GR4CM

GYPSUM RECYCLING FOR CEMENT MANUFACTURE

WASTE MINIMISATION FUND FEASIBILITY STUDY

MILESTONE THREE REPORT

2 December 2011

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1.0 Introduction

The Gypsum Recycling for Cement Manufacture (GR4CM) feasibility study was launched on August 1, 2011 with an overall objective of "reducing the amount of waste plasterboard entering the waste stream by 32% per annum through improved design and onsite management practices and increasing the amount of plasterboard being collected and recycled in the Canterbury region by 3,000-6,000 tonnes per annum".

Funding of $90,000 (plus GST) has been obtained from the Ministry for the Environment's Waste Minimisation Fund to cover the majority of the project's budgeted cost of $140,000 (plus GST).

The project has also received $50,000 funding from the project stakeholders, namely:

- Winstone Wallboards Ltd (WWB)
- Holcim Cement Limited (HCL)
- Christchurch City Council (CCC)
- BRANZ
- 5R Solutions Limited (5R)

The feasibility study has four overriding goals:

- Identify (by 31 March, 2012) a financially viable waste reduction, collection and recycling scenario that can then be implemented, promoted and scaled up over time
- Achieve a 10% reduction in plasterboard waste generated on new building projects by 31 December 2012
- Achieve an additional 200% (3,000-6,000 tonnes) of plasterboard collection in the Canterbury region per annum by 31 December 2013
- Achieve an additional 200% (3,000-6,000 tonnes) of plasterboard recycling in the Canterbury region per annum by 31 December 2013

At its core the feasibility study is about identifying or designing, if possible, **a business model for large scale waste plasterboard collection and recycling for cement manufacturing use by HCL**.

The project is split into five key milestones:

- Milestone 1 (completed 16 September, 2011): *Industry overview* (key deliverable is a report detailing a situation analysis and map of the current industry)
- Milestone 2 (completed 14 October, 2011): *International Industry Trends* (key deliverable is a report providing an overview of key international trends and technological developments in the industry internationally, and how the selective application of these might improve the industry in New Zealand)

- Milestone 3 (due 2 December, 2011): *Potential Scenarios* (key deliverable is a report detailing potential new waste plasterboard collection and recycling systems, and the risks, financial implications and potential benefits of each scenario)
- Milestone 4 (due 3 February, 2012): *Stakeholder Collaboration* (key deliverable is detailed business cases for scenarios, including pilot trial plans)
- Milestone 5 (due 30 March, 2012): *Scenario Pilot Trials* (key deliverable is a final report detailing pilot processes and outcomes, and scenario details and implementation plan)

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

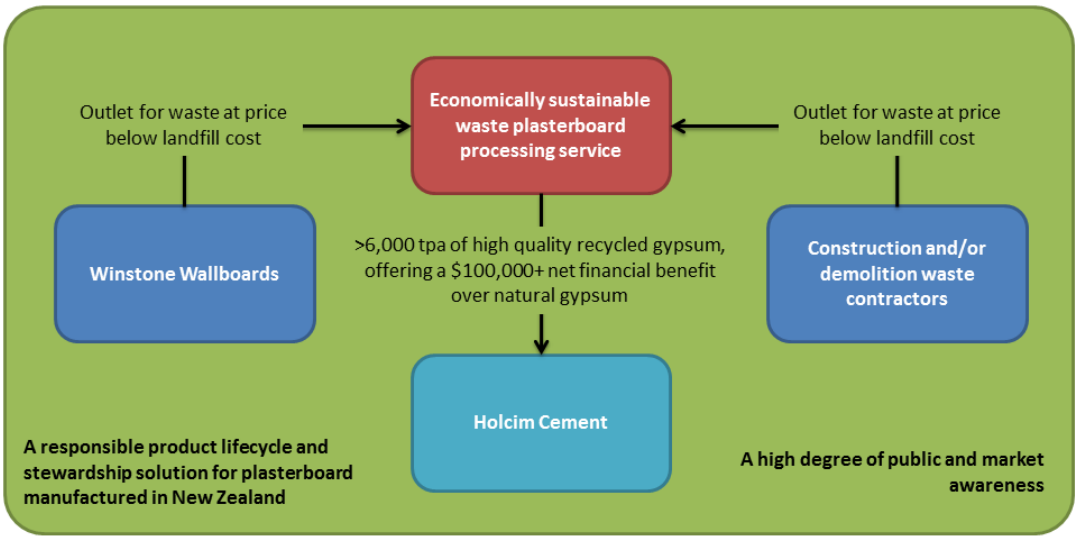
- Prepare a high-level vision for an economically sustainable gypsum recycling business model, with explicit critical success factors based on information gathered.
- Synthesise collected data to build several potential scenarios for implementing scaled-up systems for the collection, recycling and end use of waste plasterboard in Christchurch.
- Build broad supply chain and financial models around scenarios based on stated assumptions and risks, and undertake initial feasibility analysis.

2.0 High Level Vision

The GR4CM project is fundamentally focused on creating a successful and sustainable business model for processing waste plasterboard at relatively high volumes in Christchurch. The intelligence gained in the first two phases of this project, combined with the preliminary work undertaken to build the business model, would suggest that this is indeed possible.

Based on the information gained to date the high level vision for this project may be expressed as:

- A waste plasterboard processing service that **is economically sustainable** in the long term, and;
- Provides a **high quality recycled gypsum product** to Holcim Cement Limited at a delivered price that is materially below that of substitute products and at volumes in excess of 6,000 tonnes per year, and;
- Offers Winstone Wallboards an outlet for all of its **manufacturing waste** at a price that is materially below that of landfill disposal, and;
- Captures a significant portion of **construction waste and demolition waste** plasterboard by offering a **collection process that is acceptable and convenient** for waste owners at a price materially below that of landfill disposal, and therefore;
- Offers a **responsible product lifecycle and stewardship solution** for plasterboard manufactured in New Zealand with a **high degree of market and public awareness**.

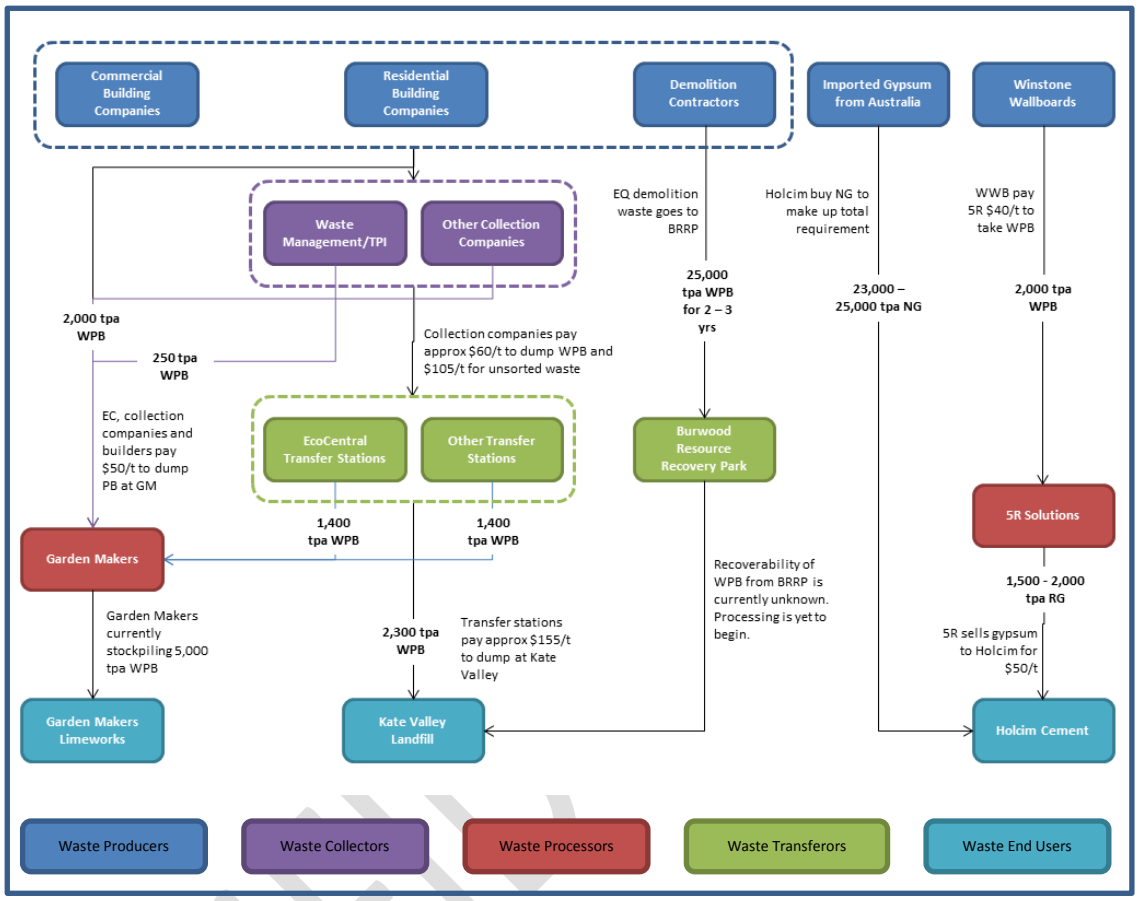


The objective of the remaining phases of the project is to develop and pilot the systems required to move the business model from its current state, to the state expressed in this high-level vision.

This involves both understanding the success factors understood from analysis of the existing industry and international best practice, as well as analysing the different scenarios that may deliver on the vision in terms of feasibility and desirability.

3.0 Existing Core Elements

The pre-existing waste plasterboard 'industry' in Christchurch may be understood (as detailed in Milestone 1) as follows:

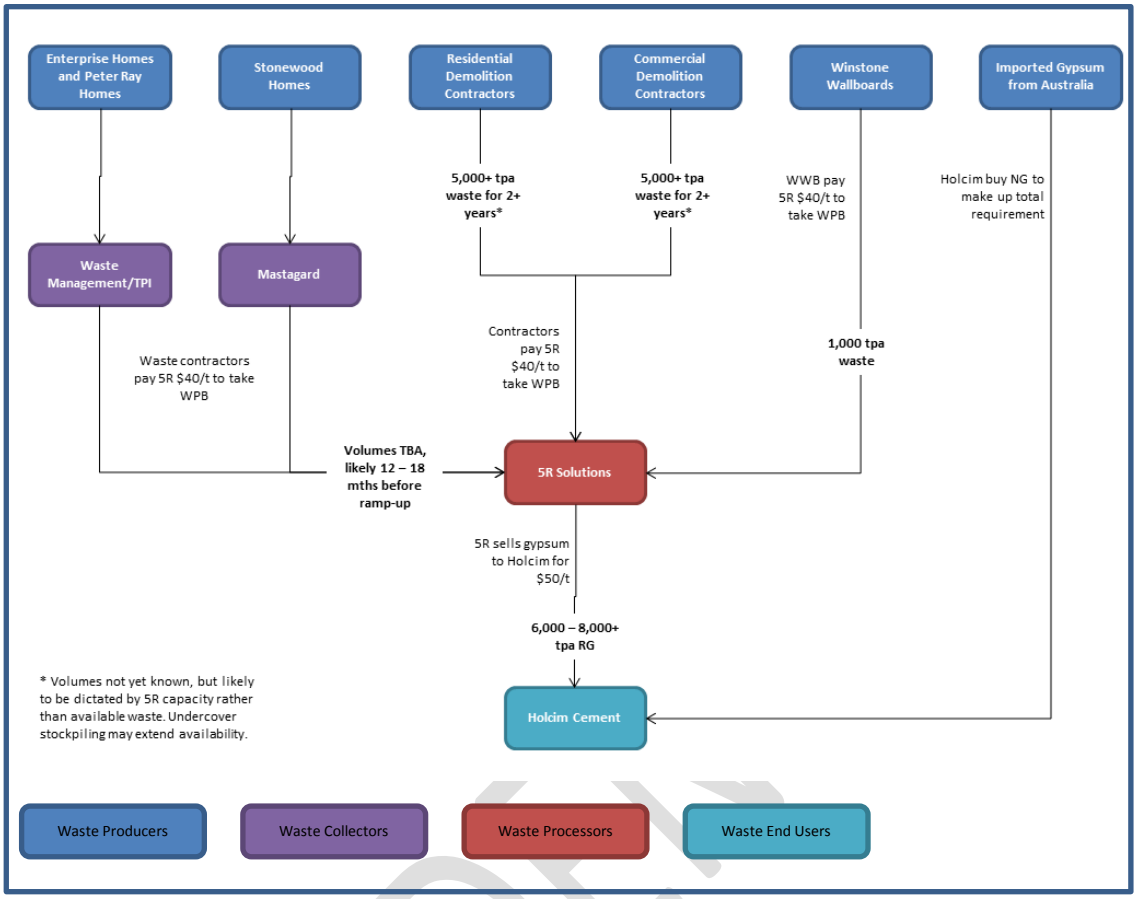


The work undertaken on the GR4CM project to date has identified a number of potential sources of additional waste plasterboard that may be able to be diverted from the waste stream and processed by 5R. These are:

- Residential construction waste
- Residential demolition waste
- Commercial demolition waste

Each of these sources of waste is considered as a 'Potential Scenario' later in this report. It should be noted that these options are strongly influenced in the short to medium term by the Christchurch earthquakes, and the volumes they offer will change greatly over time. Additional work is being undertaken to project these volumes over the next five to ten years.

To better understand how these new sources of waste might affect this project, their potential impact (in the sort to medium term) is illustrated as follows:



While commercial construction, particularly in relation to the earthquake rebuild, is another potential source of waste plasterboard initial activity is still a year or more away and little is known about how this will progress or what expected volumes may be. The new Build Green tool that is mandatory for new commercial buildings in Christchurch requires a waste minimisation plan that identifies sources of waste and strategies to divert these from landfill. This will be a key tool in pointing contractors towards plasterboard recycling once the rebuild commences.

In the Potential Scenario sections following, each of these options for additional waste is analysed and current information considered. Prior to doing so, however, it is vital to evaluate the 'core elements' of the business model to determine whether, and to what degree, these meet the success factors identified through the first two phases of the project. The 'core elements are considered to be those aspects of the current model that are already in operation: manufacturing waste supply, waste plasterboard processing at existing volumes and transportation and supply of recycled gypsum to Holcim as the end customer. In order to test the feasibility of these core elements, and identify risk factors, intelligence gathered during the first two phases of the project has been synthesised to produce a table of 'success factors' that must be satisfied in order to maximise the likelihood of a successful and sustainable business model.

In this table (and those used for each Potential Scenario), the following terms are used:

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

Success Factor	Desirability	Impact if Not Achieved	Likelihood of Achievement	Overall Fail Risk
5R must maintain **reliable and consistently available plasterboard processing** infrastructure with the ability to process required volumes.	High	High	Moderate – High	Moderate
HCL must continue to source **low transportation rates** for recycled gypsum.	High	High	Moderate – High	Moderate
The **price of recycled gypsum** (including transportation costs) must continue to offer a reasonable saving over the cost of imported natural gypsum. A net annual financial benefit of at least $100,000 must be delivered to HCL. Movements in the market price for natural gypsum may impact this saving.	High	Moderate – High	Moderate – High	Low - Moderate
At least 2,500 tonnes per annum of waste plasterboard must be secured from **new sources of waste** such as residential construction, commercial construction, residential demolition or commercial demolition. To cover overheads and generate a reasonable return on investment, 5R must process at least 4,000 tonnes of waste plasterboard per annum at current market prices and costs.	Critical	Critical	Moderate - High	Low - Moderate
HCL must construct a **covered storage facility** for recycled gypsum at its Westport site.	Critical	Critical	High	Low - Moderate
In terms of sustainability, HCL must continue to purchase recycled gypsum following **relocation to the Weston site**.	Critical	Critical	High	Low - Moderate
5R must continue to attract a **gate fee for waste plasterboard**, although this may be able to reduce form its current minimum level of $40 per tonne as volumes increase.	Critical	Critical	High	Low

Success Factor	Desirability	Impact if Not Achieved	Likelihood of Achievement	Overall Fail Risk
The **gate fee for disposal of plasterboard** for waste contractors and demolition contractors must be competitive with the costs of sending waste to landfill, given the sorting and additional transportation required.	Critical	Critical	High	Low
5R must continue to earn **sales revenue from supply of recycled gypsum** to HCL.	Critical	Critical	High	Low
The **quality of recycled gypsum** supplied to HCL must be maintained.	Critical	Critical	High	Low
An **increased cost of plasterboard disposal at landfill**, or restrictions or banning of disposal of plasterboard in landfill are desirable from a motivational perspective.	Moderate	Low	Low	Low
5R must have access to a **storage and processing facility** of sufficient size to allow it to handle and process the targeted volumes of waste. If its ability to store waste temporarily is insufficient, or if its ability to process waste to the required volumes is insufficient, targets will not be met and suppliers may lose confidence in the service. The space must be undercover to protect stored waste and must be able to be closed off in order to ensure that dust cannot escape, an Environment Canterbury requirement in order for processing to be a Permitted Activity. The site must be available at a cost no greater than $120,000 per annum.	Critical	Critical	Achieved	Low
The 5R **site must be fully consented** in accordance with regional and city council requirements.	Critical	Critical	Achieved	Low
The 5R site must be **conveniently located** in Christchurch to minimise transportation costs for waste contractors.	High	High	Achieved	Low
Acceptance protocols for waste plasterboard (specifying what can and can't be accepted) must be clear and robust with little room for interpretation.	High	High	Achieved	Low
5R must continue to earn **sales revenue from the sale of recycled paper** from waste plasterboard.	High	High	Achieved	Low
5R must continue to be able to source **plasterboard manufacturing waste from WWB**.	High	Moderate – High	Achieved	Low

Success Factor	Desirability	Impact if Not Achieved	Likelihood of Achievement	Overall Fail Risk
The requirement for **waste management plans** and minimum levels of waste diversion from commercial building sites is highly desirable to support plasterboard separation and recycling.	High	Low	Achieved (for CBD)	Low

Perhaps the greatest risk in the current business model is the reliance on a single processor. While extensive efforts were made to provide opportunities to a second processor to participate in the process, these efforts were unsuccessful. This processor, Brian Cribb, advised that he was able to secure higher returns from recycling gypsum for agricultural use, and that he would require a multi-year commitment from both suppliers and HCL before considering entering the market. He also felt that the capital investment required would be unattractive.

In addition to the risks inherent in a monopoly processor, 5R relies on rented machinery which is not widely available in New Zealand and has been withdrawn from service for repair as recently as October 2011. The failure to provide a consistent processing service may cause issues in terms of incoming waste supply (which may be mitigated by stockpiling) and in terms of supply to HCL (which is mitigated by mixing with natural gypsum as currently occurs).

As a relatively small enterprise 5R has a degree of vulnerability in terms of cashflow and capital availability, which has manifested as capacity growth has been required. It is likely this vulnerability will persist until economies of scale are realised and the profitability of the venture improves. It should be noted also that the fast growth that may be required of 5R to increase processing capacity is always a dangerous prospect for a small company that has limited capital, and such growth has destroyed many similar sized enterprises. It is important to realise that until if this occurs, and even if it does not, there is no willing second processor that can be called on to offer additional capacity.

A possibility as a contingency that has not been widely discussed is for WWB to develop and provide its own processing facility. This clearly needs to be evaluated, or at least specifically excluded. For manufacturers to have such capability is common internationally, and this capability would offer WWB significant cost savings for the disposal of manufacturing waste (in the order of $60,000 per annum). It is not 'core business' for WWB however, and would be even less so if offered to external waste owners. At this stage WWB has not expressed a desire to invest in this capability.

In addition to the risk around continuity of supply, the ability of 5R to reliably process the required volumes (at least 115 tonnes per week, and higher if all potential sources of waste are received) has not yet been tested and independently verified. This capability is critical to meeting project expectations and it might be expected that as volumes increase new process or technical issues may present themselves. The system for transporting and storing higher volumes of recycled gypsum at Westport will also need to reach unprecedented levels. This

ability to receive and process waste plasterboard, and transport and store recycled gypsum at higher volumes, will need to be tested as part of the piloting process.

The next greatest medium to long term risks to the viability of the core business model are in terms of price competitiveness to HCL. While HCL has expressed a commitment to product stewardship and the brand advantage given by using recycled gypsum a number of factors may threaten the price advantage offered by recycled gypsum in the future, and these cannot be ignored given the critical nature of HCL as the end-use customer to the viability of the business model.

The move to HCL's new plant at Weston, giving rise to potentially lower transportation costs for imported gypsum due to closer sea port proximity, may erode the price advantage offered by recycled gypsum. Given the high proportion of the cost to HCL that transportation comprises, this is a significant. Once again, while HCL have expressed a commitment to the recycled product, this commitment will come under increasing pressure if the price advantage is diminished. Given HCL's expressed target net benefit of $100,000 per annum, the best protection against this risk factor is to ensure volumes are as high as possible.

Any increases in the freight costs for transporting recycled gypsum to HCL's plant will have a similar impact to reduced total natural gypsum pricing and is also a constant risk factor subject to economic forces such as exchange rate and international oil prices. Consideration may need to be given to strategies or contingencies to mitigate this risk, such as 5R securing its own internal transportation infrastructure.

4.0 Scenario 1: Residential Construction

4.1 Overview

Currently most residential construction plasterboard waste is sent to landfill due to the relatively low volumes and the perceived costs and inconvenience of sorting plasterboard on site and transporting to a processing facility. Some small-scale trials of systems designed to facilitate plasterboard recycling from such sites have been unsuccessful, primarily due to the additional costs or low savings incurred from on-site separation, or because of the inconvenience of the system offered.

At least 6,000 homes have been condemned in Christchurch, and as many as 20,000 will ultimately be demolished and rebuilt. This extraordinary activity, when combined with ordinary growth and activity in the 'new build' market, would suggest that residential construction activity will be significant source of plasterboard in Christchurch for the next three to five years. 400kg - 800kg of plasterboard waste can be generated on a typical residential site, the potential waste stream may be in excess of 5,000 tonnes per annum for the next three years.

Unlike earthquake-related demolition activities, however, residential construction will continue – albeit at lower volumes – indefinitely, and so presents the best sustainable source of new waste plasterboard over the long term.

4.2 Progress to Date

TPI/Waste Management and Mastagard, the two largest waste management contractors in Canterbury, have agreed to partner with the GR4CM project to develop and trial systems for the effective sorting, collection and transportation of waste plasterboard from residential building sites. Each of these companies has created a 'draft solution' for collection, with TPI pursuing a 'flexibin' container exclusively for plasterboard, and Mastagard proposing a larger skip for gathering wood, steel and plasterboard, ready for basic off-site sorting.

TPI has secured Enterprise Homes and Peter Ray Homes as 'test partners' to co-develop a sorting and collection system. These companies have expressed a willingness to participate in pilots of the system developed if this scenario is pursued. A co-design workshop is to take place shortly with each of these companies working to develop new systems.

Mastagard has secured nationwide chain builder Stonewood Homes as its 'test partner', and is already trialling a preliminary version of a sorting and collection system on a one-off '7 Star' home that Stonewood is building in Lincoln as part of its commitment to the HomeStar programme. As with TPI's partners, Stonewood has expressed a desire to assist in the development of a waste plasterboard recycling system for residential construction, and has agreed to pilot this system on its construction projects if this scenario is actioned.

4.3 Success Factors

Information gathered in the first two phases of the project has been analysed to determine the critical success factors for a successful implementation of this scenario. The second phase

- “International Industry Trends” – has been particularly instructive here as international operators have undertaken significant development and testing in order to create successful and sustainable models for residential construction waste plasterboard collection and recycling.

Success Factor	Desirability	Impact if Not Achieved	Likelihood of Achievement	Overall Fail Risk
Given the low volume of plasterboard waste on a residential construction site, and hence the low likelihood of a reduced waste receptacle cost, a **lower overall cost of waste disposal** and collection is highly desirable. The aim should be 25% lower than existing co-mingled waste costs.	High	Moderate – High	Moderate	Moderate – High
The **process for sorting and disposing** of waste plasterboard must be simple and convenient.	Critical	Critical	Moderate – High	Moderate
The **system for collection** by the waste contractor must be economically viable at reasonably low volumes to ensure sustainability.	Critical	Critical	Moderate – High	Moderate
Staff involved in construction activities that involve separation and storage of plasterboard must receive **appropriate education and training** on processes and waste separation and contamination avoidance. Ultimately culture change is required to ensure separation becomes standard practice.	High	High	Moderate	Moderate
5R capacity must be sufficient to accept a volume of waste plasterboard that is acceptable to waste contractors.	High	High	Moderate	Moderate
Enforcement of acceptance protocols for on-site separation and contamination must be enforced by site managers. The waste delivered to 5R must be relatively free from contamination.	High	Moderate – High	Moderate	Moderate
The overall system developed must be able to be rolled out and **scaled up progressively** to achieve desired volumes.	Critical	Critical	Moderate – High	Low – Moderate
Construction sites must have **sufficient space on site** for the proposed waste separation/ storage solution.	Critical	Critical	Moderate – High	Low - Moderate
The collection system must offer **easy and accurate weighing and quality determination** of waste and invoicing of the waste or demolition contractor.	High	High	Moderate – High	Low – Moderate

Success Factor	Desirability	Impact if Not Achieved	Likelihood of Achievement	Overall Fail Risk
Plasterboard waste **receptacles must be kept undercover** or otherwise covered from the weather to ensure plasterboard stays dry. Receptacles must also be protected from unauthorised dumping by members of the public.	High	Moderate – High	Moderate – High	Low – Moderate
Waste pick up must be undertaken in accordance with customer expectation and requirements, at convenient times and as soon as possible after request.	High	High	High	Low – Moderate
Loads must be **visually inspected** before collection to avoid the need to reject loads off-site because of contamination.	High	Moderate	Moderate	Low – Moderate
A **range of receptacles** (bags, bins, skips) must be offered to residential builders to allow for differing waste volumes.	Moderate	Low - Moderate	Low - Moderate	Low - Moderate
Stored **plasterboard must be kept dry**, or at least kept from excessive exposure to moisture.	High	Moderate	Moderate – High	Low
The **gate fee for disposal of plasterboard** for waste contractors must be competitive with the costs of sending waste to landfill, given the sorting and additional transportation required.	Critical	Critical	High	Low
Plasterboard waste **receptacles must be easy to fill and easy to remove** from the construction site. Risks to damage of homes under construction must be eliminated or minimised.	High	High	High	Low
On site separation must occur.	High	High	High	Low
Waste contractors must be able to reliably **deliver plasterboard waste** to the 5R site at times convenient to them and must have the ability for the waste weight and quality to be determined upon delivery.	High	High	High	Low
Acceptance protocols for waste plasterboard (specifying what can and can't be accepted) must be clear and robust with little room for interpretation.	High	High	Achieved	Low
The 5R site must be **conveniently located** in Christchurch to minimise transportation costs for waste contractors.	High	Moderate – High	Achieved	Low

It is apparent that the likelihood of failure of a system for residential collection is not insignificant.

At the top of the list is the risk of being unable to offer any financial incentive whatsoever to companies that source-separate plasterboard. International efforts have identified the desirability of offering a financial saving to building companies that separate plasterboard waste, with an indicated target of 25% saving of the overall cost per tonne of disposal.

Early indications from partner waste contractors suggest that the savings in disposal gate fees from sorted plasterboard waste are largely offset by the additional costs involved in collection. Currently these contractors are proposing that the system will be no more expensive than mixed waste options, and this is viewed as acceptable by the participating building companies. Despite this, it is viewed as critical that any widely implemented system offer building companies a genuine financial benefit in order to justify the inconvenience and additional efforts involved in sorting.

The other primary risks related to this scenario centre on the design of the system for sorting and collection of waste. A system that presents too much inconvenience for contractors or results in too high a degree of waste contamination will escalate costs and reduce the desirability of participation by building companies. It is critical that:

- Builders/plasterboard installers are properly educated as to how to use the system.
- The system is easy for builders/plasterboard installers to use.
- The lead contractor/site supervisor enforces the acceptance protocols.
- The collection system is cost effective for the waste contractor.

If this scenario is actioned, these success factors will form the basis for the system design evaluation and pilot planning.

4.4 Supply Chain and Financial Implications

Under this scenario the waste contractor will collect waste from the building site and deliver it directly to 5R. Waste will be weighed and evaluated for contamination and, most probably, a sliding scale used as per the following example supplied to commercial demolition contractors by 5R:

- Scale 1 - $40.00 + GST per tonne – Clean and dry material contamination free.
- Scale 2 - $45.00 + GST per tonne – Up to 5% by volume or weight of moisture, fixings or contamination.
- Scale 3 - $55.00 + GST per tonne – Up to 15% by volume or weight of moisture, fixings or contamination.
- Scale 4 - $80.00 + GST per tonne – Up to 35% by volume or weight of moisture, fixings or contamination.

This scale, combined with a detailed acceptance protocol both ensures that received waste can be processed and ‘de-risks’ the acceptance of waste by ensuring contamination risk is retained by the waste contractor. It is not known, however, exactly how moisture levels would

be determined, and this may present an interpretation or evaluation risk that may become a point of contention with waste owners.

The partner waste contractors have been advised as to likely costings and logistical requirements, and have indicated acceptance of these requirements.

The potential financial impact on 5R is significant. If 50% of the potential 5,000 tonnes per annum is captured, the increase in income equates to $200,000 per year, and over a third of required volume is gained. Further work will need to be undertaken to determine long-term volumes and financial projections.

From 5R's perspective, the financial and supply chain implications of this scenario are positive and the additional volume aids viability. The risks are largely carried by the builders and waste contractors who must ensure the system for sorting, collection, transportation and disposal of waste is economically viable at varying volume levels.

Currently both waste contractors involved in this project have agreed to offer waste collection services for the builder, including separated waste plasterboard, at the same price as is currently paid for a co-mingled waste solution. The saving to the waste contractor (approximately 0.8 tonnes of waste at a saving over mixed waste of approximately $80/tonne) is about $64 per home. If plasterboard waste currently occupies half a skip on a residential building site (at an average cost of $350 per skip) then international best practice would suggest that a saving should be offered to the builder of $44 (25% of the existing disposal cost). This may be able to be offered once the service is scaled up, but whether it is required and whether it would act as a sufficient incentive will need to be tested as part of the pilot process based on the design of the entire system and its desirability to the building companies.

4.5 Conclusions and Recommendation

Residential construction is undoubtedly a difficult source of waste plasterboard, primarily due to the low volumes per building and the relatively low costs of disposal. These factors leave little room from a financial perspective to develop a system that is inherently more complex than the current arrangements. Furthermore, the additional effort required to sort plasterboard on site and place it in a dedicated receptacle is likely to be inconvenient and the chances of such sorting being done poorly, or waste plasterboard being contaminated with other materials, are significant.

Despite these indications, there is a growing desire from building companies to adopt this type of scheme, and internationally it is becoming more and more common. It is likely that it is the 'early adopters' that are identifying themselves as willing participants, and as scale increases the marginal costs of collection will reduce and participation may increase.

Furthermore, while on-site sorting is not yet standard practice on the residential building site, it has become so on the commercial building site, and enforcement of processes and the acceptance protocols may only need to be sustained in the medium term until such practices are equally common on residential building projects.

Ultimately it is apparent that there is a moderate chance of success in implementing this scenario with careful system design involving all key parties (building companies, waste contractors and processor).

Whether it will be widely adopted among building companies and waste contractors will likely depend on the cost-effectiveness and convenience of the system design, especially around the receptacle used and the collection method, and the cost savings offered, if any, for on-site waste sorting.

It is recommended that this scenario be advanced for further analysis and potential piloting in Milestones 4 and 5.

5.0 Scenario 2: Residential Demolition

5.1 Overview

As a result of the Christchurch earthquakes at least 6,000 homes are set for demolition, with the final total likely to be closer to 20,000 homes. As each home is likely to have three to four tonnes of waste plasterboard within it, the total volume over the next three years (allowing for storage and 'drip-feeding' if required) is approximately 20,000 tonnes per annum, well in excess of processing or demand capacity.

Some low-level residential demolition has already taken place, but will not begin to ramp up until early 2012. Existing waste plasterboard from residential demolition has been sent to the Burwood Resource Recovery Park (BRRP).

There is a low-level ongoing supply of waste plasterboard from residential demolition, but it is largely seen as a short to medium-term source as a result of extraordinary earthquake-related activity.

5.2 Progress to Date

The Christchurch Earthquake Recovery Authority (CERA) is currently finalising tenders for residential demolition with a view to focusing on smaller firms as a way of providing a business opportunity to them. CERA has expressed a strong commitment to waste minimisation and diversion as part of this process and has, at the suggestion of the GR4CM project manager, elected to include waste diversion as one of its tender evaluation criteria.

CERA has also expressed a strong desire to be associated with the 'story' the GR4CM project offers, namely the recycling of Christchurch's earthquake waste back into a critical resource (concrete) for Christchurch's reconstruction.

CERA have agreed to identify a pilot home to use as a 'test-bed' for the development of a system for effectively stripping out plasterboard. This method of removal is considered critical for the project in order to avoid uneconomic levels of contamination. Plasterboard from dwellings that have been essentially 'flattened' has been sighted at the BRRP and is considered too contaminated to process. Demolition contractors are highly incentivised to strip out electrical wiring and wood framing, so it is hoped that an economic system that allows plasterboard to be stripped out at the same time can be developed.

CERA have agreed to promote the GR4CM project with demolition contractors and are confident in a high take-up, given mixed waste disposal costs, provided an effective system can be developed for stripping out plasterboard from homes.

5.3 Success Factors

Information gathered in the first two phases of the project has been analysed to determine the critical success factors for a successful implementation of this scenario.

Success Factor	Desirability	Impact if Not Achieved	Likelihood of Achievement	Overall Fail Risk
Plasterboard must be stripped out of structures before demolition to avoid contamination and sorting issues, in a way that is economically viable for demolition contractors.	Critical	Critical	Moderate	Moderate - High
5R capacity must be sufficient to accept a volume of waste plasterboard that is acceptable to demolition contractors.	High	High	Moderate	Moderate
Stored **plasterboard must be kept dry**, or at least kept from excessive exposure to moisture.	High	High	Low - Moderate	Moderate
Enforcement of acceptance protocols for on-site separation and contamination must be enforced by site managers. The waste delivered to 5R must be relatively free from contamination.	High	Moderate – High	Moderate	Moderate
Plasterboard waste **receptacles must be kept undercover** or otherwise covered from the weather to ensure plasterboard stays dry. Receptacles must also be protected from unauthorised dumping by members of the public.	High	Low - Moderate	Low - Moderate	Low – Moderate
The collection system must offer **easy and accurate weighing and quality determination** of waste and invoicing of the waste or demolition contractor.	High	High	Moderate – High	Low – Moderate
Demolition sites must have **sufficient space on site** for the proposed waste separation/ storage solution.	Critical	Critical	High	Low
The **system for collection** by the waste contractor must be economically viable at to ensure sustainability.	Critical	Critical	High	Low
The **gate fee for disposal of plasterboard** must be competitive with the costs of sending waste to landfill, given the sorting and additional transportation required.	Critical	Critical	High	Low
On site separation must occur.	Critical	Critical	High	Low
Staff must receive **appropriate education and training** on processes and waste separation and contamination avoidance. Ultimately culture change is required to ensure separation becomes standard practice.	High	High	High	Low

Success Factor	Desirability	Impact if Not Achieved	Likelihood of Achievement	Overall Fail Risk
The overall system developed must be able to be rolled out and **scaled up progressively** to achieve desired volumes.	High	High	High	Low
Demolition contractors must be able to reliably **deliver plasterboard waste** to the 5R site at times convenient to them and must have the ability for the waste weight and quality to be determined upon delivery.	High	High	High	Low
The **process for sorting and disposing** of waste plasterboard must be simple and convenient.	High	Moderate	High	Low
Acceptance protocols for waste plasterboard (specifying what can and can't be accepted) must be clear and robust with little room for interpretation.	High	High	Achieved	Low
The 5R site must be **conveniently located** in Christchurch to minimise transportation costs for waste contractors.	High	Moderate – High	Achieved	Low

The primary failure risk in this scenario is the inability to develop an economic system for stripping out plasterboard. Design of such a system will be initiated once CERA tenders are complete but, while confidence from CERA is high that such a system will work, removing plasterboard from walls is time-consuming and difficult.

The other notable failure risk is being unable to receive sufficient volume of waste from contractors. As the waste will come in large volumes over relative short timeframes, 5R may struggle to either process or stockpile sufficient volumes to satisfy contractors. The price advantage offered will, however, likely encourage contractors to participate even if only part of their available volumes can be received.

The remaining key risks are around the quality of the plasterboard received. 5R has produced an acceptance protocol that advises contractors as to acceptable and unacceptable contamination, and this is aligned with a sliding pricing scale through which contractors pay a premium for higher levels of contamination. If this protocol is followed and the quality of waste is reasonable and easily verified upon delivery at 5R, the scenario will likely prove economically attractive to all parties. This appeal will diminish if contractors struggle to meet the required standards, or there is disagreement about the interpretation of the protocol.

5.4 Supply Chain and Financial Implications

The key challenge to the supply chain with regard to residential demolition is the variability of supply. Once residential demolition begins initial volumes could be massive and significantly outstrip 5R's ability to store and process plasterboard.

Failure to provide a destination for these waste volumes will likely lead to abandonment of the service by contractors, although a fixed volume quota may be acceptable to contractors.

In order to handle the higher volumes (which could easily exceed 5R's current capacity of 100 tonnes per week) 5R will need to identify significant covered storage capacity. Even if processing volumes can be greatly increased, HCL will still present a bottleneck in terms of its ability to receive increased volumes.

Any additional capital or infrastructural expenditure by 5R may be difficult to justify as the volume being produced by residential (and commercial) demolition will diminish almost completely once earthquake-related demolition activities have concluded. Earthquake-related construction will likely extend this increased volume period for some time, but eventually volumes will settle down to a more modest level.

The financial implications of this option are strong for both waste owners and 5R. For 5R, the volumes are high and regular (for a significant period) and the process is de-risked by the 'sliding scale' pricing model. The additional revenue and volume that 5R can expect will be determined not by available supply, but by its ability to stockpile and process waste. In any event the supply will be extremely large and sufficient to more than exceed both 5R's and HCL's volume and financial benefit requirements. These benefits must, however, be measured against any increased investment required by either party to handle additional volumes.

For waste owners the economics are not yet well understood. If three tonnes of waste plasterboard can be removed from a home, and disposed of at $40 per tonne (as opposed to $120 per tonne for mixed waste) then the contractor has saved $240. The time cost of removing waste plasterboard (based on figures from CERA) is approximately $20 per hour.

Thus, if the contractor can remove three tonnes of plasterboard from a home in less than 12 person-hours (a fairly generous allowance), they will save money. Handling and transportation costs are comparable to those for mixed waste, particularly as 5R has secured a facility close to the CBD.

CERA advise that even a modest saving will be appealing to demolition contractors due to the tight margins involved in the process. This would tend to indicate that demolition contractors would view the service as financially beneficial, particularly if the stripping process can be combined with the removal of other resources.

5.5 Conclusions and Recommendation

Residential demolition is currently the least understood of the available scenarios. There is little international or local information on how to make such a model work, and its success depends on designing a system to effectively achieve a task that is known to be extremely difficult and time consuming.

Despite this, the economic incentives necessary for making the system work appear strong, particularly given the apparently tight margins that contractors will be working under. The ability to combine the removal of plasterboard with other resource removal activities in a

home is key to making the system work and CERA believes such a combined system is highly likely to be viable and attractive to demolition contractors.

Even bearing in mind the effort required to devise an effective system, the high volume of waste plasterboard and the likely levels of motivation of demolition contractors to participate in a recovery and recycling scheme indicate that pursuing this scenario is justified.

It is recommended that this scenario be advanced for further analysis and potential piloting in Milestones 4 and 5. It should be noted however that if processing and/or storage capacity becomes a key constraint, pursuing residential construction waste plasterboard as a source of waste may not be feasible.

6.0 Scenario 3: Commercial Demolition

6.1 Overview

CERA has published a list of earthquake-affected commercial buildings that are to be demolished. This list comprises 524 buildings that are to be completely demolished and a further 138 that are to be partly demolished. The volume of plasterboard waste from these demolitions (which are well underway) is likely to be in excess of 10,000 tonnes per annum for the next 12 to 24 months. Currently, much of this plasterboard is being sent to landfill or, in some cases, sent to Auckland for disposal and processing.

CERA, and a number of demolition contractors, have advised that the requirements of commercial demolition are such that plasterboard is typically removed in large sheets as part of the 'deconstruction' approach to demolition that is required in Christchurch's CBD. This approach, combined with the relatively high costs currently being paid by contractors to landfill plasterboard, have generated strong interest in separating and recycling waste plasterboard from these sites.

6.2 Progress to Date

Initial meetings with CERA indicated a high degree of interest in participating in a plasterboard recycling service, and likely volumes well in excess of 5R's storage and processing capacity. As a government agency, compliance is a key requirement for CERA, and so confirmation was sought that 5R's processing and storage facility was consented by both the city and regional councils. This confirmation has been obtained and supplied to CERA, which is therefore able to advise contractors of the service's availability.

GR4CM representatives presented to a meeting of the commercial demolition contractors to seek interest in the service. Almost all contractors expressed their intention to participate based on the supplied pricing schedule and acceptance protocol.

It is 5R's intention to commence provision of this service from 1 December 2011. Initial service provision will be monitored as a pilot to assess medium-term viability, particularly around adherence to the acceptance protocol and effectiveness of waste delivery and weighing mechanisms.

6.3 Success Factors

Information gathered in the first two phases of the project has been analysed to determine the critical success factors for a successful implementation of this scenario.

These success factors are similar to those shown for residential demolition, except that the development of an effective mechanism for stripping out plasterboard is considered a low failure risk as this is part of the existing practice for demolition contractors.

Success Factor	Desirability	Impact if Not Achieved	Likelihood of Achievement	Overall Fail Risk
5R capacity must be sufficient to accept a volume of waste plasterboard that is acceptable to demolition contractors.	High	High	Moderate	Moderate
Stored **plasterboard must be kept dry**, or at least kept from excessive exposure to moisture.	High	High	Low - Moderate	Moderate
Enforcement of acceptance protocols for on-site separation and contamination must be enforced by site managers. The waste delivered to 5R must be relatively free from contamination.	High	High	Low - Moderate	Moderate
Plasterboard waste **receptacles must be kept undercover** or otherwise covered from the weather to ensure plasterboard stays dry. Receptacles must also be protected from unauthorised dumping by members of the public.	High	Low - Moderate	Low - Moderate	Low – Moderate
The collection system must offer **easy and accurate weighing and quality determination** of waste and invoicing of the waste or demolition contractor.	High	High	Moderate – High	Low – Moderate
Plasterboard must be stripped out of structures before demolition to avoid contamination and sorting issues, in a way that is economically viable for demolition contractors.	Critical	Critical	High	Low
Demolition sites must have **sufficient space on site** for the proposed waste separation/ storage solution.	Critical	Critical	High	Low
The **system for collection** by the waste contractor must be economically viable at to ensure sustainability.	Critical	Critical	High	Low
The **gate fee for disposal of plasterboard** must be competitive with the costs of sending waste to landfill, given the sorting and additional transportation required.	Critical	Critical	High	Low
On site separation must occur.	Critical	Critical	High	Low
Staff must receive **appropriate education and training** on processes and waste separation and contamination avoidance. Ultimately culture change is required to ensure separation becomes standard practice.	High	High	High	Low

Success Factor	Desirability	Impact if Not Achieved	Likelihood of Achievement	Overall Fail Risk
The overall system developed must be able to be rolled out and **scaled up progressively** to achieve desired volumes.	High	High	High	Low
Demolition contractors must be able to reliably **deliver plasterboard waste** to the 5R site at times convenient to them and must have the ability for the waste weight and quality to be determined upon delivery.	High	High	High	Low
The **process for sorting and disposing** of waste plasterboard must be simple and convenient.	High	Moderate	High	Low
Acceptance protocols for waste plasterboard (specifying what can and can't be accepted) must be clear and robust with little room for interpretation.	High	High	Achieved	Low
The 5R site must be **conveniently located** in Christchurch to minimise transportation costs for waste contractors.	High	Moderate – High	Achieved	Low

CERA have advised that a key risk to the service will be any aspect of unpredictability or inflexibility. Due to the pressures on contractors, it is viewed as critical that 5R receive waste at the times and in the condition agreed, and at indicated volumes. While it is viewed as acceptable (according to CERA) that 5R not be able to receive all plasterboard waste, the level indicated initially must not then be reduced. This introduces a dilemma in terms of predicting volumes as to low and conservative figure will potentially limit available volumes but too high a figure may exceed actual capacity.

Flexibility is also a key requirement, with CERA communicating that demolition contractors have found unpredictable requirements for dumping of rubble in Lyttleton Harbour, and frequent rejections of loads, extremely frustrating. The detailed acceptance protocol and sliding scale for pricing (which means no load would be rejected) was created in response to this concern.

As with residential demolition, further key risks in this scenario are contamination or dampness in waste due to insufficient sorting, co-mingling or weather damage. Given the volumes of waste and the frequency of delivery of waste from the site to 5R (and hence the short storage timeframes) these risks are not considered high. Furthermore, the tight processes in place on demolition sites and the level of detail of the acceptance protocol and pricing schedule would indicate a reasonable likelihood of compliance by contractors.

6.4 Supply Chain and Financial Implications

The supply chain and financial implications of this scenario are every closely aligned to those of residential demolition.

The financial incentives are very strong for both the demolition contractors and 5R, with little additional cost or inconvenience and strong savings for demolition contractors. 5R has indicated an initial capacity to demolition contractors of 100 tonnes per week, offering an annualised income boost of $208,000, assuming all plasterboard is free of contamination.

In terms of supply chain logistics, the number and volume of inwards deliveries to 5R, in a new facility, may present real challenges. This is a material change from current operations, with a high degree of accuracy required, and a low indicated tolerance for error from contractors. Systems will need to be developed by 5R for receiving, checking, weighing, sorting and invoicing waste, although existing systems from 5R's glass processing business may be able to be adapted.

Once again, however, the biggest challenges will be in relation to handling, storing and processing high volumes of waste over relatively short time periods.

6.5 Conclusions and Recommendation

Initial expectations were that earthquake-related demolition waste would be the least attractive new source of waste plasterboard. In fact, it is now the most voluminous and potentially the most attractive.

The waste is already being stripped in a way that is conducive to processing and recycling, and is likely to be of a high quality. The demolition contractors have a strong financial incentive to divert the waste and have expressed an enthusiasm for doing so. The limitations to pursuing this scenario are primarily around storage and processing (and demand) capacity and its inherently short to medium-term nature.

It is recommended that this scenario be advanced for further analysis and, given 5R is moving forward with providing the service, piloting in Milestones 4 and 5.

7.0 Conclusions

The short to medium term outlook for the GR4CM project is apparently very strong.

The vastly increased volumes from earthquake-related residential and commercial demolition will, if successfully obtained, more than offset reduced manufacturing waste volumes as a result of a depressed construction industry. As demolition volumes decrease in several years' time, new construction volumes will be increasing, providing a strong boost to the business model for at least three years and possibly as many as five or six.

Commercial demolition offers a relatively easy and attractive scenario with strong drivers in place and a large volume of waste available. Little change is required in terms of waste removal and handling by contractors and the resultant waste is likely to be of an acceptable quality.

Likewise residential demolition, due to escalate in early 2012, offers a potentially attractive source of waste plasterboard. Volumes are potentially higher than those offered by the remaining commercial demolition, and will be available over a longer period of time. The system required to remove plasterboard in an acceptable state from residential dwellings will require more design effort, but the incentives are also strong for residential demolition contractors, and the system may simply augment existing efforts for removing other resources.

The key challenge around both of these new sources of waste plasterboard is that, being specifically earthquake-related, they do not ultimately meet the sustainability requirements of the project in terms of the longevity of raw material supply. The volume projections for these sources are heavily loaded over the next two to three years meaning that not only will waste sharply diminish beyond this timeframe, but also that 5R's capacity will be massively exceeded during the supply timeframes.

The ability for 5R to manage temporarily high volumes is still being investigated, and the ability to containerise and store waste may even out supply. 5R may have the ability to receive and process extremely high volumes, but this will need to be aligned with a corresponding increase in HCL's ability to purchase and utilise higher volumes.

As with the demolition options, residential construction as a source of waste plasterboard will have an initial medium-term spike due to earthquake-related activity. Unlike the demolition options, residential construction offers a long-term, significant source of waste plasterboard. The development of a system that is acceptable and economically viable for both builders and waste contractors will prove challenging, but is viewed as critical in order to secure an additional waste source that is sustainable.

It is highly recommended that each of the presented scenarios is advanced for further consideration and planning undertaken to consider pilot activities. Concurrently, the expressed concerns around vulnerabilities and challenges in terms of processing should be considered by the project stakeholders, particularly in terms of the challenges presented to 5R around short-term volume spikes.

In addition, while systems are being designed and piloted to exploit earthquake-related sources of waste plasterboard, attention will also need to be given to more sustainable sources including manufacturing waste and residential construction. Efforts also need to be made by 5R to win disposal contracts for waste plasterboard from commercial construction.

Effort will also need to be focused on gathering further intelligence in terms of limits to supply, processing and demand volumes to provide more 'firm' data on projected volumes and corresponding financial implications.

8.0 Next Steps

Once the project stakeholders have considered the scenarios presented, and assuming that each is deemed worthy of further analysis, the next step is to develop detail around the systems required to make each scenario work and ensure that relevant individual stakeholders (both from the project team and wider stakeholders such as waste contractors and building companies) have had an opportunity to participate in co-design of the systems.

These more detailed plans will then be brought back to the project team for a workshop focused on optimising the systems.

The next phase of the project therefore involves:

- Working with individual stakeholders to develop detailed business cases, supply chain models and financial models around scenarios.
- Undertaking a presentation and workshop with stakeholders around scenarios to test and enhance models and ensure base level of feasibility for pilot trials before commencing.
- Integrating and synthesising stakeholder feedback into scenarios to prepare for pilot trials.

Following this process, pilot trials will subsequently be initiated for the preferred business model.