much energy is used in the home over a two week period. The two-week period allows for more data points to help stabilize average usage and helps the homeowner see a larger picture. This data can then be summarized in a data report to be utilized in the analysis phase. A sample of the data can be seen in Figure 9. Data was taken every hour for two weeks and can be seen as either an hourly total or daily total.

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Day	Hour of Day	Hourly Total	Daily Total	Unit of Measurement
3/15/20	12:00 AM	0.42	31.291	kWh
3/15/20	1:00 AM	0.422	31.291	kWh
3/15/20	2:00 AM	0.425	31.291	kWh
3/15/20	3:00 AM	0.406	31.291	kWh
3/15/20	4:00 AM	0.39	31.291	kWh
3/15/20	5:00 AM	0.414	31.291	kWh
3/15/20	6:00 AM	1.226	31.291	kWh
3/15/20	7:00 AM	1.292	31.291	kWh
3/15/20	8:00 AM	0.985	31.291	kWh
3/15/20	9:00 AM	1.317	31.291	kWh
3/15/20	10:00 AM	1.396	31.291	kWh

Figure 9. Sample Energy Baseline Data

5.2.2 Variable Baseline Data: As noted above in the data collection plan, variable data was imported from the DTE database into Excel in order to have the ability to analyze daily energy use. This data shows energy use for each day between March 15th and March 28th. On average, the homeowner used 26.07 kWh of energy a day. As can be seen in Figure 10 below, the energy use fluctuated daily, with larger values at the beginning of the data collection period. Ironically, the data collection period began at the beginning of the COVID-19 pandemic when all 4 residents were in the house at the same time every day, all day. Surveying and observing other users in the home, it was noted that large appliance use was much more prevalent the first few days of the data collection period. Other members of the house were doing multiple loads of laundry and were using items such as the oven much more frequently during this time. After the initial few spikes shown in which appliance use was higher than normal the first five days, the data begins to stabilize. Considering the first 5 days as outliers to normal energy usage based on history/feedback from the residents, the project team has decided to use energy usage from March 20th through March 28th as the baseline data for comparison purposes at the end of the project (Improve phase). When looking at the average of those dates, the energy usage mean was 23.63 kWh per day as highlighted in Figure 10.

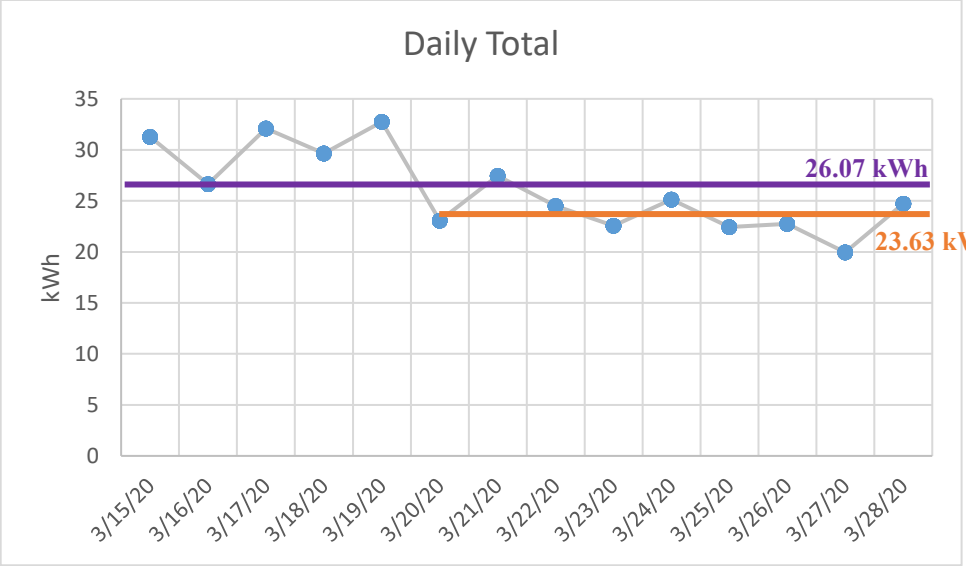

Figure 10. Homeowner Daily Energy Use

5.3 Analyze

In the analyze phase, the goal was to brainstorm potential root causes and also deep dive the baseline data gathered. This was done by using hourly data collected in addition to utilizing the history in the app. The team will also be able

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to use the live data in the DTE Insight app to better understand energy usage as it is occurring. This phase builds upon the measurement phase by continuing to study and analyze the baseline data gathered and then brainstorming concepts for improvement.

5.3.1 Graphical Analysis: While the initial baseline data highlighted daily energy use by the user, further analysis is needed to breakdown exactly what factors could be driving that usage. Looking deeper into the details of the same data in different ways can help identify potential root causes. One of the analysis tools used was a scatter plot to see how much energy was being used every hour. As noted in Figure 11 below, there is a strong correlation both at the low end and upper end of usage. On the low end of usage, the hours with no activity in the house when residents are sleeping, the temperature is set lower on the thermostat between approximately 11:00 p.m. through 5:00 a.m. On the opposite end of usage, you can see the highest usage typically around both lunch and dinner time. In general, this is when more appliances such as microwave and oven are used in the house to prepare meals. This analysis was very beneficial when developing the fishbone diagram and trying to understand potential root causes.

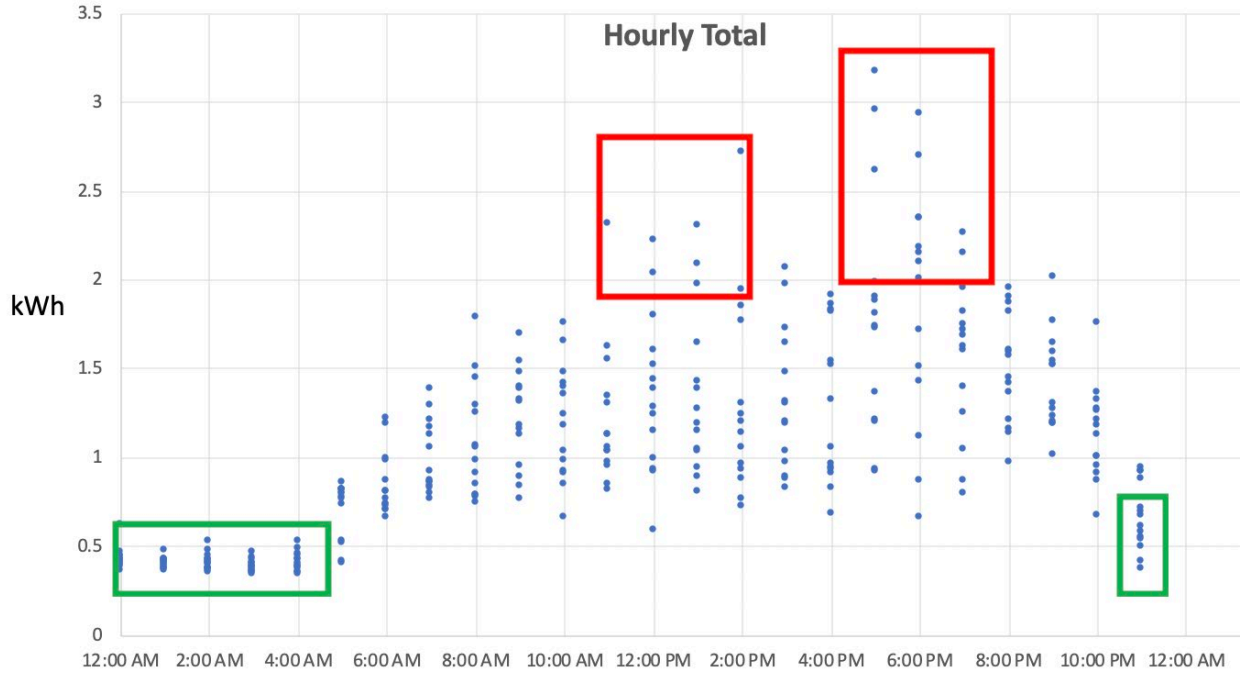

Figure 11. Scatterplot of Energy Usage by Hour

5.3.2 Fishbone Diagram: The fishbone diagram is a cause and effect tool that allows a team to brainstorm different root causes by identifying the overall issue at the "head" of the fish and then categorizing the different higher-level causes into categories along the "spine" of the fish. From there, a team can continue to brainstorm detailed reasons for each category to help drive deeper into true root causes of a problem.

In the case of home energy use, the team utilized the pareto research that was done to define the initial root cause categories. Those categories were: Heating/AC, Water Heating, Lighting and Other (mainly appliances). Ideas were then brainstormed around what drives those high-level categories to further expand the fishbone diagram. The data used from both the variable baseline data and the scatter plot analysis helped to drive additional root cause potentials and helped to narrow down the focus for the Improve phase. Seen below is the summary of the diagram and highlights potential root causes.

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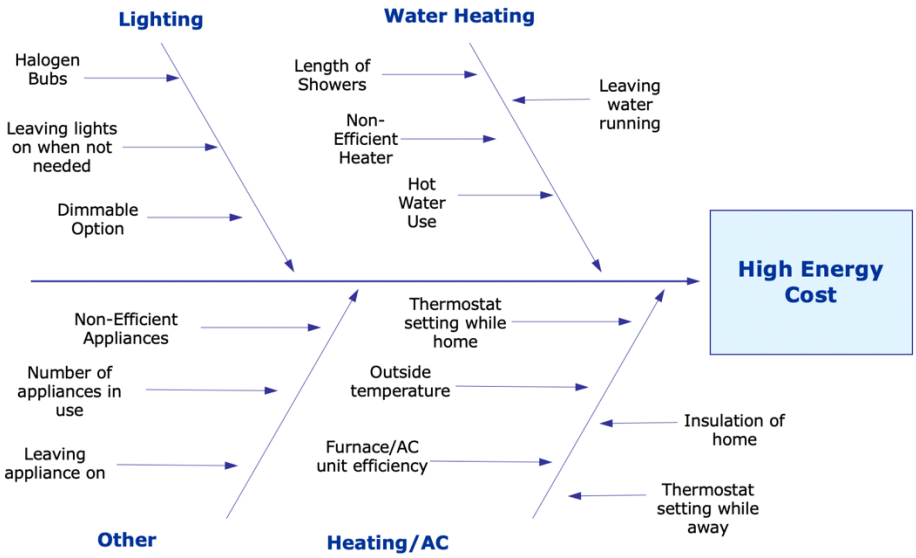

Figure 12. Fishbone Diagram

Referring back to the initial project charter in regard to what was in scope and out of scope, the fishbone diagram shown in Figure 12 highlighted two areas of improvement that could be controlled by the homeowner and the other residents in the home. Those areas were in Lighting and in Heating/AC. In the case of this home, the temperature set during the night hours is 71 F during the day and 63 F at night (between the hours of 11 p.m. and 5 a.m.). The scatter plot data highlights the difference in energy use while the resident is sleeping and confirms that temperature setting of the thermostat is a major contributor to energy usage. The scatter plot also shows a higher energy usage due to appliances but purchasing more energy efficient appliances is out of scope for this project and will not be further analyzed.

However, it is impractical to assume in the evening that a resident will use no lights or appliances. Therefore, further analysis is needed to confirm if leaving the lights on when not needed is truly a root cause in this case or if energy usage is truly dependent only on thermostat setting. For that analysis, hypothesis testing was used to confirm lighting use as a major root cause contributor.

5.3.3 Hypothesis Testing: The benefit of hypothesis testing is that it can confirm whether or not there is a significant difference between two data sets. To run a hypothesis tests, a team needs to take the following steps (Six Sigma Institute):

Step 1: Determine appropriate Hypothesis test
Step 2: State the null (Ho) and alternate hypothesis (Ha)
Step 3: Calculate test statistics
Step 4: Interpret results and accept or reject the null hypothesis

For step 1, this project utilized 2-sample t-Test as a way to compare the means of two different populations. The team wanted to understand if there was truly a mean shift in energy usage when lights were on in the house versus no lights being on due to nobody home. This data was collected via the DTE energy app which tracks live usage. For step 2, the null and alternate hypothesis were identified as noted below:

Null hypothesis (Ho): Energy usage will not change significantly whether the lights are on or off while away from the home/occupied rooms.

Alternate hypothesis (Ha): Energy usage will change significantly if the lights are left on in the home, even when the room(s) are unoccupied.

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The next step in confirming the hypothesis was to chart the data. For this, Minitab was utilized to run a 2 sample t-Test as noted in Figure 13.

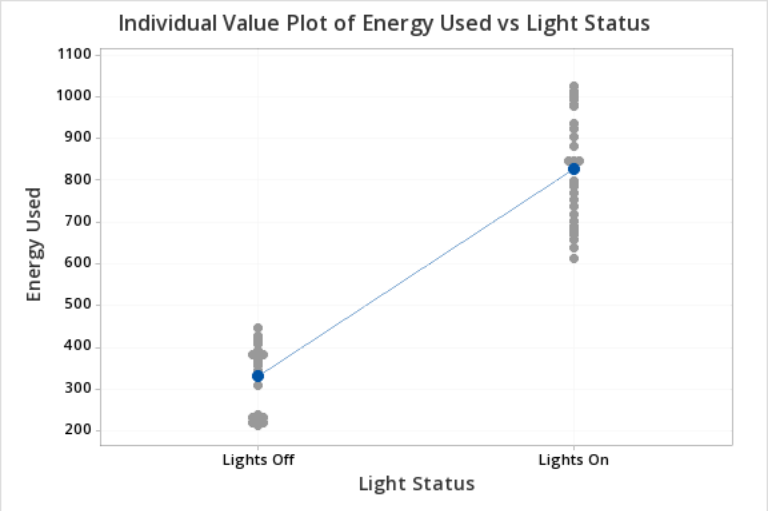

Figure 13. 2-sample t-Test

Estimation for Difference

Difference	Pooled StDev	95% CI for Difference
-495.5	105.5	(-550.0, -440.9)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-18.19	58	0.000

Figure 14. 2-sample t-Test Analysis results

Based on the results in both Figures 13 and 14, it can be concluded that the null hypothesis can be rejected and that there is a significant difference between having the lights on and the lights off when a room is unoccupied. The data highlights with 95% confidence that the usage will vary an average of 495 Watts and between 440 to 550 Watts. This data helps confirm the potential root cause identified in the fishbone diagram in regard to lighting usage for testing in the improve phase.

5.4 Improve

The Improve phase is the next phase in the DMAIC process and focuses on implementing and verifying solutions to the problems identified in the previous three phases. In the improve phase, the team will test out a proposed energy reduction plan based on two of the "in scope" contributors to the problem. In this case, the homeowner and occupants will trial changing two factors: thermostat setting and lighting usage.

5.4.1 Identify and Pilot Solutions (Implementation Plan): After factoring in two items that drive energy use and confirming them through data, an implementation plan has been developed to improve energy usage. This involves working with other residents of the house to develop and implement a solution for trial. The trial will run for one week in order to provide data to compare against the baseline.

In the case of lighting usage, the project team has sat down with all of the residents in the house to ask them to participate in the Improve phase implementation plan. The trial is simply to ask each user to turn off the lights when they leave a room or leave the house. The current homeowner and residents have a habit of leaving lights on for hours, even when the room or home is unoccupied.

In the case of temperature, the proposal is to reduce the setting of the thermostat for both the time while the residents are sleeping, as well as while they are at home using the house during the day/evening. The below simple table in.

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Figure 15 highlights the changes that will be implemented and trialed during this phase and breaks it apart into a "sleeping" time and an "active" time. As seen below, the thermostat settings at the beginning of the project are highlighted as the baseline settings. The proposal is to lower the temperature by 3 degrees while the residents are sleeping, as well as extend the time at the lower temperature by 75 minutes. This is the major focus of the trial in regard to temperature as it both extends the time in a much lower temperature range and it also reduces it by 3 degrees. During the active period where the residents are using the home, the proposal is to lower the temperature by only a degree. The active phase reduction by 1 degree will not play a huge role in the overall energy reduction but should help minimally contribute to the overall goal of reducing energy usage.

Period	Time	Temperature
Baseline Sleeping	11 p.m. – 5 a.m.	63
Baseline Active	5 a.m. – 11 p.m.	71
Pilot Sleeping	11 p.m. – 6:15 a.m.	60
Pilot Active	6:15 a.m. – 11 p.m.	70

Figure 15. Temperature Implementation Plan

5.4.2 Verify Solutions/Data Comparison: For the temperature trial during the sleeping phase, the team will break the data comparison down in two ways to verify the benefit of the potential solutions.

First, the project will compare the hourly use between the times of Midnight and 5:00 a.m. The reason for this trial is to isolate just the times when the temperature was reduced by 3 degrees overall at the thermostat and to take out the use of other energy such as lighting and appliances. The reason for removing the 11:00 p.m. hour in this case is that the homeowner was not always sleeping by 11:00 p.m. Therefore, to isolate the benefit of just the temperature reduction alone and not factor in lighting/appliance usage, it will help to analyze the data while the users were truly sleeping.

As seen in Figure 16 below, lowering the temperature by just 3 degrees alone during sleeping hours does not actually impact the overall energy use. When comparing hourly use as an average between the baseline period and the pilot period, they were actually identical.

- Average Hourly use during baseline period: 0.42 kWh
- Average Hourly use during pilot period: 0.42 kWh

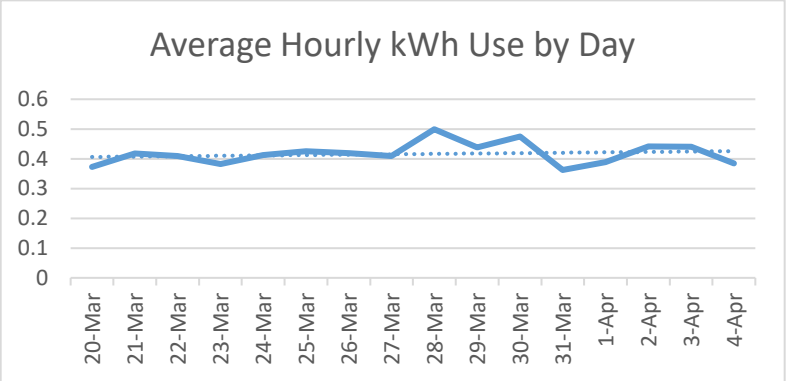

Figure 16. Average Hourly use by Day between Midnight and 5:00 a.m.

Next, the team will compare the hour of only 5:00 a.m. by day between the baseline timeframe and the pilot timeframe. This data comparison will show the benefit of extending the much lower sleeping temperature setting overall. During the baseline phase, between the hours of 5:00 a.m. and 6:00 a.m., the thermostat was set at 71. During the pilot phase,

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the homeowner kept the setting in the lower sleeping range, which was set at 60 degrees F. This will help isolate and highlight the hourly benefit of lowering the temperature by 11 degrees.

As seen in Figure 17, reducing the temperature from 71 to 60 degrees does have a major impact on energy usage. Energy use is nearly double between the baseline and pilot period. While 0.31 kW may not be a large part of a consumer bill for 1 hour, that can add up quickly on a monthly basis. It also highlights the benefits of operating a thermostat to be programmable while residents are away from the home.

During the current COVID 19 situation that is ongoing during this research project, many residents are spending almost 100% of time in their home. However, for those who are working or leaving the home during the day, a recommendation improvement would be to set a programmable thermostat to a much lower temperature in the winter and a much higher temperature in the summer. For example, if a resident leaves for work at 7:00 a.m. and does not return from work until 5:00 p.m., they could reduce energy use 3 kWh each day and it would have no effect on their comfort level.

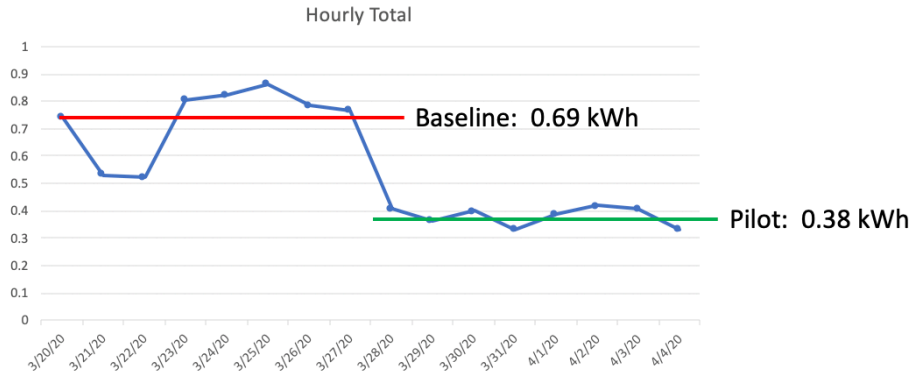

Figure 17. Average Hourly use by Day for 5:00 a.m. hour

Now that the effect of temperature alone has been reviewed and hypothesis testing previously confirmed that lighting usage also showed statistical significance, the project team will compare the overall effect of the proposed lighting solution on daily energy usage. In Figure 18 below, the data confirms that the combination of temperature changes and lighting use reduction enables the resident to utilize less energy. During the baseline period, the homeowner used 23.63 kWh per day, while during the pilot period, that usage was reduced to 20.38 kWh. The pilot plan alone helps to reduce home energy by 3.25 kWh a day. This is a 14% improvement in energy usage on a daily basis.

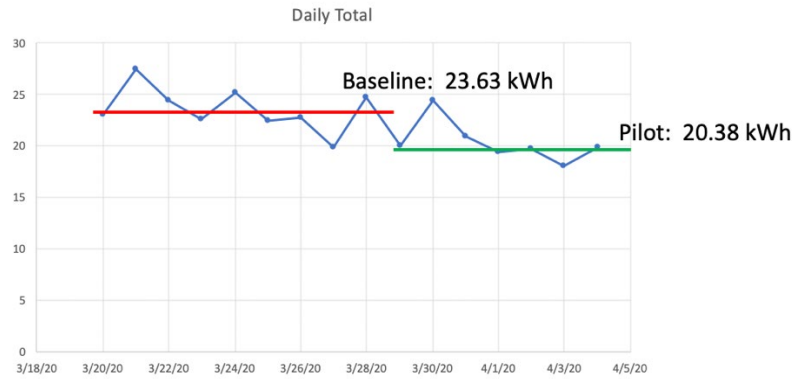

Figure 18. Average Daily Energy Use Comparison

Based on the temperature analysis above, it is known that the temperature setting at night only becomes a factor when you extend the "sleeping" period and have a major reduction in temperature of the home. That is valued at ~ 0.3 kWh for every hour that the home is held at a lower temperature. For this study, that means that the efforts to control lighting usage contributed to the majority of the energy savings on a daily basis (nearly 3 kWh) and highlights how awareness of energy use by residents in the home can help reduce overall inefficiency.

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5.5 Control

The Control phase highlights the overall conclusions from the study and also discusses lessons learned and next steps. It is also a chance to confirm that the improvements implemented are being followed and are working. In the case of this study, the goal was to reduce overall energy use on a daily basis by 10%. The improve phase demonstrated that with the proper focus and implementation by the homeowner, that this could be successfully completed. In order to track whether those improvements and actions continued, the project team tracked daily use for an additional 3 weeks and plotted the values as shown in Figure 19. As seen, while there is daily fluctuation in energy use, the data is in control and on average, the homeowner used 20.21 kWh of energy a day. This is below the 10% reduction target value of 21.27 kWh which means the efforts put in place during the Improve phase are currently working.

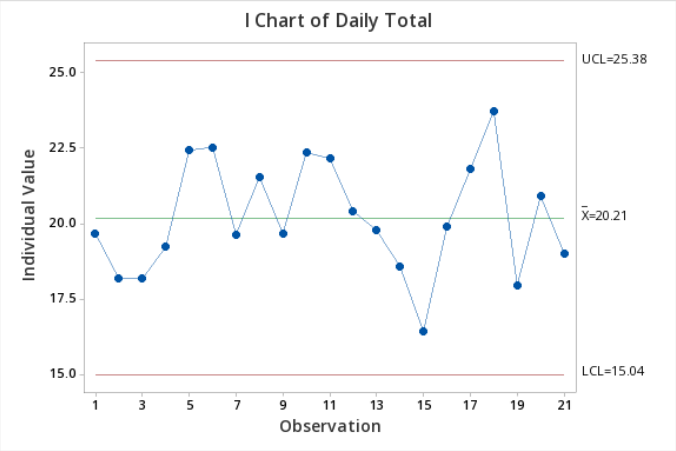

Figure 19. Control Chart of Daily Energy Use

The project team and the study participants learned a lot during this project. By the project lead showing the study participants the data, it helped them to understand how important it was to monitor energy use and to implement the recommendations to lower thermostat settings (within reason) and to manage use of lighting within the home. While the project lead is continuing to watch over the use of lighting within the home, the other residents are beginning to change their behaviors in regard to turning off lights when away from a room or the home. Driving this daily behavior will continue to help reduce overall energy use. This project is a good baseline and will help the homeowner also utilize similar data and analysis in the summer months to help maintain the energy reduction efforts.

6. Conclusion

Overall, it is important to reduce energy use at an individual level not only for the cost benefit to a residential user, but also to the overall environment. As mentioned early in the research paper, secondary energy must come from a primary source, which drives greenhouse gas emissions. If everyone took the approach that they don't really matter, it could have a huge negative impact on the environment. On the other hand, if each person took small steps towards being more energy efficient, it could have the opposite, positive effect.

The main objective for this study was to show that a homeowner could reduce overall energy consumption and lower their use by 10% with small behavioral changes. The research and study results confirm that this is possible and also highlight opportunities for future improvements such as setting the thermostat much lower or higher when away from the home for a considerable amount of time. While out of scope for this project, individual data analyzed showed that large appliance operation drives higher energy use as well. While that appliance operation will never be avoided and is part of daily life, it does highlight that a more energy efficient appliance could also help reduce energy use over time.

In conclusion, each person has a role to play in energy reduction and can make an impact not only on their wallet, but also on the overall environment. Making small changes isn't always easy, but with a little effort, they can have positive impacts.

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Biography

Nick Egli is a student enrolled in the Master of Engineering Management program in the A. Leon Linton Department of Mechanical Engineering at the Lawrence Technological University, Michigan, USA. He earned his B.S. in Engineering Management (Manufacturing Systems) from Miami University in Oxford, Ohio. Nick works for General Motors as an Engineering Manager in the Electric Power subsystem team. Prior to joining the electric power team, he spent more than 15 years in the Exterior Lighting space. Nick has over 20 years of experience in the automotive industry at both the supplier and OEM and has been involved in both design and manufacturing environments. His interest includes engineering management, leadership concepts, project management and product innovation.

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