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Biocluster Template Report

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1. Executive Summary

The goal of this report is to establish a plan to develop a biocluster at the Grantville waste transfer and landfill facility located in Gippsland. Grantville is owned by the Bass Coast shire council and run by ACE Construction Group. The Grantville facility is an optimal location for a biocluster because of its large supply of available biomass on-site that can be used as feedstock for a pyrolysis unit. By utilising Grantville as a template, other bioclusters can be developed in the Gippsland region.

To construct a plan to implement a biocluster at Grantville, it was critical for us to understand what makes a cluster successful. This knowledge is imperative to formulating next steps to develop a biocluster at Grantville that can serve as a template for future bioclusters in Gippsland. Using this methodology, we were able to determine the fundamental elements that lay the groundwork for the implementation of a biocluster. This includes general cluster selection criteria, resource mapping, and strategic partnership investigations.

It is critical to assess the value stack options associated with a biocluster. A value stack evaluates the worth of the products of a biocluster. At Grantville, this includes biochar and its associated value added products, as well as electricity production. Producing biochar using a pyrolysis unit creates various opportunities ventures for Grantville. For example, biochar could be utilised on site for leachate processing or capping the landfill, or for wholesale. Capricorn Power's Barton engine could employ the medium and high-grade waste heat from the on-site waste methane, and the excess heat from the pyrolysis unit, to produce electricity. This biocluster model could benefit Grantville financially by diverting waste from landfill.

The project's feasibility and viability needed to be evaluated to verify these benefits. Grantville could generate around \$500,000 AUD from biochar sales and \$210,000 AUD from electricity sales per annum. The cost of the project is dependent on the pyrolysis system that is purchased. However, based on conservative estimates sales achieved and costs for a pyrolysis unit capable of handling 3 times the necessary throughput, this biocluster model could offer a return on investment in under 3 years. Grantville has an abundant amount of feedstock on-site, in the form of woody and green organic waste. Supply is consistent and pyrolysing these kinds of feedstocks is proven to be an effective way of producing high quality biochar. Based on our evaluations, the development of a biocluster at Grantville is both feasible and viable.

After establishing viability and feasibility, we determined the following next steps to lay the groundwork for implementation:

1. Build a commercial input-output model
2. Assess other feedstock opportunities
3. Assess other biocluster options and education demonstrations

These next steps are adaptable; they apply to the biocluster at Grantville, but are also an effective template for the development of other bioclusters in the Gippsland area. These future opportunities will build a framework for a bioenergy network across Gippsland.

2. Introduction

Currently, biochar markets across the globe are small. Biochar is a relatively new product that has been the subject of research for less than 20 years. Through this research, it is clear that biochar is effective in a range of applications, and in the creation of higher-value products. Despite this, the biochar market in Australia is still in its infancy. This stems from a number of issues, foremost of which is a lack of understanding amongst regulators. Consequently, there is limited government support or research funding for biochar. Implementing biochar into a biocluster at Grantville could serve as a means to give biochar a leg up into the market. Most importantly, the process can serve as an example of a viable model of biochar's use in real markets, and can provide a roadmap for establishing more extensive bioenergy clusters across Gippsland. To understand how this is possible, it is critical to assess how clusters work, and how biochar and pyrolysis could fit into a biocluster.

Attention was brought to clustering as it has the potential to alleviate some of the issues that are associated with moving to larger biochar production. It presents an opportunity to push the production further, as clusters are shown to promote economic benefits to entities involved. Since the members of cluster rely on each other for the product and services, there is an incentive to make use of the waste in the cluster and begin to move towards a localised circular economy of sorts. In this way, there is potential for the biocluster to provide a sustainable method to manufacture biochar and other related products. The opportunity present would minimise the waste as much as possible, and still be efficient and cost-effective. The industries that participate in such a cluster have an inherent desire for mutual success, as all the entities in the cluster rely on one another. Because the goods and services in the cluster are intertwined, cooperation between members is incentivised.

This report focuses on the small scale implementation of a cluster at the Granville facility. This is key in establishing a framework to form a larger biocluster network throughout Gippsland. The process of evaluating the viability and feasibility of such a project can be scaled up for a potential regional bioenergy cluster. To discuss this notion, this report investigates the benefits to stakeholders for the biocluster at Grantville, along with next steps for the implementation of the biocluster.

3. Background

Clusters are a collection of companies and institutions that are located in the same region and are linked by similar services and products (Biriescu, 2010). Clusters are relevant to the development of a biocluster in Gippsland because of their dynamic ability to create economic growth in a set of related and emerging industries.

A cluster's participating members include a range of institutions and stakeholders. The biocluster cluster shown in Figure 1 is an example of a sample biocluster waste products. Part of the chain often starts with an unrefined resource, such as organic waste or cooking oil. The refining companies buy equipment to run their plants. The oils and wastes are sold to processing companies, who add value by converting it into energy or refining it further. Additional transportation companies may be involved in transporting feedstocks and products. The products may even be sent to distributors before they finally go out to end-users. Universities or research institutes nearby can generate knowledge and provide innovative technologies and research to support the industry. Various municipalities may interact with each facet of the cluster through taxes and regulations. All together, they form a complex web of products, services, and information that connect the various stakeholders.

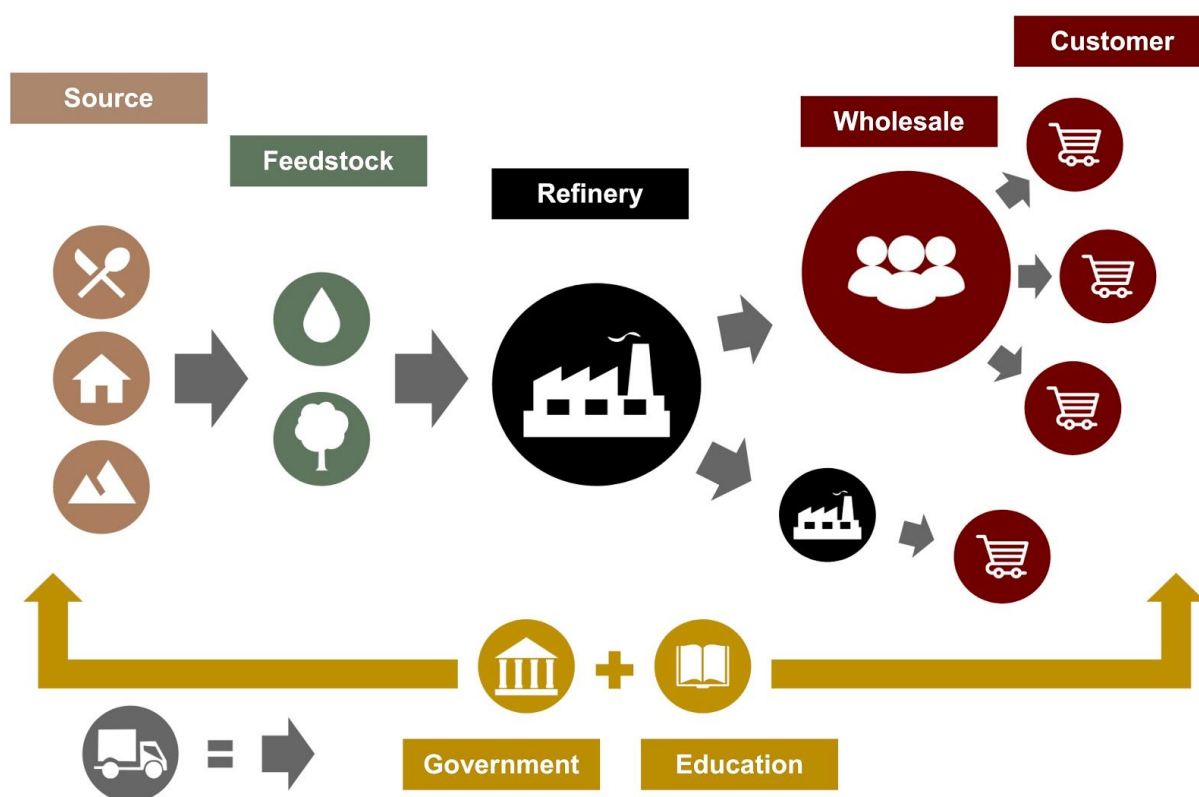


Figure 1. Resource flow in an example biocluster..

There are three main benefits of clustering, which are summarised in Figure 2 (Biriescu, 2010). These may be realised as part of the regional bioenergy cluster. Using Grantville as an example, the process would increase efficiency by diverting wood waste from

landfill and creating energy that could power the site. By using the Grantville as a template for the rest of Gippsland, and through the sharing of ideas between the biocluster constituents, innovations to the process will be uncovered. Lastly, by laying the groundwork for the regional bioenergy cluster via the biocluster at Grantville, opportunities will be created that new businesses can fulfill in the cluster.

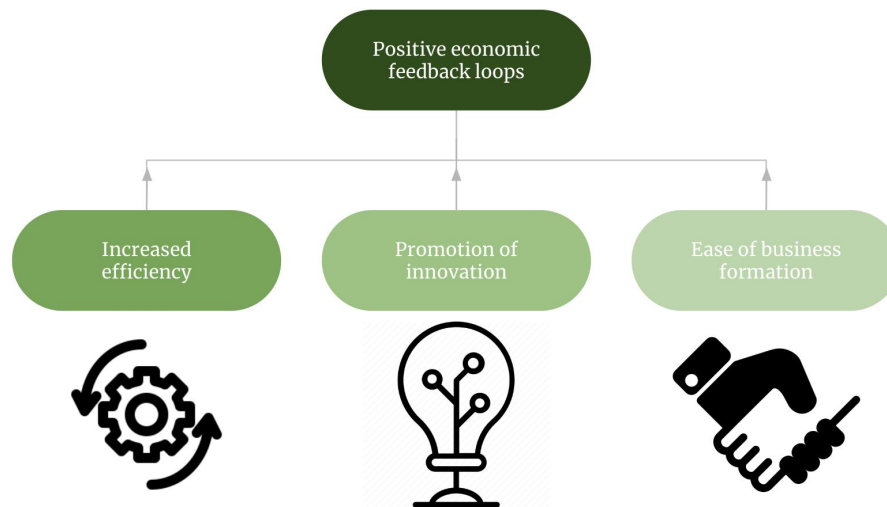


Figure 2. Three cluster benefits leading to economic growth (Biriescu, 2010).

The parameters supporting economic growth are often hard to pinpoint, as the factors affecting the economy are so dynamic, especially in a cluster. Bresnahan et al. (2001) argued that the ingredients for creating a new cluster involve both kinds of thinking and involve three components, shown in Figure 3.

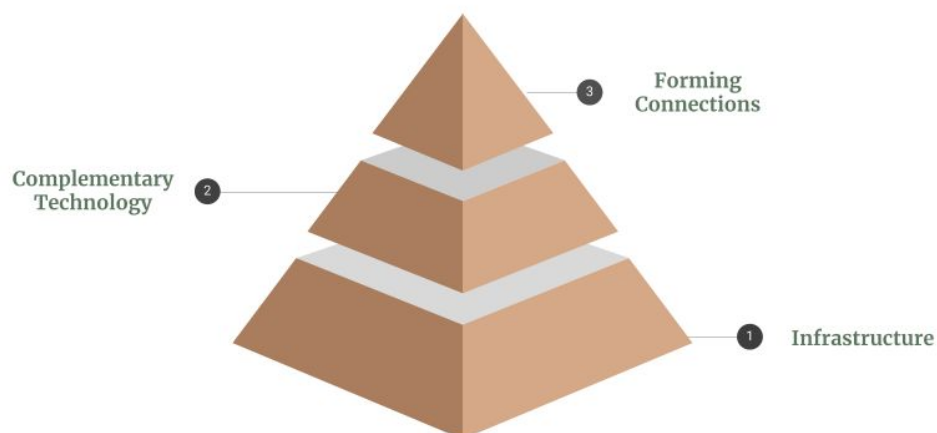


Figure 3. Components of a successful new cluster (Adapted from Bresnahan et al., 2001).

For a cluster to grow, there must be some existing economy and infrastructure (consumers, businesses, distributors, etc.) that can support the new technology. In the case of the biocluster at Grantville, this is the business surrounding the landfill. This can support the

purchase of a pyrolysis unit, for example. Second, the cluster should exploit a new technology or market that is untapped in the region. This is so that the new technology does not compete with existing markets. Silicon Valley is a good example, as this cluster was based on a new integrated circuit market. In a similar vein, the biochar industry is practically non-existent in the Gippsland region, so it is poised to fill this niche in the market. According to Carrol et al., the technology or idea should also be complementary to the existing markets surrounding it (2012). In the example of Silicon Valley, the integrated circuits complemented the surrounding communication and computing technology industries. In the case of Grantville, there are a number of on-site applications for the biochar, as well as a quarry next door that could utilise the char. The last piece of the puzzle is to connect the various pieces of infrastructure with the aforementioned complementary technology. Carrol et al. (2012) argued that the most important part of this step is establishing a pathway for sharing knowledge. The ‘social capital’ is immensely important to a cluster’s success. The various entities of the cluster must understand what each other’s goals are, share expertise, and trust one another in order to cooperate effectively. Once the cluster is established, the positive feedback loops take hold and the cluster should flourish economically.

Figure 4 is an example of a real cluster. Part of the chain often starts with an *unrefined resource*, such as the grapes. The vineyard buys *supplies*, like fertilizer and harvesting equipment. The grapes are sold to wineries or *processing companies*, who turn it into a *product* (wine). Additional *transportation* companies may be involved in transporting the grape products produced. The wineries also purchase equipment for other suppliers. The wine and grape products may even be sent to *distributors* (supermarket chains) before finally go out to the *customers*. The *universities* or *research institutes* nearby may generate *knowledge* and new *technologies* to support the industry. Various *municipalities* may interact with each facet of the cluster through taxes and regulations. All together, they form a complex web of products, services, and information that connect the various stakeholders.

ANATOMY OF THE CALIFORNIA WINE CLUSTER

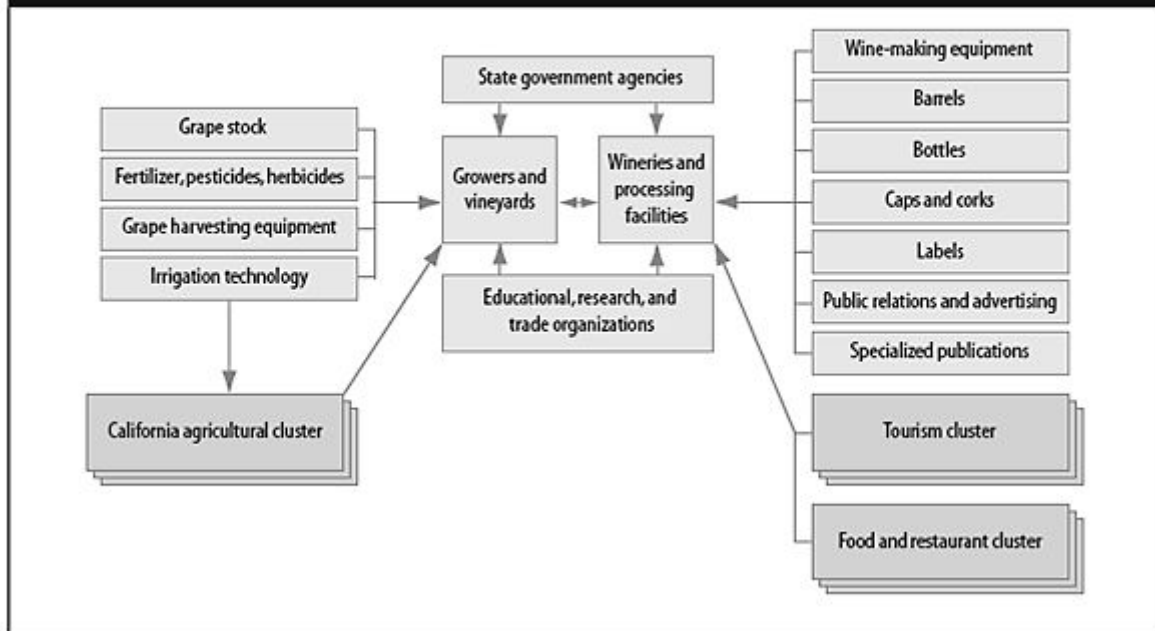


Figure 4. Resource flow in California wine cluster (Porter, 1998).

4. Methodology

4.1 Goal and Summary

The goal of this report is to identify a plan to implement a biocluster at the Grantville facility that can be used as a template to create other bioenergy clusters across the Gippsland region. To achieve this, we investigated cluster theory, delving into the economic benefits of clustering and the necessities for the creation of a new cluster. Using this knowledge as a lens, we assessed the potential at the Grantville site for a biocluster centered around converting their woody waste into energy and biochar. The process of devising such a project was developed with scaling up to the establishment of regional bioenergy clusters in mind. To complete this goal, we established three objectives. The objectives are:

1. Understand what makes a successful cluster
2. Outline the benefits in participating in a biocluster
3. Establish next steps that can be applied to a future biocluster

4.2 Understanding what makes a Successful Cluster

To understand what makes a cluster successful, it is paramount to understand cluster theory. The group used this knowledge to construct a framework for evaluating the formation of a biocluster at the Grantville facility. Figure 5 outlines the process taken to better understand cluster theory.

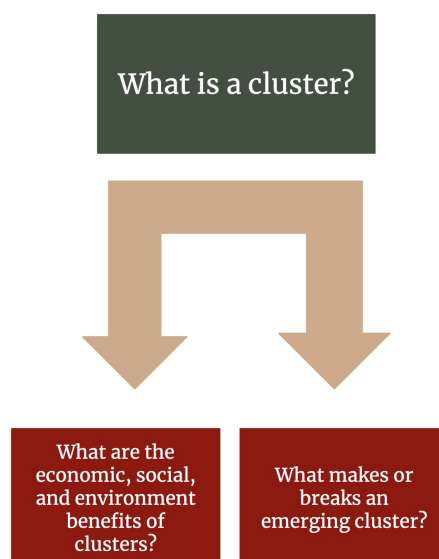


Figure 5. Outline of Objective 1 key questions.

To establish a fundamental understanding of the economics of clustering and its impacts on the businesses involved, we performed a literature review. We focused on published case studies to help us understand the real-world nuances of clustering. We were especially interested in the enabling factors and roadblocks to cluster formation and development. This allowed us to collect information on the necessary components needed to create a successful cluster, and the steps needed to maintain them.

4.3 Outline the Benefits in Participating in a Biocluster

In order to outline the benefits in participating in a biocluster, we reviewed a previous study by Trey-Masters, Ingegneri, Blomquist, & Seo (2019) that analysed the potential for a bioenergy cluster in Gippsland. The study conducted a waste survey of Warragul to assess the potential biomass in the Baw Baw Shire. After conducting the waste study, they investigated the possibility of developing a bioenergy cluster based on the Grantville site. They evaluated relevant technologies to reduce the amount of woody waste entering the landfill. A summary of technology findings are below in Table 1.

Table 1. Analysis of technology findings at Grantville.

Technologies	Viable	Companies	Value Added Products
Incineration	No	Used on site at Grantville	Heat & Power
Pyrolysis	Yes	Pyrotech, Earth Systems, Pyrocal, Rainbow Bee Eater	Biochar, Heat & Power, Syngas
Gasification	Yes	MAGS, Pyrotech	Biogas, Heat & Power
Plasma Arc Gasification	No	Zenergy Australia	Biogas, Heat & Power
Anaerobic Digestion	No	CERES	Biogas, Heat & Power, Compost

Building onto the knowledge base Trey-Masters et al. established, our team explored the theory and benefits of clustering. Consequently, we outlined the potential benefits in a value stack assessment. The value stack can then be applied to the Grantville site to assess the potential possibilities at the facility. We looked into venture options to optimise project value, viability, feasibility, and benefits for the Grantville facility. Following, we visited the site to refine the scope and possibilities that could be developed. We also outlined cluster selection criteria, so the steps taken at Grantville could be replicated at other locations in Gippsland- an initial list has been prepared by GCCN and others (Appendix G).

4.4 Establish Next Steps that can be Applied to Future Bioclusters

It was critical to establish next steps to map out the development of a biocluster at Grantville. From our meetings with ACE and the site visit, we determined three different steps to lay the groundwork for implementation. The first step is the creation of an input and output model. The inputs are the various feedstocks available on site. This includes the woody and green waste, as well as the methane produced by the landfill. The output is the biochar that is produced and its associated value added products. Depending on the feedstock used, the quality of biochar produced and its optimal end use will be different. The second step is to explore different feedstock opportunities. This includes waste from horticulture, greenhouse biomass waste, and biosolids. Lastly, the third step investigates opportunities that Grantville can move onto following the success of the first two steps. These include setting up demonstrations for employees about the benefits of clusters and renewable energy systems, and looking further into the development of an algae-based system on site. The success of the Grantville biocluster would prove the efficacy of this three step model. This would lead to the establishment of other bioclusters in Gippsland.

5. Results

5.1 Cluster Selection Criteria

The emphasis of this project was to establish a template for the creation of bioclusters across Gippsland, and project what that might look like within the circular economy of a given system. We used the Grantville facility as the location to verify the efficacy of the proposed biocluster development model.

5.1.1 Selection Criteria

It is critical to establish a benchmark level with which to assess a given cluster opportunity's value. This is to say, there are bare minimum criteria that a cluster opportunity must fulfill to even begin to consider implementation. These criteria are shown in Figure 6. A potential site for a cluster should meet all the criteria. For example, if the site in question intends to rely on government grants and funding, it may not pass the criteria because of the lengthy application time, and may have a low Return on Investment (ROI) attractiveness. As such, all facets of the project need to be taken into consideration before moving forward. Another important aspect of the cluster criteria is the social license to move forward with the project. The local community should approve of the project, otherwise it would be unethical. Finally, it is imperative that the idea of a circular economy is worked into the design of the cluster to fulfill the sustainability criterion. This includes greenhouse gas (GHG) emissions. A biocluster must reduce emissions, or at least be carbon neutral.

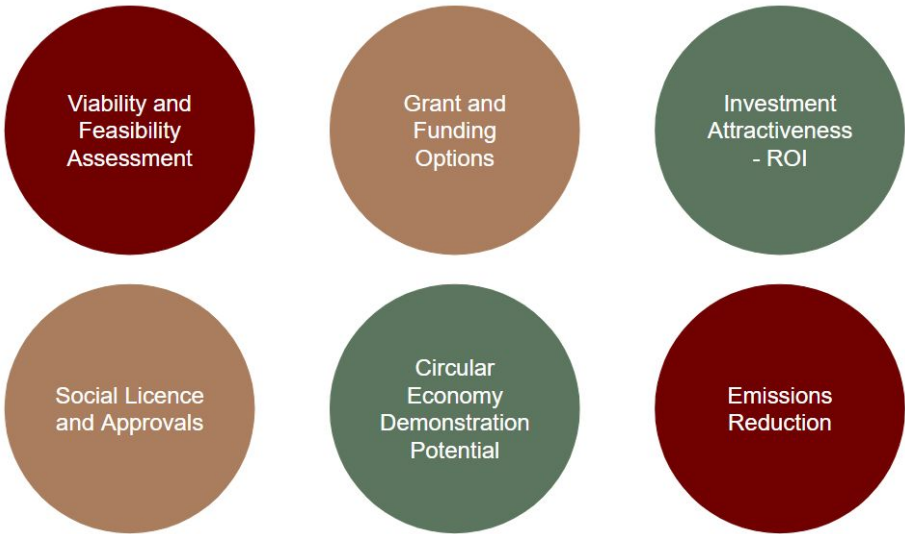


Figure 6. Minimum Cluster Criteria

The companies that take part in a cluster must evaluate the risks of participating in such a venture. Like all types of business endeavors, risks and uncertainties must be calculated beforehand. Thus, a business that is interested in participating in a cluster should be

prepared for the chance that a deal may fall through. It is up to the participating businesses to manage the risk as they see fit in order to proceed with the development of the cluster.

5.1.2 Progressive scalability

Once the selection criteria are met, there must be an assessment to determine if scale up it is possible for the cluster. If there is no potential to expand, then the project is not viable. For the project to be deemed viable, there must be a clear picture of how the cluster will grow in 5-10 years after implementation. This will allow clusters the opportunity to bring in more partners and create more revenue. Without a forward-thinking agenda, like long-term plans to bring in more partners, there is little that could be done to ensure the growth of the biocluster.

5.2 Resource Mapping

To develop a biocluster, feedstock supply options must be assessed. The feedstocks are to be mapped out and quantified. This provides a basis to develop an understanding of the production options available and potential outputs of the system. A site investigation was necessary to assess the wood and green organic waste piles. It is necessary to assess the feedstocks, as they determine what production processes are most viable and feasible. We determined that the contaminated and non-contaminated wood were not separated. At the Grantville facility, wood waste volumes are quantified on a per annum, but necessitate laboratory assessments for biochar processing viability.

After the feedstock is identified, the next step is to assess the production processes. Due to the limitations of incineration, gasification, plasma arc gasification, and anaerobic digestion, pyrolysis was determined to be the optimal technology for the Grantville facility. Pyrolysis can be readily integrated into a biocluster and produce other useful value-added products.

Resource mapping is also important because it identifies local stakeholders who can commercially use the products. For instance, Holcim, a sand excavating company next to the Grantville facility, could use the biochar. The sand is used to create concrete, and biochar has been shown to increase concrete's strength when used as an amendment (Gupta, Kua, & Tan Cynthia, 2017). They currently mix fly ash with the sand, but there are environmental concerns with its usage. Fly ash is created from coal combustion residues, which can contain high contaminant levels. This raises concerns for ecologically damaging leachates (National Academy of Sciences, 2006). Biochar created from clean organic wastes, like wood, does not have the potential for dangerous leachates. By evaluating the resources that surround a clustering location in this way, the expansion and growth of the cluster can be optimised.

5.3 Building Strategic Partnerships

In any business venture, there is a great deal of emphasis on the partnerships. Partnerships allow business ventures to grow. In order to establish these partnerships, there is

a need to establish trust with potential partners. Trust is developed over time, so the effort must be put in to create it. After the trust is established, the businesses must come together and decide how to move forward. This can be done with extensive negotiation, resulting in a contract that creates a platform in which parties can agree on. Moving forward, partners need to have a specific interest in the development of the cluster for them to continue to be a part of it. Businesses must take the initiative to move the cluster forward.

5.4 The Value Stack

5.4.1 Summary

The value stack evaluates the worth of the various outputs of a biocluster. At Grantville, this includes biochar and its associated value added products, as well as electricity production. Since biochar has such a great number of applications and products, the value stack is essential to optimise which end uses are selected for the biochar.

5.4.2 Venture Options

Biochar is highly dynamic in its usage. Appendix A gives 50 uses of char, which are summarised in the 10 categories shown in Figure 7.










Soil Conditioner			Animal Farming
Decontamination			Building Material
Biogas Additive			Drinking Water Treatment
Textiles			Wastewater Treatment
Wellness			Carbon Sequestration

Figure 7. Categories of value adds for biochar.

Since biochar's uses are so broad, it is important to consider the value of all the potential product streams. Most important to take into account is the actual market price of the product itself and the size of the market. Some products may be very high value, like activated carbon, but the market for them may be relatively small. Other products might have very low value,

like landfill capping, but represent a high volume of product. This idea is summarised with relevant biochar value adds in Figure 8.

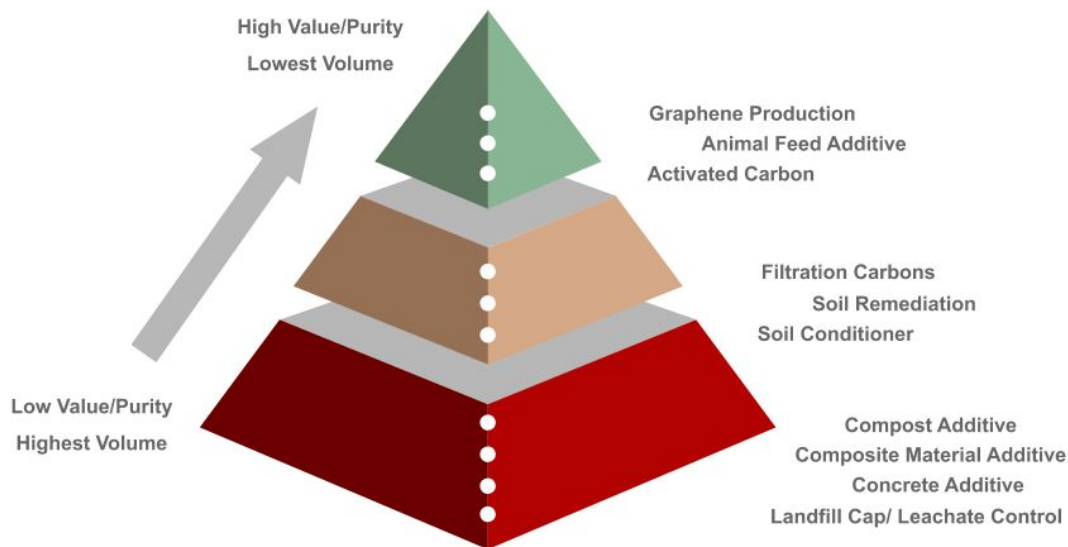


Figure 8. Biochar’s value-added streams by volume and market price.

Some applications are more convenient to the Grantville facility. On-site, the biochar could replace the need for other materials to be purchased to cap the landfill. It could also be used to filter and cap the leachate, overall expediting the process. Additionally, the Holcim quarry immediately adjacent to Grantville ships sand to Melbourne to be further processed into concrete. Grantville could sell the biochar to Holcim to mix into the sand and strengthen the concrete. These represent low value, high volume opportunities. Smaller, higher-value markets could be more profitable streams for the biochar. In many of the higher value streams, the biochar would require more processing, which complicates finding profit margins. For example, biochar would need to be further ‘activated’ to increase its surface area to be used as activated carbon. The same could be said of graphene. Biochar could be used as a feedstock for creating graphene, but would need to be transformed using another process, like sonication.

5.4.3 Project Feasibility

Building on top of the venture options, it is critical to assess the feasibility of the project. Figure 9 facilitates this by outlining mass flow and revenue associated with the operation of the pyrolysis unit at Grantville.

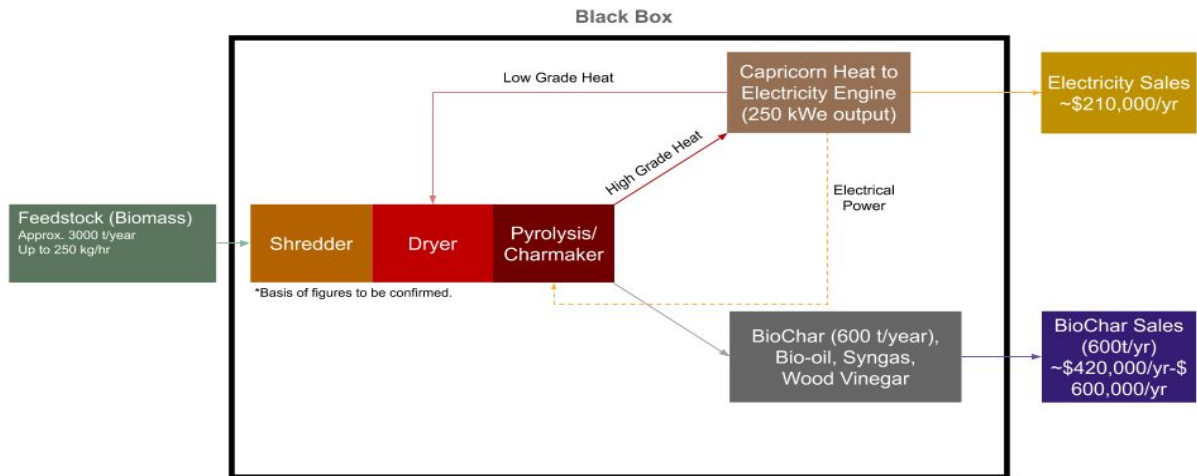


Figure 9. Simple process diagram with potential revenue.

There are a number of assumptions in this diagram. First, the mass flow of feedstock is assumed to be at the high end of the range given by Grantville. Next, the percent conversion to biochar was assumed to be 20%. Earth Systems offers multiple batch process pyrolysis units that operate at 26.7% conversion, so this estimate is conservative (Morphett, 2019). It was assumed that biochar was priced between \$700/tonne and \$1000/tonne AUD. These are typical wholesale prices for biochar produced from woody waste, as confirmed by Nigel Murphy. The electricity sales were estimated at around 10¢ AUD per kWh, which is also conservative compared to current market prices (O'Neill, 2019). Even with these estimates, the generated revenue would be at least \$600,000 AUD per annum. For context, Pyrocal's sells a continuous pyrolysis plant capable of processing 35 tonnes of biomass a day, which is more than three times the size needed at Grantville. The CAPEX for this unit is \$1.8 million AUD, and the annual OPEX is 5% of the CAPEX (J. Joyce, personal communication, November 28th, 2019). Assuming a steady \$600,000 AUD each year from revenue generated by electricity and biochar sales, it would take just over 3.5 years to pay off the oversized plant. This does not include the potential for more revenue from governmental incentives, like Australian Carbon Credit Units (ACCUs). With this in mind, it is probable that the real return on investment would be shorter than three years, making the project feasible.

5.4.4 Project Viability

With the project's feasibility established, the next question to ask is if the project is viable. To do so, it is important to consider the various inputs available. These are summarised in Table 2.

Table 2. Inputs and amounts for processes at Grantville.

Inputs	Amounts
Green Waste	7000-8000 m ³ /year
Woody Waste	2000-3000 tonnes/year
Methane	150 std. m ³ /hr

Using these values, a more detailed version of the analysis completed for Figure 9 was performed, shown in Figure 10.

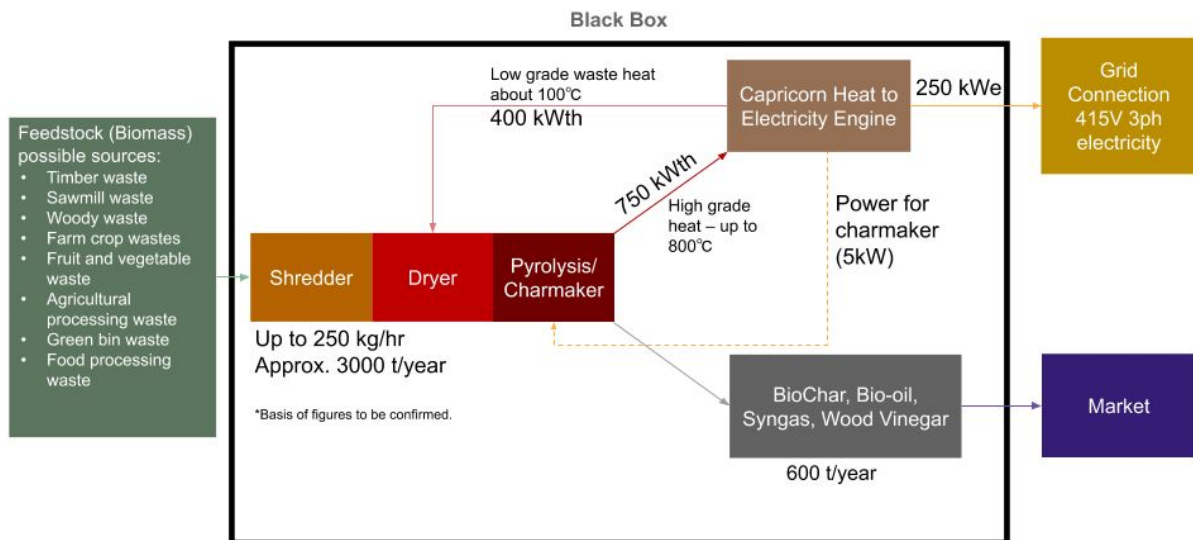


Figure 10. Process flow diagram focused on intermediary values.

If a dynamic batch pyrolysis unit like those offered from Earth Systems is chosen, the process could handle an assortment of organic feedstocks. For example, the pyrolysis unit could be used to process the on-site green waste. Gippsland is also home to many farms, as well vineyards and olive groves. These could provide high-quality biomass feedstocks, like grape marc and olive pits.

Capricorn Power’s Batron Engine pairs well with the existing processes at the Grantville facility, and would complement a pyrolysis unit on-site. The methane from the site is currently flared, so all the thermal energy is wasted. It is extremely valuable to the Grantville facility to generate electricity on-site, since they are not connected to the main electrical grid. Currently, all their on-site electricity is generated using diesel generators. By switching to the proposed model, they could generate electricity using waste products and avoid emissions at the same time. This would save money since less, or no diesel, would be required to run the site, and provide the opportunity to generate revenue through ACCUs. The low-grade heat would also be of use for leachate processing. Currently, the leachate is simply

aerated using pumps, but the low-grade heat would be at an ideal temperature for leachate evaporation. The biochar could also be used for filtration, as well as a replacement product for landfill capping. Holcim concrete ships sand to Melbourne for concrete production. Biochar could be sold to Holcim to mix in with their sand and create stronger concrete. A process flow chart across the whole facility is shown in Figure 11.

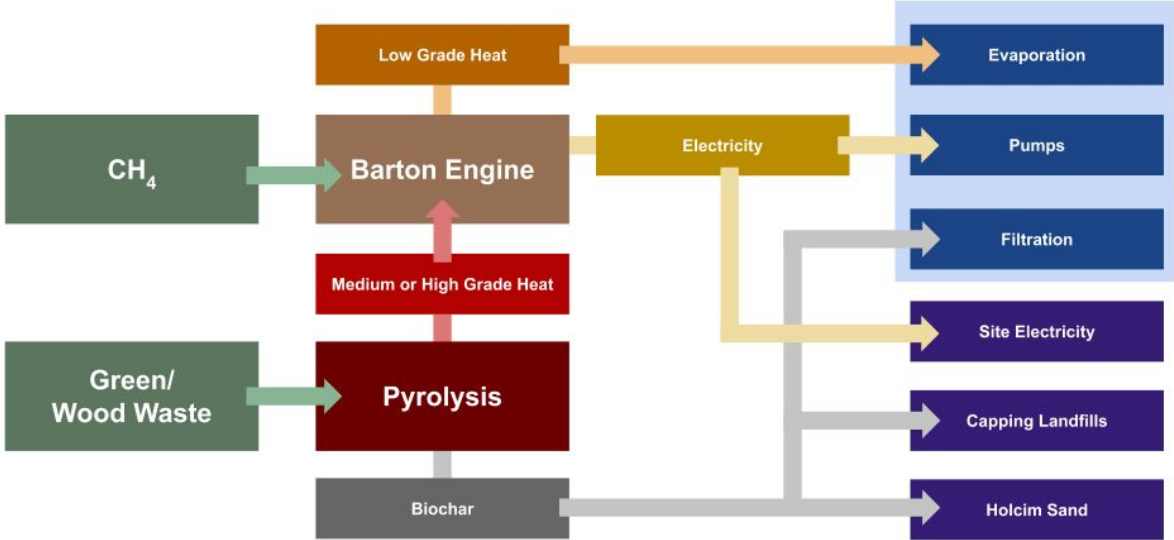


Figure 11. Process flow diagram including end processes for biochar.

5.4.5 Project Benefits

Outlining the benefits of a biocluster project in a succinct manner is critical to assess whether the project should be developed further. It is crucial that known benefits are quantified, so that options can be compared and can be pitched to potential stakeholders. These benefits include reducing the cost of existing operations, creating a product that can provide new sources of revenue, and making processes more sustainable. In the case of Grantville, the benefits that apply to the site include improvements to the leachate process, the development of a biochar production stream, reducing the cost of supplying electricity for the site, and reducing landfill and emissions.

Currently, the leachate process at Grantville begins with the landfill. As water table passes through the landfill, it is trapped by the landfill lining, and then gravity fed into the first leachate pond. In the first pond, the leachate is aerated via pumps to facilitate evaporation. This aeration is shown in Figure 12. The leachate is then pumped from the first pond into an adjacent second pond, where the same sort of evaporation process takes place.



Figure 12. Leachate aeration at Grantville facility.

This transfer station and leachate processes run on diesel-powered pumps because the site is not connected to the main electrical grid. Grantville uses approximately 1,000-1,200 L of diesel per week. This implies they spend between \$1,500 and \$1,800 AUD per week on diesel, assuming that the price of diesel is between \$1.50 and \$1.80 AUD per liter. If they were to use the electricity produced from Capricorn Power's Barton engine instead, Grantville would save between \$78,000 and \$93,600 AUD a year. Additionally, the Barton engine produces low-grade heat at a temperature of approximately 100 °C. This waste heat can be piped to the leachate ponds to facilitate evaporation. The low grade heat could also be used to expedite the drying process of the biomass feedstock before pyrolysis. The biochar produced could be utilised to accelerate the leachate process further, by using it to filter contaminants.

Biochar has a number of other useful applications on-site. First, the production of biochar diverts woody waste from landfill. However, there is an issue involved with utilising the woody waste. Under the current system at the site, contaminated wood waste, such as wood treated with copper chrome arsenic (CCA), is dumped into the same pile as non-contaminated waste wood. Contaminated wood cannot be processed into biochar. Since sorting the wood from the pile would be difficult and expensive for ACE, it is suggested that the transfer station customers sort the wood themselves upon tipping. This could be incentivised by offering a reduced fee for dumping if a consumer sorts the wood, or a fine could be levied for those who do not. Once this issue is overcome, the cleanly produced biochar can be used to cap the landfill or used in the leachate process as discussed. The biochar could also be sold in bulk to regional consumers. The Grantville site is near a sand quarry (Figure 13) that ships its sand to Melbourne to make concrete. Currently, fly ash is mixed with the sand. However, biochar has been shown to increase the 90-day strength and reduces the net carbon effect of concrete (Gupta, Wei Kua, Jun Koh, 2017). Therefore, biochar can be sold to Holcim. There are also many farms, olive groves, and vineyards that

could use the biochar as a soil amendment. Biochar offers a diverse array of customers for Grantville, as evidenced by the 50 uses outlined in Appendix A.



Figure 13. Holcim sand quarry

The main benefit to the facility, as expressed by ACE, is the on-site electricity production. Currently, the site is not connected to the electrical grid. Their electrical power needs are met with diesel generators as shown in Figure 14. With the introduction of the Barton engine, the site would gain access to 415v, 3 phase power, provided by the waste heat of the pyrolysis unit and flared methane. This will drastically reduce the amount of diesel used, and reduce operating costs for the facility.



Figure 14. One of many diesel generators in operation at the Grantville facility.

6. Next Steps

6.1 Step 1: Building a Commercial Input-Output Model

As an investor, the Grantville facility must understand how a given input, such as woody and green waste, will be converted into products, such as biochar and heat. Figure 15 shows the targeted inputs with their respective subdivisions and byproducts.

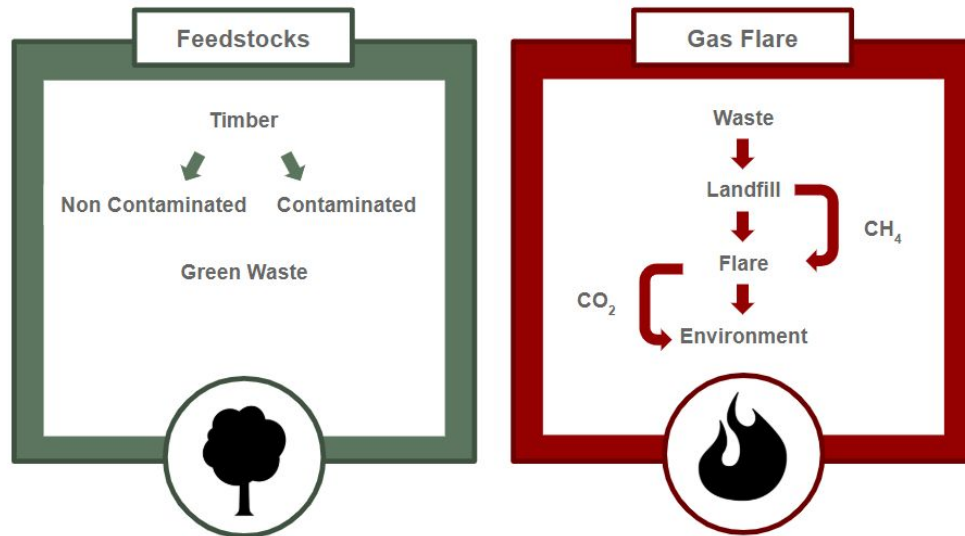


Figure 15. Inputs for Grantville facility biocluster.

Within the woody waste category, Grantville has both non-contaminated and contaminated wood. Currently, they are mixed together in the same pile. However, if they were to start using timber as a feedstock, the waste would need to be separated into two piles. This is because contaminated wood waste cannot be used to produce biochar.

Using green and non-contaminated woody waste as feedstocks for pyrolysis can also reduce, or eliminate, the need for diesel to operate the site. The medium and high-grade heat generated from the pyrolysis unit can be used in the Barton engine to produce electricity. One use for this electricity is to be used to power the pumps for the leachate pond. By using the electricity from the Barton engine instead, Grantville saves money that they would spend on diesel, while also reducing emissions. This also opens the opportunity for the site to generate extra revenue through ACCUs.

6.2 Step 2: Assessing Other Feedstock Opportunities

After establishing the viability of woody and green waste as feedstocks, Grantville can begin to explore other sources of biomass. This would allow more biochar to be produced, and thereby generate more revenue. One way to investigate other biomass sources is by developing a regional horticulture waste survey. When we visited the landfill, we noticed there were vineyards nearby that could provide waste, such as grape marc. Grantville can also look into other horticultural biomass that can be used as feedstock because the agricultural sector is significant in Gippsland. This could include olive pips, straw pellets, and paper pellets. Grape marc, in particular, has been found to produce a larger percent yield of biochar as a feedstock in slow pyrolysis compared to agricultural biomass, with a 40% biochar yield (Khiari & Jeguirim, 2018). This can be attributed to grape marc's high lignin content.

Another feedstock opportunity Grantville can explore is greenhouse biomass waste. The majority of this waste is food waste, since greenhouses mostly produce vegetables and fruit. Emissions from food waste generate more emissions than most countries do individually (Food and Agriculture Organization of the United Nations, n.d.). Additionally, growing crops in a greenhouse is a more carbon-intensive means of production because the greenhouses are artificially heated. This leads to more emissions. Reducing their emissions by pyrolysing their waste could provide them biochar to use as a soil substrate, and a chance to generate revenue with ACCUs.

The last relevant feedstock Grantville can investigate is biosolids. Biosolids are a by-product of wastewater treatment processes. It was found that using biosolids as a feedstock led to a biochar yield between 43% to 64%, depending on the temperature the pyrolysis was occurring at (McNamara, Koch, Liu, & Zitomer, 2016). This represents a very high conversion rate compared to other feedstocks. Increasing the temperature from 300 degrees Celsius to 500 degrees Celsius led to a large reduction in the biochar yield, but a temperature increase beyond that did not affect the biochar yield as much.

6.3 Step 3: Assessing Other Biocluster Options and Education Demonstrations

Dependent on the success of the first two steps, Grantville can expand production by incorporating other feedstocks. One possible way they can do this is by assessing the potential for an algae-based system on, or near, the site that can provide quality feedstock for high-value product streams, such as biodiesel and bioceuticals. Research has shown that microalgae can produce from 5,000 to 15,000 gallons of biodiesel per year per acre in an open pond culture system (Bhowmick, Sarmah, & Sen, 2019). This shows great potential for Grantville to produce another value-added product, along with biochar, that can be both environmentally and economically beneficial.

Grantville can also provide educational demonstrations about the benefits of clusters and renewable energy for the employees at the facility. Many Grantville employees lack knowledge on the benefits a biocluster at Grantville could provide. With these

demonstrations, the employees would gain a better understanding of how this biocluster would help the facility, both environmentally and economically.

6.4 Proposal for a Gippsland Bioenergy/Biocluster Network

The biocluster proposition at the Grantville waste transfer and landfill facility is meant to be a template for future biocluster projects. Critically, the case study at Grantville demonstrates the scalability of a biocluster project in Gippsland. Implementing a biocluster elsewhere in Gippsland will require a similar set of steps to the process applied at Grantville. The steps are as follows:

1. Build a commercial input-output model
2. Assess other feedstock opportunities
3. Assess other biocluster options and education demonstrations

Naturally, there are nuances to the steps shown above that depend on the given biocluster site. Before a commercial model can be developed, a team of experts and consultants that share the goal of creating good and sustainable business through bioclustering should be assembled. Projects can quickly be derailed by a lack of communication. It is imperative that ample research be performed with regards to biocluster development to ensure that no resources are wasted over the course of the project.

7. Acknowledgements

We would like to give a huge thank you to everyone who has helped us along our journey. Firstly, we want to acknowledge Peter Young, John Lawrence, and Rowan Doyle for being fantastic sponsors and mentors. Under your guidance, we have learned so much through this process, and the experience will shape our careers and lives to come. We also want to offer a big thanks to our advisors, Professors Lorraine Higgins and Lindsay Davis. They have helped us learn and develop skills that will serve us throughout our education and work experiences. Lastly, we would like to express our gratitude to all of the individuals and organizations for their help and support throughout this project:

- Snow River Innovation (SRI) - Sponsor
 - Geoff Andrews
 - John MacDonald
 - Steve Ingrouille
- Gippsland Climate Change Network (GCCN) - Sponsor
- Capricorn Power:
 - Mike Hodgkinson
 - Lyn George
 - Noel Barton
 - Shaun Scallan
 - Ross George
- ACE Contractors
 - Trevor Ryan
 - Stefan Willemse
 - Graham Cock
 - Omro Alansari
- Tom Miles
- Heidi Lee
- Nigel Murphy
- James Joyce
- Peter Burgess
- Jennifer Gregory
- Australian New Zealand Biochar Initiative (ANZBI)

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9. Appendices

9.1 Appendix A: 50 Uses of Biochar

<p><u>Biochar in Animal Farming</u></p> <ul style="list-style-type: none">● Silage agent● Feed Additive/supplement● Litter additive● Slurry Treatment● Manure composting● Water treatment in fish farming
<p><u>Use as a Soil Conditioner</u></p> <ul style="list-style-type: none">● Carbon fertilizer● Compost● Substitute for peat in potting soil● Plant protection● Compensatory fertilizer for trace elements
<p><u>Use in the Building Sector</u></p> <ul style="list-style-type: none">● Insulation● Air decontamination● Decontamination of earth foundations● Humidity regulation● Protection against electromagnetic radiation
<p><u>Decontamination</u></p> <ul style="list-style-type: none">● Soil additive for soil remediation● Soil substrates● A barrier preventing pesticides getting into surface water● Treating pond and lake water
<p><u>Biogas Production</u></p> <ul style="list-style-type: none">● Biomass additive● Biogas slurry treatment
<p><u>Treatment of Waste Water</u></p> <ul style="list-style-type: none">● Active carbon filter● Pre-rinsing additive● Soil substrate for organic plant beds● Composting toilets
<p><u>Treatment of Drinking Water</u></p> <ul style="list-style-type: none">● Micro-filters● Macro-filters in developing countries

Divers other Uses

- Exhaust filters
 - Controlling emissions
 - Room air filters
- Industrial materials
 - Carbon fibres
 - Plastics
- Metal reduction (metallurgy)
- Cosmetics
 - Soaps
 - Skin-cream
 - Therapeutic bath additives
- Paints and Colouring
 - Food colourants
 - Industrial paints
- Energy Production
 - Pellets
 - Substitute for lignite
- Medicines
 - detoxification
 - Carrier for active pharmaceutical ingredients

Textiles

- Fabric additive for functional underwear
- Thermal insulation for functional clothing
- Deodorant for shoe soles

Wellness

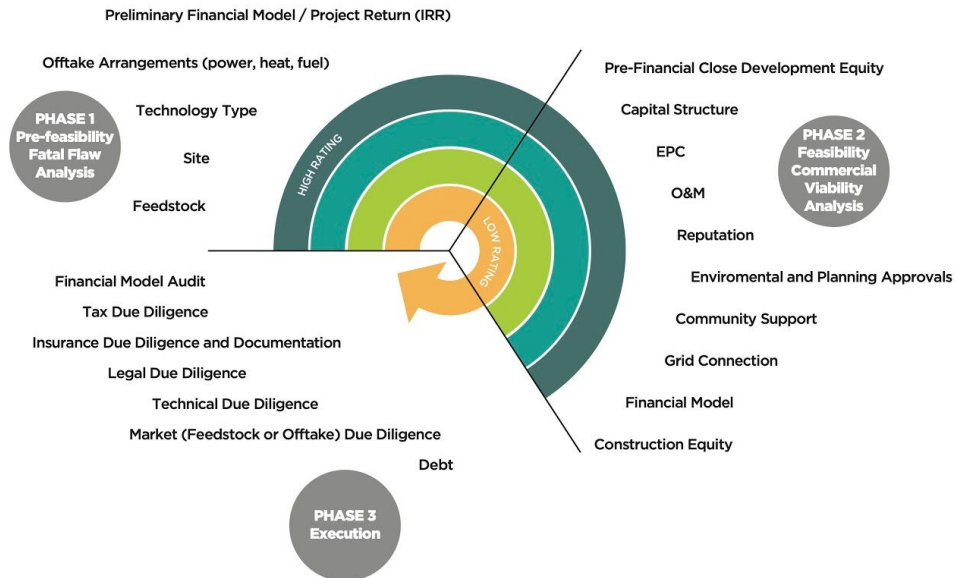
- Filling for mattresses
- Filling for pillows
- Shield against electromagnetic radiation

Source: <http://www.ithaka-journal.net/55-anwendungen-von-pflanzenkohle?lang=en>

Schmidt P. (2012). 55 Uses of Biochar. Ithaka Journal. Retrieved from <http://www.ithaka-journal.net/druckversionen/e082012-55-uses-of-bc.pdf>

9.2 Appendix B: Bioenergy Project Self-Assessment Tool

BIOENERGY PROJECT SELF - ASSESSMENT TOOL



BIOENERGY PROJECT SELF - ASSESSMENT TOOL



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 asset	<p>Feedstock type identified but either</p> <ul style="list-style-type: none"> supplier(s) not identified, or supplier(s) identified but principles of supply not discussed or agreed with supplier(s). <p>If it is unlikely that all the feedstock supply can be contracted by Financial Close</p> <ul style="list-style-type: none"> 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 TOOL



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	<p>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.</p> <p>For other outputs (e.g. RDF, liquid fuels, wood pellets, biogas) there are no offtakers identified and/or no offtake agreements in place.</p>	<p>Offtake arrangement has been decided (e.g. export to the grid and/or third party power sales under contract) for all output.</p> <p>For any contractual sales:</p> <ul style="list-style-type: none"> 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 TOOL



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.

BIOENERGY PROJECT SELF - ASSESSMENT TOOL



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).

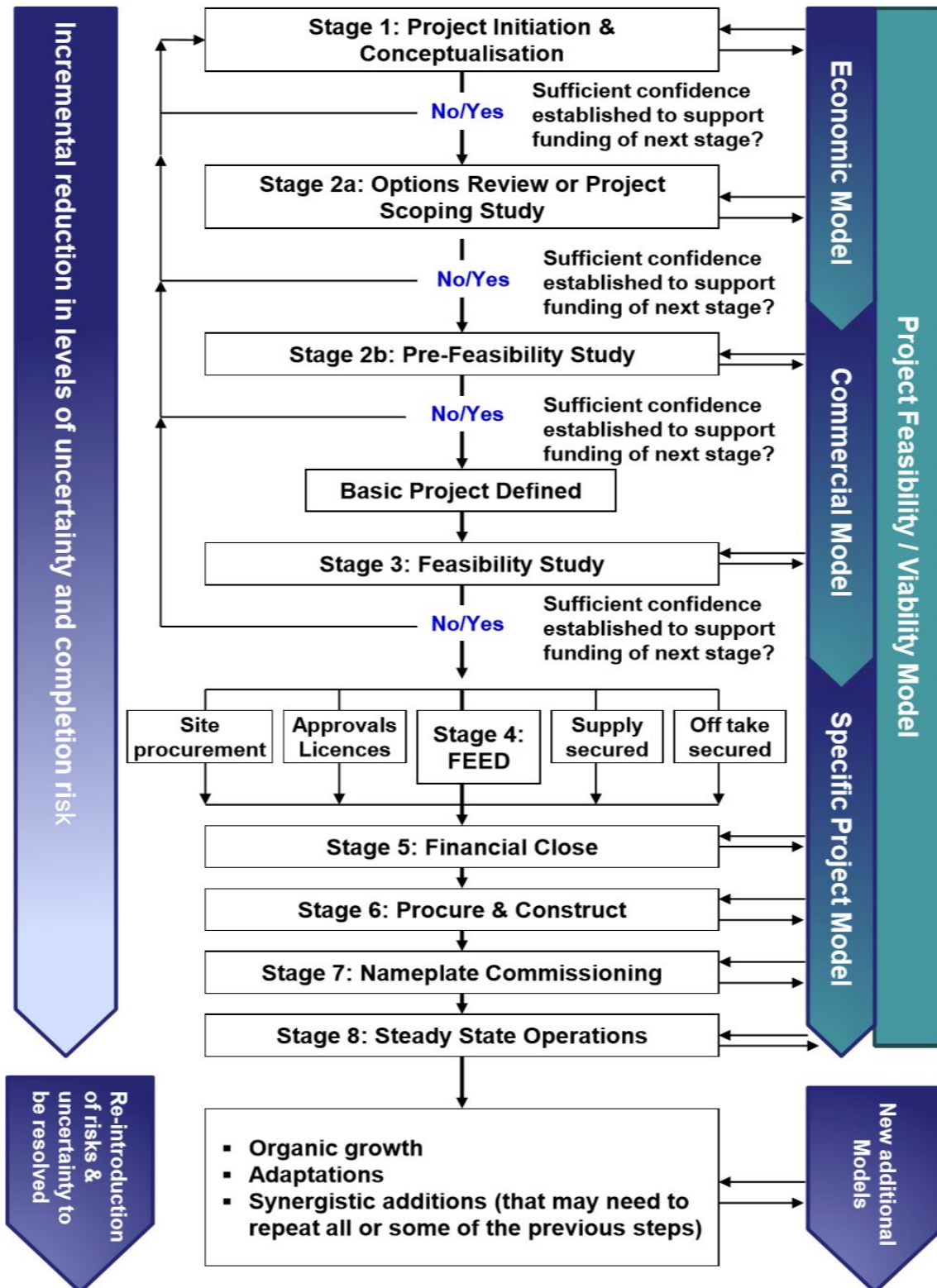
BIOENERGY PROJECT SELF - ASSESSMENT TOOL



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 Australia. (n.d.). RESOURCES: Bioenergy assessment tool. Retrieved from <https://www.bioenergyaustralia.org.au/resources/>

9.3 Appendix C: Blue Poles Project Feasibility/Viability Model



9.4 Appendix D: Overview of Pyrocal's Pyrolysis System

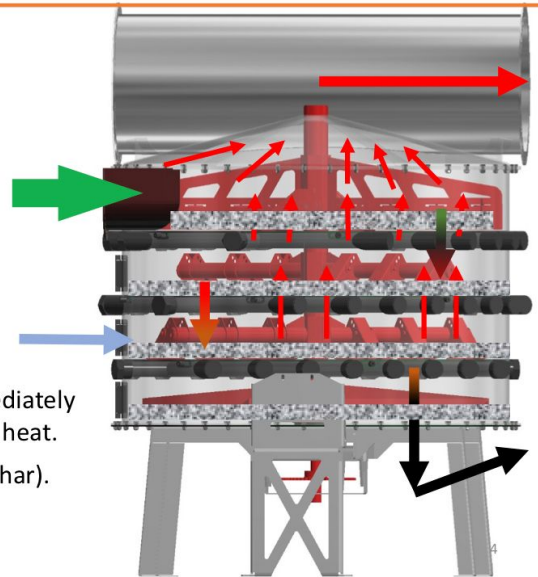
How does Pyrocal CCT work ?

Autothermal Process

1. Biomass is continuously transported downwards through multiple hearth chambers
2. Burning volatiles rise upwards to heat the biomass in seconds, by direct contact.
3. After 3 stages & ~100 seconds char is discharged & cooled.

Results in the production of:

- combustible volatiles (off-gases) that are immediately oxidised to a clean source of high temperature heat.
- a stable & highly porous carbon rich product (char).

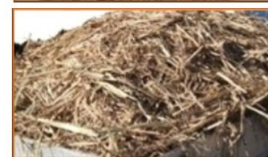


PYROCAL
PTY LTD

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Key features of CCT ?

- Emissions compliance
 - Robust thermal oxidation and wet scrubber emissions controls
- Low Installed Cost
 - Minimal site works required
 - Readily relocatable
- Accept Many Biomass Residues
 - green waste, cotton gin trash, rice hull, almond hull, grape marc, food wastes, sugarcane trash, rice straw, biosolids
- Generate Low Cost Heat
- Produce Low Cost char
- Can run for long periods unattended

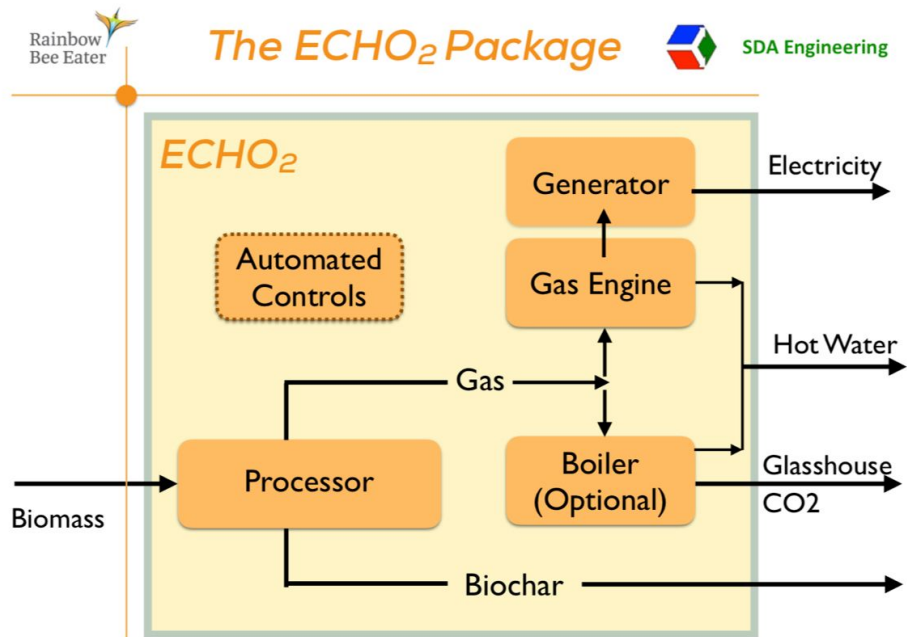


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9.5 Appendix E: Overview of Rainbow Bee Eater's Pyrolysis System



ECHO₂ module indicative specs

hot water	400 - 800	kWt
electricity	100 - 250	kWe
biochar	~ 200	kg/hr wet basis
CO ₂	~ 250	kg/hr (Boiler Option)
biomass	500 - 600	kg/hr@15-25% moisture nominal 5 - 20mm, clean
footprint ~10m x 10m		

Single module. Specs are subject to biomass characteristics and an engineering study of customer requirements. ECHO₂ comes with a warranty and a service agreement.

what biomass can be used?

clean, particles, ~ 5mm to 25mm, ~ 5 to 55% moisture

tested OK	not tested believe OK	need testing to know
hardwood	pips	rice hulls (dust?)
softwood	nut shells	others?
straw	grape vines & marc	
tomato vines/ wood chip mix	bagasse	
green waste	poultry bedding	



9.6 Appendix F: Overview of Earth System's Pyrolysis System



CharMaker MPP
mobile pyrolysis plant 

Conversion of Waste Wood to Biochar

A core expertise of Earth Systems is the development and application of technology for the pyrolytic conversion of biomass to energy and other useful solid and liquid products. The mobile batch pyrolysis furnace, the CharMaker MPP, has been designed, manufactured and patented by Earth Systems to convert woody biomass waste to a high-value biochar product on site.

Earth Systems has developed a new mobile pyrolysis plant (MPP) technology that allows biomass to be converted on-site into high-value biochar products.

Pyrolysis is the high-temperature treatment of woody waste in a low-oxygen environment to produce a special form of char known as biochar, which has a variety of valuable applications.

The mobile pyrolysis plant has a shipping container form factor for simple integration with standard transport methods, making it possible to access stockpiles of woody biomass that would otherwise have required removal and transport for disposal or conversion.

The technology is particularly useful for the treatment of invasive pest tree and plant species, providing a method of complete destruction with minimal risk of spread. A sophisticated thermal oxidiser arrangement also makes the technology suitable for contaminated biomass sources where contaminants can be volatilised and destroyed in the high-temperature afterburner flue system. The MPP units can also be deployed in batteries with a bolt-on bio-liquids recovery system for a longer-term fixed bioenergy hub arrangement.



- Global remote connectivity via smart phone and computer.
- Designed for farm and forestry machinery operation.
- High thermal energy output with capacity for high-grade heat export to industrial processes.
- Bolt on bio-liquids recovery plant also available for pyrolygneous liquids (wood vinegar/smoke water) and bio-oil.

KEY FEATURES OF THE MOBILE PYROLYSIS PLANT

- Internationally patented technology based on a novel and rapid pyrolysis process for large-sized woody biomass.
- Easily transportable unit with access to most remote areas.
- Batch processing with 13 and 30 m³ internal volume per batch for the MPP20 and MPP40 units.
- Pyrolysis converts biomass to 1–2.5 tonnes of biochar per batch.
- Processes all larger wood feedstocks, including logs. Minimal feedstock pre-treatment is required (no chipping required).
- Batch processing takes a few hours (normally 4–6 hrs per batch)
- Targeted temperature range can be selected (300–550 °C).
- Destruction of all pathogens.
- High-quality char product with a very high fixed carbon content.
- Very low to zero smoke emissions.
- Minimal operating costs: unit operates itself after loading with auto-turn off at end of run, and can be operated unattended.

RECENT APPLICATIONS

- Conversion of waste willow wood to biochar for waste management as part of an Australian government waterways program.
- Conversion of industrial hardwood flooring to saleable char for a government authority in Australia.
- Safe destruction of contaminated wood products for a major Australian industrial.
- Demonstrations for farming and agricultural use across Australia.

KEY BENEFITS OF BIOMASS TO BIOCHAR CONVERSION

- Reduce waste volumes by up to 90%.
- Carbon is locked in stable biochar to reduce CO₂ emissions.
- Depending on feedstock, biochar may be suitable for resale as agricultural, horticultural or activated charcoal.

For more information: www.esenergy.com.au



What is Biochar?

Biochar is produced from biomass (typically plant matter), and has received much interest for its potential uses in improving soil properties and for capturing and storing carbon. Potential benefits include improved nutrient and water retention, reduced soil acidity, increased cation exchange capacity, and increased habitat for beneficial soil microbes.

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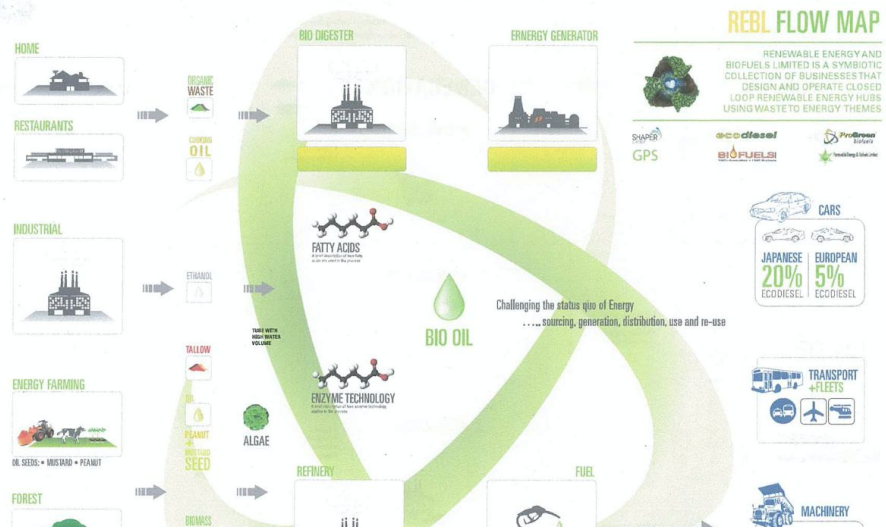
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9.7 Appendix G: List of Potential Biocluster Locations Formulated by GCCN

- Alberton
- Bairnsdale
- East Gippsland
- Heyfield
- Latrobe City
- Maffra
- Mirboo North
- Morwell
- Orbost
- Traralgon
- Warragul
- Yallourn
- Yarragon
- Yarram
- Yinnar

9.7 Appendix H: Rebl Flow Map Case Study (Sharper Group)

CASE STUDY - REGIONAL BIO-ENERGY HUB EXAMPLE



BIO-ENERGY HUB FLOW CHART

Challenging the status quo of Energy supply, generation, and use

Renewable Energy and Biofuels Limited is a symbiotic collection of businesses that design and operate closed loop renewable energy hubs using waste to energy themes

KEY FEATURES

- POSITIVE BRAND BENEFITS
- REDUCE EXPOSURE TO FUEL PRICES
- IMPROVED COMMUNITY RELATIONS
- IMPROVED GOVERNMENT RELATIONS

