Treated Timber Waste Minimisation Project

Milestone 3.1: Potential Scenarios

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MINISTRY FOR THE ENVIRONMENT
WASTE MINIMISATION FUND PROJECT

TREATED TIMBER WASTE MINIMISATION

MILESTONE 3.1: POTENTIAL SCENARIOS

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AUGUST 2013

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1.0 EXECUTIVE SUMMARY

The focus of Milestone 3 has been on working with each solution provider to develop their business case, articulate their business model and prepare initial financial projections. Responses were sought from:

- Waste Transformationz Limited (pyrolysis to create biofuels and charcoal)
- Holcim Cement Limited (cement kiln fuel and torrefaction to create cement kiln fuel)
- Solvent Rescue Limited (hydrothermal processing to create biofuels)
- Scion Research (TERAX wet oxidation/biological process to create saleable acetic acid)

Part way through Milestone 3 another pyrolysis company, AES Bioenergy, requested permission to participate in the project and, given the potential of pyrolysis as a solution and the distinctiveness of AES' approach, the project governance group allowed their participation. Late in Milestone 3 Holcim Cement publically announced their intention to close the Westport Cement Plant, effectively removing their option from consideration. Each of the remaining four solution providers has provided broad financial information and a risk profile has been built based on development, strategic and marketing plans and progress to date. From an economic perspective, the options can be compared as follows:

Table 1.1 – Financial Overview of Solutions

Description	SR*	TERAX*	WTL*	AES*
Expected capital outlay for solution	78,000,000	11,250,000	4,000,000	7,250,000
Expected grant/public funding (e.g. MFE)	7,750,000	3,000,000	1,500,000	2,375,000
Subsidised capital cost	**70,250,000**	**8,250,000**	**2,500,000**	**4,875,000**
Expected lifespan of solution equipment (years)	25	20	9	15
Amount of wood (all types) inputted per day (tonnes)	88	143	150	30
Days solution would operate each year	336	350	300	350
Volume of wood processed per year (tonnes)	**29,600**	**50,000**	**45,000**	**10,500**
Volume of wood processed over lifespan (tonnes)	**768,000**	**999,999**	**382,500**	**157,500**
Funding per tonne of wood processed over lifespan	**10.10**	**3.00**	**3.92**	**15.08**
Annual volume of saleable outputs (tonnes)	15,072	6,325	35,100	5,224
Saleable outputs revenue per tonne of wood processed	554	106	314	160
Expected revenue from treated timber (per tonne)	45	60	70	70
Total revenue per tonne of wood processed	**599**	**166**	**384**	**237**
Fixed costs per tonne of wood processed	70	5	27	49
Processing costs per tonne of wood processed	23	137	45	34
Transportation costs per tonne of wood processed	70	0	129	0
Waste processing costs per tonne of wood processed	18	12	4	6
Total expenditure per tonne of wood processed	**179**	**154**	**205**	**90**
Profit per tonne of wood processed	**420**	**13**	**178**	**147**
Annual profit	**14,043,600**	**654,999**	**8,024,375**	**1,542,925**
Total profit over lifespan of solution	**405,658,000**	**13,099,982**	**76,488,875**	**23,143,875**
Annual return on subsidised capital investment*	**20%**	**8%**	**321%**	**32%**
Total lifetime return on subsidised capital investment*	**577%**	**159%**	**3,060%**	**475%**

* Estimates have been prepared by solution provider, but altered where there is a clear justification for doing so. Further testing and validation of estimates will be undertaken in Milestones 4 and 5. For this comparison, the average of pessimistic and optimistic estimates has been used. Returns are calculated as simply the net return divided by the subsidised capital cost. Green indicates 'best result' in key category, whereas red indicates 'worst result'.

Of the four options, only Solvent Rescue has actually tested treated timber through its process and its results were inconclusive, but encouraging. This is the primary risk for each of the options. If they cannot successfully process treated timber waste at varying concentrations and produce uncontaminated, saleable outputs, they will not be feasible as a solution provider for this project. The emphasis in Milestones 4 and 5 is for each provider to undertake testing of treated timber through its process and provide verified results that demonstrate a feasible solution for such waste.

Each of the solutions, beyond the common risk around treatment chemical deportment, has a different risk profile but all have weaknesses that require further investigation and/or development.

Solvent Rescue is a small company with limited resources aiming to derive much of its revenue stream from lignin, which is a product with an emerging and uncertain market. Solvent Rescue's hydrothermal processing system is a high capital cost solution, but one that can potentially generate substantial revenue if targeted output markets can be successfully engaged. Solvent Rescue's ability to fund and commercialise its technology development is a key risk.

Scion has a strong record as a technology innovator and has developed a technology, TERAX, which has been backed by both central and local government in Rotorua. Yet Scion is planning to license, rather than operate, the technology, and the potential revenue streams from the methane it will produce are uncertain. The application with the most market interest, being methane to boost the Burwood landfill gas pipeline, appears economically unattractive. The most economically promising market, being methane as a transport fuel, requires large up-front capital investment for a user to convert vehicle fleets, and no willing end user has yet been identified.

Waste Transformationz Limited has extensive experience in producing carbon-based products and is targeting high-value outputs such as activated carbon and carbon black, with charcoal boiler fuel as a 'fall-back' contingency. The challenges in successfully supplying to these markets may be underestimated currently, and the production of consistently high quality outputs may take time and investment to achieve. The potential applications of these high value outputs, particularly activated carbon, appears incompatible with even the remote possibility of treatment chemical contamination. For this reason, convincing customers to purchase WTL's products may prove difficult.

AES Bioenergy, having engaged with this project partway through Milestone 3, is not yet as well understood as the other providers. Utilising a different form of pyrolysis to Waste Transformationz Limited, AES is focused on producing bio-oil as an alternative to heavy marine fuel for use in large ships. AES' solution is expensive and it requires relatively large public funding for relatively low processing volumes, but the presence of a potential customer is encouraging. In addition to proving that their process will be able to handle treated timber, AES will also need to establish that they can produce fuel at a price and quality specification that will keep their prospective customer engaged.

As yet, no obvious preferred option has emerged, particularly with the departure of Holcim Cement. It is expected that the upcoming testing of treated timber as a feedstock that each of the potential providers is undertaking will provide strong evidence as to the feasibility, or lack thereof, of the solutions.

2.0 INTRODUCTION

The Treated Timber Waste Minimisation project was launched on 4 March, 2013 with its overall goal being "to test the feasibility of, and subsequently develop a sustainable business model for the large scale collection and reuse, recycling and/or recovery of hazardous treated timber waste, with a particular focus on earthquake-related building and demolition waste."

This Environment Canterbury led project has received Ministry for the Environment funding of $144,900 towards the project's overall cost of $190,900, with the remainder coming from the project's governance group, consisting of:

- Environment Canterbury (ECAN) – Project owner
- Christchurch City Council (on behalf of the Canterbury Waste Joint Committee)
- BRANZ Limited
- Scion Research

The feasibility study has three key objectives:

- Identify and/or create a business case, supply chain and financial model, and end use for the collection, reuse, recycling and recovery of up to 20% (5,000 tonnes) of waste treated timber in Canterbury in such a way that it presents compelling economic and/or brand benefits to all participants in the supply chain (waste owners, processors, logistics providers and end users).

- Identify an appropriate, effective, easy to use and low-cost tool to be used by demolition companies and/or waste processors[1] for identifying treated timber on demolition and/or waste processing sites[2].

- Increase collaboration between timber waste minimisation stakeholders including demolition, timber and waste industries, Environment Canterbury, Canterbury territorial authorities, construction interest groups and the wider community to improve waste minimisation management of treated timber over its lifecycle.

Overall, the project is aimed at creating a sustainable and economically viable process or processes for the productive use of waste treated timber.

The project has been split into five key milestones:

1. **Industry Overview** (completed 10 May, 2013)

   A situation analysis and overview of the current waste treated timber industry and potential applications for treated timber waste.

2. **International Industry Trends** (completed 14 June, 2013)

   An overview of key international trends and technological developments in the waste treated timber industry internationally and how the application of different elements of these might work in New Zealand.

[1] Target users are demolition workers, transfer station workers, builders and surveyors
[2] Primarily it would be used on the demolition site, but could also be used at transfer stations, landfills and re-use locations.

3. **Part 1 – Potential Scenarios** (due 16 August, 2013)

   A report detailing potential new waste treated timber collection and reuse, recycling and/or recovery systems for application in New Zealand, and the risks, financial implications and potential benefits of each scenario.

   Part 2 - Timber Identification Tool Development (due 16 August, 2013)

   A report providing an overview of international research related to waste treated timber identification on demolition and/or waste processing sites and undertake a feasibility study on the application of this research to create a tool or toolkit suitable for use in New Zealand.

4. **Detailed Business Cases and Stakeholder Collaboration** (due 4 October, 2013)

   Detailed business cases for each preferred scenario, including pilot trial plans.

5. **Pilot Trials** (due 20 December, 2013)

   A final report detailing pilot processes and outcomes, and scenario details and implementation plan for the preferred option or options.

This report addresses the requirements of Part 1 of the third milestone 'Potential Scenarios' which are to:

- Analyse and apply collected data from Milestones 1 and 2 to build potential scenarios for implementing scaled-up systems for the collection, reuse/recycling/recovery and end use of waste treated timber in Christchurch.
- Undertake risk analyses on potential scenarios, including any potential environmental risks.
- Build broad supply chain and financial models for each scenario based on stated assumptions and risks and undertake initial feasibility analysis for each scenario.
- Revise projected reuse/recycling/ recovery target volumes (20% of total waste treated timber) and provide an estimate of total treated timber which is recyclable.

At the conclusion of Milestone 1, five potentially feasible options for utilising treated timber waste were determined, namely:

- Using pyrolysis to create biofuels and charcoal (Waste Transformationz Limited)
- Using torrefaction to create cement kiln fuel (Holcim Cement Limited)
- Using unprocessed (but ground) treated timber as cement kiln fuel (Holcim Cement Limited)
- Using hydrothermal processing to create biofuels (Solvent Rescue Limited)
- Using the TERAX process to create saleable acetic acid (Scion Research)

Subsequently a second company, AES Bioenergy, has identified itself as having a well-developed pyrolysis process that also has potential for utilising treated wood waste. Following agreement from the project governance group, and for the sake of a robust and complete analysis, AES Bioenergy's solution is also considered in this report.

All figures in this report are in New Zealand Dollars. Where converted from United States Dollars, a rate of US$0.80 to NZ$1.00 has been used.

3.0 TARGET VOLUMES REVISION

In Milestone 1 of this project the different sources of treated timber in Christchurch were estimated to give the following overall treated timber volumes over the next fifteen years:

Table 3.1 – Total Estimated Treated Timber Flows in Christchurch (2013 – 2028)

Waste Source	Approx. Expected Tonnage (per annum)	Approx. Expected Tonnage (15 year total)
Earthquake-related demolition	1,600 *	24,000
Earthquake-related residential construction	1,600	24,000
Earthquake-related commercial construction	150	2,250
Non-earthquake-related activity	13,500	202,500
Totals	**16,850**	**252,750**

* Assuming the stockpile is used evenly over the fifteen year period

Based on this estimate, the project target of reuse, recycling or recovery of 20% of treated timber volume would equate to 3,370 tonnes per annum.

As the project has progressed, it has become clear that the first stream, earthquake-related demolition waste treated timber, is unlikely to be a viable source of wood for processing through the options being considered, with the possible exception of Waste Transformationz Limited's solution. If no economically attractive disposal/recovery option is available to Transwaste for this stockpile, it is most likely that it will be buried in a specially created cell at Burwood Landfill with the intention of mining at a later date for recovery of the wood waste.

The business models for each of the options being evaluated in this project for processing of waste treated timber include a reliance on 'gate fee' revenue for receipt of waste wood. This gate fee would be pegged against the cost of the only other available option for treated timber wood waste, being landfill. Landfill gate fees for treated timber are typically in excess of $100 per tonne, so a gate fee of between $50 and $80 for receiving waste wood offers a strong revenue source for processors and is a compelling proposition for waste owners looking to reduce costs.

Given the volumes of wood waste from sources other than the 'stockpile' it would make little sense for processors to accept a large volume of waste wood at a substantially reduced gate fee, and most of the processors have in fact already specifically excluded this option. Waste Transformationz Limited has said that, should they be successful early in their development with accessing high value markets, processing this stockpile is 'a possibility'.

Unless Waste Transformationz Limited (or some other unknown operator) is willing to process the stockpile waste, it appears most likely that the waste treated timber at Burwood Resource Recovery Park will be landfilled and not immediately utilised in a productive manner. It may also be reasonably assumed that the probability of a processor subsequently incurring substantial cost to 'mine' and remove contaminants from the landfilled waste wood is very low.

This situation may not have a significant effect on treated timber waste volumes, however. The work undertaken by BRANZ on Milestone 3.2 indicates that the Residential Red Zone, which has and will continue to contribute substantially towards the demolition treated timber waste stream, is largely comprised of homes built before 1970. These homes would be built primarily from untreated native timbers. BRANZ's work also suggests that most Christchurch homes are built on foundations made from concrete, rather than treated timber, further reducing the expected volumes of treated timber from demolition.

While there will certainly be substantial volumes of treated timber from new homes that have been demolished, and from decks and fencing in residential demolition areas and commercial buildings, the volume of treated timber from earthquake related demolition may be slightly lower than previously thought. While this appears to somewhat mitigate the probable loss of the existing stockpile as a source of waste treated timber for potential processing, there is not enough data to guide an accurate reconsideration of the previous estimates for this waste source and so the overall estimates from Milestone 1, including the treated timber reuse/recovery/recycling target of 3,370 tonnes per annum, have been retained.

In order to achieve this target an average waste processing volume of 9.2 tonnes of waste treated timber per day would be required. If a processor dilutes waste treated timber with untreated timber or other waste streams to process it, as would be expected, this estimate can be used to calculate the size/throughput of plant required to meet the project target. A process that targets 10% waste treated timber would need to process approximately 100 tonnes of waste per day to achieve the project target. Processes that are able to process higher concentrations of waste treated timber may achieve the target at a smaller scale, or may exceed the target.

In fact, a processing target of 100 tonnes a day has been the baseline communicated to all potential processors since the beginning of the project, and most of the potential solution providers would be able to take concentrations of treated timber well above 10%. Therefore the target of 20% of waste treated timber being reused, recycled or recovered by a solution or solutions identified in this project continues to present as reasonable, and may even be conservative.

4.0 CRITICAL SUCCESS FACTORS

The Critical Success Factors outlined below provide a benchmark against which to measure each potential scenario. The factors describe the desirable attributes for a potential new waste timber reuse, recycling and/or recovery system for Christchurch, and indicate which are most critical in projecting the likely success or failure of a scenario.

The critical success factors are weighted based on the following factors:

- Desirability: How appealing is the success factor in terms of the business model? How advantageous would its presence be to overall success?
- Impact if Not Achieved: How damaging would failure to fulfil the success factor be to the feasibility of the business model in terms of this project?
- Overall Importance: Taking into account the desirability of the success factor and the impact if it is not achieved, how important is the success factor?

Each of the potential scenarios, in terms of risk analysis, is then measured against these critical success factors in terms of:

- Likelihood of Achievement: Based on current information, how likely is it that the required success factor will be fulfilled to the required level?
- Overall Risk: Taking into account potential impacts and likelihood of achievement, what is the current risk presented to the project by the success factor?

Based on the information gathered in the project to date, the following are considered to be the Critical Success Factors for a waste treated timber utilisation business model:

Table 4.1 – Critical Success Factors

Success Factor	Desirability	Impact if Not Achieved	Overall Importance
Process can process both treated and untreated wood – based on Milestone 3.2, sorting of wood is not considered economic	Essential	Failure	Essential
Process can handle all forms of treated timber (including CCA) – determining treatment types is not considered economic	Essential	Failure	Essential
Treatment chemical deportment has been independently verified – independent verification as to where treatment chemicals end up in the process is essential	Essential	Failure	Essential
Process offers competitive return on capital investment (net of any public funding) within the expected lifespan of the technology – the likely need to secure private capital funding for the solution will require a competitive return on investment	Essential	Failure	Essential
Processor has access, or likely access, to capital required to establish and operate a sustainable business – even a solid concept will fail without sufficient financial backing	Essential	Failure	Essential

Success Factor	Desirability	Impact if Not Achieved	Overall Importance
Process gate fees for waste wood offer a discount from landfilling of waste wood (including transportation costs for suppliers) – the scenario must offer a compelling alternative to landfilling of waste wood	Essential	Failure	Essential
Process operates profitably – for the business model to be sustainable it must be profitable as no ongoing subsidies are expected	Essential	Failure	Essential
Process outputs are realistically saleable – revenue-generating outputs from the process must actually be able to generate market demand through a competitive advantage and meet market quality standards	Essential	Failure	Essential
Process output market demand is sustainable over time – output market demand must offer a high likelihood of sustainability over time in order to generate revenue for the process	Essential	Failure	Essential
Process meets air emissions standards – a process that produces air emissions beyond what is permitted will obviously not be lawful	Essential	Failure	Essential
Processor has the required consents to operate, or is likely to be able to obtain these – in terms of resource consenting the provider must be able to demonstrate acceptability to Environment Canterbury and Territorial Authorities	Essential	Failure	Essential
Process waste streams can be safely disposed of – a responsible disposal or processing solution for any waste streams must be demonstrated	Essential	Failure	Essential
Processor has access to an appropriate processing site or the means to secure one – there must be reasonable evidence that such a site is likely to be secured	Essential	Failure	Essential
Process is safe and does not present a high risk of harm to people or the environment – processes that are considered high risk in terms of harm are not considered sustainable	Essential	Failure	Essential
Process recovers energy or otherwise utilises waste wood productively – chemical extraction and/or mass reduction of treated wood waste are starting points but the goal is to productively utilise the wood	High	High	High
Process technology has been proven domestically using treated timber as a feedstock – having processed treated timber under New Zealand conditions, even at pilot scale, is seen as highly desirable	High	High	High
Process can handle treated timber at a range of concentrations - the exact composition of a waste wood feedstock is unlikely to be known so processors must be able to handle differing levels of dilution or be utilising other waste streams to dilute treated timber	High	High	High

Success Factor	Desirability	Impact if Not Achieved	Overall Importance
Processor has ready access to capabilities/skills required including engineering, management, marketing etc. – if such skills are not currently available, the costs of accessing such skills must be built into the process budget	High	High	High
Process can realistically begin operation at commercial scale by end of 2015 – lengthy development timeframes or other lead-in requirements will negatively impact a solution's ability to meet earthquake-related needs in Christchurch	High	Moderate-High	Moderate-High
Process equipment has a lifespan in excess of 15 years – unless the capital expenditure for a process is low, such a lifespan is a reasonable minimum to provide return on private and public investment	High	Moderate-High	Moderate-High
Process outputs are free from treatment chemicals – outputs should not create downstream contamination issues for users to manage	High	Moderate-High	Moderate-High
Process has a high likelihood of public acceptability (i.e. is not likely to attract public opposition) – it is desirable that the solution has a relatively high degree of likely public acceptability based on the location and nature of the process	High	Moderate-High	Moderate-High
Processor has a strong commercial reputation and track record – it is desirable that the processor has strong business acumen and a track record of business success to mitigate implementation risk	High	Moderate	Moderate-High
Process is able to be scaled up economically and can operate at smaller or larger volumes – the ability to scale up over time and to work economically at lower volumes as well as very large volumes is advantageous especially in a single-provider model	High	Moderate	Moderate-High
Process technology has been proven internationally using treated timber as a feedstock – if the technology has not been proven in New Zealand, it will be important that it has successfully been tested internationally with treated timber	High	Moderate	Moderate-High
Process technology is reliable over time and well established – the degree of track-record, reliability and simplicity of the technology is important and novel or first-generation technologies will be considered higher risk	High	Moderate	Moderate-High
Process is located close to feedstocks/suppliers to minimise transportation costs – the more outlying the processor the more likely it is that waste wood will be sent to landfill or that processor gate fees will need to be lowered to compensate suppliers	Moderate-High	Moderate	Moderate
Process outputs are storable, and need not be utilised immediately – outputs that can be stored and transported (such as solid or liquid fuels) offer more market flexibility than outputs which are used immediately such as heat or electricity	Low-Moderate	Moderate	Moderate
Process allows recovery and resale of timber treatment chemicals – resale of treatment chemicals is desirable as it diverts a potentially hazardous waste stream back into reuse	Moderate-High	Low-Moderate	Moderate

Success Factor	Desirability	Impact if Not Achieved	Overall Importance
Process can receive wood without any processing such as chipping – the more robust and flexible the process in terms of feedstock particle size, the better	Moderate	Low-Moderate	Low-Moderate
Process technology can be easily relocated if necessary – the ability to relocate the processing equipment if needs or waste creation activities change is advantageous	Moderate	Low-Moderate	Low-Moderate
Process can handle high degrees of feedstock contamination e.g. silt – waste producers are unlikely to remove any such contamination unless a compelling cost advantage is offered to do so	Moderate	Low-Moderate	Low-Moderate
Process output markets are local, reducing transportation costs - while not essential, local utilisation of process outputs where a sustainable market exists reduces risks such as foreign currency fluctuation	Moderate	Low-Moderate	Low-Moderate
Process set-up requires low or no public funding – a reliance on large volumes of public funding to make a business model feasible is not desirable, but some level of public funding may be appropriate	Moderate	Low-Moderate	Low-Moderate
Process produces, or has the ability to produce, multiple saleable outputs – diverse outputs may mitigate market risk and allow outputs to change if demand decreases	Low-Moderate	Low-Moderate	Low-Moderate
Process requires minimal repairs and maintenance – the process equipment should be as simple and durable as possible to minimise operating costs	Low-Moderate	Low-Moderate	Low-Moderate
Process can handle other 'difficult' waste streams – the ability for the process to handle other priority waste streams (such as tyres) would be seen as advantageous	High	Low	Low-Moderate
Process can handle other waste streams as an alternative feed stock – the ability for the process to handle other waste streams to smooth out fluctuations in supply and/or generate diverse gate fee revenue streams mitigates supply market risk	High	Low	Low-Moderate
Process is likely to stimulate development of technologies which may have a downstream economic benefit for New Zealand – the ability to foster valuable technology that may have international applications would be seen as advantageous	High	Low	Low-Moderate
Process is self-sustaining in terms of operating energy and other inputs – the ability for the process to generate its own process energy minimises operating cost fluctuation risk	Low-Moderate	Low	Low

Due to the complexities around life cycle assessment the processors have not been evaluated in terms of carbon emissions. For this study, it is assumed that the differences in carbon emissions between each process will be negligible.

5.0 SCENARIO ANALYSIS – SOLVENT RESCUE / HYDROTHERMAL PROCESSING

5.1 Scenario Overview

Solvent Rescue began as a processor for dry-cleaning chemicals and other hazardous chemical wastes. As the company has progressed and grown they have explored other opportunities for their technology, including a project with NIWA to convert algae, sewage sludge and seaweed into a bio-crude oil which closely resembles natural fossil-based crude oil. More recently, their attention has turned to a two-stage process to produce valuable outputs from treated wood waste.

The first stage of the process receives chipped wood waste. The lignin (an organic substance that binds the cells in wood together) is extracted as 'black liquor' which has potential market value. Early testing suggests the treatment chemicals will be isolated and extracted within a sludge waste output at this stage. The solvents used in the lignin extraction are recovered and reused and the remaining organic matter, which should be free of contamination, proceeds to the second stage.

The second stage (using a supercritical water reactor) receives the remaining dry matter from the lignin extraction, which is mainly cellulose and hemicellulose, and converts it into bio-crude oil products, water and carbon dioxide.

Solvent Rescue is currently operating a pilot plant on their site just outside of the Christchurch CBD. They have undertaken initial testing on CCA treated timber through their process and, while this was promising, not all of the treatment chemicals could be accounted for and further testing and independent evaluation was required.

In order to develop their technology Solvent Rescue applied for a Ministry for the Environment (MFE) Waste Minimisation Fund grant to build a larger plant (which could process 2 tonnes of wood a day) and to undertake further testing including independent validation of findings. This process has not yet commenced, as MFE has required Solvent Rescue to meet a number of criteria including the engagement of a professional project manager. It is now understood that these criteria have been met and Solvent Rescue expect that funding will now be available and testing can commence shortly. Solvent Rescue director and head developer Chris Bathurst says that testing of CCA treated timber, and independent validation of treatment chemical deportment, should take place within the first few months of their project.

Solvent Rescue's process can potentially produce a number of saleable outputs from treated timber waste, including lignin, marine diesel, naphtha and bitumen. The markets for these products are considered in Section 5.2. Solvent Rescue also intends to charge a gate fee for inwards wood waste, while still offering waste owners a considerable saving over landfill charges. A key requirement for wood supplied is that it be chipped ready for processing. Solvent Rescue do not have the plant to process the wood in this manner, nor do they have on-site facilities for storing wood, so it is probable they would seek to partner with a demolition or waste management company who would receive and process the waste on their behalf and transport it to Solvent Rescue for a fee. The costs involved in this are reflected in the net fee allowed for by Solvent Rescue in their financial projections.

The initial plan by Solvent Rescue, in relation to the larger processing volumes that addressing Christchurch treated timber wastes would require, is to build a 20 tonne a day plant on their existing site and continue to receive wood from a processing partner. As the business gains momentum (and investment) they would scale up the existing plant to a 100 tonne a day plant.

The larger plant would require securing a site further out of Christchurch and lowering their inwards gate fees to compensate waste owners for the costs of delivering waste to a site on the city fringe. The Solvent Rescue technology is designed around scalability and can be added to incrementally without making any preceding capital investment redundant.

5.2 Output Market Analysis

Solvent Rescue has proposed four saleable output markets from its process: lignin, marine diesel, naphtha and bitumen.

Lignin

Figure 5.1 – Lignin 'Black Liquor'

Lignin has a number of potential valuable uses, including as a replacement for plastic in injection moulding, in production of polyurethane foam and, more recently, to produce carbon fibre. However "all these new uses account for only 2% of the generated lignin and the remaining is mostly burnt for energy as low efficient fuel." (TMB, 2012).

Solvent Rescue advise that, in their view, the key to developing a valuable market for lignin is to separate it out with the minimum of damage to the chemical structures. Solvent Rescue expect their process to achieve this.

It is clear that utilising lignin as a boiler fuel, its most common usage, does not generate a high return with a price of about $125 – 250 a tonne. Industry focus is instead on converting lignin into plastics or other higher value outputs.

A leader in this space, German company Tecnaro, created a product called Arboform which was launched in 1998 and is marketed as a 'bioplastic'. Their current production, according to Tecnaro, is 5,000 tonnes per annum although it is noted that their production in 2009 was only 275 tonnes, so either massive growth has occurred or Tecnaro is overstating its production (EIO, 2013). Tecnaro says that Arboform is used for automotive interiors, in construction, in electronics, in furniture making and in most applications where plastic would otherwise be used. The current price for Arboform is $8.31 per kg, which is on the high side compared with regular plastics.

A study undertaken for the US Department of Energy on the potential value of lignin considers the use of lignin in plastics as a 'long-term opportunity' that requires considerable investment over the next ten to twenty years (Holladay et al, 2007). Fuel use is considered the only immediate opportunity, whereas 'macromolecules' including use in carbon fibre, adhesives and resins is considered a 'medium-term opportunity' requiring some technology development over the next five to twenty years. Use in macromolecules is considered to have a 'medium to high' level of difficulty to successfully achieve and a 'medium' market risk. Most other uses are considered highly difficult and with a high market risk. The report repeats the (apparently common) adage that "you can make anything you want out of lignin…except money".

The report also considers that the market value for lignin is difficult to estimate, but states the following in terms of differing potential uses (converted from imperial to metric units):

- Liquid fuels: $0.33 – 1.47 per kg or $0.26 – 1.16 per litre
- Macromolecules: (including adhesives, resins, carbon fibre): $0.56 – 2.84 per kg

Solvent Rescue head Chris Bathurst notes: "while I cannot identify actual products or actual customers due to…confidentiality agreements, I have physically seen actual polyurethane foam items made from lignin we produced in 2007/2008 and which had been valued by a Japanese company at $2.50 per kg for the lignin feedstock. This polyurethane foam had been reputably tested for strength and fire resistance to 200 degrees Celsius in a building standards test."

Solvent Rescue have valued their output lignin (in the Financial Models shown in Section 5.3) at $1.00 – 2.52 per kg. This seems a reasonable estimate in terms of price but realistic demand is currently an unknown.

Scion and others are currently evaluating the potential for lignin to create new products or replace existing ones. Scion reports that its scientists "have their eye on lignin as a potentially valuable candidate" to replace non-renewable resources in uses such as "biofuels, bioplastics, rubber replacements and new materials" (Scion, 2011).

A forestry industry commentator further notes that "addressing markets worth more than $130 billion worldwide, researchers say that lignin from trees could become the main renewable aromatic resource for the chemical industry in the future. The first opportunity could emerge as early as 2015 from the direct substitution of phenol in most of its industrial applications: phenolic resins, surfactants, epoxy resins, adhesives or polyester." (Forestryexpo, 2011).

Overall it would appear, as one writer notes, "scientists like the technical potential for lignin. Note though that the research is being done by academics and governments. The economic availability of lignin as a large scale resource may be a long way off." (TMB, 2012).

This is a key challenge for Solvent Rescue: lignin has huge potential but a limited current demand for high-value uses. This represents a substantial risk to Solvent Rescue as approximately two-thirds of their projected revenue is based on the sale of lignin, and their business model will quickly fail if this revenue is not realised.

In addition, the US Department of Energy report on lignin highlights that quality and consistency are key concerns in lignin extraction (Holladay et al, 2007). Solvent Rescue will need to be able to demonstrate to any potential purchaser that they are able to reliably and consistently meet quality standards.

Marine Diesel

Marine diesel oil, which is commonly used to fuel fishing vessels and smaller boats (as opposed to bunker fuel used for international shipping), is the second largest projected saleable output for Solvent Rescue.

The New Zealand Ministry of Transport tracks marine diesel pricing over time, with current FOB spot pricing at approximately $1,078 per tonne (MOT, 2013). Pricing trends in the spot market are illustrated in the following diagram:

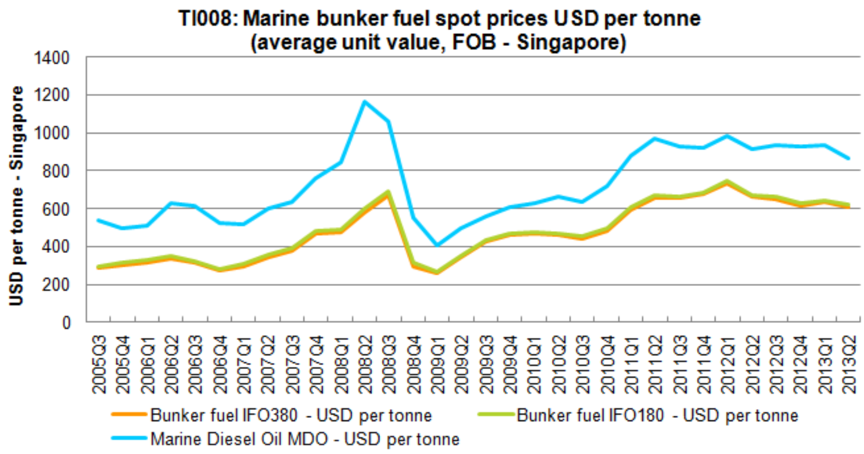

Figure 5.2 – Marine Diesel Pricing 2005 – 2013 (MOT, 2013)

Marine diesel is typically sold at major sea ports by companies such as Z Energy and Caltex, all of which must adhere to strict quality standards as dictated by ISO 8217:2012. The potential damage to marine engines that could be caused by quality issues in fuel (and the resulting liability issues for the fuel supplier) indicates that Solvent Rescue would need to seek compliance with this standard, a potentially lengthy and expensive exercise. The ISO standard requires a range of tests to be conducted including density, sulphur content, oxidation stability and water volume (Intertek, 2013). Solvent Rescue aims to mitigate this risk by ensuring their product is used as an additive to regular supplies at up to 50% of total volume.

In its financial modelling, Solvent Rescue has used a price of $301 – 402 per tonne for marine diesel sales. Based on the information above, this is a very conservative price. In addition, it seems likely that local demand would be strong, particularly at the proposed production volumes (432 – 3,520 tonnes per annum), although users are likely to be locked into supply contracts with existing suppliers, resulting in a likely lag in securing customers.

The biggest challenge in successfully selling marine diesel is likely to be consistently meeting (and being able to demonstrate compliance) with the rigorous quality requirements customers will expect. Achieving ISO accreditation and maintaining a robust testing regime will not be inexpensive activities.

Naphtha

Naphtha is a liquid hydrocarbon similar to petroleum, and is the third saleable output proposed by Solvent Rescue. Naphtha has several uses including lighter fluid, camping stove fuel and chemical feedstock but Solvent Rescue intend to target naphtha as a blending component in the production of petroleum fuel.

Globally, naphtha prices have been extremely volatile in recent months, from $877 per tonne early in the year to $627 per tonne in April and approximately $1,065 currently (Platts, 2013). Very little information is available regarding naphtha use in New Zealand, and Solvent Rescue has not yet identified a specific potential target customer. However, Solvent Rescue advises that their team has successfully trialled using 50% naphtha in their personal vehicles, and would probably target a fuel company such as Z Energy or Caltex as a potential customer to utilise naphtha as a fuel blending agent. Solvent Rescue also advises that testing has been undertaken using a sample of their naphtha in a test engine at the Ruakura race facility. This was identified as having an octane rating of roughly 70% and reportedly had "diesel properties". Despite these encouraging results, overall demand for naphtha as a fuel additive is not yet known.

Solvent Rescue is targeting $600 – 700 per tonne for naphtha sold which may be optimistic given current price volatility. As with marine diesel, the proposed use as a fuel additive will require the naphtha to be of a very high standard, with little room for inconsistency. Further information will be required from Solvent Rescue to determine if naphtha is a realistic saleable output. As with marine fuel, Solvent Rescue aims to mitigate risk by offering naphtha for blending at up to 50% in regular fuel supplies.

Bitumen

Figure 5.3 - Bitumen

Bitumen in New Zealand is largely used for road sealing by companies such as Fulton Hogan and Isaacs. It is supplied by companies such as Z Energy and Delta Corporation, typically as a by-product of the oil-refining process (ZE, 2013). New Zealand's bitumen market is considered fairly static at approximately 165,000 tonnes per annum, with about 75% of this coming from Marsden Point oil refinery (NZLG, 2012).

Bitumen pricing relates closely to fuel oil pricing and follows the same trends. Hence, as petrol becomes more expensive in New Zealand, so does bitumen. Unlike other commodities, there is no standard 'spot price' for bitumen, but it appears to be typically in the $627 – 877 per tonne range, reaching as high as $1,003 in 2008 (Contrafed, 2008).

New Zealand demand appears strong, with product availability a frequent issue as the result of a single tanker servicing all bitumen deliveries from Marsden Point (NZLG, 2012). Although Solvent Rescue projects a bitumen production volume of only 288 – 3,520 tonnes per annum (a maximum of 2% of the domestic market), should the bitumen produced meet the roading industry's high standards, it is likely this supply would be appealing, particularly as roading contractors are often caught with unexpected cost increases due to movements in oil prices, a factor which would not impact Solvent Rescue.

The price range suggested by Solvent Rescue of $500 – 600 appears to be in line with market expectations.

5.3 Financial Model

Solvent Rescue has provided two financial models, one for a plant that operates at 20 tonnes per day, and a second for a plant that operates at 100 tonnes per day.

The financial model for a 20 tonne per day plant is as follows:

Table 5.1 – Solvent Rescue 20 Tonne Plant Financial Projections

Description	Pessimistic Estimate*	Optimistic Estimate*
Capital Expenditure		
Expected capital outlay for solution	28,000,000	24,000,000
Expected grant/public funding (e.g. MFE)	1,000,000	2,000,000
Subsidised capital cost	**27,000,000**	**22,000,000**
Expected lifespan of solution equipment (years)	12	20
Amount of wood (all types) inputted per day (tonnes)	15	20
Days solution would operate each year	320	352
Volume of wood processed per year (tonnes)	**4,800**	**7,040**
Volume of wood processed over lifespan (tonnes)	**57,600**	**140,800**
Revenue		
Lignin revenue (per tonne)	1,000	2,500
Volume of Lignin per tonne of wood processed (tonnes)	0.20	0.25
Annual volume of Lignin (tonnes)	960	1,760
Lignin revenue per tonne of wood processed	**200**	**625**
Marine diesel revenue (per tonne)	300	400
Volume of Marine diesel per tonne of wood processed (tonnes)	0.09	0.10
Annual volume of Marine diesel (tonnes)	432	704
Marine diesel revenue per tonne of wood processed	**27**	**40**
Naphtha revenue (per tonne)	600	700
Volume of Naphtha per tonne of wood processed (tonnes)	0.07	0.12
Annual volume of Naphtha (tonnes)	336	845
Naphtha revenue per tonne of wood processed	**42**	**84**
Bitumen revenue (per tonne)	500	600
Volume of Bitumen per tonne of wood processed (tonnes)	0.06	0.10
Annual volume of Bitumen (tonnes)	288	704
Bitumen revenue per tonne of wood processed	**30**	**60**
Expected revenue from receiving treated timber (per tonne)	50	50
Total revenue per tonne of wood processed	**349**	**859**
Annual volume of saleable outputs from solution (tonnes)	**2,016**	**4,013**
Expenditure		
Fixed costs per tonne of wood processed	183	109
Processing costs per tonne of wood processed	25	20
Inwards/outwards transportation costs per tonne of wood processed	75	65
Waste stream disposal/processing costs per tonne of wood processed	27	8
Total expenditure per tonne of wood processed	**310**	**202**
Summary		
Annual volume of wood processed (tonnes)	**4,800**	**7,040**
Revenue per tonne of wood processed	349	859
Expenditure per tonne of wood processed	310	202
Profit per tonne of wood processed	**39**	**657**
Annual profit	**188,000**	**4,622,640**

Description	Pessimistic Estimate*	Optimistic Estimate*
Total profit over lifespan of solution	**2,256,000**	**92,452,800**
Annual return on subsidised capital investment	**1%**	**21%**
Total return on subsidised capital investment over lifetime	**Less than 0%**	**320%**

* Estimates have been prepared by solution provider, but altered where there is a clear justification for doing so. Further testing and validation of estimates will be undertaken in Milestones 4 and 5.

The financial model for a 100 tonne a day plant is as follows:

Table 5.2 – Solvent Rescue 100 Tonne Plant Financial Projections

Description	Pessimistic Estimate*	Optimistic Estimate*
Capital Expenditure		
Expected capital outlay for solution	84,000,000	72,000,000
Expected grant/public funding (e.g. MFE)	7,000,000	8,500,000
Subsidised capital cost	**77,000,000**	**63,500,000**
Expected lifespan of solution equipment (years)	20	30
Amount of wood (all types) inputted per day (tonnes)	75	100
Days solution would operate each year	320	352
Volume of wood processed per year (tonnes)	**24,000**	**35,200**
Volume of wood processed over lifespan (tonnes)	**480,000**	**1.056,000**
Revenue		
Lignin revenue (per tonne)	1,000	2,500
Volume of Lignin per tonne of wood processed (tonnes)	0.20	0.25
Annual volume of Lignin (tonnes)	4,800	8,800
Lignin revenue per tonne of wood processed	**200**	**625**
Marine diesel revenue (per tonne)	300	400
Volume of Marine diesel per tonne of wood processed (tonnes)	0.09	0.10
Annual volume of Marine diesel (tonnes)	2,160	3,520
Marine diesel revenue per tonne of wood processed	**27**	**40**
Naphtha revenue (per tonne)	600	700
Volume of Naphtha per tonne of wood processed (tonnes)	0.07	0.12
Annual volume of Naphtha (tonnes)	1,680	4,224
Naphtha revenue per tonne of wood processed	**42**	**84**
Bitumen revenue (per tonne)	500	600
Volume of Bitumen per tonne of wood processed (tonnes)	0.06	0.10
Annual volume of Bitumen (tonnes)	1,440	3,520
Bitumen revenue per tonne of wood processed	**30**	**60**
Expected revenue from receiving treated timber (per tonne)	20	45
Total revenue per tonne of wood processed	**344**	**854**
Annual volume of saleable outputs from solution (tonnes)	**10,080**	**20,064**
Expenditure		
Fixed costs per tonne of wood processed	87	52

Description	Pessimistic Estimate*	Optimistic Estimate*
Processing costs per tonne of wood processed	25	20
Inwards/outwards transportation costs per tonne of wood processed	75	65
Waste stream disposal/processing costs per tonne of wood processed	27	8
Total expenditure per tonne of wood processed	**214**	**145**
Summary		
Annual volume of wood processed (tonnes)	**24,000**	**35,200**
Revenue per tonne of wood processed	344	854
Expenditure per tonne of wood processed	214	145
Profit per tonne of wood processed	**130**	**709**
Annual profit	**3,130,000**	**24,957,200**
Total profit over lifespan of solution	**62,600,000**	**748,716,000**
Annual return on subsidised capital investment	**4%**	**39%**
Total return on subsidised capital investment over lifetime	**Less than 0%**	**1,079%**

* Estimates have been prepared by solution provider, but altered where there is a clear justification for doing so. Further testing and validation of estimates will be undertaken in Milestones 4 and 5.

5.4 Risk Analysis

Based on the information gathered in the project to date, the following Success Factors are considered the key areas of risk for this scenario option:

Table 5.3 – Solvent Rescue Risk Analysis

Success Factor	Overall Importance	Likelihood of Achievement	Overall Risk
Process output market demand is sustainable over time – Bitumen and marine diesel are considered sustainable. Limited information is available in relation to naphtha, and lignin is still considered an emerging and uncertain market	Essential	Low - Moderate	High
Process outputs are realistically saleable – Bitumen and marine diesel are considerably saleable based on analysis done to date. Lignin and naphtha are somewhat unknown and considered medium to high risk outputs from a marketability perspective	Essential	Low - Moderate	High
Process operates profitably – Each of the financial models provided demonstrate a profit, but the pessimistic estimate at smaller scale offers a model close to breakeven. Profitability hinges on successful marketing of lignin, which is uncertain	Essential	Low - Moderate	High
Processor has access, or likely access, to capital required to establish and operate a sustainable business - This is a major issue for Solvent Rescue which has limited access to capital. Highly successful testing as part of the MFE funded pilot will assist here, but this is as yet uncertain	Essential	Low - Moderate	Moderate - High

Success Factor	Overall Importance	Likelihood of Achievement	Overall Risk
Processor has ready access to capabilities/skills required including engineering, management, marketing etc. – Solvent Rescue is an entrepreneurial small company with limited working capital and limited access to expertise beyond the core technical team. A project manager has been engaged for their MFE-funded testing, but objective management and successful sales expertise will be required and is not currently in place	High	Low - Moderate	Moderate - High
Process offers competitive return on capital investment (net of any public funding) within the expected lifespan of the technology – The pessimistic financial models offer a negative return on investment over the life of the capital assets. The process will have to perform at least moderately well given the large capital investment required	Essential	Moderate	Moderate - High
Processor has a strong commercial reputation and track record – Solvent Rescue is often described as a somewhat disorganised, entrepreneurial company with strong potential. Its reputation is based more on innovation than commercial success, but it has apparently established a firm track record in its solvent-based business	Moderate-High	Moderate	Moderate - High
Treatment chemical deportment has been independently verified – Initial testing is promising, but mass balance was not achieved. Further testing will commence shortly	Essential	Moderate	Moderate
Process waste streams can be safely disposed of – The treatment chemicals output by the process do not currently have a safe disposal pathway. Recovery may be possible, but disposal at landfill is unlikely to be permissible given the concentration of chemicals	Essential	Moderate	Moderate
Process can process both treated and untreated wood – Solvent Rescue have confirmed that treated wood does not present any challenge to their process, subject to treatment chemical deportment	Essential	Moderate	Moderate
Process technology has been proven domestically using treated timber as a feedstock – The process has been tested using CCA treated timber with promising initial results, but without a complete mass balance on treatment chemicals	High	Moderate	Moderate
Process can realistically begin operation at commercial scale by end of 2015 – Solvent Rescue have advised that it would take approximately two years to move from their 2 tonne a day plant which is not yet under construction to a 20 tonne a day plant	Moderate-High	Low	Moderate
Process technology has been proven internationally using treated timber as a feedstock - No known international precedent exists internationally for using treated timber through the process	Moderate-High	Low	Moderate
Process outputs are free from treatment chemicals – Initial testing is moderate in this regard, and Solvent Rescue are very confident in achieving this, but no independent verification is yet available	Moderate-High	Moderate	Moderate
Process is able to be scaled up economically and can operate at smaller or larger volumes – Solvent Rescue can operate at smaller volumes but achieves economies of scale at larger volumes, and scale-up is considered technically straightforward by Solvent Rescue. This requires a very large capital investment though	Moderate-High	Moderate – High	Moderate

Success Factor	Overall Importance	Likelihood of Achievement	Overall Risk
Process output markets are local, reducing transportation costs – While the lignin market is as yet uncertain, other outputs should be able to be utilised locally	Low-Moderate	Moderate	Moderate
Process can handle all forms of treated timber (including CCA) – The process can apparently handle any form of treated timber, but verified testing has not yet been undertaken	Essential	Moderate – High	Low - Moderate
Process equipment has a lifespan in excess of 15 years – Solvent Rescue advise that their 20 tonne plant would last between 12 and 20 years, and their larger plant between 20 and 30 years	Moderate-High	Moderate - High	Low - Moderate
Process technology is reliable over time and well established – While the process itself has operated successfully for some time, this has only been at a small scale	Moderate-High	Moderate – High	Low - Moderate
Process set-up requires low or no public funding – Substantial public funding would be required	Low-Moderate	Low	Low - Moderate
Process requires minimal repairs and maintenance – The process requires significant maintenance, but this is allowed for in operational budgets	Low-Moderate	Low - Moderate	Low - Moderate
Process allows recovery and resale of timber treatment chemicals – The process offers a strong chance of being able to technically extract treatment chemicals, but whether this can be done economically is not yet known	Moderate	Low - Moderate	Low
Process can receive wood without any processing such as chipping – Wood must be chipped, but an allowance has been made for this in revenue estimates	Low-Moderate	Low	Low
Process is self-sustaining in terms of operating energy and other inputs – The process requires electricity to operate	Low	Low	Low
Process is safe and does not present a high risk of harm to people or the environment – The process is a 'closed loop' with few waste streams and apparently low risk of contamination, although it does operate at high pressures. Solvent Rescue's liquid outputs are volatile and potentially carcinogenic, but Solvent Rescue are experienced in handling such chemicals	Essential	Moderate - High	Low
Process gate fees for waste wood offer a discount from landfilling of waste wood (including transportation costs for suppliers) – Solvent Rescue has set reasonable gate fees, although the gate fees for the larger scale operation will only be attractive if the site is reasonably accessible	Essential	High	Low
Process meets air emissions standards – Solvent Rescue's processes are already in operation under an existing resource consent and meet air emission standards, with emissions being almost exclusively carbon dioxide	Essential	High	Low
Processor has the required consents to operate, or is likely to be able to obtain these – Solvent Rescue has resource consent for its current site and there is no evidence to suggest it would fail to secure one for a larger site further out of Christchurch	Essential	High	Low
Processor has access to an appropriate processing site or the means to secure one – Solvent Rescue have an existing site and a larger site on the fringes of Christchurch should pose no exceptional challenge to secure	Essential	High	Low
Process recovers energy or otherwise utilises waste wood productively – The process generates saleable outputs equivalent to between 42% and 57% of the mass of wood processed	High	High	Low

Success Factor	Overall Importance	Likelihood of Achievement	Overall Risk
Process can handle treated timber at a range of concentrations – Solvent Rescue consider treated timber concentration as of no concern in their feedstock considerations	High	High	Low
Process has a high likelihood of public acceptability (i.e. is not likely to attract public opposition) – Solvent Rescue has not attracted negative publicity to date as it is low-odour and low-noise and has no hazardous air emissions	Moderate-High	High	Low
Process is located close to feedstocks/suppliers to minimise transportation costs – Solvent Rescue is located close to the CBD, which should be convenient for rebuild and ongoing waste streams. Relocation for scale purposes may alter this	Moderate	High	Low
Process outputs are storable, and need not be utilised immediately – All outputs have a degree of stability which would allow for temporary storage and transportation	Moderate	High	Low
Process technology can be easily relocated if necessary – Processing equipment is able to be deconstructed and relocated	Low-Moderate	High	Low
Process can handle high degrees of feedstock contamination e.g. silt – The process can handle most forms of contamination including nails and plastic	Low-Moderate	High	Low
Process produces, or has the ability to produce, multiple saleable outputs – Multiple saleable outputs are proposed for the process	Low-Moderate	High	Low
Process can handle other 'difficult' waste streams - The process can handle tyres and potentially hazardous chemicals provided these are blended at less than about 5% in the feedstock	Low-Moderate	High	Low
Process can handle other waste streams as an alternative feed stock - The process can handle any organic waste	Low-Moderate	High	Low
Process is likely to stimulate development of technologies which may have a downstream economic benefit for New Zealand – Solvent Rescue's technology is 'cutting edge' and has received significant overseas interest. There is strong potential for development and value generation	Low-Moderate	High	Low

5.5 Initial Feasibility Analysis

It is clear that Solvent Rescue presents a medium to high risk option, but offers tremendous and somewhat diverse revenue potential if it can achieve its current goals. It is a highly entrepreneurial and innovative company with a promising solution but, like many such New Zealand small businesses, faces great challenges in commercialising its innovation.

Solvent Rescue is extremely confident of its process, and has both external grant funding and encouraging initial testing to justify this confidence, but there are substantial difficulties presented by this option as a solution to treated timber waste in Christchurch.

The size of capital investment required to commercialise Solvent Rescue's operation is significant. Currently there is little 'hard data' to justify such an investment which places a strong emphasis on the importance of the testing phase Solvent Rescue is soon to embark upon. The preliminary testing suggests that CCA treatment chemicals would not be passed into saleable products, but rather to the waste 'sludge', which may be able to be concentrated for reuse in the timber treatment industry. However, in the initial testing the volume of treatment chemicals found in the outputs did not add up to that in the original samples so no mass balance could be achieved, and the results must be deemed inconclusive. More reliable testing results should be obtained within the next few months, determining with some confidence whether Solvent Rescue offers a technically viable solution for treated timber. Yet, even if it does so, its success is not assured.

Beyond technical requirements, much hinges on Solvent Rescue's ability to successfully sell products into four diverse commodity markets. While each of these markets is for high value products, each will require distinct marketing efforts and barriers to entry will certainly be present in all four. Existing suppliers will not welcome competition, especially in the oil-based markets, and potential customers may be reluctant to move away from current supply agreements for what will initially be very low volumes.

The oil-based product markets are likely to be more straightforward than lignin, which is still very much an emerging market. There are many potential productive and valuable uses for lignin, but the ability to sell large volumes at high prices is far from assured.

Furthermore, with all of these markets quality control will be paramount, and the ability to sell outputs could quickly dissipate if quality issues materialise. The required investment in quality control systems, processes and accreditation will likely prove a real challenge for Solvent Rescue based on its very limited access to capital, which has the potential to be an insurmountable barrier to successful commercialisation and growth.

With these factors in mind, the emphasis for further investigation and development in relation to Solvent Rescue in the remaining project milestones will be:

- Ensuring independent testing validates Solvent Rescue's belief as to the deportment of treatment chemicals and confirming saleable outputs as being contaminant-free
- Further investigation of proposed output markets (especially lignin), ideally validated as feasible by sample target customers
- Development of a plan around quality control and required accreditations for proposed output markets
- Further validation and refinement of capital, revenue and costing estimates
- Further investigation around likely access to funds for capital expenditure subject to successful testing
- Further analysis and planning around scale up and timeframes. Solvent Rescue estimate a timeframe of two years to go from a 2 tonne a day plant (which is not yet commissioned) to a 20 tonne a day plant and presumably a longer timeframe again to reach a 100 tonne a day throughput

6.0 SCENARIO ANALYSIS – SCION / TERAX WET OXIDATION

6.1 Scenario Overview

Scion's TERAX process was developed to process biosolids, and Rotorua District Council has recently committed to build and deploy a full scale plant processing 11,500 tonnes of waste a year from late 2014.

The TERAX process has two stages. The first stage is a low temperature, low pressure biological phase that begins to break down waste and dissolve much of the solid matter. The second stage is a 'wet' or hydrothermal oxidation which operates at high pressure and high temperature to break the waste down into a soluble carbon, water, carbon dioxide and residual ash. The valuable output of the process, being the carbon, can then be converted into a range of different products. In Rotorua it is converted into acetic acid, which offsets ethanol required in its wastewater treatment plant, currently costing up to $1 million a year.

The TERAX process can theoretically handle any organic waste, and it has been successfully lab-tested with untreated wood. Treated wood waste has not yet been tested, but such testing is planned to be undertaken in "the next few months". Scion are confident that the treatment chemicals will deport to the residual ash for disposal at landfill, but acknowledge that arsenic present in the waste wood may be water soluble and contaminate the water used in the process. In this case additional effort may then be required to extract the arsenic from the water, with resulting costs. Scion does not believe arsenic volatilisation is possible because of the process conditions of TERAX. In the Milestone 1 analysis of this project it was suggested that the treatment chemicals present in the waste wood may cause the biological phase of the TERAX process to fail. Scion acknowledges that this is a possibility, but believes that if this eventuates the biological phase could simply be omitted. This would increase processing costs but apparently does not render TERAX unfeasible for processing of waste treated wood.

Scion's business model for TERAX could be based on an upfront licensing fee for the technology (to a council or waste management company) but no decisions have yet been made as to how this might work. Scion have built a financial model based on the receipt of external grant funding to offset capital costs for building the plant, which may result in a reduction of any up-front or ongoing licensing fee if development costs are part of such funding. Under this arrangement Scion would also benefit from an impetus and profile around the successful implementation of the TERAX technology. No discussions have yet been initiated with a potential purchaser or operator of the TERAX process, but Christchurch City Council would be the obvious primary candidate and there is a confirmed aversion in the council to technologies that are perceived as risky or unproven. Scion believe a waste management or large infrastructure company are also likely candidates.

Once a plant (which is projected to process approximately 140 tonnes of waste per day) is operational, Scion believes a wide range of potential wastes could be processed without difficulty, and they would target food waste in particular to dilute treated timber content. This may reduce the projected volumes of wood waste processed, but would not materially alter the financial projections supplied by Scion. It is projected that the TERAX process has the ability to handle 64% of the overall waste in Rotorua and has the potential to handle a wide variety of waste streams in Christchurch including green waste and non-recyclable plastics.

Waste would need to be supplied to the TERAX process in a chipped form (1 to 3mm particles) so it is likely that the operator would need to partner with a third party to receive and process waste and deliver it to the processing site. The costs of this are reflected in the projected gate fees for waste.

As demand grows the TERAX plant, which is somewhat modular, can be scaled up. From an economic perspective, TERAX is designed to work best at a larger scale.

6.2 Output Market Analysis

Scion has advised that the output of the TERAX process would be a “highly degradable, sterile carbon source” with a variety of potential uses. Based on application to the Christchurch market, Scion have determined that the most appropriate saleable outputs would be methane for supply through the Burwood Landfill Gas Treatment Plant, or methane for use as a transportation fuel for one of the Christchurch-based bus fleets or another large commercial transportation fleet.

Scion has said that, should these output markets prove unfeasible, they would suggest consideration of using gas generated for electricity production. This has the potential to earn \$1 – 3 million in revenue, plus potential additional revenue from utilising heat. At this stage no detailed work has been undertaken on this option, and it will need to be further considered in Milestone 4.

Methane to Burwood Landfill Gas Treatment Plant

Figure 6.1 - Burwood Landfill Gas Treatment Plant (CCC, 2010)

The Burwood Landfill Gas Treatment plant was established to supply energy to council-owned facilities in Christchurch utilising methane gas produced by the retired Burwood Landfill as organic material decomposed.

The plant previously supplied gas to two boilers and a cogeneration plant at the QEII sports complex, as well as supplying energy for the Civic buildings and the art gallery in the CBD (CCC, 2010). The biosolids plant in Bromley is also connected to the pipeline.

The Canterbury earthquakes destroyed the QEII complex, reducing the demand for gas, but the council’s Water and Wastewater Treatment Manager James Feary says that there is “potential interest” for further methane supply. Feary believes that there are probable customers for the gas if the supply is reliable and quality is high and consistent.

Feary points out that, should a technology supplier wish to locate their operation at Burwood, the resource consent restrictions would prove challenging. Current operations at Burwood landfill (in terms of the Burwood Resource Recovery Park) are covered by a resource consent that dictates all activities must be “earthquake-related”. The consent also restricts activity to between 7am and 5pm weekdays and for three hours on Saturdays. Both the waste and time restrictions, driven by local resident discomfort with the re-activation of a retired landfill, are likely to limit the successful operation of a TERAX plant at Burwood. Once earthquake rebuild-related wood waste ceases a new resource consent, which is likely to be publically notifiable and strongly opposed, would be required. Furthermore if, as Scion intends, TERAX wished to receive food waste or other organic wastes (which are clearly not earthquake-related) to co-process with wood waste, the same consenting issues arise. The permitted operating hours would also prove too restrictive for successful operation, as TERAX is a ‘24/7’ operation.

The alternative is to secure a location somewhere else on the pipeline, such as at the former QEII site or along Pages Rd near New Brighton, or somewhere else reasonably close that can be easily connected to the pipeline. The availability of a suitable site is not yet known.

Feary advises that the current costs associated with the landfill methane are about $60,000 per month for $800m^3$ of gas per hour. This equates to a price of about 10c per cubic metre or approximately $90 per tonne. Scion have allowed for a price of $75 – 150 per tonne for methane in their financial projections, which appears reasonable.

Methane for Transportation Fuel

The key potential users of methane as a transportation fuel in Christchurch are the local bus fleets or some other large commercial transportation operator. The largest bus fleet operator in Christchurch, Red Bus, operates about 200 buses in the greater Christchurch area. Red Bus is a Council Controlled-Trading Organisation (CCTO), with all of its shares being held by Christchurch City Holdings Ltd, which in turn is owned by the Christchurch City Council (RB, 2013).

Red Bus CEO Paul McNoe says that a previous trial of LPG by the organisation was unsuccessful and there is little appetite to look at alternative fuels unless there is a compelling commercial imperative. More recently, ethanol fuel was evaluated, but its low calorific value relative to diesel fuel (30 MJ/kg for ethanol versus 45 MJ/kg for diesel) meant that buses would have had to carry significantly more fuel, limiting passenger carrying capacity, or would need to refuel during the day which is viewed as unfeasible.

Methane gas has a calorific value of approximately 55MJ per kg, avoiding the issues that ethanol presents, but McNoe advises that it is the need to invest in capital expenditure for the fleet that would prohibit a serious consideration of methane as a fuel. McNoe says that retrofitting existing buses is unlikely to be economically viable, so new buses would need to be purchased that are already able to handle methane. There are no plans to purchase new buses in the next three to four years as the current fleet is relatively new.

Sam Wilkes at Environment Canterbury, which has overall responsibility for most of Christchurch's bus activity, says they would also consider a move to methane as a low priority due to financial pressure associated with the earthquake. Environment Canterbury has trialled using biodiesel with some success but Wilkes comments that this was largely due to the fact that no infrastructure or vehicle modification was required.

Setting these issues aside, McNoe advises that an alternative fuel would need to offer a compelling cost benefit over diesel fuel. While the actual diesel fuel price paid by Red Bus could not be revealed due to commercial sensitivity, assuming a 20% discount on diesel pump prices gives a figure of about $1.24 a litre or approximately $1,476 per tonne. Allowing for the difference in calorific value and a 30% price advantage for methane over diesel, methane would need to be priced below $1,263 per tonne, which is an attractive price point.

If a transportation fuel customer can be found, Scion's economic model will improve dramatically. However, the scale and demand required (up to 8,500 tonnes of methane a year) narrows the field of potential customers and at such a scale the capital expenditure by a user required would be very large and may be prohibitive.

6.3 Financial Model

Scion has prepared a financial model for a plant receiving 143 tonnes of waste a day as follows. The pessimistic scenario contained in this model reflects sale of methane for supply to the Burwood pipeline (which would require a price increase or subsidy from Christchurch City Council), whereas the optimistic scenario relates to successfully securing a transportation fuels market. Scion acknowledges that this financial model is preliminary and will require refining:

Table 6.1 – Scion 143 Tonne Plant Financial Projections

Description	Pessimistic Estimate*	Optimistic Estimate*
Capital Expenditure		
Expected capital outlay for solution	15,000,000	7,500,000
Expected grant/public funding (e.g. MFE)	2,000,000	4,000,000
Subsidised capital cost	**13,000,000**	**3,500,000**
Expected lifespan of solution equipment (years)	20	20
Amount of wood (all types) inputted per day (tonnes)	143	143
Days solution would operate each year	350	350
Volume of wood processed per year (tonnes)	**50,000**	**50,000**
Volume of wood processed over lifespan (tonnes)	**999,999**	**999,999**
Revenue		
Methane biogas revenue (per tonne)	100	1,200
Volume of Methane biogas per tonne of wood processed (tonnes)	0.08	0.17
Annual volume of Methane biogas (tonnes)	4,150	8,500
Revenue per tonne of wood processed	**8**	**204**
Expected revenue from receiving treated timber (per tonne)	100	20
Total revenue per tonne of wood processed	**108**	**224**
Annual volume of saleable outputs from solution (tonnes)	**4,150**	**8,500**
Expenditure		
Fixed costs per tonne of wood processed	6	4
Processing costs per tonne of wood processed	190	84
Inwards/outwards transportation costs per tonne of wood processed	0	0
Waste stream disposal/processing costs per tonne of wood processed	17	6
Total expenditure per tonne of wood processed	**213**	**94**
Summary		
Annual volume of wood processed (tonnes)	50,000	50,000
Revenue per tonne of wood processed	76	116
Expenditure per tonne of wood processed	213	94
Profit per tonne of wood processed	**-104**	**130**
Annual profit	**-5,214,995**	**6,524,993**
Total profit over lifespan of solution	**-104,299,902**	**130,499,866**
Annual return on subsidised capital investment	**Less than 0%**	**186%**
Total return on subsidised capital investment over lifetime	**Less than 0%**	**3,629%**

* Estimates have been prepared by solution provider, but altered where there is a clear justification for doing so. Further testing and validation of estimates will be undertaken in Milestones 4 and 5.

6.4 Risk Analysis

Based on the information gathered in the project to date, the following Success Factors are considered the key areas of risk for this scenario option:

Table 6.2 – Scion Risk Analysis

Success Factor	Overall Importance	Likelihood of Achievement	Overall Risk
Process offers competitive return on capital investment (net of any public funding) within the expected lifespan of the technology – The scale of capital investment required for the TERAX process (including treated wood waste) is as yet somewhat uncertain, as is the likely revenue stream. These factors must work at an 'optimistic' level to provide a positive return on investment	Essential	Low - Moderate	High
Treatment chemical deportment has been independently verified – No testing of any kind has yet been undertaken on treated timber	Essential	Low - Moderate	High
Process operates profitably – Profitable operation is far from certain, and processing costs may increase depending on the results of testing with treated timber	Essential	Low - Moderate	High
Process technology has been proven domestically using treated timber as a feedstock – Treated timber has not yet been tested	High	Low	High
Processor has the required consents to operate, or is likely to be able to obtain these – Scion is operating a plant with Rotorua DC, but this does not include treated timber. As air emissions are low, this is unlikely to be a concern. Seeking to operate at Burwood landfill is likely to raise very challenging consenting issues	Essential	Low - Moderate	Moderate - High
Process can handle treated timber at a range of concentrations – High concentrations of treated timber are likely to cause issues for the biological phase of the TERAX process. If the feedstock is likely to be primarily wood, this phase may be omitted	High	Low - Moderate	Moderate - High
Process can process both treated and untreated wood – Scion is confident the process can handle all forms of wood waste, but this is as yet only theoretical	Essential	Moderate	Moderate - High
Process can handle all forms of treated timber (including CCA) – Treated timber has not yet been tested, but as the system is 'closed loop' treated timber should be able to be processed. Processing costs may become prohibitive however	Essential	Moderate	Moderate - High
Processor has access, or likely access, to capital required to establish and operate a sustainable business – Capital would need to come from a third party and is substantial. Scion would not seek to operate the technology	Essential	Moderate	Moderate - High
Processor has access to an appropriate processing site or the means to secure one – To access the Burwood pipeline, a processing site would need to be reasonably close to the pipeline, limiting potential sites (which do not need to be very large). No specific site has yet been identified	Essential	Moderate	Moderate - High
Process has a high likelihood of public acceptability (i.e. is not likely to attract public opposition) – Air emissions are unlikely from the TERAX process, but location near the Burwood pipeline is likely to face resident opposition	Moderate-High	Low - Moderate	Moderate - High
Process technology is reliable over time and well established – The TERAX process has proven itself in the processing of biosolids, but is still new and has not been tested with treated timber	Moderate-High	Low - Moderate	Moderate - High

Success Factor	Overall Importance	Likelihood of Achievement	Overall Risk
Process waste streams can be safely disposed of – It is not yet known if the residual ash from the TERAX process would be acceptable to Kate Valley landfill	Essential	Moderate	Moderate
Process outputs are realistically saleable – There is a likely demand from Christchurch City Council for methane gas, whereas demand for transportation fuel is more speculative	Essential	Moderate – High	Moderate
Process technology has been proven internationally using treated timber as a feedstock – While the individual elements of the TERAX technology are in use internationally, Scion advises that the full process is novel and proprietary. Treated timber has not been used at all internationally	Moderate-High	Low	Moderate
Process outputs are free from treatment chemicals – Scion believes that all treatment chemicals will be retained in residual ash, or possibly within waste water, but this is not yet proven	Moderate-High	Moderate	Moderate
Process output market demand is sustainable over time - If a compelling market for methane can be found , this is likely to be sustainable over time	Essential	Moderate – High	Low - Moderate
Process can realistically begin operation at commercial scale by end of 2015 – Scion has said that design and construction of a new plant would take one to two years	Moderate-High	Moderate-High	Low - Moderate
Process allows recovery and resale of timber treatment chemicals – Scion have advised that recovery of treatment chemicals from the ash is a possibility, but has not yet been tested	Moderate	Moderate	Low - Moderate
Process can receive wood without any processing such as chipping – TERAX requires wood or other waste to be chipped to particles 1 – 3mm in size	Low-Moderate	Low	Low - Moderate
Process technology can be easily relocated if necessary – It is understood that the TERAX plant design is expected to be site specific but could be designed to be relocated	Low-Moderate	Moderate	Low - Moderate
Process produces, or has the ability to produce, multiple saleable outputs – The TERAX process produces carbon which has several potential applications, but which is the only saleable output	Low-Moderate	Moderate – High	Low-Moderate
Process is self-sustaining in terms of operating energy and other inputs – TERAX requires electricity and chemical inputs	Low	Low	Low
Process gate fees for waste wood offer a discount from landfilling of waste wood (including transportation costs for suppliers) – Gates fees have been set at a level which compares favourably with landfill costs	Essential	High	Low
Process meets air emissions standards – Scion advise that carbon dioxide is the primary gas emission from the process	Essential	High	Low
Process is safe and does not present a high risk of harm to people or the environment – It is not expected that the TERAX process presents any substantial human or environmental risk	Essential	High	Low
Process recovers energy or otherwise utilises waste wood productively – Biogas/methane would be produced by the process	High	High	Low
Processor has ready access to capabilities/skills required including engineering, management, marketing etc. – Scion is a large, professional and capable organisation, but implementation would be carried out by an appropriately qualified commercial operator	High	High	Low

Success Factor	Overall Importance	Likelihood of Achievement	Overall Risk
Process equipment has a lifespan in excess of 15 years – Scion has stated that the engineering specification for the plant would require a minimum lifespan of 20 years	Moderate-High	High	Low
Processor has a strong commercial reputation and track record – Scion will not be the processor, but Scion does have a strong reputation. Likely processors will almost certainly be commercially strong	Moderate-High	High	Low
Process is able to be scaled up economically and can operate at smaller or larger volumes – Scion state that TERAX has a probable minimum economic size of about 30 tonnes of waste per day, but scale up (and achieve economies of scale) relatively easily	Moderate-High	High	Low
Process is located close to feedstocks/suppliers to minimise transportation costs – An exact processing site has not been chosen but the need to be close to the Burwood pipeline will make the site convenient for waste owners	Moderate	High	Low
Process outputs are storable, and need not be utilised immediately – Output methane gas can be stored and efficiently piped or transported	Moderate	High	Low
Process set-up requires low or no public funding – Public funding is not seen as essential, but would be sought	Low-Moderate	Moderate	Low
Process can handle high degrees of feedstock contamination e.g. silt – Scion confirm that the TERAX process can easily handle most forms of contamination	Low-Moderate	High	Low
Process output markets are local, reducing transportation costs – Scion proposes that output methane would be piped into the existing Burwood pipeline	Low-Moderate	High	Low
Process requires minimal repairs and maintenance – The TERAX plant is considered robust and reliable and does not require inordinate levels of maintenance	Low-Moderate	High	Low
Process can handle other 'difficult' waste streams – TERAX is likely to be able to handle most forms of organic waste, including non-recyclable plastics and biosolids	Low-Moderate	High	Low
Process can handle other waste streams as an alternative feed stock - TERAX is likely to be able to handle most forms of organic waste	Low-Moderate	High	Low
Process is likely to stimulate development of technologies which may have a downstream economic benefit for New Zealand – TERAX is proprietary technology with wide potential application domestically and internationally	Low-Moderate	High	Low

6.5 Initial Feasibility Analysis

A key advantage to Scion's TERAX process is that it is backed by such a strong and reputable organisation, and has achieved a level of success already, albeit with other waste streams. Its ability to handle diverse waste streams is also appealing.

However TERAX does have some key and significant risks around its current technology status and business model. The TERAX technology is clearly promising, as evidenced by the confidence expressed in it by an external grant funder in providing substantial funding, and by Rotorua District Council in partnering with Scion to build a plant for local use. Scion's credibility as an innovative and commercially grounded organisation has clearly assisted here. Yet, as became evident in Milestone 2, the introduction of treated timber as a feedstock in otherwise successful processes can quickly destroy economic and process feasibility.

The major hurdle to accurately assessing feasibility of the TERAX process for processing treated timber is the fact that no testing of any kind has yet been undertaken to understand the behaviour of treatment chemicals through the process, and Scion acknowledges that there is some doubt as to how these chemicals will behave. The results of this testing, which is planned to take place within the next two to three months, will certainly assist in assessing feasibility.

Scion believes that treatment chemicals will deport to the residual ash (which must then be disposed of) and concedes that some arsenic may be present in the wastewater (which must also then be processed and disposed of once it becomes too contaminated to reuse).

Even giving Scion the benefit of the doubt from a scientific perspective, as they are clearly highly capable in this area, the behaviour of the treatment chemicals in their process may greatly impact the economics of the process. Water may or may not be contaminated and the biological stage may or may not be feasible, dependent on the concentrations of treated timber. Either of these factors may add significant cost to the process. If other waste streams are required to dilute the treated timber waste in the process then, while this may improve the overall feasibility of the process, it diminishes its value as a solution for the large volumes of treated timber waste Christchurch will generate over the next fifteen years and beyond, or requires that a larger scale plant be built.

The other major factor impacting feasibility is Scion's business model for deployment of TERAX in Christchurch. As a research organisation it is not Scion's core business to actually operate a technology like TERAX; this responsibility would be passed to a third party such as a council or waste management company. Scion's return on investment would likely be a licensing fee or possibly, in this case, simply market credibility and learning from applying the technology to treated timber.

This business model then requires the risk in the process to be largely borne by a third party, which would logically be Christchurch City Council. Christchurch City Council's City Water and Waste Unit Manager Mark Christison has expressed a strong reluctance on the part of the council to invest in novel and unproven technologies, and it is likely that TERAX would be viewed as falling into this category.

Scion feel that a waste management or technology company may wish to invest in the technology, but without any clear indication from Scion that it has a potential licensee/operator for TERAX, it is difficult to see the process as yet realistically feasible from a business model perspective.

The intended output market also presents real difficulties for Scion's TERAX business model. Transportation fuel production, while certainly a possibility, would require substantial capital investment from a potential user, and both the city council and Red Bus have indicated they are not likely to focus on such alternative fuels in the foreseeable future, although a compelling cost driver may alter this perspective. Other potential customers may certainly be interested, but there is no current evidence of a high-demand market for methane as a transport fuel in Christchurch, and this will require further investigation.

The other option for TERAX gas output is boosting the gas levels in the Burwood pipeline as landfill gas declines over time. Christchurch City Council has expressed an interest in this in principle. The Council's estimates of current costs (providing a benchmark for the value of methane output) suggest that either the revenue stream for the TERAX process would be unattractive, or the council would need to subsidise its operation, which is viewed as unlikely.

Furthermore the logical operating site, being Burwood landfill, would place unacceptable restrictions on the operation of TERAX (which is a 24/7 process) due to the current resource consent. It is accepted that changing this consent would probably require a public process that would see consent changes strongly opposed by local residents. Such public opposition may be an issue regardless of where the TERAX plant is located if it needs to be relatively close to the Burwood pipeline, which runs close to residential areas for its entire length. If a more outlying site can be connected to the pipeline and the capital costs of doing so are not prohibitive, this would be a preferable option.

Scion has noted that, should other methane options prove unfeasible, on-site electricity generation is a possibility. It is understood such activity has been undertaken utilising landfill gas as a fuel at existing landfill sites. Costings and potential revenue from this are not yet known, but they are believed to be similar in magnitude to methane gas production for the Burwood pipeline.

Overall, if Scion is able to successfully target and supply transportation fuels as its saleable output, it has the potential to offer significant savings to an end user. Provision of methane for supply to the Burwood pipeline is perhaps an 'easier sell' but does not appear upon initial analysis to offer a feasible economic option.

With these factors in mind, the emphasis for further investigation and development in relation to Scion and TERAX in the remaining project milestones will be:

- Ensuring Scion's internal testing and independent testing validates Scion's belief as to the deportment of treatment chemicals and confirming saleable methane gas as contaminant-free
- Further investigation as to the feasibility of Scion's business model for TERAX, notably around potential site locations and consenting challenges and a motivated licensee for the technology
- Further investigation into feasibility of output markets, including electricity generation
- Further validation and refinement of capital, revenue and costing estimates, particularly around process and waste disposal costs

7.0 SCENARIO ANALYSIS – WASTE TRANSFORMATIONZ LIMITED / PYROLYSIS

7.1 Scenario Overview

Waste Transformationz Limited (WTL) is a company based at the Otaki Clean Technology Centre which brings together a number of organisations with extensive experience in utilising pyrolysis technology to produce charcoal for the domestic barbeque market. Based on this experience, WTL has successfully trialled processing of forestry waste in the Hawkes Bay into charcoal suitable for industrial fuel, and has also partnered with Professor Jim Jones at Massey University to investigate the conversion of different bio-wastes, including sewage, into biochar suitable for agricultural or fuel use. It is through this partnership that WTL are now focusing on the ability of modified pyrolysis units to successfully process treated timber.

WTL's mobile pyrolysis units, like all pyrolysis units, convert wood into charcoal by applying heat (at a relatively low temperature) to wood in the absence of air. Unlike the pyrolysis solution offered by AES Bioenergy in Section 8, WTL focuses on the production of biochar rather than biooil by altering the speed of the process. WTL's pyrolysis process is a batch process that carefully captures and filters gases to avoid any hazardous air emissions. As a batch process WTL does not require wood to be finely shredded before processing. WTL advise they would intend to operate the process seven days a week, but for only twelve hours a day, which would be advantageous if a consent is sought to operate near a residential area.

It is believed that treatment chemicals from processing treated wood will be captured exclusively in the biochar, and WTL are currently working with Massey University on a process to economically separate and extract the contaminated carbon leaving a contaminant-free and saleable carbon with a number of potential uses. WTL believe there is a reasonable likelihood that treatment chemicals may be able to be extracted and reused or sold. WTL acknowledges the need to ensure the processing of treated timber does not cause hazardous air emissions or contaminated saleable outputs, but is both confident in the innovations being tested and in the expertise of Professor Jim Jones, who is leading their research into the proposed solutions.

WTL has created a hierarchy of desirable saleable outputs for their pyrolysis process. At the top of this list is activated carbon, which has application in water treatment, food production and other industrial uses. Next is carbon black which is used primarily in the production of tires, but also in printing ink and paint. The least desirable, but still saleable, output is charcoal which can be used as an alternative to coal. In addition, WTL's process will also produce a large volume of biogas, which WTL intends to sell into the Burwood Landfill Gas pipeline in Christchurch as well as use in its process.

WTL's plan is to seek investors in Christchurch to establish and operate a processing facility. It is likely that they would partner with a waste management company and jointly initiate a private waste transfer facility to receive wood waste including treated wood. The aim would be to develop and run a 150 tonne a day site, but WTL may start with a 50 tonne facility depending on market interest in saleable outputs. WTL have said that, if they are able to successfully produce and sell higher value outputs such as carbon black or activated carbon then income from gate fees becomes unimportant and these fees may be able to be set very low or removed. Depending on their success in producing for higher value markets, WTL may be prepared to process the existing stockpile at Burwood Resource Recovery Park without a gate fee.

7.2 Output Market Analysis

WTL have identified four saleable outputs from their process, with a reliance on lower value outputs being their 'pessimistic' scenario and an emphasis on higher value outputs being their 'optimistic' scenario. The four saleable outputs are activated carbon, carbon black, charcoal and producer gas.

Activated Carbon

Figure 7.1 – Activated carbon (Wiki, 2013)

Activated carbon is carbon or charcoal that has been produced in such a way as to have many small pores that greatly increase the surface volume of the carbon, such that one gram of carbon can have as much as 2,000m^2 of surface area. This feature of activated carbon makes it a key component in many chemical reactions and for adsorption, where particles bind to the surface of a substance.

The ability to adsorb makes activated carbon a valuable resource for such varied applications as coffee decaffeination, air and water purification, medicine and sewage treatment. This wide variety of uses means that the global market for activated carbon is strong and growing.

In the US, the implementation of the US Environmental Protection Agency's Mercury and Air Toxics Standards is forcing operators of coal-fired power plants to upgrade their facilities, which requires extensive use of activated carbon. This is driving much of the growth in the US market for activated carbon, which is predicted to grow by more than 11% a year over the next five years (YF, 2013). Prices for activated carbon may reach \$3,750 per tonne but appear to typically range from \$250 – 2,500 per tonne.

New Zealand based Paul Dorrington, who works with Nelson-based Carbonscape and has some experience with carbon product markets, says that small scale supplies in New Zealand can attract prices as high as \$12,000 per tonne, but that bulk high grade materials are usually between \$500 – 1,250 per tonne.

Dorrington says that key drivers for activated carbon pricing include surface area, ash, moisture and origin. High grade activated carbon has a surface area greater than 1,000m^2 per gram whereas the highest grades have surface areas above 2,000m^2 per gram. Ash should be as low as possible, and is typically around 6%. Moisture content should also be as low as possible.

One challenge in servicing the activated charcoal market, according to Dorrington, will be potential concerns over treated timber chemical residues in the carbon, particularly if food or water-related usages are targeted. These concerns may preclude usage or reduce market value, even if absolute assurances as to the carbon being contaminant free can be given because of perceived risk. This may mean the carbon is more likely to be used in deodourisation or contaminant removal from industrial emissions, where the carbon will ultimately be landfilled and may attract a lower price.

At this stage, no quality specification has been produced for WTL's activated carbon output, so factors such as surface area are not yet known. Establishing a quality standard will be part of WTL's testing process.

Another barrier to entry, according to Dorrington, may be the likely 'vigorous' response from incumbent suppliers in the market to protect market share. Such a response will likely emphasise specialist suppliers' ability to provide product backup and support in contrast to a processor producing multiple outputs for multiple markets. This is less of an issue, according to Dorrington, if lower value activated carbon applications are targeted.

With these factors in mind, WTL's targeted revenue of $750 – 2,000 per tonne for activated carbon appears slightly high and a price of $500 – 1,000 appears more justifiable given the risks inherent in their production. WTL have advised that they would not produce activated carbon at a price below $750 per tonne, and would instead focus on carbon black at this level. At around $1,000 per tonne, it is likely that WTL will be able to secure a captive market for their activated carbon outputs, provided they are contaminant-free.

WTL report that they have begun to actively market their ability to potentially produce activated carbon and carbon black and have received considerable market interest from international buyers.

Carbon Black

Figure 7.2 – Carbon black (Wiki, 2013b)

The second targeted output for WTL is carbon black. Carbon black is a fine powder or granular substance that, like activated carbon, has a high surface area to volume ratio, although this is not as high as that of activated carbon. Carbon black is valued for its intense colour, and is used primarily for tire manufacture and other industrial rubber products, although it is also used in plastics, electrical components, high performance paints and printing inks (CB, 2012).

Use of carbon black as a reinforcement agent in industrial rubber production accounts for 90% of carbon black use. Tire manufacture alone accounts for 73% of world consumption. Specialty products such as printer inks and paints accounts for only 8% of carbon black usage by weight, but the prices that can be secured for these higher value outputs (which require higher quality carbon black) are much higher (CBS, 2011). China, the United States and Western Europe are the primary current users of carbon black, but China is expected to account for 35% of carbon black use by 2017 (ASD, 2013).

The value of the carbon market grew 34% between 2008 and 2012, to an estimated $17.5 billion annually on volumes of approximately 9 million tonnes (PRD, 2013). This equates to an average price per tonne of approximately $1,875 per tonne. Currently the price for carbon black appears to sit in the range of $1,000 – 2,750 per tonne depending on quality.

Carbon black quality is determined by four key factors: particle size, structure, surface area and surface activity. Higher quality carbon black has very small particle sizes (with 'grit' having been removed), structure and surface area that promotes 'stiffening' when mixed with other chemicals and surface activity that promotes increased abrasion resistance (RPN, 2010).

As with activated carbon, quality may be an issue for WTL as any use of carbon black is likely to require the absence of heavy metal contamination. Access to markets apparently dominated by large industrial players may also prove a challenge for a small volume producer. The size of the carbon market in New Zealand is not yet known.

Finally, it should be noted that carbon black is recognised by the International Agency for Research on Cancer as possibly carcinogenic to humans (IARC, 2009). WTL will need to implement the appropriate health and safety precautions to ensure those operating their units and handling carbon black are not exposed to undue risk.

Overall, WTL's targeted price for carbon black, at $750 - $1,300 per tonne appears reasonable, but more evidence as to the feasibility of the market for a niche supplier is required. WTL are actively researching this.

Charcoal

Figure 7.3 – Charcoal (Wiki, 2013c)

WTL proposes the production of 50 - 100kg of charcoal for every tonne of wood processed through their system. It is intended that this wood would serve as a direct alternative to mined coal for boiler usage. WTL reports that their testing has suggested a calorific value for pine charcoal at 30 – 32 GJ per tonne. This may be slightly high, but its energy value is certainly higher than the coal in common use in Christchurch which, according to Synlait's Petru Hoja, is typically closer to 19 GJ per tonne.

Synlait, which uses approximately 125 tonnes of coal per day, would be a key target customer for WTL's business model. In order to successfully service this market, Hoja has advised that a provider must achieve the following:

- As Synlait does not have fuel mixing equipment or storage space on their milk powder plant (near Darfield) all incoming fuel must be pre-mixed. This means that if charcoal was being blended with coal as a fuel, this blending would need to be done off-site prior to delivery.
- The charcoal would need to have a calorific value of between 17 and 26 GJ per tonne
- The charcoal would need to be supplied at a cost below $7 per GJ to compete with current coal supplies

Synlait have suggested that there is no minimum supply quantity, subject to the factors above, and that, while renewable fuels are attractive, they must still be cost competitive.

In terms of pre-mixing charcoal with coal, WTL report that they have been in contact with the operators of Synlait's fuel marshalling yard in Rolleston and have confirmed their ability and willingness to pre-mix as required.

In terms of calorific value, charcoal actually sits higher than Synlait's permissible range. It is not yet known how flexible Synlait is, nor whether WTL can reduce the quality of their charcoal. This will require confirmation as part of Milestone 4.

At 26 GJ per tonne, the upper limit of Synlait's heating value range, WTL's targeted charcoal price would be about $7.69 per GJ, above Synlait's price requirement. If charcoal can be supplied at 30 GJ per tonne, the price per GJ would be $6.67, slightly below Synlait's requirement. Whether this price is acceptable will ultimately depend on whether Synlait is flexible in its heating value limits. Assuming it is not, WTL's charcoal price would need to be below $182 per tonne. Given the impact of other saleable output values, it is unlikely that this price reduction will negatively impact WTL's business model to any great degree.

WTL have suggested that, should the production of activated carbon and carbon black prove unfeasible, they could instead focus on the production of charcoal as a coal substitute. Financial modelling suggests that, unless pessimistic scenarios for costs and gate fees are realised, this would still prove strongly profitable.

Producer Gas

WTL's intention is to sell producer gas, or biogas, into the Burwood Landfill Gas Treatment Plant in the same manner as is proposed by Scion. While the projected price allowed for by WTL (at between $65 and $98 per tonne) is reasonable in this regard, the same logistical difficulties that face Scion in supplying into this pipeline would also be faced by WTL, namely consenting restrictions for operation out of Burwood, or the challenges of finding an alternative location within easy connection range of the pipeline.

Unlike Scion, WTL had not identified transportation fuels (which have a much higher return) as an option for its producer gas, which makes up 55% of the total outputs of processing. This market will be more closely investigated in Milestone 4 and may present a feasible option for both WTL and Scion.

7.3 Financial Model

WTL has provided two financial models, one for a plant that operates at 50 tonnes per day, and a second for a plant that operates at 150 tonnes per day.

The financial model for a 50 tonne per day plant is as follows:

Table 7.1 – WTL 50 Tonne Plant Financial Projections

Description	**Pessimistic Estimate**	**Optimistic Estimate**
Capital Expenditure		
Expected capital outlay for solution	2,200,000	2,000,000
Expected grant/public funding (e.g. MFE)	100,000	500,000
Subsidised capital cost	**2,100,000**	**1,500,000**
Expected lifespan of solution equipment (years)	7	10

Description	Pessimistic Estimate	Optimistic Estimate
Amount of wood (all types) inputted per day (tonnes)	50	50
Days solution would operate each year	300	300
Volume of wood processed per year (tonnes)	**15,000**	**15,000**
Volume of wood processed over lifespan (tonnes)	**105,000**	**150,000**
Revenue		
Charcoal revenue (per tonne)	200	200
Volume of Charcoal per tonne of wood processed (tonnes)	0.12	0.08
Annual volume of Charcoal (tonnes)	1,800	1,200
Charcoal revenue per tonne of wood processed	**24**	**16**
Carbon Black revenue (per tonne)	750	1,300
Volume of Carbon Black per tonne of wood processed (tonnes)	0.08	0.10
Annual volume of Carbon Black (tonnes)	1,200	1,500
Carbon Black revenue per tonne of wood processed	**60**	**130**
Activated Carbon revenue (per tonne)	750	2,000
Volume of Activated Carbon per tonne of wood processed (tonnes)	0.03	0.05
Annual volume of Activated Carbon (tonnes)	450	750
Activated Carbon revenue per tonne of wood processed	**23**	**100**
Producer Gas revenue (per tonne)	65	98
Volume of Producer Gas per tonne of wood processed (tonnes)	0.55	0.55
Annual volume of Producer Gas (tonnes)	8,250	8,250
Producer Gas revenue per tonne of wood processed	**36**	**54**
Expected revenue from receiving treated timber (per tonne)	60	80
Total revenue per tonne of wood processed	**252**	**450**
Annual volume of saleable outputs from solution (tonnes)	**11,700**	**11,700**
Expenditure		
Fixed costs per tonne of wood processed	34	31
Processing costs per tonne of wood processed	38	38
Inwards/outwards transportation costs per tonne of wood processed	129	129
Waste stream disposal/processing costs per tonne of wood processed	4	4
Total expenditure per tonne of wood processed	**205**	**202**
Summary		
Annual volume of wood processed (tonnes)	15,000	15,000
Revenue per tonne of wood processed	252	450
Expenditure per tonne of wood processed	205	202
Profit per tonne of wood processed	**85**	**253**
Annual profit	**710,250**	**3,720,500**
Total profit over lifespan of solution	**4,941,750**	**37,205,000**
Annual return on subsidised capital investment	**34%**	**248%**
Total return on subsidised capital investment over lifetime	**137%**	**2,380%**

* Estimates have been prepared by solution provider, but altered where there is a clear justification for doing so. Further testing and validation of estimates will be undertaken in Milestones 4 and 5.

The financial model for a 150 tonne per day plant is as follows:

Table 7.1 – WTL 150 Tonne Plant Financial Projections

Description	Pessimistic Estimate	Optimistic Estimate
Capital Expenditure		
Expected capital outlay for solution	4,000,000	4,000,000
Expected grant/public funding (e.g. MFE)	1,000,000	2,000,000
Subsidised capital cost	**3,000,000**	**2,000,000**
Expected lifespan of solution equipment (years)	7	10
Amount of wood (all types) inputted per day (tonnes)	150	150
Days solution would operate each year	300	300
Volume of wood processed per year (tonnes)	**45,000**	**45,000**
Volume of wood processed over lifespan (tonnes)	**315,000**	**450,000**
Revenue		
Charcoal revenue (per tonne)	200	200
Volume of Charcoal per tonne of wood processed (tonnes)	0.10	0.05
Annual volume of Charcoal (tonnes)	4,500	2,250
Charcoal revenue per tonne of wood processed	**20**	**10**
Carbon Black revenue (per tonne)	750	1,300
Volume of Carbon Black per tonne of wood processed (tonnes)	0.10	0.10
Annual volume of Carbon Black (tonnes)	4,500	4,500
Carbon Black revenue per tonne of wood processed	**75**	**130**
Activated Carbon revenue (per tonne)	750	2,000
Volume of Activated Carbon per tonne of wood processed (tonnes)	0.03	0.08
Annual volume of Activated Carbon (tonnes)	1,350	3,600
Activated Carbon revenue per tonne of wood processed	**23**	**160**
Producer Gas revenue (per tonne)	65	98
Volume of Producer Gas per tonne of wood processed (tonnes)	0.55	0.55
Annual volume of Producer Gas (tonnes)	24,750	24,750
Producer Gas revenue per tonne of wood processed	**36**	**54**
Expected revenue from receiving treated timber (per tonne)	60	80
Total revenue per tonne of wood processed	**263**	**504**
Annual volume of saleable outputs from solution (tonnes)	**35,100**	**35,100**
Expenditure		
Fixed costs per tonne of wood processed	29	26
Processing costs per tonne of wood processed	46	44
Inwards/outwards transportation costs per tonne of wood processed	129	129
Waste stream disposal/processing costs per tonne of wood processed	4	4
Total expenditure per tonne of wood processed	**208**	**203**
Summary		
Annual volume of wood processed (tonnes)	45,000	45,000
Revenue per tonne of wood processed	263	504
Expenditure per tonne of wood processed	208	203

Description	Pessimistic Estimate	Optimistic Estimate
Profit per tonne of wood processed	**56**	**301**
Annual profit	**2,503,250**	**13,545,300**
Total profit over lifespan of solution	**17,522,750**	**135,455,000**
Annual return on subsidised capital investment	**83%**	**677%**
Total return on subsidised capital investment over lifetime	**484%**	**6,673%**

* Estimates have been prepared by solution provider, but altered where there is a clear justification for doing so. Further testing and validation of estimates will be undertaken in Milestones 4 and 5.

7.4 Risk Analysis

Based on the information gathered in the project to date, the following Success Factors are considered the key areas of risk for this scenario option:

Table 7.3 – WTL Risk Analysis

Success Factor	Overall Importance	Likelihood of Achievement	Overall Risk
Process can process both treated and untreated wood – WTL have not tested their units with treated timber, but are confident in their ability to successfully process treated wood waste	Essential	Low - Moderate	High
Process can handle all forms of treated timber (including CCA) – WTL have not yet initiated testing of treated timber	Essential	Low - Moderate	High
Process technology has been proven domestically using treated timber as a feedstock – WTL has not yet tested treated timber	High	Low - Moderate	High
Process has a high likelihood of public acceptability (i.e. is not likely to attract public opposition) – Thermal processing of treated timber is likely to attract negative public attention	Moderate-High	Low - Moderate	Moderate-High
Process outputs are free from treatment chemicals – WTL have yet to commence testing to verify this, but advise that, should low levels of treatment chemicals be present in outputs, they would focus on charcoal production and ensure copper, chromium and arsenic levels below those of coal	Moderate-High	Low - Moderate	Moderate-High
Process technology has been proven internationally using treated timber as a feedstock – There are some international precedents for pyrolysing treated timber, but treatment chemicals are problematic in these applications	Moderate-High	Low - Moderate	Moderate-High
Treatment chemical deportment has been independently verified – A Massey University-based research project into treatment chemical deportment and handling will commence shortly	Essential	Moderate	Moderate
Process outputs are realistically saleable – Each of the saleable outputs is considered reasonably feasible, but carbon black and activated carbon are markets in which WTL has no current experience and these markets are considered complex	Essential	Moderate	Moderate

Success Factor	Overall Importance	Likelihood of Achievement	Overall Risk
Process meets air emissions standards – Arsenic volatilisation through pyrolysis is less likely than through other processes, and WTL is confident of its ability to avoid hazardous air emissions, but this has not yet been tested and verified. WTL have said they will not deploy a solution that cannot contain air emissions with certainty	Essential	Moderate – High	Moderate
Process technology is reliable over time and well established – Pyrolysis is a very well established and simple technology, but WTL is proposing innovation to handle treatment chemicals that is not yet well understood	Moderate-High	Moderate	Moderate
Process output markets are local, reducing transportation costs – It is likely that higher value markets (activated carbon, carbon black) will be international, whereas lower value markets (charcoal, producer gas) will be local	Low-Moderate	Moderate	Moderate
Process offers competitive return on capital investment (net of any public funding) within the expected lifespan of the technology – All options presented by WTL offer a strong return on investment, which will be dependent on successfully processing treated timber	Essential	Moderate – High	Low - Moderate
Processor has access, or likely access, to capital required to establish and operate a sustainable business – WTL's proposal requires relatively low capital and WTL have engaged several potential investors who are apparently very impressed with the technology	Essential	Moderate – High	Low - Moderate
Processor has access to an appropriate processing site or the means to secure one – The processing site required by WTL for its 150 tonne plant would be the footprint of 15 20 foot containers, which is not very large. No specific site has been identified but the need to connect to the Burwood pipeline does limit potential sites	Essential	Moderate – High	Low - Moderate
Process is safe and does not present a high risk of harm to people or the environment – Carbon black is the only potentially hazardous output, and careful handling will be required	Essential	Moderate – High	Low - Moderate
Process equipment has a lifespan in excess of 15 years – WTL's kilns have an estimated lifespan of only 7 – 10 years to allow for potential corrosion by treatment chemicals, but their low capital cost and high ROI allow for replacement. The current test kiln has been in operation for 12 years	Moderate-High	Moderate	Low - Moderate
Process set-up requires low or no public funding – WTL have indicated a requirement for between $100,000 and $2,000,000 in public funding for their solution	Low-Moderate	Moderate	Low - Moderate
Process allows recovery and resale of timber treatment chemicals – WTL have suggested this may be possible, but processing costs are likely to prove prohibitive	Moderate	Low - Moderate	Low
Process can handle high degrees of feedstock contamination e.g. silt – WTL have said that small amounts of dirt and silt do not cause problems with their process	Low-Moderate	Moderate – High	Low
Process gate fees for waste wood offer a discount from landfilling of waste wood (including transportation costs for suppliers) – WTL's model is not focused on incoming gate fees and competitive prices should be able to be offered, especially if the sale of higher value outputs is successful	Essential	High	Low
Process operates profitably – Each of WTL's financial model scenarios is profitable and revenue and cost forecasts are, at this stage, considered reasonable	Essential	High	Low

Success Factor	Overall Importance	Likelihood of Achievement	Overall Risk
Process output market demand is sustainable over time – Each of the output markets, if accessible, is considered sustainable	Essential	High	Low
Processor has the required consents to operate, or is likely to be able to obtain these – Subject to air emissions being contained no obvious barriers to obtaining consents are identified. As the process is likely to run only 12 hours per day (as opposed to 24 for some) a consent for operation near a residential area is relatively likely	Essential	High	Low
Process waste streams can be safely disposed of – The main waste output from WTL's process is contaminated charcoal. This is likely to be able to be landfilled safely if treatment chemicals cannot be economically extracted	Essential	High	Low
Process recovers energy or otherwise utilises waste wood productively – WTL's process utilises the energy value in the wood very effectively	High	High	Low
Process can handle treated timber at a range of concentrations – WTL have advised no limits on treated timber feedstock concentrations	High	High	Low
Processor has ready access to capabilities/skills required including engineering, management, marketing etc. – WTL has a team of highly experienced directors and advisors across a variety of disciplines	High	High	Low
Process can realistically begin operation at commercial scale by end of 2015 – WTL have concluded that the lead time they face is primarily to complete the research project and testing relating to the use of CCA treated timber. Once this is resolved WTL advise they would be able to commence production within a few months, with the full production of 15 units taking about 12 months to complete	Moderate-High	High	Low
Processor has a strong commercial reputation and track record – WTL has 15 years' experience in the production of charcoal by pyrolysis of wood	Moderate-High	High	Low
Process is able to be scaled up economically and can operate at smaller or larger volumes – WTL has a modular system capable of operating economically at small and large volumes	Moderate-High	High	Low
Process is located close to feedstocks/suppliers to minimise transportation costs – It is proposed that WTL operate close to Christchurch city so as to provide ease of access for waste owners and to connect to the Burwood pipeline	Moderate	High	Low
Process outputs are storable, and need not be utilised immediately – All saleable outputs are able to be stored and transported	Moderate	High	Low
Process can receive wood without any processing such as chipping – WTL have advised that wood need not be pre-processed	Low-Moderate	High	Low
Process technology can be easily relocated if necessary – WTL's pyrolysis units are containerised and relocatable	Low-Moderate	High	Low
Process produces, or has the ability to produce, multiple saleable outputs – WTL has multiple saleable outputs and considerable flexibility in configuring its output streams	Low-Moderate	High	Low
Process requires minimal repairs and maintenance – WTL's technology is relatively straightforward and requires minimal maintenance	Low-Moderate	High	Low

Success Factor	Overall Importance	Likelihood of Achievement	Overall Risk
Process can handle other 'difficult' waste streams – WTL's units can handle many waste streams, including tires and dried sewage sludge	Low-Moderate	High	Low
Process can handle other waste streams as an alternative feed stock – WTL can receive a wide range of waste streams, including most organic wastes. Sewage sludge and tires have also been successfully tested and WTL is also investigating the possibility of pyrolysing plastics such as milk bottles	Low-Moderate	High	Low
Process is likely to stimulate development of technologies which may have a downstream economic benefit for New Zealand - Should WTL develop technology to successfully process treated timber, this will have clear technology export value	Low-Moderate	High	Low
Process is self-sustaining in terms of operating energy and other inputs – WTL's process requires diesel and electricity to operate	Low	Low	Low

7.5 Initial Feasibility Analysis

WTL is clearly well advanced in its development with pyrolysis technology and is actively involved in finding new carbon output markets, with some encouraging initial results. WTL's potential outputs are diverse and flexible, with the real possibility of producing and selling very high value carbon products.

Yet all of WTL's potential rests on its ability to remove all (as in the case of higher value products) or the vast majority (as in the case of charcoal) of treatment chemicals from its saleable outputs. At this stage the ability to handle treated timber is speculative as no laboratory testing of any kind has been undertaken. Some confidence can be derived from the involvement of Massey University's Jim Jones in the process but, as demonstrated in Milestone 2, the ability to technically process and extract treatment chemicals does not necessarily lead to a commercially sustainable process, particularly due to processing costs. WTL is taking the initiative in validating its technology innovation by engaging Jones to refine and test its process for handling treatment chemicals and producing low or no-contamination outputs, but at this stage WTL only has a potential solution, and nothing has been proven. As with all of the other proposed solutions, everything hinges on the upcoming testing and piloting processes, and most of the (substantial) risk in WTL's proposed solution depends on the outcome of this testing process.

In WTL's favour are the low cost, scalability and simplicity of their solution. Pyrolysis is not complicated, the equipment is modular and relatively inexpensive, and operation is straightforward, requiring only six operators for a large cluster of 15 pyrolysis units. WTL could potentially start with a smaller number of units, at relatively low capital cost, and grow the cluster as demand and output markets are proven and capital investors become persuaded to participate through proven performance. As manufacturers of the units, WTL can produce more as required and easily ship the containerised kilns to Christchurch without undue delay.

The flexibility in WTL's potential output markets is also an advantage, with relatively low value and saleable charcoal as the easiest option and more speculative markets such as carbon black and activated carbon as higher-value target markets. Initial analysis on these higher value markets suggests that they are sustainable and growing, and do indeed attract high prices. These markets will potentially be export-based which, as WTL suggests, may require a marketing partner with experience in interacting with such markets. WTL appears to have a network that would suggest forming such a partnership would not be difficult.

Quality of higher value outputs is a complete unknown currently, and will very much determine the likelihood of output saleability and the market price. Quality requirements for carbon black and activated carbon are particularly exacting and market prices vary greatly based on such factors as particle size and surface area. Investigation undertaken into these markets to date indicates that producers that succeed do so by consistently achieving high quality and consistency based on expertise and experience in production. WTL has no experience yet in producing carbon black or activated carbon and will, at best, need time to reach targeted product quality and consistency standards. Thus it cannot be assumed that WTL will immediately attract its desired prices for these products and may take some time to do so.

Even if this is the case, however, its ability to 'fall back' on charcoal production (where it has most experience) as a contingency somewhat de-risks WTL's offering, provided it can produce charcoal that has contaminant levels below the coal it is seeking to supplement.

WTL's business model is also relatively low risk based on its degree of engagement with a number of potential investors (which are known to the author but cannot be named for commercial sensitivity reasons) and its intention to operate its technology directly, rather than pass risk to another party. WTL's experience in operating pyrolysis units commercially, along with the experience and skill represented within its organisation, gives a degree of confidence in its ability to successfully commercialise its technology. This is, of course, provided its efforts to effectively and economically process treated timber prove successful. If this can be achieved, WTL offers a potentially highly profitable and sustainable solution.

With these factors in mind, the emphasis for further investigation and development in relation to WTL in the remaining project milestones will be:

- Ensuring WTL's research and development process in partnership with Massey University confirms that their pyrolysis technology can successfully process treated timber
- Further investigation into the feasibility of output markets, particularly activated carbon and carbon black, and into the likely quality specifications of WTL's outputs
- Further validation and refinement of capital, revenue and costing estimates

8.0 SCENARIO ANALYSIS – AES BIOENERGY LIMITED / PYROLYSIS

8.1 Scenario Overview

Auckland-based Alternative Energy Solutions Limited (AES), which was not identified as a potential solution provider for treated timber waste in Christchurch until the commencement of Milestone 3, is focused on the production of bio-oil from fast pyrolysis.

Fast pyrolysis, with a short reaction time for biomass within the pyrolysis unit, produces more bio-oil than slower methods which produce greater quantities of biochar and syngas. AES has some experience in pyrolysing biomass, with a 1 tonne demonstration plant in operation out of their Pukekohe based headquarters and another 1 tonne plant in the commissioning phase in Japan. While treated timber has not been tested through these units, AES has successfully produced bio-oil as a 'green fuel', most appropriate for marine use, from forestry residue waste.

AES is proposing the operation of two 25 tonne per day plants in Christchurch, offering a total throughput of 15,000 tonnes of wood waste per year. As with other pyrolysis processes the AES system operates at a relatively low temperature and AES believes that the timber treatment chemicals will deport to the biochar leaving contaminant-free syngas (which would provide 60% of the plant energy requirements) and saleable bio-oil. Volatilisation of arsenic is not expected.

The plants themselves have a footprint equivalent to a 40 foot container and are relocatable. They are designed to be easy to operate and require little maintenance. Incoming wood waste would be chipped and AES have provided for the purchase of an appropriate shredder in their financial projections. This allowance allows for a relatively high gate fee for incoming wood wastes as no margin needs to be paid to a waste management partner for pre-processing.

In addition to the syngas produced, which would be used to power the plant itself, the process produces contaminated biochar and bio-oil. The oil would be stored in purpose built tanks to be supplied as marine fuel and the biochar stored in airtight containers to avoid self-ignition, which is a known risk with biochar from fast pyrolysis. AES believes that the treatment chemicals can be extracted from the biochar utilising an acidic chemical process, but this has not yet been tested. This extraction process is viewed as an option rather than a core element of the business model, and if unsuccessful, contaminated biochar would be landfilled.

AES are currently upgrading their demonstration plant and will undertake testing of CCA treated timber through their kiln in September and October with a view to validating their hypotheses on treatment chemical deportment and the feasibility of economical treatment chemical extraction.

AES has a focus in terms of saleable outputs on heavy engine fuel in a marine environment, but considers that use as a boiler fuel is a back-up option. AES has stated their intention to employ high temperature ceramic filters in the plant to ensure a quality liquid bio-fuel output. This will be matched with a laboratory testing process to verify the suitability of the output as a marine fuel for a specific customer. AES advises that they are negotiating a memorandum of understanding with a "major world-wide shipping company" for the supply of 50,000 tonnes of marine engine fuel, subject to price, security of supply and quality conditions being met.

If the extraction of treatment chemicals is possible and economically viable, AES would look to sell these chemicals and also the decontaminated biochar.

As AES is a relative newcomer to the project, more extensive analysis will clearly be required during Milestones 4 and 5.

8.2 Output Market Analysis

Marine Fuel

The market for marine fuel is considered in Section 5.2. AES has advised that they would target production of heavy fuel oil, or bunker fuel, for larger ships. Whereas marine diesel attracts a price of approximately $1,078 per tonne, bunker fuel is closer to $762 per tonne.

As with marine diesel, quality control would be paramount in successfully servicing demand for heavy fuel oil, although AES have signalled their understanding of, and commitment to, achieving high quality standards. These standards will, of course, require that timber treatment chemicals are not present in the pyrolysis oil, an outcome which is certainly possible.

The ability to 'lure' customers away from large and stable suppliers would also be expected to be a challenge, but the existence of a potential MOU for marine fuel supply is clearly a huge advantage for AES here. If they are able to provide fuel at a quality specification and price that is mutually agreeable, and with reliable volumes that meet their potential customer's demand, AES is in a very strong position to succeed in commercialising their technology. However, achieving this position is clearly not a given. AES must be able to verify that the liquid output of their process is not contaminated with treatment chemicals, which is far from a certainty, and they must be able to build confidence in security of supply, all at a price lower than incumbent fossil fuels. The processing and quality control costs may prove to be barriers to achieving the required price point.

AES also acknowledges that bio-oil has a lower calorific value than heavy fuel oil (17MJ/kg versus 41MJ/kg for heavy fuel oil) thus increasing by a factor of 2.4 the volume of fuel that must be stored or carried for equivalent energy value. This would then indicate that, in order to be competitive and account for lower calorific value and increased handling and storage costs, bio-oil for marine fuel use probably needs to be below $360 per tonne. At $350 per tonne, AES appear to have set an appropriate price point for their output.

Despite the challenges in servicing AES' target market, it must be acknowledged that the existence of even early stage negotiations with an engaged potential end user is a strong benefit to AES' proposed solution.

Biochar

Biochar, or pyrolysis charcoal, has been considered as a coal alternative in Section 7.2 with an indicated market price of about $180 per tonne. AES have confirmed they would focus on biochar as a fuel, rather than its potential as an agricultural soil conditioner. AES' allowance of $100 per tonne for decontaminated biochar is considered conservative, provided treatment chemicals can be economically extracted.

AES have noted that biochar from fast pyrolysis is potentially hazardous in that it can self-ignite and must be kept in airtight containers. This presents a potential safety risk to AES' solution and will need to be carefully managed.

Treatment Chemicals

The extraction of treatment chemicals (arsenic, copper and chromium) from waste treated timber has been considered in Milestones 1 and 2 and is not considered economically feasible based on existing technologies.

AES are proposing to "leach the char with hydrochloric acid or ammonium chloride". The output solution would then be "neutralised with sodium carbonate or hydroxide and then concentrated by evaporation to a saturated solution or slurry". AES say the resulting slurry would be chemically similar to the original mixture used to treat wood, with the addition of sodium chloride, and may be able to be reused. It is estimated that less than one drum of the solution would be produced each day.

AES estimate that chemical extraction will cost between $1.4 and 2.5 million dollars to implement, with additional ongoing chemical costs. These capital and operational costs are reflected in the 'optimistic' financial model in Section 8.3. Further detail would be required as to the saleability of treated timber chemicals, which has not yet been evaluated, but the additional net revenue a successful implementation of this process would attract suggests that the process may be worthwhile if technically proven.

It should be noted once again, however, that many organisations around the world have invested heavily in chemical extraction of copper, chromium and arsenic from treated timber and none is known to work economically at a sustainable level. This does not mean it cannot be done, but investment in such technology should be approached with caution.

8.3 Financial Model

AES has provided an initial financial model for processing 30 tonnes of treated timber a day. The pessimistic scenario would be enacted if AES are not able to recover and resell treatment chemicals, whereas the optimistic scenario allows for sale of biochar and treatment chemicals. AES note that they have yet to determine site rental or compliance costs and these have been omitted from the model as follows:

Table 8.1 – AES 30 Tonne Plant Financial Projections

Description	Pessimistic Estimate*	Optimistic Estimate*
Capital Expenditure		
Expected capital outlay for solution	6,000,000	8,500,000
Expected grant/public funding (e.g. MFE)	2,000,000	2,750,000
Subsidised capital cost	**4,000,000**	**5,750,000**
Expected lifespan of solution equipment (years)	15	15
Amount of wood (all types) inputted per day (tonnes)	30	30
Days solution would operate each year	350	350
Volume of wood processed per year (tonnes)	**10,500**	**10,500**
Volume of wood processed over lifespan (tonnes)	**157,500**	**157,500**
Revenue		
Bio-oil revenue (per tonne)	350	350
Volume of Bio-oil per tonne of wood processed (tonnes)	0.38	0.50
Annual volume of Bio-oil (tonnes)	3,990	5,250

Description	Pessimistic Estimate*	Optimistic Estimate*
Bio-oil revenue per tonne of wood processed	**133**	**175**
Biochar revenue (per tonne)	0	100
Volume of Biochar per tonne of wood processed (tonnes)	0.00	0.10
Annual volume of Biochar (tonnes)	0	1,050
Biochar revenue per tonne of wood processed	**0**	**10**
Treatment chemicals revenue (per tonne)	0	1,000
Volume of Treatment chemicals per tonne of wood processed (tonnes)	0.00	0.02
Annual volume of Treatment chemicals (tonnes)	0	210
Treatment chemicals revenue per tonne of wood processed	**0**	**15**
Expected revenue from receiving treated timber (per tonne)	70	70
Total revenue per tonne of wood processed	**203**	**270**
Annual volume of saleable outputs from solution (tonnes)	**3,990**	**6,510**
Expenditure		
Fixed costs per tonne of wood processed	45	54
Processing costs per tonne of wood processed	29	39
Inwards/outwards transportation costs per tonne of wood processed	0	0
Waste stream disposal/processing costs per tonne of wood processed	12	0
Total expenditure per tonne of wood processed	**86**	**93**
Summary		
Annual volume of wood processed (tonnes)	10,500	10,500
Revenue per tonne of wood processed	203	270
Expenditure per tonne of wood processed	86	93
Profit per tonne of wood processed	**117**	**177**
Annual profit	**1,229,950**	**1,855,900**
Total profit over lifespan of solution	**18,449,250**	**27,838,500**
Annual return on subsidised capital investment	**31%**	**32%**
Total return on subsidised capital investment over lifetime	**361%**	**384%**

* Estimates have been prepared by solution provider, but altered where there is a clear justification for doing so. Further testing and validation of estimates will be undertaken in Milestones 4 and 5.

8.4 Risk Analysis

Based on the information gathered in the project to date, the following Success Factors are considered the key areas of risk for this scenario option:

Table 8.2 – AES Risk Analysis

Success Factor	Overall Importance	Likelihood of Achievement	Overall Risk
Process can process both treated and untreated wood – AES have not yet tested treated wood through their process, but are confident in their ability to process it successfully	Essential	Low - Moderate	High

Success Factor	Overall Importance	Likelihood of Achievement	Overall Risk
Process can handle all forms of treated timber (including CCA) – AES have not yet tested treated timber but plan to include CCA and boron treated samples in their upcoming testing process	Essential	Low - Moderate	High
Treatment chemical deportment has been independently verified – No testing has yet been undertaken, and there is a very real chance that output bio-oil may be contaminated with treatment chemicals	Essential	Low - Moderate	High
Process technology has been proven domestically using treated timber as a feedstock – As far as is currently known, treated timber has not been tested as a pyrolysis feedstock in New Zealand	High	Low - Moderate	High
Process outputs are free from treatment chemicals – AES are confident all treatment chemicals will deport to the biochar, which runs counter to some international research which suggests treatment chemicals may be present in gas and/or liquid phases	Moderate-High	Low - Moderate	Moderate-High
Process has a high likelihood of public acceptability (i.e. is not likely to attract public opposition) – Thermal processing of treated timber is likely to attract negative public attention	Moderate-High	Low - Moderate	Moderate-High
Process technology has been proven internationally using treated timber as a feedstock – There are some international precedents for pyrolysing treated timber, but treatment chemicals are problematic in these applications	Moderate-High	Low - Moderate	Moderate-High
Process meets air emissions standards – AES do not believe their process will volatilise arsenic but this has been known to occur with pyrolysis. No allowance for emission management has yet been indicated, but this is likely to emerge during testing	Essential	Moderate	Moderate - High
Process set-up requires low or no public funding – AES requires a relatively high level of public funding	Low-Moderate	Moderate	Moderate - High
Processor has the required consents to operate, or is likely to be able to obtain these – The main potential impediments to consenting are control of air emissions and the volatility of biochar	Essential	Moderate	Moderate
Process waste streams can be safely disposed of – Depending on which option is selected, AES may have to dispose of contaminated char. This is unlikely to be problematic if buried in a landfill. If chemical extraction takes place more hazardous processing chemicals may need to be disposed of	Essential	Moderate	Moderate
Process outputs are realistically saleable – AES's primary saleable output, marine fuel, is considered an appropriate market subject to product quality requirements and AES' price point is reasonable	Essential	Moderate – High	Moderate
Process is safe and does not present a high risk of harm to people or the environment – AES must ensure that air emissions (if any) are carefully managed and that biochar is handled carefully to avoid self-ignition	Essential	Moderate – High	Moderate
Process technology is reliable over time and well established – Pyrolysis is a very well established and simple technology, but chemical extraction of treatment chemicals, if pursued, is a novel process	Moderate-High	Moderate	Moderate
Process produces, or has the ability to produce, multiple saleable outputs – AES is primarily and realistically focused on a single saleable output	Low-Moderate	Low - Moderate	Moderate

Success Factor	Overall Importance	Likelihood of Achievement	Overall Risk
Process offers competitive return on capital investment (net of any public funding) within the expected lifespan of the technology – AES' solution offers strong capital returns on both optimistic and pessimistic scenarios, provided treated timber can be successfully processed	Essential	Moderate – High	Low - Moderate
Process operates profitably - AES' solution is strongly profitable on both optimistic and pessimistic scenarios, provided treated timber can be successfully processed	Essential	Moderate – High	Low - Moderate
Processor has access to an appropriate processing site or the means to secure one – Each of AES' units is the size of a 40 foot container and room is also required for dryers, a shredder and storage tanks. The site must also run 24/7. Finding such a site should not prove problematic, but it is likely to be in the city fringes or beyond. AES have not yet allowed for site lease costs in their financial model	Essential	Moderate – High	Low - Moderate
Processor has ready access to capabilities/skills required including engineering, management, marketing etc. – Information on AES' team is not yet available, but technical skill appears to be high, and marketing and management ability is suggested by AES' international development	High	Moderate – High	Low - Moderate
Process equipment has a lifespan in excess of 15 years – AES believe a lifespan of 12 – 15 years for equipment is realistic	Moderate-High	Moderate – High	Low - Moderate
Processor has a strong commercial reputation and track record – AES has a reasonable commercial track record from what is known of them, including the upcoming commissioning of a plant in Japan and a partnership with a Canadian engineering firm	Moderate-High	Moderate – High	Low - Moderate
Process can handle other 'difficult' waste streams – AES has tested no other waste streams through its process	Low-Moderate	Low - Moderate	Low - Moderate
Process can handle other waste streams as an alternative feed stock – AES has tested no other waste streams through its process	Low-Moderate	Low - Moderate	Low - Moderate
Process can handle high degrees of feedstock contamination e.g. silt – AES have not advised whether their unit can tolerate such contamination, but minimal amounts are unlikely to prove difficult	Low-Moderate	Moderate – High	Low - Moderate
Process output markets are local, reducing transportation costs – AES are working with a potential customer, but it is not known whether this is local or international. It is likely that, should this not materialise, local markets can be found for marine fuel	Low-Moderate	Moderate – High	Low - Moderate
Processor has access, or likely access, to capital required to establish and operate a sustainable business – AES has an equity partner that, while known to the author, is commercially sensitive. It is likely that if testing is successful, capital can be successfully obtained	Essential	High	Low
Process gate fees for waste wood offer a discount from landfilling of waste wood (including transportation costs for suppliers) – Projected gate fess are well below landfill costs	Essential	High	Low
Process output market demand is sustainable over time – The demand for heavy marine fuel is considered sustainable	Essential	High	Low
Process recovers energy or otherwise utilises waste wood productively – AES extracts a high degree of energy from the waste wood in the form of oil, gas and char	High	High	Low

Success Factor	Overall Importance	Likelihood of Achievement	Overall Risk
Process can handle treated timber at a range of concentrations – AES have not advised any limitations as to treated timber concentrations through their process	High	High	Low
Process can realistically begin operation at commercial scale by end of 2015 – It is estimated that the basic AES unit would take 10 – 12 months to establish. The commissioning of chemical extraction equipment, if feasible, would take longer	Moderate-High	High	Low
Process is able to be scaled up economically and can operate at smaller or larger volumes – AES technology can be scaled up with 30 tonne per day modular units	Moderate-High	High	Low
Process allows recovery and resale of timber treatment chemicals – AES plan to test their ability to extract treatment chemicals shortly, but chemical extraction is likely to prove uneconomic	Moderate	Low - Moderate	Low
Process is located close to feedstocks/suppliers to minimise transportation costs – AES is likely to be based on the city fringe or beyond but this should not prove unduly inconvenient to waste owners compared to waste transfer stations	Moderate	High	Low
Process outputs are storable, and need not be utilised immediately – All saleable outputs are able to be stored and transported	Moderate	High	Low
Process can receive wood without any processing such as chipping – AES advise that wood must be pre-chipped prior to processing, but they have included the cost of the requisite equipment for this in their capital budget	Low-Moderate	High	Low
Process technology can be easily relocated if necessary – AES pyrolysis units are containerised and relocatable	Low-Moderate	High	Low
Process requires minimal repairs and maintenance – AES technology is relatively straightforward and requires minimal maintenance	Low-Moderate	High	Low
Process is likely to stimulate development of technologies which may have a downstream economic benefit for New Zealand - Should AES develop technology to successfully process treated timber, this will have clear technology export value	Low-Moderate	High	Low
Process is self-sustaining in terms of operating energy and other inputs – AES provides 60% of kiln energy needs through the use of syngas, but also requires electricity and, should chemical extraction prove feasible, processing chemicals such as hydrochloric acid	Low	Moderate – High	Low

8.5 Initial Feasibility Analysis

The inclusion of AES Biotechnology's fast-pyrolysis solution alongside WTL's slower pyrolysis solution provides a useful basis for comparison. With fast pyrolysis the emphasis is on bio-oil as an output and the charcoal is potentially a 'sacrificial' output that captures treatment chemicals. This contrasts with WTL's technology which emphasises marketability of the solid output of pyrolysis while acknowledging that treatment chemicals must be separated from it. Both solutions rely on the low probability of arsenic volatilisation, which is not a given, and both technologies may face having to deal with exactly this issue.

It is likely that the majority of treatment chemicals in a fast pyrolysis process will deport to the biochar, and so AES is prudent in isolating this and building options around it. Their option for extracting copper, chromium and arsenic from treated timber by using an acid-based process is broadly similar to other chemical extraction processes considered in Milestone 1. These processes tend to be expensive, utilising large volumes of processing chemicals, and are likely to lead to an incomplete extraction of treatment chemicals. The probable result is a high processing cost and unusable biochar. AES is not exclusively depending on this extraction working, however, and is merely identifying it as an option to be evaluated and tested in coming months as they prepare their solution for processing treated timber.

AES' 'pessimistic' – and probably realistic – scenario is that treatment chemicals cannot be economically and successfully extracted and so the biochar output from their process will be landfilled offering, at worst, a substantial mass reduction to landfill. Fast pyrolysis biochar is highly flammable – and can self-ignite – but AES is not new to the technology and has clearly developed systems to handle the biochar safely.

Should chemical extraction prove feasible, AES' revenue focus is on the sale of bio-oil for use as a fuel for shipping. The presence of treatment chemicals in this fuel would render it unusable, and this is a clear potential risk in pyrolysis. This will, of course, be established with certainty in the upcoming testing regime AES is pursuing. Marine fuel is seen as a relatively attractive and sustainable market, but barriers to entry for a new market entrant will not be insignificant. AES reports that it is well advanced in negotiating with a potential customer here subject to meeting the customer's pricing, quality and reliability requirements. If AES can meet these requirements and the commercial relationship is confirmed, AES will be in a strong commercial position, offering a compelling return on investment.

Yet the capital cost for AES' solution ($6 – 8.5 million) for a plant that processes just 30 tonnes of wood waste per day is very high, especially compared to WTL's solution which is about one third of the cost of AES' plant for nearly twice the daily volume. Due to the high capital cost for AES' technology, a large level of government funding is required and a strong return on this investment may not be perceived unless AES agree to internally fund additional units.

Overall, AES is considered a relatively high risk both because of the cost of its solution and the fact that treated timber is clearly a recent consideration in their development. As AES has engaged with this project only in Milestone 3, more focus will need to be given to their process in Milestone 4 to determine its robustness and feasibility. Ultimately, much will hinge on the outcome of its testing processes which will commence in September based on a newly modified test kiln.

With these factors in mind, the emphasis for further investigation and development in relation to AES in the remaining project milestones will be:

- Monitoring AES' testing process, with a particular focus on the deportment of treatment chemicals and the technical and economic feasibility of treatment chemical extraction
- Monitoring of AES' progress in securing a customer for its bio-oil, and its ability to meet this customer's requirements. Should this relationship not proceed, an understanding will need to be built as to whether engaging a different customer or customers is probable, based on the nature of the relationship breakdown
- Further investigation into AES' capability, experience, process and technology
- Further validation and refinement of capital, revenue and costing estimates

9.0 SCENARIO UPDATE – HOLCIM CEMENT LIMITED / CEMENT KILN UTILISATION

The use of treated timber as a cement kiln fuel for Holcim emerged from Milestones 1 and 2 as a relatively low risk potential solution with strong international precedent. During Milestone 3 Holcim advised that the level of capital investment required for torrefaction technology would encourage them to substantially increase the low volumes previously indicated, to the point where this option could have potentially utilised most of the treated wood waste available in Christchurch.

To move forward with the evaluation of torrefaction, Holcim had assigned several staff to evaluate different technologies, and one of their process engineers visited the US to personally assess a number of options in mid-July. The conclusion from this visit was that torrefaction looked promising, and the intention was to move forward with the testing of CCA treated timber through the candidate technologies to ensure it could be effectively processed.

However, on the 2nd of August, 2013 Holcim publically announced their intention to cease cement production at their Westport plant. Cement for the New Zealand market will instead be imported through a new import terminal, which will take two to three years to come online. At this point Holcim will, for the foreseeable future, no longer produce cement in New Zealand. Technically the new plant planned for Weston, near Oamaru, is 'on hold', but it is understood this is unlikely to proceed.

Clearly, the capital investment and lead time required to implement a torrefaction facility would be completely unjustified with Holcim as the end user. Holcim's Glenn Lightfoot says that there is a chance that a business unit of Holcim could potentially purchase and operate the torrefaction technology, and seek to supply torrefied treated wood waste to an external customer, but this option is considered "highly unlikely".

Based on this information, the use of treated wood waste as a cement kiln fuel for Holcim is considered unfeasible and will not be further considered in terms of this project.

10.0 CONCLUSIONS

The following table provides a direct financial and return-on-investment comparison between the potential options. Where differing scale options have been provided, the larger is shown. The lowest or 'worst' performer against key indicators is highlighted in red, whereas the highest or 'best' performer is highlighted in green:

Table 10.1 – Financial Overview of Solutions

Description	SR*	TERAX*	WTL*	AES*
Expected capital outlay for solution	78,000,000	11,250,000	4,000,000	7,250,000
Expected grant/public funding (e.g. MFE)	7,750,000	3,000,000	1,500,000	2,375,000
Subsidised capital cost	**70,250,000**	**8,250,000**	**2,500,000**	**4,875,000**
Expected lifespan of solution equipment (years)	25	20	9	15
Amount of wood (all types) inputted per day (tonnes)	88	143	150	30
Days solution would operate each year	336	350	300	350
Volume of wood processed per year (tonnes)	**29,600**	**50,000**	**45,000**	**10,500**
Volume of wood processed over lifespan (tonnes)	**768,000**	**999,999**	**382,500**	**157,500**
Funding per tonne of wood processed over lifespan	**10.10**	**3.00**	**3.92**	**15.08**
Annual volume of saleable outputs (tonnes)	15,072	6,325	35,100	5,224
Saleable outputs revenue per tonne of wood processed	554	106	314	160
Expected revenue from treated timber (per tonne)	45	60	70	70
Total revenue per tonne of wood processed	**599**	**166**	**384**	**237**
Fixed costs per tonne of wood processed	70	5	27	49
Processing costs per tonne of wood processed	23	137	45	34
Transportation costs per tonne of wood processed	70	0	129	0
Waste processing costs per tonne of wood processed	18	12	4	6
Total expenditure per tonne of wood processed	**179**	**154**	**205**	**90**
Profit per tonne of wood processed	**420**	**13**	**178**	**147**
Annual profit	**14,043,600**	**654,999**	**8,024,375**	**1,542,925**
Total profit over lifespan of solution	**405,658,000**	**13,099,982**	**76,488,875**	**23,143,875**
Annual return on subsidised capital investment*	**20%**	**8%**	**321%**	**32%**
Total lifetime return on subsidised capital investment*	**577%**	**159%**	**3,060%**	**475%**

* Estimates have been prepared by solution provider, but altered where there is a clear justification for doing so. Further testing and validation of estimates will be undertaken in Milestones 4 and 5. For this comparison, the average of pessimistic and optimistic estimates has been used. Returns are calculated as simply the net return divided by the subsidised capital cost.

Direct financial comparisons between the four current options highlight some of the key benefits and risks inherent in each one, namely:

- Overall, the best return on investment is offered by WTL's pyrolysis process based on its low capital cost, low funding requirement and high projected profitability, but its operating costs are high based on its dependency on servicing export markets

- Solvent Rescue's solution offers the best ongoing value extraction and profitability from wood waste, and is projected to operate for the longest, but its extremely high capital cost and funding requirements impact overall return on investment
- Scion's TERAX process offers the highest overall volume of wood to be processed and provides a public funder the best return on investment, but uncertainty around revenue streams means that it offers the lowest profitability and return on overall investment
- AES' solution offers the lowest stated operating costs, but its high relative funding requirement presents the lowest return on investment for a public funder

It should be noted, however, that these financial projections are preliminary at best and cannot be yet deemed reliable from an investment evaluation perspective. Rather, they provide an overall 'feel' for where each of the solution providers is pitching their technology in terms of scale and operations, and communicate valuable information about the expectations of each operator.

What is encouraging from these comparisons is that each solution provider has been able to craft a basic business case for their solution that shows conceptual profitability. It is true that these models contain many assumptions (and most probably substantial guesswork), but the numbers shown are mid-points between pessimistic and optimistic cases, and convey that the solutions have at least the potential to operate profitably. It is tempting to simply magnify cost estimates and discount revenue streams based on the natural tendency of technology entrepreneurs to do the opposite, but it is instead intended that these models will be greatly refined and rigorously tested in Milestones 4 and 5.

At this stage there is insufficient data to determine the most promising solutions, primarily because each faces the same technical hurdle: proving that they can actually process treated timber effectively and economically. In this regard Solvent Rescue is slightly ahead of others in that they have undertaken preliminary tests that show promising results. There is no inherent technology innovation required for Solvent Rescue to confirm its ability to process treated timber, but rather a confirmation of early indications. Each of the other providers must either develop or refine technology to handle treatment chemicals, or must undertake initial testing of theoretical conclusions as to the deportment of treatment chemicals. In any case, revenue generation potential and feasibility is very much only 'potential' until this testing is complete.

The markets in which each of these options plan to generate revenue are quite diverse with surprisingly little crossover. Some, such as boiler fuel, are relatively established and low value, whereas others such as carbon black and lignin are considerably more complex and high value. Again, it is tempting to be conservative, dismissing the more speculative markets and focusing on those that can generate known products for safe markets. Yet it is considered too early in the process to do this, and the ability to successfully sell into these markets is currently neither proven nor disproven. Certainly if a solution provider can substantiate its claim to be able to sell high quality waste-derived products at a higher value into a sustainable market, this is preferable. A balance must be struck here between output value and market accessibility and sustainability. Solution providers such as WTL that have considerable flexibility in how they configure their saleable outputs will likely be able to present a more 'balanced portfolio' here that will enable them to develop more complex markets over time.

Another variable among the solution providers is the business model created and the likely ability of each provider to actually deliver on its plans. Scion has a unique model in this space as it simply aims to develop and license its technology; it is not the provider so would not carry the majority of the risk. Yet Scion has a strong record as a technology innovator and its role as developer mitigates this risk somewhat for a potential investor. Each of the other providers is a small, entrepreneurial technology developer with some experience in endeavours closely connected to what is being proposed. Each of these providers is evidently technically strong, with varying degrees of managerial and marketing capability.

Each of these smaller providers also has varying degrees of ready access to the large capital funding that implementation of their solutions will require. This will be a key determinant of success, as even the most promising technology will fail if it is undercapitalised. The development of revenue markets will probably take longer than providers expect and unless cashflow can be boosted by an equity partner, failure risk will be high. This is a common experience for New Zealand technology companies.

All four potential solution providers must be considered high risk offerings currently based on the lack of verification of their ability to process treated timber. Even beyond this, each has weaknesses and vulnerabilities that will require further consideration in Milestones 4 and 5.

For Solvent Rescue, its reliance on the sale of lignin is a concern given the emerging nature of this market and the global concerns over the potential for generating revenue from lignin. All of Solvent Rescue's markets require stringent quality control, which may be hard for a small company to achieve. A key limitation for Solvent Rescue is the fact that it is technology-led, largely based on one man's vision and considerable expertise. For Solvent Rescue to succeed in implementing its proposed solution it must grow quickly beyond its current state and attract large capital investment to build a fully functional and professional organisation. Solvent Rescue is proposing to develop an $80 million plant that generates about $18 million in revenue each year. This is a challenging proposition for a small technology company.

For Scion, with their TERAX technology, the first point of focus is identifying a potential buyer that recognises its potential and is willing to invest the substantial capital (more than $8 million) required to deploy it. The list of potential buyers is probably not extensive, especially given the currently limited commercial application for TERAX's outputs. There is definite interest in boosting declining landfill gas levels with methane from TERAX, but it is unlikely that Christchurch City Council would directly invest in such technology, and the estimated value of the methane to the council suggests this is not an economic option. Thus it is likely that Scion would have to find an operator of a large transportation fleet that would be willing to invest in new vehicles, or vehicle modifications, across its fleet. If this can be achieved, there are large savings to be made. It is apparent, however, that Scion has not yet begun the process of actively identifying a potential buyer, and timeframes for doing so are as yet unknown.

For Waste Tranformationz Limited, much of the risk in their process (beyond its ability to process treated timber) lies with the unknown nature of its target markets and its ability to successfully sell into them. WTL is obviously well connected and has a large group of experienced directors and advisors across a range of disciplines. Yet the majority of their projected revenue comes from markets that are, as yet, unknown to them. Carbon black and activated carbon particularly, whilst potentially attracting very high prices, are not likely to be easy markets to penetrate. The fact that such high prices are charged for these products (up to $2,000 per tonne) suggests, from a basic microeconomic perspective, that they are not straightforward to produce. Quality specifications will be high and the fact that WTL's offerings will be produced from contaminated waste may prove a marketing challenge that negatively impacts price. WTL's offering would be substantially de-risked by the presence of a potential volume buyer engaged based on a price and quality specification that WTL has proven it can meet.

For AES Bionenergy, the focus will be on the progress made towards meeting the requirements of their tentative marine fuel buyer. The presence of an end use customer is an encouraging sign for AES' proposed solution, but it is easy for the customer to indicate commitment to a price and quality standard and may be considerably more difficult for AES to meet it. If AES can successfully process treated timber waste to produce a non-contaminated marine fuel that meets the required quality standard, at a competitive price, AES will be in a strong position. Yet its solution is a comparatively expensive one, and is a much less attractive proposition for potential government funding than other options, largely because of its low throughput. AES' system is scalable and modular, however, and additional projections will be required to understand how capital costs and funding expectations will operate at larger scales.

11.0 NEXT STEPS

Milestone 1 of this project has focused on trends and developments that are currently active in New Zealand and Milestone 2 has focused on international trends and developments and their implications for the New Zealand context. Milestone 3 has focused on initial risk analyses for potential scenarios and building basic models of how they might operate.

Milestone 4 continues the process of analysing and evaluating each potential scenario, with more detail and robustness being the focus. Attention also turns to the pilot testing processes for each solution provider. This milestone is intended to include:

- Development of detailed business cases, supply chain models and financial models for each preferred scenario. These will be more robust and detailed than the broad models outlined in Milestone 3.
- Undertaking presentations and workshops with project partners on each scenario to test and enhance the supply chain and financial models and ensure a base level of feasibility for the pilot trials of each scenario before commencing.
- Integration and incorporation of project partner feedback into scenarios to prepare for pilot trials, including assessment of a timber identification toolkit if applicable.

As each solution provider is already in the process of initiating pilot testing of treated timber through their proprietary processes, Milestone 4 will have more of a focus on building the business cases and financial models for scenarios and understanding risk mitigation strategies. Collaboration among the project team and with solution providers will aim to ensure risks in business models are appropriately addressed.

Milestone 5 will complete this process and provide a level of oversight and monitoring of pilot testing and business model development so that, at the conclusion of Milestone 5, a clear recommendation can be made as to the most promising solution or solutions.

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