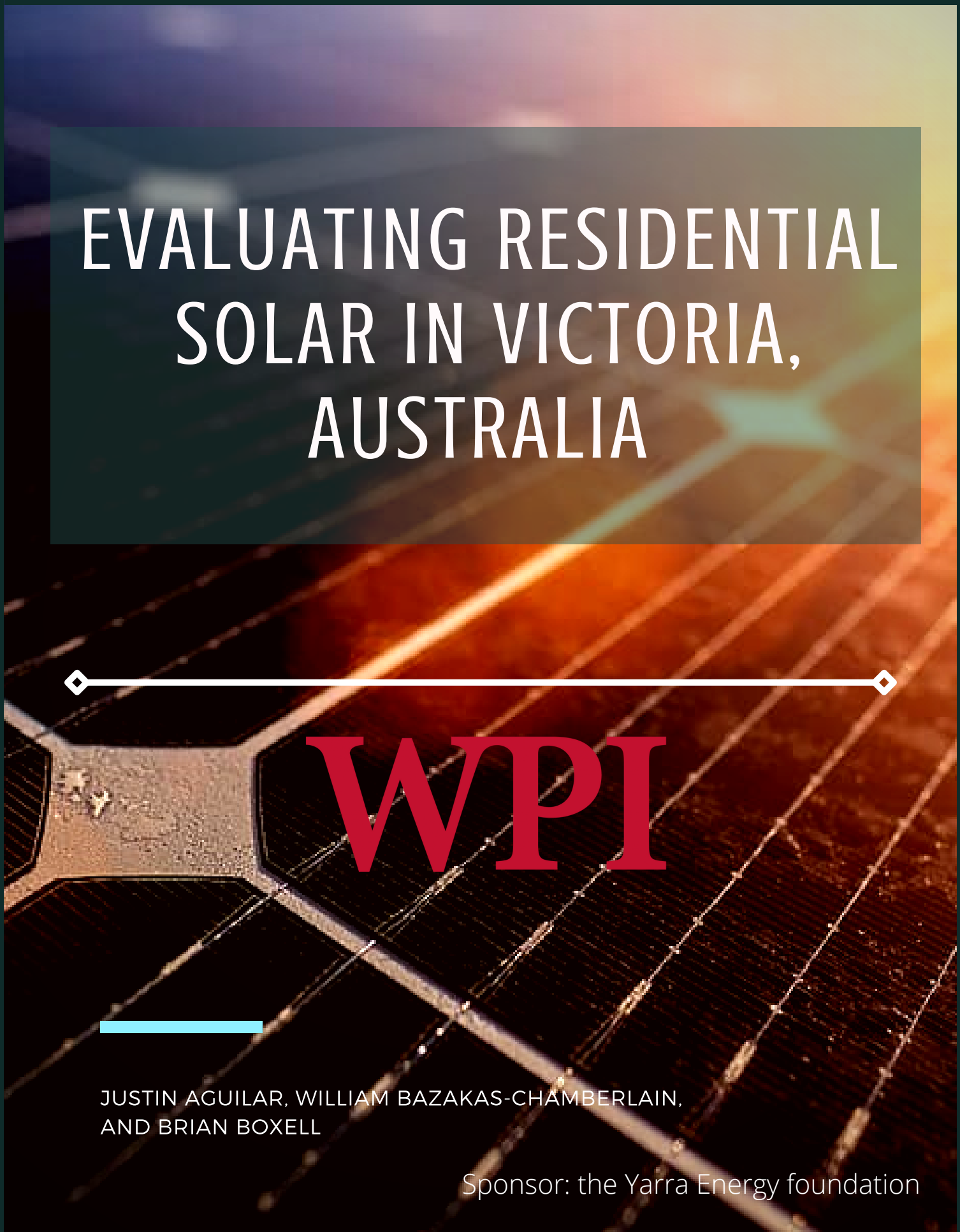

EVALUATING RESIDENTIAL SOLAR IN VICTORIA, AUSTRALIA

WPI

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Sponsor: the Yarra Energy foundation

ABSTRACT

Residential solar in Australia gives the common person the opportunity to fight the global climate crisis, while also saving on their personal energy bills. This project's goal was to understand why residents chose to adopt solar and analyze their experiences as solar homeowners owners. Through surveying and interviewing current solar owners, we identified the financial benefits of solar, the current client base, motivations for installing, and ways to further residential renewable energy.

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INTRODUCTION

Solar energy is on the rise in Australia, skyrocketing from 2% of the total energy consumption in 2016 to 7% in 2021. Despite this, solar still has a long way to go before it becomes the country's primary source of energy (energy.gov.au 2021). Slowly, solar and other forms of renewable energy, such as wind and hydro power are becoming increasingly viable and affordable. Not only do these renewable energy alternatives reduce natural gas emissions and pose little threat to the environment, they also pose an opportunity for significant financial savings for homeowners. (energy.gov.au 2021).

The residential sector is extremely important in pursuing energy transition, as it accounts for 10.5% of Australia's overall energy use (Australian Energy Statistics 2020), and household energy practices tend to influence the industrial sector (YourHome, 2021). Unfortunately, due to the expensive startup costs and the long overall installation process of switching to renewable energy, some are hesitant about adopting solar and remain dependent on fossil fuels. Currently, only 21% of residencies in Australia use solar PV systems (Australia Renewable Energy Agency, 2021). Persuading the rest of Australian homeowners to change to solar will be a challenge.

To address this challenge, the Victorian government is promoting renewable energy at the residential level. The government is actively working towards its net carbon-zero goal in the residential sector by presenting homeowners with plenty of avenues towards renewable energy. One initiative is the solar homes program, which offers a $1,400 AUD rebate on solar panel purchases to qualifying candidates. The government also provides funding to multiple renewable energy non-profits including the Yarra Energy Foundation which aims to work on local renewable energy projects.

The Yarra Energy Foundation (YEF) is a non-profit organization which has the goal of advancing renewable energy to create a greener, more climate friendly energy environment. By connecting homeowners to reliable solar panel and energy retailers, YEF, as well as other renewable energy organizations, make solar easily accessible to all homeowners by streamlining the solar installation process and making it as cheap, easy, and convenient as possible. To improve the solar user experience, YEF needs information on early adaptors' experiences with solar, and personalized user perspectives on their solar installations. YEF is looking to communicate with current users of solar to identify positives as well as deficiencies in all aspects of the solar user experience, so that they can adapt and improve their solar programs accordingly.

Part of streamlining the installation process and improving solar user experience is examining past residential solar installations to understand the landscape of the solar installation process. This entails communicating with current users of solar energies to inquire about their experiences, both with the installation process and their furthered experience with solar power. This will expose deficiencies in all aspects of the solar user experience and allow YEF to adapt and improve their upcoming solar programs and initiatives.

This project aims to provide Yarra Energy Foundation with data on the potential savings solar provides to homeowners, as well as an insight on the user experience that comes from owning a solar photovoltaic system. This information will allow YEF to continue to improve their solar energy program. In addition to providing YEF with this information, this project will present homeowners with paths to further their journey in adopting renewable energy. This includes informing them about programs that specifically target large energy consumers in the home like water heaters, as well as creating some informational material to help encourage homeowners to convert to solar. These insights will be invaluable to YEF as they continue to improve their solar energy program and help to contribute to the national push for net-zero carbon emissions one home at a time.

BACKGROUND

THE AUSTRALIAN ENERGY CRISIS

Despite being a country with an abundance of natural renewable resources and the potential to be a renewable energy powerhouse, Australia continues to be dependent on fossil fuels, being the world's second largest exporter of coal. (Hobday, Fulton, Pecl, 2018). Coal is an essential part of Australian life, being both an important factor of its economy and its primary source of energy. In fact, over two-thirds of Australia's energy production is sourced from coal alone, while all forms of renewable energy total a mere 2% (AU DISER, 2020). The Australian power grid is deeply rooted in coal, but as climate change worsens, the need to wane off of coal grows. The past decade has brought an unusually high number of natural disasters like the "Angry Summer" of 2012-2013 and the Black Summer bushfires of early 2020. Average temperatures are on the rise as well, promising summer heatwaves that will be devastating to local ecosystems and facilitate more disasters such as wildfires (Grose, Gergis, Canadell, Ranasinghe, 2021). These climate phenomena are increasing in both intensity and duration, and can only be mitigated by transitioning to a renewable energy regime.

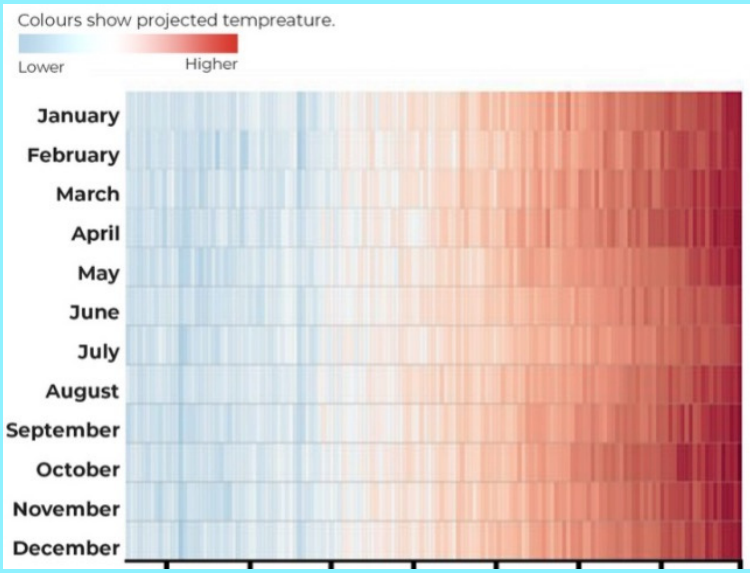


Figure 1: A Prediction of Warming Trends in Australia

The continent of Australia has the highest concentration of solar radiation of any continent, making it a prime candidate for the uptake of solar energy or photovoltaic systems. Still, however, less than 1% of Australia's energy production comes from solar, and it only contributes to 7% of the nation's energy consumption (Yu, Halog, 2015) (ministir.gov.au 2021). Solar energy is a promising alternative to fossil fuel because it is a green source of energy that can be easily accessed by almost all homeowners, especially in particularly sunny countries like Australia. However, photovoltaic systems are still a relatively young and undeveloped technology, and its commercialization is still being researched. Roadblocks like accessibility difficulties for some, support from government and utility companies, and bugs with the technology still stand in the way of solar energy becoming Australia's primary energy source. Technology must continue to improve and strive to address problems like accessibility and reliability issues to make solar an effective replacement for fossil fuels, and ultimately help guide Australia towards a net-zero emissions future.

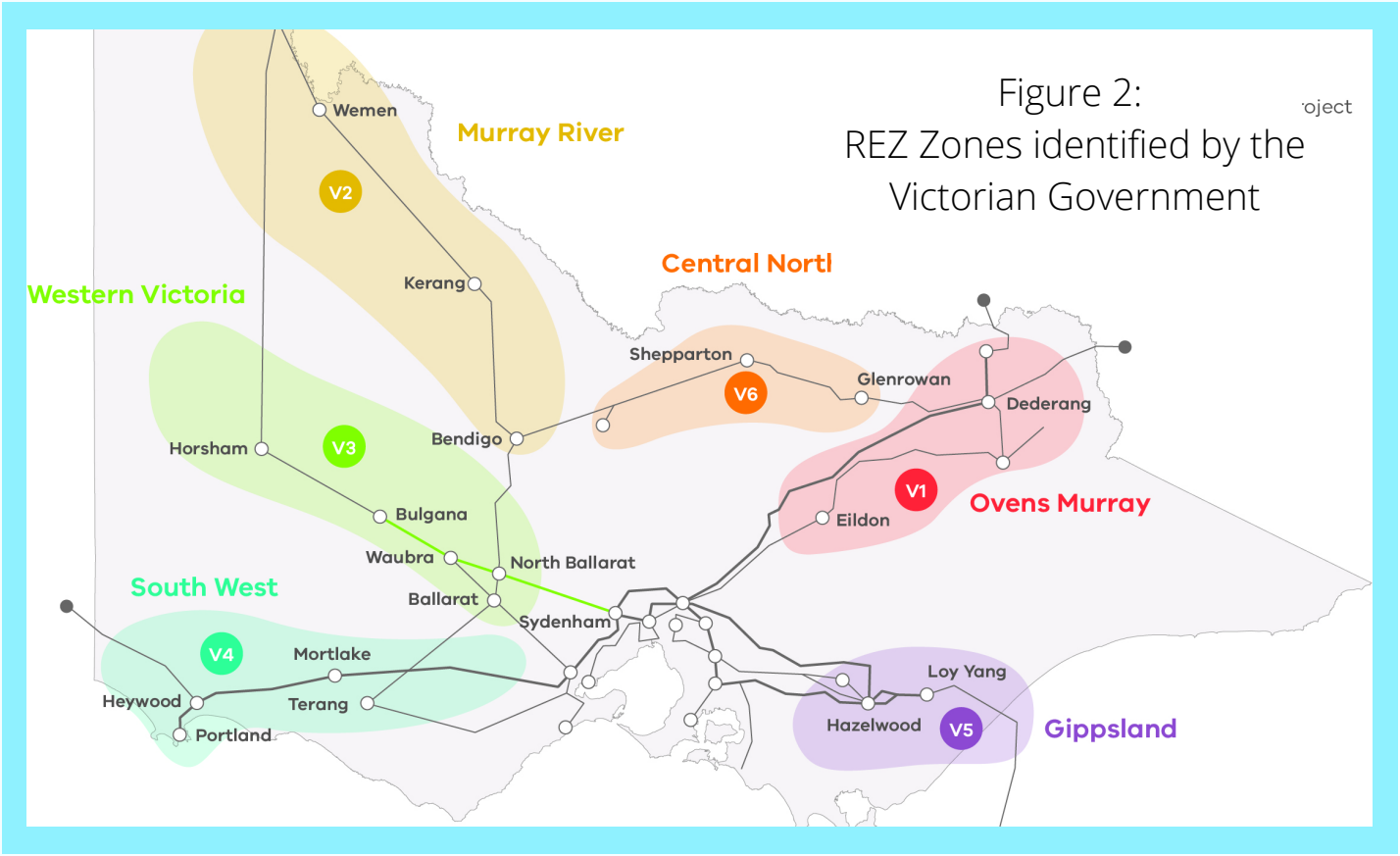
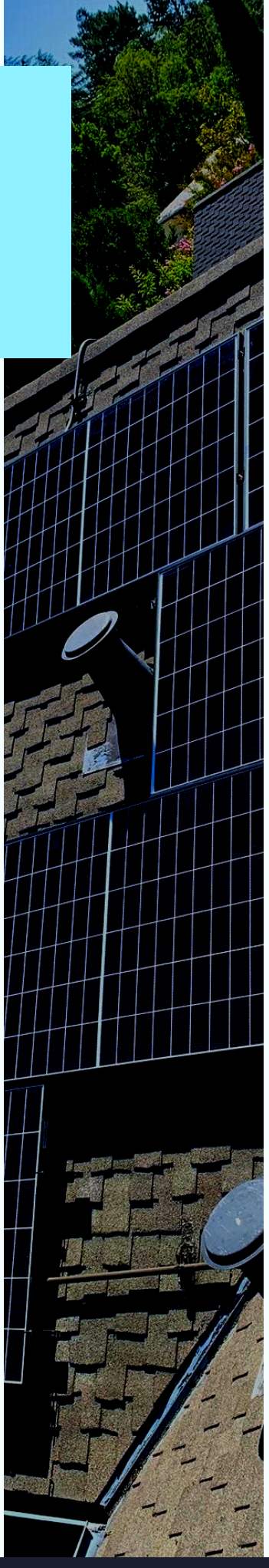


Figure 2:
REZ Zones identified by the Victorian Government

RENEWABLE ENERGY ZONES

Currently, most of the PV systems that are operating in Australia are small-scale residential panels, though there has been a steady increase in commercial installations in recent years (Australian Renewable Energy Agency 2021). Most of the photovoltaic installations in Australia have been done in the Victoria area, especially around the city of Melbourne. In order to help increase the number of solar PV systems in the Victoria area, the Victorian Government has developed a $1.6 Billion AUD clean energy package for the 2020-21 state budget to invest in renewables, grid infrastructure, energy efficiency and decarbonization projects. Given that infrastructure for the transmission of clean energy is a limiting factor in implementing more renewable energy, a large portion of this budget will go into developing Victoria Renewable Energy Zones (REZ). The idea of a REZ is to help the Victorian Government deliver new renewable energy systems faster and more efficiently by focusing on one REZ at a time. This will additionally help keep the process of delivering renewable energy systems more streamlined and can efficiently expand the renewable energy grid. The Government has already created a $540 Million REZ budget for creating this infrastructure (Australian PV Institute 2021). Since this is a very new initiative (released for consultation in February 2021), the government is still developing a system for future utilization. However, the REZ project shows the recent interest the Victorian Government has taken in increasing the amount of solar energy used by the community. This shows a promising future for the area regarding renewable energy, even with Australia's strong dependency on the coal industry.

SOLAR HOMES PROGRAM



In August of 2018, the Victorian government implemented the Solar Homes Program. This initiative enables more homeowners to get access to solar by providing government rebates on the cost of PV's. This program is only available to homes that have not previously participated and do not currently have PVs installed. The program also requires that participants have property valued at less than $3 million AUD and a household income of less than $180,000 AUD per year (Solar Victoria). Any homeowner that meets these requirements can apply for a rebate on Solar Victoria's website.

The rebates are estimated to cover about 50% of the startup cost of solar panels, with the amount being up to $1,400. To further reduce the up-front cost, homeowners can apply for an interest free loan up to the amount of $1,400. The loan is required to be paid off after four years but can be paid off sooner with lump-sum payments. This means if the total cost of a home's system is $2,800 or less, there will be no up-front cost to the homeowner. Despite this, the average cost of a solar system for an average 4-person home is between $5K to $7K in Australia, leaving many households unable to afford solar PV even with these rebates in place.

COMMUNITY POWER HUBS

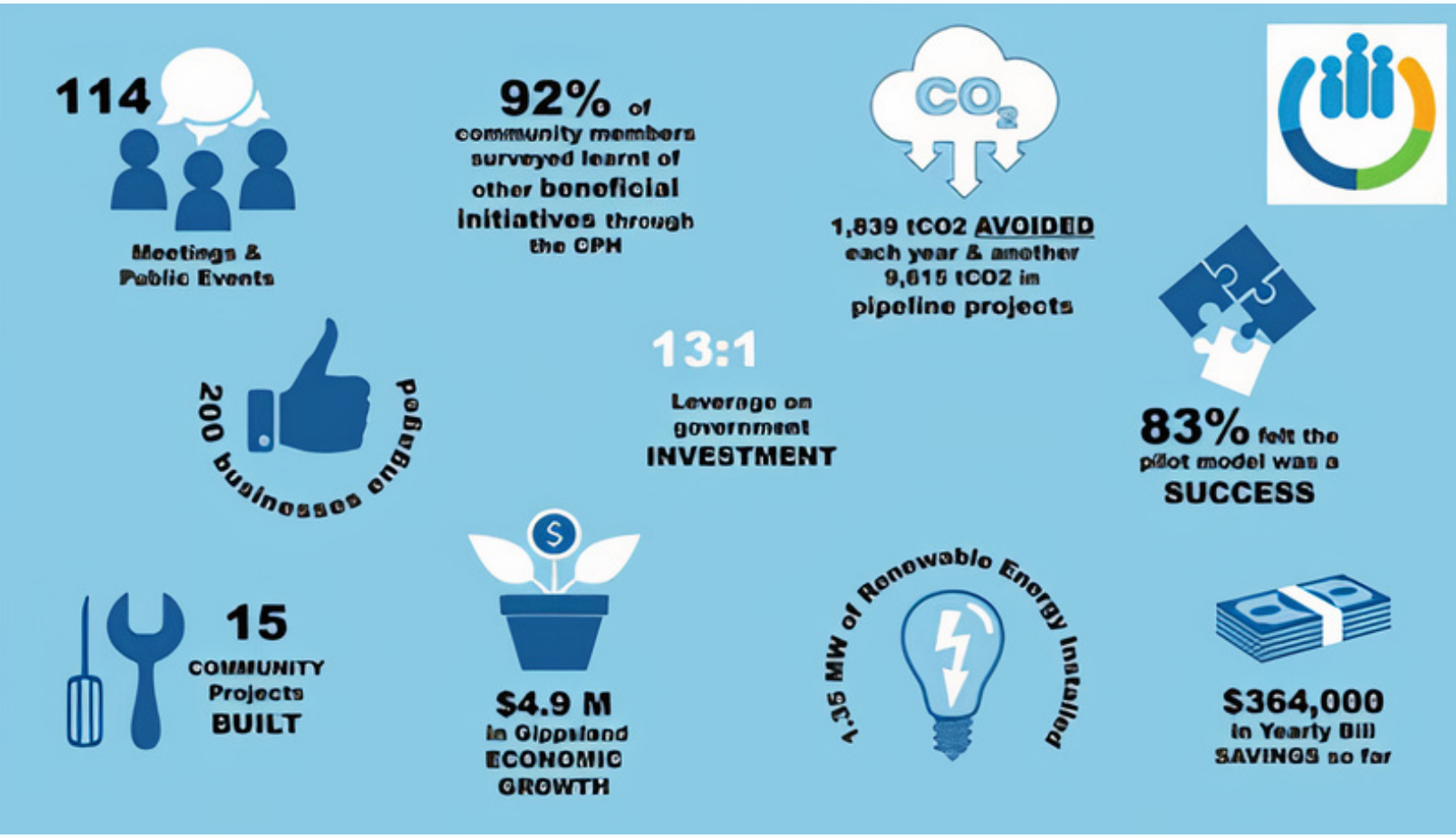


Figure 3: Infographic consisting of community power hub initiatives

State and local governments in Australia are actively working to promote solar energy and to help make it available to all residents interested. The state government of Victoria has created and helped fund seven community power hubs across the state. A community power hub is a collective of groups, organizations, and experts that collaborate to complete local renewable energy projects. These groups are instrumental in improving access to renewable energy sources like solar energy one community at a time.

The first community power hub was their pilot program in the Latrobe Valley in Gippsland. The Latrobe Valley Community Power Hub (LVCPH) successfully completed 15 local renewable energy projects and was responsible for $4.9 million in economic growth, all in its first 2 years (Community Power Hub, 2021). LVCPH paved the way for six more community power hubs to follow, including one headed by Yarra Energy Foundation.

YARRA ENERGY FOUNDATION'S INITIATIVE

Promoting renewable Energy

Yarra Energy Foundation is a not-for-profit organization established by Yarra City Council in 2010 whose mission is to spread the use of renewable energy across the state of Victoria. They provide services like solar install consultations and coordinating small renewable energy initiatives to help Victoria's residential sector achieve a green future. So far, Yarra has coordinated the installation of 18,000 Solar panels (which is equal to roughly 3 MW of installed solar PV) and helped over 4,000 people become engaged with solar energy.

YARRA ENERGY FOUNDATION

WHY HOMEOWNERS SWITCH TO SOLAR

In 2008, the total installed capacity of Residential PVs in Australia was 23MW. Eight years later, in 2016, this amount skyrocketed to 3700MW with approximately 16% of all Australian residencies having a PV system. This large increase can be attributed to a multitude of factors, including the increase of grid electricity prices, the decrease of installation costs for PV technology (primarily due to reduced silicon prices and the general optimization of the technology), and the implementation of government incentives for solar panel price rebates (Bondio, Shahnazari, McHugh, 2018). Australia's growth in residential solar PV systems shows no sign of slowing down, with an estimated 21% of all Australian residencies having a PV system as of July 2021 (AU DISER, 2021). This is great for Australia and its residents, but it is important to know why residents chose to or are planning to adopt solar technology in order to understand how Australia can sustain the growth of solar in the residential sector.

In 2014-2015, local utility companies in the Queensland region conducted the Queensland Household Energy Surveys which collected energy information from approximately 4,000 households in the state (Bondio, Shahnazari, McHugh, 2018). Figure 3 depicts which motivational factors most influence intenders and adaptors of solar to install solar PV systems. For most factors, the responses are reasonably close between the intenders and the adopters, with a few exceptions in the "an offer too good to refuse", "reduce bills and "self sufficiency" sections. The disparities in the first two factors indicate that a good offer or financial incentive is a strong instigator of indenters becoming adopters. On the contrary, "self sufficiency" leans in favor of intenders, which indicates that some intenders might be holding out for a solar provider that gives them more control over their energy than what

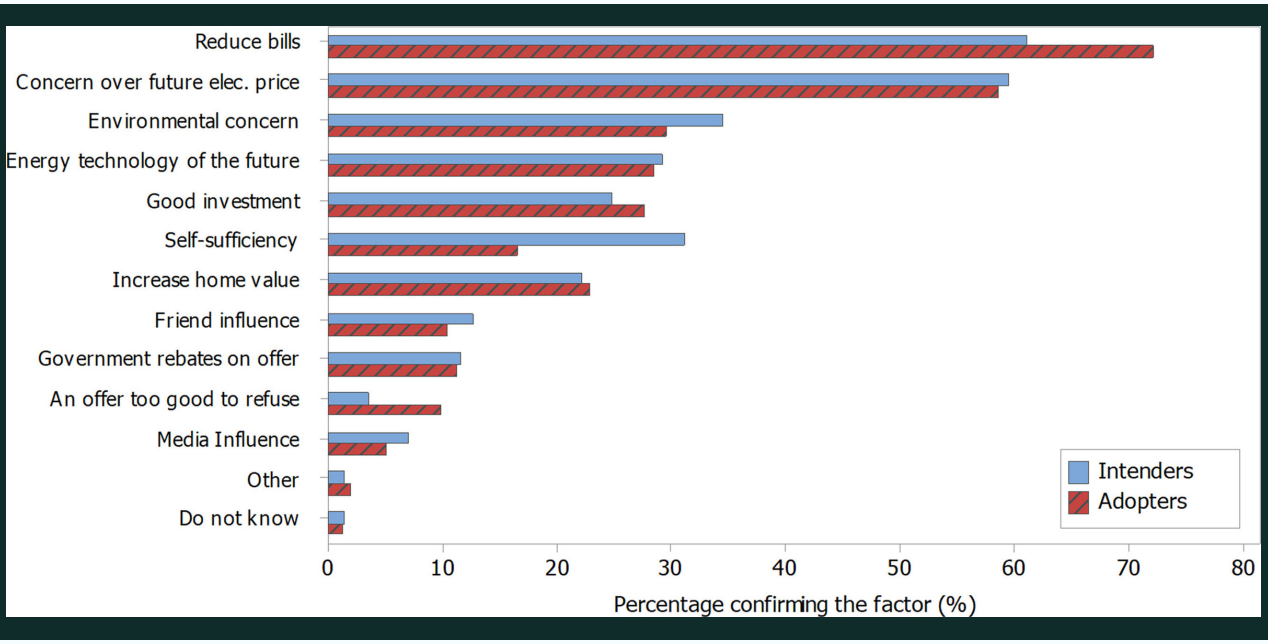


Figure 4: A Prediction of Warming Trends in Australia

current providers offer now. For both the intenders and adopters, electricity billing concerns are the top reasons why homeowners are interested in solar. Reducing their current bill and fear for the steady rise of electricity costs drive homeowners to want to generate their own electricity. Just beneath those reasons lies the environmental benefits of switching to solar, a global issue that the whole world must work together to combat.

COMPLEXITIES WITH INTRODUCING SOLAR ENERGY IN THE RESIDENTIAL SECTOR

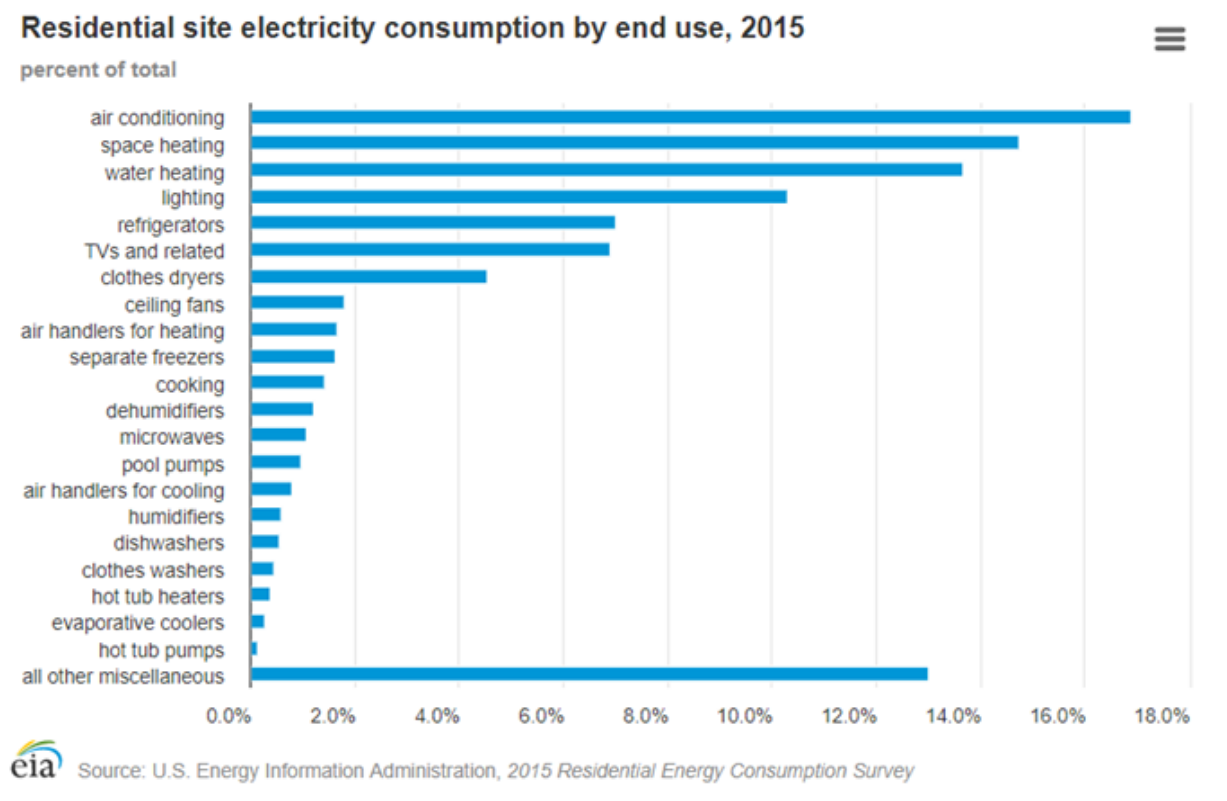
The current model of residential solar implementation is based on participating homes having their own set of solar panels that independently provide sufficient electricity for the household's needs. In theory, this decades old model is the simplest possible implementation of solar energy, but in practice, it is still overcomplicated. Participating households must still be connected to the local power grid in order to compensate for solar power's current unreliability (Kalkbrenner, 2019). PV systems cannot operate around the clock unless they have an energy storage system (battery), which most systems do not include. Moreover, certain geographical locations are less suitable than others due to the lack of sunlight. Similarly, locations are subject to interruption due to weather, especially overhead clouds, requiring residencies to draw from energy in the local grid. One attraction to the current residency-based solar model is that households can generate power and sell excess back to their utility company, which is mutually beneficial for both homeowners and the utility company. However, this entails a significant complication to power grids, which would have to support bidirectional energy transmission. This raises the installation cost of solar and will ultimately cause more maintenance work to be done on the complex system (Worthmann, Kellett, Grune, Weller, 2014).

Another barrier to the spread of residential solar is the decreasing number of homeowners in Australia. Most renters would not pay for a solar install on a property that is not theirs because they would not rent long enough to earn a return on their initial investment. The landlords of these properties also have little reason to adopt solar because in most rental agreements the landlord is not responsible for paying the electric bill. In 1995, 18.4% of households were rented in Australia, and this number increased to 32% in 2016, with most of these being rented from private landlords and a small amount from government housing (Australian Institute of Health and Welfare, 2021). This means that almost a third of all houses in Australia are not suitable for solar for the simple reason that they are rental properties. These are just some of the issues that are impeding the popularization of PV systems among many, and it is clear that the current residential model of solar energy needs to be reengineered to be more viable, sustainable, cost effective, and reliable.

MAJOR HOUSEHOLD ENERGY USAGE

When looking at electricity consumption on the residential scale, it is possible to categorize the consumption into different parts. This is useful in order to determine the biggest consumers of electricity in the average home. In the United States, the average household consumes 11,000 Kilowatt-hours per year (US Energy Information Administration 2021). Most of this energy usage is consumed via multiple different heating systems (primarily space and water heating systems), which total to 28.5% of the total consumption. Air-Conditioning units follow this, making up approximately 17% of the total energy usage. These are followed by lighting at 10%, refrigerators at 7%, and TV's and electronics at 7%. Despite these values coming from 2015, the percentages have remained mostly constant up until the current year of 2021.

Figure 5: Residential electricity use in the United States (2015)



Compared to the 11,000 Kilowatt-hours US households consume, the Australian average is significantly lower, averaging at 6500 KW-H per year. In addition to the much lower energy consumption average, the distribution of energy is also significantly different. On average, 40% of energy consumption is a combination of air-conditioning and heating, and 23% is used by water heating systems. Refrigerators and lighting are similar to the US data, clocking in at 8% and 7% respectively (Adam 2021, Figure 5). In order to continue to cut down on overall energy usage in households in Australia, cooling, heating, and water heating systems should be the primary target areas. While YEF acknowledges these other energy contributors as important consumers of energy, their primary focus is reducing energy through the consumption water heaters contribute.

HOT WATER HEATERS

As water heating systems are one of the biggest contributors to energy consumption, this is one of the most ideal areas to work on to reduce energy consumption. Hot water heaters are an essential appliance found in every home that account for approximately 18% of home energy consumption on average (Water Heating, 2020). There are five main types of hot water heaters: conventional storage, demand based, heat pump, tankless coil/indirect, and solar. Each type of heater has certain advantages and disadvantages to them, namely the type and amount of energy consumed, method of heating water, and its storage capacity. These parameters make each type of water heater a good candidate for different needs of residences. However, besides solar water heaters, most water heaters draw energy either from natural gas or fossil fuel powered electricity. Given the popularity of these fossil fuel-based systems, clearly there is room for improvement in residential hot water heater technology as Australia works towards its carbon-zero future.

The push to transition residences to more efficient forms of water heating is road blocked by homeowners' willingness to replace their water heaters. Typically, water heaters are only replaced when they die because they are expensive. Then, when homeowners need to get a new water heater as quickly as possible, the most readily available type is conventional storage water heaters, which is one of the least energy efficient types. For information on the common types of water heaters, see Appendices D-G, which focus on each type individually.

METHODOLOGY

This project was intended to assist Yarra Energy Foundation advance residential solar uptake in the state of Victoria. This was done by surveying early solar adopters who have previously worked with YEF about their experiences with both the installation and the usage of the technology.

This project focused on the financial incentives of switching to solar by analyzing the effect solar energy has had on homeowners electricity consumption, as well as changes in their electricity bills. This project also collected information on the major appliances that contribute to energy usage in the home, specifically water heater systems to assist YEF in creating future energy efficiency programs. The data collected was used to create informative deliverables for YEF that can improve their current energy programs and highlight space for new initiatives. These deliverables emphasized the benefits of solar PV ownership and can be used to promote solar to prospective homeowners.

Objectives:

1. Understand the experiences that homeowners in Victoria have had with their solar PV systems.
2. Understand the financial benefits that solar energy has provided to these homeowners.
3. Inform current solar energy users of new Yarra Energy Foundation programs that help improve home energy efficiency.
4. Promote solar energy to prospective homeowners by educating them on costs, benefits and accessibility.

METHOD 1: THREE-PART SURVEY

The primary data collection for this project was done through a three-part survey process. The first of these parts was an initial survey in which we gauged interest in a further in-depth written survey and phone interview. This survey was sent to 444 of YEF's contacts. In addition to asking for interest in an online and phone survey, the initial survey also acted as a way for YEF to reconnect with their previous clients, as well as gather some preliminary information about their solar systems. The survey questions are included to the right.

The initial survey had a response rate of 44 out of 444 users. Of these 44 responses, 20 of the participants opted into the In-Depth online survey, and 21 opted into the phone survey.

For the In-depth online survey, we initially had a very low response rate. Because of this, we opted to send the survey to the entire list of 444 people instead of just those who opted into the initial survey in order to try to increase the response rate. This was successful and raised our response rate from 6 to 49 responses. This survey had a multitude of objectives, including understanding the user experience with solar, understanding the financial savings users could make by switching to solar, and gauging interest in future YEF initiatives to become more energy efficient. The In-Depth survey questions are included below.

INITIAL SURVEY QUESTIONS

Q1. Have you noticed a decrease in your electricity bill since you installed you solar PV system?

Q2. What percentage would you say you have saved on your electricity bill since you installed your solar PV system?

Q3. Which of the following changes have you made to your behavior (if any) to optimize your solar system? (Select all that apply)

Q4. Would you like some tips on how to get as much as you can out of your solar system?

Q5. Have you switched electricity retailers since your solar system was installed?

Q6. The Yarra Energy Foundation is interested in helping you save more money on your energy costs. Would you be interested in helping us help you with a short 10–15-minute phone survey?

Q7. Would you be interested in helping us help you with an additional, more in-depth online survey?

Q8. Lastly, YEF is interested to learn how and when your energy is consumed. Would you be interested in allowing us access to your NMI consumption data so we can identify the hours during the day that you use the most energy? This data will be for YEF's research purposes and will not be redistributed elsewhere.

Q9. Feedback is always welcome! Also, if you had any queries about all things energy, please feel free to ask below and we'll get back to you as soon as we can.

Q8. Lastly, YEF is interested to learn how and when your energy is consumed. Would you be interested in allowing us access to your NMI consumption data so we can identify the hours during the day that you use the most energy? All data is anonymous and is only used for this research piece.

Q9. Feedback is always welcomed! Also, if you had any queries about all things energy, please feel free to ask below and we'll get back to you as soon as we can.

IN-DEPTH SURVEY QUESTIONS

Q1. Do you own or rent the home where your solar system was installed?
Q2. How long have you lived in your current household?
Q3. Including yourself, how many people live in your home?
Q4. Did you or anyone in your household frequently work from home pre-pandemic?
Q5. Do you or anyone in your home frequently work from home during the pandemic?
Q6. Are you retired or semi-retired?
Q7. What age range do you belong to?
Q8. What is your household income range?
Q9. Do you have insulation?
Q10. Do you have double glazed windows?
Q11. Do you have a gas connection?
Q12. Are you interested in transitioning away from gas within the next 3 years?
Q13. If interested, what do you consider your major challenges in doing so?
Q14. If no, what are the main reasons you wouldn't?
Q15. Rank the following, from 1 most contributed to 7 least contributed, to your decision to install solar PV?
Q16. If you haven't switched energy retailers since you installed solar pv, would you be interested in switching retailers for cheaper alternative retail plans?
Q17. If no, what are the main reasons you have remained with your energy retailer?
Q18. Would you be prepared to switch energy retailers for 100% green power?
Q19. What is your average monthly electricity cost?
Q20. How satisfied are you with your current electric costs post solar install?
Q21. If somewhat or very dissatisfied, how likely would you have installed your solar PV system knowing what you know now?
Q22. Do you believe that being home more often during Covid-19 has led to greater energy use than pre-pandemic times?
Q23. Would you be interested in adding battery storage to your existing system?
Q24. If yes, how likely are you to add a home battery within the next 3 years?
Q25. If no, what are the main reasons why you wouldn't add a home battery?
Q26. Would you be interested in participating in a community or local battery?
Q27. Would you be interested in participating in an electric vehicle bulk buy?
Q28. If yes, would you be interested in participating within the next 3 years?
Q29. What type of hot water heater do you have?
Q30. How old is your current hot water heater unit?
Q31. Would you be interested in upgrading your hot water unit to an energy efficient upgrade that best suits your needs?
Q32. How familiar are you with electric heat pump hot water systems?
Q33. Are you aware that your hot water unit can account for roughly one third of your annual energy costs?
Q34. Would you be interested in learning more about these options through YEF?
Q35. When participating in the solar program, what factors influenced your decision?
Q36. If anything, what would you hope to change about the installation process?
Q37. How many times have you had to have maintenance done on your solar PV system?
Q38. How many times per year did you experience an interruption of service (power outage) before your transition to solar?
Q39. How often have you experienced an interruption of service with your solar PV

PHONE INTERVIEW QUESTIONS

Q1. How long have you lived in your current household?

Q2. Including yourself, how many people live in your household?

Q3. Do you own or rent your place of residence?

Q4. Do you have a battery for your solar system?

Q5. Are you retired?

Q6. Stop me when I say your age range: (25-35, 35-45, 45-55, 55-65)

Q7. Stop me when I say your household income bracket: (Less than $15k / $15k-$29,999 / $30k $49,999k / $50k-$74,999 / $75k-$99,999 / $100k-$150k / $150k+)

Q8. Do you have a grid or gas connection (or both)?

Q9. Do you know what type of water heater you have? How old is it? If offered, would you be interested in switching to a more energy-efficient water heater from YEF?

Q10. Have you found yourself adopting any behavioral changes to improve your energy efficiency?

Q11. What was your original inspiration for installing a solar energy system?

Q12. Have you experienced any significant power outages since installing solar?

Q13. How has solar energy impacted your monthly electricity bill?

Q14. What advice would you give to homeowners who are now looking at transitioning to solar energy?

Q15. What advice, if any, would you give to prospective homeowners about the transition process?

Q16. Thank you for your time with me today. I know on the short survey you took a while back you checked no on participating in a written survey, but would you reconsider taking it to further provide us with information on your experiences?

Lastly, we planned to call 8 users in order to gain some personalized answers in regard to their solar installation and usage. Of these 8, we managed to contact 3 users, while the rest failed to answer the phone and respond to an email asking to schedule a phone survey time slot. These three surveys gave us some valuable insight for our analysis and was utilized in our deliverables where appropriate. The phone survey questions are included to the left.

This project as a whole aims to understand the personal experiences of homeowners with solar photovoltaic systems since their conversion to solar energy. One of the most important aspects of a homeowner's solar experience is the installation process, as this is the aspect of solar energy that most directly relates to YEF's work. Since one of YEF's primary objectives are to connect homeowners to solar providers and assist with the installation process, it follows that they are interested in feedback from their clients on these topics. Additionally, collecting this information was useful to this project as we aim to inform prospective residential consumers of the benefits of solar and what they can expect in the installation process.

The three-part survey also attempts to gauge behavioral changes that homeowners might have made as a result of solar intervention and their interest in renewable energy. These questions will focus on potential changes in awareness of energy consumption and how solar intervention has impacted their interest in other renewable energy initiatives. However, we expect that most homeowners will not explicitly be aware of changes in their energy consumption behavior, which will yield few useful responses to these questions. To supplement these questions, we will also be able to draw conclusions from homeowners' metering data that will be collected. Since the energy consumption on metering data reports is broken down by time of day and day of the week, we compared when homeowners are using their electricity to highlight any behavioral changes that residents might not be aware of.

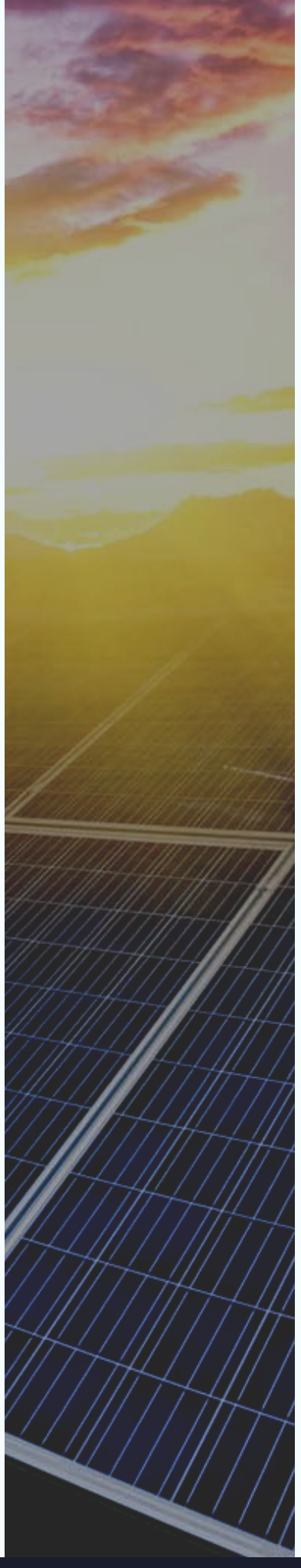
Additionally, Both the written questionnaire and the phone interview data collection methods served a secondary purpose as a communication medium to promote YEF's new renewable energy initiatives that homeowners may not be aware of. Primarily, this will include promoting YEF's new hot water heater initiative, which heavily relies on homeowners' knowledge of the program and their willingness to participate.

METHOD 2: METERING DATA

In addition to the basic solar questions and gauging interest in further surveys, another important aspect of the initial survey was to ask users if we could access their NMI data. The users NMI data (National Metering Identifier) provided access to solar homeowners' energy metering data and billing information that details all the quantitative information on how residents consume energy. This information allowed us to calculate the amount residents saved by analyzing their energy consumption before and after adopting solar.

The first step in finding the amount residents saved by adopting solar was to collect residents' energy consumption data from the last year in order to determine their energy usage habits. The realized cost savings can be calculated based on the decrease in grid drawn energy since each home's transition to solar. As mentioned in the previous section, behavioral changes that we found like being more energy conscious since transitioning to solar should also be evident in homeowners' metering data and translate to changes in energy finances.

We also found residents upfront cost of installing solar through the surveys mentioned above. This is an important factor in performing a cost analysis on solar as it will be compared to the calculated savings from solar to create an estimate for how long solar panels take to pay for themselves. We considered the government rebates residents received when installing their panels. This was because the calculated time it takes panels to pay for themselves was shorter for these residents and may not reflect the experiences of those intending to purchase solar without government rebates. To account for this, we created figures for the return on investment with and without receiving rebates.



METHOD 3: DATA SYNTHESIS

For this project, most of our analysis was done within Microsoft Excel, and consisted of drawing correlations between the results of the questions asked on the surveys. The conclusions that we can draw from studying solar homes will be useful to prospective residential solar users as we can educate them about the benefits that they can expect from solar PV. We will create informational materials promoting solar from this data.

The deliverable will most likely take the shape of an easy-to-read infographic that highlights positive experiences and testimonials from current solar residents, as well as evidence of solar energy savings. As mentioned previously, the most common reason for adoption or intended adoption of solar is to reduce bills with the second most common reason being concern over future electricity prices.

The deliverable used for promotion will also aim to ease doubts and bad perceptions residents may have about solar technology, primarily being that residents often assume they cannot afford solar due to the large upfront cost. These residents may not know how quickly panels can pay for themselves or might not know about government incentives and rebates that can help with the upfront cost.

While it will include information about the positive environmental impact residents can make by switching to solar, the deliverable will be mainly focused on the personal gain residents will experience from adopting the technology. Not only are factors based around personal gain the biggest motivating factors for those adopting solar, by focusing on personal gain the resident does not need to have an interest in the environment or climate change.

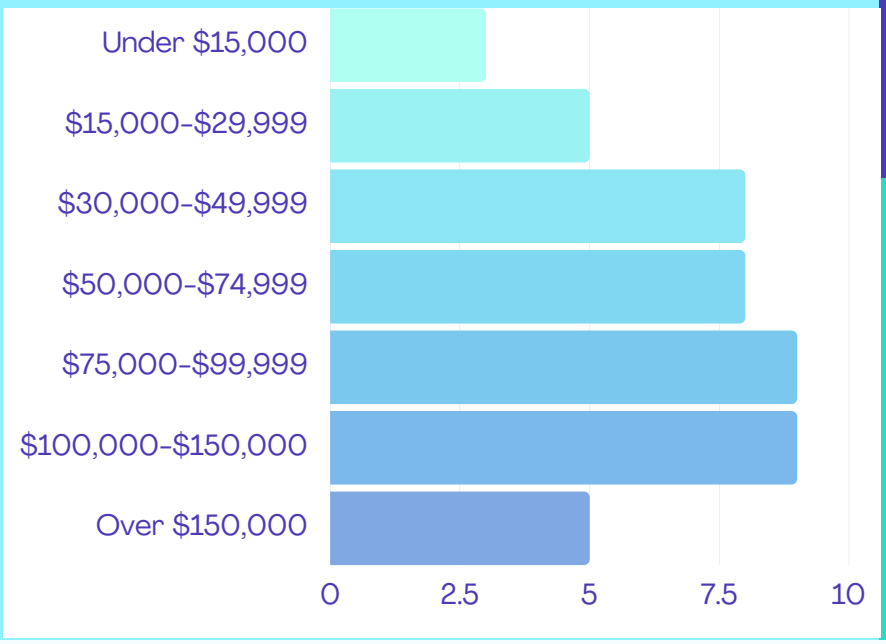
RESULTS

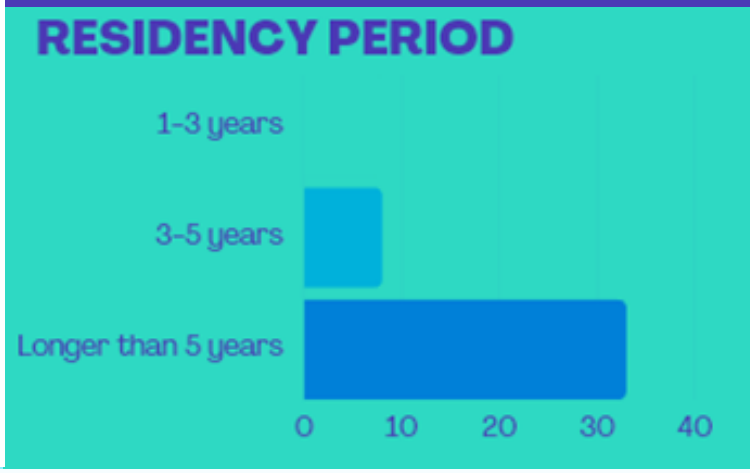
DEMOGRAPHICS

To find out who current solar customers are, early adopters of solar were asked to provide household demographic information as part of the in-depth survey. The demographic information collected included the number of people in a household, the age of the respondent, household income, whether the respondent owns or rents their home, and how long respondents have lived in their current household.

Demographic data on solar owners allows YEF to see what their average solar resident looks like. Along with this, YEF will be able to identify groups of people who are underrepresented in solar ownership and can potentially help YEF target other groups for solar installation.

Figure 6: Demographic information for Income, Residency, and Age





Through the survey, we found that respondent's income on average was $79,787.23 AUD. This piece of information is important to gather, as price plays a huge factor in whether a homeowner adopts solar panels or not. Additionally, we found that a majority of participants have lived in their household for longer than 5 years, which suggests that there should have been more ranges to choose from. Lastly, we found that the average age of participants was 62 years old, which lines up with participants of YEF's initiatives being mostly retirees. This does suggest that YEF can try to branch out to younger age ranges in the future, however.

HOMEOWNERS' SAVINGS AWARENESS

The Queensland Household Energy Surveys determined that the most important aspect of a solar PV system is the financial benefit that comes with it. For a user to be satisfied with their solar system or a prospective homeowner to consider converting to solar, they need to believe that the return on investment has justified their purchase of solar. One aspect of this project is to gather metering data that numerically proves or disproves solar PV's economic efficiency. Given that we did not expect most homeowners to keep precise track of their savings from solar, a few questions of the survey were designed to measure solar user's satisfaction based on their perceptions of their electric bills and not the numbers. Ideally, we would be able to cross reference the results of these questions with homeowners' actual billing data, but due to limitations with data collection and the seven-week span of the project, we were not able to gather such information. We did, however, gather their energy use data which could be used to estimate how users' bills might compare to each other, but this data did not span to before solar installation, so a complete savings analysis was not possible. Through the questions we asked homeowners, we determined that most homeowners do believe that solar has saved them a substantial amount on their energy bills.

When asked to estimate how much they have saved compared to their bills before solar installation, over 50% of respondents report "a lot" or more savings, while only 2% reported no savings at all. The results of this question were about expected, with a majority of answers at the middle value, creating a normal distribution bell curve. Here, 52% of people reported "a lot" or more savings" (See Figure 7) .

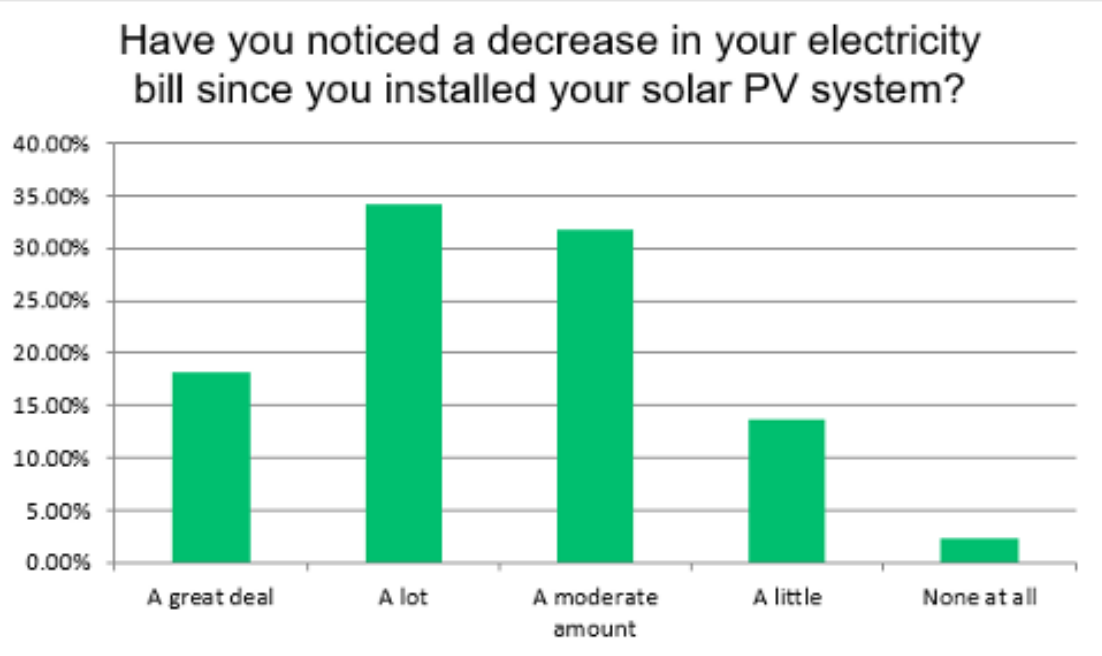


Figure 7: How much residents estimate they saved after switching to solar

When those who reported savings were asked to estimate the percentage they have saved since switching to solar, the results were a lot less consistent. These results indicated a high concentration of homeowners at the extremes, either at the high end of savings or the low end. This distribution is vastly different from the qualitative question in Figure 7, which indicates that there is a significant amount of people who responded that they saved an average to high amount, when in reality, they saved less than their peers. This means that those people could be using their solar PV system more effectively and save more as a result, but might not be aware that they are not using it to its greatest extent.

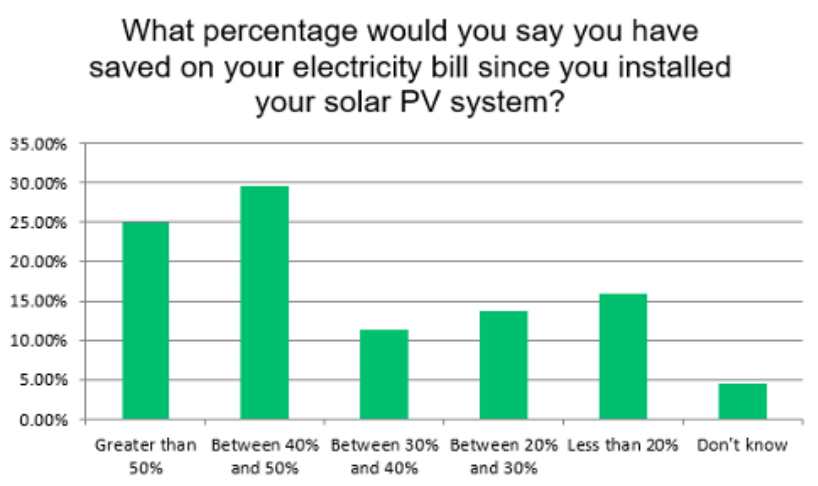


Figure 8: Residents estimated decrease in electricity bills

When we looked into correlations between savings and energy efficient behaviors, we found no consistent relationships. In fact, some results showed illogical trends like that those who practice things like draught proofing and have shifted their schedules to revolve around their solar generation hours save 2% less energy on average than those who do not. Statistics like this further indicate that there is a lot of room for improvement in how homeowners currently implement solar-efficient behavioral changes to make them more effective. In general, the comparison between estimated savings and qualitative questions indicate that homeowners might not be aware of possible improvements that can be made to make their solar PV systems more efficient and effective.

USER EXPERIENCE OF SOLAR PANEL OWNERSHIP

To understand the user experience with residential solar, the in-depth survey asked residents about the installation process, their overall satisfaction, and any power outages they experienced. Overall, respondents were satisfied with their system as 37 of 48 or 77% reported being satisfied, where only 9 or 19% reported being dissatisfied with 2 respondents being neither satisfied nor dissatisfied. The 9 dissatisfied respondents were asked if they would still install solar knowing what they know now being a solar owner, 3 would be likely to, 3 would be unlikely to, and 3 couldn't say. This question shows that even if residents experienced frustration during installation or aren't saving as much as expected, most still don't regret installing their system.

When asked, if anything, what would you change about the installation process, only 23 of 49 total respondents answered the question, which is an indication that either there isn't much to change about the installation process or that residents simply wouldn't know what to change. When looking at the responses 8, or 35% of residents report that they wouldn't change anything while 3, or 13% of residents reported having a good experience with the installation. 3 residents reported issues with the installers used by their supplier. YEF currently uses a different supplier than the one these residents used which is hopefully resulting in less issues.

The rest of the results for the installation process question fit into 4 categories; those who experienced minor issues in the process, those who wish more technology came with their system, those who experienced communication issues, and those who wish they could change what they had installed. The minor issues reported were not specific enough to analyze but included frustration with the process of connecting to the grid. The residents who want more technology were specifically looking for an upfront way to track energy use and financial benefits of their system. While solar monitoring technology does exist, we do not know if these residents' retailers provide it or if it was made known to them. Residents reporting issues with communication lead back to the supplier previously used by YEF, which again hopefully has been improved upon with YEF's new supplier. Finally, of the 2 residents who wish they could change what they installed; one regrets only having panels on one side of their roof while the other wishes they had a battery installed. We would hope the installer uses the most optimal panel layout and this resident either doesn't realize that or just wants a bigger system that covers both sides of their roof. Although there is still the possibility that this resident's panel layout should be changed. The last response to the installation process was a resident who regrets not installing a battery with their system. Batteries can be installed anytime, and this resident would be a perfect participant in an upcoming YEF residential battery bulk buy.

Overall, a high level of satisfaction shows that YEF is doing their job well and properly managing their programs. A proven high satisfaction rate should ease the worries of those who think solar isn't the right choice for them.

WHY SOLAR WAS ADOPTED

When asked which factors most contributed to their decision to install solar, residents' biggest factor was found to be wanting to reduce their energy bills, which was expected. The second most frequently reported factor was environmental concerns, which shows that many people are interested in switching without necessarily having monetary savings as their primary motive (though it was still a secondary motive for most users). The figure below showcases these factors by averaging the factors based on where each participant ranked each factor on a scale of 1 to 7:

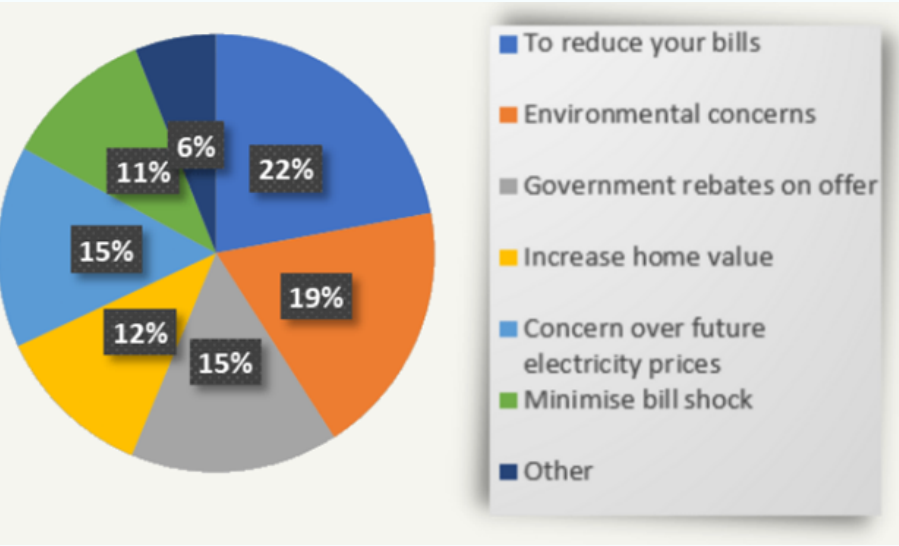


Figure 9: Most important factors that influenced early adopters' decision to install solar

Additionally, it was found that 34 out of 45 of those surveyed (77.7%) are willing to switch retailers in order to achieve 100% green power. Despite this, 58% of those surveyed said they were not prepared to pay above $50 per year in order to achieve 100% green energy, with 25% of them not being willing to pay any amount of money at all. This data is very promising, as it shows that a substantial amount of people are willing to increase their yearly electricity cost to be more environmentally friendly. 14 of those surveyed (31%) said they were willing to pay up to $150 extra per year. With a sizable percentage willing to pay extra, new initiatives could help the Victoria area continue to work towards 100% green energy.

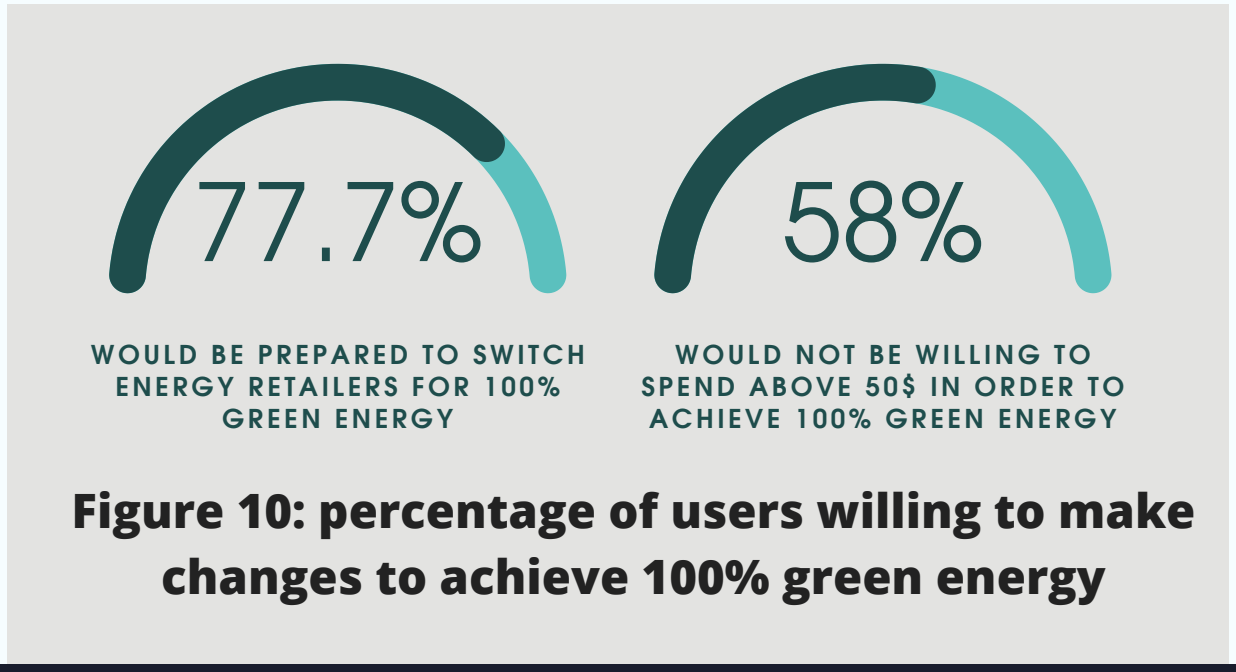


Figure 10: percentage of users willing to make changes to achieve 100% green energy

BENEFITS OF RESIDENTIAL BATTERIES

One of the biggest factors that affects a solar systems efficiency is whether it's connected to a domestic battery. Domestic batteries greatly increase the initial cost of a solar system, so one of the main objectives of our cost analysis was to evaluate the viability of domestic batteries being installed with solar systems.

The Yarra Energy Foundation provided us with the energy use data of data of 11 residents, 3 with a battery, 8 without. Based on the energy use of these 11 residents, our estimated energy bill calculations show a reduction in energy bill cost for battery systems when compared to no battery systems. The 8 residents without batteries use an average of 448 kWh per month of grid energy while those with a battery draw 287 kWh per month. At a cost of 24 cents/kWh we estimated that those without a battery could expect a monthly bill of $107.42, compared to $68.81 of those with a battery. This results in a $38.61 monthly savings for having a battery. This may seem like a large reduction, but before making any claims we must also factor in the energy residents with solar export back to the grid. Those without batteries exported an average of 293 kWh per month, while those with a battery exported 269kWh per month. If this energy was sold back to the grid at 6 cents/kWh it would bring the residents average energy bills down to $89.85 for those without a battery and $52.68 for those with a battery. This means on average residents with batteries pay $37.17 less per month compared to those without batteries.

Out of 11 residents with energy use data, we had access to the initial system cost of 6 of them, 2 with residential batteries and 4 without. The 4 residents without batteries had an average system cost of $10,434 while the 2 residents with batteries had an average cost of over double that at $22,111. On average those with batteries paid $11,667 more for their system. It is important to look at system cost when comparing battery to regular systems.

HOT WATER HEATER INITIATIVE

A key section of the surveys and interviews focused on homeowners' hot water heaters to gather information on what the common types are, the average age, and understand the level of knowledge that homeowners have about water heaters. While our initial research indicated that a strong majority would have a gas storage water heater, the data collected strongly suggests otherwise. In fact, only 32% of homeowners surveyed have a gas storage water heater. However, it is true that fossil-fuel powered systems still control a majority of the market with a share of 61% between both gas storage and gas instantaneous systems. 61% is certainly a majority, but it is not strongly disproportionate since it suggests that 39% of homeowners have navigated switching to renewable energy systems, which are still a relatively new technology. These options included solar electric supplemented by both electric and gas, as well as heat pump water heaters which are an entirely electric option. We broke down the reported current age of water heaters and found that the average age of gas systems is 6.6 years old, while renewable systems are only about 5.1 years old. This suggests that homeowners have more recently begun converting to renewable alternatives.

These 39% of homeowners have switched to more efficient water heating technologies on their own accord, only influenced by advertising and initiatives that are currently available. Since solar and heat pump water heaters are still commercially new technologies, the rate of uptake among consumers is impressively high for 39% of homeowners to have already adopted these. However, this is almost unsurprising since 57% of respondents report being aware that hot water heaters can be responsible for up to a third of their annual energy costs. Additionally, the survey respondents were early adopters of solar energy who are likely to be more energy and environmentally conscious than the average person, so the findings from this sample group might not accurately scale up to reflect the distribution across all homes.

By factoring together, the 61% who still rely on fossil-fuel water heating and its likeliness to grow when scaled to the general population, there is a large base of people who could switch to a more efficient water heater. Additionally, 65% of respondents indicate being interested in learning more about water heater initiatives from YEF. Based on our findings in these surveys, we concluded that YEF's prospects of a water heater initiative including bulk buys and informational sessions are justified and worthwhile since there is a sufficiently large base of interest.

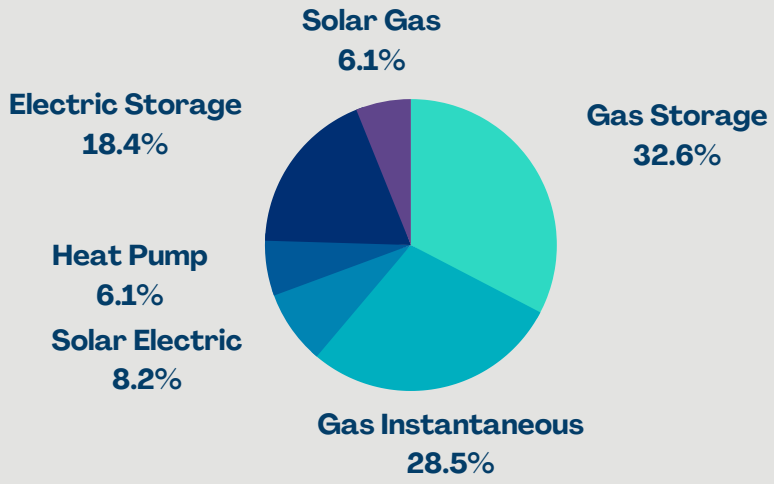
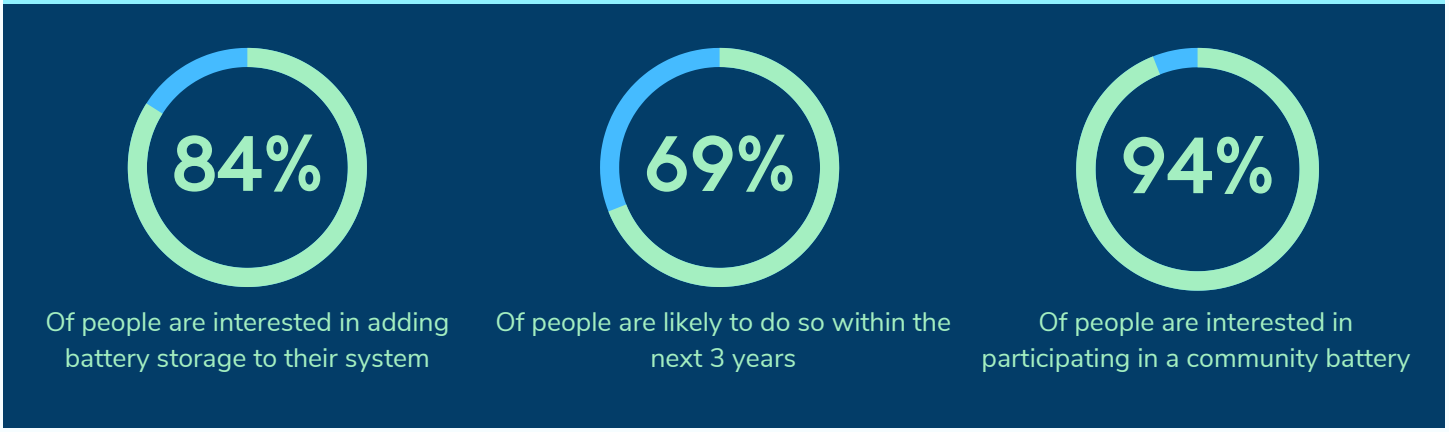


Figure 11:
The distribution of types of heaters is more evenly spread than expected. Almost 40% have a renewable energy system.

YEF'S FUTURE INITIATIVES

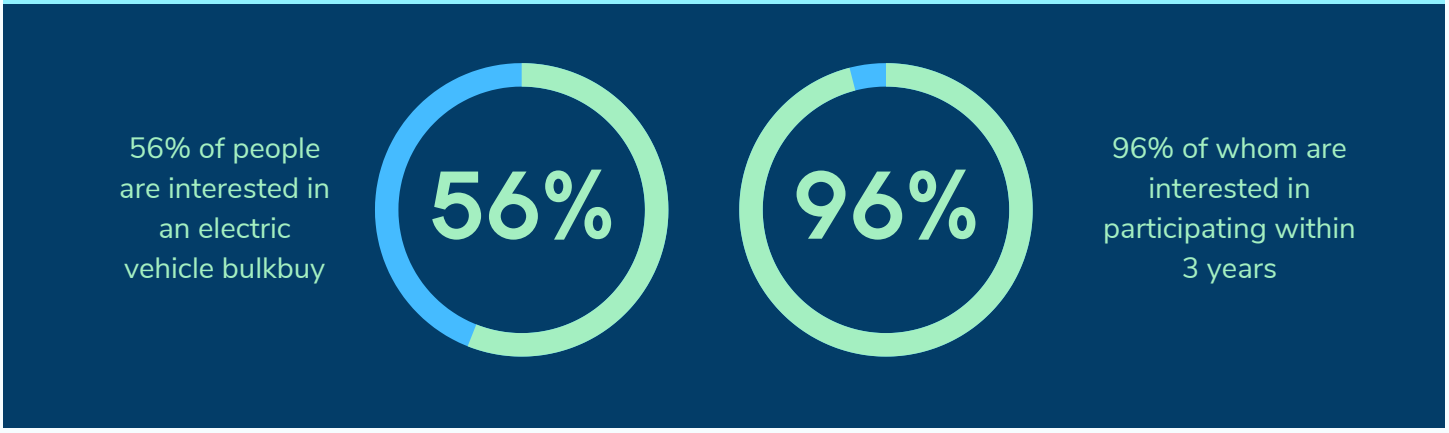
Based on our analysis, it is clear that people are very interested in installing batteries to their solar systems in the near future, with 84% of those surveyed being interested in batteries, and 69% of those interested in doing so within the next 3 years. Additionally, it was found that 94% of users were interested in participating in a community battery.

Figure 12: Residents Interest in batteries



The main concerns we found were batteries initial cost, as well as the user not generating enough power for them to feel a battery is necessary. As this is a relatively small population, we do believe YEF should work to help users install batteries to their systems, as well as consider a community battery initiative.

Figure 13: Residents Interest in Electric Vehicles



56% of those surveyed marked some interest in an electric vehicle bulk buy, and almost all of those are interested in participating within the next 3 years. With this data, we do believe it would be beneficial for YEF to pursue this initiative, as well as one with water heaters, though a battery initiative should be higher priority if only one can be done in the near future.

FUTURE INITIATIVE RECOMENDATIONS

Based on all of the information that we collected throughout this project and our analysis of the data, we have concluded what renewable energy initiatives YEF should pursue in the near future that will most appeal to and be of value to solar homeowners.

Firstly, we have concluded that batteries are the most important initiative to capitalize on due to the overwhelming interest in them among solar homeowners. Since 75% of people are interested in installing a battery, there is a significant base of people who would likely participate in YEF led programs. Even higher, 94% of people are interested in participating in a community battery initiative. These statistics are a convincing base for a series of battery-oriented YEF programs. Since YEF is already working on community batteries, we recommend that they also work on a domestic battery program for those who are not ideal candidates for participation in a community battery.

We then rank a water heater initiative as the second most important possibility for YEF to pursue. Our findings show a large base of people who still have gas powered water heater systems, and also indicate a trend of homeowners switching and environmental consciousness. YEF could easily step in on this trend and assist those looking to switch with the process.

Finally, the portion of people who reported being interested in an electric vehicle bulk buy blew away our expectations, indicating that it would be a great program for YEF to pursue. Given how large of an investment a new car is, it is astounding that 56% of people are interested, with 96% of whom are willing to participate in the next 3 years. The price of electric vehicles is a significant barrier to their uptake that a bulk buy program would help lessen.

We believe that the information collected in this project will serve as a solid justification for the enactment of these future programs, and that they will make a significant impact on solar homeowners and their journey in renewable energy.

CONCLUSION

For the Yarra Energy Foundation to advance the uptake of residential solar in Victoria, they must understand why homeowners choose to invest in solar as well as their previous clients' experiences as solar owners.

Our research was meant to assist YEF in better understanding these topics and through this we have developed multiple assertions. YEF's average solar client is a middle-class retirement age homeowner which does not seem to be a very diverse group. We have also found that most of these homeowners are satisfied with the savings solar provides and almost none regret installing their system. While we identified that residents primarily installed solar to reduce electricity bills many also chose to install out of concern for the environment, with residents being in favor of making changes to adopt green energy and some would even pay more for green energy.

Deciding whether residents should buy residential batteries or not is too case specific to make a definitive claim for either side, but they do provide a significant reduction in monthly bills and a significant increase in system cost which prolongs the time to earn a return on investment. YEF should still investigate a residential battery program or bulk buy due to the high level of interest from residents. An electric water heater program should also be a priority for YEF due to the large population of solar investors that still have gas powered water heaters and the overall interest from homeowners. Residents also showed interest in an electric vehicle bulk buy which YEF should implement at some point but should probably come after batteries and water heaters.

APPENDIX

APPENDIX A: WHAT IS THE SOLAR INSTALLATION PROCESS

Before even beginning the process of installing solar panels on a residential building, it must first be checked that solar energy is even viable in the first place. Usually, residential solar is installed on rooftops, so this will consist of a check of the buildings roof in order to make sure that there is enough space and sunlight for energy to be created. Additionally, the roof's structure will be checked in order to make sure the weight of the panels can be supported. After the site is approved, the solar company one is working with will likely recommend an optimal solar panel system. If the residents approve of this design, permits with the local planning and zoning commission will be obtained by the installer, and paperwork for any government incentive programs will be filled out.

From there, the equipment will be ordered by the installer, and then installed once it gets shipped. After construction, a representative from both the local planning and zoning commission and the user's electric company will visit the home for an inspection on the newly built panels. If the inspectors see no issue with the installed panels, the solar panels can then begin collecting and generating solar energy for the building (PowerScout 2021).

APPENDIX B: POSSIBLE IMPLEMENTATIONS OF COMMUNITY BATTERIES

The simplest system that utilizes a community battery model is a Community Energy Management System (CEMS). The main idea of CEMS is to connect a selection of residencies to a community battery, and have each household collect energy for themselves, and sending additional energy generated to the battery. When homes are unable to generate enough energy for themselves, they will begin to start drawing from the battery storage system. This system protects all households involved from potential blackouts, as well as ensuring that they stay powered throughout the entire day, even when one may be unable to collect solar energy themselves (Zhang, Luo, Dong, Liu, and Ranzi 2020).

Another potential method is utilizing a microgrid system in order to completely isolate a neighborhood from the grid, being completely reliant on their solar generation. A microgrid, in simple terms, is a smaller version of the main grid, which includes all of the necessary components to be self-sufficient, such as generation, storage, and ways to monitor energy. The main benefit of this method is that microgrids are generally able to use the full potential of renewable energy as opposed to the main grid. In most cases, with the current technology, microgrids are very challenging to implement, as it's hard to be completely reliant on renewable energy. Even with a community battery storage system, nonrenewable energy sources are usually required to allow a microgrid to function completely independently. There are some cases of microgrids being completely renewable, however these are very rare and are generally on a very small scale. As technology in the area expands, microgrids will be able to become more and more feasible as an option for renewable energy implementation (Siamwala, Gupta, and Rice 2019) (Sardi, Mithulananthan, Islam, and Gan 2021).

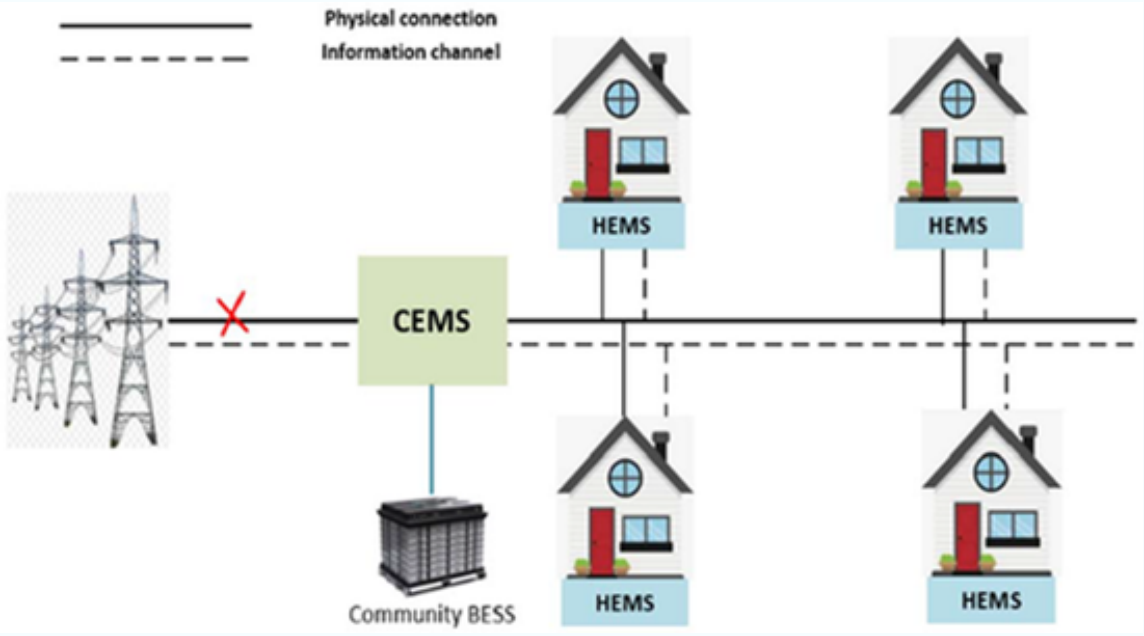


Figure 14: Community Energy management System Model

APPENDIX C: COMMUNITY BATTERIES THE SOLUTION

The foremost solution to the inherent issues with the current solar energy model is to supplement every community of solar households with a battery, creating fully self-sustaining micro-electrical grids. Community batteries are an emerging model that has only been made possible in the past few years thanks to leaps forward in battery technology. In this model, entire neighborhoods are connected to large batteries that provide a constant source of energy storage to supplement and stabilize their individual PV generation systems. As previously mentioned, one of the problems with PV systems is their inability to constantly generate power due to the location of the sun or weather phenomena among many possible sources of interruption. Community batteries would mitigate this problem by improving each residency's access to solar generated power through their neighbor instead of themselves (Kalkbrenner, 2019). Community batteries are a promising emerging technology that solve many of the issues with modern PV systems that will be explored and promoted throughout this project.

As a new arising technology, it is important to highlight the benefits that are gained from the implementation of community batteries as well as some of the drawbacks. Some identified advantages are the increased reliability and spread of solar energy, and possible cost savings for residents. There are also some drawbacks to the technology, one being the unknown lifespan of the system, if the lifespan isn't long enough, they may be deemed impractical.

The main advantage of community battery systems is increasing the overall reliability and security of one's energy system. In the case where one user's solar panels are unable to generate power for a long period of time, due to damage or the angle the panels are placed on the rooftop, a community battery allows one to utilize excess power created from others in the community until their panels are operational again. This system also protects users from partial power outages and is beneficial for communities both part of and farther away from the grid (Zhang, Luo, Dong, Liu, and Ranzi, 2020).

Community battery systems could also be beneficial because of its potential to save residents money. One way of doing this is allowing residents to avoid paying peak prices for electricity by using an energy management system. For partially grid dependent systems, an electricity management system will have residents draw from the battery during peak hours when grid electricity is the most expensive, during not peak hours the solar energy produced will mainly go to charging the battery, while the resident draws from the grid. This means the resident will avoid paying peak prices for electricity and only draw from the grid when its cheapest. (Schram, 2021)

If a community energy storage system was big enough, and reliable enough, a proposed advantage would be allowing residents without a PV system installed to start using renewable energy by connecting to a community battery. If a resident's grid provider does not offer renewable options, then buying from neighbors could be a solution.

APPENDIX D: CONVENTIONAL AND DEMAND-BASED STORAGE WATER HEATERS

Conventional storage water heaters are the most common type of residential water heater. The premise of these water heaters is that each home has a large, insulated tank (typically 20-80 gallons) that stores preheated water (Water Heating, 2020). The water in this tank is stored at approximately 120℉ and is available for use when needed. Because of imperfect thermal insulation, hot water storage means that energy will be used to maintain this temperature even when hot water is not actively being used. Additionally, the size of the tank limits how much hot water is available for use before the tank is depleted. While larger tanks help with this, they are less thermally efficient and exponentially more expensive. However, the convenience of having hot water immediately at the ready contributes to storage-based water heaters being the standard for residential water heaters. Traditionally, these systems are powered by either natural gas or propane, however the last few years have brought an uptick in electric powered storage water heaters. The typical lifespan of storage-based water heaters is 10-15 years, but it varies based upon location, usage, and fuel type.

Demand-based water heaters are small heating units installed in close proximity to hot water outlets like sinks and showers. Rather than having one central hot water supply, this model of hot water heating has several units that are able to perform more efficiently individually. Each water heater has a small heating element that activates when water flows through the system and heats the amount of water that passes through. This process means that no energy is wasted maintaining dormant hot water. Additionally, it is more thermally efficient to heat small quantities of water at a time. However, demand-based water heaters are limited in the flow rate of hot water that they can manage. Typically, these heaters manage between 2-5 gallons per minute of hot water depending on the size of the heater. This makes demand-based water heaters ideal for smaller homes with lower water consumption requirements. For homes that use 41 gallons of hot water per day, demand-based water heaters can be between 24%-34% more efficient than conventional storage systems. If demand-based heaters are installed at each water outlet, they can be as much as 50% more efficient than conventional counterparts. While the upfront cost of these systems is higher due to installation complications, the return on investment based on energy efficiencies typically pay off within 5 years. Additionally, the expected lifespan of these systems is more than 20 years per installation (Water Heating, 2020).

APPENDIX E: HEAT PUMP WATER HEATERS

Rather than generating their own heat energy, heat pump water heaters transfer energy from surrounding air into the water that is being heated. This allows heat pump water heaters to operate 2-3 times more efficiently than conventional storage water heaters. Similarly, to a fridge that draws heat from the inside of a container to the outside, heat pump water heaters draw heat from the outside of a water storage tank and transfer it to the inside. Heat pump water heaters are solely electric based water heating systems, making them a good candidate for solar homes that generate excess electricity. One limitation of heat pump water heaters is that they only run effectively in climates that vary from 40 ℉-90 ℉. While this limitation excludes a lot of climates, this is acceptable for Victoria, which ranges from 42℉-80℉ average daily temperatures. Heat pump water heaters are some of the most thermally efficient water heaters and have a life expectancy of 13-15 years (Water Heating, 2020).

APPENDIX F: TANKLESS COIL/INDIRECT WATER HEATERS

Tankless coil water heaters are another method of on-demand water heating that involves water flowing through a heated coil when hot water is required. Indirect water heaters are a variation of the coil heating method that introduces a storage tank. Coil heaters are one of the most affordable methods of water heating due to their simplicity and ease of installation. Unfortunately, they are also one of the most thermally inefficient methods because they rely on natural gas or oil burning to power the heated coil. Tankless coils can also be electrically powered, but the process of conducting heat through a coil is thermally inefficient. The typical life span of these heaters is 15-20 years, which combined with its low cost, makes indirect water heaters an attractive option (Water Heating, 2020).

APPENDIX G: SOLAR WATER HEATING

Solar water heating involves a dedicated solar collector panel that collects solar heat energy, then transfers the energy into a water storage tank. This method operates solely on energy collected from the sun, meaning that it is the greenest process of water heating despite not being technically thermally efficient. This process does not interact with residential PV systems, rather it is its own entirely separate energy collection system. Solar water heating can operate in any climate regardless of average temperature due to the thermal collection design of the thermal solar panel. One key advantage of solar water heating is its life expectancy: solar thermal systems can last beyond 20 years because of the simplicity of the process. Unfortunately, installation costs are higher due to the more involved installation process of both the storage tank and the thermal solar panel. However, they have the lowest operating cost of any form of water heating because the only energy they consume is solar (Water Heating, 2020).

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