ANALYSIS OF THE POTENTIAL ECONOMIC IMPACT OF LARGE SCALE RESIDENTIAL ENERGY EFFICIENT RETROFITS IN THE CITY OF YARRA

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This report represents the work of one or more WPI undergraduate students submitted to the faculty as evidence of completion of a degree requirement. WPI routinely publishes these reports on its web site without editorial or peer review.
Abstract

The Yarra Energy Foundation (YEF) seeks to make the city of Yarra carbon neutral by the year 2020 through a series of initiatives, one of which is a large scale energy-efficiency retrofit of its residences. We conducted an economic analysis of the costs and associated benefits of the retrofit so that YEF can inform and inspire government agencies, local companies, and residents to make the necessary investment and engage in the collaboration needed to carry out the large scale retrofit program. With 100% of the retrofits completed by 2020, we estimated that a total of $608.4 million AUD would be injected into the local economy.
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Executive Summary

Climate change has impelled the world to consider sustainable practices. The major contributors for climate change are greenhouse gases such as carbon dioxide, methane and water vapour (Schneider, 1989). Our carbon dependent lifestyle is one of the main contributors to the current high level of emissions. To diminish the effects of climate change, it is essential to transform to an energy efficient lifestyle that approaches carbon neutrality.

Zero carbon emissions can be achieved by energy efficient practices, implementation of carbon taxes, carbon emissions trading and recycling. Demolishing a residential home and rebuilding it from scratch in order to increase energy efficiency is financially infeasible. For homeowners, one of the ways to reach carbon neutrality is through retrofitting their homes. Retrofitting is the replacement of older equipment with energy efficient household appliances. Typically, equipment for heating and cooling, hot water and lighting, as well as, the installation of insulation and draft proofing are of interest to retrofitters. Lowering energy use for one home is relatively insignificant, but retrofitting an entire community will make a substantial contribution to the reduction of carbon emissions. This retrofitting process is described in the value chain below.

Convincing homeowners to engage in retrofitting has proved to be a difficult task. Major barriers, including lack of knowledge, interest and financial support, contribute to a low participation in retrofitting. However, if a large number of residents work together with companies involved in retrofitting, a large scale discount can be achieved. It is this collaboration between contributors that the Yarra Energy Foundation (YEF) is promoting to the City of Yarra.

The Yarra Energy Foundation was established with the mission of transforming Yarra into a carbon neutral city by 2020. This initiative has been named "Project Zero" and has been the main focus of YEF since their inception. YEF plans on reaching this goal through educating the public and using strategies to inspire the community to implement efficient energy consumption methods. This is a challenging goal; therefore, support from the community is crucial to YEF’s success.
For this project, we were asked by YEF to perform an economic analysis of city-wide residential retrofits. Specifically, we investigated:

- The total cost to retrofit the entire residential sector
- Potential energy savings that could be realised from the retrofits
- Potential economic benefits of retrofitting including potential job creation
- What strategies may be employed by local contractors to lower retrofit costs

With the results of this project, YEF will be able to show local businesses, government agencies and residents of Yarra the economic benefits that could be generated from collaboration in large scale retrofitting plans.

Large scale retrofitting initiatives bring along positive economic outcomes such as a significant amount of demand for skilled and semi-skilled labour, as well as a high amount of investment in the retrofitting industry. A study done by Environment Victoria in 2009 reported that the Solar Water Heating industry and the Energy and Water Efficiency industry are among the industries that have grown considerably due to an increase in retrofitting activities (Rutovitz, et al., 2009). More specifically, the Solar Water Heating industry in Victoria has been growing at approximately 20% per year since 2001 and has the potential to almost double its labour demand by 2020 due to an increased number of retrofits (Rutovitz et al., 2009). In the case of the Energy and Water Efficiency industry, its labour demand in Victoria could increase by nearly 60% by 2018 if large scale retrofitting takes place (Rutovitz et al., 2009). As another example, Deloitte conducted a study in 2009 to estimate the potential economic benefits of the “1200 Buildings” retrofitting project, an initiative of the City of Melbourne aiming to retrofit 1200 office buildings in the city. The study reported that an additional $1.3 billion AUD would be spent in retrofitting and 800 new full time positions would be created by 2020 in the industry if the large scale initiative is successful (Deloitte, 2009). This project created a research space for us, and it shows an example of the potential positive economic effects that can be achieved from large retrofitting initiatives.

Energy savings also translate into economic and monetary benefits. The City of Yarra currently imports $60 to $80 million AUD worth of energy resources every year (Yarra Energy Foundation, 2012a). Through these residential retrofits across the municipality, substantial energy savings can be realised. Currently, the money spent on imported energy is guaranteed to leave the municipality; after the retrofits, any savings on energy have the potential to be spent locally, converting this reallocation of funds into a great opportunity for local economic stimulus and industry growth. These demonstrations of positive economic outcomes derived from large scale retrofitting serve as an indicator of the potential economic benefits that a successful implementation of the retrofitting initiative could bring to the City of Yarra.
In order to quantify the potential economic benefits of large scale retrofitting in Yarra, we designed and created an economic model that produces six different outputs:

a) Total potential investment going to the industries involved in retrofitting
b) Geographic distribution of investment between Yarra, Melbourne, Victoria and elsewhere
c) Total estimated demand for each retrofitting product/service per year
d) Total potential Full-Time Employment (FTE) positions created per year for each type of job
e) Potential discount on products and labour due to volume discounts associated with large scale retrofitting
f) Total potential savings on energy bills that could be reallocated to the local economy

These quantifiable outputs are of interest to all the stakeholders that YEF is aiming to incentivise and thus will serve the organization in their efforts. We designed the model to be flexible and serve as a live tool for YEF to use in the future. Nearly every input is editable; this will allow them to adjust the model based on changes in assumptions, changes in energy prices and even check against real results.

From this model we found some interesting and compelling results. This project is considering the retrofitting of 30,000 homes and the scale of the aggregate results reflects this. Assuming the retrofitting schedule provided by YEF is accomplished, we are expecting a total investment of $608 million AUD, $399 million AUD of which will go towards the products to be installed and the additional $209 million AUD towards all associated labour needed to perform these retrofits.

Naturally, these retrofits will demand a large amount of labour services to install, audit, and manage these projects. We expect a total demand of 2.24 million man-hours of labour; 416 thousand hours for ticketed trades and 1.82 million man-hours for semi-skilled labourers such as energy auditors, project managers and general labour. We estimate to have a peak in labour demand in the year 2017 of 256 FTE positions demanded.

Retrofitting a home has a powerful impact in energy usage and greenhouse gas reduction. Our estimates show that there will be a reduction in energy usage from gas by roughly 79%, in energy usage from electricity by 56%, and in CO\text{2} emissions by about 71%, compared to the current consumption. The lower energy consumption can reduce the peak demand of energy, which will both reduce the energy cost for the homeowner, and indirectly reduce carbon emissions.

The calculated average cost of an entire retrofit is approximately $19,800 AUD. Investing in a retrofit has financial benefits for homeowners. Within the time frame of YEF’s retrofitting initiative, we estimated there will be an average annual monetary savings of $1,560 AUD due to retrofits. Savings will increase over time as a result of increasing energy prices; in 2030, annual savings are expected to be $2,420 AUD. These savings can be an economic driver for Yarra’s economy since homeowners have more disposable income from energy savings. The savings resulting from the energy-efficiency retrofits
are estimated to be $815 million AUD from 2013 to 2030. We anticipate the majority of these savings will be reinvested in the local economy.

The present available discounted cost due to large scale of an average retrofit is about $17,860. This represents a 10% discount of the original retrofit cost. Retrofit investment has profitable returns for all dwelling types and the return on investment ranges from -2% to 34% with the discount. Offering a more favourable discount to homeowners could make retrofitting more attractive in Yarra and contribute to grow business in this sector.

While independent outputs of the model serve as reference point, assumptions made in the creation of the model inevitably produce uncertainty. Therefore, it is crucial to perform a sensitivity analysis to investigate the major contributors to the output. We varied input parameters to investigate the magnitude of effects those inputs have on the outputs of the model. We found that of the four major sectors of investment for these retrofits, insulation and draft proofing had the biggest impact on total investment. It follows that any change in investment or discounts achieved in this sector will make the largest change on our aggregate numbers. It was insulation and draft proofing that gained the largest portion of investment followed by heating/cooling, water heating and finally lighting. Aside from division of investment, we found that the dwelling types that contributed the largest portion of investment were on-your-own units and followed closely by Victorian one storey homes.

After looking at different breakdowns of investment, we tried to identify what factors had the biggest impact on job creation. Interestingly, when considering the number of dwellings for each type, we found that Victorian one-storey homes had the largest impact on labour demand, with on-your-own units making a similar contribution. The insulation and draft proofing sector had the largest impact on labour demand. This is primarily because this section contained the installation of windows, which takes a considerable number of man-hours.

Aside from investment breakdown analysis and industry development, we needed to consider a change in retrofitting schedule. YEF provided us their assumptions for the schedule to retrofit the whole community. We reran our model with a schedule that was slightly more uniform in distribution and we found that a change in schedule primarily affected the peak demand for labour as well as the monetary value of energy savings. With a more uniform distribution, the peak demand for labour is lower and this may be easier for the community to match. Any excess demand that can’t be satisfied by the community will require the importation of labourers from other councils. We also noted that with a more uniform schedule, the monetary value of energy savings decreased, in some instances as much as 5%.

With the findings and outputs of the model we hope to give YEF the resources that they need to market the prospects of residential retrofitting to other government agencies and contractors. Through our analysis, we have identified that via collective action and scale, the cost to retrofit can decrease
significantly. In addition, the economic incentives surrounding potential job creation and energy savings are abundant. The cost of one retrofit is expensive, yet 10% of residents in Yarra have already retrofitted their homes. Any incentives from discounts due to collective action and scale will accelerate the rate at which homeowners decide to retrofit.
1. Introduction

The topic of climate change has been an increasingly important but controversial issue. While climate change is considered by the Intergovernmental Panel on Climate Change (IPCC) to be a consequence of both natural variation and human activity (Intergovernmental Panel on Climate Change, 2007), the main cause of climate change has been attributed to the greenhouse effect, triggered by the emissions of greenhouse gases such as carbon dioxide, methane, and water vapour (Schneider, 1989). In order to limit the emissions of carbon dioxide, Australia and several other countries have ratified the Kyoto Protocol, an international agreement that requires involved countries to meet a carbon reduction standard. Australia has ratified for the second commitment phase of the Kyoto Protocol, which started in 2013 and will end in 2020 (Harvey, 2012).

Many of Australia’s cities, including Melbourne, have been affected by significant changes in weather patterns which are consequences of greenhouse gas emissions (Houghton et al., 2001). In February of 2011, an intense tropical storm flooded the Melbourne suburb of Elwood resulting in $2 million AUD in damage (Fitzgerald, 2012). With such clear indications of the detrimental effects of climate change and its impact, many local governments have initiated solutions in the form of carbon neutrality programs.

The City of Yarra, a council of Melbourne, has implemented its own initiatives towards this goal of carbon efficiency. To show their dedication to the cause, the council created the Yarra Energy Foundation (YEF), a publicly funded organisation designed to investigate carbon efficiency practices and apply them to the residences and businesses of Yarra (Yarra Energy Foundation, 2011-12). YEF has embarked on several projects designed to reduce greenhouse gas emissions. More recently, the organisation has shifted its focus towards residential retrofits - energy efficient upgrades via remodelling and appliance replacement. Residential retrofits are an important step for the community to reach carbon neutrality. The environmental benefits of these retrofits are largely understood, but YEF is interested in the positive effects that a large scale retrofitting initiative can have on the local economy.

In addition to creating a more environmentally friendly and sustainable city, household retrofitting potentially offers economic opportunities for the City of Yarra. Greater application of retrofitting activities can create additional green technology related opportunities within the local job markets, such as increased demand for retrofit installation technicians and energy-efficiency consultants. Wages and salaries received from these newly created jobs can also encourage expenditure by the workforce and hence allow more local economic activities. As a result of what is known as the multiplier effect, each dollar spent by the workforce will multiply and produce more
spending as it circulates through local businesses. These economic developments can result in higher living standards for local citizens and a more desirable city for current residents, businesses, and investors. To help envision the effect of residential retrofitting on the economic structure of the city of Yarra, an informed, context specific, economic model was constructed.

Given the potential that residential retrofitting offers both in terms of environmental sustainability and economic growth, YEF is interested in finding ways to promote and market retrofitting to the private sector, the media and commercial partners since the current level of local interest and support for such initiative does not match their expectations. YEF believes that presenting the quantifiable benefits of the retrofits on the local economy to retrofitting companies in Yarra as well as government agencies will contribute to the acceptance and execution of their retrofitting plan. For this purpose, we modelled and quantified the economic impact that such retrofits will have on the City of Yarra, focusing on job creation, industry development and the reallocation of monetary energy savings to the local economy. Our project addressed the needs of YEF by creating and analysing a value chain of the retrofitting activities and developing a model of the economic impact of retrofits, concentrating on the three aspects described above. As a parallel deliverable, an estimate of the discounted retrofitting cost per home resulting from large scale demand was provided to YEF.
2. Background

A variety of initiatives aiming to reduce carbon emissions currently exist around the world. One of the means for achieving the goal of carbon neutrality is the retrofitting of residential buildings, which involves energy efficient upgrades and refurbishments. Homeowners are fully responsible for the decision to retrofit and there are a variety of incentives and barriers impacting households’ involvement. Figure 1 in section 2.1.2 shows a diagram including several drivers and barriers applicable to residential retrofitting. Aside from environmental and individual household benefits, these retrofitting activities impact local job opportunities and industry development, benefiting the local economy.

The governments of Australia and the state of Victoria have played an important role in supporting retrofitting and other initiatives locally. In 2010, the Yarra Energy Foundation was established with the objective of creating a carbon neutral city by 2020 via Project Zero. Project Zero encompasses a variety of carbon neutrality initiatives, one of which aims to motivate and assist Yarra businesses and residents on retrofitting their buildings. Our project focused specifically on residential buildings. In order to assist YEF in incentivising Yarra locals to retrofit, data on the retrofitting activities was collected and then disseminated in the forms of a value chain and economic model. As represented in Figure 1 mentioned above, a quantification of the potential local economic uplift will act as an important driver to promote residential retrofitting.

2.1. Becoming Carbon Neutral

2.1.1. Approaches toward Carbon Neutrality

Several activities have been implemented in recent years with the objective of achieving carbon neutrality including implementation of a carbon tax, carbon emission trading, and recycling. The application of carbon taxes is an initiative being pursued in several developed countries and nation states. Ireland, British Columbia (Canada), Finland, Sweden, Great Britain, New Zealand and Australia are examples of places where carbon is taxed (Carbon Tax Center, 2013). A review of examples and the implementation of carbon taxes and carbon emission permits was published by Paul Ekins and Terry Barker in the Journal of Economic Surveys in 2001. Ekins and Barker stated that “the objective of carbon tax is to slow global warming, usually in the context of agreed targets for limiting or reducing GHG [greenhouse gases] emissions” (Ekins & Baker, 2001). A parallel idea is the concept of carbon emissions trading through which “emitters have access to emission permits which they can trade among themselves” (Ekins & Baker, 2001). The purchase of such permits or certificates allows emitters to produce only a given level of GHG, limiting the quantity of these gases under penalisations and fines. Finally, recycling has been increasingly encouraged as it “reduces more pollution, saves more energy
and reduces greenhouse gas emissions more than any other activity besides source reduction” (Campaign for Recycling, 2013), as noted by the Campaign for Recycling, a US-based non-profit environmental advocacy organisation.

Carbon neutrality is the result of a combination of initiatives rather than the outcome of one. As described above, the initiative concerning our project is retrofitting buildings. Retrofitting derives lower consumption of energy and direct demand savings including less air conditioning or heating use and reduced water and lighting consumption (Al-Ragom, 2003). Residential retrofitting provides a great opportunity for carbon reduction in Yarra as approximately 16% of the council’s total emissions in 2005-2006 came from the residential sector (Yarra Energy Foundation, 2012e).

2.1.2. Residential Building Retrofitting

When a new building is constructed, it is naturally limited by the efficiency of the technology available. Over time the building becomes obsolete, or at least relatively inefficient, to the next generation of homes and appliances available on the market. Rebuilding a home from scratch in order to meet a modern standard of energy efficiency is financially ineffective. A common and encouraged solution to this problem of relative inefficiency is retrofitting, the act of upgrading parts or equipment that have become technologically obsolete. In the context of this particular project, retrofitting involves replacement of home appliances and renovations to the home which are designed to enhance energy efficiency. A list of several basic types of retrofits divided by retrofit category can be found in Table 1 below. The whole state of Victoria, as well as other states across the Australian nation, is working towards upgrading household energy efficiency.

<table>
<thead>
<tr>
<th>Category</th>
<th>Type of Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting</td>
<td>Light bulbs replacement</td>
</tr>
<tr>
<td></td>
<td>Automatic switches</td>
</tr>
<tr>
<td></td>
<td>Increasing sunlight inside</td>
</tr>
<tr>
<td>Insulation/Draft Proofing</td>
<td>Windows foam insulation</td>
</tr>
<tr>
<td></td>
<td>Doors foam insulation</td>
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<tr>
<td></td>
<td>Walls foam insulation</td>
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<tr>
<td></td>
<td>Floor insulation</td>
</tr>
<tr>
<td>Heating/Cooling</td>
<td>Central HVAC systems</td>
</tr>
<tr>
<td></td>
<td>Automatic AC systems</td>
</tr>
<tr>
<td></td>
<td>Windows lamination</td>
</tr>
<tr>
<td>Water Heating</td>
<td>Solar panels installation</td>
</tr>
<tr>
<td></td>
<td>New energy efficient water heaters</td>
</tr>
</tbody>
</table>

Table 1: Types of Retrofits by Retrofit Category

Retrofitting allows a home to reach a new level of energy efficiency without excessive expenditure; however, retrofits are still an expensive and involved process. Currently, YEF is
encouraging the residents of Yarra to consider retrofits with emphasis on four different categories: heating/cooling, insulation/draft proofing, lighting, and water heating. According to a previous study conducted by the organization, these retrofitting activities require an estimated average investment of $12,000 AUD¹ per home in Yarra (Tabor, 2011). The Yarra Energy Foundation is making strides in educating the public on the opportunities that retrofits can bring to the environment, the residential sector, and ultimately the local economy (Yarra Energy Foundation, 2012f).

As is the case with most technologies, energy efficiency methods and appliances are always improving and introducing new standards. Due to a variety of barriers, the average household finds themselves inefficient in comparison to the technological forefront (Alberini, Banfi, & Ramseier, 2011). These barriers have created what is known as an “Energy Efficiency Gap: a wedge between the cost-minimizing level of energy efficiency and the level actually realized” (Allcott & Greenstone, 2012). Homeowners considering an energy efficient retrofit find themselves facing a slew of important factors, the largest of which are financial, but include other needs such as comfort and convenience. A large portion of those who decide to make energy efficient upgrades to their homes do so with the intention of helping the environment (Zundel & Stieß, 2011).

Advocates of energy efficient retrofits frequently market renovations to the homeowners in the form of a sound investment to the home. While there is often a large down payment for extensive retrofits, savings due to lower monthly energy bills can be realised and eventually a breakeven point may be reached (Alberini et al., 2011). Even though the market value of the home increases after a retrofit, there are a considerable number of market barriers that are preventing individuals from embarking on the retrofitting process. The large down payment, immediate sunk costs, difficult access to credit, and uncertainty in the future market are overwhelming to non-expert homeowners when deciding to retrofit their home (Alberini et al., 2011). A visual representation of these barriers along with some incentives can be seen below in Figure 1.

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¹ Our analysis delivered a more refined estimation which will be discussed later.
Some studies have evaluated home retrofit investments to have a return on investment of up to 25%; however, others have found it to be much lower at 1.5-3.1\% (Alberini et al., 2011). These uncertainties in the profitability of the investment, as well as other market factors, make the retrofitting process confusing, intimidating, and out of reach to homeowners who are neither experts on the subject nor have disposable assets.

While retrofitting one home may have a healthy impact on the environment, retrofitting an entire community could have substantial benefits. Savings of energy on that scale alleviate the effect on the environment as well as the strain on the local energy resources. The City of Yarra, home to 80,000 residents, has the potential to save up to 65,000 tonnes of greenhouse gas emissions if retrofits continue through 2020, according to data provided by YEF (Yarra Energy Foundation, 2012d). These regional retrofits will not only alleviate greenhouse gas emissions but can also instil long-term growth in the local economy and the energy efficiency job market as well.

2.2. Government Leadership and Support

The approaches described above have been the product of collaborative work between national and local governments. Government has played the largest role in reducing carbon emissions by establishing legislation, creating leading organisations with carbon neutrality goals, and supporting projects with the same objectives. The Australian government is environmentally conscious and has targeted to reduce every Australian’s carbon footprint by approximately one third to one half (Department of Climate Change, 2012). The Australian government is investing more than $5 billion AUD throughout the country in clean technology development and commercialisation (Department of...
Climate Change, 2012). Moreover, the government is aiming to invest in renewable energy resources and introduce a standardised carbon tax to citizens (Department of Climate Change, 2012).

The Australian government is also developing and organising policies through Clean Energy Future, an environmental organisation, to support businesses and households to lower carbon emissions by retrofitting in the business sector and creating employment to progress the Australian economy. The encouragements of the government in Australian businesses helped generate new jobs in carbon farming, sustainable design, and retrofitting (Department of Climate Change, 2012). Clean Energy Future predicted there will be 1.6 million jobs created by 2020 and the average income of the workers in the green energy industry will increase about 16%\(^2\) by 2020 (Clean Energy Future, 2012). In addition, the governmental organisation, Skills for Carbon Challenge, provides programmes that educate in green skills and sustainability principles which cover a wide range of industries including the retrofitting industry (Department of Climate Change, 2012).

The state of Victoria also has a sustainability mission and funds a multitude of municipalities and non-profit activities related to carbon efficiency. The Swan Hill Rural City Council, for example, was offered a grant by Sustainability Victoria to review energy use and ultimately retrofit council-owned buildings to be more energy efficient. Likewise, Sustainability Victoria, an environmental organisation, is funding the efforts of the Hepburn Shire Council in their goal to review past and current utility consumption data and recommend retrofit options to 211 of their buildings in the public sector (Sustainability Victoria, 2011).

In addition to funding individual projects in local municipalities, the state of Victoria offers other financial incentives. For example, to inspire businesses and homeowners to make energy efficient retrofits, the state of Victoria has a greenhouse gas emission credit program. The Essential Services Commission (ESC), a program within the Victorian State government, has begun an initiative designed to fuel energy efficient renovations within the state (Essential Services Commission, 2012). This program, called the Victorian Energy Efficiency Target Scheme (VEET), is designed to incentivise both retailers as well as consumers to take part in energy efficient practices through the installation of efficient appliances within their homes and businesses. The thought process behind these renovations is described as:

Accredited Person X encourages Consumer Y to purchase a high efficiency product by offering a cash ‘discount’. Y purchases the product and assigns to X the right to energy efficiency certificates equivalent to emissions saved by installing the product. The certificates are then purchased by Energy Retailer Z to surrender towards its obligation under the scheme. So X effectively sets a discount based on the price it can get for the certificates from Z, plus administration costs. Y benefits from discounted product prices and lower energy bills resulting from reduced energy use (Essential Services Commission, 2012).

\(^2\) These statistics are in comparison to data from 2010.
This scheme, formulated and implemented in 2009, has already shown great progress. In the Commission’s report for the 2011 year, a total of over 9 million VEECs (Victorian Energy Efficiency Certificates) have been distributed since the program’s inception (Essential Services Commission, 2012). Each of these certificates represents one metric ton of green-house gases which total an equivalent of 765,160 Victorian households becoming carbon-neutral for three years (Essential Services Commission, 2012). This VEET scheme is scheduled to continue into the year 2030. While these efforts are substantial, it is clear this movement is just the beginning.

2.3. The City of Yarra and Yarra Energy Foundation

The City of Yarra takes an active role in local sustainability within the state of Victoria. Over an area of 19.5 square kilometres, Yarra is home to 79,500 people with 34,600 households (City of Yarra, 2012). Figure 2 shown below depicts a map of the location of the City of Yarra in Melbourne. Table 14 in Appendix A includes a breakdown of the residential sector by dwelling type. This table shows a description of each dwelling type, along with the number of dwellings to be retrofitted. It is important to recognise the variety of dwellings in Yarra, because the types and quantities of retrofits will vary according to each dwelling. Despite a population growth of 10,000 people since 2000, the Yarra City Council has already cut energy use by 17% over the last decade (City of Yarra, 2012), and local efforts to reduce carbon emissions continue. In 2012, the Yarra City Council decided to direct $765,000 AUD towards the installation of solar panels in commercial buildings and energy efficient light bulbs for street lights.

![Figure 2: Map of the City of Yarra (Yarra City Council, 2013)](image)

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3 This is based on a statistic given in the ESC’s VEET Performance report which states that 2.7 million certificates would be equivalent to 675,000 Victorian households becoming carbon-neutral for one year.
The Yarra Energy Foundation is a leading organisation on promoting reduced use of energy and energy efficiency initiatives. YEF is a public, non-profit foundation with the sole mission of reaching carbon neutrality in Yarra by 2020. YEF’s main source of funding is the Yarra City Council. In 2011, Yarra Energy Foundation received an initial grant of $600,000 AUD. YEF receives help and contributions (financial, technological and human capital) from numerous stakeholders such as businesses, government agencies, students, and volunteers for their projects. YEF partners with industrial organisations such as General Electric, City West Water, Red Energy and CSR Building Products, education and training organisations such as Kangan Institute, and other community organisations such as Kunexion.

YEF established the Project Zero initiative to accomplish its grand carbon neutrality objective. To achieve this, YEF needs to break through three barriers: lack of environmental awareness, financial constraints, and inaccessibility to support. Project Zero’s mission is “to help citizens transform the municipality into a place where Zero Carbon Living, Learning and Earning is not only possible, but normal” (Yarra Energy Foundation, 2012g). The residential retrofitting initiative of Project Zero is expected to account for 11% of the overall emissions reduction target, according to the data provided by YEF. The organisation has an initial plan for carrying out these retrofits until the year 2020. They have estimated how many homes need to be retrofitted as well as the types and quantities of retrofits that must be completed. However, as the investment is coming directly from homeowners, YEF’s plan is subject to change dependent on the ability and willingness of Yarra residents to retrofit.

2.4. Greater Scale Benefits for Yarra

YEF anticipates that the retrofitting of residential buildings will add significant value to the local economy. In order to accurately analyse the spectrum and magnitude of the potential economic uplift, analytical tools, such as a value chain, must be utilised. Raphael Kaplinsky, author of *A Handbook for Value Chain Research*, explained that the value chain “describes the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to the final consumers, and the final disposal after use” (Kaplinsky & Morris, 2001, p. 4). A value chain identifies and clarifies the financial factors and outcomes involved in the retrofitting process. An example of a value chain is shown in Figure 3 below.
Figure 3: Example Value chain of forestry, timber and furniture (Posthuma, 2003)

Even though activities, presented as the blocks of the value chain diagram, are important, “the value chain is not a collection of independent activities. Value activities are related by linkages with the value chain” (Kaplinsky & Morris, 2001, p. 7). For instance, Figure 3 shows the linear chain of activities from raw product, to complete product purchased, used, and recycled or discarded by consumers. Each of these activities acts as a prerequisite for the next, as dictated by the arrows connecting each box. These main activities located in the middle column of the image (i.e., forestry, sawmills, furniture manufacturers and buyers) are supported by additional inputs required for each activity’s completion (i.e., design, machinery, logistics, paint). Identifying the inputs, activities and their logical links of connections in a value chain diagram such as Figure 3 will both identify the variables within the process, and the process by which value is added to the system.

Once created, a value chain can be analysed to discover pertinent information about financial factors and outcomes. This project utilised the value chain associated with retrofitting activities to build the economic model to determine and quantify the potential economic uplift in the City of Yarra, with a special focus on green energy job creation and industry development.

2.4.1. Potential Job Creation and Industry Development

As with any type of business initiative, associated industries experience development as a consequence of a higher demand. This in turn has the potential to grow the local economy as more jobs are created and more money circulates among the different business areas. The pertinent industry
related to our project work is building retrofitting. While the value chain we created as part of this project identified which industries have the opportunity to grow and where jobs may be created, the economic model quantified the magnitude of the two outcomes. Furthermore, the value chain and economic model were jointly used to analyse the potential reallocation of monetary energy savings to the local economy. The model is based on the number of homes to be retrofitted in YEF’s plan, the timeframe, and the types and quantities of retrofits to be implemented, which in turn determined the magnitude of the retrofits and the size of the impact on jobs and industry development.

Job creation as a consequence of green initiatives is already occurring in Victoria. A study from the non-profit organisation Environment Victoria reported that “[Victoria has] established green industries, employing tens of thousands of Victorians” (Rutovitz et al., 2009). This study points to the Solar Water Heating industry and the Energy and Water Efficiency industry as two industries that have experienced considerable development in Victoria as a consequence of business activities which aim to reduce carbon emissions.

The majority of the households in Victoria use traditional sources of energy. In the case of water heating this typical source is natural gas. Utilisation of alternative sources of energy is far from being widespread, with statistics showing that as little as 3% of households in the state utilise energy from solar water heating in their homes (Rutovitz et al., 2009). This creates an enormous potential for the implementation of solar water heating systems and the development of the Solar Water Heating industry. According to data reported by Environment Victoria, this industry has been growing since 2001 at a rate of about 20% per year (Rutovitz et al., 2009). Despite this growth, there is still only one manufacturing facility in the Solar Water industry in Victoria. Environment Victoria also reported the existence of state and federal policies such as rebates and certificates that intend to motivate the population to adopt solar water heating (Rutovitz et al., 2009).

A large number of employment positions can be created in this industry by increasing the implementation of retrofits. The industry is currently responsible for 700 jobs and $78 million AUD in revenue per year in the state. According to Environment Victoria, with adequate planning and policy implementation, “increasing the proportion of solar water heating in Victorian households to 30 percent by 2020 would require 57,000 installations per year.... [t]his would create approximately 1500 new jobs.... while reducing Victoria’s emissions by 1.8 million tonnes per year” (Rutovitz et al., 2009). The distribution of jobs, as laid out by Rutovitz and colleagues (2009), can be seen in Figure 4.
One of YEF’s areas of focus for retrofitting is water heating. An increase in the demand for installation of water heating systems may have the potential to create the types of jobs detailed by Rutovitz and colleagues (2009) including plumber positions, manufacturing, distribution and sales jobs, administrative and research positions. Administrative, and distribution and sales jobs are activities that can be done better by locals without a significant amount of training. Retrofitting companies naturally prefer to employ local workers on local projects. These are jobs more desirable because semi-skilled workers can enter the workforce immediately without delays due to training or skills acquisition. It is worth noting that skilled workers will also be demanded; however, the labour supply in this case may not be readily available because people would have to be trained.

The Energy and Water Efficiency industry is already well developed and of a considerable size in the state of Victoria (Rutovitz et al., 2009). However, despite the fact that this industry is already in a thriving position, it has the potential to be expanded as a result of an increasing number of residential retrofits. According to data from Environment Victoria (2009), the industry is accountable for 12,000 jobs and $1.2 billion AUD per year in Victoria. Environment Victoria reported in 2009 that the local and federal governments had planned to invest $370 million AUD in this industry from 2010 to 2012, with the potential to create 4,800 jobs (Rutovitz et al., 2009).

Large scale retrofitting induces job creation, an important effect that concerns YEF. Retrofitting at a large scale in the City of Yarra has the potential to create a relatively significant number of new jobs in the council. The study from Environment Victoria estimated that 6,900 new jobs could be created in the Energy and Water Efficiency industry if 1 million homes in Victoria are retrofitted within 5 years. Furthermore, “more than 40 per cent of water and energy efficiency jobs are likely to be semi-skilled, opening up opportunities for unemployed workers” (Rutovitz et al., 2009). This is certainly beneficial
because a wide variety of people could potentially do these jobs, bringing down training and skill barriers. Figure 5 is an estimate of work hours by type of job related to home retrofits.

![Figure 5: Estimated work hours by type, home retrofits (Rutovitz et al., 2009)](image)

Increased demand in retrofitting activities will not only create new jobs, but also generate a market for new job skills. The non-profit organisation “Skills Australia” published a study in 2011 on the impact that energy efficiency activities are having on jobs and skills. Skills Australia argued that as a result of new energy efficiency initiatives, several job positions will require more developed skills (Skills Australia, 2011). Skills Australia identified some of the main positions and jobs impacted including auditing and reporting, installation and maintenance of appliances, building assessment, and marketing buildings in commercial and residential sectors. This translates into a potential source of employment for workers who would be willing to acquire knowledge in any of these areas. However, as there generally exist barriers for workers to gain these skills, experts fear an approaching shortage of supply for these types of jobs (Skills Australia, 2011). Skills Australia predicts “shortages of building scientists, assessors and auditors, refrigeration and air-conditioning mechanics, VET teachers, and people with qualifications and experience in delivering sustainable business solutions” (Skills Australia, 2011). These results suggest that there is a wide variety of positions which will be highly demanded in the near future. This wide spectrum of positions include technical/business consulting jobs which involve assessing and auditing buildings as well as designing solutions to meet sustainability goals.

As part of the efforts to reduce the effects of this potential skills shortage, several plans related to workforce development are being implemented. Training programs are taking place to prepare people for the requirements of the job market. In New South Wales (NSW), there was “a 44% increase in the number of NSW vocational students enrolled in one or more energy efficiency skills units of
competency or modules from 2008 to 2009” (Skills Australia, 2011) as reported by the National Centre for Vocational Education Research (NCVER). This speaks to the accomplishments that these workforce planning programs have had over the past years. The consequences of this skills shortage phenomenon could be experienced in the City of Yarra as well, and was taken into consideration when developing the value chain and economic model. Given what has been happening on green jobs creation in the state of Victoria, it is evident that the same effects apply to the City of Yarra, on a smaller scale, as a consequence of residential retrofitting activities. Our project investigated these local economic effects in response to YEF’s desire to determine this impact and use it to promote residential retrofits in Yarra.

2.4.2. Additional Disposable Income from Money saved on Energy Bills

A direct consequence of a home retrofit is reduced consumption of energy. Lower energy usage results in lower energy bills that free up money to be spent elsewhere. This additional disposable income can be invested in the local economy and cycle through different economic areas. As money cycles through the economy, its real value is amplified beyond its nominal value. This multiplier effect is a direct consequence of fractional reserve banking which is employed in free market economies. Money saved in a bank is available to be loaned and can be borrowed by other people who would also put a fraction of it in a bank, allowing a third borrower to claim this money. This process repeats indefinitely and increases the real value of each dollar, in some instances even reaching five times its nominal value (Federal Reserve Bank of Chicago, 1992).

The retrofitting that Project Zero is trying to incentivise could bring along a great amount of savings on energy bills for households in Yarra. YEF was interested in obtaining an estimate of the total disposable income for the Yarra community that would result from savings in energy bills. The organisation wanted to get an idea of the potential additional investment that could go into the local economy due to lower energy bills, with the objective of marketing Project Zero to the retrofitting industry and government agencies. Our research provided an estimate for this total disposable income based on average individual energy savings.
3. Methodology

Our goal was to assist Yarra Energy Foundation with marketing the residential retrofitting plan to the private sector, the media, and commercial partners with the objective of stimulating households to carry out the retrofits. In order to accomplish this goal, we divided the project into the following objectives:

1. Evaluate YEF’s existing data on targeted homes suitable for retrofitting and types of retrofits proposed in order to determine the inputs of the economic model.
2. Establish a value chain to identify the value and distribution of labour.
3. Create an economic model of retrofitting processes to identify distribution of investment and potential job generation.
4. Estimate the potential discount for retrofitting at a large scale.

To accomplish these objectives we analysed the financial data provided by YEF to determine the inputs of the economic model. We employed a variety of interviewing and analytical techniques to generate a value chain and economic model as a means to inform YEF so they may confidently market their retrofitting program.

3.1. Evaluate YEF’s existing Data to determine the Inputs of the Economic Model

Evaluating YEF’s existing data was useful in determining the three vital inputs for the model to be developed:

- The number of homes which YEF expects to have retrofitted by 2020 in order to partially achieve the carbon neutrality goal
- The retrofitting products and services that will be implemented

Data was retrieved from several previous analyses done for YEF on the topics described above. We analysed four documents: “Master thermal analysis and charts” (Yarra Energy Foundation, 2012b), “Residential upgrade cost breakdowns” (Yarra Energy Foundation, 2012c), “Retrofit Trajectory” (Yarra Energy Foundation, 2012d) and “YEF Hot Water Analysis” (Yarra Energy Foundation, 2012h). The first, second and fourth documents provided data on the retrofitting methods proposed by YEF and the costs associated. They also included an estimate of the number of retrofits necessary to achieve the portion of the final carbon neutrality goal accountable to residential retrofits. The third document contained data detailing YEF’s projection on how many homes must be retrofitted in order to partially achieve the goal.
We first did an annual grouping of the estimations on the number of homes to be retrofitted and calculated the planned progress percentage to be accomplished each year towards the final goal. We then created a master retrofit schedule table so YEF’s plan was easier to visualize and edit. As a third step, for each retrofitting product in YEF’s plan, we identified its manufacturer, model and the category it belongs to, out of the four categories proposed by YEF: lighting, insulation/draft proofing, heating/cooling and water heating. Finally, we quantified the frequencies of these retrofitting products dividing them by dwelling type according to the ten different types detailed in Table 14 in Appendix A. Different dwellings required different combinations of each retrofit activity. An example of the format worksheet used to outline the retrofitting configuration of each dwelling type is included in Table 15 in Appendix A.

3.2. Establish a Value Chain to Identify the Value and Distribution of Labour

The major steps for compiling the value chain involved discovering the retrofitting activities, determining the links between them, and finding the specific division of labour for the retrofitting process. After collecting the previously mentioned data, a better understanding of the value and distribution of labour was formulated. This level of understanding was obtained through semi-standardised interviews with well-informed employees from retrofitting companies in Melbourne.

Through YEF’s CEO Alex Fearnside, we contacted representatives of retrofitting companies who were familiar with the steps involved in the retrofitting activities they each provide. These representatives involved department heads, project leads, and executives. We conducted semi-standardised interviews at the sites of the retrofitting companies and at YEF’s office. Semi-standardised interviews offered the flexibility to ask specific questions, while simultaneously uncovering new ideas. During each interview, we asked informants about what processes were involved in their retrofitting services, and how these processes are supported financially, using a combination of written notes and audio recording to document our findings. The interview outlines used for several interviews are included in Appendix B. A detailed list of sources for all the information we obtained is included for reference on Table 16 in Appendix C.

A data analysis on the documents “Master thermal analysis and charts”, “Residential upgrade cost breakdowns”, “Retrofit Trajectory”, and “YEF Hot Water Analysis” provided significant insight for documenting the value chain. The outcome of this data analysis in combination with the data collected from the interviews resulted in a value chain diagram, which was used as a procedural model for the retrofitting process. In addition to being a useful visualisation tool, the value chain created was a means of investigating the unknown financial variables of the retrofits. Our final value chain model is included in section 4.1.
3.3. **Create an Economic Model of the Retrofitting Process to identify Distribution of Investment and Potential Job Generation**

We gathered information for the economic model through several semi-standardised interviews with local professionals that work on the retrofitting industry. The sample for this portion of the methodology consisted of local manufacturers of energy efficient appliances, retrofitters, consultants and local agencies such as YEF who advocate retrofits. We gathered information from them about rough expenditure breakdown on these retrofits. YEF agreed to introduce our team to a variety of experts in the field and made suggestions towards who was best to contact for this data. Each of the interviewees was a specialist in their respective field and provided first-hand experience in regards to retrofit expenditure and cost analysis. Among others, individuals from the following corporations were suggested: Ecovantage, a local company in the lighting industry, Apricus, a water heating systems supplier, and CSR, a building materials supplier.

Each interview began with a brief summary of our project with YEF as well as how the information that they provided could be helpful to the team, YEF, and the retrofitting efforts all together. From these interviews we intended to get explicit breakdowns of how the money a homeowner spends on the retrofit is distributed among all of the parties involved in the process, as well as labour required for each refurbishment. Every retrofit category is different, each requiring different materials and labour and generating different cost profiles. We were specifically interested in what portion of the money spent on retrofitting is going towards labour versus equipment.

From the expenditure breakdowns, an economic model of the residential retrofits was produced. This model consists of data about individual retrofit expenditure breakdowns by category that ultimately was aggregated into several figures that reflect the possible uplift generated by retrofitting the entire community. YEF provided a series of retrofitting plans which vary for several different types of home dwellings. For each of these plans, we investigated the breakdown of a homeowner’s investment into categories including equipment and installation labour.

3.4. **Estimate the Potential Discount for Retrofitting at a Large Scale**

Retrofits at a large scale, in thousands of building units, can induce greater cost savings than the retrofit of a single home. YEF was aware of how cost affects customers’ decisions to invest in retrofitting. Through this method, we were able to identify discount opportunities for large scale residential retrofitting in Yarra. The desired data for this method was composed of a list of discounted costs given the demanded quantity of each type of retrofit.

Discounts can be obtained in both equipment and installation labour. For the purpose of the project, we focused only on discount on equipment. In order to estimate this discount, we interviewed
distributors of retrofitting products which were previously identified in the interviews with retrofitting companies. We defined a range of discount possibilities based on the information obtained from the interviews. The interviews were semi-structured in order to obtain specific information about retrofit discounts, while also being able to establish an open discussion. The questions that we asked to approach the objective of potential discount evaluation for large scale retrofitting are detailed in Appendix B.

Each of the methods was built upon the previous. YEF’s initial data served as a platform which fed the other three methods. Figure 6 is a visual representation of how the methods were structured. The base of our research was the analysis of YEF’s existing data. The value chain identified the location of value and the contributors or stakeholders in the retrofitting process. Finally, the economic model, which comprises analysis on potential investment, labour demand, large scale discount and monetary value of energy savings, was developed with the help of YEF’s initial information and interviews with these previously identified stakeholders on expenditure breakdown and job creation.

Figure 6: Methods Pyramid
4. Results and Discussion

4.1. Value Chain of the Retrofitting Process in Yarra

Our value chain model illustrates the creation of value associated with the YEF residential retrofitting plan and showcases the plumbers, electricians, advisory positions, and semi-skilled labourers that contribute to the installation. This value chain served as the framework for the development of the economic model. Figure 7 below shows the detailed value chain of the retrofitting process.

The chain begins with the decision of a homeowner to undertake an energy efficient retrofit. Since every home is different, an energy auditor first inspects the customer’s home. This audit creates a framework for the entire retrofit, selecting the appropriate retrofit products from each of the categories (i.e., hot water, heating and cooling, lighting, and insulation/draft proofing). The advisor conducts a consultation with the homeowner to review the suggested framework and guide them...
through the decision process. The framework is forwarded to the project manager who develops a plan and oversees the retrofit process. The combination of advisory and supply contribute to each specific retrofit category. After completing the retrofit, the homeowner will experience energy saving benefits and the local economy will be stimulated through the labour involved in the project.

Electricians are involved in the installation of energy efficient heating/cooling systems and/or hot water systems. These installations typically take approximately two hours and require specific skills and knowledge. Electricians may also be necessary if other retrofit projects affect the wiring within the home. Installing energy efficient light bulbs is a relatively simple process that does not require a ticketed electrician. This work can be performed by semi-skilled workers, who are paid less and are more available than the skilled trades. Semi-skilled workers also perform the work associated with insulating and draft proofing the home.

Plumbers are required to install energy efficient hot water tanks. This is an involved process that can take more than a day. If a homeowner chooses to install a solar hot water system, an additional couple of hours will be required from the plumber to install solar evacuation tubes.

The creation of the value chain model informed us of the contributors necessary to accurately model the economic benefits of the retrofitting initiative. Through the visualisation of the value chain, we identified the labourers we would need to account for: energy auditors, advisors, project managers, plumbers, electricians, and semi-skilled workers. A quick analysis of the flow of the value chain informed the relationships within the installation cost breakdown section of the economic model.

4.2. Economic Model of the Retrofitting Process in Yarra

4.2.1. Introduction and Structure of the Economic Model

The economic model created for the project is a means to achieve YEF’s ultimate objective: market the retrofitting initiative in a more successful way to the different stakeholders in the community, via educated estimations of the potential impact that the retrofitting initiative may have on the local economy. The model will serve YEF’s purpose by producing the following outputs:

a) Total potential investment going to the industries involved in retrofitting, per year and cumulative through 2020

b) Geographic distribution of investment between Yarra, Melbourne, Victoria and elsewhere

c) Total estimated demand for each retrofitting product/service per year

d) Total potential Full-Time Employment (FTE) positions created per year for each type of job

e) Potential discount on products due to volume discounts associated with large scale retrofitting

f) Total potential savings on energy bills that could be reallocated to the local economy as an additional investment
The expectation is that YEF will be able to present these figures to retrofitting companies, government agencies and Yarra residents as a way to stimulate retrofitting activity. The outputs of the model will be relevant to these different constituencies in a variety of ways. The potential investment going into the local economy as well as the estimated demand for retrofitting products and services will be of interest to retrofitting companies in the area that are searching for business opportunities. YEF aims to get these stakeholders involved in contributing to the retrofitting initiative once they realize the scale of the business opportunities that it may present for them. The potential FTE positions generated will interest not only retrofitting companies but also government agencies and Yarra residents who may be currently looking for employment. Finally, the potential discount due to large scale retrofitting and the potential savings on energy bills will motivate Yarra households at an individual level.

A complete understanding of the structure of the economic model is required before its functionality can be explained. The model developed for YEF consists of nineteen worksheets divided in three categories: input data worksheets, modifiable data worksheets and output data worksheets. The information on the input data worksheets and the modifiable data worksheets come together to produce the results shown in the output data worksheets. The worksheets correspond to each of the three categories as described in Table 2 below:

<table>
<thead>
<tr>
<th>Input Data Worksheets</th>
<th>Modifiable Data Worksheets</th>
<th>Output Data Worksheets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Products and Costs</td>
<td>Master Retrofit Schedule</td>
<td>Product and Labour Demand Summary</td>
</tr>
<tr>
<td>Installation Costs and Labour</td>
<td>Retrofitting Plan for each Dwelling Type (10 sheets)</td>
<td>Potential Investment by Year</td>
</tr>
<tr>
<td>Energy Savings</td>
<td>FTE Positions by Type of Job</td>
<td></td>
</tr>
<tr>
<td>Investment Analysis</td>
<td>Locality Breakdown</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Economic Model worksheets and their categories

A description of each of the worksheets in the model is provided below:

**Products and Costs**

This worksheet contains a list of all the products used broken down by retrofitting category. Blank spaces are provided to facilitate adding new products in the future. This worksheet is the main hub for adding, removing and modifying products and their costs. For each product the information included is:

- Retrofitting category
- Product ID, Manufacturer and Model
- Short description
- Unit used
• Total product cost (only product, excluding installation)
• Total cost to homeowner (product + installation)
• Percentage breakdown of the locality of the equipment cost in materials and manufacturing
• Money breakdown of the locality of the total equipment cost

Installation Costs and Labour
This worksheet is very similar to the first one. The main difference is that it shows installation costs instead of product costs. This worksheet is linked to the first worksheet so every change made to any product in the first sheet will automatically be applied to this worksheet. For each product the information included is:
• Retrofitting category
• Product ID, Manufacturer and Model
• Short description
• Unit used
• Total man-hours of each type of trade job required for installation and pay rate
• Total man-hours of each type of semi-skilled job required for installation and pay rate
• Total installation cost (excluding product cost)
• Percentage breakdown of the locality of installation labour

Master Retrofit Schedule
This worksheet provides a schedule for the installation of energy efficient retrofits for each of the ten dwelling types by year and cumulative through 2020.

Retrofitting plan for each dwelling type
There is one worksheet for each of the 10 dwelling types. A description of each dwelling type is included in Table 14 in Appendix A. These worksheets contain the configuration of products that will best serve the specific dwelling type. The retrofitting configurations are subject to change and the model allows for the flexibility of adding, removing or changing products on the different dwellings. For each dwelling type the information included is:
• Short description of the dwelling type
• Several area dimensions
• Products and services needed to retrofit the dwelling along with the quantities
• Total cost per product/service, separated into equipment cost and labour cost
• Total man-hours required to install the given quantity of each product or perform each service, separated into ticketed positions and semi-skilled positions
- Money breakdown of locality for each product in $ AUD
- Estimated total cost of retrofitting the dwelling

It is important to note that the model is configured in such a way that all the information (e.g., costs, man-hours, and locality breakdown) for each product needed in each dwelling type is automatically inserted when the Product ID is entered in the worksheet.

**Energy Savings**

This worksheet summarises the results of energy savings in $ AUD, as well as reduction in CO$_2$ emissions. It offers the flexibility to change energy prices. Outputs are shown in the form of:
- Annual and cumulative gas and electricity energy saved
- Annual and cumulative gas and electricity monetary savings
- Annual and cumulative total monetary savings
- Annual and cumulative CO$_2$ emissions reduction from gas and electricity

**Investment Analysis**

This worksheet provides a calculation of the breakeven period and the return on investment (ROI) for the retrofit of a single dwelling of each type. This is a parallel analysis that goes along with the energy savings calculation.

**Product and Labour Demand Summary**

For each product or service, this worksheet calculates the following outputs:
- Total expected annual demand in units from 2013 to 2020
- Aggregate number of hours required for each type of job for the entire time span of the initiative (2013-2020)
- Aggregate equipment and installation costs for the entire time span of the initiative (2013-2020)
- Aggregate locality cost breakdown

**Potential Investment by Year**

This worksheet contains two tables. The first table details the potential aggregate investment that goes into the retrofitting industry per year and the second table shows the same numbers in a cumulative manner. One of the main figures highlighted in this sheet is the total potential aggregate investment for the entire time span of the initiative. Both tables also include a breakdown of the locality of the yearly investment.
FTE Positions by Type of Job

This worksheet contains the summarized results of the job creation aspect of the economic model. It displays the total man-hours required per year for each type of job and their equivalent in FTE positions.

4.2.2. Operational Process of the Economic Model

One of the main objectives in the design of the model was to make it as user-friendly as possible. In addition to providing the necessary outputs, it is easy to enter and modify information as it becomes available or changes. The model contains labels and instructions that show the end user what data is editable and how to modify it. A short tutorial was carried out with the future end users of the model in order to provide them with key guidelines for its utilization. This section aims to describe the general operational process behind the model with the expectation that any potential end user is able to understand how data flows and acts as inputs and outputs. If the end user wants a thorough description of the functionality of the model, a fully detailed explanation of how the outputs were calculated, and the basic formulas that were used is included in Appendix D.

Figure 8 below is a representation of how the model works. The data for the retrofitting products, installation labour, and energy savings components is included in the light blue “feeder” boxes. These components act as inputs (highlighted as blue in the diagram) along with the retrofit plans of all dwelling types and the master retrofit schedule components (highlighted as red in the diagram). The combination of these inputs produces the six different outputs detailed in section 4.2.1 (highlighted as green in the diagram). The data in the light blue feeder boxes can be modified at any time without affecting the functionality of the model. By allowing for this flexibility, the economic model can accommodate any scenarios that come up in the future, constituting a “living” model rather than a rigid one.
4.2.3. Outputs of the Economic Model

The economic model that we developed for YEF has a lot of versatile features and powerful results that will help YEF promote their retrofitting initiative to various leaders of local industry as well as government agents who could facilitate this process. It has been designed to be able to accommodate a change in master retrofit schedule, products, dwelling archetypes, as well as energy prices. From this model, we hope to identify potential industry growth, potential labour demand generated, and the energy savings that could be realised by the residents of Yarra.

Modelling the economic impact of retrofitting an entire community is a complex process requiring a large number of assumptions. These assumptions have varying effects on the outputs from
the model. Over time we anticipate that additional research and first-hand experience with the retrofits will allow these assumptions to be refined. Each time the assumptions are refined, the accuracy of the model will improve. A list of all assumptions utilised in the construction of the model is included in Appendix E.

By modelling a variety of retrofit completion scenarios, we can illustrate the impacts on the community by year and cumulatively. YEF has researched and concluded that currently, 10% of the housing stock has already been retrofitted and approximately one percent more is retrofitted annually. This assumption is referred to as the “business as usual” (BAU) scenario, and acts as our baseline. Along with this BAU scenario, an “optimistic” scenario of 100% adoption is considered. Finally, an “expected” scenario of 60% adoption is analysed. The flexibility of the model allows for an easy change of inputs and assumptions, facilitating these different scenarios.

4.2.3.1. Potential Investment Outputs

One of the most interesting outputs from this model is a calculation of the total investment being made within the local economy. In every retrofitting scenario, the homeowner is funding the whole project and that money goes into the hands of the retrofitting contractors. A flow diagram of the investment generated by retrofits can be found in Figure 30 in Appendix F. The largest component of money goes towards the materials and equipment being installed. Naturally, a portion of the investment goes to the manufacturer of the equipment, which may be overseas, somewhere in Australia, or in Yarra itself. A smaller but still significant portion goes towards the labour services required for installation. The money spent on labour stays in the local economy. This model has the capacity to estimate what portion of the total investment recycles through the local economy.

The model estimated that as much as $608.3 million AUD will be invested between now and 2020, under the 100% adoption scenario. These numbers are of interest because the money goes to local corporations, workers and ultimately families and helps fuel the local economy. We have calculated that $399.2 million AUD of the $608.3 million AUD will be invested on the materials and equipment that are being installed, while the remaining $209.1 million AUD will be invested on the labour services required to complete these installations. We had originally considered investigating the geographic breakdown of retrofitting investment but found that it was too difficult given the short schedule of our research. Nonetheless, we realized that this was of great importance to YEF and the community so we left the flexibility and framework for this analysis in the economic model. The framework allows for aggregate breakdowns of total investment in materials, manufacturing labour and installation labour. The model also provides these statistics for a single home of each dwelling type, and per annum with consideration to the retrofitting schedule.
Further breakdowns of equipment and installation labour figures are presented below. Figure 9 shows the annual investment in equipment and product broken down by category. The categories that capture most of the investment are insulation/draft proofing and heating/cooling. This may be explained by the extensiveness of the retrofits being done in these categories as well as the high prices of some of the products. Figure 10 depicts the annual investment in installation labour by category. A new category is added here, advisory services, which comprises project management and energy auditing labour. Insulation/draft proofing and heating/cooling also capture most of the investment in labour; however, it is interesting to note that the insulation/draft proofing represents a larger portion of the total investment in installation labour whereas heating/cooling represents a smaller portion of the total. This allows us to draw conclusions as to where to target and aim for discounts in equipment and installation labour prices. Figure 11 represents the total cumulative investment through 2020 broken down by category. It is also apparent here that insulation/draft proofing and heating/cooling take most of the investment.

![Annual Investment in Equipment by Category ($ AUD)](image)
Figure 10: Annual Investment in Installation Labour by Category

Figure 11: Cumulative Total Investment by Category
A different percentage breakdown, outlining the total investment by category is shown below in Figure 12. It is important to note that this figure does not include the investment corresponding to advisory services. It is clear from this graph that a large majority of the investment for these retrofitting activities will be allocated towards insulation, draft proofing, and windows. Windows represent the largest portion of the money going towards this sector at $211 million AUD; without windows this section would only be approximately $102 million AUD, which would place it second to the heating and cooling industry at $188 million AUD. Windows are expensive mainly because of their high cost to install; most dwellings don’t have the proper frame work for the energy efficient double glazing and extensive labour is required.

![Distribution of Cumulative Investment by Category ($ AUD)](image)

**Figure 12: Distribution of Cumulative Investment by Category**

All outputs and numbers above refer to the optimistic, complete schedule case. As explained at the beginning of the section, two other cases are analysed: BAU and 60% adoption of retrofit schedule.

Table 3 below shows the key outputs for potential investment under all three scenarios for the purpose of comparison. Figure 13 is a visual representation of the different investments for the three scenarios. The investment going to the economy in the complete schedule case is more than 12 times the investment under the BAU case. This comparison serves as a means to demonstrate the great impact that a successful retrofitting initiative would have in the local economy.
4.2.3.2. Potential Labour Demand Outputs

Approximately $209 million AUD will be invested on the labour services to complete the master retrofit schedule under the optimistic scenario, as mentioned in the potential investment section. This reflects the fact that a considerable amount of labour is required to retrofit the whole residential sector and a large demand for labour will be generated by this plan. In the model we make the distinction between several ticketed positions such as electricians, plumbers, as well as several non-ticketed positions such as auditors or project managers. We estimate that to complete the retrofit schedule, a total of 2.24 million man-hours will be required, with the following breakdown: 298 thousand man-hours from electricians, 118 thousand man-hours from plumbers, and 1.82 million man-hours from all...
the semi-skilled trades. The peak demand for labour occurs in 2017, demanding 256 FTE positions. Of this 256 FTE positions, 34 plumbers, 14 electricians, 14 auditors, 28 project managers, and 166 additional general labourers are required, as shown in Figure 14 below. This graph shows the annual labour demand in FTE positions for each job type.

![Annual Labour Demand by Job Type](image)

**Figure 14: Annual Labour Demand by Job Type**

Different types of jobs will have different demand. Figure 15 is a percentage breakdown of the cumulative labour demand by job type. The greatest employment opportunities will occur in general labour partly because a wide variety of jobs are denominated as general. This labour category comprises all non-ticketed jobs. A low level of training is required for these employment positions; thus, it would be easy for Yarra residents to become employed as soon as the labour is demanded, after a short training program. Plumbers and project managers are the jobs with the second highest demand, even though their demand is much smaller than general labour. Plumbing requires training and certifications; therefore, the average Yarra resident wouldn’t be able to become employed as a plumber unless he goes through an extensive training process. The same concept applies to project management where a large amount of learning and experience is required. Taking this into consideration, the additional employment opportunities created in these two areas would not be applicable to the general Yarra community but could rather attract experienced and certified workers from outside Yarra.

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4 FTE conversions have been made using the following relationship: 1 FTE : 1775 man-hours
In summary, there is a significant amount of labour demand created which has the potential to generate potential new jobs for Yarra residents and non-residents. It presents a large opportunity for local industry development as well. While a large portion spent on the equipment may leave the region, most of the investment made on installation labour will be injected directly into the local economy as the workers come from inside the municipality.

A comparison of the labour demand for each of the three different scenarios considered in the project is shown in Table 4 below. Figure 16 represents these numbers in a visual manner and depicts the impact that a successful retrofitting initiative would have on labour demand. The demand for each type of job is 12.5 times larger for the full retrofit case than for the BAU case.
4.2.3.3. **Energy Savings Outputs**

If retrofitting of Yarra progressed according to YEF’s master schedule, a tremendous amount of energy could be saved and the associated savings in their energy bills realised. Figure 17 below shows the expected energy usage in 2020 from gas, electricity and carbon emissions, as percentages of the current energy usage and carbon emissions respectively.\(^5\)

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\(^5\) Current energy usage and carbon emissions is considered as 100%
Retrofitting a household can cut energy use from gas by 79%, electricity power by 31% and carbon emission by 71%, compared to the current usage and emissions. We have also estimated (1) the average annual energy and monetary savings per household, and (2) the accumulated energy and monetary savings for the total number of homes which YEF aims to retrofit. Figure 18 shows the average annual monetary savings per home, for two different time frames.

![Figure 18: Average Annual Monetary Savings per home by investment period](image)

The figure above shows that the average annual savings is $1,560 AUD in 2020, the time frame for the retrofitting initiative. By 2030, the energy savings in Yarra will approach maximum due to the assumption of the full completion of the retrofitting trajectory; in this timeframe, individual households can save an average of $2,420 AUD per year. These savings are about 1.6 times larger than the monetary savings from now to 2020 due to the increasing energy prices forecasted in the future. This shows that the investment benefits of retrofitted homes could continue after the retrofitting program is completed.

An analysis was performed to determine which retrofit category has the highest ratio of energy savings (MJ) over investment (i.e. cost efficiency). Each of the retrofit categories has different levels of energy savings and efficiencies to offer. Since home retrofits can prove to be an expensive endeavour, working on one category at a time might be easier for the homeowner to undertake. Given this fact, it’s important to consider which retrofitting category offers the largest energy savings per dollar invested.

We were given energy savings assumptions per dwelling type by YEF. Through the economic analysis, we found the ratio of mega Joules saved over investment per dwelling type. We then took a weighted average to find what the typical home could expect from retrofitting in each category. Table 5 below shows our results.
The most energy saved per dollar spent can be obtained by investing in heating/cooling; its ratio is 6.3 MJ per dollar. The second highest ratio corresponds to water heating, followed by insulation/draft proofing, and finally lighting. Lighting represents an extremely small proportion of energy saved per dollar but is the least expensive and simplest investment. It is important to note that, without an investment in windows, which are a relatively inefficient investment, the ratio for insulation/draft proofing improves to 3.46 MJ per dollar. This would move insulation/draft proofing ahead of water heating; therefore, any homeowner that is not considering retrofitting windows, should consider insulation/draft proofing before water heating.

Savings in individual homes will accumulate to produce savings for the entire Yarra community. Table 6 below illustrates the cumulative energy and monetary savings for all the homes to be retrofitted in YEF’s master schedule. Figure 19 is a visual representation of the cumulative monetary value of energy savings for gas and electricity. By the end of 2020, it was estimated that the Yarra residential sector could save up to 186,000 MWh and 6,940,000 Giga-joules of energy equivalent to $194.1 million AUD. If we extend the period of study and consider the savings after completion of the retrofitting initiative (i.e. 2013-30), the entire Yarra residential sector could cut the overall energy use from both gas and electricity by over three times compared to energy savings before 2020. The energy saved is sufficient to supply electricity to approximately 91,598 average-size four-person homes in one year.\(^6\)

Additionally, Yarra residents would save an estimate of $815 million AUD in energy bills over the next 17 years. This tremendous amount of savings can be spent by the residents in the local economy. The decrease of energy demand can result in a more steady and predictable power supply to the Yarra community. This can lower the peak energy demand for the local community and can have a further impact on reducing the charge rate of energy generation.

\(^6\) The amount of electricity power per average-size household was calculated by ENERGY MADE EASY from the Australian Government.)
Yarra residential sector only covers the 30732 households YEF planned to retrofit in their master retrofit schedule.

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**Table 6: Cumulative Energy and Monetary Savings by investment period**

<table>
<thead>
<tr>
<th>Investment Period</th>
<th>2013 - 2020</th>
<th>2013 - 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Energy Savings from Gas for Yarra residential sector⁷</td>
<td>6,940,000 GJ</td>
<td>22,400,000 GJ</td>
</tr>
<tr>
<td>Total Energy Savings from Electricity for Yarra residential sector</td>
<td>186,000 MWh</td>
<td>606,000 MWh</td>
</tr>
<tr>
<td>Total Monetary Savings for Yarra residential sector (in $ AUD)</td>
<td>$194.1 M</td>
<td>$815.0 M</td>
</tr>
</tbody>
</table>

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**Figure 19: Cumulative Monetary Value of Energy Savings for gas and electricity**

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⁷ Yarra residential sector only covers the 30732 households YEF planned to retrofit in their master retrofit schedule.
The City of Yarra will import a total of $107 million AUD worth of energy resources in 2020 if no additional retrofits take place (Yarra Energy Foundation, 2012a). This is a significant amount of money leaving the local Yarra economy, thus any efforts to minimize this importation could make a large impact. Through these residential retrofits across the municipality, energy savings have been estimated to be $48 million AUD in 2020, as shown in Figure 20. This represents a 45% decrease in money invested in imported energy. Currently, all the investment on imported energy is guaranteed to leave the municipality; after the retrofits, any savings on energy have the potential to be spent locally, converting this reallocation of funds into a valuable opportunity for local economic stimulus and industry growth. These demonstrations of positive economic outcomes derived from large scale retrofitting serve as an indicator of the potential economic benefits that a successful implementation of YEF’s large scale retrofitting initiative could bring to the City of Yarra.

A visual comparison of the money flow of expenditure and savings in energy bills for three different cases is useful for understanding the scale of the potential impact of the reallocation of energy savings to the local economy. The three cases are: the current situation, the expected situation in 2020 with 100% completion of retrofits, and the expected situation in 2030 reflecting cumulative results with 100% completion of retrofits. Figure 21, Figure 22 and Figure 23 show the diagrams for these cases respectively. In the current situation, there exist no savings in energy bills and all the money spent in energy bills is leaving Yarra. In the 2020 expected situation, more money should be spent in energy bills as a result of increased energy prices; however, due to the retrofits carried out, only about 55% of that money would actually be spent in energy bills. The remaining 45% represents savings that could be reallocated to the local economy. The money saved can be spent by residents in local small businesses or other economic agents. The same concept applies to the cumulative 2030 expected situation with
larger amounts. These visual representations provide a clearer representation of the magnitude of the potential economic benefits that savings in energy bills have in the entire community.

Figure 21: Flow Diagram of the Current Expenditure on Energy Bills

Figure 22: Flow Diagram of the Estimated Expenditure and Savings on Energy Bills in 2020
4.2.4. Sensitivity Analysis

In the previous section, three scenarios were analysed and their key outputs compared. The purpose of this section is to provide a more in depth sensitivity analysis on how total potential investment and potential labour demand change as a function of a variation in the master retrofit schedule. We specifically analysed four different aspects:

- Sensitivity on total average cost of retrofitting a single home
  - How does the average cost change based on discounts to all categories together?
  - How does the average cost change based on discounts to each category, keeping all other categories undiscounted?

- Sensitivity on total potential investment
  - By how much does total potential investment decrease with each 10% decrease of the master retrofit schedule for all dwelling types?
  - By how much does total potential investment decrease with each 20% decrease of the master retrofit schedule of each dwelling type, keeping the schedule of all other dwelling types unchanged?
• Sensitivity on total labour demand
  o By how much does total labour demand decrease with each 10% decrease of the master retrofit schedule for all dwelling types?
  o By how much does total labour demand decrease with each 20% decrease of the master retrofit schedule of each dwelling type, keeping the schedule of all other dwelling types unchanged?

• Sensitivity on annual potential investment and annual labour demand
  o How does the spread of these two annual figures change with a change in the spread of the annual master retrofit schedule?

In order for the retrofit scheme to be realised, residents must follow through on an individual basis; the most influential incentive to the resident is the savings relative to total cost to retrofit the home. Ranging from $12,000 to $45,000 AUD, Figure 24 shows the total investment required per category for a full home retrofit of each dwelling type. The average total cost of retrofit across all the dwelling types is $19,800 AUD, and on average, insulation/draft proofing corresponds to $10,180 AUD of that sum. Between the dwelling types, a large townhouse accounts for the highest cost of a home retrofit at $43,550 AUD. It may be difficult to convince customers to engage in a home retrofit with such a high cost.
A discount on retrofitting products is feasible if multiple customers engage in a simultaneous home retrofit process. Figure 25 below shows the average investment of a homeowner based on the discount given to one category of products involved in the retrofit. For instance, if only the heating/cooling products had a 20% discount, and the rest of the products were not discounted, the average homeowner will pay $1,000 AUD less on their retrofit. It is apparent from Figure 24 that insulation/draft proofing contributes the most to the total investment per home. If only insulation/draft proofing products received a 20% discount, the average homeowner would save $1,190 on their total retrofit. It is important to note that the figure below only represents the product discount. It is likely that along with the products, a labour discount would be realised as well.

![Cost of Average Home Retrofit Based off singular category discount ($ AUD)](image)

**Figure 25: Average Cost of Home Retrofit by discount level on products**

After analysing how a decrease in the master retrofit schedule as a whole affects potential investment and labour demand, as described in section 4.2.3.1, it is also important to investigate the change in total investment and total labour demand with a variation on the schedule of each single dwelling type. A feasible future scenario in Yarra may involve different dwelling types being retrofitted at different schedules and at some point one or more dwelling types may have to be prioritised. Therefore, it is important to analyse the effects of a zero completion or partial completion schedule of a particular dwelling type in the total potential investment and total labour demand.

Figure 26 below shows how sensitive the total potential investment is to a reduction in the schedule of one dwelling type, keeping all other dwelling types at full completion. Three dwelling types, OYO_L, VT1_L and VT1_S, have the steepest slopes, thus affecting total investment the most. A ranking of dwelling types based on how much they influence total investment is shown in Table 7, from most...
influential to least influential. This ranking may be used to determine a priority for dwelling types to retrofit in order to maximize the total investment. By retrofitting the most influential types as a priority and ensuring that they achieve full schedule completion, the opportunity cost of retrofitting one dwelling type over another could be minimised.

Figure 26: Change in Total Investment with Independent Change in Schedule of each Dwelling Type

<table>
<thead>
<tr>
<th>Rank</th>
<th>Dwelling Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OYO_L</td>
</tr>
<tr>
<td>2</td>
<td>VT1_L</td>
</tr>
<tr>
<td>3</td>
<td>VT1_S</td>
</tr>
<tr>
<td>4</td>
<td>OYO_S</td>
</tr>
<tr>
<td>5</td>
<td>WB_L</td>
</tr>
<tr>
<td>6</td>
<td>TH_L</td>
</tr>
<tr>
<td>7</td>
<td>VT2_L</td>
</tr>
<tr>
<td>8</td>
<td>WB_S</td>
</tr>
<tr>
<td>9</td>
<td>TH_S</td>
</tr>
<tr>
<td>10</td>
<td>VT2_S</td>
</tr>
</tbody>
</table>

Table 7: Rank of Dwelling Types by Influence on Total Investment - largest to smallest influence

A similar approach was taken for analysing labour demand. Figure 27 below shows how the total labour demand responds to a reduction in the schedule of one dwelling type, keeping all other dwelling types at full completion. It is apparent that the three dwelling types with the most influence on labour demand are VT1_L, OYO_L and VT1_S. These types are also the most influential for total investment. A similar ranking to the one above was constructed for dwelling types and their influence

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on labour demand; it is shown below in Table 8. This ranking may be used to determine a priority for dwelling types to retrofit in order to maximize the labour demand created. The same concept of opportunity cost minimisation explained for the total investment ranking applies to this case.

![Change in Labour Demand with Independent Change in Schedule of each Dwelling Type](image)

**Table 8: Rank of Dwelling Types by Influence on Total Labour Demand - largest to smallest influence**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Dwelling Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VT1_L</td>
</tr>
<tr>
<td>2</td>
<td>OYO_L</td>
</tr>
<tr>
<td>3</td>
<td>VT1_S</td>
</tr>
<tr>
<td>4</td>
<td>WB_L</td>
</tr>
<tr>
<td>5</td>
<td>OYO_S</td>
</tr>
<tr>
<td>6</td>
<td>VT2_L</td>
</tr>
<tr>
<td>7</td>
<td>WB_S</td>
</tr>
<tr>
<td>8</td>
<td>TH_L</td>
</tr>
<tr>
<td>9</td>
<td>TH_S</td>
</tr>
<tr>
<td>10</td>
<td>VT2_S</td>
</tr>
</tbody>
</table>

One of the largest assumptions made in the creation of this model was the schedule for retrofits throughout the municipality. We recognized the significance of this assumption and decided to investigate a new pattern for the retrofit schedule.
As shown in Figure 28 above, the blue line represents the schedule provided and accepted by YEF, while the red line represents our alternative more uniform schedule. Since both of these retrofitting schedules account for the entire housing stock being retrofitted, the estimates for aggregated investment and labour demand will be unaffected. The largest result of this new choice in schedule is a change in the peak demand for labour. As mentioned previously, according to YEF’s original schedule there will be a peak demand for labour services in 2017. According to the new more uniform trajectory, the peak appears in the same year; however, the peak is greatly lowered. Table 9 below outlines the differences.

<table>
<thead>
<tr>
<th>Schedule</th>
<th>Skilled Labour</th>
<th>Semi-Skilled Labour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plumber</td>
<td>Electrician</td>
</tr>
<tr>
<td>Original</td>
<td>34</td>
<td>14</td>
</tr>
<tr>
<td>Uniform</td>
<td>28</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 9: Peak Labour Demand by Job Type

It is apparent that the peak demand will be lowered across all positions and this may be easier for the industry to meet, especially if the rate of new labourers entering the industry is limited. Apart from lowering of the peak demand, the average change in demand from year to year is also lowered. In the original plan, annual demand varied an average of 44% between years over the entire eight year
period; under the more uniform retrofit plan, this fluctuation has been reduced to 18% on average over the eight year period. This reduction in fluctuation can help stabilize the demand for labour allowing longer employment for any new positions generated by the retrofits.

Aside from distribution of labour demanded throughout the schedule, another effect of this change in schedule happens on the monetary value of energy savings as well as the reduction of CO$_2$ emissions. For this model, we have assumed that energy prices are steadily increasing and that the CO$_2$ emissions reduction for electric power is steadily decreasing. The more uniform schedule mixed with this change in energy rates has in fact lowered the cumulative amount of carbon reduced as well as monetary value of the energy being saved. However, this change is minor, reflecting a 2% difference in money saved and a 5% difference in carbon emissions reduction.

4.3. Potential Discount due to Large Scale Retrofitting

Retrofitting an individual home can be expensive and financially inefficient. The inconvenience and large investment can turn away homeowners from retrofitting their properties. If the capital investment of retrofitting is noticeably lowered, retrofitting can be more attractive for homeowners. A discount on retrofitting products can be achieved by purchasing them in a large scale. This discount may motivate the community to participate in YEF’s retrofitting initiative. After our interviews with multiple retrofitting companies, we investigated potential discounts for their products when bought in a large scale. Table 10 and

Table 11 summarize our findings.

<table>
<thead>
<tr>
<th>Product</th>
<th>Retrofitting Category</th>
<th>Discount</th>
<th>Original Price</th>
<th>Discounted Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecobulbs Lighting</td>
<td>10%</td>
<td>$2.40</td>
<td>$2.16</td>
<td></td>
</tr>
<tr>
<td>LED</td>
<td>12.7%</td>
<td>$33.00</td>
<td>$28.80</td>
<td></td>
</tr>
<tr>
<td>Apricus AG-315-26NG-30 tube s/stearl gas boost</td>
<td>15%</td>
<td>$5,926.00</td>
<td>$5,037.00</td>
<td></td>
</tr>
</tbody>
</table>

Table 10: Potential Discounts for Lighting and Hot Water

Assuming the discounts for the products for insulation, heating and cooling and hot water can be generalised as 15%, which is the discount we acquired for Apricus water heating product.

<table>
<thead>
<tr>
<th>Retrofitting Categories</th>
<th>Discount Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation/Draft Proofing</td>
<td>15 %</td>
</tr>
<tr>
<td>Heating/Cooling</td>
<td>15 %</td>
</tr>
<tr>
<td>Hot Water</td>
<td>15 %</td>
</tr>
</tbody>
</table>

Table 11: Assumed Potential Discounts for Insulation/Draft Proofing, Heating/Cooling and Hot Water
After gathering all the discount prices for retrofit products, we input the new price to the product list and ran our economic model once again to obtain new investment values for all dwelling types. The return on investment (ROI) and the payback periods were also calculated to compare the financial effectiveness of retrofitting on your own and retrofitting at a large scale. The higher the ROI, the more profitable the investment. For the breakeven periods or the payback period, a lower period indicates a more attractive investment. The new average discounted cost of the retrofit plan of a single home is detailed in Figure 29 below.

![Comparison of Cost to Retrofit a Home individually and in large scale ($ AUD)](image)

**Figure 29: Comparison of Cost to Retrofit a Home individually and in large scale**

The cost of retrofitting a home for large-scale retrofitting is approximately 90% of the original “retrofitting on your own” cost. Although the discount we applied for the large-scale discount calculation is between 10% and 15%, the total investment has a labour cost element which lowers the overall discount due to our zero labour discount assumption.
<table>
<thead>
<tr>
<th>Dwelling</th>
<th>No Discount</th>
<th>Discount</th>
<th>No Discount</th>
<th>Discount</th>
</tr>
</thead>
<tbody>
<tr>
<td>OYO_S</td>
<td>11</td>
<td>10</td>
<td>8.16%</td>
<td>9.39%</td>
</tr>
<tr>
<td>OYO_L</td>
<td>14</td>
<td>13</td>
<td>5.32%</td>
<td>6.30%</td>
</tr>
<tr>
<td>TH_S</td>
<td>16</td>
<td>15</td>
<td>3.35%</td>
<td>4.36%</td>
</tr>
<tr>
<td>TH_L</td>
<td>19</td>
<td>18</td>
<td>0.70%</td>
<td>1.60%</td>
</tr>
<tr>
<td>WB_S</td>
<td>4</td>
<td>4</td>
<td>30.95%</td>
<td>33.82%</td>
</tr>
<tr>
<td>WB_L</td>
<td>13</td>
<td>12</td>
<td>6.51%</td>
<td>7.65%</td>
</tr>
<tr>
<td>VT1_S</td>
<td>25</td>
<td>23</td>
<td>-2.31%</td>
<td>-1.47%</td>
</tr>
<tr>
<td>VT1_L</td>
<td>26</td>
<td>25</td>
<td>-3.00%</td>
<td>-2.15%</td>
</tr>
<tr>
<td>VT2_S</td>
<td>8</td>
<td>8</td>
<td>12.77%</td>
<td>14.42%</td>
</tr>
<tr>
<td>VT2_L</td>
<td>11</td>
<td>10</td>
<td>8.30%</td>
<td>9.56%</td>
</tr>
</tbody>
</table>

Table 12: ROI and Breakeven period for individual and large scale retrofitting

Table 12 summarises the ROI and the breakeven period of individual and large-scale investment. Retrofitting of all dwelling types shows a positive ROI, which indicates investing in retrofit is a profitable option. WB_S and VT2_S are the most financial favourable for retrofitting due to its lowest payback period and the highest ROI among all dwelling types. The payback period before discount ranges from 4 to 26 years and most dwelling types have a payback period between 10 and 20 years. We can see that large scale retrofitting can reduce the payback period for most dwelling types by about 1 to 2 years and increase the ROI for 0.7% to 2.7 %, making the retrofitting investment more attractive to homeowners as they would realise financial benefits sooner.

The discounted retrofit investment figure can be used to demonstrate to Victorian government agencies that a lower retrofit cost can accelerate the retrofitting activities in Yarra. By doing so, government agencies can eventually be convinced to financially support large-scale retrofitting project in Yarra.

4.4. Potential Labour Shortage due to additional Retrofitting Demand

As mentioned previously, a total of 2.24 million man-hours will be demanded by this retrofitting schedule. This is a massive amount of work to be completed, and, while it won’t all be happening at once, it will challenge the labour capacity of Yarra. Table 13 outlines the demand for each labour position on an annual breakdown based on the schedule outlined by YEF.
<table>
<thead>
<tr>
<th>Year</th>
<th>Plumber</th>
<th>Electrician</th>
<th>Auditor</th>
<th>Project Manager</th>
<th>General</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>7</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>34</td>
<td>52</td>
</tr>
<tr>
<td>2014</td>
<td>14</td>
<td>6</td>
<td>6</td>
<td>11</td>
<td>69</td>
<td>105</td>
</tr>
<tr>
<td>2015</td>
<td>23</td>
<td>9</td>
<td>9</td>
<td>19</td>
<td>116</td>
<td>176</td>
</tr>
<tr>
<td>2016</td>
<td>31</td>
<td>13</td>
<td>13</td>
<td>26</td>
<td>155</td>
<td>237</td>
</tr>
<tr>
<td>2017</td>
<td>34</td>
<td>14</td>
<td>14</td>
<td>28</td>
<td>166</td>
<td>256</td>
</tr>
<tr>
<td>2018</td>
<td>29</td>
<td>11</td>
<td>12</td>
<td>24</td>
<td>138</td>
<td>215</td>
</tr>
<tr>
<td>2019</td>
<td>19</td>
<td>7</td>
<td>8</td>
<td>16</td>
<td>89</td>
<td>139</td>
</tr>
<tr>
<td>2020</td>
<td>11</td>
<td>4</td>
<td>4</td>
<td>9</td>
<td>51</td>
<td>79</td>
</tr>
</tbody>
</table>

Table 13: Annual Labour Demand by type of job

As it can be seen from the table, a peak in demand occurs in 2017 with a total of 454,434 man-hours demanded. This peak will require the work of 256 FTE positions. Currently, the construction industry in Yarra has an estimated capacity of 1,625 full time labourers. These labourers would easily complete the predicted increase in demand for 2017 but this schedule presents work opportunities in addition to the labour already demanded by the existing market. This disparity can fuel industry growth and, with the right awareness, there is time to train and increase the community labour capacity before a major shortage is found and labourers from other regions come in for the jobs. Aside from this work that is being produced for the workers of Yarra, new positions will need to be created and new individuals will need to be trained. After this industry growth, more citizens of Yarra will be trained and occupied, furthering their value in future projects and job opportunities.
5. Conclusions and Recommendations

YEF’s retrofitting initiative has the potential to inject a large amount of investment to the local economy and retrofitting industry. In a Business as Usual (BAU) scenario, the total potential investment estimated through the economic model was $48.7 million AUD through 2020. Under a 100% successful YEF’s retrofitting initiative scenario, it was estimated that a total of $608.4 million AUD would enter the industry through 2020. An intermediate scenario, involving 60% completion of the entire master retrofit schedule, was also analysed and the corresponding investment was $365 million AUD. This comparison provides an idea of how beneficial to the local economy a completely successful YEF’s retrofitting initiative would be. Yarra’s Gross Regional Product (GRP) is estimated to be $8.717 billion AUD (City of Yarra, 2012). The total potential investment attributed to a YEF’s fully successful retrofitting initiative corresponds to 7% of the GRP, which gives a sense of the magnitude of this potential investment.

The sensitivity analysis performed on total investment showed that, following a linear relationship between master retrofit schedule and total investment, each 10% decrease in completion of the schedule results on a reduction of $60.8 million AUD on the total cumulative investment. Furthermore, we determined the dwelling types whose reduction in schedule completion has the most impact in the total investment. These three types are respectively, OYO_L, VT1_L and VT1_S, and should be given a priority if possible and necessary when retrofitting the community in order to maximize total investment. Additionally, we performed an analysis to determine the most cost efficient of the four retrofit categories through the calculation of a MJ/$ ratio. We concluded that heating/cooling and water heating are the categories that represent the most energy savings per dollar invested in each category. However, it is important to note that insulation/draft proofing becomes considerably more effective than water heating if windows are not included in the retrofit.

The other aspect that the economic model analysed was job creation, in the form of man-hours required and FTE positions generated. The total man-hours that would be demanded through 2020 in a BAU scenario are 179,000. In comparison, under the case of a fully executed and successful large scale initiative, 2.235 million man-hours would be required in the same timeframe. A midpoint of 1.341 million man-hours demanded corresponds to the intermediate scenario of 60% completion. These results demonstrate the significant impact that a successful large scale initiative incentivised by YEF would have on employment generation in Yarra and Melbourne. With such high labour demand, the City of Yarra could grow to become a source of employment in these areas for workers from Melbourne. Additionally, workers from Yarra could gain significant experience that would make them more desirable in outside markets. Local construction businesses also have the opportunity to diversify their business focus by incorporating energy-efficient retrofits to their business scope.

The sensitivity analysis for labour demand produced similar results to the analysis on total investment. Each 10% decrease in completion of the master schedule would result in a linear reduction
of approximately 223,500 man-hours through 2020. In the case of labour demand, the same three dwelling types, VT1_L, OYO_L and VT1_S, are the ones that produce the most impact when their schedules change. The difference with total investment is that the VT1_L is the most influential for labour demand and has a large advantage over the OYO_L and VT1_S. These types should be prioritized in the retrofitting plan in order to maximize the labour demand created.

The sensitivity analysis also investigated the distribution or spread of the master retrofit schedule. Our model is extremely dependent on the retrofitting schedule so an analysis regarding the effects of a change in retrofit schedule was performed. We found that a more constant retrofit schedule will result in a higher initial demand for labour but an overall minimised peak demand. Aside from the effect on peak demand, the energy savings which are incurred across the municipality are also affected. Any delay to retrofits will result in lower monetary savings, but any retrofits produced earlier will result in more savings as time develops.

Money savings due to retrofitting will be about $1,560 AUD in 2020 for an average household. Savings begin after a home is retrofitted, thus it is financially more beneficial for homeowners to retrofit their home earlier in order to enjoy savings for a longer period of time. If the retrofitting master schedule is accelerated, the savings for local home retrofitters can reach a maximum at an earlier period and as a result, the local economy can benefit sooner from the reallocation of the money spent in energy. This redistribution of money spent in energy can serve as an economic impulse for Yarra businesses. The decline in gas and electricity power demand in Yarra residence can minimise the fluctuation in the needs of energy supply. This stabilisation of energy demand can reduce energy cost and indicate a more secure future when facing energy shortages.

A discount due to large scale retrofitting would reduce the total cost for an average household from $19,800 AUD to $17,862 AUD, which is equivalent to approximately a 10% discount. Offering higher discounts in retrofits to homeowners in Yarra could be a positive strategy for retrofitting businesses as residents would be more inclined to retrofit their homes if offered lower prices. Higher discounts can be achieved by collaboration in large scale retrofitting programmes and further negotiation. Such programmes should focus on effective logistics organisation of home retrofits. The utilisation of labour is more efficient when a higher percentage of work capacity is used. For instance, instead of working on retrofitting one or two homes at a time, all homes in an entire street could be retrofitted at a time with large scale cooperation and effective work load planning. As a consequence, retrofitting companies can lower their fixed costs and save on other costs such as transportation. There is a large field of opportunity for Yarra residents and businesses in the topic of large scale discount; communication and cooperation are key elements in order to seize this opportunity. We recommend that obtaining discounts in insulation/draft proofing and heating/cooling products and services is
prioritized because these categories account for 85% of the total investment and thus produce a higher total net discount.

It may be beneficial to further investigate the local labour that is available within the City of Yarra. The retrofitting scheme that YEF has proposed not only has the potential for employing ticketed and semi-skilled labour within Yarra, but also creates training opportunities for the labour Yarra cannot immediately provide. Knowing the current workforce available for these retrofits, in combination with the understanding of the peak demand of FTE positions, will allow YEF to get a better understanding of these training opportunities.

Another source of economic benefit for the local economy can be investigated through the scrutiny of the products involved in the retrofitting scheme. One method that will help in this investigation is the creation of a bill of materials. This division of the more structurally complex products involved in the proposed retrofits will showcase opportunities for local manufacturers to provide the product. Although not all the money for a complex product will go to the local manufacturer, the mass demand for these products will provide a fraction of this benefit towards the local economy.

We would also recommend researching the supply chain for the products involved in the retrofitting plan. As of now, most of the products are being manufactured outside of Australia. If YEF can identify where the value is being added to the supply chain, they can pinpoint areas where the local economy is lacking contribution, which will inform them of areas of potential local business opportunities.

The report we have written draws conclusions based on the completion of the proposed retrofitting schedule, therefore a plan to implement the completed schedule needs to be realised. This plan will ensure that all the benefits to the local economy mentioned in this report will come to fruition. It may also be beneficial to investigate how to incentivize Yarra residents to take part in the retrofit scheme, as this entire plan depends on the willingness of the consumers to engage.


Intergovernmental Panel on Climate Change. (2007). Climate change 2007: the physical science basis. *Agenda, 6*, 07.


## Appendix A: Supplemental Tables

<table>
<thead>
<tr>
<th>Reference ID</th>
<th>Dwelling Type</th>
<th>Number of Buildings to retrofit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OYO_S</td>
<td>Own Your Own - Small</td>
<td>4,394</td>
<td>OYO unit in 3 storey block, brick veneer, slab on ground, suspended slab upper floors, pitched or flat metal roof. Ceiling height = 2.7m</td>
</tr>
<tr>
<td>OYO_L</td>
<td>Own Your Own - Large</td>
<td>4,394</td>
<td>OYO unit in 3 storey block, brick veneer, slab on ground, suspended slab upper floors, pitched or flat metal roof. Ceiling height = 2.7m</td>
</tr>
<tr>
<td>TH_S</td>
<td>Townhouse - Small</td>
<td>1,022</td>
<td>Townhouse/Dwelling, 2 storey semi-detached, brick veneer, slab on ground, (presumed timber joist 1st floor) pitched roof</td>
</tr>
<tr>
<td>TH_L</td>
<td>Townhouse – Large</td>
<td>1,022</td>
<td>Townhouse/Dwelling, 2 storey semi-detached, brick veneer, slab on ground, (presumed timber joist 1st floor) pitched roof</td>
</tr>
<tr>
<td>WB_S</td>
<td>Weatherboard - Small</td>
<td>2,228</td>
<td>Victorian single storey, free standing, timber frame weatherboard, 3m ceiling, pitched metal roof.</td>
</tr>
<tr>
<td>WB_L</td>
<td>Weatherboard – Large</td>
<td>2,228</td>
<td>Victorian single storey, free standing, timber frame weatherboard, 3m ceiling, pitched metal roof.</td>
</tr>
<tr>
<td>VT1_S</td>
<td>Victorian – Single Storey Small</td>
<td>6,084</td>
<td>Victorian single storey double brick terrace, pitched metal roof</td>
</tr>
<tr>
<td>VT1_L</td>
<td>Victorian – Single Storey Large</td>
<td>6,084</td>
<td>Victorian single storey double brick terrace, pitched metal roof</td>
</tr>
<tr>
<td>VT2_S</td>
<td>Victorian – Double Storey Small</td>
<td>1,638</td>
<td>Victorian double storey double brick terrace, pitched metal roof. Total window area = 11.1</td>
</tr>
<tr>
<td>VT2_L</td>
<td>Victorian – Double Storey Large</td>
<td>1,638</td>
<td>Victorian double storey double brick terrace, pitched metal roof. Total window area = 29.3</td>
</tr>
</tbody>
</table>

Table 14: Dwelling Types with Reference ID, Number of Homes and Description
<table>
<thead>
<tr>
<th>Product</th>
<th># Units</th>
<th>Unit</th>
<th>Equipment</th>
<th>Labour</th>
<th>Trade Positions</th>
<th>Semi-skilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating/Cooling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Heating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour Services</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 15: Retrofitting Plan for a particular dwelling type
Appendix B: Interview Questions

General Interview Guidelines for Energy Efficiency
Contractors/Suppliers

Name of the Company:
Name of Employee/Position/Field of expertise:
Date of interview:

- What retrofitting activities have you worked on in the past?

- For a typical retrofit:
  - What tasks are involved?
  - How long does each task typically take (Man-Hours/activity)?
  - What workers are typically involved?
- For each of those workers mentioned
  - How much are they paid
- Compensation
  - What rates do you charge?
  - What does this go towards? (e.g. Salary/Materials/Equipment/Marketing/etc...)

<table>
<thead>
<tr>
<th>Dwelling Type</th>
<th>Typical Retrofit(s)</th>
<th>Professional(s) involved</th>
<th>Paid Rates</th>
<th>Man-Hours</th>
<th>Product Cost</th>
<th>Allocation of revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
o What skillsets are currently in demand in order to continue these efforts?

o What are the costs of the products used in the retrofits?

o What is the locality of the products used and the professionals involved?
  ▪ Yarra?
  ▪ Melbourne?
  ▪ Victoria?

• Has your company investigated potential discounting due to large retrofit programs?
  o Would you be able to give us a quote of an estimated discount? (given demand in Yarra for the next eight years)
  o How long would this discount be applicable for?

Remarks
**Interview Guidelines for ARUP**

- What national retrofitting programs have you worked on in the past?

- Could you describe to us the role of each of specialist in ARUP in accordance to a residential retrofit program? (engineers, consultants, technicians etc.)

- What additional skillsets are currently in demand in order to continue your efforts?

- If the residential retrofitting plan proposed by YEF were to take place, what tendencies would there be in terms of the locality of the products used and the professionals involved?
  - Yarra?
  - Melbourne?
  - Victoria?

- Has your company investigated potential discounting due to large retrofit programs?
  - Would you be able to give us a quote of an estimated discount? (given demand in Yarra for the next eight years)
  - Could you reference some resources regarding large scale retrofit programs?
Questions for Electrician Residential Retrofitters

1. What residential retrofitting activities have you worked on in the past 12 months (HVAC/Lighting/Hot Water)?

2. For a residential retrofit (HVAC/Lighting/Hot Water), what electrical tasks are usually involved? And how long does each task typically take? (This may be as general as installing a heater, wiring a light fixture, or installing any other appliance)

3. Compensation
   - What rates do you charge? Are they on a per service basis? Or an hourly rate?
   - At what rate are you, or the typical electrician, compensated at? (Note: This is confidential information, but is essential for the model that we are producing. None of this information will be used in connection to any individuals)

4. Have you or your company investigated potential discounting due to large retrofit programs? Any information in regards to large programs completed in the past, and the discounts that were associated with them would be greatly appreciated. Even if exact numbers can’t be reproduced, a general discount estimate (I.E. 5%-10%) would be helpful.

5. Do you have any additional remarks, comments, or recommendations that you feel would help us in our efforts to capture this information?
Questions for Andrew Rowe from CSR

6. What residential retrofitting projects have you worked on?

7. For a residential retrofit (e.g. Insulation), what skilled and unskilled tasks are usually involved? And how long does each task typically take? (This may be as general as applying double-glazing, wall insulations, etc.)

8. What is the raw material cost for some typical products you provide for retrofitting services?

9. Compensation
   - What rates do you charge? Are they on a per service basis or project basis? Or an hourly rate?
   - At what rate are you, or the typical installers, compensated at? (Note: This is confidential information, but is essential for the model that we are producing. None of this information will be used in connection to any individuals)

10. What is the locality of the products used and the professionals involved (e.g. Yarra, Melbourne, Victoria)?

11. We have high level information on the insulation retrofits proposed for each dwelling type considered by YEF, can you provide your input on this? (See attached excel document)

12. Have you or your company investigated potential discounting due to large retrofit programs? Any information in regards to large programs completed in the past, and the discounts that were associated with them would be greatly appreciated. Even if exact numbers can’t be
reproduced, a general discount estimate (i.e. 5%-10%) would be helpful.

13. Do you have any additional remarks, comments, or recommendations that you feel would help us in our efforts to capture this information?
Appendix C: List of Sources of Information

<table>
<thead>
<tr>
<th>PRODUCTS AND COSTS</th>
<th>Product ID</th>
<th>Data</th>
<th>Source</th>
<th>Confirmations</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1-L2</td>
<td>All</td>
<td></td>
<td>Bruce Easton, EcoVantage</td>
<td></td>
</tr>
<tr>
<td>HC1-HC5</td>
<td>All</td>
<td></td>
<td>Anthony Tabor, YEF Data</td>
<td>Andrew Rowe, CSR</td>
</tr>
<tr>
<td>I1-6</td>
<td>All</td>
<td></td>
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<td>Andrew Rowe, CSR</td>
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<td>Andrew Rowe, CSR</td>
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<td>W1-2</td>
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<td>Anthony Tabor, YEF Data</td>
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</tr>
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<td>W3</td>
<td>All</td>
<td></td>
<td>Ben Cole, NewGenSolar</td>
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<tr>
<th>INSTALLATION COSTS AND LABOUR</th>
<th>Product ID</th>
<th>Data</th>
<th>Source</th>
<th>Confirmations</th>
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<td>Plumber Rate</td>
<td>Ben Cole, NewGenSolar</td>
<td>Andrew Rowe, CSR</td>
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<td>All</td>
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<td>General</td>
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<td>Bruce Easton, EcoVantage</td>
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<td>HC1-2, HC4-5</td>
<td>General</td>
<td></td>
<td>Andrew Rowe, CSR</td>
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<td>HC1-2, HC4-5</td>
<td>Plumber Hours</td>
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<td>Andrew Rowe, CSR</td>
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<td>Electrician Hours</td>
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<td>W1-2</td>
<td>Plumber Hours</td>
<td>Jim Castles and Alex Fearnside, YEF</td>
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<td>W1-2</td>
<td>Electrician Hours</td>
<td></td>
<td>Jim Castles and Alex Fearnside, YEF</td>
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<td>W3</td>
<td>Plumber Hours</td>
<td>Ben Cole, NewGenSolar</td>
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<td>W3</td>
<td>Electrician Hours</td>
<td>Ben Cole, NewGenSolar</td>
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<td>LS1-2</td>
<td>All</td>
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<td>Anthony Tabor, YEF Data</td>
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<tr>
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<td>Total Inst Cost (Per Unit)</td>
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<td>Andrew Rowe, CSR</td>
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<td>I7-11</td>
<td>Total Inst Cost (Per Unit)</td>
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<td>I13-14</td>
<td>Total Inst Cost (Per Unit)</td>
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<td>Total Inst Cost (Per Unit)</td>
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Table 16: List of Sources of Information collected
Appendix D: Detailed Functionality of the Economic Model

Each of the outputs and other figures of the economic model are calculated using a particular combination of inputs that can be changed at any point in time by the end user. A detailed summary of how outputs and figures are calculated, including inputs used and their relationship, and way of presenting results, is shown in Table 17 below. A descriptive explanation of the table is also included for further reference; however, we recommend and think that looking at the table will suffice to understand the functionality of the economic model.

<table>
<thead>
<tr>
<th>Figure</th>
<th>Presented as</th>
<th>Inputs</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cost to Retrofit per one home</td>
<td>Equipment and Installation</td>
<td>A Products and quantities for each dwelling type</td>
<td>Sum of A*B for each product</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B Equipment + Installation Cost per product</td>
<td></td>
</tr>
<tr>
<td>Total Man Hrs Required</td>
<td>Per type of job</td>
<td>E Man Hrs required per unit of product</td>
<td>E*F for each type of job</td>
</tr>
<tr>
<td></td>
<td>Per year</td>
<td>F Total Estimated Demand of Retrofitting Products</td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Output</th>
<th>Presented as</th>
<th>Inputs</th>
<th>Relationship</th>
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</thead>
<tbody>
<tr>
<td>Total Potential Investment</td>
<td>Equipment and Installation</td>
<td>C Total Cost to Retrofit per one home</td>
<td>Sum of C*D for each type</td>
</tr>
<tr>
<td></td>
<td>Per year and cumulative</td>
<td>D Number of homes of each type to be retrofitted</td>
<td></td>
</tr>
<tr>
<td>Total Potential FTE Positions created</td>
<td>Per type of job</td>
<td>G Total Man Hrs Required for each type of job</td>
<td>G/H for each type of job</td>
</tr>
<tr>
<td></td>
<td>Per year and cumulative</td>
<td>H Man Hrs per FTE position in one year (1775 hrs)</td>
<td></td>
</tr>
<tr>
<td>Total Estimated Demand of Retrofitting Products</td>
<td>Per product</td>
<td>A Products and quantities for each dwelling type</td>
<td>Sum of A*D for each product</td>
</tr>
<tr>
<td></td>
<td>Per year</td>
<td>D Number of homes of each type to be retrofitted</td>
<td></td>
</tr>
<tr>
<td>Potential Discount due to Large Scale Retrofitting</td>
<td>Discounted Cost to Retrofit per home</td>
<td>B Equipment + Installation Cost per product</td>
<td>B*(1-I) and apply new costs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I Estimated % discount for each product</td>
<td></td>
</tr>
<tr>
<td>Geographic Distribution of Investment</td>
<td>Investment going to each locality area</td>
<td>J Locality breakdown of cost to retrofit each dwelling type (in $)</td>
<td>J*D for each locality area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D Number of homes of each type to be retrofitted</td>
<td></td>
</tr>
<tr>
<td>Monetary Value of Energy Savings</td>
<td>Gas and Electricity</td>
<td>K Gas/Electricity Savings per unit of dwelling type</td>
<td>Sum of K<em>D</em>L for each dwelling type</td>
</tr>
<tr>
<td></td>
<td>Per dwelling type</td>
<td>L Assumed Energy Prices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Per year and cumulative</td>
<td>D Number of homes of each type to be retrofitted</td>
<td></td>
</tr>
</tbody>
</table>

Table 17: Detailed Summary of Calculation of Outputs and Figures

When new products are added and/or existent products are modified or deleted in the “Products and Costs” sheet, the changes are automatically recorded and applied to the “Installation Costs and Labour” sheet. In all of the ten retrofitting plans, every figure (equipment costs, labour costs, man-hours required and locality breakdown) for a particular product is linked to its Product ID and the
number of units. The Product ID matches a product with its figures which are included in the “Products and Costs” and “Installation Costs and Labour” sheets, and scales these figures according to the number of units of the product required in that dwelling type. Consequently, by just adding a new Product ID and specifying the number of units, all the figures of a specific product come up in the sheet. The sum of all these figures for the products required for a specific dwelling type provide aggregate retrofitting costs and labour required on a per unit of dwelling type basis. A feature that adds to the flexibility of the model is that the master retrofit schedule can be easily modified. The real number of homes in the schedule is subject to change in the future and has an effect in every output of the model; therefore, making the master schedule editable contributes to the accuracy of the economic model.

The total potential investment going to the retrofitting industry is calculated via scaling up the cost to retrofit an individual dwelling by the number of dwellings of that type detailed in the master retrofit schedule. The sum of the aggregate costs for each dwelling results in the total potential investment figure. This number is further broken down into investment in equipment and investment in labour. The geographic distribution, also known as locality breakdown, of this investment is estimated by looking at the locality breakdown of the cost to retrofit in each dwelling type and scaling up these values according to the number of homes in the master retrofit schedule.

As mentioned in section 4.2.1, the “FTE Positions by Type of Job” sheet contains a summary of the job creation aspect of the model. Total man-hours required by trade each year is computed with the labour of each trade or semi-skilled worker required per unit of product and the annual demand of every product. The number of FTE positions by trade is calculated through dividing the total man-hours required by trade each year by 1,775 hours. This is the official number of work hours per year per FTE position in Australia, according to the Australian Government Fair Work Ombudsman (Fair Work Australia, 2013).

The “Product and Labour Demand Summary” sheet shows several outputs as a function of the different products and services used. The estimated annual demand for products is obtained by looking at the products and quantities required for one retrofit of the different dwelling types, scaling that number up according to the master retrofit schedule on a per year basis, and ultimately summing the products used in all retrofits of all dwelling types. For example, X units of product L1 are required in each dwelling type; X multiplied by the total number of retrofits planned in 2014 for each type gives the total units of product L1 required per dwelling type in that year; adding all these totals results in the estimated annual demand for product L1 in 2014. Based on these estimated product demands, the total man-hours required per type of job for each product is easily computed. This figure is obtained by multiplying the number of man-hours required per unit of product, which is available in the “Installations Costs and Labour” sheet, by the cumulative estimated demand of that product. The total
potential investment per product is calculated in the same manner by multiplying unit cost and cumulative estimated demand.

The underlying logic of the economic model is rather straightforward and simple. The data from the input data sheets is combined with the information on the modifiable data sheets in order to produce the results in the output data sheets. Every part of the model is clearly labelled as “data input”, “modifiable data” and “output data” so that the end user knows what to change. Its design makes it a “living” model and allows for flexibility making it possible to obtain updated outputs by just changing the inputs and rerunning the model at any point in time.
Appendix E: List of Assumptions of the Economic Model

- Trajectory outlined by YEF is an accurate forecast
- Ceiling insulation retrofitting already completed
- No assumptions made about behaviour of residents
- All indirect materials are wrapped into labour costs
- Lighting is proportional to floor area of dwellings. A relationship of $L = \left(1 - \frac{1}{2} \cdot \left(1 - \frac{A}{\overline{A}}\right)\right) \cdot \overline{L}$ was used. Where $L$ is lighting required, $A$ is area of the dwelling, $\overline{L}$ is average lighting required across the municipality, and $\overline{A}$ is average floor area across the municipality.
- Each dwelling archetype is broken into a small and a large scenario. We are assuming a 50/50 distribution between the different size scenarios.
- All labour being considered for the installation process will be assumed to be local to the City of Yarra.
- FTE positions will be calculated with the following relationship $1 \text{ FTE} = 1,775 \text{ Man-hours}$.
- Every dwelling which is categorized into a dwelling archetype will receive identical retrofits.
- Aggregate energy savings were projected for the municipality and we are assuming an average for all dwelling types in regards to savings due to lighting and hot water.
Appendix F: Investment Flow Diagram

Figure 30: Flow Diagram of the Investment generated from Retrofits