Creating a Bioenergy Roadmap for Gippsland, Victoria

An Interactive Qualifying Project
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Abstract

The goal of this project was to assist Snowy River Innovation in Melbourne, Victoria in the development of a bioenergy framework in Gippsland, Victoria. The project team conducted an initial survey of New England, USA bioenergy and investigated eight case studies from the region. The team also researched eight additional case studies from enterprises in Victoria, Australia to investigate bioenergy technologies being utilized in both regions. The team also conducted a food-waste survey of Warragul, Victoria as well as developing a viability and feasibility template for the Grantville landfill facility.

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- **Warragul Food Waste Survey Participants**
- **Peter Young (SRI)**
- **Geoff Andrews (SRI)**
- **John Lawrence (GCCN)**
- **Rowan Doyle (Capricorn Power)**
- **Noel Barton (Capricorn Power)**

Executive Summary

Snowy River Innovation (SRI) is a company whose mission is to improve the development and adoption of innovation and sustainability opportunities and projects in regional and rural Australia. SRI requested assistance laying out a bioenergy framework for the Gippsland region to support the Gippsland Climate Change Networks (GCCN) objective of building a regional delivery framework for Bioenergy developments in Gippsland, Victoria. In turn, GCCN, with the support of SRI, obtained sponsorship for the research project from Victorian State Government through Sustainability Victoria.

The goal of this research project was to assist GCCN and SRI and its project partners, with the initial analysis of two potential Gippsland bioenergy projects. The research project will subsequently initiate a development framework for the nascent Gippsland Bioenergy Roadmap through the context of viability and feasibility.

To achieve this goal, the WPI team, in association with SRI, created three research objectives:

1. Developed an analytical overview of bioenergy projects in the New England region, USA, as well as several relevant case studies in Victoria, Australia
2. Conducted a representative survey over 50 organizations' food-waste streams in Warragul, Gippsland to deliver a gap analysis in the national Australia ABBA Data survey
3. Created an initial template to determine the viability and feasibility of using bioenergy feedstocks in Gippsland by analyzing bioenergy feedstock recovery options in Warragul and Grantville, Gippsland

Climate change is an undeniable fact of life in today's world. The signs of climate change are visible around the world. In the last 650,000 years, the Earth has experienced seven distinct cycles of glacial advance and retreat, part of which being the various ice ages throughout history. However, the present cycle is far different than the rest because of the presence of humans (NASA 2019). Overall, the planet's average surface temperature has increased by 1.62 degrees Fahrenheit since 1880, which is a result of the increasing amount of carbon dioxide and other greenhouse gases in the atmosphere. Along with the general rise in temperature, Earth's oceans have also seen an increase of more the 0.4 degrees Fahrenheit within the top 700 meters. The difference between this era and those that came before is that there is a probability as large as 95% that this global warming trend has been caused by humans. Thus, the world as a whole is looking towards more renewable energy sources.

A renewable energy alternative to the popular methods of solar and wind power is bioenergy. Bioenergy is a source of renewable energy that entails producing energy from biomass, or organic matter. Bioenergy as a source of energy has yet to grow to as large a scale as solar and wind power have. However, many governments around the world are actively searching for viable methods of bioenergy production. The initial cost of producing bioenergy from biomass such as vegetable and animal derived organic materials is more expensive than energy from burning fossil fuels. Bioenergy also requires a very large amount of space in order to harvest and store biomass. To this end, rural landscapes like Gippsland in Australia, are very practical locations for bioenergy to be introduced.

The generation of bioenergy occurs in three main steps: production or gathering of organic matter to form the biomass feedstock, processing of this biomass into usable outputs, and utilization of the outputs (KPMG, 2018). Unlike other forms of renewable energy, which rely on external natural forces and often have limits on the time of generation, bioenergy is able to run anywhere at any time. Bioenergy is the third largest form of renewable energy globally (International Energy Agency [IEA], N.D.). The creation of new bioenergy initiatives requires an understanding of the potential commercially available biomass feedstock profiles, viable technologies and processes. The Australian Biomass for Bioenergy Assessment (ABBA) aims to provide information on potential feedstocks present in the various states and regions of Australia and offers a comprehensive review of bio feedstocks at a regional and local level.

In the southeastern quarter of Victoria, the Gippsland rural region stretches from the outskirts of eastern Melbourne for approximately 500 kilometers. The Gippsland region has an extensive network of electricity and gas transmission infrastructure managed by privately and publicly owned entities that are operated and managed by asset managers and energy retailers. Electric power generation in Victoria and Australia currently relies on fossil fuels as its main source of energy with other utility scale renewable energy generation solutions actively being investigated, including onshore and offshore wind, and solar energy. Fossil fuels are non-renewable resources that consist of petroleum, natural gas, and coal. Fossil fuels are primarily used for electricity and heat production but create byproducts that stimulate the greenhouse effect and climate change.

In order to reduce the impact that Gippsland is making through the use of fossil fuels, the region is beginning to assess scaled bioenergy development opportunities. In Gippsland, the Australian Bureau of Statistics and the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), "agriculture and timber production are potential sources of raw material for new investment in biomass and biofuel industries" (Commonwealth of Australia 2018).

In a world with growing populations and economies, it is inevitable that more waste products will be created by society. To combat this, waste management policy in Victoria, and Australia as a whole, is based on minimizing or avoiding waste (SWRRIP 2018). Where waste is generated, it is now assessed as a value added resource. There is unknown potential for energy generation within landfills because the waste has not been extracted for all of its energy capacity. Bioenergy may serve as a very fitting method of extracting this unused energy from waste products.

Our first objective was to undertake an analytical overview of bioenergy projects in the New England region, USA, as well as several relevant Victorian case studies. The analysis took the form of eight case studies from New England focusing on different aspects of bioenergy, such as independent dairy farms, larger corporations, urban food waste, and research organizations. Also completed were eight relevant case studies of bioenergy facilities in Victoria, Australia that serve as a comparison to the New England research.

Our second objective was to develop a methodology for efficiently collecting food waste data as a potential bioenergy and value added resource by undertaking a Warragul Food Waste Survey. We also conducted food waste assessments and surveys of as many as 150 food and hospitality SMEs[1] in the Warragul area to provide a representative sample and generated a qualitative and quantitative report and integrate the data into the ABBA database.

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[1]Small and Medium Enterprises

The Warragul Food Waste Survey had two principal objectives. The first was to develop an effective data collection methodology applicable to food and hospitality SMEs. The second was to detail the volume of food waste generated by industry sector in a representative regional town in order to fill a gap in the Australian Biomass to Bioenergy Assessment (ABBA) database.

The research team focused on 150 businesses, of which 70 were marked as high priority. They split into sub teams that focused on the CBD and the surrounding outer township. Each team conducted a brief in-person survey of representative SMEs using Google forms, complemented by a photographic waste assessment. The team converted the data from estimated litres of waste to kilograms, then categorized the data by waste type and business type using the ANZSIC[2] code format.

The project produced a substantial improvement in the survey response rate over previous models and demonstrated a promising data collection methodology for this industry sector while also generating useful data insights.

The last objective was to assist SRI to further develop a viability and feasibility framework that assesses the production potential of commercial bioenergy starting with 2 projects in Gippsland - Grantville Landfill facility and in Warragul. The scope of research project focused on completing Phase One of the selected Bioenergy Australia project self-assessment tool found in Appendix L.

In Warragul, the research team used the results of the ABBA food waste survey to determine the viability of a localized bioenergy hub using anaerobic digestion as a core bioenergy clustering attractor and solution. The WPI and SRI research team worked with Sustainability Victoria to provide locational data as an initial step to minimize the cost of transporting food waste to a potential digestor. Sustainability Victoria aims to develop the commercial feasibility aspects of the Warragul project as an exemplar project opportunity to demonstrate and promote similar opportunities in Victoria initially.

For the analysis of Grantville, the research team of WPI and SRI went to the Grantville facility to undertake a visual assessment of the feedstocks available. Also obtained was data on every transaction the landfill processed in the past year, including separate reports for the annual green waste amnesty program. The team then compiled the data provided by the operator into a singular document consisting of separate reports, followed by the extraction of all the green waste for further analysis.

The next step involved researching five possible waste processing methodologies (incineration, gasification, pyrolysis, plasma arc gasification, anaerobic digestion) followed by narrowing the potential waste to energy options to either pyrolysis or gasification. We requested technology specifications and price estimates from different pyrolysis and gasification systems available for supply in Australia. We assessed the potential power generation capabilities of appropriate local feedstock, followed by an estimate of the approximate revenue that could be produced. This enabled the time frame for return on investment (ROI) and payback rate to be calculated. The team also determined an initial estimate on the commercial feasibility and provided to Snowy River and its project partners.

For our first objective, we performed extensive background research into the state of bioenergy in New England. This was accomplished through a general research profile of the region, reinforced by eight specific case studies. We found the general profile of bioenergy in New England to be dominated by the burning of woody biomass and wood chips for use in

[2]Australia and New Zealand Standard Industrial Classification

heating systems, with rare cases including using the heat to power steam turbines for electricity generation.

The case studies we researched include programs such as large-scale anaerobic digesters, wood pellet burning to heat schools, research on biogas production from oil crops, and even seaweed farms to cultivate biomass. The anaerobic digestion case studies were particularly useful in this project as they allowed us to compare the size and range of feedstocks available in New England and Gippsland to determine viability and feasibility. For example, the case study on Barstow Farm details an anaerobic digester using roughly 12 million kilograms of organic waste every year, which is a reference number we used when determining the viability of a digester in Warragul. In addition to the New England case studies, we also researched eight case studies in Victoria, Australia. From these case studies, we discovered that anaerobic digestion is much more common throughout the region compared to New England. The climate is also less harsh than in New England, negating much of the need for heat from wood burning. There are slight similarities between the two regions, such as the amount of timber dairy and timber production.

The second objective of the project focused around the survey of 50 or more food and hospitality businesses to compile quantitative data on food waste usage in Warragul. The Warragul Food Waste Survey had two principal objectives. The first was to develop an effective data collection methodology applicable to food and hospitality Small and Medium Enterprises (SMEs). The second was to detail the volume of food waste generated by industry sector in a representative regional town in order to fill a gap in the Australian Biomass to Bioenergy Assessment (ABBA) database. We developed a survey methodology that was more than effective in achieving the response rate goal set forth by Sustainability Victoria. Of the businesses surveyed, an estimated 624,267 kilograms (624 tonnes) of food waste is produced per annum. Most of the food waste comes from restaurants, cafes and supermarkets. Compared to the Barstow Farm case study, this number is an order of magnitude lower. However, a smaller scale anaerobic digester could still be viable in this specific case, but we recommend looking elsewhere as Warragul already showcases many sustainable waste practices already.

The feasibility and viability analysis for the Grantville Landfill was slightly more difficult as we did not initially have data on the mass of available feedstocks as we did with the Warragul study. We received data on all of the transactions that the landfill processed in the last year, including the amnesty period where green waste can be dumped for free. In order to determine the viability of using the green waste at the landfill for bioenergy, we researched five technologies that included incineration, pyrolysis, gasification, plasma arc gasification, and anaerobic digestion. From this research, we chose to move forward with pyrolysis and gasification as potentially viable methods, contacting local companies for quotes for the landfill project. We received quotes from two companies, Pyrocal and Pyrotech, and thus based our analysis on the products provided by those two. Using the quotes we received, we can recommend that Snowy River Innovation and Capricorn power perform further research into both Pyrocal and Pyrotech in order to determine the best fit for their needs.

To assist the creation of new bioenergy sector development in Gippsland, the team took part in three related projects, treating each as an objective. The first project was an overview study of New England bioenergy, eight New England case studies and eight case studies in Victoria. This data was then presented to a number of local organizations to educate them on potential bioenergy technologies and opportunities. The second project was the Warragul Food Waste Survey, which gathered data to understand possible feedstocks. The team then organized the data by business type to allow it to be uploaded into the ABBA database and sent for future processing to determine the optimal location for a potential community anaerobic digester. Third, we analyzed the data from a year's worth of transactions at the Grantville Landfill to determine if the green waste was commercially viable for bioenergy generation. After the quantity of green waste was confirmed we calculated the potential capital generation potential of the processing and determined what the window of return on investment of the various technologies would be.

While these projects may seem disconnected from each other, they provide beneficial information for the promotion of bioenergy in Gippsland. In fact, Sustainability Victoria is planning to utilize the methodology developed in the Warragul Food Waste Survey to conduct more surveys in other areas of Gippsland. Snowy River Innovation and Capricorn Power are also going to use the feasibility study to determine whether to move forward with green waste processing at the Grantville Landfill. The team hopes the findings and recommendations from this project will be used by our partners to showcase the opportunities for future investment and potential in bioenergy and inform other teams who are working on similar projects.

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1.0 Introduction

Climate change is an undeniable fact of life in today's world. The signs of climate change are visible around the world. In the last 650,000 years, the Earth has experienced seven distinct cycles of glacial advance and retreat, part of which being the various ice ages throughout history. However, the present cycle is far different than the rest because of the presence of humans (NASA 2019). Overall, the planet's average surface temperature has increased by 1.62 degrees Fahrenheit since 1880, which is a result of the increasing amount of carbon dioxide and other greenhouse gases in the atmosphere. Along with the general rise in temperature, Earth's oceans have also seen an increase of more the 0.4 degrees Fahrenheit within the top 700 meters. The difference between this era and those that came before is that there is a probability as large as 95% that this global warming trend has been caused by humans.

The effects of global climate change are already observable in the environment. Glaciers that make up the area around the Earth's poles have shrunk, and large chunks are falling into the ocean (NASA 2019). In addition, ice on rivers and lakes has been breaking up earlier. These effects were predicted by scientists long ago and could result in even more drastic changes such as accelerated sea level rise and extreme heat waves. The Intergovernmental Panel on Climate Change, which comprises more than 1,300 scientists from a multitude of countries around the world, expects a temperature rise of 2.5 to 10 degrees Fahrenheit over the next century if no changes are made.

The causes of climate change are many, with the primary cause being the greenhouse effect that occurs in Earth's atmosphere. This results from heat from the sun becoming trapped in the atmosphere by long-lasting greenhouse gases such as water vapor, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These greenhouse gases are being emitted through human activities, mainly the burning of fossil fuels such as coal and oil. However, the clearing of rainforests and other land has also had an effect by reducing the amount of plants that can consume the greenhouse gases.

Fossil fuels, the main culprit of greenhouse gas emissions, have been the world's main source of energy generation since the industrial revolution. Fossil fuels include coal, crude oil, and natural gas obtained from underground sources. These fossil fuels are burned in order to generate the energy for the world's population, which then releases these harmful greenhouse gases into the atmosphere, where they stay semi-permanently (NASA 2019).
These fuels are non-renewable energy sources. However, even though they are non-renewable, worldwide consumption continues to increase as the global population rises and countries experience rapid economic growth.

According to the National Aeronautics and Space Administration (NASA), solutions to climate change include a two-pronged approach:

1. **Mitigation -** Reducing emissions of and stabilizing the levels of heat trapping greenhouse gases in Earth's atmosphere.

2. **Adaptation** - Adapting to the already present climate change.

The goal of mitigation is to reduce human impact on the environment through the reduction of fossil fuel usage around the world in order to stabilize the rapidly rising levels of greenhouse gas emissions. The primary solution is to utilize renewable energy sources instead of burning fossil fuels, the most popular being wind and solar energy. To date, there has been a large movement to use more renewable energy methods. However renewable energy made up only 6.2% of the energy consumed in Australia in 2017, with fossil fuels such as brown coal accounting for over 90% of energy consumption (Australian Government 2018). This is mainly due to the face that fossil fuel burning infrastructure is already in place in almost every area of the world and thus is an easier way to produce energy than developing completely new infrastructure for renewable energy.

A renewable energy alternative to the popular methods of solar and wind power is bioenergy. Bioenergy is a source of renewable energy that entails producing energy from biomass, or organic matter. Bioenergy as a source of energy has yet to grow to as large a scale as solar and wind power have. However, many governments around the world are actively searching for viable methods of bioenergy production. The initial cost of producing bioenergy from biomass such as vegetable and animal derived organic materials is more expensive than energy from burning fossil fuels. Bioenergy also requires a very large amount of space in order to harvest and store biomass. To this end, rural landscapes like Gippsland in Australia, are very practical locations for bioenergy to be introduced.

Through working with Snowy River Innovation and other Australian renewable energy agencies, the WPI research team determined the viability and feasibility of a future bioenergy network in the Gippsland region. This project provided a foundation for future bioenergy projects in Gippsland and throughout Australia as a whole, with the hope that bioenergy becomes as prevalent a source of renewable energy as solar and wind.

2.0 Background

2.1 The Case for Bioenergy

In humanities' quest to diminish dependency on fossil fuels, bioenergy stands out for its versatility and robustness. Its versatility emerges from its ability to produce a variety of different types of power and on a continuous basis, as distinct to intermittent sources such as solar PV and Wind. While it can make heat, and electric power, similar to other renewable energy sources and fossil fuels, it is the only renewable way to produce fuels and petroleum-like products (Environmental and Energy Study Institute [EESI], N.D.).

The generation of bioenergy occurs in three main steps: the production or gathering of organic matter to form the biomass/feedstock, the processing of this biomass into its outputs, and the utilization of the outputs (KPMG, 2018). The initial feedstock comes in six broad categories: agricultural waste, wood waste, municipal and industrial organic waste, animal residue from farming, seaweed and algae, and wastewater. Each type of biomass has different methods of processing, and each method of processing returns different types and quantities of energy. According to a 2014 study by the Victorian Local Sustainability Authority, there are three key ways biomass is converted into energy. These are direct combustion, thermo-chemical, and biochemical processes (Victoria Local Sustainability 2014). More information about these processes can be found in Appendix A.

Bioenergy generates these energy types in a closed loop system, where any greenhouse gases produced by the processing of biomass are captured to create new feedstock. Bioenergy gains its robustness from its relation to the carbon cycle. Unlike other forms of renewable energy, which rely on external natural forces and often have limits on the time of generation, such as solar energy's need for direct sunlight, bioenergy is produced by utilizing the process of photosynthesis, which converts solar energy into chemical energy and can store the energy for supply on demand and at competitive commercial costs.

This energy can be processed to create heat, power and biofuels (U.S. Energy Information Administration, 2018). This allows for the generation of power at any point, in any location. There is no time when power cannot be produced, and any organic material may be used.

Bioenergy is the third largest form of renewable energy globally and generates 9% of the world's total primary energy supply. This included 4% of the transportation sector, which is 90% carbon based currently. (International Energy Agency [IEA], N.D.). Worldwide bioenergy generated 493 Terawatt-hours of power in 2017. Biomass and bioenergy are primarily used in developing countries and rural areas. In fact, 50% of the energy produced in the continent of Africa comes from biomass. Bioenergy accounts 73% of all global renewable energy supplies, making it the largest source of renewable energy globally (Schröder, 2011). Since 2014, the use of bioenergy worldwide has grown by 2.3% every year. Currently bioenergy accounts for only 1.4% of Australia's total energy generation, however the Australian government has a goal of increasing this number through policy changes and increased information (Department of Environment and Energy 2018).

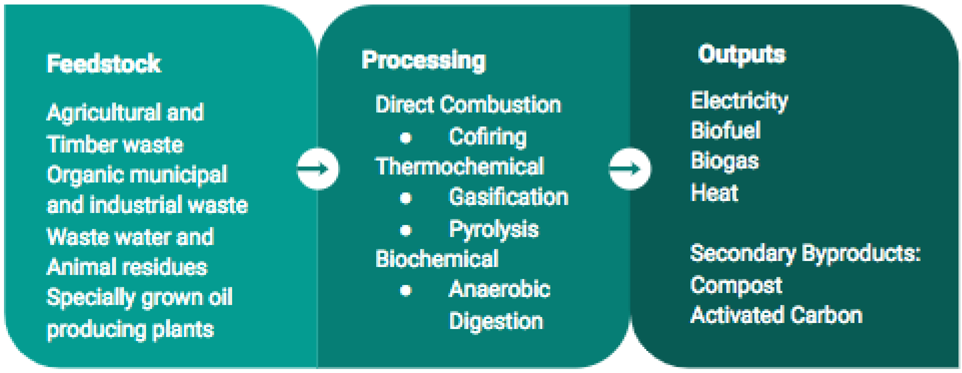


Figure 2.1: Overview of Bioenergy Processes

Biomass has a mutually impactful relationship with the communities from which it is gathered. The type and output of bioenergy is impacted by the feedstock from the communities, however the outputs of the bioenergy process have impacts on the surrounding environment. The production of biomass can affect macroscopic elements, such as the types and quantities of plants grown in an area, as well as the microscopic elements, such as the soil or water quality. When biomass is produced in an unsustainable way, the surrounding ecosystems can be devastated, as crops can leach essential nutrients from the soil.

It can also lead to crops being grown that do not have economic incentives aside from biomass. Therefore, the production of biomass must be done utilizing sustainable farming practices, and a thorough understanding of the existing ecosystem and cultural environment must be conducted to minimize potential disruptions or contaminations. This will also allow for the current waste products of the region to be better understood and utilized as biomass. This can supplement incomes, increase the value of rural land, and allow for more skilled labor in rural environments. (ESSI, n.d.).

The creation of new bioenergy sectors needs an understanding of potential biomass feedstock profiles and how they convert into power, heat and where possible, value added products such as activated carbon from biochar.

The Australian Biomass for Bioenergy Assessment (ABBA) aims to provide this feedstock profile data by creating a comprehensive database of all of the natural biomass present in the various states and townships in Australia. This database will allow for greater understanding on the impact bioenergy plants will have in a region, as well as what areas are ripe with waste that can be used for bioenergy production. The ABBA project is a subsection of the larger Australian Renewable Energy Mapping Infrastructure (AREMI), which is being undertaken due to a $2.19 million grant from the Australian Federal Government (Australian Renewable Energy Agency, 2016). This project seeks to collect available data on renewable energy for input in the ABBA database. This will allow Australian businesses to better understand and utilize the renewable resources available to generate energy and other value added byproducts. Currently, the assessment is underway.

2.2 Energy Resources in Gippsland

In the southeastern quarter of Victoria, the Gippsland rural region stretches from the outskirts of eastern Melbourne for approximately 500 kilometers. The region is made up of the six local government areas: Bass Coast, Baw Baw, East Gippsland, Latrobe, South Gippsland and Wellington, as well as the major regional centers of Bairnsdale, Sale and Traralgon. Gippsland covers roughly 20 percent of Victoria's total area (41,557 square kilometers) and has a population of about 279,400 people (Commonwealth of Australia 2018).

The Gippsland region has an extensive network of electricity and gas transmission infrastructure managed by privately and publicly owned entities by asset managers and energy retailers. On the map below, it shows that the majority of Victoria's energy is produced by coal and gas as Victoria currently relies on fossil fuels as its main source of energy. Fossil fuels are non-renewable resources that consist of petroleum, natural gas, and coal. Fossil fuels are primarily used for electricity and heat production, but create byproducts that stimulate the greenhouse effect and climate change.

However, there are considerable utility scale renewable energy generation solutions being investigated such as offshore wind and exportable liquid hydrogen. Another solution that Gippsland is currently investigating is bioenergy, which is depicted in pink on the map below. In order to reduce the impact that Gippsland is making through the use of fossil fuels, Victoria is beginning to reassess the potential utilization of bioenergy for the commercial generation of electricity. According to the Australian Bureau of Statistics and the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), there is potentially abundant opportunities for bioenergy generation from Gippsland's agribusiness and forestry sectors. By utilizing Gippsland's agriculture and timber production, there could be potential reliable feedstock sources to enable new investment in biomass and biofuel industries (Commonwealth of Australia 2018).

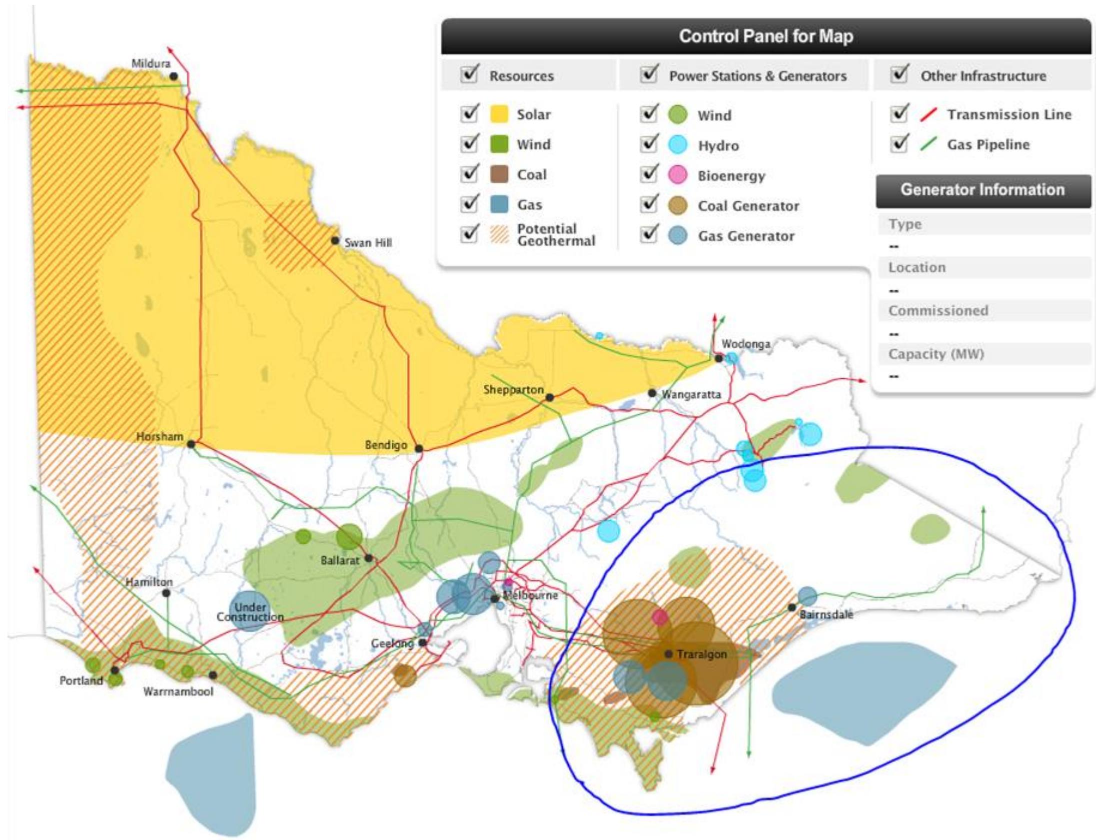


Figure 2.2. Location of energy resources in Victoria; circled region is Gippsland (State Government of Victoria 2019)

2.2.1 Dairy Production

Dairy production is a driving force of Gippsland's economy as well as Gippsland's main land use. The gross value of Gippsland's agricultural production has valued at close to $1.7 billion. It makes up about one-third of Victoria's dairy production and approximately one-fifth of Australia's dairy production. Gippsland's fertile soils as well as reliable rainfall allow the region to have an advantage towards dairy production. There is also a high investment in land irrigation, dairy processing plants, and infrastructure that promotes food manufacturing and adds value within Gippsland (State Government of Victoria 2014).

Cattle waste can be converted into bioenergy through anaerobic digestion. Based on the Victorian biomass data collected for the national ABBA project, approximately 158,744 tonnes of the organic wastes generated were from dairy manure and effluent from the dairy cattle industry (Sustainability Victoria 2017). According to a study conducted by Pennsylvania State University, a cow produces around 7.7 kg of volatile solid waste a day, of which approximately twenty to thirty percent is converted to biogas, which is one of the usable outputs of anaerobic digestion. The daily effluent from an anaerobic digester contains about 24 kg of nitrogen for every 100 cows. Tests using biogas as the only fuel in a gasoline engine showed that a digester for 100 cows produced the energy equivalent of 76 liters of gasoline per day (Homan 2012). In Gippsland alone, there are approximately 3000 farms that specialize in cattle farming with an assumed average of 150 cattle per farm. This means that the amount of biogas produced daily could potentially be equivalent to approximately 34,200 liters of gasoline, which can create about 445 megawatts per hour of electricity. The amount of electricity produced can power up to 444,600 homes at once assuming one megawatt can power up to 800 to 1,000 homes for an hour (California Energy Commission 2019).

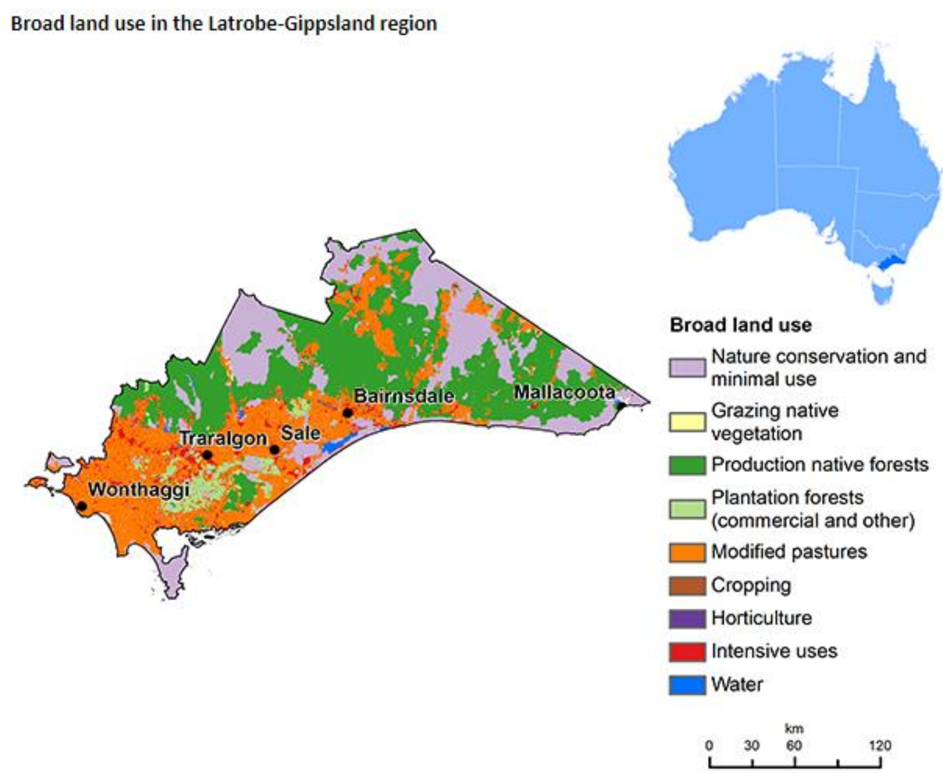


Figure 2.3. Land use in Gippsland (Commonwealth of Australia 2018)

2.2.2 Timber Production and Timber Waste

Gippsland's timber resource is mainly composed of native and plantation forests. Managed native forests are reliable sources for hardwood used in manufacturing, building materials, and quality paper production. Native timber harvesting, particularly in areas across east Gippsland, is crucial for communities such as Orbost and Heyfield in supplying opportunities for jobs and skills (State Government of Victoria 2014). Plantation timber on leased public land or land operated under license by commercial forestry operators also makes up the majority of the region's timber resource. Roughly 25 percent of Victoria's plantation forests are located in Gippsland. According to ABARES, the total output for Gippsland's timber production from plantations and native forests spans about 1.4 million hectares (Commonwealth of Australia 2018). The timber resource provides options to use timber waste in new processes such as bioenergy. From the biomass data collected for the ABBA project, about 460,358 tonnes of timber could be used as biomass feedstock (Sustainability Victoria 2017). Further development of bioenergy technology could also lower Gippsland' carbon footprint.

2.3 Bioenergy Clusters, Supply-Chains and Hubs

Industry clusters are geographically condensed and interconnected by the course of exporting goods and services that promote wealth creation in a region. Companies that are involved can include "specialized suppliers, service providers, and associated institutions in a particular field that are located in the same region" (University of Nevada, Las Vegas 2019). An industry cluster depicts the entire value chain of a broadly established industry from suppliers to end products. A more detailed look into bioenergy clusters can be found in Appendix B.

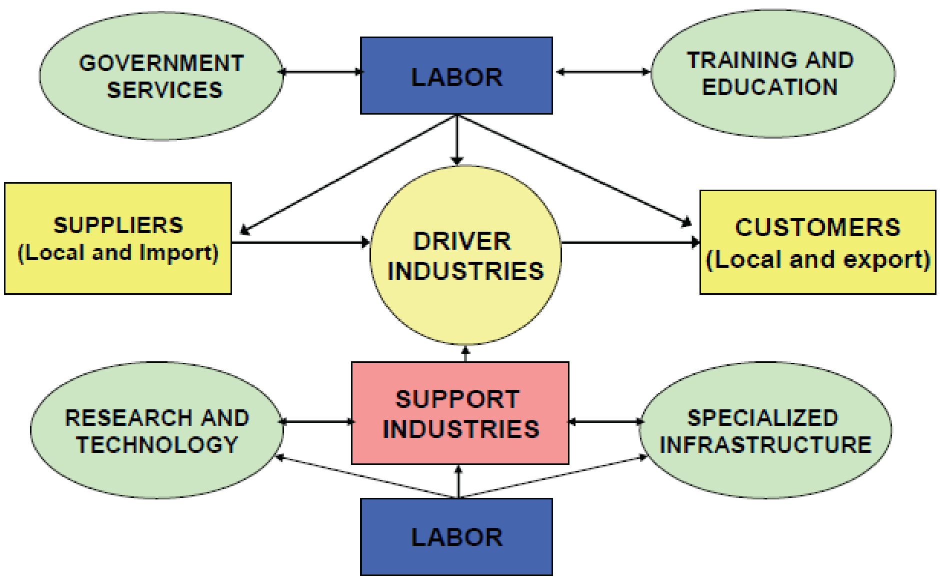


Figure 2.4. Industry cluster map (University of Nevada, Las Vegas 2019)

An industry cluster represents the general developed industry while a supply chain represents a more specific development within a singular company. Supply chaining involves a network between a company and its suppliers to create and issue a certain product. The supply chain depicts the steps required to get the product or service to the customer.

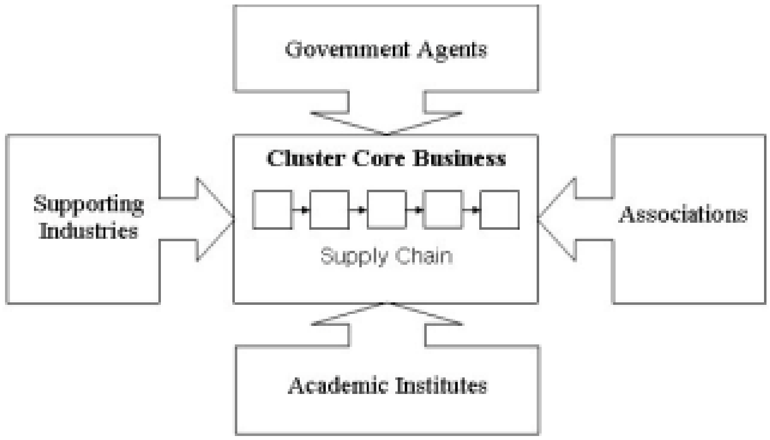


Figure 2.5. Cluster map and supply chain (Chakpitak, Sureephong, Buzon, and Bouras 2008)

Three important elements are needed to successfully collaborate between the supply chains within the overall cluster:

1. Trust and commitment
    a. There is a drive to collaborate for long periods of time with more involvement in the task of improving the collective benefits.
2. Communication
    a. Each company is able to analyze and develop the supply chains' principle functional system, which improves the whole cluster.
    b. Each supply chain is able to have a better understanding of one another's limits, constraints and priorities.
3. Adaptation
    a. Even if the price of the product has risen, the company focuses primarily on the delivery time. This increases the quality of product sales and allows quicker responses to special demand (Sureephong, Chakpitak, Buzon, and Bouras 2008)

Imagine an athlete for a sports team. They have coaches, friends, and family supporting them. Those people "supply" the athlete with skills and advice. Through the connections established and assistance provided, the athlete eventually develops the end product: his or her performance and success during competition. A cluster occurs when all of the athletes within the team work together towards a shared goal: to compete and win competitions.

A bioenergy supply chain focuses on activities from biomass production, biomass logistics of storage and transportation, bioenergy production, and distribution to customer. Similar to other supply chains, a bioenergy supply chain involves "various distinct stages with different ownership entities such as farmers, biorefineries, distributors, and oil companies. Its performance highly depends on the network design, planning, and operations" (Lim and Ouyang 2016). Specifics of the intermediate processes and logistics steps may vary such as conversion, storage, and transportation. These specifics depend on the types of biomass used, conversion technology utilized, and bioenergy produced. However, the system and flow of the bioenergy supply chain are very similar to that of a general supply chain.

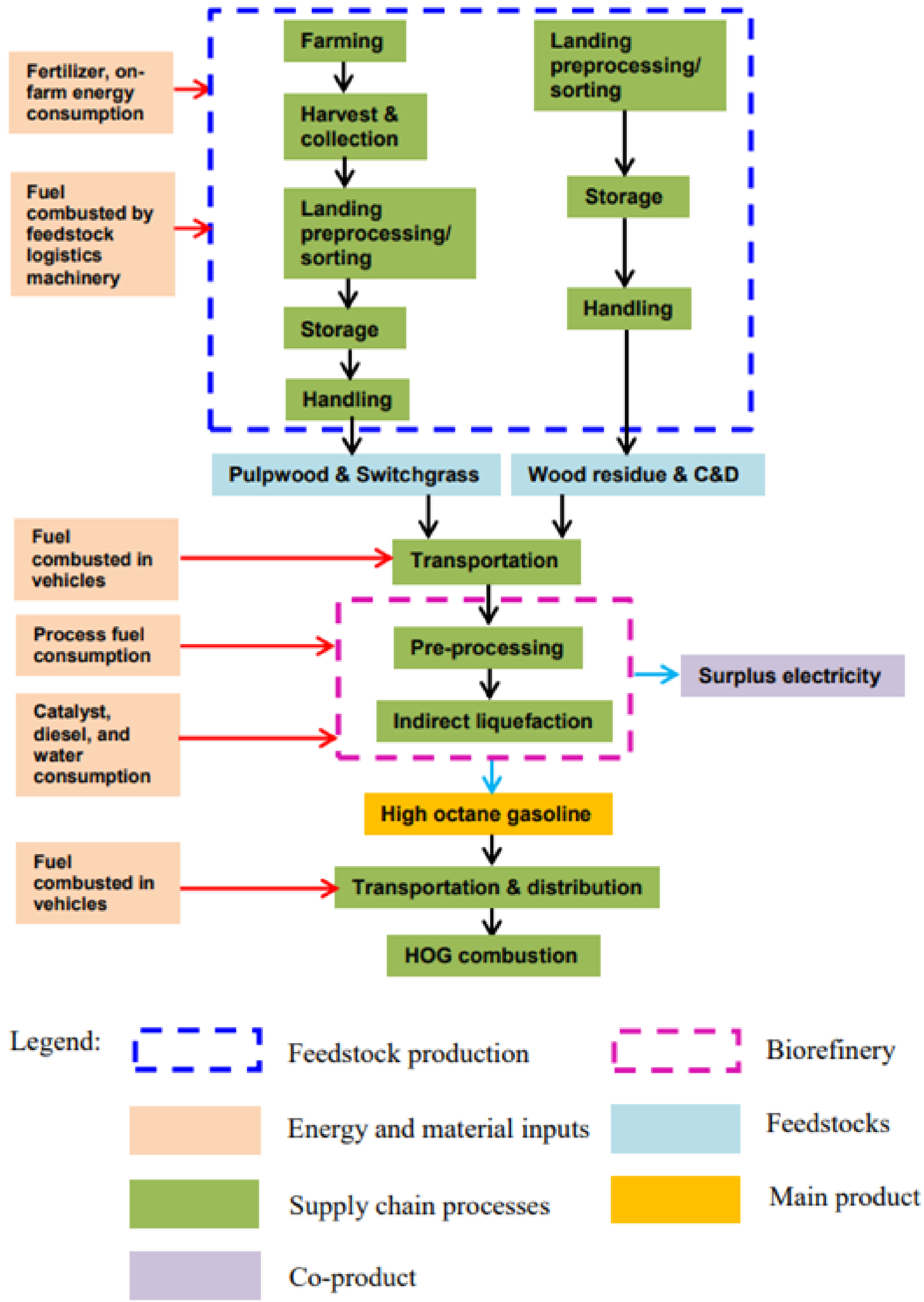


Figure 2.6. General stages in a bioenergy supply chain sustainability analysis (Lim and Ouyang 2016)

Similar to an economic hub comprised of concentrated economic activity, an energy hub involves activity towards energy production. In our case, the energy production is bioenergy. A hub has a similar role to the supplier, providing support towards certain supply chains. A cluster, on the other hand, is many industries that work together by supporting and relying on one another. A bioenergy cluster could be developed around farming waste streams, food waste collection and processing, landfill facilities, waste heat energy from fossil fuel fired generation and manufacturing processes. In supply chain management, a hub refers to a centralized, integrated logistics system used to cater to different destinations. These destinations may include customers, stores, or small warehouses (NC State University 2003). In hubs, products can be stored efficiently and properly. Labeling or documentation can also be easily accomplished through the utilization of hubs. Hubs are an essential part of supply chaining and is designed to lower the overall transportation costs. Hubs are generally located in areas relatively close to customers.

Figure 2.7. Hub distribution system (MBASkool 2018)

Currently, the demand for bioenergy in Gippsland is not very large due to its surplus of coal and gas. For a bioenergy industry to be successful, profitability must be achieved at beginning of production (Bush, B. & National Renewable Energy Laboratory 2013). Unfortunately, biofuel prices could be unstable when initiating production. This instability includes more expensive feedstock prices and positive or zero production capacity. There are two major problems regarding to biomass: moisture and consistency. The less moisture the biomass has, the higher quality the converted energy from the biomass. However, the less moisture it has, the less it weighs, resulting in lower biomass sales prices. In addition, most bioenergy systems are created to use certain materials based on their size, shape, and range of individual fuel particles. If the materials do not meet the specified requirements, they could cause blockages or contamination that will eventually ruin the installation. There must also be a steady supply of biomass, especially since biomass generally does not have a large storage capacity. For the industry to be dependable, regular deliveries must be made. The production of biomass should not be limited in terms of maintain a constant output of bioenergy. In Victoria, the bioenergy market is relatively small and suppliers will have to act as liaisons between the producer and consumer. For better chances of success, Sustainability Victoria states that suppliers should target areas where natural gas and LPG are not used. In addition, suppliers should focus more towards the transportation of the biomass to the end consumers as well as the utilization of the biomaterials that are processed (Victoria Local Sustainability 2014).

2.4 Reusable Waste Usage in Victoria

In a world with growing populations and economies, it is inevitable that more waste products will be created by society. Waste management policy in Victoria, and Australia, is based on minimizing or avoiding waste, and where waste is generated, to examine it as a value added resource.

Over the next 30 years, it is estimated that the amount of material handled in Victoria alone will reach 20 million tons, up from 12.7 million in 2016 (Sustainability Victoria 2018). This increased waste production is being addressed in Victoria by limiting the large amounts of material sent to landfills, but also by making sure that these landfills are used as a last resort for waste. With recovery of resources in mind, Victoria aims to reuse as much of the waste as possible, either by recycling or 'wTe' (waste to energy) (Sustainability Victoria 2018). Essentially, extracting every possible bit of energy from this waste will help increase the environmental justice of the waste management process by promoting sustainability and lowering the amount of material sent to landfills. Bioenergy may serve as a very fitting method of extracting this unused energy from waste products.

Currently in Victoria, waste is reused in recycling and 'wTe', with 67% of materials being recovered in some way (Sustainability Victoria 2018). This number can increase significantly, though, according to SWRRIP (Statewide Resource and Recovery Infrastructure Plan). Although 67% of materials being recovered is an impressive number, it must become much higher if sustainability is a top priority. Currently, wTe is lower on the 'waste hierarchy' than materials recovery (Sustainability Victoria 2018). However, much of the waste in Victoria, such as organic, plastic, and metal waste, has more recoverable material left in it once it reaches the landfill for good following the materials recovery phase (Sustainability Victoria 2018). There is unknown potential for energy generation sitting in landfills because the waste has not been used to its full potential. Although all waste will have some residual material which must be sent to the landfill, SWRRIP plans to make sure all possible energy is retrieved before the residual waste is commissioned to this last resort. Not only will this lower landfill usage, it will create a new source for energy generation.

As seen below and in Appendix G, specific goals and methods have been laid out by SWRRIP to accomplish the task of bettering the usage of waste.

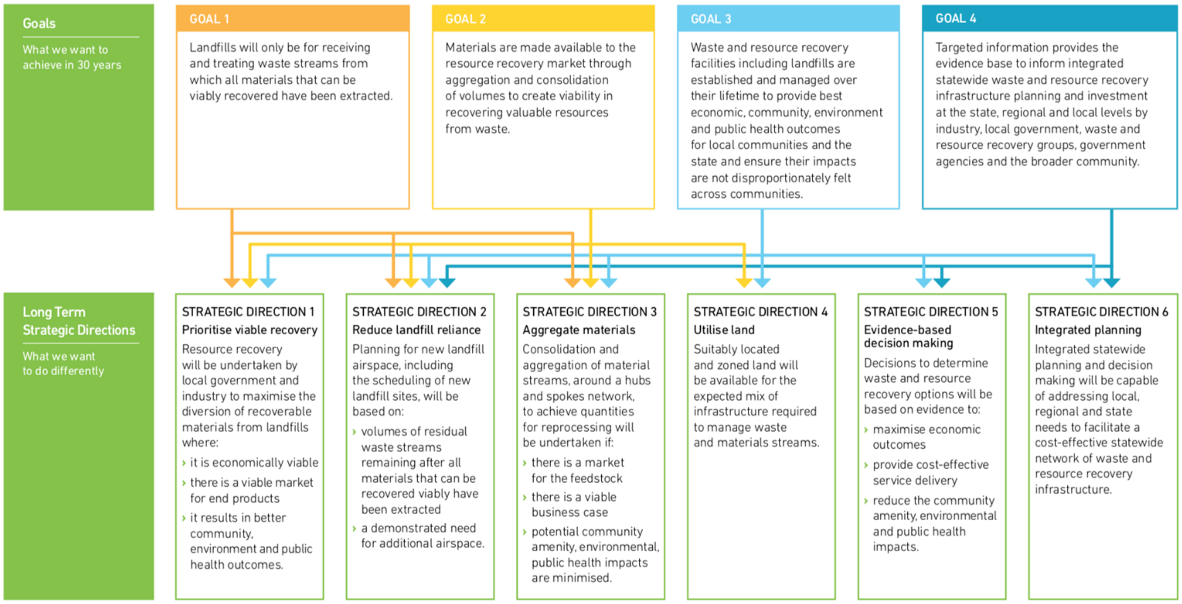


Figure 2.8. SWRRIP goals and strategies (Sustainability Victoria 2018)

Infrastructure is a key for more resource recovery to become a reality. The necessary industries must be nearby to the waste site in order for this goal to be effective. Victoria uses a ‘hub and spoke’ idea to think of how this system will work. The locations managing and processing the waste can be thought of as the ‘hubs’ with all the secondary operations such as transportation and sorting being the ‘spokes’ (Sustainability Victoria 2018). Ideally, the spokes would be as small or as close as possible to the hubs to maximize efficiency. Having a close-working infrastructure will help to create a more circular economy with regards to waste management processes. This relates back to the idea of a cluster and how having dependent industries relying on one another in a nearby area can lower the total transportation efforts; the result is a more sustainable energy production system. Clustering the waste management systems helps to increase their efficiency and create a more circular economy. Because of this, it may be very suitable for a landfill to be tied in with a bioenergy industry cluster. Even though 100% circularity will never be achievable, Victoria could be brought closer to this ideal goal by having a close-knit system where bioenergy is sourced from local waste products to produce sustainable energy.

3.0 Methodology

Snowy River Innovation requested assistance laying out a bioenergy framework for the Gippsland region. The mission of this project was to assist in existing projects relating to this effort, for Snowy River Innovation and other interested parties. Our group developed three distinct objectives to provide a framework for completing this mission. An overview of the objectives can be found below.

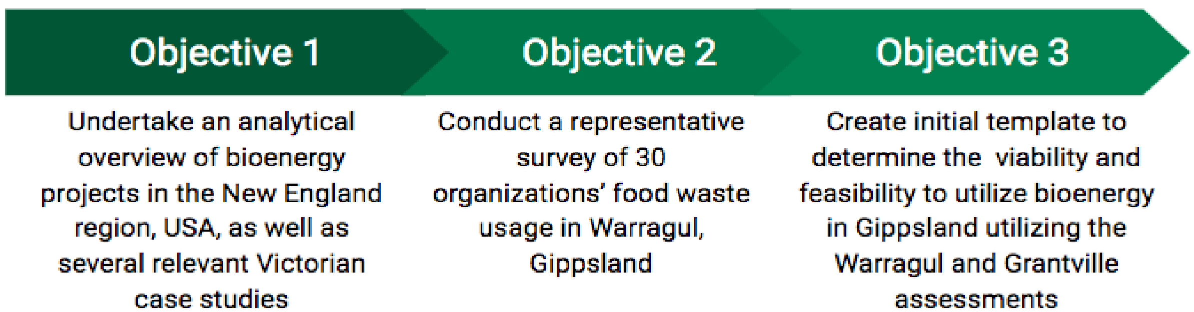


Figure 3.1: Overview of objectives

3.1 Objective I

Undertake a technology trend assessment, market analysis and supply chain analysis of bioenergy projects in the New England USA region, providing examples and case studies, as well as case studies focused on Victoria, Australia to allow for initial comparative analysis.

Our first objective was to complete an analysis of the current state of bioenergy in New England. The scope of this analysis was determined by Snowy River Innovation. The analysis took the form of eight case studies from New England, focusing on different aspects of bioenergy, such as independent dairy farms, larger corporations, urban food waste, and research organizations. These case studies focused on new research, motivations to use bioenergy, costs of implementation, and benefits that have been gathered. We also completed eight case studies from Victoria, Australia to serve as a comparison to the New England research. In the creation of these case studies we reached out to local organizations to conduct semi-structured interviews via phone, email or in person and independent web-based research into the organizations and their supply chains. These interviews focused around the drivers of bioenergy, the costs and issues, the gains and rewards, and any lessons that the subjects learned that would work as best practices, or what to avoid doing in the future. The response rate to these interview requests was poor, and thus we did not conduct any interviews with companies in New England.

In addition to these case studies, we explored a list of topics of interest sent to us by Snowy River Innovation to help guide our understanding. These inquiries provided an overview on the broader aspects of the sector while also prompting us to find information crucial to helping guide decisions in Gippsland. This objective helped us inform our partners about current technology and development of bioenergy in New England. Once the research was complete, we presented our findings to Snowy River Innovation, Gippsland Climate Change Network, Sustainability Victoria, and Capricorn Power, along with other stakeholders in a summit on bioenergy.

3.2 Objective II

Develop a methodology for collecting food waste data and test it during the Warragul Food Waste Survey. Conduct food waste assessments and surveys of as many of 150 food and hospitality SMEs in the Warragul area as possible. Generate a qualitative and quantitative report and integrate the data into the ABBA database.

One of the important components of assisting in the viability and feasibility analysis of Gippsland was to determine the sources and amounts of feedstock available for energy production. To date there had been no successful studies on the quantity of pre consumer food waste in Australia. This information could provide new feedstocks and new avenues for waste-to-energy bioenergy and the creation of local microhubs. Previous efforts to generate this data via email surveys failed, with only 6 usable responses out of 500 surveys. Sustainability Victoria hoped to increase the response rate over 25%, ideally upwards of 50%. This would allow them to have a more detailed quantitative understanding of food waste in the area in and around Warragul for uploading into the Australian Biomass for Bioenergy Assessment (ABBA) database. They requested help from Gippsland Climate Change Network (GCCN) and Snowy River Innovation (SRI), who determined that Warragul would be a representative population for the greater Gippsland area. SRI and GCCN then worked with Baw Baw Sustainability Network to narrow down the 150 small and medium food and hospitality enterprises to 50 high priority, representative businesses. We then were tasked by Snowy River Innovation to develop a methodology to achieve the response rate and conduct the survey. We participated in a five hour visual food waste assessment training with Dr. Trevor Thornton.

Sustainability Victoria provided us with a new draft of a Survey Monkey survey that asked simple quantitative questions about amounts of food waste. However, there were some issues with this survey. Some of the questions were ambiguous or had leading answers, and some answers did not fit the conditions on the ground. We therefore compiled a new version of the survey in the form of a Google Form. This allowed us to easily edit the questions and have immediate access to the data we collected. We were also provided a script compiled from GCCN. However, this script was unnecessarily wordy and we determined that a shorter more concise explanation worked better.

Upon arriving in Warragul, we first canvassed the Warragul CBD, and conducted initial interactions with businesses. These interactions aimed to familiarize us with the protocol, introduce the project to local businesses and set up appointments for later in the week for some larger businesses. We planned to walk from business to business before getting a full understanding of the layout of downtown Warragul. However, an analysis of the list of companies revealed that this was not feasible for all of the survey sites, as many were located far from the CBD. We had access to a truck, and our sponsors drove us to the farther locations.

We then developed a day to day methodology after completing the initial work. The first task of this methodology was mapping the most efficient route to take between that day's targeted businesses. This was done using routexl.com and planner.myrouteonline.com. These websites have a maximum of 20 addresses that can be uploaded, so we scoped out 20 businesses to survey per day.

After conducting the route mapping, we split up into two teams: one to conduct surveys inside the Warragul central business district (CBD) and one to survey the businesses outside the CBD. In order to get to these outside businesses, the outside team was driven by survey team managers, Peter Young and John Lawrence, who had access to a truck. Splitting into two groups allowed for an average of 20 businesses per day to be surveyed.

The methodology of conducting the surveys was the same between the two groups. At first, both teams recited the recommended introduction to the first person they encountered at each business. However, the first person was generally a less senior employee. They would often be confused or overwhelmed after hearing the names of multiple government organizations in the first sentence of interaction. Therefore, the methodology changed to shorten the information given to less senior employees. We found that a few sentences of introduction were all that was needed in order to speak to a manager. In particular, the words "free" and "short" were great motivators, as well as "Sustainability Victoria." This adjustment helped move the surveying process along more effectively. After an employee brought a manager, the team provided more information about the project and its goals. They also made sure the manager was aware that information would be published but that it would be aggregated and no individual markers would be connected to the businesses. The team then asked the survey questions from the Google Form, outlined in Appendix K. Afterwards, the team asked the manager if they could look at the bins inside and outside the business, lifting the lids of the receptacles and taking photos of the total number of bins, the number of bins for each waste stream and the surface level contents of each bin. If the manager said yes, this was done. The survey and the photographs were all taken on mobile phones. Following the completion of the survey, the team would thank the manager so they knew the team had left the site.

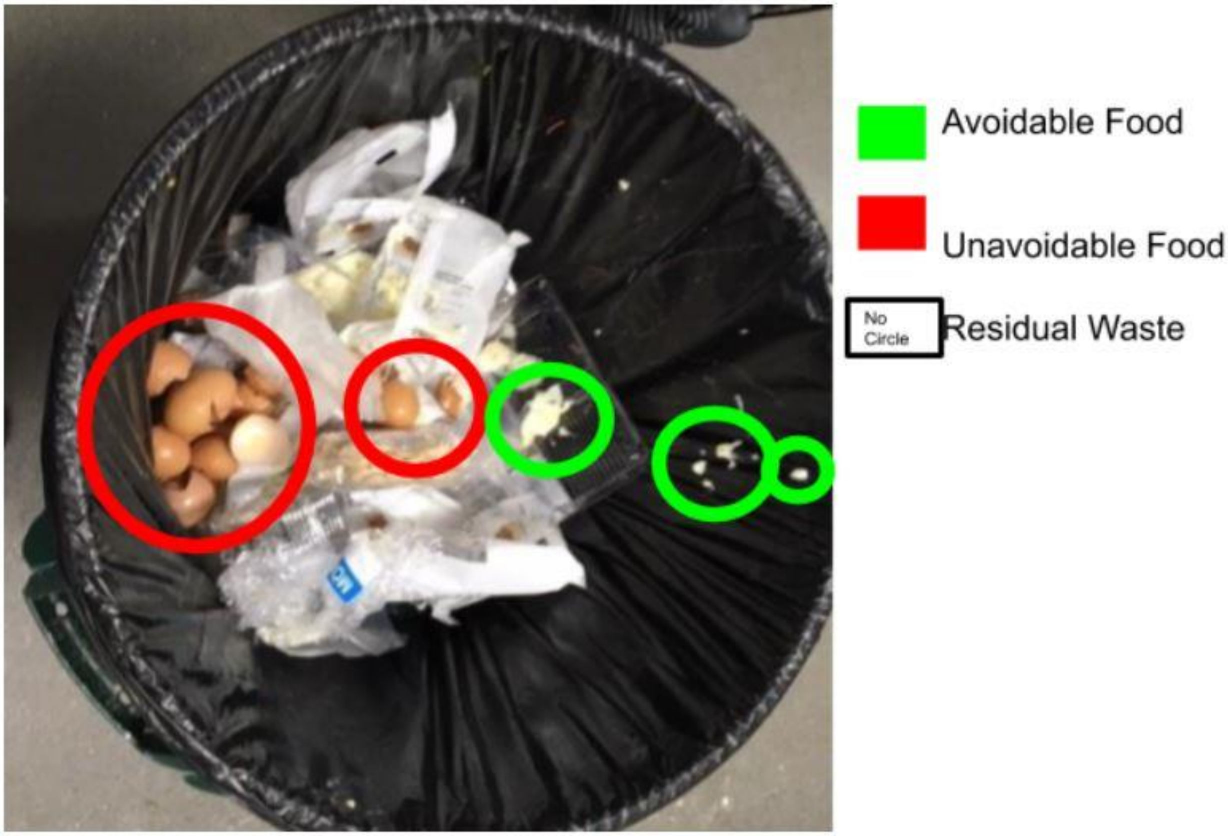


Figure 3.2: Example of bin used in waste assessment

Both teams met up three times per day, first to map the route and split into smaller teams, then at lunch to compare results, and finally at the end of the day to compare notes and discuss the data generated. At this time, everyone would record the businesses that had been surveyed in the spreadsheet to avoid visiting the same place twice.

After three days of surveying, the entire team sat down together and analyzed the photos of the bins at each site, performing a visual assessment of the percentages (by volume) of waste in each bin in accordance with the prior waste assessment training. Some of these visual assessments were deemed to be not-representative, as some businesses had recently had their waste collected. A visual assessment of a mostly empty bin could provide inaccurate data as to a good representation of 'percentage of food waste from that site'. This photo analysis process was performed as a team to reduce individual assessor bias. The data from each site was captured in a spreadsheet, and once all businesses had been surveyed, the data analysis began.

The total waste stream volume of each business was calculated by looking at the photos of waste bins at each establishment before converting this data into cubic metres. The team then compared the businesses self-reported food waste percentage to the percentage of food waste found in the visual assessment and multiplied the total bin volume by the larger value. Doing this reduced the likelihood of inaccurate visual assessments by the surveying team. The photos of the assessment were then used to determine the levels of compactness (low, medium or high) and the type of packaging (loose/packed). These values were used in relation to the conversion density data provided by Dr. Trevor Thornton to convert the volumes of food waste into kilograms (kg). These conversion factors can be found in Appendix I. The self-reported food waste was assumed to have a low level of compaction and no packaging. This was based on what was seen in the photographs, and also ensures that the data would not be an overestimation. Having the food waste in kg allows the data to be used when making a recommendation for a biomass waste to energy system, such as an anaerobic digester, as the waste food feedstock would be measured in mass rather than volume. After this, a summary section was generated to display the total kg of food waste per week for each business type. The summary also listed how many businesses of each ANZSIC code were surveyed. Complete recommendations for improving the methodology are detailed in a later section.

3.3 Objective III

Assist SRI and its stakeholders to develop an initial framework (viability and feasibility) to assess the bio-hub development opportunity at Grantville, Bass Coast Shire, and a potential micro bio-hub for Warragul (applying the SV Warragul ABBA Data survey findings).

The last deliverable to assist in the viability and feasibility study of producing bioenergy in the Grantville Landfill and in Warragul. This was focused on the completion of phase one of the bioenergy project self-assessment tool found in Appendix L.

In Warragul, we used the results of the ABBA food waste survey we conducted, along with existing ABBA data, previous food waste data, and other supporting research done while in Melbourne to determine the viability of a localized bioenergy hub utilizing anaerobic digestion. We worked with Sustainability Victoria to provide location data to allow the potential digestor to be located in a place that allowed high volume producers to be close by to minimize the cost of transporting food waste, as well as to organize the data into business specific places. Sustainability Victoria handled the commercial feasibility aspects of this project.

For the analysis of Grantville, we took an entirely different approach. This part of the project focused solely on the Grantville Landfill, and thus we traveled out to the location and performed a visual assessment of the feedstocks available. We were also able to obtain data on every transaction the landfill processed in the past year, as well as more information about "amnesty" where people are able to drop off green waste for free. The amnesty program runs from November to December and exists to prevent fires in the drier part of the year.

Once we received the data we began to analyze it. First, we extracted all of the information from the individual reports and compiled it into one summary document. We then discovered that the units for the data were inconsistent, with some measured in tons and others in cubic meters. We organized this data into two columns and then marked each transaction that utilized green waste to isolate it for further data analysis. We also attempted to separate the waste that was going into the landfill from waste that was transferred out, as the site serves as both a transport station and a landfill. We did this by isolating what waste the landfill charged for and included the amnesty waste in this group. After isolating the different waste streams we researched 5 possible waste processing methodologies. These were incineration, gasification, pyrolysis, plasma arc gasification, and anaerobic digestion. We found potential suppliers for 3 of these technologies (pyrolysis, gasification, and plasma arc gasification). We decided not to pursue plasma arc gasification, incineration or anaerobic digestion in the treatment of the green waste. Incineration was already being used at the landfill to burn off the methane generated from the landfill. Capricorn Power still hopes to utilize the waste heat generated from this incineration to power Capricorn engines on the site.

We reached out to the companies that provide pyrolysis and gasification systems and received quotes and more information on their systems. We then generated potential power generation potential of the local feedstock and determined the secondary commercial byproducts and their estimated earning potential to determine the time frame for return on investment (ROI). This allowed us to make a recommendation on whether the project was commercially viable and what technology to use depending on the required outputs. After we completed the viability and feasibility analysis of both bioenergy sites, we made recommendations to our partners on how to approach the issue moving forward regarding bioenergy as a whole in Gippsland.

4.0 Results

After moving through the steps outlined in our methodology, we gathered results for our objectives, found below. This section is organized by objective, starting with the New England background research and case studies. This begins with an overview of the objective before going into more information regarding the history of bioenergy and current funding and research organizations. It then lists the eight New England case studies, followed by the eight Victorian case studies. This section then details the quantitative and qualitative data collected during Warragul Food Waste Survey, and lastly discusses the work and subsequent conclusions of the feasibility and viability study of using bioenergy in the Grantville Landfill.

4.1 New England Background Research

The goal of this objective was to have a strong foundation in bioenergy prior to the start of the project, as well as inform our partners of new bioenergy developments occurring in New England. We picked a wide spectrum of case studies in New England, ranging from large scale anaerobic digester sites to educational centers on bioenergy. From these case studies, we achieved a deeper understanding of the bioenergy industry across New England. We discovered that many of the northern states burn wood chips and woody biomass in order to heat buildings such as homes and businesses. This corroborated our previous background research on the subject of bioenergy in the region. However, we also discovered examples of other types of bioenergy like anaerobic digestion. Several of our case studies use this process to compost organic materials and create biogas and energy, meaning that this practice is much more widespread than we had originally realized. These anaerobic digesters are more in line with the technology utilized in Australia, where the climate makes bioenergy is more relevant than bioheating.

Along with these case studies on New England bioenergy, we also produced a summary of eight case studies on Australian bioenergy, specifically in the state of Victoria. Through both sets of case studies, we were able to make a comparison between the two regions and their methods for bioenergy production. Overall, the Victorian climate is much less harsh than that of northern New England in the winter. Thus, Australians have less of a need for wood-burning heaters in the winter and have given more thought to other forms of bioenergy. However, there is still a sector for bioenergy production through the burning of wood, but instead of providing heat to homes, the process heats boilers and turns turbines for electricity generation. Many of these case studies detail the use of anaerobic digestion or composting as a form of biogas and energy generation, making the technology much more prevalent than in New England. This is likely because the economy of Victoria is more agricultural than that of New England, meaning that the feedstocks for anaerobic digestion are much more readily available in the region. An overview of New England bioenergy and sixteen case studies that we researched for this objective are detailed below.

4.1.1 New England Bioenergy Profile

Bioenergy, in general, makes up just a small percentage of most countries' overall power output, but in the New England area of the United States many people are starting to rely on this renewable source of energy. Natural gas pipelines in New England supply most of the heat to states like Massachusetts. However, these pipelines do not reach as far north as New Hampshire and Maine, forcing the populations of these states to rely more on oil and electricity to heat their homes. As a result, many residents and companies of these states are looking towards more renewable sources of energy, with bioenergy becoming an important contender.

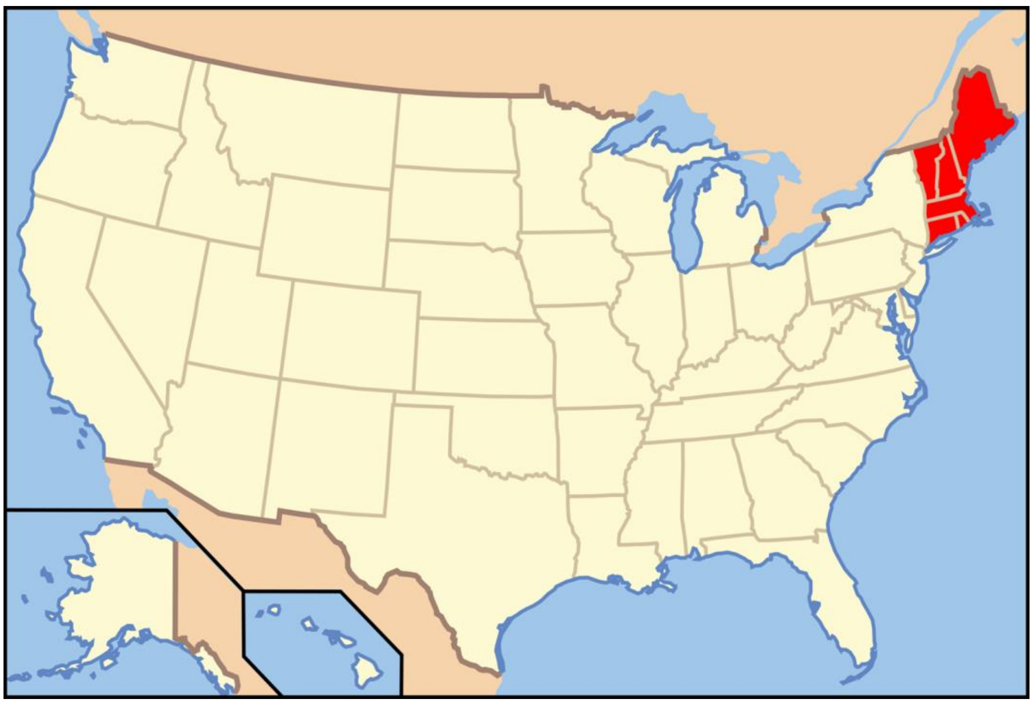


Figure 4.1: Map of U.S. with New England highlighted

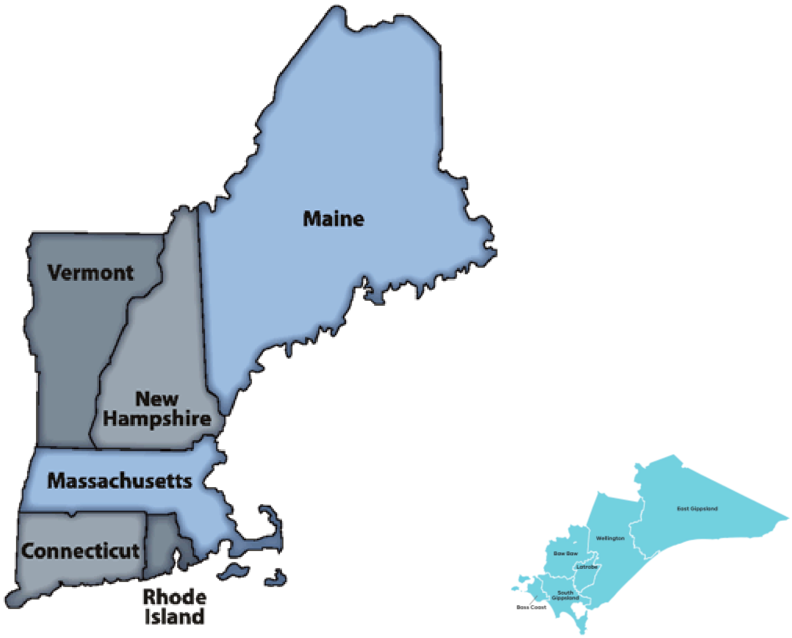


Figure 4.2: Scale between New England (HFMA 2019) and Gippsland (Victoria State Government 2018)

In New Hampshire specifically, most, if not all, of the bioenergy industry is focused on using the waste products from the forestry industries to create wood pellets for heating homes and businesses (Roos 1999). For larger scale operations, this heat is used to create steam, which in turn powers turbines for power generation. This process is almost entirely carbon neutral since the CO_2 emissions from the power plants are then reabsorbed by the other plants and trees in the area.

The reasons that these wood pellets are used for this heating are plentiful. Firstly, the pellets are created from wood industry residues that would otherwise go unused in their respective industries, which follows the ideology of reducing waste and using it to create green power. Using the wood pellets also makes heating efficient and comfortable for consumers (Roos 1999). Heating with bioenergy residentially requires less work and attention by local or national infrastructures since the heating is almost entirely operated by the consumer. In these small scale residential cases, it is simply easier and less expensive for consumers to heat this way than with electricity. For example, heating with electricity alone could cost upwards of US $3,830 while heating with wood pellets can be significantly less expensive (Kroetz 2008).

The process of bioenergy heating in New Hampshire and other states in northern New England also integrates with various other industries in the area. The bioenergy industry associates with the various wood industries in the area. These include, but are not limited to, logging industries, paper mills, and potentially even real estate developers that clear land for new developments. Access to and integration with these industries make it much easier for the bioenergy industry in New England to obtain feedstock for the production of energy and heating (Roos 1999). These industries are upstream of bioenergy in the supply chain, but there are industries downstream as well, not including residential and commercial heating. For example, the wood stove industry has been affected heavily by the advent of the bioenergy industry in

New Hampshire. Previously, very few people used these stoves, but as demand for more renewable energy sources increased, so did the volume of stoves and wood pellets that were sold in the state. This shows that an increase in the production of energy from biomass can benefit not only the world as a whole by reducing the carbon footprint of energy production, but also many other downstream industries.

The bioenergy situation in the state of Maine is quite similar to that in New Hampshire, but undeniably more advanced. Currently, bioenergy represents greater than 25% of all electricity generation in Maine, making it one of the premier states in the use of bioenergy. Again, similar to New Hampshire, Maine creates its power through the burning of waste and residues from the various logging and wood-based industries in the area (Roos 1999). Considering that the state is extensively covered in forest, these are massive industries, thus allowing the state to reach the level of bioenergy production that it has so far. The same supply chain structure exists in both states — upstream to the wood industries and downstream to the various heating element industries.

One of the main differences between the two states appears in the analysis of the supply and transportation methods existent in Maine compared to those in New Hampshire. As mentioned before, the wood industries in Maine already have an impressive presence and thus have various logging routes, roads, equipment, and knowledge of the industry (Roos 1999). All of this previously existing infrastructure makes the transport and storage of biomass for the creation of energy or heat simple. The fact that so much infrastructure needed for bioenergy already exists in Maine heavily contributes to the success of the industry in the state, however it is not the only reason bioenergy has been successful. The environmentally-conscious climate in the state has also contributed to this success. Throughout the inception of the bioenergy industry, Maine has seen plenty of helpful government legislation, coupled with local support and willingness to integrate all of these industries together in a cluster. This is much like what the Gippsland Bioenergy project seeks to do, showing that not only does Australia need a good base for the industry, but also support of the population in order to reduce the use of fossil fuels.

Relating to the transportation of these large amounts of biomass, D. Timmons and C. Mejia performed an analysis into the dependence of bioenergy on fossil fuels used in transportation in the New England area. The main focus of this was to determine a relationship between diesel fuel costs and bioenergy production. Although bioenergy is a seemingly carbon neutral source of renewable energy, the biomass used in energy production is still transported in large trucks, trains, or other fossil fuel burning transportation methods (Timmons & Mejia 2010). Much of the bioenergy created in New England is the result of burning woody biomass, which on its own has almost no carbon footprint since CO_2 is then reabsorbed by other plants. However, the entire supply chain is not carbon neutral due to the burning of fossil fuels in the transportation of this biomass. To make matters worse, since most of the biomass is from the wood-based industries, the sources are dispersed widely across the region, increasing the dependence on truck transportation.

This study (Timmons & Mejia 2010) aimed to discover a relationship between diesel and biomass (wood chip) prices in New England. In simpler terms, as the price of diesel fuel rises, is there a significant rise in the prices of the biomass itself. The reasoning behind this question is because transportation alone accounts for roughly 18 to 29 percent of the final delivered cost of biomass fuel (Timmons & Mejia 2010). On top of this statistic, motor fuels (mostly diesel fuels) account for 93.1 percent of total fossil fuel energy input into the production of bioenergy, meaning that a correlation between the two prices would affect the total price of bioenergy twofold. Also, even with all of the previous logging infrastructure in place, the transport of biomass averages distance of 96 kilometers (roughly 60 miles) in order to arrive at the plant were the biomass will be burned. This means that considerable amounts of diesel fuels are being burned with every biomass shipment that travels from the source to the plants. With the energy density of biomass being much lower than fossil fuels, they require more fuel to be burned carrying larger loads. The result is an almost unnoticed, but still present, carbon footprint.

Although this problem seems large, it is realistically of much less concern than the report initially makes it out to be. First, the method of burning/processing the biomass highly affects the energy generated. These methods include direct combustion and gasification in relation to the industry in New England, where both methods provide excellent energy ratios (Timmons & Mejia 2010). The study also mentions the "net energy ratio" for various biomass feedstocks, which is defined as the total energy available from the biomass divided by the fossil fuel energy required to produce this bioenergy. For logging residues and other woody biomass, like what is used primarily in New England, this ratio is 23.5, meaning that the bioenergy produced by each shipment is around 23.5 times more than the fossil fuel energy used in the transportation. In addition to these findings, Timmons and Mejia also discovered, through an in-depth analysis, that for every US$1.00 per liter increase in diesel fuel prices, there would be a resulting US$5.59 per Mg increase in the price of wood chips and other woody biomass. They also found that land clearing, usually for residential development, does not strongly affect the price or supply of wood chips as most still come from the logging industries. This study finally concluded that although there is a small dependence of biomass prices on fossil fuel prices, that relationship is modest.

In addition to the biomass usage in both Maine and New Hampshire, other New England states have explored bioenergy as a main source of renewable energy. Vermont, the state that neighbors New Hampshire burns wood for heat and energy generation like its sister state. However, instead of using large scale power plants, townships in Vermont use much smaller, more efficient burners to provide heat to public institutions such as schools (Mittlefehldt & Tedford 2014). As such, forests now provide heat for roughly 20% of Vermont's public institutions, which has saved these townships over US $1.7 million in oil costs alone. Although these three states have blossoming bioenergy industries, the stage is set quite differently in the state of Massachusetts. Biomass harvesting has been a hotly debated topic in this state (Markowsky-Lindsay et al. 2012), due to concern over the health of the forests, which cover most of the state, and impacts to air quality and carbon emissions. The study by Markowski-Lindsay et al. showed that 69% of all forests in Massachusetts are owned by private landowners, while the other 31% are owned by state or federal institutions. Due to opposition from both private and state landowners, it is estimated that only between 80k and 369k dry tons of biomass are available per year, which would put the energy output of bioenergy at just 0.09-0.42% of Massachusetts total energy consumption, making it less viable in the more southern New England state.

Bioenergy development is fairly restricted to woody biomass in New England, however the industry is consistently growing due to a more environmentally-friendly political and social climate. New England, somewhat more than other areas, is giving more attention to renewable energy sources such as bioenergy as more conventional heating sources are becoming scarcer (Kroetz & Friedland 2008). Along with the environmental benefits, an increase in the use of bioenergy could also reduce the United States' dependence on other countries and their oil and fuel. There is also potential for more bioenergy usage in the future. For example, more and more people could heat their homes and businesses with wood chips and pellets rather than fossil fuels. This doesn't necessarily have to occur in just northern New England, but could also spread to the more southern states where natural gas still reigns supreme. The diesel used in transportation of biomass could also be replaced by biodiesels from other bioenergy clusters to even further reduce the reliance of bioenergy on fossils fuels and raise the net energy ratio even higher. Some thought must be given to the landscape in the area as well, as most of New England is very rocky and mountainous, making transportation or harvesting difficult in some places, like Maine, and may not provide an accurate representation of what could happen in Gippsland. Overall, the bioenergy industry in New England is very promising and can grow even further, allowing the Gippsland project to look towards New England as an example of what to do.

4.1.2 Bioenergy Research Organizations

To meet the high demands needed for renewable energy, many different research organizations play critical roles in finding new ways to extract as much energy possible from whatever fuels are at hand. Bioenergy is no exception to this, with countless organizations and universities working towards creating more power from biofuels. Just in 2017, the US Department of Energy announced four new research centers to further assist in the development of 'sustainable, cost-effective bioproducts and bioenergy'(US Department of Energy, DOE Bioenergy Research Centers N.D.). Initially, $40 million was divided up between the four locations, with five years of funding planned. Two of these centers are joint collaborations with local universities, University of Wisconsin-Madison and University of Illinois-Urbana Champaign, which is typical, as many universities contribute to renewable energy research and provide sharp, innovative ideas to these projects.

	Sustainability	Feedstock Development	Deconstruction	Conversion
GREAT LAKES BIOENERGY RESEARCH CENTER	Conduct long-term studies of producing bioenergy crops on marginal land.	Design improved dedicated bioenergy crops.	Develop renewable biomass deconstruction and separation strategies.	Develop novel biomass conversion microbes.
cbi THE CENTER FOR BIOENERGY INNOVATION	Optimize water and nutrient use in dedicated bioenergy crops.	Create multiomics tools for developing high-yield bioenergy crops.	Advance integrated and consolidated thermophilic bioprocessing.	Generate drop-in biofuels and bioproducts from biomass and lignin residues.
JBEI Joint BioEnergy Institute	Study environmental resilience of engineered bioenergy crops.	Engineer plants for atom-economical conversion into biofuels and bioproducts.	Develop feedstock agnostic biomass deconstruction processes using renewable ionic liquids	Develop high-throughput synthetic biology tools and hosts for scalable, atom-economical biofuels and bioproducts.
CABBI CENTER FOR ADVANCED BIOENERGY AND BIOPRODUCTS INNOVATION	Integrate economic and environmental analyses for biomass supply.	Develop "plants as factories" concept for biofuels and bioproducts.	Develop product separation technologies for in planta production.	Establish automated biofoundry concept for fuels and bioproducts.

Figure 4.3: Bioenergy Research Centers' goals (United States Department of Energy N.D.)

Similarly, the University of Vermont has contributed new ideas towards bioenergy research in the New England Region. Slightly different in its scope, UVM has focused on oilseed crop research. Oilseed crops include sunflowers, canola, and soybeans, and yield oil to be used for on-farm fuel production and culinary uses. The leftover byproduct may then be used as livestock feed. This is important for creating more circularity and diversification of New England farms. UVM has focused on how they can create the best practices for oilseed production with the given growing conditions. To get results and insight on how to improve the current growing processes, UVM has studied various planting dates, fertility trials, and seeding rates (Housekeeper 2015).

Cornell University has attempted to increase their use of biofuels through CURBI (Cornell University Renewable Bioenergy Initiative). This is a campus-wide initiative to lower the dependence of fossil fuels for the heating loads. CURBI has also looked into 'stackable' technologies, where the waste product of one energy source can be a fuel for another, making the whole process more circular. "While the carbon reduction potential of CURBI research and demonstration is relatively small, CURBI can help identify larger-scale agriculture-based opportunities to produce bioenergy that could significantly offset traditional energy sources" (Cornell University Renewable Bioenergy Initiative N.D.). CURBI currently gets the energy resources from Cornell University Agriculture Experiment Station (CUAES), and receives funding from the National Institute of Food and Agriculture (NIFA). Whereas other recipients of funds from NIFA use the money to cover faculty salaries, CURBI uses these funds to directly fund important research projects (Cornell University Agriculture Experiment Station N.D.).

4.1.3 Bioenergy Funding Programs

With so much research and interest in bioenergy, having the necessary funding is what helps to keep these companies and organizations moving forward. These funds come from many different agencies and programs that have clean energy goals in mind. The US Department of Energy (DOE) and EPIC in California are two examples that heavily fund various bioenergy initiatives.

Both of these agencies have very specific goals in mind for which they target certain companies to fund. The US DOE has stated that it wants to lower the price of drop-in fuels to $3/gallon by 2022. This goal has been reflected in the specific choices of projects they have chosen to fund in the last year. For any expanding industry, it is important that the funding is going where the improvement is needed so that necessary innovations are prioritized. In 2018 alone, the DOE allotted $80 million towards 36 projects that support this. Projects that support the lowered drop in fuel price goal include renewable hydrocarbon fuels and other bio-based fuels, but the DOE also supports initiatives for generating power from non-food and waste biomass. More specifically, some of the projects that the DOE has chosen to fund in 2018 include: 1) those which make more efficient conversion processes to minimize waste streams to improve the economic viability of biofuels, and 2) early state R&D that seeks to find a non-food dedicated energy crop that can be used for all types of biopower. Also in 2018, the DOE stated that it would be funding two projects, from University of Tennessee and Northwestern University, which will aim to generate affordable ethanol and decrease the biofuel production time, respectively (Bioenergy Technologies Office Closed Funding Opportunities N.D.).

EPIC, or the Electric Program Investment Charge, is a program in California developed to support the investment of clean energy technologies that provide benefits to electricity ratepayers (California Energy Commission, FAQs about EPIC, N.D.). EPIC, which receives its funds from rates charged to electricity ratepayers from different electricity companies, has provided $162 million dollars annually since 2012. This money is used to address policy and funding gaps in the deployment, development, and commercialization of clean energy innovation (California Energy Commission, FAQs about EPIC, N.D). Specific to bioenergy, EPIC has recently in 2017 announced a funding program for $23 million to support various bioenergy initiatives. These include the innovation, research, deployment, and evaluation of techniques for energy production with woody biomass (Graham 2017).

4.1.4 New England Case Studies

4.1.4.1 Barstow Farm Anaerobic Digester

Figure 4.4: Barstow Farm anaerobic digester (Barstow's Anaerobic Digester: Farm Powered, N.D.)

New England has many excellent implementations of bioenergy in various sizes and types. Located in Hadley, Massachusetts, the Barstow farm uses local resources to provide power to itself as well as to its surrounding partners. Having only a few energy feedstock connections, the Barstow Farm anaerobic digester is a great example of a micro-hub. This digester is one of the largest and most modern of its type in New England. Built in 2013, and with recent expansions in 2016, the Barstow digester has become even more powerful (Barstow's Anaerobic Digester: Farm Powered, N.D.).

The Barstow Farm partnered with Vanguard Renewables in 2015, and their bioenergy generation process succeeds due to their partnership with Cabot Creamery, local restaurants, and food processors. This collaboration of local companies creates a micro-hub, operating on a relatively small scale, but still providing significant benefits to the players in the hub. Since the companies involved can each provide something to each other, this network creates a closed loop, zero waste energy generation process. The process starts with the organic byproducts of Cabot Creamery's milk and butter production, as well as the food waste produced by local restaurants, supermarkets, and other companies. After Barstow's digester converts these to energy, the power is sent back to Cabot to make more dairy goods, completing the circular process.

The technical process of converting the waste to usable energy is very effective. Barstow takes in the organic byproducts and 14,000 tons yearly of food waste and combines it with the

9,000 tons of manure produced yearly at the farm. These are combined in the 600,000 gallon digester on site (Barstow's Anaerobic Digester: Farm Powered, N.D.). This tank contains many microorganisms to act like a stomach, which convert the fats and sugars into biogas. This biogas is then used to operate the 800 kW engine, installed in 2016 (previously a 300 kW engine). Prior to the installation of the bigger engine, the system annually produced 6000 MWh of electrical energy, 7,040 MMBTUs of thermal energy, and 30,000 tons of organic, odor-free fertilizer. That amount of electrical energy is enough to power 1000 homes' annual needs (EPA 2017). This energy generation process produces many types of beneficial supplies to the farm and creamery. Barstow Farm thrives off their digester's generation in many ways, through the decreased energy costs, free heat, increase in farm outputs due to the ample organic fertilizer, reduction in the use of chemicals to yield better crops, and odor reduction. Cabot Creamery also benefits from the power that is sent from Barstow. The extra power helps Cabot to make more dairy goods, benefiting their business. In turn, this creates more dairy byproducts to supply to Barstow, making this process full circle.

4.1.4.2 Quantum Biopower

Figure 4.5: Quantum Biopower Southington, CT facility (Quantum Biopower N.D.)

Quantum Biopower is a bioenergy production and consulting company originally based out of Southington, Connecticut. The company is credited with creating Connecticut's first anaerobic digester with the purpose of creating electricity and biogas (Quantum Biopower N.D.). They also claim to be the first U.S. company to develop and construct a food waste to energy center. Food waste is the United States' largest percentage of waste, but also happens to be the least recycled. Generally, when food waste is disposed of, it is thrown in the trash because normal recycling does not accept it and most people are unaware than it can be used in more useful ways. This is where Quantum Biopower wants to make an impact.

Quantum Biopower's first overarching goal is to reduce the amount of food waste that goes into landfills all over the country. Their main method of doing this is to develop and construct anaerobic digestion facilities for interested parties. These facilities allow for the quick composting of organic material, including paper food packaging, cardboard, and other compostable materials in addition to pure food waste. This process then results in electricity and biogases, which can be used as substitutes for natural gas, which is currently the main source of heat for this area of the United States. For example, the facility at Southington, CT is able to produce 420,000 ft^3 of biogas per year, which can result in 5,080 tons of CO_2 avoidance per year (Quantum Biopower N.D.). These digesters are also very convenient as they require very little human intervention and actually run on almost fully automated software for maintenance and upkeep. Any leftover products from these facilities are not wasted either - they are turned into organic soil amendments and compost blends instead of being thrown into a landfill.

Another goal of Quantum Biopower is to educate the population on the benefits of anaerobic digestion and biomass to energy as a dependable source of power. As mentioned before, many people simply throw away their food waste due to lack of knowledge as to what else they could do, but Quantum seeks to teach interested bodies, and later the wider population, about the technology, trends, and sustainability of anaerobic digestion as an energy generation method. Through this, they attempt to create eco-friendly and environmentally conscious communities in the hopes that they will eventually relinquish fossil fuels as an energy source. To this end, Quantum Biopower will continue to partner with various municipalities, food waste generators, and even transportation companies and create a more environmentally friendly world.

4.1.4.3 University of Massachusetts Extension Programs

Figure 4.6: University of Massachusetts' CAFE program (UMass Center for Agriculture, Food and the Environment, N.D.)

The University of Massachusetts Center for Agriculture, Food and the Environment (CAFE) is a project run by the University of Massachusetts Amherst to engage the communities of Massachusetts in rural and urban areas and spread research produced by the university on best farming practices, food science and clean energy tactics. This program has three main stations in Central Massachusetts in Worcester, Western Massachusetts in Amherst and eastern Massachusetts in Boston, as well as a number of research stations on various farms across the region. The CAFE program is really a collaboration of many smaller programs in UMass

Amherst with similar goals. Each of these smaller programs is more specific in its scope, and focuses in on educating a smaller subsection of the population (UMass Center for Agriculture, Food and the Environment, N.D.).

There are two main extensions of the CAFE program that pertain directly to conditions in Gippsland and bioenergy. The first is the Crops, Dairy, Livestock and Equine program (CDLE). This program is a collaboration between professors in the departments of plant, soil and insect studies, as well as professors from the department of animal sciences. The CDLE focuses on farms with livestock, such as dairy and horse farms, and provides information on best practices on sustainable and effective farming. It contains a number of resources on utilizing renewable energy in regard to dairy farms (UMass Extension Crops, Dairy, Livestock & Equine Program [CDLE], N.D.a). The CDLE has two main recommendations in regard to bioenergy on dairy farms. The first is planting oil fuel crops for dual use as feed and fuel. The plants, after being processed to remove the oil, have more market value as feedstock than the oil itself will generate. This allows for waste products to be repurposed to promote more sustainable energy practices, and allows farms to have more control over their fuel and feed production. It notes that some farms have found it useful to collaborate with other smaller farms to joint purchase a small oil extractor due to the cost of the equipment, which ranges from $400 to $1300. If farmers do not want to produce their own oil, they also advise collaborating with nearby restaurants. CDLE further advises farms to look into biodigesters to generate biogas from manure to use in heating or producing electricity from steam, or planting corn for bales and purchasing a small pellet producer, which will produce energy without compromising soil quality. They recommend utilizing this generated power locally, as there needs to be a larger utility company to utilize the biomass created on farms for large scale energy production based on the transportation capabilities of rural Massachusetts (CDLE, N.D.b).

The second extension that pertain directly to Gippsland and bioenergy is the Clean Energy Extension. This extension works primarily in urban areas with businesses and industries to help lower the initial market barriers that are preventing the broad implementation of clean energy across Massachusetts. In this area they host a list of resources and case studies that can be used by organizations to gain funding for the creation and utilization of renewable energy. They also send out a newsletter containing their current news. Currently they do not have as much direct research into bioenergy, however they have lists to resources and case studies of local communities and tips about utilizing bioenergy for sustainable heating and cooling (UMass Clean Energy Extension, N.D.).

There are also two active research programs being funded by the CAFE program into bioenergy, specifically anaerobic digestion. The first of these programs is looking into the use of Thermococcus Paralvinellae to digest waste milk and process it to produce hydrogen gas. The milk that is being used will be from cows who have been treated for mastitis and contain a antibiotic Ceftiofur, which needs to be removed in order to process the waste milk. This processing will occur at around 80˚C as the T. Paralvinellae used is a hyperthermophile. This project aims to find a use for the waste milk, which is a large portion of the total commercial organic waste in the region (Holden, N.D.). The second research project aims to better understand how brown fungi process and break down wood without using enzymes. Currently, the preparation of wood and other biomass is an expensive and complicated process that use some hazardous chemicals and require high heat treatment in order to break down the lignin recalcitrance barrier, which guards the cellulosic compounds that are key for bioenergy production. This project aims to utilize the Chelator-mediated Fenton (CMF) technique utilized by brown fungi to break apart the lignin barrier. Unlike previous methods of freeing up cellulosic compounds this would utilize free radicals that would damage the wood without producing damaging waste products or requiring excessive heat (Goodell, N.D.). These two projects are still being completed, and a final report has not been published. However, they are exciting opportunities for the future of biochemical bioenergy production and offer a glimpse at a brighter future ahead.

4.1.4.4 United States Department of Agriculture

The United States Department of Agriculture (USDA) aims to promote agriculture production globally. They also intend to preserve natural resources through conservation of supplies and restoration of forests. The USDA consists of several agencies including the Farm Service Agency (FSA). The FSA tackles various projects such as the Biomass Crop Assistance Program which strives to provide financial support to owners and operators who want to create and deliver biomass feedstocks. The FSA has designated state offices such as the one located in Amherst, Massachusetts.

The USDA partnered with the United State Environmental Protection Agency and the United States Department of Energy to conduct a study in 2014. This study aimed to determine a roadmap for supplying and utilizing biogas. In New England, there are several locations where biomass is being converted into biogas. The Jordan Dairy Farms, located in Rutland, Massachusetts, resides a micro-hub known as where they utilize an anaerobic digester. The digester converts biomass ranging from cow manure to leftovers from ice cream and salad dressing production. The Forest Bioproducts Research Institute (FBRI) at the University of Maine has a 1,500-gallon anaerobic digester that can generate biogas at a rate of ten cubic meters per day. The digester hydrolyzes the biomass to sugars. The sugars produced are then converted to levulinic acid and formic acid at a rate of 160 kilograms per day which is then utilized as biofuel (United States Department of Energy 2017).

In the United States alone, over two thousand biogas sites operate. However, there are more than 11,000 additional biogas systems that could be working to convert biomass into bioenergy. According to the USDA, biogas could become a very reliable renewable energy source if every potential system is put into account. When taken together, these biogas sources could supply 41 billion kWh per year of electricity from 654 billion cubic feet of biogas per year. This is equivalent to powering more than 3 million homes for one year or producing 2.5 billion gallons of gasoline for automotives (United States Environmental Protection Agency 2014).

4.1.4.5 University of Connecticut Seaweed to Energy Project

The University of Connecticut (UConn) Seaweed Energy Project is an example of a bioenergy project making use of a non-traditional energy source. This project is an effort between researchers from UConn and researchers of Woods Hole Oceanographic Institution (WHOI). Recently, they received a $5.7 million grant from the US Department of Energy (UConn Today 2017). The goal of this funding is to expand on the current seaweed farming so that further mass production can increase the seaweed biofuel market. This money will go towards the tools and technology needed to pursue this goal by increasing growth numbers.

The money will be split into two research groups: a group of biologists and geneticists, and research for an autonomous monitoring system (Weber 2017). $3.7 million is going towards the group of biologists and geneticists in effort to determine a breeding program for sugar kelp, or Saccharina latissima, which could increase the yields of this brown seaweed by 30%. To do this, Charles Yarish will be leading the study. He is the lead scientist and oversees the cultivation and nursery systems at UConn and the National Marine Fisheries Service Labs. Yarish aims to create an extensive germplasm collection of sugar kelp, with an isolation of cultures that is selected to be well suited for offshore breeding, highly productive as bioenergy feedstock, and temperature tolerant (UConn Today 2017). Similarly, Cornell has begun to work on applying DNA sequencing to breed certain traits of seaweed that are most beneficial for this type of project. The remaining $2 million will be used towards the development of a system that can autonomously monitor the large scale seaweed farms without human intervention. This will increase the productivity of the process by reducing human effort to track the seaweed growth progress. In addition to these two research groups, there is also work being done at the University of Chicago and University of Puerto Rico to develop similar seaweed growing programs in tropical agricultures. This tropical weather harvesting would produce red seaweed, known as Eucheuma isiforme.

There is certainly a reason for the Department of Energy to support this bioenergy project. By expanding this domestic seaweed farming in less than 5% of the United States' waters, up to 50 million jobs could be created, since most seaweed currently used in the US is imported from elsewhere (UConn Today 2017). Seaweed makes sense as a source for bioenergy because it avoids the growing competition for fertile land, energy intensive fertilizers, and freshwater resources that typical bioenergy sources need for production. Seaweed can be used to create energy in a few different ways, including oil extraction and methane production. It is estimated that the combination of red and brown seaweed in the US could yield up to 10% of the nation's transportation fuel, through the 300 million dry tons that could be annually produced (UConn Today 2017). Charles Yarish has also stated that it is possible to produce the seaweed at less than $80/ton, which is cheaper than corn, wheat, or rice (Weber 2017).

4.1.4.6 John. R. Briggs Elementary School Wood Pellet Boiler

Figure 4.7: Student Art from John R. Briggs Elementary School (Stowers 2015)

In 2013, the John R. Briggs elementary school in Ashburnham MA undertook the expansion of their overcrowded 1960's era school building to better accommodate the 525 students who were currently enrolled. This new facility is 87,000 square feet, over 74% larger in square footage than the previous building (Massachusetts Department of Energy Resources [DOER], 2015). It was therefore important for the building planning committee to determine the best way to heat the new, larger building. After reaching out to local community members to better understand options they received information from individuals who utilized modern wood heating and other renewable energy to heat their own homes. This helped lead them to decide upon using a wood pellet boiler that was supplemented by a propane boiler. With this wood pellet boiler, the school hoped to simultaneously reduce both the cost of heating the larger building, as well as limit the school's reliance on fossil fuels. This turned out to be the case. The cost of heating the new building is consistent with the cost of heating the previous building (~$60,000) despite the new building being one and a half times larger overall (DOER, 2015). From 2015-2016 the school saved an estimated $70,000 compared to alternative heating costs for similar sized spaces (Massachusetts Forest Alliance [MFA], 2017).

The wood pellet burner the school utilized is the Viessmann Pyrot 540 boiler. The Viessmann functions by heating water to about 180˚F or 83˚C and storing the heat in a 1,500 gallon thermal storage tank to improve efficiency (DOER, 2015). This boiler has both a primary and secondary combustion chamber, allowing for lower emissions. To further limit emissions and improve efficiency, the oxygen level of the combustion chambers is carefully monitored to ensure the most efficient combustion (MFA, 2017). This boiler utilizes wood pellets which are produced using compressed sawdust and wood shaving by a local company, Sandri Energy Systems. The pellets are delivered every 5 weeks between October and April, or the primary "heating season". This results in a total of around 169 tons of pellets used per heating season, costing on average $217 per ton. The pellets are loaded into a 28 foot tall, 44 ton metal silo located outside the school (MFA 2017). This silo automatically feeds the pellets into the boiler as needed, and shows when the level of pellets is low. During peak usage times the system utilizes a propane boiler to supplement demand. This propane boiler is also used outside of the normal heating season if there is need for heating. Ash that is produced by the boiler is collected at the base of the boiler by an auger. This ash is used by the local custodians as a replacement for lime, to stabilize the PH of the soil around the school. The machine is cleaned about every 500 hours (DOER, 2015). For the first year of operation specialized contractors handled the cleaning and trained the custodians on proper care. For every subsequent year the custodians have been in charge of cleaning and maintaining the boiler.

This project cost the school $550,000, but the school was able to lower this cost by applying for grants. Combined the school received approximately $350,000 in grants from the Massachusetts School Building Association and the US Department of Energy (MFA, 2017).

This project had three lessons for others attempting to use modern wood heating. The first was to find an experienced team, due to wood pellet boilers being relatively new in the US. They suggested reaching out to European boiler manufacturers if local experience is lacking. Additionally, they recommended being patient the first year, as fossil fuel systems and wood pellet systems have differences in terms of operation. It also takes time to properly train staff, redesign control systems, and optimize when and how to deal with the longer start up and shutdown times in wood based systems. At the end of the day though, the school is very happy with the transition. The use of the wood boiler has increased the public image of the school throughout the community and led to the school gaining national recognition as a Verified Leader in Collaborative Education. As a result of this project, Overbrook Middle School, another local school, decided to implement a modern wood boiler in their reconstruction. They chose the exact same model of wood boiler as Briggs (DOER, 2015).

4.1.4.7 Woodchip System at Quabbin Administration Building

The Vermont Energy Investment Corporation (VEIC) is a non-profit organization located in Chittenden County, Vermont. The VEIC aims to reduce the economic and environmental costs of energy consumption through practices focused towards energy efficiency and renewable energy. The organization consists of several branches such as the Biomass Energy Resource Center (BERC). The BERC seeks to advance the utilization biomass energy within the general communities in North America. BERC collaborates with the local community, colleges and universities, businesses, and the local, state, and federal government.

In late 2008, a $480,000 wood chip heating system was installed at the Quabbin Administration Building located in Belchertown, Massachusetts. This building claims to be the first state-government building heated by biomass in Massachusetts (BERC 2008). With over 15,000 visitors at the Quabbin Administration Building every year, the state government has had a growing interest in utilizing biomass systems in public facilities. In 2005, Quabbin was chosen by the Massachusetts government to be the first project. The boiler annually burns approximately 350 tons of wood chips which replaced about 22,000 gallons of gas. The boiler initially utilized hardwood sawmill chips that were constantly "screened and consistent in moisture content" (BERC 2008). Currently, it can utilize a wide variety of chips that are now stored in Quabbin's former coal storage bin. This project aims to reduce carbon dioxide by 220 tons and reduce fuel costs by $75,000 in the first year with the help of a multicyclone and advanced computer combustion control system. This also projected to repay the original investment of the boiler within six years (BERC 2008).

4.1.4.8 Limlaw Pulpwood and Chipping

New England used to thrive on the success of paper mills. However, in recent times almost all of the paper mills across New England have closed down, causing previous suppliers of wood pulp to search for new ways to use their product and new people or organizations to sell to (Biomass Energy Research Center N.D.). This is the case for one Vermont man named Bruce Limlaw. His family wood-supply business has been running since before the invention of the automobile and used to thrive by selling wood pulp to the various paper mills in the area like many other wood suppliers. However, as that industry failed, his family looked towards wood chips as a new source of income. Now, there are very few mills spread around New England, and if any of them went out of business, these wood pulp suppliers would be impacted heavily. The first three wood chip fueled power plants in Vermont and western New Hampshire were supplied by the Limlaws and a few other companies.

Now, as the industry changes even further, more organizations and institutions are moving towards bioenergy as a source of heat and power. Bruce Limlaw recognized this and shifted his focus from selling to the power plants to selling wood chips to schools. Schools started installing biomass heating systems in the 1980's, which required a much finer wood chip product than the industrial sized boilers owned by the power plants (Biomass Energy Research Center N.D.). First, these finer chips came from sawmills, but as that industry declined as well, Limlaw realized that he could use "bolewood" chips, made from the previously unusable stems of trees once sold for wood pulp. These bolewood chips provide a bark-less high quality product, easily usable in the small scale boilers in schools and businesses. Limlaw has also been able to benefit other industries using the byproducts of his chip screening process. He sells the sawdust to farmers for use in animal bedding and the less fine chips can still go to the larger power plants who have the ability to burn them effectively.

Currently, biomass heating systems heat dozens of schools, colleges, and government facilities, with more installing them every year. Some communities are even looking into developing district wide biomass heating systems. Limlaw himself run his own self-sufficient bioenergy hub on his own property, which heats his house and two shops purely off of biomass heating. This study shows that bioenergy is not only beneficial to the environment, but also to many companies in the supply chain who, with the decline of paper mills, would have found it very difficult to stay in business without this new industry appearing and buying their wood chips.

4.1.5 Victorian Case Studies

4.1.5.1 Berrybank Farm, Windermere, VIC

Figure 4.8: Berrybank Farm anaerobic digester (Department of Environment 2017)

Berrybank Farm is a piggery located in Windermere, Victoria between Ballarat and Learmonth. The piggery itself was established in 1970, but in 1991 they undertook an ambitious two million dollar project to convert waste methane from the pigs into electricity and heat for the piggery. At that point in time, the pig population numbered over 20,000, creating a vast amount of methane. Over many years, the proprietors have transitioned from just a piggery component to a business model that also includes power generation and compost/fertilizer production. This project also ended up saving Berrybank Farm over 100 Megaliters of water annually.

Berrybank has developed a seven step process for the generation of heat, electricity, and fertilizer, detailed as follows:

1. Automatic and continuous waste collection from pigs
2. Grit Removal
3. Slurry Thickening
4. Primary Anaerobic Digestion
5. Secondary Anaerobic Digestion
6. Biogas Purification
7. Generation of Electricity

Biogas is produced in steps 4 and 5 during anaerobic digestion, but there are also secondary byproducts produced in these stages such as high quality compost and fertilizer. The biogas (usually a high percentage of methane) is then combusted in a generator, also known as a "genset". The gas is then purified, removing all traces of hydrogen sulfide, which would corrode the engine and generator if left in the gas.

Along with the fertilizer and compost, heat is another very important byproduct of this complicated process, and is quite important to the survival of the pigs. The proprietors of Berrybank Farm have a three stage process for capturing and reusing the waste heat from the electricity generation process. The first of these stages is to attach heat exchangers to the exhaust of the "gensets", so that the energy that would otherwise be wasted can be used to heat the boilers that maintain the temperatures in the digesters. The next stage is to install thermal pads in the pig pens to ensure the survival of piglets that might not survive otherwise with the current heat lamp setup. The final of the three stages is using an absorption chiller in order to convert the waste heat into cooling for the hotter summer months in the pig pens. This will use four 30 kW heating and cooling coils to cool 400 farrowing pens, along with keeping the grain silos cool to prevent infestation.

Some benefits of the project include an estimated savings of $82,500 through the energy recovery project, along with 1,200 kWh of energy recovered daily, assuming current generator running times. This will allow the generators to produce more electricity, around 190 MWh per annum, with around half of that power saving being used to reheat the boilers. Surplus energy will also be sold to the grid, meaning that this reusing of energy will make the farm a profit, along with avoiding 740 tonnes of CO_2 production per year. The total investment in heat recovery is roughly $720,000, with a return on investment of about 17% for each stage of energy recovery. (Department of Environment 2017).

4.1.5.2 Smorgon Fuels

The Smorgon Group started out as a steel recycling company in the late 1990's, but as peak oil approached, they identified an oil alternative and branched out into biodiesel research and production. They created a special division of the company to focus on the production of biofuels, creating their first batch from used cooking oil in 2005. In 2012, Smorgon Fuels had become one of Australia's largest biodiesel manufacturers, with a 100 million liter biodiesel plant situated at Laverton North, employing roughly 30 people in production, sales, and support.

There are a variety of feedstocks used in the production of biodiesel (BioMax) at Smorgon Fuels. The feedstocks are as follows:

- Food waste: off-grade or rancid materials, almost any food unfit for human consumption
- Algae: oils and fats produced by algae can then be turned into biodiesel, microalgae transform normal CO_2 emissions into vegetative matter and oxygen
- Used cooking oil: sourced from the hospitality industry, Smorgon Fuels provides storage vats to restaurants and a collection service to bring it to the plant

- Juncea DJL200: similar qualities to canola oil, but grows in low rainfall environments and is unfit for human consumption
- Poppy seed oil: byproduct of the pharmaceutical industry

There are also a few feedstocks the Smorgon Fuels is not currently attempting to use in the production of biofuels:

- Canola oil: can be processed into a very high quality fuel, but is a food grade oil able to be consumed by humans
- Palm oil: high freezing point along with environmental concerns about land used for palm oil plantations makes this option not viable
- Tallow: high freezing point, like palm oil, and too expensive for effective biofuel production

The biodiesel produced by Smorgon Fuels is used mostly in cars, but also finds uses in the running of farm machinery as well as being used in indoor generators due to the lack of smoke emissions. It is also currently produced in smaller batches to be able to use all of the different feedstocks effectively. There are also a few challenges for this industry that could make it difficult to find value in producing biofuels. The first is being able to source economically viable feedstocks, since cooking oil increased rapidly in price by about $400/tonne between 2007 and 2012. Another challenge is the demand and cost of production. Biofuels are more expensive to produce than fossil fuels, resulting in an increased consumer purchase price. Sometimes the idea that biofuels are sustainable are enough for people to rationalize the increased cost, but some don't want to pay more for what they see as the same product. Thus, the companies producing biodiesel in Australia only numbered three by 2012. Another challenge is competition with outside sources. First of all, biofuels have to compete with fossil fuels in general, which is difficult to the inexpensive nature of fossil fuels. Also, many international biodiesel producers are subsidized to export their product to Australia, which then creates harsh competition with local, unsubsidized producers. (Department of Environment 2017).

4.1.5.3 BeBioenergy, Kaniva, VIC

BeBioenergy was established by a fourth generation farmer out of Kaniva, Victoria named Steven Hobbs. His farm is a typical mixed farm, which grows an assortment of cereal, legume, and oilseed crops. He also raises Merino sheep and Prime lambs. Steven's grandparents sourced energy from oats in the past, so he realized he could do something similar to meet the growing demand for energy on the farm. Thus, in early 2000, he purchased an oilseed expeller and began researching using vegetable oil as a fuel source, resulting in the production of a small biodiesel plant using the mustard and canola crops grown on the farm. He also quickly realized that the byproducts of fuel production could be used on the farm as well.

Hobbs states that historically, farmers have relied heavily on solar energy to meet all energy demands in agriculture. However, he utilizes a different source of solar energy, since oil plants store solar energy from photosynthesis as an energy dense lipid or fat, which can then be used as fuel. Between the 1940's and 1970's many farmers turned to crude oil as a fuel source since it was much cheaper than any other options, but Hobbs hopes that more renewable sources such as the vegetable oil that he is using can resurface and become the face of agricultural energy once again.

The overall cost for growing these oilseed crops for fuel is based on a multitude of factors including crop yield, oil content of the crops, extraction efficiency with the oilseed press, and cost of growing the crop. The cost of growing cereal crops is roughly $150 per hectare, while oilseed crops far exceed that with canola costing in the range of $350 per hectare. Hobbs has been testing less expensive crops than canola, such as mustard seed which has a similar price per hectare to the cereals he already grows. As it stands, mustard seed has about 70 percent of the yield of canola and is grown at less than half the cost, making it a promising candidate for fuel production from vegetable oil.

Currently, Steven Hobbs dedicates roughly 5 to 7 percent of the total cropped area on the farm to fuel producing crops, since vegetable oil has a high energy density (similar to mineral diesel) and the engines have a high thermal efficiency and less energy is lost as heat. In order to extract the oil from the crops for use in biodiesel production, he uses continuous screw oilseed expellers to cold press the oil. This process results in two different products, the vegetable oil for use in fuel production and "press cake". Press cake is very useful in many applications throughout the farm economy. For example, it is a high protein alternative for use in feed for the sheep and lambs on the property as well as providing a rich fertilizer to stimulate the growth of new crops. The system is not perfect however, as some mineral diesel is still required for start up and shutdown of the process, but overall Steven Hobbs has reduced his consumption of mineral diesel by 80 percent through the use of vegetable oil-based biodiesel. (Department of Environment).

4.1.5.4 Reid Brothers Sawmill, Yarra Junction, VIC

Reid Brothers Timber has been operating a sawmill at Yarra Junction in Victoria since the 1940's. Every year, they process roughly 17,500 cubic meters of timber, where 5,000 cubic meters of that is dried in a kiln. Originally, Reid Brothers Timber used liquid petroleum gas (LPG) in the boilers that supply heat to the kiln for the drying of timber. However, they realized that there was a growing expense every year to keep this system supplied with LPG. In addition to the increasing fuel costs, the company was also paying over $1,200 every month to send waste timber to a landfill, adding up to $14,400 every year. Seeing that they could improve in these areas, Reid Brothers started installation of a wood fired boiler instead of an LPG boiler.

In 2005, Melbourne Company Steam Systems supplied Reid Brothers Timber with a 1 MW-th (Megawatt thermal) system. This system burns roughly 70 to 80 tonnes of timber waste every week to heat the drying kilns and cost Reid Brothers $360,000 to install. This timber waste is comprised of sawdust from the mill itself, clean up material, some green material, and sometimes waste material from other timber businesses, all with a moisture content in a range from 10 to 50 percent. This system also has a walking floor fuel supply and automated ash removal along with a sensor suite that allows very detailed monitoring of the entire process. Since the system has been in place, it has run constantly for 11 months throughout the year, with minimal maintenance required. There have been few issues, one of which being “bridging”, where the timber waste would form an arch in the hopper. This issue has since been solved by excluding sticks from the feedstock.

The most important aspect of this project for Reid Brothers Timber was the cost and savings installing this new system entailed. As mentioned before, the upfront cost of the 1 MW-th system was $360,000 and it costs $15,000 annually for operation and maintenance. The original LPG boiler system used 360,000 liters of fuel per year, but with the additional kilns it used 450,000 liters per year. At a price of roughly 60 cents per liter for LPG, this means that it cost about $270,000 every year to run the LPG boiler system. With the new wood-fired system, there is no longer a need for this expense every year, saving the company this amount yearly. Another previous cost to Reid Brothers Timber was the waste disposal cost for bringing the timber waste to landfill. This cost the company $14,000 annually, but since they now use all the timber waste in the wood-fired boiler, this is another costs that has disappeared. This results in a yearly savings of $269,000 from using the new wood-fired boiler system, allowing the payback of the system in only 1.3 years.

Not only does Reid Brothers Timber use the wood-fired boiler to heat the kilns, they also use the excess heat that would normally go to waste in order to create steam for use in an Organic Rankine Cycle (ORC). The excess heat warms up a working fluid, usually and organic chemical, at lower temperatures and pressures than the steam Rankine cycle. This ends up reducing overall operation and maintenance costs compared to steam cycle systems, along with allowing the ORC systems to be attached to the boilers easily. By attaching these ORC systems to the wood-fired boiler, Reid Brothers Timber generates their own electricity and actually saves them roughly $10,000 every year on electricity costs. Reid Brothers Timber is an interesting example of a commercially viable method of using timber waste instead of fossil fuels, much like what happens throughout New England. (Department of Environment).

4.1.5.5 South Eastern Organics Processing Facility, Melbourne, VIC

The city of Melbourne has now approved a new South Eastern Organics Processing Facility for the city and surrounding councils. The feedstock for this facility includes garden and organic waste from council-run kerbside green waste collections. This feedstock will amount to 12,000 truckloads of green waste yearly, which will then be composted into potentially 50,000 tonnes of high-grade compost. This mechanical and biological treatment plant will treat organic waste that is transported in by the eight participating Melbourne councils, which will in turn heavily reduce emissions and the amount of avoidable waste going to landfill. The councils hope to use this compost in local council-owned parks and gardens.

The plant is proposed to cost $65 million and is being built by Sacyr Group, a leading international waste management company. It is proposed to avoid more than 65,000 tonnes of CO_2 emissions every year, which is an 85 percent reduction of the emissions that would be produced if the green waste went to landfill instead of being processed in this facility. This would be equivalent to removing 13,900 cars from the road each year. The facility will use a fully-enclosed, in-vessel aerobic composting and maturation process to compost this green waste, which is planned to be operation in mid-2019 and run for 15 years with the potential for a five year extension to the program. The plant storage reservoirs are completely closed and use an efficient and reliable deodorisation system which complies with the most stringent standards within the sector.

As mentioned before, eight Melbourne councils are participating in this project. The following councils will be sending their food and organic waste to the facility: Bayside, Cardinia, Casey, Frankston, Glen Eira, Greater Dandenong, Kingston, and Monash. These councils are all part of the Victorian Metropolitan Waste and Resource Recovery Group (MWRRG). They are charged gate fees to use the facility and the majority of the compost will be sold back to the councils for use in community parks and gardens, as mentioned previously. This is an important step in government and council support for using waste in various ways other than simply diverting it to landfill. (Clean Energy Finance Corp n.d.).

4.1.5.6 Power from Dairy Manufacturing Waste, Leongatha, VIC

The Murray Goulburn Co-operative set their sights on producing biogas using the waste produced in dairy manufacturing at their Leongatha facility in Victoria. The Murray Goulburn Co-operative was first established by dairy farmers in 1950, but since then has grown to be one of Australia's largest dairy foods companies, supporting thousands of different dairy farming businesses. They were acquired by Saputo Dairy Australia in May 2018.

The biogas facility at Leongatha initially cost $1.82 million to install and the installation took a total of 18 months. The company received support from government organizations such as Sustainability Victoria through the Renewable Energy Support Fund, and the payback period for the project is expected to be at most three years. After all of the capital is paid back, the Murray Goulburn Co-operative expects to see savings around $600,000 every year in reduced energy costs, due to reduced need for grid energy along with income from the many renewable energy certificates earned from the project.

At the Leongatha facility, they use local milk to manufacture dairy products e.g. butter, cheese, milk powder, and milk. The waste products from these manufacturing processes are then put into an anaerobic digester, which results in the production of biogas. This biogas mostly consists of methane and carbon dioxide. The digester alone can produce 9,600 cubic meters of this biogas each day. The next stage of the process includes removing impurities and moisture from the gas with a scrubber. With this process, 99 percent of the methane gas from the dairy waste products is destroyed and greenhouse gas emissions from grid electricity are offset by the clean renewable energy generated. Another benefit of this facility is that untreated effluent is no longer being dumped into Venus Bay and polluting the water. Once the digestion process is complete, the biogas runs two engines that can produce up to 760 kW of electricity per year, which is only used on site, not exported to the grid. In the future, the Murray Goulburn Co-operative seeks to install a steam turbine to utilize the waste heat for energy generation up to 1000 kW every year. (Rural Industries Research and Development Corporation n.d.).

4.1.5.7 Beaufort Hospital Biomass Heating System

This project was a result of extensive investigation and active interest in bioenergy application led by the Central Highlands Agribusiness Forum (CHAF). CHAF recognized the Beaufort Hospital, located at Beaufort, Victoria, as a suitable site for demonstrating bioenergy application since the hospital had an inefficient gas boiler. In February 2014, a 110kW Hargassner wood chip fueled boiler was installed at the hospital. The heating system was implemented into the hospital's current heating parallel to the LPG boilers. Both boilers are connected by a separate heat exchanger so that fluids from both systems do not mix (Victoria Local Sustainability Accord 2014). The boiler is fueled by hardwood chips supplied by a local sawmill and is located in an area for easy access for fuel deliveries. The boiler is also housed in a 12-meter shipping container that includes a fuel store and filing system. This allows the hospital to remove or relocate the system if necessary. The LPG system is retained as backup. It is primarily used during peak loads such as very cold weather and When biomass boiler is offline. The wood chip boiler undergoes maintenance and cleaning 12 days per year. Also, the LPG system automatically turns on if the wood chip boiler experiences an event of failure (Victoria Local Sustainability Accord 2014).

The boiler has the capability to connect to the internet to notify and alert hospital staff as well as maintenance contractors being able to access the system remotely. This allows constant monitoring of the system without the need for anyone to actually being present with the system.

After the first 12 months of installation, LPG use reduced by 37,041 L with LPG prices of $1.19 per L. The hospital saved $26,798 while reducing greenhouse gas emissions by about 56 tonnes per year. This installation cost the hospital $428,937, with $418,150 invested on the boiler unit and fuel store. The Beaufort Hospital expects the payback period for the installation to take about 12 years (Victoria Local Sustainability Accord 2014).

4.1.5.8 Australian Tartaric Products (ATP), Colignan VIC

Australian Tartaric Products (ATP), located in Colignan, Victoria, utilizes grape waste from local wineries to extract tartaric acid that is then sold back to the wine industries. ATP is the largest natural tartaric supplier in Australia. Tartaric acid is an organic acid mostly found in grapes that can be extracted after the process of winemaking. It can be used in wine as a preservative and to adjust pH levels and flavor. To extract the tartaric acid, three types of raw materials are collected:

1. Grape marc: skins and seeds remaining from juice-pressed grapes
2. Lees: solids removed from wine during filtration
    a. Filter aids, yeasts, etc.
3. Sludge: yeast and solids removed from wine after fermentation (Biomass Producer 2013)

The grape marc is pre-treated to extract the tartaric acid which leaves 'spent' grape marc and a 'grape wine.' The grape wine is then mixed with the lees and sludge, which are also pre-treated, before being distilled to create grape spirit. Grape spirit is grape wine that has been distilled to create an alcoholic drink. The remains after the distillation is then taken to ATP's acid plant where the tartaric acid is extracted (Biomass Producer 2013).

In 2013, ATP installed a biomass boiler with the intention to decrease costs of gas to create steam to operate the distillery and tartaric acid plant. The boiler is fueled by the spent grape marc generated after the pre-treatment process. The spent grape marc is burned in the boiler to generate steam to power the company's operations. ATP collects the waste from local wineries for free so the businesses save money since the waste is not being sent to landfills. ATP annually collects approximately 90,000 tonnes of grape waste with 50,000 tonnes being grape marc. Unlike most other organic materials, grape marc is difficult to compost due to its acidic properties. In addition, the grape marc is stored in a purpose-built concrete bunker and must be stacked in a specific way in order to minimize degradation, sun and rain exposure, and loss of moisture. Once the grape marc has been pre-treated, the spent grape marc in presses in order to remove some of the water before it is used as feedstock for the boiler. The moisture of the spent marc is carefully controlled in order to maintain the consistency of the feedstock. The boiler utilizes a closed-looped system. The spent grape marc is sent into a hopper, then is mechanically pushed into a large combustion chamber. The eight megawatt biomass boiler is able to generate ten tonnes of steam an hour (Australian Tartaric Products 2014).

The biomass boiler needs to be supervised at all times by a trained boiler attendant so ATP had to employ six new people. While the steam being generated is running the distillery as well as the marc and acid plants, there is an excess amount of steam being created. ATP utilizes this surplus to generate electricity to help power ATP's bioenergy plant (Australian Tartaric Products 2014). ATP use four turbines that use the steam to create electricity through an organic Rankine cycle (ORC). Essentially, the turbines act as fans operating in reverse. Unlike conventional fans where electricity needs to be inputted to blow air, high speed air causes the spin the turbines to about 30,000 revolutions per minute to generate power. Any remaining steam would condense and return to the boiler to be reused. ATP is located at the end of the power lines within its area which caused line losses to occur frequently so ATP is currently disconnected from the grid. However, the additional electricity generated can also be traded if there is a sufficient amount (Biomass Producer 2013).

Before the start of the project, using grape marc as biomass feedstock was considered to very risky since it was a waste stream that had not been processed in that matter. However, RANDI, ATP's parent company located in Italy has already commissioned a boiler similar to the one ATP was proposing so the risk was reduced. It was also beneficial that ATP already had an abundant supply of grape marc onsite. The main risk was if the boiler could handle the feedstock. Due to the use of a closed-looped system, a large combustion chamber is needed to effectively create steam from the spent grape marc (Biomass Producer 2013).

The project cost ATP $11 million, where $7.5 million was invested on the boiler unit, installation, and infrastructure. Initially, ATP was awarded a $40,000 grant under the Australian Industry Group and the EPA Victoria Sustainability Covenant to perform a viability study on converting spent grape marc to energy. ATP succeeded in receiving two additional grants: $1.8 million from the Victorian Government Regional Infrastructure Development Fund and $1.7 million from the Australian Government's AusTrade Clean Energy Australia Fund. ATP also were able to receive financial aid from the National Australian Bank (Australian Tartaric Products 2014).

The boiler has managed to reduce ATP's carbon emissions by 10,000 tonnes and energy costs by over $2 million annually. The amount of energy ATP utilizes from the grid has decreased by 43% and its LPG usage by 90%. ATP estimates their payback period for the development of the biomass boiler to be about 4.8 years. Currently, ATP is investigating the use of waste from the biomass boiler ('grape ash') as a fertilizer or soil conditioner (Biomass Producer 2013).

4.2 Warragul Food Waste Survey

The Warragul Food Waste Survey had two principal objectives. The first was to develop an effective data collection methodology applicable to food and hospitality Small and Medium Enterprises (SMEs). The second was to detail the volume of food waste generated by industry sector in a representative regional town in order to fill a gap in the Australian Biomass to Bioenergy Assessment (ABBA) database.

The research team focused on 150 businesses, of which 50 were marked as high priority. Utilizing route mapping software to determine the best route to visit these businesses, they split into sub teams that focused on the CBD and the surrounding outer township. Each team conducted a brief in-person survey using Google forms, then a photographic waste assessment. They later converted the data from estimated litres of waste to kilograms using a density conversion table, then categorized by waste type and sorted by business type.

4.2.1 Creating a Data Collection Methodology for Food and Hospitality SME's

The Warragul Food Waste Survey and Assessment exceeded the initial goal set by SV and GCCN regarding the number of businesses surveyed. In all, we reached 65 businesses, 52 of whom were willing to partake in the survey, while 13 rejected it, providing an 80 percent response rate. The process provided a much higher success rate than the online only survey method trialed in the past, which had a response rate of approximately three percent (14/500), with even fewer (6/14) responses containing complete and useful information. The process confirms that the method of face-to-face surveying adopted was highly effective.

The first goal of this objective was to develop an effective methodology for data collection for SV, which they can replicate in other townships throughout Gippsland. The first iteration of the survey came directly from SV in the form of a Survey Monkey survey (App XX). This instrument had a few issues, discussed previously in the methodology chapter, such as ambiguous wording and technical issues. Thus, we moved forward with a Google Forms survey, which allowed quick editing to refine the questions and easy access to the data collected. We also found that the script given to us by GCCN for approaching businesses was unnecessarily wordy and complicated for the purpose of this survey. One discovery that we made was that a shorter introduction was more effective in achieving a higher response rate, as participants would lose interest after the longer explanation and be less engaged in the survey. After the preamble, we would ask our survey questions and then take photographs of the waste bins at each business. The photos were used in the visual waste assessments at the end of the process.

In order to enact this methodology, we discovered that it was easier to split into two separate teams: one to survey the inner part of the central business district (CBD), and one with access to a vehicle to survey any satellite enterprises that were slightly farther away. This was much more time-conscious than having the entire survey team targeting the CBD, and also allowed for a higher number of surveys, averaging over 20 per day. The route for the team that surveyed outside of the Warragul CBD used online route planners to calculate the most effective use of time when on the road. An overview of the methodology developed for SV can be found in the table below.

Table 1: Methodology Overview

- **Preparation**
  - Receive 5 hour waste audit training from waste consultant Dr. Trevor Thornton.
  - Arrive in Warragul and conduct preliminary interviews of businesses to raise awareness and schedule best times for future visits
  - Confirm reliable transportation
- **Delivery**
  - Daily preliminary work
    - Utilize a route mapping software to plan out routes for the coming day
    - Split into two teams, one for inside the central business district (CBD), one for outside the CBD. Each team consisted of two to three researchers.
  - Internal CBD Team
    - Walk from business to business, targeting all companies in the specific area generated by the route mapping software
    - At each business, conduct the Google Form survey and conduct a photographic waste assessment using mobile phones
      - Emphasize the words “free,” “confidential” and “short” to get the business on board
      - Give a brief overview of the survey to lower level employees, and a longer description to managers
    - Meet up with external team mid-day for a review, and at the end of the day to assess progress, compare results and plan the following day’s work
  - External Team
    - Drive to each business that is outside the CBD, determined by the route mapping software
    - At each business, apply same approach as the Internal CBD team
- **Followup**
  - Conduct visual waste assessments based on the photographs
  - Categorize the businesses into Australian and New Zealand Standard Industrial Classification (ANZSIC) codes
  - Categorize waste type
  - Convert litres into kg utilizing the conversion charts provided
    - Assume ‘low’ compaction and ‘loose’ packaging for business reported food waste

We faced an assortment of challenges while undertaking this survey as well. One of the major difficulties was a result of the lack of planning that went into the creation of this survey. When we approached some larger businesses, it became obvious that we needed an appointment with management or a more senior employee in order to ask any questions or take photographs of the food waste. We encountered this problem at the larger organizations such as the regional hospital and the country club. Therefore, in order to include these larger organizations, future surveys should have more preparation work including making these appointments and reaching out to the community ahead of the actual survey process. The other difficulties that we faced such as language barriers, were less disruptive to the survey process, and did not prevent us from performing the survey, except in one case. Overall, our data collection proceeded smoothly throughout the whole process and we were able to get a representative sample of many of the food and hospitality SME's in Warragul for Sustainability Victoria.

4.2.2 Generating Food-Waste Data of Warragul to Fill a Gap in the ABBA Database

After we completed the survey process, we performed the single level visual waste assessments through the photographs we took after asking our questions. This process utilized the prior training we received and allowed us to analyze the data and convert the volume measurements of food waste into total mass produced in the township of Warragul.

Below is a breakdown of the amount of waste by each Australia and New Zealand Standard Industry Classification (ANZSIC) code, as well as the number of businesses surveyed by code. We have given a complete record of responses and assessment results to Sustainability Victoria for further analysis and uploading into ABBA data. Of the businesses surveyed, an estimated 624,267 kilograms (624 tonnes) of food waste is produced per annum. Most of the food waste comes from restaurants, cafes and supermarkets, ANZSIC codes 4511 and 4110. The following table breaks down the amount of food waste generated by each type of business surveyed.

Table 2: Food waste by business type

ANZSIC Code	No. of establishments surveyed	Kg / Week	Kg / Week per establishment
Accommodation (ANZSIC 4400)	1	33	33
Bakery (ANZSIC 1174)	3	528	176
Cafés or Restaurants (ANZSIC 4511)	25	6354	254
Child Care Centre (ANZSIC 8710)	3	133	44
Church (ANZSIC 9540)	1	21	21
Community Group - Club (ANZSIC 8790)	3	593	198
Nursing Home/Aged Care Facility (ANZSIC 8601)	3	236	79
School Canteens or Take Aways (ANZSIC 4512)	8	1024	128
Supermarket (ANZSIC 4110)	4	3085	771
Total	Businesses Surveyed	Kg / Week	Kg / Year
	51	12007	624364

In addition to this quantitative data, we also amassed useful qualitative data from interactions with local food and hospitality SMEs. A selection of quotes from these interactions is found below.

Table 3: Quotes from local businesses

Quote	Source (General)
"We are doing a lot. We have degradable bins and a large container to collect food waste next to our rubbish. However, we definitely have a long way to go."	Local Grocer
"We don't have a lot of food waste. Most of it is taken by consumers as this is a take away place. Any green waste gets composted and any meat gets fed to the dogs."	Take Away Owner
"The only food that goes into the rubbish are orange peels. All other lunch waste is composted in the worm bins or fed to the chickens out back."	Childcare operator
"We try to reuse as much of our prep waste as we can, but there are limits on what we can do with table scraps once people eat it."	Cafe Owner
"We donate all of the bread on the shelves at the end of every day to local charities. However, we can't donate the pastries that have meat or milk due to corporate regulations. We try to make less of those so that we don't throw much of them away, but that is an obstacle we are facing."	Bakery Owner
"We do not have much waste that is not recycled. We only have paper and cardboard, but all of our bottle caps are saved for local kindergarten classes. Our plastic spoons are even donated to an art student to depict how much plastic is wasted."	Ice Cream Shop Owner
"I do not have any food waste. I have 6 large compost bins outside, as well as dogs and chickens. All of the leftover food from any of the events I cater ends up being either eaten or utilized to grow more food"	Local Caterer

This research indicated that the population of Warragul was already diverting a significant proportion of food waste from landfill. For example, multiple businesses had connections with local farms, where they would send the scraps from food preparation for use in animal feed for pigs and chickens. Larger businesses such as supermarkets sent the food they could no longer sell like expired bread to charities or the homeless population. We also discovered that many business owners were already very aware of the ways in which they can use their food waste other than sending it to landfill. The general population also were very conscious of the environment already, as evidenced by the many sustainable practices already in place in the town.

4.3 Development of Evaluation Framework for Bioenergy in Gippsland

Our third project objective was to develop an evaluation framework for the feasibility and viability of bioenergy in Gippsland. Starting with our analysis of the Warragul food waste data and using data from the Grantville Landfill, we used the data we aggregated on the type and size of feedstocks available for bioenergy production to perform an initial viability and feasibility analysis.

From our analysis of the Warragul Food Waste Survey and Assessment, we found that the 51 businesses that responded to the survey produced roughly 624 tons of food waste every year. It is safe to assume that since we did not survey the whole of Warragul, the actual amount of food waste from the town is higher than the number we calculated. Sustainability Victoria hopes to use this food waste in a process such as anaerobic digestion to produce energy for the township. As a comparison, the anaerobic digester at Barstow Farm in Hadley, Massachusetts uses in excess of 12,000 tons of organic waste per year in its energy production. The amount produced by Warragul is an order of magnitude below what Barstow Farm utilizes, but an anaerobic digester can still work on this smaller scale to produce energy for the town.

The feasibility and viability analysis for the Grantville landfill was slightly more difficult as we did not initially have data on the mass of available feedstocks like we did with the Warragul study. We asked ACE Contractors, the overseers of the landfill, to provide us with data on the amount of green waste dumped at the landfill. From this, we received data on all of the transactions that the landfill processed in the last year, including the amnesty period where green waste can be dumped for free. This data is proprietary, so we are unable to showcase it in this report. We then converted the green waste into tonnes using a conversion chart provided by the Western Australian Waste Authority (Western Australia Waste Authority, 2009).

Now that we had the data, we researched various bioenergy processes and companies that could provide them. These technologies included incineration, pyrolysis, gasification, plasma arc gasification, and anaerobic digestion. A graphic containing a broad analysis of the technologies.

Technologies	Viable	Companies	Value Added Products
Incineration	X	Currently used on site	• Heat & Power
Pyrolysis	✓	Pyrotech Earth Systems Pyrocal	• Biochar • Heat & Power • Syn-gas
Gasification	✓	MAGS Pyrotech	• Biogas • Heat & Power
Plasma Arc Gasification	X	Zenergy Australia	• Biogas • Heat & Power
Anaerobic Digestion	X	Case studies CERES	• Biogas • Heat & Power • Compost

Figure 4.9: Comparison of waste processing technologies

Through contact with an expert at the Center for Education and Research in Environmental Strategies (CERES), we discovered that anaerobic digestion (AD) would not be useful for the processing of the landfill's green waste as the larger pieces were much too dry to be used effectively. AD also struggles to process larger pieces of timber which are present at Grantville Landfill. The leafy green waste has potential for use in anaerobic digestion, but since we cannot use the entire feedstock, we chose to avoid anaerobic digestion as a solution for the landfill. In addition, plasma arc gasification is a much too complicated process for use at the landfill and is only available from one company in Australia, so we chose not to proceed with this option either. Incineration was initially a valid option, as the overseer of the landfill was originally only interested in producing heat to power engines on-site. However, through research of pyrolysis and gasification, we discovered that they were superior processes that had multiple valuable outputs besides heat. Incineration could also have serious issues processing the treated timber waste, as this feedstock is prevented from being incinerated by Australian law due to release of toxic chemicals. Incineration is currently used to burn the methane gas in the landfill with a flare. Capricorn Power already has plans to use the heat generated by burning the gas to power one of their engines.

Thus, the potential technologies to process the woody biomass were narrowed to pyrolysis and gasification. Pyrolysis is the heating of biomass to extremely high temperatures without oxygen, thus not burning the feedstock. This process produces heat, along with valuable byproducts such as biochar and syn-gas. Gasification is the same process with a small, controlled amount of oxygen and no combustion, producing only heat and biogas. The four companies we researched that provided pyrolysis and gasification systems were Pyrotech, Pyrocal, Earth Systems, and Terragon (MAGS). We analyzed each system in terms of advantages and disadvantages of each system, summarized in the following tables.

Table 4: Advantages of different waste to energy systems

Advantages			
Pyrocal	**Pyrotech**	**MAGS**	**Earth Systems Charmaker**
Lots of feedstocks	Lots of outputs	No pre-processing required	Not much pre-processing required
Biochar has multiple uses	Mobile; Takes up little ground space	Automated biochar removal system	Feedstock can have a moisture content of up to 50%
Generates thermal energy, could use for engine	Generates gas for thermal energy production	Fully automated for remote monitoring	Easily transportable, comes in shipping crate
3 sizes	2 sizes (2 & 10 tonnes of feedstock	Small, compact, efficient	
Local (based in Toowoomba, Queensland)	Creates multiple outputs with one process	Creates its own syngas for fueling	
Implemented in 8 countries		Can process a wide variety of materials	
Scrubs Waste		Prevents the release of hazardous particulates and acid gases	

Table 5: Drawbacks of Different Waste to Energy Systems

Drawbacks			
Pyrocal	**Pyrotech**	**MAGS**	**Earth Systems Charmaker**
Only one output	Highly specified feedstocks	Slow: ~1 tonne per day	Can only handle woody waste
Potentially more expensive	More work needed in feedstock preparation		
	Smaller MTPD units consume more electricity		
	65 days/year needed for maintenance		

From this summary of advantages and disadvantages, we chose to eliminate Terragon's MAGS system. This was entirely due to the speed at which it processes the waste, which is much too low to be effective at the scale that the Grantville Landfill required, especially during amnesty. From further research, this system was designed for use on large ships and thus would not be viable for this land-based application.

We were not able to proceed with a more in depth analysis of Earth Systems 'Charmaker' system, as we did not get a response from the company. The specifications used in the initial advantages and disadvantages comparison came from Earth systems' website (Earth Systems N.D.).

We moved on to contact the remaining three companies for specifications and rough quotes of the cost of implementing their systems.

4.3.1 Pyrocal

Pyrocal offers systems that simply processes the feedstocks for the end products like heat and biochar. Their largest system (CCT 18 Dual) that only processes the feedstocks is priced at $2.85M AUD (Joyce 2019). They offer a different system that contains an additional piece of equipment to generate electricity, but it priced at $6.4M. With hopes to use a Capricorn Power engine, we think the system without a electricity generator is a better option at this stage of the feasibility study. However, this $2.85M system (CCT 18 Dual) is far too large for usage at Grantville Landfill, as it can process up to 1300 kg/hour, (15,600 tons of wet green waste per year) (Joyce 2019). Pyrocal offers a smaller system (CCT 12) that handles 250 kg/hour, (~3000 tons of wet green waste per year), which is much more appropriate for the amount of green waste present at the landfill.

In our analysis of their system though, we only received price and specifications of the largest $2.85M system, so we had to scale down the numbers for the smaller system. For example, their largest system produces 8.6 tons of biochar per 48 tons of wet green waste, resulting in ~18 percent of the feedstock producing biochar (Joyce 2019). Having 3371 tonnes of annual green waste at the Grantville site, we estimate that 604 tonnes of biochar will be produced per year with the Pyrocal system. Using the rate of $150/tonne of biochar provided by Pyrocal, this biochar can generate up to $90,000 per year if sold off.

A key specification of these systems that we are interested in is their production of thermal energy. Pyrocal's CCT 12 system produces 0.75 MW_{th} (Joyce 2019). On a yearly basis, this comes out to 6570 MWh of thermal energy. Using a 30% efficiency for thermal to mechanical energy, and a 96% efficiency for mechanical to electrical energy, we estimated 1892 MWh of usable electrical energy per year can be generated from the Pyrocal system at Grantville Landfill. With a rate of $70/MWh, this converts to $132,451 once sold to the grid.

In total, we estimate that the Pyrocal system can generate $223,064 per year, combining the revenue of biochar and electricity. Assuming the cost of the smallest CCT 12 system to be $1.5M, the payback period for the system alone is 6.72 years. This does not take into account any connections to the grid that may be necessary to implement the system, or any additional pieces of equipment needed to efficiently run the system, such as dryers or conveyor belts.

4.3.2 Pyrotech

Pyrotech's largest system (10T), which can handle more than 3000 tonnes of feedstock on an annual basis, costs $890,000 US dollars (USD), or roughly $1.25M Australian dollars (AUD) (Karantonis 2019). The 10T system will produce 16 barrels of biocrude oil, 16 barrels of wood vinegar, and 1 tonne of biochar per day per 10 tonnes of woody biomass (Karantonis 2019). The 10 tonne system can handle up to 3650 tonnes per year, which is a good fit for the landfill's green waste intake. Like the Pyrocal system, it is only the pyrolysis stage and would require another component, like a Capricorn Power engine, to produce electricity.

Producing one tonne of biochar per day, 365 tonnes can be produced per year. Using the same rate for biochar as provided from Pyrocal, $150/tonne, it is estimated that about $54k of biochar could be produced per year with the Pyrotech system.

The produced biocrude oil has a higher heating value (HHV) of 24 MJ/kg, about half that of standard crude oil. This, when combined with the wood gas, can produce 18 MW_{th} of energy when burned in a combined heat and power (CHP) system (Karantonis 2019). Burning off these byproducts of the pyrolysis stage would be the only feasible way to generate enough heat to fuel a Capricorn Power engine. With 18 MW_{th} able to be produced per day, 6570 MWh can be produced on a yearly basis. Using the same 30% efficiency for thermal to mechanical energy, 96% for mechanical to electrical, and $70/MWh, $132,451 can be generated once this electrical energy is sold to the grid.

A large benefit presented by the Pyrotech system is the production of wood vinegar. This byproduct is effective in stimulating plant growth and reducing usage of chemical fertilizers

(Wood Vinegar Australia N.D.). One barrel is around 159 litres, so 16 barrels of wood vinegar per day results in around to 928,560 litres per year. For reference on price, we researched actual wood vinegar distributors. We found that Green Man Char sells 200 litres of wood vinegar for $550 (Green Man Char N.D.). The Pyrotech system can produce around $2.5M worth of wood vinegar if this rate is accurate. However, this estimate is likely higher than the actual value, and research has not been done as to whether any further processing is required to make the wood vinegar commercial. Even with any processing costs involved, the $2.5M potential value confirms that the wood vinegar could be a profitable byproduct of using the Pyrotech system at Grantville Landfill.

In total, we estimate that the Pyrotech system can generate $183,026 per year, combining the revenue of biochar and electricity without taking into account the value of wood vinegar. With the cost of the Pyrotech system being $1.25M, the payback period for the system alone (without wood vinegar) is 6.8 years. This does not take into account any connections to the grid that may be necessary to implement the system, or any additional pieces of equipment needed to efficiently run the system, such as dryers or conveyor belts. With the wood vinegar taken into account, the payback period can be significantly shorter. Because we are still unsure about the value of this byproduct, we do not want to include it in the profitability of the system.

4.3.3 Final Grantville Data Analysis

Once we received these quotes, we analyzed the data to determine the commercial opportunities of each technology. To this end, we used the ratios above to calculate the amount of each value added secondary output that could be generated by the feedstock and researched pricing online. We also used information on the thermal energy generated provided by the companies, as well as proprietary calculations provided by Capricorn Power to determine the amount of energy that could be produced. We then compared the potential yearly earnings to the quotes provided by the companies to calculate the potential return on investment (ROI) and the commercial feasibility of the project. We found that the project was commercially feasible, as the plant could generate between $223,064 and $2,541,832 per year and the technology cost between $890,000 and $2,000,000.

5.0 Conclusions and Recommendations

In summary, this project has assisted in the creation of a framework for future bioenergy sector development in Gippsland and potentially statewide with findings that are potentially transferable nationally.

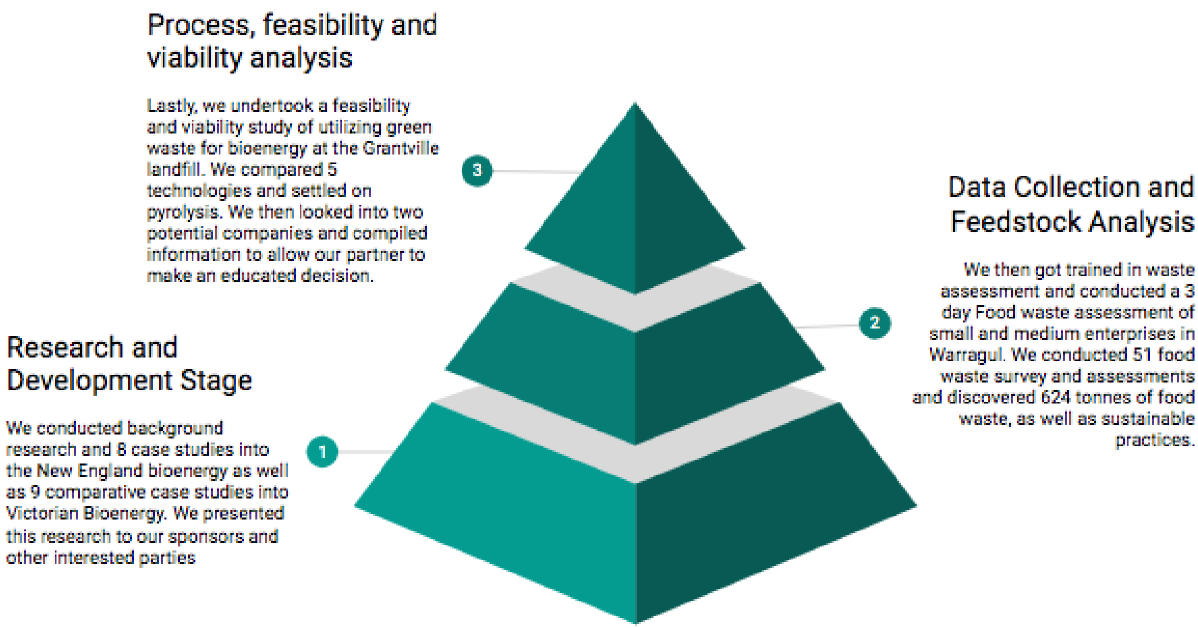


Figure 5.1: Visual representation of our project approach

First, in order to start the project, initial research and understanding were needed. We achieved this through the initial overview survey of New England bioenergy and eight case studies in Victoria. This data was then presented to a number of local organizations to further discussion of the similarities and differences between bioenergy technologies and opportunities in the United States and Australia.

Second, we collected data through the Warragul Food Waste Survey to understand possible feedstocks. The survey and waste assessment achieved a success rate of 81 percent and through the results, we estimated that the participating businesses generate over 624 tonnes of waste per year. The data was then organized by business type to allow it to be uploaded into the ABBA database and sent for future processing to determine the optimal location for a potential community anaerobic digester.

Third, we analyzed the data from a year's worth of transactions at the Grantville Landfill to determine if the green waste collected there was commercially viable for bioenergy generation. Green waste transactions were extracted from the data for independent analysis. In addition, we researched potential technologies for processing the green waste, focusing in on pyrolysis and gasification. We then contacted suppliers of the technologies to get quotes. After the quantity of green waste was confirmed we calculated the potential capital generation potential of the processing, and determined what the window of return on investment of the various technologies would be.

While these projects may seem disconnected from each other, they were necessary steps, laid out by the interested parties, within the existing bioenergy efforts in Gippsland, Victoria. In fact, Sustainability Victoria is planning to utilize the methodology developed in the Warragul Food Waste Survey to conduct more surveys in other areas of Gippsland. Snowy River Innovation and Capricorn Power are also going to use the feasibility study to determine whether to move forward with green waste processing in Grantville. The presentation on our project, containing the New England and Victorian Case studies will be used by our partners to showcase the opportunities for future investment and potential in bioenergy, and inform other teams who are working on similar projects.

Expand on Warragul Survey Methodology

In order to achieve the most representative results for future surveying efforts similar to the Warragul Food Waste Survey, we recommend using our methodology. This generated methodology proved to be very successful in getting a high response rate, as well as usable data. In person surveys achieved a response rate of 80 percent, which is significantly higher than the initial online survey efforts trialed by Sustainability Victoria in 2016.

The following recommendations may further improve the survey data collection:

1. Refine the questions currently used in the Survey Monkey model provided by SV to ensure greater clarity and ease of use if applied to digital data collection.
2. Collect survey responses in-person using a Google Form type platform, preferably with results automatically transferred to a shared Google Sheets file (or similar).
3. Allow for adequate time in the survey township to ensure that assessments can be scheduled to coincide with when bins are full for the most representative results.
4. Contact larger businesses in advance to schedule a 15 minute meeting with the kitchen manager.
5. Ensure a vehicle is available for transport between survey sites to support the survey team.

Suggested Waste to Energy Technology for Grantville Landfill Site

Based on our data analysis of the last year of transactions at Grantville Landfill, we suggest further analysis of Pyrotech and Pyrocal. Pyrotech does not produce the waste heat needed to power a Capricorn engine on its own, but the thermal energy can be generated via burning the gas and oil. It also has more commercially viable secondary byproducts, which could increase earning potential for the landfill. Pyrocal only generates biochar, but also produces the heat needed to power a Capricorn engine. Therefore the choice of company is dependant on the the importance of secondary byproducts. If SRI wants to go forward with product production and generate electricity via the burning of the secondary products than Pyrotech would be the best fit. If they would rather primarily focus on generating electricity without additional burning Pyrocal would be the optimal choice. Both systems are capable of generating the same amount of thermal energy, and therefore electricity, so the focus on secondary processing with more value added products vs less processing with less products will be the deciding force in the decision of which technology to use.

Our project served to further bioenergy projects in Gippsland and help future projects, and was successful in these goals. The NE vs Victoria analysis will be used by Snowy River Innovation to educate future investors and, potentially, future WPI students. The Warragul Food Waste Survey provided Sustainability Victoria with a working methodology that they plan to implement in other townships to generate more data. The data we generated will also be fed into the ABBA database. Lastly, the analysis of Grantville will allow Snowy River Innovation to move forward with the project confidently, as we have determined it is viable and commercially feasible. They will have the opportunity to make an informed decision on the technology they want to use based on desired outputs of the landfill and other involved parties and investors. We also individually benefited from an in depth education into the current state of commercially viable sustainable businesses.

References

Argonne National Laboratory. (2015, September). *Supply Chain Sustainability Analysis of Indirect Liquefaction of Blended Biomass to Produce High Octane Gasoline.* Retrieved from https://publications.anl.gov/anlpubs/2015/10/121460.pdf

Australian Government Department of Environment and Energy. (2018, August). *Australian Energy Update 2018*. Retrieved from https://www.energy.gov.au/sites/default/files/australian_energy_update_2018.pdf

Australian Renewable Energy Agency. (2016, January 7). *The Australian biomass for bioenergy Assessment project*. Retrieved from: https://arena.gov.au/projects/the-australian-biomass-for-bioenergy-assessment-project/

Australian Tartaric Products. (2014). *Australian Tartaric Products.* Retrieved April 1, 2019, from http://www.australiantartaric.com.au/Home.aspx

Barstow Farm. (N.D.) *Barstow's Anaerobic Digester*: Farm Powered. Retrieved from https://www.barstowslongviewfarm.com/anaerobic-digester/.

Bellini, E. (2018, April 25). *Netherlands: Land prices are rising due to increasing development of solar parks*. Retrieved from https://www.pv-magazine.com/2018/04/25/netherlands-land-prices-are-rising-due-to-increasing-development-of-solar-parks/.

Biomass Energy Resource Center (BERC). (2008, Autumn). *Woodchip System at Quabbin Ignites Interest in Massachusetts.* Retrieved from https://www.biomasscenter.org/resource-library/case-studies/government-facilities/quabbin-administrative-building

Biomass Energy Research Center (N.D.) *Limlaw Pulpwood and Chipping*. Retrieved from https://www.biomasscenter.org/

Biomass Producer, & Australian Government: Rural Industries Research and Development Cooperation. (2013). *Powering a Distillery on Grape Waste.* Retrieved April 1, 2019, from http://biomassproducer.com.au/case_study/powering-a-distillery-on-grape-waste/#.XMFOzi-B0Wq

Bush, B., & National Renewable Energy Laboratory. (2013, May 21). *Biomass-to-Bioenergy Supply- Chain Scenario Analysis (BETO Analysis Platform Peer Review, Ed.).* Retrieved January 11, 2019, from https://www.energy.gov/sites/prod/files/2016/05/f31/analysis_and_sustainability_bush_11263.pdf

California Energy Commission. (N.D.). *Frequently Asked Questions about the Electric Program Investment Charge Program (EPIC).* Retrieved from https://www.energy.ca.gov/research/epic/faq.html.

California ISO. (2019). *California ISO Glossary*. Retrieved from https://www.energy.ca.gov/glossary/ISO_GLOSSARY.PDF

Chakpitak, N., Sureephong, P., Buzon, L., & Bouras, A. (2008, June 3). *Cluster Development and Knowledge Exchange in Supply Chain.* Retrieved from http://www.academia.edu/4399567/Cluster_Development_and_Knowledge_Exchange_in_Supply_Chain

Clean Energy Finance Corp. (n.d.). *Innovative solution for organic and food waste targets landfill and emissions.* Retrieved from https://www.cefc.com.au/case-studies/innovative-solution-for-organic-and-food-waste-targets-landfill-and-emissions/

Commonwealth of Australia. (2018, November 07). *About my region – Latrobe-Gippsland Victoria.* Retrieved January 11, 2019, from http://www.agriculture.gov.au/abares/research-topics/aboutmyregion/vic-latrobe

Cornell University. (N.D.). *Cornell University Renewable Bioenergy Initiative (CURBI).* Retrieved from https://cuaes.cals.cornell.edu/sites/cuaes.cals.cornell.edu/files/shared/documents/CURBI_FAQs.pdf.

Cornell University (N.D.). *Cornell University Agricultural Experimentation Station.* Retrieved from https://cuaes.cals.cornell.edu/funding/.

Department of Environment and Energy (2018, August). *Australian Energy Update 2018.* Retrieved from https://www.energy.gov.au/publications/australian-energy-update-2018

Department of Environment. (2017, September 06). *Energy in Victoria*. Retrieved from https://www.energy.vic.gov.au/about-energy/energy-in-victoria

Department of Environment. (2017, September 06). *Turning piggery waste into electricity.* Retrieved from https://www.energy.vic.gov.au/renewable-energy/bioenergy/turning-piggery-waste-into-electricity

Department of Environment. (2017, September 06). *Converting oils into biodiesel*. Retrieved from https://www.energy.vic.gov.au/renewable-energy/bioenergy/converting-oils-into-biodiesel

Department of Environment. (2017, September 06). *Farm grown energy*. Retrieved from https://www.energy.vic.gov.au/renewable-energy/bioenergy/farm-grown-energy

Department of Environment. (2017, September 06). *Sawmill powered by wood waste*. Retrieved from https://www.energy.vic.gov.au/renewable-energy/bioenergy/sawmill-powered-by-wood-waste

Earth Systems. (N.D.) *Charmaker MPP (Mobile Pyrolysis Plant)*. Retrieved from https://www.esenergy.com.au/charmaker-2.

Elisabeth Schröder, Klaus Thomauske, Benjamin Oechsler and Sabrina Herberger (2011, July 27). *Activated Carbon from Waste Biomass, Progress in Biomass and Bioenergy Production*. Retrieved from: https://www.intechopen.com/books/progress-in-biomass-and-bioenergy-production/activated-carbon-from-waste-biomass

Environmental and Energy Study Institute. (N.D.) *Bioenergy (Biofuels and Biomass)*. Retrieved from https://www.eesi.org/topics/bioenergy-biofuels-biomass/description

EPA (2017, October 2). *Project Profile: Barstow's Longview Farm*. Retrieved from https://www.epa.gov/agstar/project-profile-barstows-longview-farm.

Goodell, Barry. (N.D.) *The Science and Engineering for a Biobased Industry and Economy*. Retrieved from https://ag.umass.edu/cafe/nifa-planned-research-initiatives/science-engineering-for-biobased-industry-economy

Graham, L. (2017, April 7). *California Announces Proposed Recipients Of $23 Million In Bioenergy Grants.* Retrieved from http://blog.braginfo.org/entry/california-announces-proposed-recipients-of-23-million-in-bioenergy-grants.

Green Man Char. (N.D.) *Wood Vinegar Bio-Stimulant.* Retrieved from https://greenmanchar.com.au/products/wood-vinegar.

HFMA. "New England Chapters." *New England Chapters*, Health Financial Management Association (HFMA): Maine Chapter, 2019, www.mainehfma.org/site/epage/97768_263.htm.

Holden, James. (N.D.). *Waste Milk Remediation and Hydrogen Gas Production Using a High-Temperature Anaerobic Digester*. Retrieved from: https://ag.umass.edu/cafe/nifa-planned-research-initiatives/waste-milk-remediation-hydrogen-gas-production-using-high

Housekeeper, E. (2015, August 15). *UVM Professor Researches the Benefits of Oilseed Crops for Biodiesel Production.* Retrieved from https://learn.uvm.edu/blog/blog-sustainability/oilseed-production-in-vermont.

International Energy Agency. (N.D.). *Bioenergy and biofuels*. Retrieved from: https://www.iea.org/topics/renewables/bioenergy/

Joyce, J. (2019, April 11). *Pyrocal system at Grantville Landfill (VIC, Australia) [containing Pyrocal Brochure (Appendix P) and Pyrocal Data Sheet (Appendix O)]*. [E-mail to the authors].

Karantonis, C. (2019, April 12). *Pyrotech system at Grantville Landfill (Vic, Australia) [containing specifications seen in Appendix N]*. [E-mail to the author].

KPMG, & Bioenergy Australia. (2018, December 04). *Bioenergy state of the nation report*. Retrieved from: https://s3-ap-southeast-2.amazonaws.com/piano.revolutionise.com.au/news/vabsvwo5pa8jnsgs.pdf

Kroetz, K. & Friedland, A. (2008, April 3). *Comparing Costs and Emissions of Northern New England Space Heating Fuel Options*. Retrieved from https://www.sciencedirect.com/science/article/pii/S0961953408000925.

Lang, A., & Lang, T. (2019, April 13). *Information on Anaerobic Digestion* [E-mail to the author].

Lim, M. K., & Ouyang, Y. (2016). *Biofuel supply chain network design and operations.* Retrieved from http://publish.illinois.edu/mlim/files/2012/12/Lim_Ouyang_Biofuel-SCN_Final.pdf

Markowski-Lindsay, M., Catanzaro, P., Damery, D., Kittredge, D. Butler, B., Stevens, T (2012, March 26) *Forest-Based Biomass Supply in Massachusetts: How Much is There and How Much is Available.* Retrieved from: https://www.ncbi.nlm.nih.gov/pubmed/22562005

Massachusetts Department of Energy Resources. (2015, July). *Briggs Elementary School, Ashburnham*. Retrieved from: https://www.mass.gov/files/documents/2016/09/xu/green-communities-case-study-ashburnham-briggs-school.pdf

Massachusetts Forest Alliance. (2017, March). *John R. Briggs Elementary School*. Retrieved from: https://www.massforestalliance.net/wp-content/uploads/2017/03/Case-Study-Briggs.pdf

MBASkool. (2018). *Hub*. Retrieved from https://www.mbaskool.com/business-concepts/operations-logistics-supply-chain-terms/12977-hub.html

Mittlefehldt, S., Tedford, C (2014). *Benefit or Burden? Environmental Justice and Community-Scale Biomass Energy Systems in Vermont*. Retrieved from: https://www.liebertpub.com/doi/10.1089/env.2014.0019

NASA (2019, April 23). *Climate Change Evidence: How Do We Know?.* Retrieved from https://climate.nasa.gov/evidence/.

NC State University. (2003, October 14). *Supply Chain Resource Cooperative*. Retrieved from https://scm.ncsu.edu/scm-articles/article/success-with-hub-and-spoke-distribution

New Hampshire Public Utilities Commision. (2017, October). *New Hampshire Renewable Energy Fund Annual Report*. Retrieved from http://www.puc.state.nh.us/sustainable%20energy/Renewable%20Energy%20Fund/2017%20REF%20Report%20to%20Legislature%20FINAL%20-%20revised%202017-10-30.pdf.

Stowers, Christina. (2015, August 20). *Massachusetts Schools Switch to Wood Pellets.* Retrieved from https://www.energy.gov/eere/articles/massachusetts-schools-switch-wood-pellets

Pennsylvania State University. (2012, March 5). *Biogas from Manure*. Retrieved from https://extension.psu.edu/biogas-from-manure

Porter, M. (2018, November-December). *Clusters and the New Economics of Competition.* Retrieved from https://hbr.org/1998/11/clusters-and-the-new-economics-of-competition.

Quantum Biopower (N.D.) *About Us*. Retrieved from http://www.quantumbiopower.com/.

RCM International. (2019). *RCM Digesters*. Retrieved April 11, 2019, from http://www.rcmdigesters.com/

Renewable Energy Vermont. (2014, July). *Biofuels*. Retrieved from http://www.revermont.org/technology/bioenergy/biofuels/

Roos, A., Graham, R., Hektor, B., Rakos, C. (1999, March 4). *Critical Factors to Bioenergy Implementation*. Retrieved from: https://inis.iaea.org/collection/NCLCollectionStore/_Public/31/048/31048099.pdf?r=1&r=1

Rural Industries Research and Development Corporation. (n.d.). *Power from dairy manufacturing waste.* Retrieved from http://biomassproducer.com.au/case_study/power-from-dairy-manufacturing-waste/

State Government Victoria, & Gippsland Local Government Network. (2014, May). *Gippsland Regional Growth Plan*. Retrieved from https://www.planning.vic.gov.au/__data/assets/pdf_file/0026/94544/Gippsland-Regional-Growth-Plan-May-2014.pdf

Sustainability Victoria. "Biomass 2016." *Checkbox Survey*, 2016, https://checkbox.sustainability.vic.gov.au/Checkbox/Survey.aspx?iid=2bae2757-3596-41f9-83f1-7a95169e4480.

Sustainability Victoria. (2018, March 15). *Statewide Waste and Resource Recovery Infrastructure Plan Victoria 2018 (SWRRIP).* Retrieved from https://www.sustainability.vic.gov.au/About-us/Publications/SWRRIP-2018

The Economist. (N.D.) *Part 1: Innovation Clusters – Why companies are better together.* Retrieved from http://destinationinnovation.economist.com/part-1/.

Timmons, D. & Mejia, C (2010, April 16). *Biomass Energy from Wood Chips: Diesel Fuel Dependence?*. Retrieved from https://www.sciencedirect.com/science/article/pii/S0961953410001376.

UConn Today. (2017, October 21). *Fueling the Future With Seaweed*. Retrieved from https://today.uconn.edu/2017/10/fueling-future-seaweed/#.

UMass Center for Agriculture, Food and the Environment.(N.D.a). *Extension Outreach Overview*. Retrieved from: https://ag.umass.edu/extension-outreach

UMass Clean Energy Extension. (N.D). *About UMass Clean Energy Extension*. Retrieved from: https://ag.umass.edu/clean-energy/about-umass-clean-energy-extension

UMass Extension Crops, Dairy, Livestock & Equine Program. (N.D.a). *About the Crops, Dairy, Livestock, and Equine program.* Retrieved from: https://ag.umass.edu/crops-dairy-livestock-equine/about

UMass Extension Crops, Dairy, Livestock & Equine Program. (N.D.b). *Renewable Energy Production on Dairy Farms.* Retrieved from: https://ag.umass.edu/crops-dairy-livestock-equine/fact-sheets/renewable-energy-production-on-dairy-farms

United States Department of Energy. (2017, December). *Biofuels and Bioproducts Process Pilot Verification Capabilities RFI Responses*. Retrieved from https://www.energy.gov/sites/prod/files/2017/12/f46/pilot_rfi_responses.pdf

United States Department of Energy. (N.D.). *DOE Bioenergy Research Centers.* Retrieved from https://genomicscience.energy.gov/centers/.

United States Department of Energy (N.D.). *Department of Energy Provides $40 Million for 4 DOE Bioenergy Research Centers.* Retrieved from https://www.energy.gov/articles/department-energy-provides-40-million-4-doe-bioenergy-research-centers.

United States Department of Energy. (N.D.). *Bioenergy Technologies Office Closed Funding Opportunities.* Retrieved from https://www.energy.gov/eere/bioenergy/bioenergy-technologies-office-closed-funding-opportunities#2018_36.

United States Environmental Protection Agency, United States Department of Agriculture, & United States Department of Energy. (2014, August). *Biogas Opportunities Roadmap*. Retrieved from https://www.usda.gov/oce/reports/energy/Biogas_Opportunities_Roadmap_8-1-14.pdf

University of Nevada, Las Vegas. (2019). *Industry Clusters*. Retrieved from https://cber.unlv.edu/SNBDI/industry.html

U.S. Energy Information Administration. (N.D.) *Biomass—renewable energy from plants and animals*. Retrieved from https://www.eia.gov/energyexplained/?page=biomass_home

Victoria Local Sustainability Accord. (2014, April 28). *Central Highlands and Wimmera Southern Mallee Biomass Supply Chain Strategy*. Retrieved from: https://www.pyrenees.vic.gov.au/files/assets/public/environment_fire_prev/bioenergy-docs/biomass_supply_chain_strategy.pdf

Victoria Local Sustainability Accord. (2014, April 28). *Final Report on the Beaufort Hospital Biomass Heating System*. Retrieved April 1, 2019, from https://www.pyrenees.vic.gov.au/files/assets/public/environment_fire_prev/bioenergy-docs/hospital_boiler_final_report.pdf

Victoria State Government. "Victoria's Gippsland Region." *Regional Development Victoria*, Victoria State Government, 27 Sept. 2018, www.rdv.vic.gov.au/victorias-regions/gippsland.

Weber, C. (2017, November 21). *New England Researchers Race to Turn Seaweed Into Biofuel*. Retrieved from http://www.wshu.org/post/new-england-researchers-race-turn-seaweed-biofuel#stream/0.

Went, J. (2017). *Australian Biomass for Bioenergy Assessment (ABBA).* Retrieved from http://gccn.org.au/wp-content/uploads/2018/03/RRE004-ABBA-Factsheet_Gippsland.pdf

Western Australia Waste Authority (2009). *Converting volumes to tonnes.* Retrieved from http://www.wasteauthority.wa.gov.au/media/files/documents/GN6VoltoTonnes.pdf

Wikimedia Commons. "File:Map of USA New England.svg." *Wikimedia Commons*, Wikimedia Commons, 26 June 2006, http://commons.wikimedia.org/wiki/File:Map_of_USA_New_England.svg.

Wood Vinegar Australia.. (N.D.) A*bout Wood Vinegar*. Retrieved from http://www.woodvinegar.com.au/wood-vinegar/.

Glossary

Anaerobic Digestion (AD): the process of decomposing biomass by bacteria in an oxygen free environment
Australia and New Zealand Standard Industry Classification (ANZSIC): a classification system created by the Australian and New Zealand governments in order to compare industrial statistics more easily
Australian Biomass to Bioenergy Assessment (ABBA): a national project to identify biomass resources for bioenergy across Australia, funded by the Australian Renewable Energy Agency
Biochar: a charcoal byproduct produced from pyrolysis stored in the soil to reduce carbon dioxide emissions
Biofuel: a condensed form of biogas
Biogas: a gas produced through the fermentation of organic matter (i.e. methane)
Biomass: organic matter used as fuel for energy generation
CBD: central business district
Circular Economy: an economic system focusing on reducing waste and taking advantage of the resources currently available
Direct Combustion: the combustion of biomass to produce direct heat or to generate electricity
DM: dry matter
Earth Systems: an environmental and consulting firm out of Hawthorn, Victoria, Australia
Feedstock: raw or organic material used to fuel a machine or industrial process
Gasification: the process of burning biomass with limited oxygen
Greenwaste: any organic waste that is compostable; also known as "biological waste"
LPG: Liquified Petroleum Gas
MC: moisture content
Organic Rankine Cycle (ORC): a process involving a high molecular mass organic fluid with a liquid-vapor phase change that occurs at a temperature lower than the water-steam phase change
Plasma Arc Gasification (PAG): an thermal process involving the use of plasma which converts organic matter to syngas; the syngas is typically composed of hydrogen and carbon monoxide
Pyrocal: pyrolysis plant provider our of Toowoomba, Queensland, Australia
Pyrolysis: the heating of biomass to extremely high temperatures without oxygen, thus not burning the feedstock
Pyrotech: a mobile pyrolysis plant provider out of Melbourne, Victoria, Australia
ROI: return on investment
SWRRIP: Statewide Resource and Recovery Infrastructure Plan
Syngas: synthetic gas
Terragon (MAGS): a Canadian environmental technologies company

Appendices

Appendix A: Additional Information on Bioenergy Production

The following is supplemental information on the various methods of bioenergy processes, including direct combustions, thermochemical processing, biochemical processing, and anaerobic digestion.

Direct Combustion

In direct combustion, biomass is combusted in boilers to produce direct heat or steam to generate electricity. This method is the most commonly used option in the world. It is very versatile, able to use almost all kinds of feedstock, and the primary feedstock used are highly compressed pellets made of wood. Other materials may also be made into pellets, and used in this process based on the available biomass of the region. By forming pellets from the base biomass the feedstock becomes easier to transport and store, and allows the process of combustion to become automated. This process is very effective if the waste heat from electricity production is utilized as heating. This method allows for the use of cofiring, where biomass and fossil fuels work in tandem to produce more energy, utilizing the higher energy density of fossil fuels. Co-firing has become very common in Europe and Asian countries, as it has a low cost compared to a new power station and lower emissions than pure fossil fuels (KPMG, 2018). Direct firing also can create valuable secondary by products, such as activated carbon, which is used in medicine, steel production, and many other industries (Schroder, 2011).

Thermochemical Processing

The thermochemical process converts feedstock into gas, oil, methanol or hydrogen using extremely high temperature without combustion. The three most common thermochemical processes are pyrolysis, gasification, and liquefaction. The most cost effective method of thermochemical processes, and therefore the most widely used, is gasification. In gasification biomass is burned with limited oxygen. This produces a gas known as syngas, or synthetic gas. After the production of syngas, the gas is produced using chemical processes to remove contaminants, such as tar prior to its use in cars and to transform it into a biofuel. This process allows for the production of transport fuels for passenger vehicles and other generators (Sikarwar, 2017).

Feedstock that is suitable for these processes is woody green waste. Through thermochemical processes, more heat than power tends to be produced. Also, the volume of feedstock is typically lower for power production by processes such as direct combustion. It is typically about 1,500 to 2,000 tonnes per MW of thermal output, and 5,000 to 10,000 tonnes per MW of power output. This range is due to the moisture content range of the feedstock and to efficiency of the process. High cellulose clean stream with higher moisture content (MC), between 40 to 60 percent, may be more suited to pyrolysis. Woody material with under 20 percent MC can suit gasification, though under 15 percent is more ideal. Clean streams of woody material with MC up to 50 percent are acceptable for combustion (Lang, A. 2019).

Biochemical Processing

The last major method of processing biofuels is biochemical processes. These processes use microorganisms to convert and treat the waste into usable end products. The most common biochemical process is that of anaerobic digestion, in which microbes degrade biomass in oxygen-free conditions. This creates methane-rich gas, which can then be burned instead of natural gas. It is also possible to produce a number of different bioproducts utilizing the same methods. Ethanol and butanol can be produced through fermentation of biomass, and other chemicals, such as ammonia and methanol can be produced using thermochemical firing and gasification (KPMG, 2018).

Anaerobic Digestion

Anaerobic digestion is a form of biochemical processing of organic feedstocks. It is the process of decomposing biomass by bacteria in an oxygen free environment. A variety of biomass can be utilized for this process including animal, food, and green waste. The bacteria produce methane, a substitute for natural gas that can be utilized for producing heating and electricity (Victoria Local Sustainability Accord 2014). The biomass feedstock can be a mixture of woody wastes with a moisture content (MC) of up to 40 percent and leafy green waste with a low cellulose content and MC of over 60 percent. This feedstock would typically be what would be coming into a township landfill from park, gardens, and small industries. Another possible option for feedstock for an anaerobic digestion system is using macerated leafy green waste as a part of the feed, along with industrial clean putrescible wastes such as residues from food processing. The finer the maceration of the input feedstock, the more suitable it is for anaerobic digestion. The feasibility of utilizing anaerobic digestion is dependent on the quality of the feedstock. For instance, feedstocks with high energy content such as high fats, sugars, proteins, starches as well as feedstocks with low cellulose content are really suited to anaerobic digestion (Lang, A. 2019).

The scale of anaerobic digesters can go from about one cubic meter upwards. The scaling is often dependent of the feedstock measured in cubic meters per year. The determination of scaling an anaerobic digester depends on the output of biogas per cubic meter of feedstock at the dilution to be used. A typical dilution is approximately 10 to 20% dry matter (DM), but for a 'dry' AD system it may be over 50% DM. For scale, it also relates to the use of the biogas produced. For example, a three cubic meter plug flow anaerobic digester system using cattle manure at 20% DM as feedstock will produce enough biogas for cooking for a large rural family. On the other hand, a 30 cubic meter system with a towage tank using a high biogas production feedstock can run a small generator a few hours a day. This is assuming that the biogas requirement for lighting, cooling, and generators per kWh of power output are all known (Lang,

A. 2019).

There are various types of anaerobic digesters that can be used depending on the scale of the digester.

- Plug Flow Soft bag-type: digests manure from ruminant animals
    - Example: dairy, beef, sheep manure
        - Collected as semisolids (10% to 60% solid) daily to weekly with minimal contamination (i.e. dirt, gravel, stones, straw) and delivered to a collection point (RCM International 2019)
- Capped Lagoon: a cover floats on the surface of a properly sized anaerobic lagoon receiving flush manure to recover methane (RCM International 2019)
- Heated Tanks: designed for scraped or pull-plug pig or dairy waste in moderate climates
    - Able to handle different manure floors and is relatively inexpensive to build and operate (RCM International 2019)
- Chinese Fixed-Dome Plant: a digester with a fixed, non-movable gas holder, which sits on top of the digester
    - When gas production starts, a slurry is displaced into a compensation tank
        - Gas pressure increases with the volume of gas stored and the height difference between the slurry level in the digester and the slurry level in the compensation tank
    - Costs of a fixed-dome biogas plant are relatively low (Lang, A. 2019)

The system at the Centre for Education and Research in Environmental Strategies (CERES) was originally a soft bag type plug flow anaerobic digester, and the present one is a rigid tank with some storage of biogas built in. There are also differences in capital cost, lifespan and durability and efficiency. For instance, the capped lagoon is cheapest but least efficient and the heated tank is highest capital cost and most efficient. The digester company, known as Gecko, and located in Ballarat, is a hybrid: a plug-flow bladder inside an insulated long box. The containerized anaerobic digestion system Gecko has produced is scaled towards a commercial sale model for a 350 cow dairy farm (Lang, A. 2019).

Appendix B: Bioenergy Clusters

The following details supplemental information on industry clusters and how they may apply to bioenergy applications.

In simple terms, "Innovation clusters are geographic concentrations of specialized industries and technologies" (Hill & Engel-Cox 2017). An innovation cluster aims to concentrate all necessary industries to one central location. The industries that make up a cluster can be energy source suppliers, power generation itself, energy storage, and industry manufacturing. By having all of the necessary industries in a single location, the entire process of generating power is streamlined. Governments will often support clustering with policies focused towards economic development, which comes about through improving the time and effort needed to reach an end goal, or product. One of the main goals of renewable energy is to efficiently and effectively use the supplies available to generate more sustainable power. For fully maximizing this idea of efficiently creating power, clustering is a necessity. Clustering can be the key to success, especially for bioenergy industries that thrive from easily accessible energy sources.

For an innovation cluster to succeed, there are some 'ingredients' that must be present to promote success. These different elements are technical skills, accommodation of policies, infrastructure, and low cost initial structures (The Economist N.D.). Technical skills are a vital part of the cluster in developing ways to make energy from the available sources. Having a cluster closely tied to research universities to support them can greatly help the cluster. Clusters not only bring in groundbreaking technology to the energy generation process, but also help receive funding and grants from various organizations. Closely tied universities and research centers can also help to bring new minds to the center by promoting work opportunities (Porter 1998). Another crucial aspect for the success of a cluster is accommodation of policies by the different businesses in the cluster. This relates to the management of each industry in the cluster region and how they can react to changes in policy. It also relates to how well each industry can change with respect to the other industries. All of the 'players' in the cluster should be working with one another to promote widespread economic success. Each industry should work with each other in such a way that greater productivity is achieved than if the different players were working separately or in isolation from one another (The Economist N.D.). Infrastructure is also quite important to the effectiveness of a cluster. Without the needed physical commodities to run to the best of its ability, the cluster will not be the best it can be. When many related industries have the necessary infrastructure in a close proximity, a cluster can be formed when they start working together for better efficiency. However, not all clusters are formed by fortune of the nearby locations of various infrastructures. Some clusters are planned out, and that is where the final 'ingredient' comes in: low cost initial structures. When planning an innovation cluster, one of the biggest setbacks can be the upfront costs. Minimizing these costs is crucial so that quick profitability can be seen and the initial loans to build the infrastructure are as small as possible.

Despite the main goal being economic value, clustering has other positives that directly benefit the industries involved. One of these is the inter-industry competition that stems from the teamwork that a cluster promotes. Being on a team and working with others naturally creates a competitive vibe that can bring out the best of each member. Ideally, the different members of the cluster can push the other industries to be their best because of the reliance on one another. The networking between companies and the sharing of knowledge will also contribute towards the overall success seen by the cluster. When one industry is succeeding, they are making the jobs of the other industries easier by being a reliable player on the team and fulfilling all of the demands that the other players require from them (Porter 1998).

Another side effect of a working cluster that is a benefit to the industries involved is the ability to draw in innovative people (The Economist N.D.). Like previously stated, a close relationship with a research university can help bring knowledge to the cluster by informing students and researchers of the areas of research available within the cluster's industries. A cluster can also attract outsiders by just being effective in itself. A successful cluster acts like a booming hub of innovation that further attracts innovative minds. Silicon Valley, California is a good example of this, home to many high-tech companies and thousands of promising start-ups. This area is a cluster of technology, and the countless start-ups are proof that a successful industrial area will draw in even more potential success.

As a cluster grows and becomes more successful, certain factors come into play that will pose a challenge to any further growth. When a cluster is first created, it can thrive off of the reasons for successful development in the first place. For example, Gippsland is a rural land with room for industrial growth. This should make the initial infrastructure relatively cheap to build. With an abundance of land for development, initial costs should be low. Assuming the cluster can make it past the struggles that any start-up business faces, the industries will continue to grow, spread, and occupy more land. This may consist of offices for research, buildings for power production, or simply farmland for growing energy sources. No matter the case, land will eventually become more limited and a rise in price will likely be seen. The Netherlands is an excellent case of this happening (Bellini 2018). With the increase in number of solar parks in the Netherlands, the supply of land has decreased, driving up the prices. London's 'Silicon Roundabout' is a second example where large initial success was followed up with struggles (The Economist N.D.). This tech-cluster is located outside of London and initially thrived due to the low costs of rent and very open immigration policies. Five years after the initial boom of the cluster, the industries saw a double in rent prices and a tightening of the immigration policies, which made any further growth much more difficult. As can be seen from these examples, as well as many other cases, creating a successful cluster is not a simple task. While having the previously mentioned elements that are needed to start a cluster is essential, they are not a guarantee that future operations will be economical. If all plans are met with success, though, clustering different industries in an energy innovation or production process can be significantly more economical and efficient than non-clustered industries.

Appendix C: Previous ABBA Survey Questions:

The following appendix details the questions from the previous attempt of the ABBA data survey, along with an introduction to the survey.

Images of previous ABBA Surveying efforts:

The original survey was an online survey that was sent to 260 organizations. It was split up into 5 sections. It started with the following introduction before splitting into 5 question sections:

"Biomass producers may have opportunity to turn their biomass into an investment opportunity by assisting in an Australia-wide biomass for bioenergy assessment (ABBA). ABBA aims to identify biomass waste streams at the source which are available for recovery into value-add products. This involves updating an interactive map with detailed information about biomass resources across Australia to attract investment in the renewable energy sector, particularly for bioenergy.

ABBA aims to assist organisations convert biomass residues from a cost-to-business into a feedstock with beneficial outcomes. This forms an important step in the process of diverting biomass residues from landfill, and other inefficient end processes, to extract value from biomass, benefiting the economy as a whole.

Sustainability Victoria (SV) invites you to participate in the 2016 Biomass Survey of Victoria. A 10 minute survey seeking the following information:

the type of industry you are involved in
your average total annual production
the total amount and type of waste or residues produced
the proportion of residue that is currently used
any issues associated with collecting or using residues that may currently be underutilised.

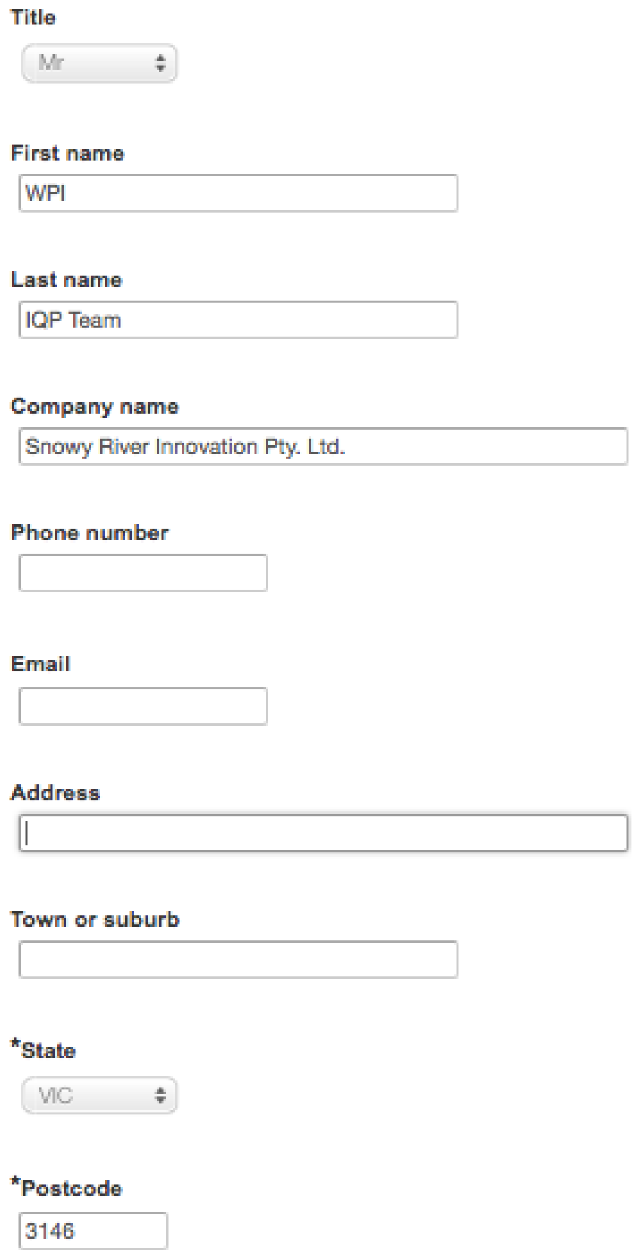
Industry specific data was obtained in 2011 as part of the Regional Biomass Assessment undertaken by Regional Development Victoria (RDV) and this data is now due for an update and expansion. The project will generate new datasets, and where possible, model data for estimating future residue flows, all of which will then be made compatible for uploading to the Australian Renewable Energy Mapping Infrastructure (AREMI) platform. The AREMI platform is an interactive map incorporating highly sophisticated analytics making it possible to display multiple layers of data simultaneously: http://nationalmap.gov.au/renewables/. Any data provided by respondents which is noted as being confidential or commercially sensitive will be aggregated in such a way that individual respondent's results are not disclosed.

The Australian Renewable Energy Agency (ARENA) has provided funding to the Rural Industries Research & Development Corporation (RIRDC) to undertake ABBA and SV has taken the role of lead to deliver ABBA in Victoria.

In completing the survey, if you are happy for Arcadis, who are hosting the survey, to contact you to clarify or follow up on any information provided please leave your contact details.

Should you have any other queries, please feel free to email aap.biomass2016@arcadis.com or contact the Arcadis project manager, Selina Mok on ph: 03 8623 4118." (Sustainability Victoria, 2016)

The first section was on basic personal information and was largely optional. The only required fields were the current state and zip code.



Title

Mr

First name

WPI

Last name

IQP Team

Company name

Snowy River Innovation Pty. Ltd.

Phone number

Email

Address

Town or suburb

*State

VIC

*Postcode

3146

Figure A.1: Initial ABBA survey section 1 questions (Sustainability Victoria 2016)

The second section focused on the industry type of the organization being surveyed. They could choose up to three options from a list of 8, with the last option being other.

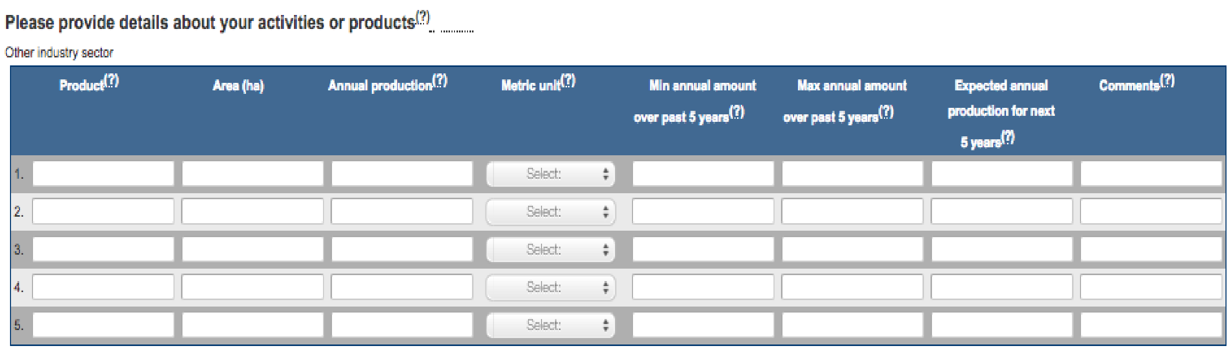
***Please select your industry type and sector (maximum 3)**

Type

- [ ] Food processing
- [ ] Crops and horticulture
- [ ] Other processing
- [ ] Land, water and forest management
- [ ] Services, retail and construction
- [ ] Livestock
- [ ] Waste management
- [x] Other industry sector

Figure A.2: Initial ABBA survey section 2 question (Sustainability Victoria 2016)

The third section was related to their current activities and products. They could select between tonnes and cubic metres.



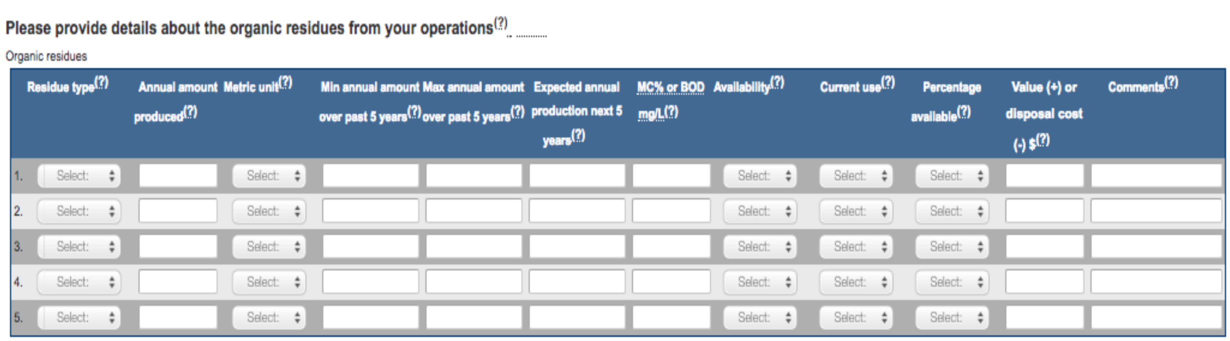
Please provide details about your activities or products(?)

Other industry sector

	Product(?)	Area (ha)	Annual production(?)	Metric unit(?)	Min annual amount over past 5 years(?)	Max annual amount over past 5 years(?)	Expected annual production for next 5 years(?)	Comments(?)
1.				Select:				
2.				Select:				
3.				Select:				
4.				Select:				
5.				Select:				

Figure A.3: Initial ABBA survey section 3 questions (Sustainability Victoria 2016)

Section four addresses the specific organic residues present or generated by their operations.



Please provide details about the organic residues from your operations(?)

Organic residues

	Residue type(?)	Annual amount produced(?)	Metric unit(?)	Min annual amount over past 5 years(?)	Max annual amount over past 5 years(?)	Expected annual production next 5 years(?)	MC% or BOD mg/L(?)	Availability(?)	Current use(?)	Percentage available(?)	Value (+) or disposal cost (-) $(?)	Comments(?)
1.	Select:		Select:					Select:	Select:	Select:		
2.	Select:		Select:					Select:	Select:	Select:		
3.	Select:		Select:					Select:	Select:	Select:		
4.	Select:		Select:					Select:	Select:	Select:		
5.	Select:		Select:					Select:	Select:	Select:		

Figure A.4: Initial ABBA survey section 4 questions (Sustainability Victoria 2016)

They could select residue type from the following drop down:

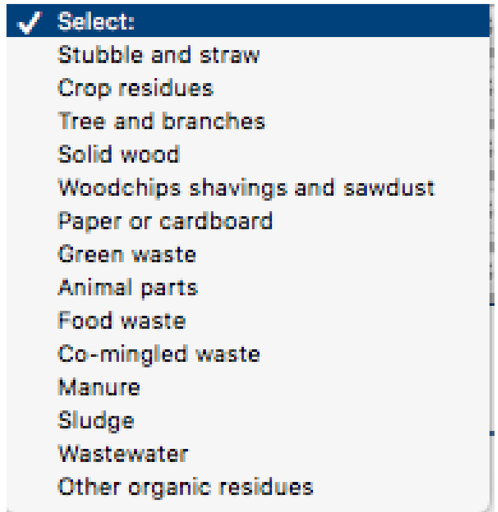


Figure A.5: Initial ABBA survey section 4 residue drop down (Sustainability Victoria 2016)

They could also select same metric amounts units as before along with yearlong or seasonal availability.
They could select the current use the waste from the following drop down:

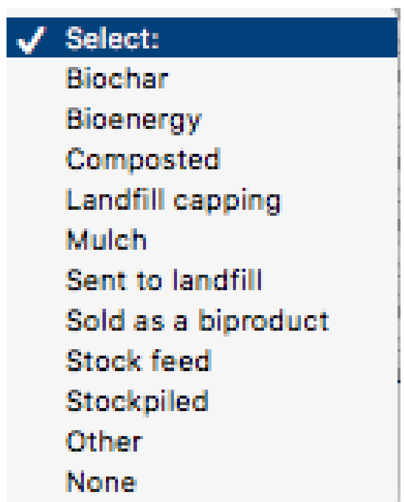
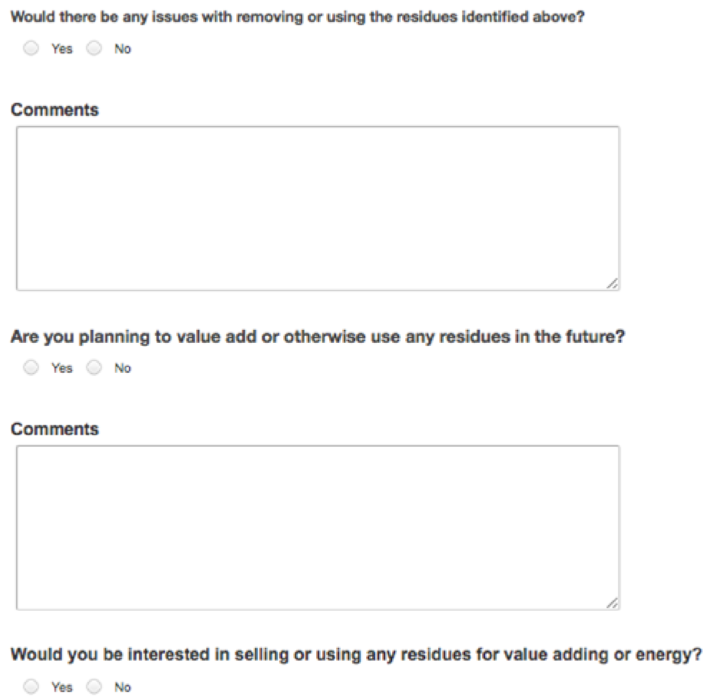


Figure A.6: Initial ABBA survey section 4 waste use drop down (Sustainability Victoria 2016)

Lastly, they could select percentage available in increments of 0% from 10% to 100%.

The last section of the survey dealt with additional questions regarding issues regarding the residue, as well as planned future use.



Would there be any issues with removing or using the residues identified above?

Yes No

Comments

Are you planning to value add or otherwise use any residues in the future?

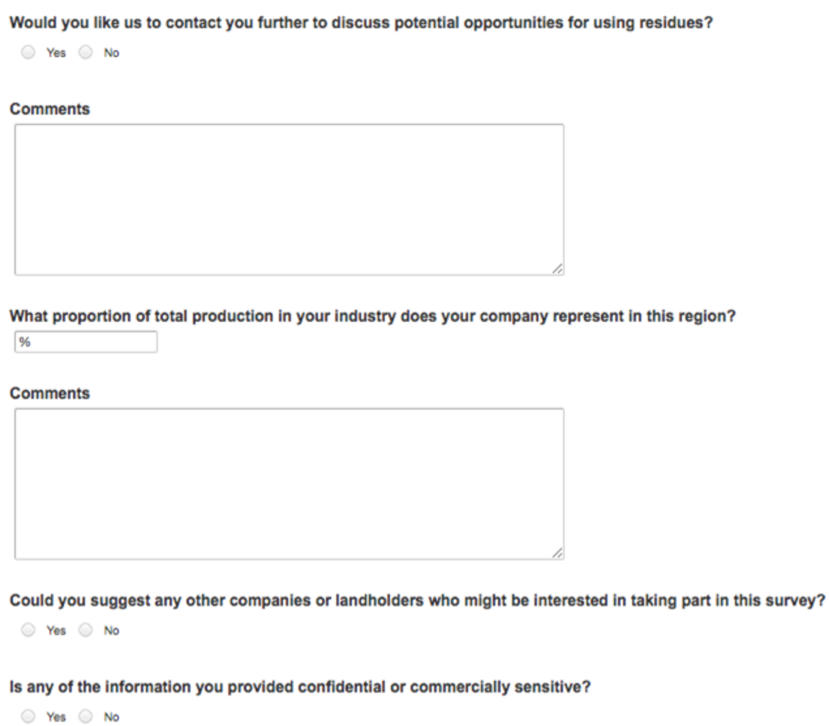
Yes No

Comments

Would you be interested in selling or using any residues for value adding or energy?

Yes No

Figure A.7: Initial ABBA survey section 5 questions part A (Sustainability Victoria 2016)



Would you like us to contact you further to discuss potential opportunities for using residues?

Yes No

Comments

What proportion of total production in your industry does your company represent in this region?

%

Comments

Could you suggest any other companies or landholders who might be interested in taking part in this survey?

Yes No

Is any of the information you provided confidential or commercially sensitive?

Yes No

Figure A.8: Initial ABBA survey section 5 questions part B (Sustainability Victoria 2016)

Appendix D. New Survey Questions from Sustainability Victoria

The following appendix details the improved survey questions that Sustainability Victoria sent to the team before conducting the food waste survey.

The revised survey utilized Survey Monkey. It started with the following introduction before asking 11 questions.

"Sustainability Victoria is delivering the Australian Biomass for Bioenergy Assessment, a national project, for Victoria. The project generates biomass data (food waste and other wastes that break down in landfill generating methane) and provides this to the public via the Australian Renewable Energy Mapping Infrastructure platform where the data is presented and can be downloaded for free. At Warragul, in conjunction with the Gippsland Climate Change Network, we are conducting food waste assessments of local businesses to investigate if food waste recovery is viable using an advanced and sustainable solution, diverting it from landfill.

Sustainability Victoria seeks your support in conducting a food waste assessment of your business through response to this simple survey.

Please take this less than 5 minute survey so we can assess whether a sustainable solution is viable, for generating renewable heat, power and nutrients which can be used locally in agriculture."

The survey then asked the following questions where each indented bullet is either a check box or a text box:

1. What is the name and address of your business?
    a. Business name:
    b. Business address:
2. What type of business are you operating?
    a. Cafe
    b. Restaurant
    c. Bar and bistro
    d. Pub
    e. Take-away
    f. Hotel
    g. Bakery
    h. Grocer
    i. Food manufacturer
    j. Other (please specify)

3. How many full time employees (on an equivalent bases) does your business employ?
    a. 0 - 9
    b. 10 - 99
    c. 100 - 199
    d. 200 - 999
    e. 1000+
4. If you know the square meter area of your business please provide this below.
5. What size bin do you deposit food waste in the business?
    a. 10 gallon container
    b. 40 Litre
    c. 120 Litre
    d. 140 Litre
    e. 240 Litre
    f. Other (please specify)
6. How many bins of this size or others do you deposit food waste into?
    a. 1
    b. 2
    c. 3
    d. 4
    e. Other bin size
7. How often are these bins picked up for collection by your waste services provider?
    a. Daily
    b. Twice a week
    c. Once a week
    d. Once a fortnight
    e. Monthly
8. On average how full are these bins at the time of pick up?
    a. 25% full
    b. 30% full
    c. 50% full
    d. 75% full
    e. 100% full
    f. Other (please specify)
9. What proportion of these bins at the time of pick up are filled with food waste?

   a. 100%
   b. 75%
   c. 50%
   d. 30%
   e. 25%
   f. Other (please specify)
10. Could you advise the weight of these bins at pick up?
    a. 10 kg
    b. 25 kg
    c. 50 kg
    d. 75kg
    e. 100 kg
    f. 150 kg
    g. 200 kg
    h. 250 kg
    i. Other (please specify)
11. If you'd like to obtain the results of the survey please leave your contact details here:
    a. Name:
    b. Email address:
    c. Phone number:
12. Thank you for taking the time to complete the survey. Sustainability Victoria will send to respondents the results of the survey to those who left us with their details.

Appendix E. Script provided by Sustainability Victoria and GCCN

The following letter was the initial introduction meant to be read to the survey participants in Warragul before asking the survey questions and conducting the waste assessment.

Warragul Food Waste Survey

Guidelines for Survey and Audit Researchers: JL 16 March

Suggested Pitch to Businesses

Hi. I am …….and on behalf of the Victorian Government, I am undertaking a FREE short waste assessment in local food businesses for the ***Warragul Food Waste Survey.***
Is the manager available (will only take a few minutes), or are you able to help?
To The Manager This ***Project*** is funded by Sustainability Victoria, supported by the local Baw Baw Sustainability Network and coordinated in Warragul by the Gippsland Climate Change Network. The aim is to look at the possibility of improving food waste management in this area, and hopefully reducing costs to you.
Basically, we are need to know about the type and volume of food waste produced in an average week, and how it is managed.
After the survey, if OK, I need to look in the bins inside and outside so I can work out what types of food waste and the volumes are being generated. . It will take less than 10 minutes to complete the brief survey and then I can conduct the our short waste assessment (Just need to look in your bins)
Here's some more information about the project. (flier)
Note that this information will be kept strictly confidential and your business will **not** be individually identified in any analysis or reporting of data collected.

After conducting the waste assessment go back in and thank the person – this is for thanks and also to let them know you have left the premises.

FAQ's for Businesses (Please ADD to these….)

Focus of THIS key project to assess waste from local food and hospitality businesses.

Who will this project help? :

- local businesses with their waste issues, reducing collection costs etc.
- local and state authorities plan better management of waste and particularly organic food waste.
- the Australian Biomass for Bioenergy Assessment (ABBA) , investigating opportunities for using waste rather than sending it to landfill.

Why Warragul? : Warragul has been chosen to represent a Victorian regional town for this important work.

Who supports this project? :

- **Sustainability Victoria – the state coordinator of waste management policies and activities** (Victorian State Government)
- **Gippsland Climate Change Network:** the leading Gippsland-wide climate change group
- **Baw Baw Sustainability Network** eg. Dr Malcolm McKelvie, BBSN President: 'This is a great chance for

Warragul businesses to step up and participate in a project of national significance, as we all face a growing waste crisis'.

- **TBC: Warragul Business Group:** Terese Mitchell, WBG President highlights the value to local businesses. 'By collecting data about their organic waste, businesses can be helped to reduce it, saving expensive removal costs and the planet too'

Some Further Tips – Waste Audits

Bin Sizes: 120, 240 (commonest), 660, 1100 litres

Bin Colour Codes: If local council collected the lids are **RED** (GW), **YELLOW** (Recyclable) **or LIGHT GREEN** ('Garden' waste)
If commercially collected however, bins could be of any colour !

Calculating Bin Volume: Calculate as total litres for that waste stream (eg., 2 x 240 lit MGB = 480 litres) as some may have different size bins for the same stream.

Waste Categories: Add plastic containers, metal (including Al cans), glass and residual (ie., what goes to landfill)

Trevor attached density data so volumes can be converted to weight.

Moisture Content: Note auditors need to observe **if the waste is wet** – specially for paper and cardboard.

Degree of Compaction:

- Low – just basically sitting there an effort made to compress or compact
- Medium – pushed down and the volume is less than if the material was low as above
- High – is compacted such as in a baler or compaction vehicle.

Appendix F. Letter of Engagement from GCCN for Warragul Survey

The following is an informational flyer provided by GCCN to be given to survey participants if they requested more information about the survey.

Warragul Food Waste Survey – Gippsland Climate Change Network (GCCN)

GCCN
GIPPSLAND CLIMATE CHANGE NETWORK

Dear Sir/Madam,

Do you know that 73% of Victorians prefer to buy from businesses that show they care about climate change? In addition, we need to look at how wastes are managed so we can develop improved strategies.

Your business can cut costs by saving on energy and materials, better managing waste and improving the efficiency of your operations.

The ***Warragul Food Waste Survey*** is funded by Sustainability Victoria, supported by Baw Baw Sustainability Network and delivered locally by the Gippsland Climate Change Network.

The project will survey local food service, retail and manufacturing businesses to see whether there's opportunity to divert food waste from landfill and towards beneficial uses.

A team of local and U.S. students is undertaking the survey and waste assessment, supervised by professional staff.

The project involves a brief survey with a staff member who best understands your business waste management practices. In addition, to gain an understanding of the types and volumes of food waste produced in an average week, we will conduct a waste assessment (visual inspection), of your waste and recycling bins.

Recovering value from food waste aligns with Victoria's developing 'Circular Economy', recovering products to their highest potential value and reducing carbon emissions. Some Foods may also be able to be used for charitable purposes.

We seek your participation in the project to support these objectives and to help your business.

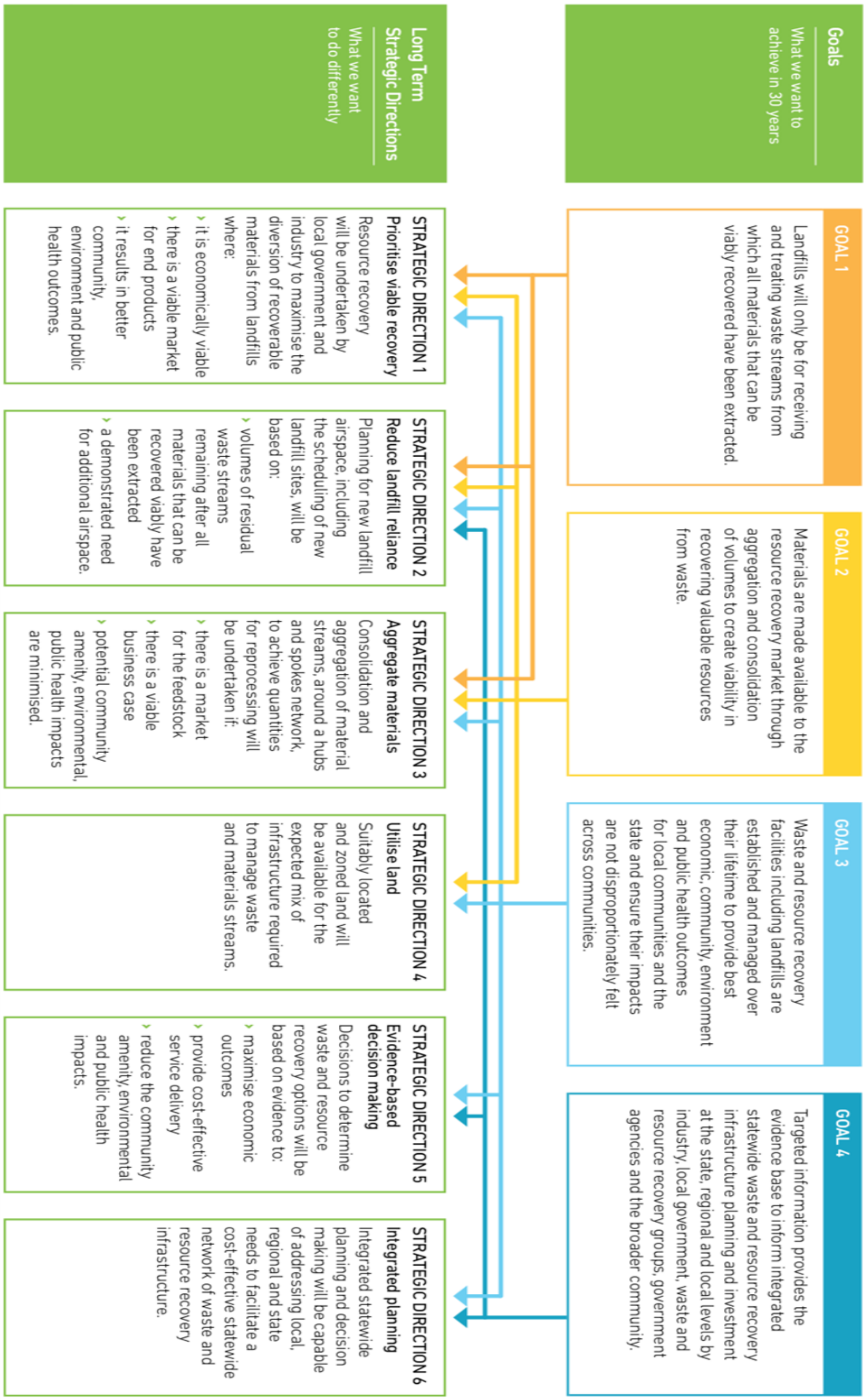
If your business is already diverting its food waste, particularly for charitable uses, we applaud you and hope that you continue this practice. However, we would also like to understand what types and volumes you do generate.

If your business food waste produced goes to landfill it would be appreciated if you could please take the short time required for the survey and waste assessment. Be assured that all information will be kept strictly confidential and your business will **not** be individually identified in any analysis or reporting of data collected.

(Cr) Darren McCubbin
Chair
Gippsland Climate Change Network

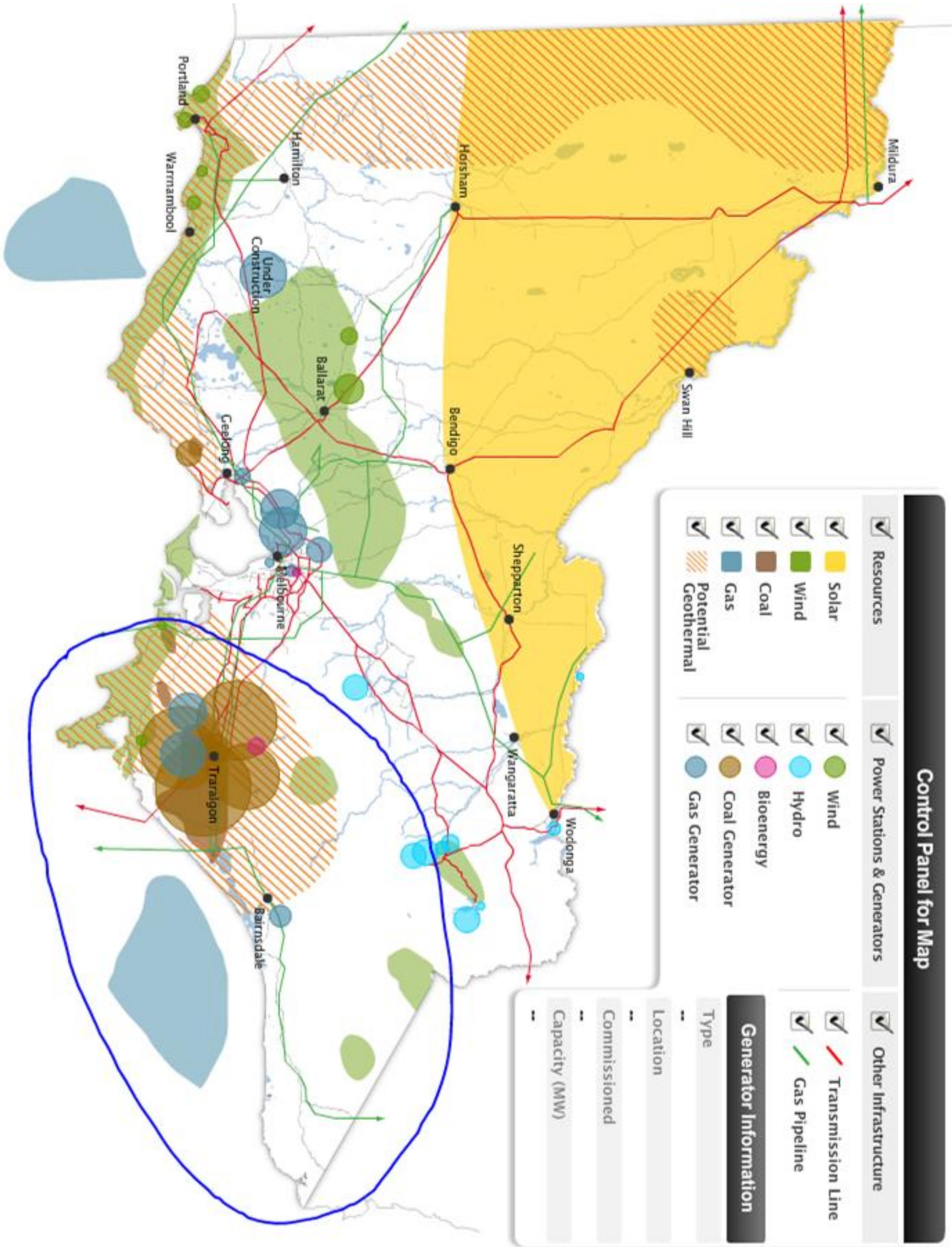
71 Hotham Street, Traralgon, VIC 3844
ABN: 45 791 072 676

Appendix G: SWRRIP Waste Usage Goals



SWRRIP Waste Usage Goals (Sustainability Victoria 2018)

Appendix H: Location of Energy Resources in Victoria; Circled Region is Gippsland



Location of Energy Resources in Victoria; Circled Region is Gippsland (State Government of Victoria 2019)

Appendix I: Density Data

The following table shows the waste density data provided by waste consultant Trevor Thornton, used in the conversion from volume to mass of waste.

Table 6: Waste density data

Waste Material	Density - kilograms per cubic metre		
	[L] Low	[M] Medium	[C] Compacted
Paper	76	152	228
Compacted Dry Cardboard	130	130	130
Compacted Wet Cardboard	260	260	260
Loose Dry Cardboard	55	55	55
Loose Wet Cardboard	190	190	190
Waxed Cardboard	55	92	130
Plastic Drink Containers	170	170	360
Plastic PVC	170	170	360
Polystyrene	14	21	28
Plastic – Other (specify)	170	170	360
Plastic - Bags & Film	39	78	156
Glass Drink Containers	280	280	280
Glass Containers	280	280	280
Glass – Other (specify)	280	280	280
Aluminium	120	120	120
Steel Containers	120	120	120
Metal - Ferrous	139	139	139
Metal - Non ferrous	139	139	139
Wire Bundles	70	70	70
Food - Packaged	514	1029	1029
Food – Loose Production	343	514	1029
Bags with Recyclables	65	120	220
Bags with Waste	87	170	348
Bags with Green Waste	91	227	445
Wood – (treated)	180	220	260
Wood – (untreated)	120	160	360
Wood – MDF/Chipboard	156	156	156
Wood - Fence	120	160	360
Wood - Furniture	160	170	400
Wood – Other (specify)	120	160	360
Vegetation – branches	91	227	445
Vegetation – grass clips	91	227	445
Vegetation – tree stumps /logs	150	450	900

Textiles	91	120	240
Textile - Furniture	91	120	240
Textile – Carpet / Mattress /Underlay	100	150	350
Insulation	37	37	37
Rubber Other (specify)	91	91	91
Tiles	470	550	640
Soil / Cleanfill / Clay / Dirt	922	922	922
Rocks	818	828	828
Bricks	818	828	828
Rubble > 150mm	1048	1048	1048
Concrete / Cement	1150	1150	1150
Plaster/Plasterboard	227	227	227
Cement Sheet	227	227	227
Prescribed Waste (specify)	227	440	1600
Whitegoods (detail)	105	113	120
E-waste (detail)	265	265	265
E Waste Small Appliances	265	265	265
E Waste TV, Computers, Peripherals	265	265	265
Glass - Sheet Laminated	280	280	280
Wood - Pallets	400	400	400
Wood - Sawdust	400	400	400
Foam	37	37	37
Rubber - Vehicle Tyres	263	263	263
Rubber - Hose	91	91	91
Rubber - Fan Belts	91	91	91
Glass Other - Fibreglass	37	37	37
Compacted Dry Cardboard - Books	130	130	130
Plastic - Bags & Film - Bulky Bags	39	78	156
Plastic - Bags & Film - Shrinkwrap	39	78	156

Appendix J: Warragul Food Waste Google Form Survey Questions

This appendix details the final updated survey questions used in the Warragul Food Waste Survey.

Warragul Food Waste Assessment

Form description

LGA name

○ Baw Baw Shire

Facility Name

Short answer text

ANZIC Facility Type

1. Bakery
2. Café
3. Catering Kitchen
4. Catering Non-commercial
5. Child Care Centre
6. Community Group - Club
7. Convenience Store
8. Delicatessen
9. Distribution Storage Warehouse

10. Food Retailer

11. Hospital

12. Nursing Home/Aged Care Facility

13. Restaurant

14. School Canteen

15. Supermarket

16. Take Away

17. Domestic Kitchen

18. Accommodation

19. Sporting Club (Seasonal)

20. Food Manufacturer

21. Mobile Community Group

22. Food Vehicle

23. Sporting Club

Size of Facility in Square Metres/Number of Seats/Counter Service

Short answer text

Number of Staff (EFTE) (Full Time)

Short answer text

Bin Type

- [ ] General Waste
- [ ] Garden/organic
- [ ] Co-Mingled
- [ ] Paper/Cardboard
- [ ] Oil can
- [ ] Glass
- [ ] Other

Number of Bins

Short answer text

Bin Size (L)

- [ ] 120
- [ ] 240
- [ ] 660
- [ ] 1100
- [ ] Other...

Collection Frequency

Short answer text

Percent Full

Short answer text

Percent Food-waste (Estimate?)

Short answer text

Any idea of the weight of the bins?

Short answer text

Notes

Long answer text

Figure A.9: Google Form survey

Appendix K: Previous SV Methodology for Choosing Businesses

The following appendix details the original methodology used by Sustainability Victoria for determining which businesses to survey in the original, unsuccessful survey.

The original ABBA assessment reached out to 260 organizations across Victoria with a very basic survey. The organizations were chosen semi-randomly, with considerations towards local government authorities (LGA's) and population. The following steps outline the process for choosing these organizations that Sustainability Victoria implemented previously (Nick Chrisant, personal communication, February 2019):

Step 1:

Create six (6) strata (levels) from the Rural Waste & Resource Recovery Groups (RWRRGs), excluding the large rural cities (Ballarat, Bendigo, Geelong).

1. Select one (1) LGA from each RWRRG.

Step 2:

Create a 7th stratum consisting of Ballarat, Bendigo and Geelong.

1. Select one.

Step 3:

Create 3 Metropolitan strata of approximately equal population, by geography, e.g. inner, mid and outer suburbs.

1. Select two (2) LGAs from each.

This gives a total of 13 LGAs.

Within each selected LGA:

Step 4:

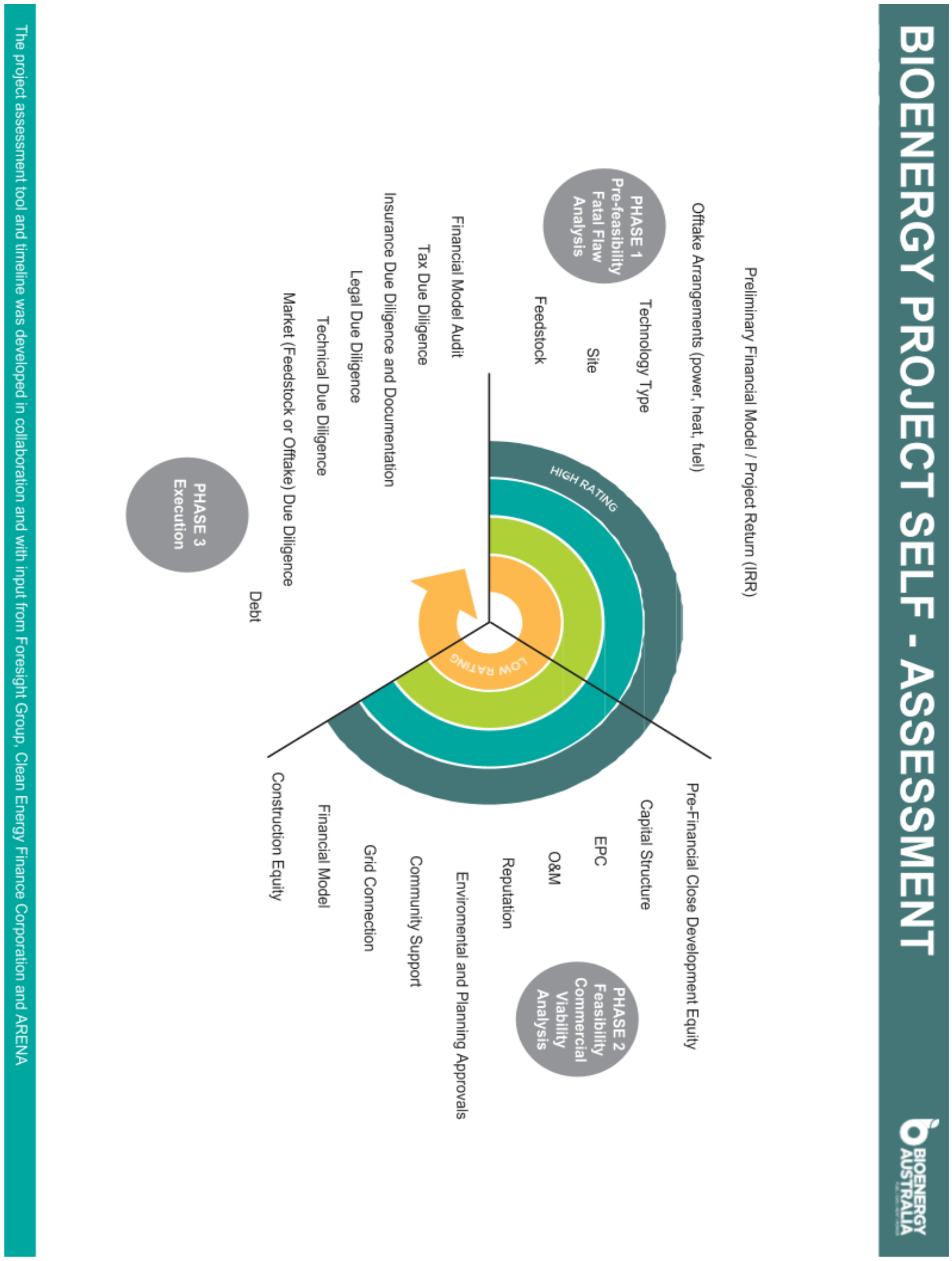
Select 5 enterprises (businesses) from code ***4511 - Cafes and Restaurants***, one (1) non-employing and four (4) employing businesses.
Note: The enterprises could be selected regardless of employment, as it is possible that the final sample will include enough of each.

Step 5:

For each selected ANZSIC code ***4511 - Cafes and Restaurants***, select all in-scope enterprises (other business types) from a 2 km radius from the same vicinity (LGA).

Appendix L: Bioenergy Project Self-Assessment Tool

The following appendix shows the Bioenergy Project Self-Assessment Tool sourced from Bioenergy Australia. This tool outlines a three stage process, the first of which was mostly completed through this project.



BIOENERGY PROJECT SELF - ASSESSMENT

Factor	Low Rating	Medium Rating	High Rating
Feedstock Type and Supply	No specific feedstock source identified yet or the feedstock is at risk of not being available for the life of the assest	Feedstock type identified but either • supplier(s) not identified, or • supplier(s) identified but principles of supply not discussed or agreed with supplier(s). If it is unlikely that all the feedstock supply can be contracted by Financial Close • evidence is in place that demonstrates that there is sufficient feedstock within an economically viable proximity to the project (aim for 3x coverage within a 1-2 hours transport time (depending on site location), and/or • Letters of Support or MOU(s) are in place for the majority of the uncontracted portion.	Feedstock contractually secured from creditworthy counterparty, including quality, volume, and price. Transport risks minimal.
Site (may either be leased or purchased).	No Site	Suitable site identified but not secured.	Site contractually secured and suitable.

BIOENERGY PROJECT SELF - ASSESSMENT

Factor	Low Rating	Medium Rating	High Rating
Technology	Not proven with same feedstock at similar scale elsewhere in the world.	Technology is proven with same feedstock at similar scale but technology providers not shortlisted.	Technology is proven with same feedstock at similar scale* and technology providers shortlisted if not selected.
Offtake Agreement	For power, no offtake likely because there is either no ability to connect into the grid or no behind the meter solution for 100% of the energy output with take or pay terms. For other outputs (e.g. RDF, liquid fuels, wood pellets, biogas) there are no offtakers identified and/or no offtake agreements in place.	Offtake arrangement has been decided (e.g. export to the grid and/or third party power sales under contract) for all output. For any contractual sales: • the counterparty is identified, • key principles with the counterparty have been discussed, and • the counterparty's creditworthiness has been considered and justifies ongoing engagement.	Offtake for all of the project's output is contractually secured, including volume and price, with creditworthy counterparty on take or pay basis.

*Scaling up risk may be considered if there is a sensible modularised approach

BIOENERGY PROJECT SELF - ASSESSMENT

Factor	Low Rating	Medium Rating	High Rating
Project Internal Rate of Return ("IRR") (This can be approximated by calculating the IRR on the Projects forecast EBITDA)	Project IRR below commercial level. Material grants required to attract third party investment.	Acceptable project IRR relative to risk based on high level indicative costings and revenue streams.	Acceptable project IRR relative to risk of project including appropriate contingencies based on detailed third party procured costings and revenue streams.
Pre-Financial Close Development Equity	No or very limited development equity. Requires grants and/or new development capital raise.	Limited development equity available and/or grant funding application submitted.	Sufficient development equity and/or grants committed to fund Project until Financial Close.
EPC and O&M (While the wording of the ratings provided relates to EPC only, the principles and approach cover both EPC and O&M)	Approach not defined or no intention to lock in EPC wrap. EPC Contractors approached to submit EPC expressions of interest have limited experience, have a weak creditworthiness or have not delivered a project in Australia before and do not have a clear strategy on how to successfully deliver a project in Australia.	EPC tender process well progressed and shortlisted bidders identified. EPC Contractors participating in tender process and shortlisted are reputable, creditworthy and can demonstrate experience in successfully delivering suitable reference plant(s).	EPC Contractor selected. Principles agreed for a fixed price fixed date EPC agreement with technically experienced, quality counterparty who has previously constructed in Australia and has successfully delivered suitable reference plants (i.e. plants of similar scale, same technology, same/similar feedstock).

BIOENERGY PROJECT SELF - ASSESSMENT

Factor	Low Rating	Medium Rating	High Rating
Reputation	Key parties involved in project have historic reputational issues which are likely to be problematic with respect to the ability to deliver and operate project successfully.	Key parties involved have immaterial historic reputational issues (e.g. small fines or negative press coverage which has since been corrected) which are unlikely to threaten the success of the project.	Key parties involved are highly reputable with no reputational issues.
Environmental and Planning Approvals	Not commenced or likely to be problematic or expensive.	Process to obtain Development approval and relevant EPA licence has commenced (i.e. pre-lodgement meetings with Council have been held) with no signals from Council or EPA that approvals will not be forthcoming.	All approvals in place including any output quality standards, and awarded without significant stakeholder objections or onerous conditions, including any output quality standards.
Community Support	No intention to engage community or have not yet engaged or engagement has occurred but Community is/likely to be against project.	Engagement commenced with community and minimal and immaterial concerns raised to date which are not likely to be a hindrance to project development and ongoing viability.	Community and other key stakeholders (eg local govt) highly engaged and supportive of project.

BIOENERGY PROJECT SELF - ASSESSMENT

Factor	Low Rating	Medium Rating	High Rating
Grid connection (Electricity or Gas)	Not commenced or likely to be problematic, cost prohibitive or exposed to grid constraints.	Grid connection discussion with grid network operator is highly advanced and there is minimal risk that an acceptable connection offer will not materialise.	Contractually committed. Costs and delivery time locked down with transmission or distribution network service provider.
Financial Model	Not prepared or too basic.	Model prepared but detail and functionality needs to be improved.	Sophisticated financial model developed by professional modeller including a variety of graph outputs and sensitivities. External model audit proposed.

Figure A.10: Bioenergy Self-Assessment Tool from Bioenergy Australia

Appendix M: Email Conversation with Pyrotech Containing Specifications

Dear Avery,

Thank you for showing your interest into our technology and seeing as a solution to treat the green waste and timber that the Grantville Landfill is collecting. We are familiar with the Capricorn Power technology and its uses for harvesting thermal heat and converting it into electricity and we know that our technology can compliment the operations of the Capricorn unit buy utilising both our bio-crude oil and syn-gas through a CHP application. I attach for your viewing relevant information about our technology and what it does. Do give you an estimated cost per unit is easy, however you should consider the peripherals that would be required such as a chipper, a dryer, conveyor belt and other that might require to create this application. As you understand all these depend of the volume of green waste and timber they want to treat on annual capacity as sizing is relevant to volume. Our 10 T MPP can treat 3000 tonnes of feedstock on an annual basis and can be scaled up according to supply of feedstock by adding pyrolysers into blocks. Each 10 T MPP will produce 16 barrels of bio-crude oil with 24 MJ/kg HHV on a daily basis, the same amount in wood vinegar, and 1 tonne of bio-char. The electrical nett energy that you will get by attaching a 50 Kw genset will be 50 kw/h or 1.2 MW a day.
The thermal energy from one 10 T MPP by combusting the bio-crude and syngas into a CHP application is 18MW on 24 hour basis. We currently have 2 models. A 2T MPP and a 10 T MPP. Price for just the mobile pyrolysis plant landed in Australia in Melbourne port with importation taxes and custom clearance is $ 420,000 US for the 2 T unit and $ 890,000 US for the 10 T unit. GST Included. I hope I have answered your questions about our technology. If you need our assistance for completing the feasibility study and guide you through technical matters with peripherals and operations we are more than happy to help you. If you have further questions please do not hesitate to get in contact with me.

Kind Regards

Christos Karantonis

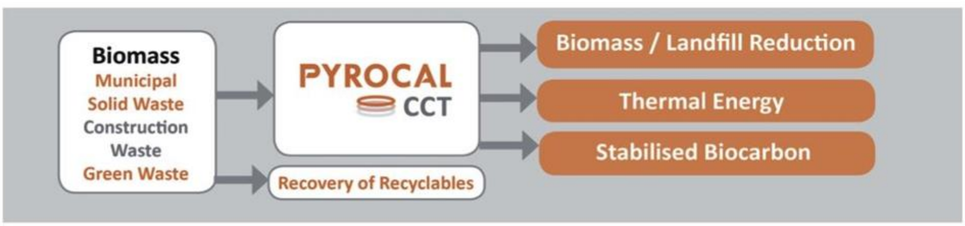
CEO/Managing Director/Founder
Pyrotech Energy Pty Ltd

Level 13/114 Williams st
Melbourne 3000
P: 1300 714 305
M: +61 0417690252
Email: christos.k@pyrotechenergy.com

Appendix N: Pyrocal Data Sheet

Continuous Carbonisation Technology for Char and Electricity Production

Pyrocal Continuous Carbonisation Technology (CCT) converts biomass into stabilised biocarbon and thermal energy that can be used to generate electricity. There is also a 70% to 90% reduction in the volume of biomass. For example, most non-recyclable waste can be beneficially diverted from landfill.

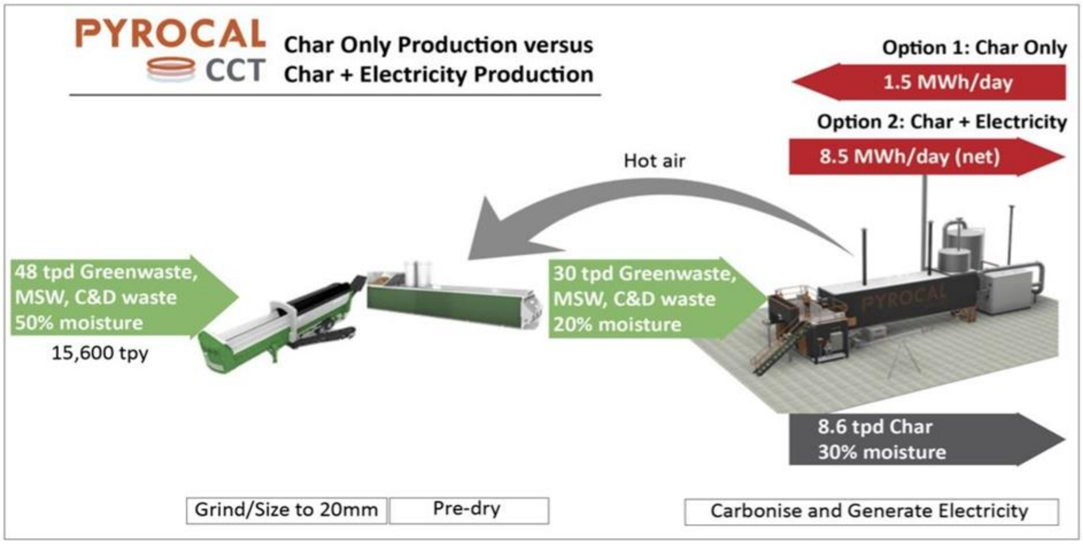


With a proven track record, Pyrocal CCT systems have been implemented commercially since 2014. The development of the company's innovative technology started in Australia in 2009. We are based in Toowoomba, Queensland where we operate a full scale commercial system and conduct R&D.

Pyrocal CCT systems have been deployed across eight countries in a variety of applications. We have the technical and engineering skills to customise systems to meet specific process needs.

pyrocal.com.au

Example Landfill Reduction Scenario



Revenues and Costs	Char Only Production	Char + Electricity Production
Gate Fee Revenue	$50/tonne, $2,400/day	$50/tonne, $2,400/day
Electricity Generated*	-	$200/MWh ($1,700/day)
Char Revenue	$150/tonne, $1,290/day	$150/tonne, $1,290/day
Operating and Maintenance Cost	$800/day	$1,000/day
Electricity Cost	$200/MWh ($300/day)	-
Net Revenue	$2,890/day ($925k/year) on $2.0M Capex	$4,390/day ($1.4M/year) on $4.5M Capex

* The generated electricity is for site consumption, displacing electricity purchased elsewhere.

Uses for Char from Carbonisation

- Landfill capping.
- Landfill leachate control.
- Metal smelting (for example copper, zinc). Allows recovery of minerals.
- Electrowinning of precious metals (for example gold, palladium, platinum)
- As an activated carbon substitute in gold recovery.
- Cement kiln fuel supplement.
- Asphalt additive.

For Further Information

T +61 7 4639 2009
E enquiries@pyrocal.com.au
W pyrocal.com.au

PYROCAL PTY LTD

Pyrocal Pty Ltd
27 Heinemann Road
Wellcamp QLD 4350

Figure A.11: Pyrocal data sheet

Appendix O: Pyrocal Brochure

Frequently Asked Questions

Don't plastics produce toxic compounds when heated?

In an uncontrolled environment, like an open fire, plastics do indeed release toxic compounds when they are heated or burnt. In a controlled environment, like the close coupled hearth, oxidiser and lime dosed scrubber of a CCT system, the toxic intermediates are immediately converted to CO_2, H_2O, N_2 and safe calcium complexes such as $CaSO_3$, $CaCl_2$, CaF_2 and $CaBr_2$.

Doesn't thermal treatment of MSW create dioxins?

Any combustion system that allows low temperature combustion (i.e. below 400 deg C), high temperature pyrolysis (above 750 deg C) and/or holds partially combusted gases at temperatures in the region of 200-400 deg C for periods exceeding a second, can generate dioxins. Once created dioxins are very hard to destroy. The conditions for dioxin formation are avoided in Pyrocal's CCT process. Specifically, pyrolysis is conducted below 750 deg C, oxidation is conducted, to completion, well above 400 deg C (typically at 800-900 deg C), and the hot flue gases are then rapidly quenched in a heat exchanger or wet scrubber.

How are heavy metals captured?

The least volatile heavy metals are retained in the porous carbon (char) that is discharged from the hearth. Those metals that are released into the flue gas stream are reacted with calcium (in the form of lime dosed into the feed and scrubber) to form chemically stable salts, which are mixed back into the char.

How is SOx controlled?

Most of the sulphur in the feed is retained in the porous carbon (char) that is discharged from the hearth. Any sulphur that is released from the hearth ultimately reacts with the calcium (in the form of lime dosed into the feed and wet scrubber) to form stable calcium salts.

How is NOx controlled ?

In MSW carbonisation, little NOx is produced because the fuel nitrogen levels are low and peak temperatures are too low to produce significant thermal NOx. What is produced is largely captured by reaction with lime in the wet scrubber.

What happens to halogenated or fluorinated compounds such as PFAS, Teflon etc ?

At temperatures exceeding 350 deg C (i.e. in the hearth) these compounds breakdown into smaller molecular fragments which are mostly released to the oxidiser. These monomer fragments (e.g. tetra fluorethylene) oxidise to carbonyl fluoride in the oxidiser, which then converts to hydrogen fluoride in the scrubber, which reacts immediately with lime to form the safe insoluble salt calcium fluoride.

For Further Information

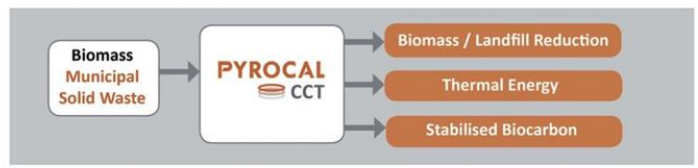
T +61 7 4639 2009
E enquiries@pyrocal.com.au
W pyrocal.com.au

Pyrocal Pty Ltd
27 Heinemann Road
Wellcamp QLD 4350

PYROCAL
PTY LTD

Continuous Carbonisation Technology for Municipal Solid Waste

Pyrocal Continuous Carbonisation Technology (CCT) converts biomass into stabilised biocarbon and thermal energy, with a resulting reduction in the volume of biomass. When this technology is applied to Municipal Solid Waste (MSW), most household waste can be beneficially diverted from landfill.



With a proven track record, Pyrocal CCT systems have been implemented commercially since 2014. The development of the company's innovative technology started in Australia in 2009. We are based in Toowoomba, Queensland where we operate a full scale commercial system and conduct R&D.

Pyrocal CCT systems have been deployed across eight countries in a variety of applications. We have the technical and engineering skills to customise systems to meet specific process needs.

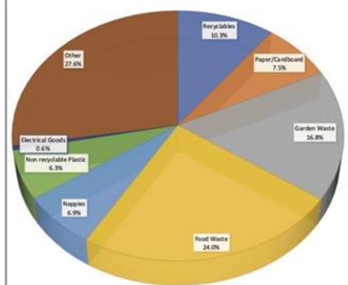
pyrocal.com.au

Fate of Municipal Solid Waste Components in a Pyrocal CCT System

Waste Type / Typical Percent by Mass	Fate in Pyrocal CCT	Notes
Plant & animal derived residues (organics) 30-70%	Carbonised with char yield approximately 25% of dry matter.	Contribution to heat balance is very little when moisture is greater than 50%.
Paper, cardboard and packaging 10-30%	Carbonised with char yield approximately 20% of dry matter.	Key source of heat release for autothermal operation.
Plastics (e.g. packaging, disposable nappies) 10-20%	Carbonised with char yield approximately 5% of dry matter.	Some plastics have char yields up to 35% by mass. Main source of heat release for autothermal operation.
Tins and metal 3-10%	Pass through with some loss of zinc and some oxidation.	Recoverable from char. Larger fragments by light ball milling and screening at 4mm. Smaller fragments by density separation (air or vibration).
Ceramics and glass 2-8%	Pass through with some sintering of glass.	Can be density separated from char if necessary. Otherwise does no harm in most end-uses.
Biohazardous material (used health products, unused medicines) <1%	Carbonised with char yield approximately 15% of dry matter.	Biohazards are eliminated.
Hazardous waste – Batteries, ewaste, <1%	Pass through with some release of volatile metals which are captured downstream in the scrubber.	Non-volatile fractions recovered in metal stream. Volatile metals captured in scrubber.
Hazardous waste – Pesticides/Herbicides/ Paints, waste oils <1%	Vaporised in the hearth and destroyed in the thermal oxidiser.	
PFOA/PFOS (PFAS)	Vaporised in the hearth and destroyed in the thermal oxidiser.	Halogens such as fluorine are converted to safe calcium salts in scrubber.
Treated timber <1%	Carbonised with char yield approximately 22% of dry matter. Some release of volatile metals which are captured downstream in the scrubber.	Can be a significant source of Cu, Cr and As in the char, which can impact on suitability for end use.
Asbestos Radioactive materials	Not normally expected at detectible levels. Unaltered by process. Will end up in char and scrubber effluent.	Must be monitored for in the incoming feed and outgoing char so that contaminated materials can be segregated.

Note: Metals are immobilised in char, which means reduced leaching potential.

Garbage Composition 2010*



* Regional waste management Goulburn Valley, VIC
Source: www.environment.gov.au

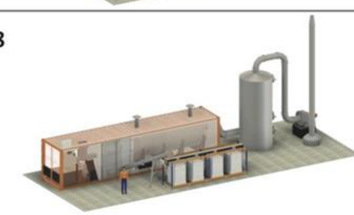
Uses for Char from MSW Carbonisation

1. Metal smelting (for example copper, zinc). Allows recovery of minerals.
2. Electrowinning of precious metals (for example gold, palladium, platinum)
3. As an activated carbon substitute in gold recovery.
4. Landfill capping.
5. Cement kiln fuel supplement.
6. Asphalt additive.

Pyrocal CCT 12

250 kg/hr biomass
0.75 MW_{th}

Pyrocal CCT 18



650 kg/hr biomass
2 MW_{th}

Pyrocal CCT 18 Dual

1300 kg/hr biomass
4 MW_{th}

Emissions Standards Compliance (Australia, EU, USA)

pyrocal.com.au

Figure A.12: Pyrocal brochure