Sparking a change:
Illuminating the path to an all-electric home

Abstract

Global climate change caused by carbon emissions is an escalating problem. In Australia, the residential sector contributes significantly to the country's carbon footprint. The goal of our project was to promote homeowner transition to an environmentally sustainable, all-electric home. Conducting expert and homeowner interviews and surveys, we identified benefits, technical elements, and perceived barriers to this transition. We then developed appropriate print and digital materials that city councils can use to reach residents and encourage transitioning throughout inner Melbourne.

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Saving our planet: A household approach to reducing carbon emissions

According to NASA, as a result of carbon emissions, global climate change is raising temperatures worldwide and is responsible for the increasing severity of natural disasters, including violent storms, extreme flooding, and severe droughts.[1] In Australia, negative effects of increased carbon emission output have been seen across the nation. The Australian Climate Change Authority (ACCA) has determined that global climate change has caused flooding in the northwest and drought in the southeast (Figure 1) as well as deterioration of the Great Barrier Reef ecosystem. If the carbon output is not reduced, the average temperature across Australia is expected to increase 4° C over the next 17 years.[2]

Figure 1. Extremes in precipitation (2001-2009): Drought in red and flooding in blue[3]

With the goal of mitigating global climate change, the ACCA has budgeted Australia's carbon emission output until 2050 (Figure 2). If current output does not change, Australia is set to exceed this budget within 17 years. A significant contributor to Australia's carbon emissions is the residential sector. To help address this, the Moreland Energy Foundation Ltd. (MEFL), a non-profit organization, is helping homeowners of Moreland and other surrounding cities within inner Melbourne become more environmentally sustainable. MEFL is working to encourage practices that maintain a healthy environment. To do so, they are working closely with government officials, local city councils, and the communities they serve.[4]

Figure 2. Carbon emissions budget allocation on a global, national, and local scale[5]

Within a household, gas powered appliances directly contribute to carbon emissions; when gas is burned, carbon dioxide is released as a result. By transitioning away from gas powered appliances, carbon emission output from a household can be significantly reduced. This will reduce the residential sector's impact on global climate change, helping Australia to stay within its carbon emissions budget. When a household has become "all-electric", the appliances use only electricity— the cooktop, water heater, and home heater— as well as insulation throughout the walls, ceiling, and floor. It is not a requirement for an all-electric home to have solar panels; however, they can be included. An all-electric home, unlike gas-powered homes have the potential to be powered by only renewable energy sources, allowing the home to have little to no carbon emissions. One way that homeowners can help decrease carbon emissions is by transitioning to an all-electric home.

Positive Charge, MEFL's community outreach enterprise, is currently establishing a campaign to convince homeowners to transition to an all-electric home. Our project aimed to help with this initiative, and we achieved the following three objectives:

1. Identified the technical, environmental, economic, and behavioral issues associated with a transition to an all-electric home.
2. Assessed the perceptions and attitudes of homeowners in the greater Melbourne area in regards to transitioning to an all-electric home.
3. Created multimedia outreach materials to encourage behavioral change in the community.

By completing these objectives we were able to produce several types and sizes of campaign materials and also to create a website design for when the all-electric campaign is launched. As a result, we delivered the information and materials Positive Charge needed to implement this campaign in a digestible manner for both homeowners and City Councils.

Combating global climate change on a residential level

The "Greenhouse Effect" is a natural phenomenon that keeps the earth warm. Greenhouse gases (GHGs), such as carbon dioxide (CO_2) and nitrous oxide (N_2O),

in the atmosphere trap heat escaping from the Earth's surface. Unfortunately, the concentrations of GHGs have been increasing rapidly over the last 150 years due to human industrial and agricultural practices, causing global climate change in the form of rising temperatures.[1]

Scientists, policy makers, and citizens of the world are increasingly concerned about global climate change. The U.S. National Oceanic and Atmospheric Association (NOAA) reported August 2016 as the hottest August in 137 years and marked it as the "16th consecutive month of record warmth for the globe".[6] Climate change will impact several parts of the global ecosystem according to NASA: Sea levels will rise 1 to 4 feet (0.3 to 1.2 meters) by 2100; hurricanes will become stronger and more intense; droughts and heat waves will occur more frequently in some regions while precipitation will increase in others; temperatures will continue to rise; the arctic will likely become ice-free; and ecosystems will continue to be disrupted.[7] It is the responsibility of every nation to reduce their carbon emission output to mitigate these effects.

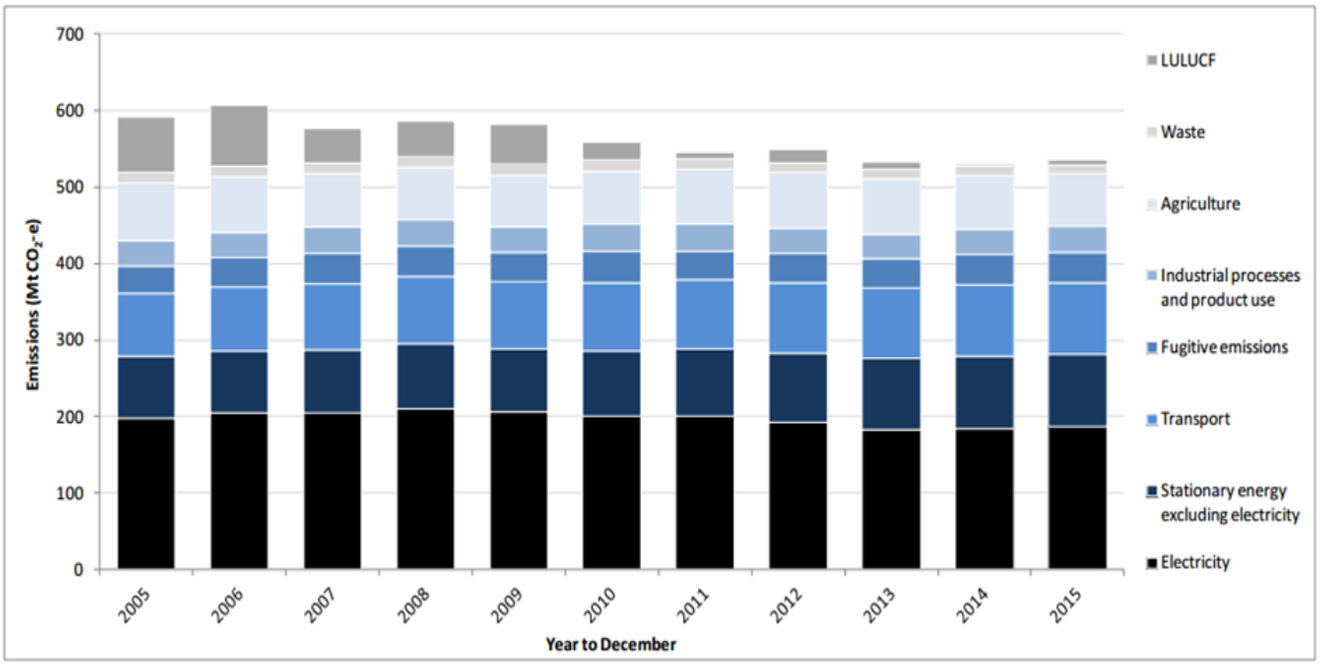

Figure 3. Australia's carbon emission contribution over the past decade [9]

Australia's coal and gas reliance

Carbon dioxide released from the burning of fossil fuels such as coal and gas is one of the major contributors to global climate change. In Australia, electrical generation contributes significantly to carbon emissions because Australia produces over 85% of its electricity from burning coal and gas. Australia's Department of the Environment reported electrical generation alone contributed to 35% of Australia's carbon emissions in 2015 (Figure 3).[8] The other 15% of Australia's electricity does not have this negative effect; it is generated by hydroelectric dams and other cleaner, renewable energy sources, according to the Office of the Chief Economist (OCE). To decrease its emissions, Australia must not only reduce electricity demand but also increase utilization of renewable sources of electricity.

Homeowners play a part

The OCE broke down electrical consumers in Australia by sector (Figure 4) showing that the largest consumers are residential (23%), commercial (24%), and manufacturing (26%) sectors.[9] While the residential sector uses 23% of Australia's electricity, it accounts for 26% of the total energy

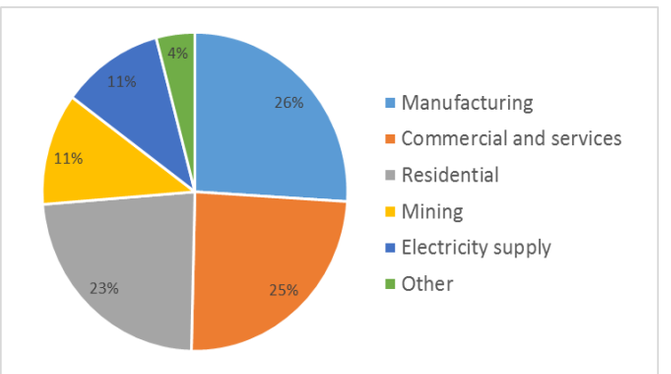

Figure 4. Distribution of Australian electricity consumption (2013-2014)

consumed from all sources including electricity, gas, and petrol. Residential reliance on gas and electricity suggests major inefficiencies within the home. The greatest culprits are heating, air conditioning, and water heating, together accounting for 63% of a home's energy consumption.[10] If these household energy needs were approached in a more efficient and environmentally sustainable way, they could reduce energy usage and GHG emissions within the residential sector.

Environmental benefits: Electricity does not have to be dirty

Homes powered by electricity can produce just as many GHGs as those powered by gas because electric generation most commonly comes from fossil fuels. Electricity, however, has the potential to be the cleaner solution as it can be generated from solar, wind, and hydro. Gas, on the other hand, is a non-renewable energy source. This allows for an opportunity to reduce GHG emissions by transitioning homeowners from gas to electric appliances.

Electric energy-efficient appliances have also improved substantially in recent years through government programs and manufacturer efforts.[11] The Australian government and environmental organizations such as MEFL have developed a variety of educational and incentive programs promoting sustainable behavior and the adoption of more efficient appliances within homes. By advocating for efficient, electric appliances, our project aims to reduce GHG emissions within households.

Technical requirements

Homeowners may need to make minor technical upgrades and structural changes in preparation for electric appliances. In Palo Alto, California, USA, the city's utilities department (CPAUD) found that homes making this transition needed electric panel upgrades to subsequently handle an increase in electric capacity.[12] Structural changes may also be needed for new appliances. For example, reverse cycle air conditioner wall units (Figure 5) would require drilling into the wall to install a support structure to hold the appliance. In the case of a split unit system for a reverse cycle air conditioner, air ducts would have to be run through the walls of the home. These are just a few upgrades necessary for a transition; however, each home is unique. It is important for our project that we communicate to homeowners that any home can install electric appliances – it is only a matter of what makes the most sense for their particular situation.

To help homeowners make the right choices, the Australian government has created a website called "YourHome" as a guide to planning, building, and renovating environmentally sustainable homes. The website offers information to the public on options for different types of appliances, operating cost comparisons, and GHG emission comparisons.[13]

Figure 5. Fully installed reverse cycle air conditioning unit

Financial considerations

There are certain financial obstacles homeowners may face in the transition to an all-electric home. A goal of our project is to educate homeowners on the options available to help overcome the financial hurdles of this transition and promote sustainable practices in their community. Purchasing new appliances and paying for their installation are upfront costs. For example, in the Palo Alto program, the CPAUD found that electric panel upgrades for a full transition to electric appliances might cost anywhere from 2,500 to 5,000 USD. [12]

However, some costs can be lessened. For example, the city of San Francisco, California, USA, encouraged 10,000 homeowners to replace their water heaters with energy efficient ones; the city partnered with manufacturers to facilitate a bulk buy program, selling the heaters at a lower cost.[14]

In Australia, the Renewable Energy Target (RET) program provides small-scale technology certificates (STCs) to homeowners who purchase electric water heaters. These certificates can be redeemed for cash based on market worth (currently around 40 AUD per certificate). Most of the time, these certificates are factored into cost estimates for homeowners, serving as an upfront discount that can range from a few hundred to over one thousand dollars. The number of certificates homeowners receive is based on the amount of energy the appliance will produce over its lifetime, the location of the home, brand of appliance, appliance model, and installation date.[15]

Behavioral considerations: It's a matter of trust

Community trust is a concern when marketing sustainable practices. A previous WPI project with

MEFL and Positive Charge looked at barriers of sustainability adoption within the Moreland community, finding that trust between the community and the organization advocating change played a major role[15]. Residents were most trusting of "neighborhood houses" — public spaces, run by the Moreland City Council local government, where community members can go to meet new people and participate in educational, social, recreational, and support programs. Respondents also trusted local cultural groups in which they were members. Other commonly trusted groups are listed in Table 1.[16]

The power of trust was best shown in MEFL's GreenTown program. Partnering with Environment Victoria, another organization focused on improving sustainability, MEFL developed a campaign to improve sustainable practices within culturally and linguistically diverse (CALD) communities. Previous attempts proved highly ineffective due to materials printed only in English. These materials also did not target cultural practices of specific neighborhoods. GreenTown changed this by working with members of several CALD communities across Victoria, delivering home energy assessments and recommendations for improvements in the residents' native languages, and through a familiar face — a member of their own community. This not only led to greater participation, but also to revelations about cultural differences relating to sustainability that could be addressed. For example, GreenTown found that many Arab households tend to have unusually high water usage because it is a cultural standard to wash dishes in the sink under running water; adding a flow reducer to the sink allowed for cultural practices to stay in place while having a positive impact on the environment. Assessments offered in the same language and from familiar community members established trust, allowing MEFL and Environment Victoria to reach over 13,000 people. A follow-up survey determined 97% of these residents had learned something about sustainability.[17]

Table 1. Trusted sources of gathering information within the community[15]

Type of Group	Percent of respondents who trusted this group
Neighborhood Houses	100%
Local Cultural Group	50%
Sports/Recreation Club	40%
Faith/Religious Group	33%

Reaching the masses

The WPI project also advised Positive Charge on how effective communication could be established with different demographics within Moreland. The group found that the 65 year and older segment was most difficult to reach due to the number of telemarketer phone calls they receive daily, making them untrustworthy of phone solicitation. Positive Charge was also not connecting with younger, 18 to 34-year-olds, because social media and other popular channels used by this demographic were not utilized. Finally, the CALD community was not being reached in their native languages, which meant a large portion of the population was not receiving information.[16]

The role of Positive Charge

Positive Charge has taken these previous findings into consideration when offering services to homeowners. The services are free and without obligation, publicized through trusted city councils, who recommend Positive Charge to their residents. Positive Charge wants to become an "eco-concierge," serving as the party who researches, procures, and recommends products to homeowners – removing all the hard work from consumers. City councils would partner with Positive Charge for this service, allowing the homeowners in their community to sign up. Homeowners would not pay for the service, but rather, all products the homeowner purchases through Positive Charge would reward the Positive Charge team with a commission, factored into the overall cost. This allows the service to remain free for homeowners, city councils to increase their effectiveness within the community, and Positive Charge to make an impact on carbon emissions within the community.[18]

Running a service such as this one, however, requires community participation and willingness to change. Gaining the community's trust, MEFL relies on the endorsement of community leaders, organizations, and city councils to gain credibility. This has allowed MEFL to see much higher participation in their programs.

Positive Charge tasked us with creating outreach materials to persuade homeowners to transition to an all-electric home. Using the research outlined here, we proposed a plan of action to collect additional information from homeowners and alternative energy experts, information that would help us create persuasive and relevant content for effective outreach materials.

Methodology: Using research to develop persuasive campaign materials

In the previous section, we overviewed information on the transition to an all-electric home. We then conducted more local research to develop our campaign materials.

Objective 1: Identified issues in transitioning to an all-electric home

After gathering our background information, we investigated the technical, environmental, economic and behavioral issues more deeply through online research and interviews with local experts who understood these issues in the context of Melbourne.

Online research

We conducted online research about all-electric homes and reviewed demonstration projects that shared homeowners' journeys (e.g., Josh's Home[19] and The New Joneses[20]). These projects illustrated technical requirements and showed the steps homeowners took to complete the all-electric transition. This helped us identify specific appliances that comprise all-electric homes. From an economic and environmental standpoint, we researched the general price and efficiency for each type of appliance comparatively. However, because this campaign may not be immediately dispersed and the information could be obsolete by the time of distribution, we did this to gain a general idea of the current state of the market and the technology. We also compiled information about the technical issues from various organizations' websites such as Beyond Zero Emissions[21] (BZE) and the Victorian State Government[22].

Interviews

We interviewed sustainability experts, including Jason Cox, Rachel Maddocks, and Lucy Best from MEFL; trailblazers in the sustainability field, including Ross Harding, CEO of Finding Infinity, and Donna Luckman, CEO of the Alternative Technology Association; and local government officials, including city councilwoman Katherine Cocks. We designed interview questions on each transition topic, tailoring questions to the interviewee's expertise. All interviewees gave verbal consent (see Supplemental Materials, Part B). Examples of the questions we asked are given in Table 2, while complete interview scripts and notes are in Supplemental Materials, Part C.

Table 2. Example interview questions, segmented by topic

Example Interview questions	
Consumer Attitude	
Where do you think the community may be most hesitant towards changing out their appliances?	*When considering sustainability, what are the most important factors for homeowners and why?*
Technical Requirements	
Could you describe some of the steps a homeowner would need to take to become all-electric?	*How can homeowners remove their existing gas appliances and sources, perhaps recuperating some of their losses?*
Financial Impacts	
What can be done to address the costs of becoming all-electric?	*Are there incentive programs besides the ones that Positive Charge offers, in place to help [homeowners]?*
Environmental Difference	
Why do you believe all homeowners should care about their emissions contribution?	*While working with many local governments, have you found that most are willing/want to work to become more sustainable?*

Objective 2: Assess attitudes of homeowners in Melbourne

Although we learned about homeowner attitudes from our background research and expert interviews, we wanted to obtain more information from local homeowners themselves. We designed a homeowner survey of 22 questions, to help us understand how homeowners thought and felt about the topics below so we could then tailor our materials to them.

What is the current state of the home?

The different condition of homes was identified. We asked how many people live in the home, the size, and the age of the home (older homes tend to suffer from draughts and energy inefficiency).

What power sources are used in the home?

We asked what power sources are used for specific appliances. By asking homeowners to categorize

their cooktop, water heating, and home heating from a list of common types we found in survey pretesting, we were able to establish the point at which the average home might start the transition to all-electric and to identify appliance preferences.

How much do homeowners spend on gas and electric bills?

This gave us context for understanding the financial implications of the transition. MEFL staff helped us determine appropriate price brackets for costs per quarter; we asked homeowners to choose the bracket that suited them.

Why have homeowners transitioned or not transitioned to all-electric?

We asked questions that determined whether and why homeowners had transitioned or not. This showed what mattered most to homeowners. We filtered homeowners into four groups (those who had transitioned, those in process, those interested in beginning to transition, and those not interested), allowing us to compare the attitudes of homeowners across and within each group.

What level of transition might homeowners commit to?

We asked all homeowners if they would rather do a complete transition all at once (including renovations), transition over time, or something in between. They categorized how much they were willing to spend per year on this transition, giving us an idea of an average budget. In addition, we gathered information on whether their city council's involvement would influence their willingness to consider different levels of transitioning, giving us the ability to reassure city councils their homeowners wanted this campaign.

What is the best medium for communication?

To determine the best medium for reaching homeowners, we asked them their age and to choose from a list of media they utilize. This allowed us to compare findings with the previous MEFL studies while ensuring up to date preferences of each demographic. Example survey questions can be found in Table 3 on page 7; the complete survey can be found in Supplemental Materials, Part E.

Our survey was distributed using Qualtrics to 11,465 homeowners on the Positive Charge email list, all in inner Melbourne. A preamble established the respondent's rights (Supplemental Materials, Part F). Respondents were incentivized to complete the survey with a raffle prize. The survey was completed by 963 homeowners. This 8.4% response rate was an improvement over the sponsor's anticipated response rate of 1-2%.

As a part of our survey we asked homeowners if they would be interested in an interview about their thoughts on sustainability and the transition of their home. We planned to turn these homeowner interviews into case studies for Positive Charge and city councils to use to encourage behavior change. We received 281 affirmative responses to interviews and divided these homeowners into three categories based on their home's current position. These three groups were *completely transitioned*, *currently transitioning*, and *have not transitioned*. We then looked at responses to specific questions to determine which interview candidates would be best for case studies. We emailed between five and eight homeowners from each category and began conducting our interviews and building case studies.

Objective 3: Encourage behavioral change through outreach materials

Through background research, interviews, and surveys we outlined all the components of transitioning to an all-electric home. We also identified potential barriers for homeowners and determine the key information they wanted to see, helping us to create campaign content.

When interviewing experts, we also asked them about the goals and strategies they would suggest for persuading homeowners (see Table 4 for sample questions; Supplemental Material, Part D, for scripts).

Table 4. Example questions posed to experts about effective campaign materials

Deliverable	
Are there any government incentive programs for homeowners to change their behavior?	*Is taking a home completely off the grid the end goal, or do you believe the end result should make homes produce more than they consume?*
What kind of program do you envision helping homeowners become educated on the products and process they must undertake to retrofit their homes?	*If you were to distribute a singular page of information to educate people on the transition, what 3 key points would you want addressed?*

Table 3. Example homeowner survey questions (continued on right)

Homeowner Survey Example Questions		
Target Information	Question Number	Example Question
Starting condition of a home	5-6, 11-12	*How old is your home? (in years, approximately) [Enter number of years]*
Power sources for appliances	7-10	*What type of home heating do you use in your home? (Check all that apply)* • *Gas* • *Reverse cycle air conditioner (heating)* • *Electric/Electric Space Heater* • *Wood Burning* • *Hydronic* • *None* • *Unsure* • *Other (Please specify)*
Gas and electric expenses	13-16	*On average, how much do you pay for electricity to your home each quarter? (Choose one)* • *$0/qtr* • *$1-$249/qtr* • *$250-$499/qtr* • *$500-$749/qtr* • *$750-$999/qtr* • *$1000+/qtr*
Why/why not transitioned	17-23	*What factors contributed to your transition to an all-electric home? (Check all that apply)* • *A friend recommended the transition* • *My council recommended the transition* • *Government incentives* • *I wanted to save money on energy bills* • *I wanted to lower my emissions* • *My house already had electric power* • *I installed solar panels and wanted to use the energy they generate* • *My existing appliances were already electric* • *Other (List all)*
Level of homeowner commitment	24-27	*How much money would you be willing to spend towards becoming all-electric? (Choose one)* • *$0/yr* • *Less than $500/yr* • *$500/yr* • *$1000/yr* • *$3000/yr* • *$5000/yr* • *$5000+/yr*
Best medium to connect with homeowner	28-30	*If your city council did the research and provided you with information about the procedure and costs for transitioning to an all-electric home, how likely would you be to participate? (Choose one)* • *Highly likely* • *Likely* • *Not likely* • *Not at all* • *Unsure*

This expert advice informed our approach and materials. We also asked for general opinions about the all-electric home, such as the necessity of solar panels and how the electrical grid fits into the picture.

To choose a design and medium, we considered homeowner feedback, expert interview knowledge, and modified MEFL's previous campaign templates. We also examined campaign materials from other effective organizations, such as the ATA and BZE to determine formats and channels that were most effective. We considered print and online formats, drafting several iterations with feedback from sponsors.

A recap of our entire research and design process can be found below (Figure 6).

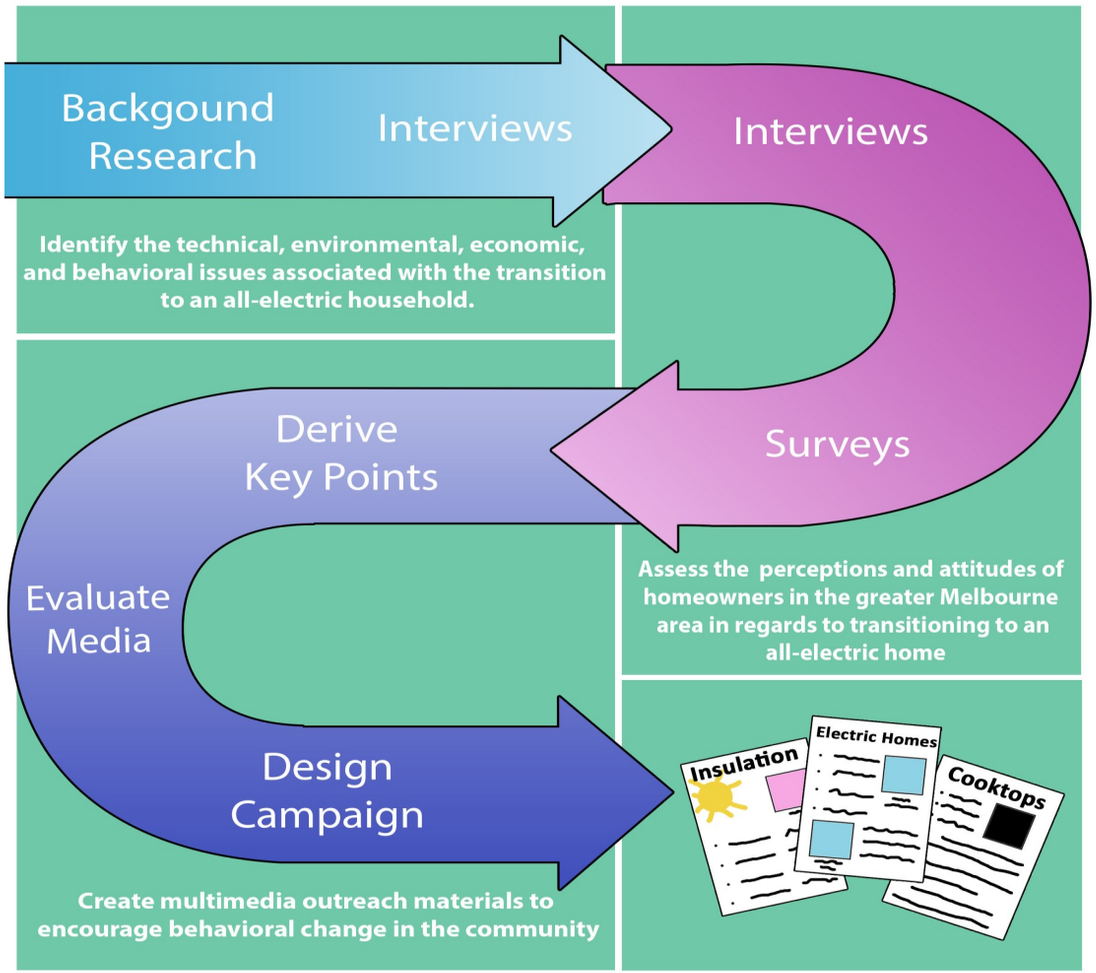

Figure 6. Summary of methods followed to create campaign materials

Results and outcomes: Through the eyes of the homeowner

This section summarizes our final results and deliverables.

Online and expert advice on technical and behavioral issues

A cooktop can have a gas range, a ceramic electric range, or work through induction. The important points we found for each appliance were: reverse cycle air conditioners can be used to cool and to heat, heat pumps extract heat from the environment and only use electricity as needed, and that induction cooktops heat up pans through magnetism, not directly through the cooktop. Complete notes from our research on these appliances can be found in Supplemental Materials, Part I.

Through our interviews with various sources, we have identified some parallels in topics of discussion and kept these points in mind upon creation of the materials. These points include the following.

The importance of comfort and health

We have learned that homeowners are not willing to compromise the comfort of their home to save money on monthly utility bills. Since each homeowner has a unique definition of comfort, each will have different standards. Many people also emphasize that a comfortable home is a healthy home. With the global temperature rise, summer days are getting more extreme. Especially for vulnerable groups, such as the elderly or very young children, maintaining a constant temperature of their home is essential to good health.

Homeowners do not have much knowledge of appliances

Experts suggested that homeowners did not have much knowledge of current technologies available for appliances in their home. Positive Charge employees advised we include appliance options in our materials.

Behaviors of homeowners can be irrational

MEFL staff indicated that there was sometimes no rational force behind homeowner decisions. This was indicated especially in homeowners with solar, who were described as getting solar because they see it on other homes and believe that it must be the norm. The staff explained to us that, ideally, solar panels are the last step in the transition to an all-electric home because homeowners should transition their appliances and reduce their usage as much as possible to optimize the size of the solar system they purchase. Some homeowners even purchase solar panels while they still have gas appliances, limiting the amount of solar energy the home can actually use. Because of this, in order to induce change, certain strategies must be taken to encourage homeowners. This includes making the campaign a community effort— setting a goal within the community to reduce emission or have a target number of homes to transition. This strategy requires the coordination of city councils and community leaders so that the homeowners are getting information from sources that they deem trustworthy.

Melbourne homeowners: Attitudes and knowledge about transitioning

124 of the 963 survey respondents were non-homeowners, so we only analyzed the remaining 839 surveys from homeowners. We also followed up with face to face interviews with several homeowners who were willing to be interviewed. The data gathered from these 839 homeowners led us to the following conclusions.

Older homes with multiple residents

We found the average home to be 59 years old, with the oldest being 170 years. This aligns with our expectation of the building stock being outdated in inner Melbourne. Respondents' homes were typically 3 bedrooms, with 2 to 3 occupants— most were living with families or partners. We learned that homes with multiple people occupying them used more energy that homes only housing a single person.

A preference for gas-powered appliances

An overwhelming number (82%) of homeowners use gas to power their cooktops. This stems from cheap gas prices combined with perceptions of its superior cooking performance speed, familiarity with the fuel, aesthetics, and ability to control heat.

A large number of respondents (68%) indicated they use gas for water heaters, although a small percentage (14%) reported using solar water heating. Instantaneous gas water heaters are popular due to their ability to immediately meet demand without storing any hot water. Solar prevalence is due to previous government incentives and programs within the community to adopt solar water heating.

Electricity used for some heating and cooling

Although gas was most commonly used for home heating (68%), a significant number of homeowners (39%) use electric reverse cycle air conditioners to heat their home. This contradicted experts' estimate that many homes are not using their reverse cycles for heating in the winter. Fifty one percent of homeowners cool their homes with reverse cycle air conditioners, in combination with ceiling or tabletop fans (40%). A large portion of respondents (20%) said they still utilize electric evaporative coolers, which disperse cooled water vapor throughout ducting inside a home, however, have poor efficiency due to their lack of insulation, suggesting many homes have room to improve the cooling systems within their homes.

We also looked at correlations between each of the most popular power sources (Table 5, on page 10). The strongest correlation was between those who owned reverse cycles for both cooling and heating. The remainder of the methods – gas, electric, hydronic, and evaporative — did not correlate with one another to any large strength. This indicates that many homeowners do not own appliances that are of a singular power source, gas or electric, but have both.

In addition, homeowners who reported having gas cooktops were not as likely to report having other gas appliances in their home. This suggests that it might be logical, as gas prices continue to rise, for homeowners to replace their gas cooktop with electric induction. They could be paying higher gas connection fees for just one appliance, therefore, justifying a higher upfront cost of a new induction cooktop. This would be especially true for those who own a solar PV system large enough to power all appliances, as that could help reduce their electric bill and would eliminate their gas bill entirely.

How much do homeowners spend on gas and electric utility bills?

An overwhelming number of homeowners (92%) spend less than $500 per quarter on their electric bills. This is split fairly evenly (44% to 40%) between those

Table 5. Correlation of power sources within a home

	Gas water heating	Gas cooking	Gas cooling	Electric cooling	Rev. cycle cooling	Evaporative cooling	Hydronic heating	Gas heating	Rev. cycle heat	Electric heating
Gas water heating	-									
Gas cooking	0.23**	-								
Gas cooling	0.02	0.05	-							
Electric cooling	0.03	0.00	0.01	-						
Rev. cycle cool	0.03	-0.04	-0.07*	-0.21**	-					
Evaporative cool	0.07*	0.07	-0.02	-0.08*	-0.36**	-				
Hydronic heating	0.01	0.01	-0.03	-0.04	-0.07*	0.05	-			
Gas heating	0.24**	0.25**	0.05	0.15**	-0.13**	0.23**	-0.26**	-		
Rev. cycle heat	-0.05	-0.10**	-0.05	-0.17**	0.74**	-0.28**	-0.14**	-0.21**	-	
Electric heating	0.01	-0.01	0.03	-0.01	0.03	-0.07*	-0.06	-0.11**	0.02	-

Notes: % that responded "Yes"

who spend less than $249 and those who spend $250-$499. In regards to gas bills, most homeowners (75%) spend less than $249 per quarter to power their appliances. Nearly half (48%) spend between $100-249. Overall, we gathered that electric bills are higher for the average homeowner than gas bills, however, this can be attributed to the fact that more of their appliances are powered by electricity, including lighting and electronics, while gas has limited demand.

Becoming all-electric can remove most homeowners' gas bills, saving them $400-1000 per year in usage costs and additional fees connecting the gas line to their home. While becoming all-electric would raise electric bills, electric-efficient appliances and proper insulation would minimize this increase. Adding solar panels to a home would further reduce the operating cost.

Reasons homeowners transition or do not transition to all-electric

To determine why or why not a homeowner has transitioned to all-electric, we first looked at the frequencies of the responses where we asked why or why not they transitioned. Of all respondents, 5% had fully transitioned and 8% had already started. Of the other 87% who have not started the transition, 36% said they would consider it while 51% said they would not.

The most common reasons some had transitioned or had begun the process were environmental or economic. In order of frequency, respondents answered *to lower my emissions*, *to fully utilize my solar panels*, *to reduce my energy bills*, and *because my home already had electric power*. Fourteen percent also said it was partly due to their city council recommendation. This is significant, showing city councils had a bigger impact on a homeowner's decision than our previous research had suggested.

We asked those who said they would not transition, what their reasons were. The options included *no consideration*, *the upfront cost*, or *extensive infrastructure changes*. Contrary to our previous research, we found that homeowners were not afraid of researching the appliances on their own or of the extensive payback time. It is evident that they are aware that there will be a payback. However, we learned that they hesitate on the upfront cost for the appliances, the renovation to their home, and not having enough motivation to take action.

Homeowners appear to be satisfied with their gas appliances. While they want to save more money, owning a gas appliance does not affect whether those interested in the transition want to know more about "opportunities for long term savings" or "costs associated with the transition." Homeowners appear to want to learn how to save money on their utility bills without giving up their gas appliances.

The amount people were willing to spend did not relate to wanting to know more about the opportunity for long term savings or the costs associated with the transition. This suggests that homeowners willing to spend money were not concerned with the upfront costs and are aware of the long-term payback. But those who did not want to spend the money also did not care about the long-term payback. Similarly, homeowners who installed solar panels did not want to know more about costs associated with the transition. Although utilizing solar panels and electric

appliances simultaneously will significantly reduce a homeowner's energy bill, this is not common among homeowners. These irrational behaviors suggest that homeowners install solar panels to have a sense of satisfaction in generating green electricity, rather than their desire to install appliances to consume it. One reason to transition is to save on utility bills, but some homeowners cannot justify the upfront costs for long-term payback. Educating homeowners on the financial implications behind the transition would potentially help.

We conducted a logistic regression to predict whether respondents answered "I want to know more about the costs associated with the transition" and to determine what factors impacted their desire to know more about the costs. This regression (Table 6) was able to successfully model 36.9% of the population. Interestingly, except for homeowners that had gas cooktops, no other survey questions about home appliances predicted a "yes" response. This suggests that targeting homeowners who exclusively use gas for cooking may be a population that could potentially be interested in learning more about these cost savings and could eventually be convinced to make the switch. Further, homeowners who were willing to invest more upfront costs, were interested in learning more about government rebates, and were interested in learning about long term savings were more likely to respond "yes". This is suggestive that addressing the financial aspects of the transition (both costs and benefits) would be of interest to homeowners.

What level of commitment do homeowners have?

We asked homeowners interested in transitioning and those who already started how much they would be willing to spend per year to transition. For those who were uninterested in transitioning, we categorized

Table 6. Logistic regression to determine factors contributing to wanting to know more about costs

Factor	B	Sig.
(Constant)	0.073	0.48
Your Age	-0.017	0.444
Gender	0.05	0.098
How old is your home? (In years, approximately)	0	0.541
How many bedrooms are in your home?	0.019	0.332
How many individuals live in your home?	-0.03	0.057
On average, how much do you pay for electricity to your home each quarter?	-0.014	0.489
On average, how much do you pay for gas to your home each quarter?	0.035	0.093
Do you have Solar Panels on your home?	0.013	0.676
Gas home heating	0.014	0.727
Reverse Cycle Air Conditioner (Heating) home heating	0.013	0.778
Electric/Electric Space Heater home heating	0.031	0.501
Hydronic home heating	-0.032	0.549
Gas home cooling	-0.152	0.279
Electric home cooling	-0.02	0.718
Reverse Cycle Air Conditioner (Cooling) home cooling	0.014	0.768
Evaporative home cooling	0.015	0.729
Gas cooktop	0.087	0.036*
Gas water heating	0.036	0.402
Solar water heating	0.092	0.088
How much money would be willing to spend towards becoming all-electric?	0.032	0.003*
[I would like to know about] Available government assistance	0.301	0**
[I would like to know about] Opportunities for long term savings	0.323	0**

Notes: Respondents who would not consider the transition were considered to have answered $0/year.
*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed)

them in the $0 per year bracket. We found that of those who had not transitioned, 52% would not be willing to spend any money at all per year, 13% would be willing to spend up to $500 per year and 35% would be willing to spend more than $500 per year. Knowing that the transition can be made over a long time period by switching appliances as they need to be replaced, the transition may be more financially practical for homeowners than they may think.

In addition, we asked homeowners to gauge their interest in participating in a program sponsored by their city council providing guidance on the procedure and costs of going all-electric. What we found was that most homeowners (83%) would be interested in hearing more on the procedure and costs around the all-electric home from their city council. While 38% may not be considering the transition now, only 4% overall do not want to hear more on the all-electric home. This is tangible evidence for city councils that homeowners are open to hearing more information about this, even if they may not want to take immediate action.

Overall, many homeowners may be willing to consider the transition and invest yearly towards becoming all electric, whether that be to draught proofing or install electric appliances.

What is the preferred medium for communication?

Finally, we looked at the preferred media for reaching homeowners. The most frequently mentioned channels of communication were, in order of: email, internet site, city councils, live demonstrations, and community groups- although there exists an inherent bias in that our survey was only administered by email. However, even considering the bias, this aligns with the previous MEFL study— residents look for information from trusted neighbors and councils.

How did research and interview findings contribute to design?

Based on our research and interviews, we implemented our findings into our outreach materials. Due to costs and technology of appliances constantly changing, we decided not to focus on appliance specifics— the individual brand, cost, and levels of efficiency— in our materials.

Learning that upfront cost was a major factor strongly influenced our writing of the campaign materials, as we focused on the cost savings over time. We highlighted that the whole process need not happen all at once, with the goal of not overwhelming the target audience with the prospect of a high upfront price tag.

Creation of outreach materials

The above findings led us to the creation of our campaign. Through the survey and interviews, we learned that people do not respond well to large amounts of information at once; therefore, we created granulated materials of different lengths so that homeowners can access more information at their leisure. We created five separate materials for Positive Charge to distribute: A postcard, a double letter, an A4, case studies, and a mockup of a website. Each deliverable was designed from past templates provided by Positive Charge, maintaining consistency with their brand.

Postcard

The first component of our campaign was a postcard (Figure 7), introducing homeowners to Positive Charge and the idea of an all-electric home.

A simplistic theme highlighted main ideas and drew viewers in.

The diagonal line was consistent throughout the campaign creating a recognizable style.

Details were added to the back as an over-view of the all-electric home.

For more information, the Positive Charge website link and phone number was added to the bottom.

In all materials, a small space was left for the logo of any council that buys this campaign.

Figure 7. Postcard: Front and back

Double letter

The double letter, or DL, (Figure 8) is a double sided, envelope sized letter that city councils will mail to homeowners and place near reception desks in the city council buildings.

A green electric supplier was introduced, should the homeowner not want to get solar.

Different options were presented to homeowners, to show they can transition in the way that works best for them.

Bullet points identified the four components of the all-electric home.

Benefits were advertised to make the transition sound easy and attractive.

More detailed information gave homeowners a deep understanding of the campaign for all-electric.

Figure 8. Double Letter (DL): Front and back

A4

Our sponsors also asked us to create an A4 (Figure 9) which is best described as a large double sided fact sheet. The A4 is used by both Positive Charge as well as city councils to help understand, in further detail, the aspects of the all-electric home.

A call to action was used in the main title to draw the reader's interest.

Information was presented on why the all-electric home is a good option, as well as a brief overview on the components.

A case study from a local family was used to make the transition seem tangible.

Details on each individual part of the all-electric home were introduced.

FAQ and answers were given on how to start the process and why homeowners should transition.

Figure 9. A4: Front and back

Case Studies

As we stated previously, word of mouth is effective for sparking change in a community. A case study (Figure 10) is an efficient way to facilitate this. Through case studies, we can share the experiences of homeowners in Melbourne.

Each title was chosen to highlight an important benefit from the homeowner's transition.

Each case study was summarized to give an overview of the story while showing others how simple it can be to transition.

Case Study

positive charge

Reducing utility bills by going all-electric

Jon Rawlings and his family moved into their Melbourne home about three years ago. Due to the high bills incurred from heating their home with underfloor electric slab heating, the family looked to becoming more efficient and all-electric. With advice from Positive Charge and personal research, Jon felt prepared to begin making his journey.

"...although we may not be at the very vanguard of eco-change we are trying to do as much as possible within our means."

In the past 3 years Jon and his family have installed a reverse cycle air conditioner, heat pump water heating system, energy efficient washer machine and dishwasher, 5 kW solar array, and replaced lights with LEDs. All these upgrades have helped to reduce their gas and electricity bills year round.

"We decided that although going solar and all electric would cost money and may have a long payback, for those who can afford to, we must do what we can now"

Despite the low cost of gas appliances, Jon opted for the electric alternatives for two major reasons; to reduce his family's gas bills and to gain a sense of satisfaction knowing they were making a difference for the environment.

"It is clear we need to act with urgency on reducing our carbon emissions..."

Jon hopes that in the next two years he will be able to complete his journey to all-electric and no longer be reliant on gas. Currently he is working on doubling glazing his windows, while considering:

Jon and his family couldn't be happier with their move to all-electric and solar.

"The next stage of the transition to low carbon living is to replace the gas cook top with an electric induction stove"

A family picture was used to create a personal connection for readers.

Quotations were added to bring in the voice of the homeowner about the transition.

Figure 10. Example homeowner case study

Website

One of the most important components of our campaign will be the website (Figure 11), a place where interested homeowners can navigate to the links and details they most want. The website contains all of the information we have gathered about the all-electric home— the specific components, the benefits, as well as some of the barriers.

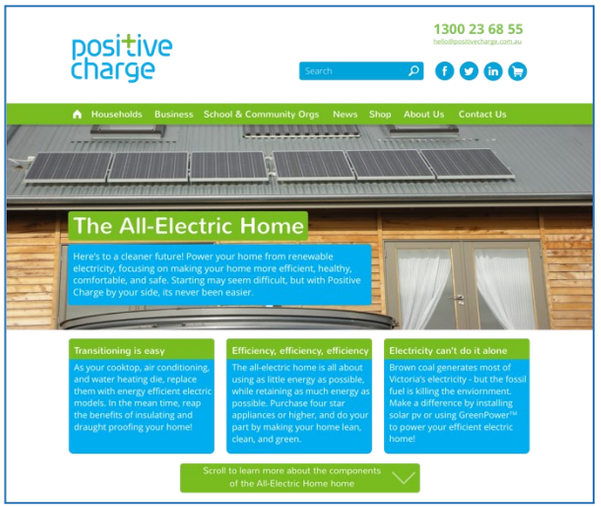

Image of solar panels on roof, gave readers immediate idea of electric home and the text established immediate benefits.

Three boxes mimicked site's column style and established general overview of all-electric home: ease, efficiency, and environment.

Diagram highlighted part of home being spoken of.

Introduction described what the appliance is and how it works.

Second paragraph explained specific aspects of an appliance or answered a specific question about it.

Pro/con visual showed the gas vs electric debate and established what an appliance provides for the homeowner.

Explained how to begin, redirecting homeowners to PC hotline to secure specific advice and connect with suppliers.

Links to case studies for homeowners to read more about; used quotes to draw their interest.

Figure 11. Website home page (top), an appliance page (bottom left), and case study page (bottom right)

Recommendations and conclusions: The next steps

While working with the Moreland Energy Foundation we were able to interview 19 experts in the sustainability field, obtain survey responses from over 960 homeowners, and interview 8 homeowners about their transition to an all-electric home. We organized, analyzed, and interpreted the information to develop a campaign tailored toward MEFL and Positive Charge's vision and included information homeowners were looking to know more about.

With our campaign, Positive Charge will be equipped to encourage homeowners to transition to the all-electric home by making it simple and easy for them to obtain information on each component. This will help to reduce the amount of carbon emitted each year from the City of Moreland and help them reach their goal of becoming carbon neutral by the year 2050. Other councils that purchase the campaign from Positive Charge will also benefit in the same ways as Moreland.

In order for MEFL and Positive Charge to have this kind of impact, we recommend that Positive Charge take the following actions:

Educate homeowners on the economic implications of the transition.

Establish the mindset that homeowners are not paying for an entire appliance, but rather for a small additional cost to go electric when their gas appliances fail- a "delta". This delta is what should be considered upfront cost. Provide information on government assistance to reduce the upfront cost and information on the payback time for the appliances.

Emphasize that homeowners have the power to choose electric.

Ensuring homeowners are aware of the electric options before their appliances fail is critical towards the adoption of the all-electric home. Installers will try to convince homeowners to make a quick fix with a cheap, gas appliance. It is on the homeowner to be adamant with their decision to have electric installed.

Market the all-electric home not as an alternative, but as a strong rival to gas.

The all-electric home is safer, more efficient, and just as or more luxurious than a home that uses gas. As such, we recommend to portray the all-electric home as the strong competitor that is a sensible economic and lifestyle choice. Also, we believe that advocating for homeowners, to make leaving their gas companies simple, would further boost the appeal of electricity.

Gather additional case studies of homeowners, to inspire change in others.

Success stories and personal testimonies can influence a homeowner's decision making. Discussion of safety, comfort, and economics are all appropriate and effective points homeowners will want to know more about.

Emphasize green electricity or solar panels within the all-electric home.

Being all-electric is not enough to be environmentally conscious, as the generation of electricity via coal is just as bad, if not worse, than using gas. Pairing the all-electric home campaign with solar bulk buys, or recommending renewable electric companies, would be beneficial to the environment and to homeowner's utility costs.

Establish a minimum for homeowners to consider when purchasing appliances.

Informing homeowners of the minimum efficiency and size they should be purchasing would greatly enhance their experience with performance and economic savings. In addition, stress to the homeowner to purchase the most energy efficient appliances that their budget allows, providing an easy solution to reduce overall usage. We believe the usage of testimonies and text based research can help establish a good efficiency standard for the all-electric home.

Consider other appliances in future campaigns on the all-electric home.

Lights, computers, TVs, and laundry all consume electricity, yet we have focused mainly on the largest household appliances like heaters and cooktops. We recommend adoption of LED lighting and other, smaller appliances to further improve running costs and reduce environmental impact.

Supplemental Materials for this project (authorship page, survey and interview preambles, interview scripts and notes, full survey, research notes, and deliverables) can be found at http://www.wpi.edu/E-project-db/E-project-search/search, using key words from the project title.

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References

[1] National Aeronautics and Space Administration. (2016). A blanket around the earth. Retrieved from http://climate.nasa.gov/causes/

[2] Climate Change Authority. (2012). Targets and progress review: Fact sheets and (FAQ). Retrieved from http://www.climatechangeauthority.gov.au/node/169/

[3] Australian Government. (2015, April). *Rainfall deciles* [Adapted Image]. Retrieved from http://www.bom.gov.au/climate/updates/articles/ a010-southern-rainfall-decline.shtml

[4] Moreland Energy Foundation Ltd. About. Retrieved from http://www.positivecharge.com.au/about

[5] Climate Change Authority. (2014, June 18). *Carbon Budget Allocations for 2013 to 2050* [Image].

[6] National Oceanic and Atmospheric Administration. (2016). Global Analysis - August 2016. Retrieved from https://www.ncdc.noaa.gov/sotc/global/201608

[7] National Aeronautics and Space Administration. (2016). The consequences of climate change. Retrieved from http://climate.nasa.gov/effects/

[8] Department of the Environment. (2016). *Quarterly update of Australia's national greenhouse gas inventory: December 2015.* Australian Government.

[9] Office of the Chief Economist. (2016). *Energy in Australia 2015.* Department of Industry, Innovation, and Science. Retrieved from http://www.industry.gov.au/Office-of-the-Chief-Economist/Publications/Documents/energy-in-aust/Energy-in-Australia-2015.pdf

[10] Australian Greenhouse Office. (2003). *Global warming: Cool it!* Government of Southern Australia

[11] Australian Government. (n.d.). Energy-efficient appliances. Retrieved November 7, 2016, from http://yourenergysavings.gov.au/information/energy-efficient-appliances

[12] Sheyner, G. (2015, July 30). Palo Alto looks to get people to switch off natural gas. *Palo Alto* Retrieved from http://www.paloaltoonline.com/news/2015/07/30/palo-alto-looks-to-get-people-to-switch-off-natural-gas

[13] Australian Government. (n.d.). Australia's guide to environmentally sustainable homes. Retrieved November 7, 2016, from http://www.yourhome.gov.au/

[14] White, S., Turner, A. & Chong, J. (2016). What California can learn from Australia's 15-year millennium Drought. Retrieved from http://theconversation.com/what-california-can-learn-from-australias-15-year-millennium-drought-55300

[15] Australian Government. (2015, June 25). Small-scale technology certificates. Retrieved November 3, 2016, from http://www.cleanenergyregulator.gov.au/RET/Scheme-participants-and-industry/Agents-and-installers/Small-scale-technology-certificates

[16] Gillette, B., Inzerillo, T., Van Nostrand, T., Zhao, Y. (2015). Understanding Barriers and Incentives for Sustainability (Undergraduate Interactive Qualifying Project No. E-project-21315-204922). Retrieved from Worcester Polytechnic Institute Electronic Projects Collection: https://web.wpi.edu/Pubs/E-project/Available/E-project-121315204922/unrestricted/MEFL_Final_Report_Dec14.pdf

[17] Bailey, N. (2011). *Environment Victoria's program.* Victoria, Australia: Environment Victoria.

[18] Positive Charge. What we've achieved. Retrieved from http://www.positivecharge.com.au/councils/what-weve-achieved/

[19] Byrne, J. (n.d.). Josh's House. Retrieved October, 2016, from http://joshshouse.com.au/

[20] The New Joneses. (n.d.). Retrieved October, 2016, from https://www.thenewjoneses.com/

[21] Beyond Zero Emissions. (n.d.). Beyond Zero Emissions: Ten-year pathways to a zero-carbon Australia. Retrieved October, 2016, from http://bze.org.au/

[22] Australian Government. (n.d.). Your Home: Australia's guide to environmentally sustainable homes. Retrieved October, 2016, from http://www.yourhome.gov.au/