GR4CM

GYPSUM RECYCLING FOR CEMENT MANUFACTURE

WASTE MINIMISATION FUND FEASIBILITY STUDY

MILESTONE TWO REPORT

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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 (due 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 second milestone, 'International Industry Trends', which are to:

- Review published research and presentations detailing successes and failures in the implementation of waste plasterboard recycling systems.
- Research technological advancements and emerging trends in the collection and recycling of waste plasterboard internationally.
- Explore the impacts that new technologies and changes in current design and construction practices would have on the collection and recycling of waste plasterboard in New Zealand.

2.0 Research Methodology

A large volume of research exists regarding industry best practice for plasterboard recycling internationally. A number of organisations, such as the Waste and Resources Action Programme (WRAP) based in the UK, have undertaken independent research and case studies to determine how greater efficiencies and better outcomes can be achieved in the recycling of waste plasterboard into gypsum.

In addition, much of this research refers back to a small number of companies that have led the way in the development of proprietary technologies to improve viability of plasterboard recycling business models.

In order to undertake the research contained within this report, the following documents and websites have been reviewed:

- *Alternative Disposal Methods for Gypsum Board Waste*, Jerry Walker, International Conference on Natural and Synthetic Gypsum 2000 Presentation
- *Assessment of the Logistics of Waste Plasterboard Collection MFE Interim Report*, Grant Emms and Bob Batenburg, May 2006
- *Bibliography on Gypsum Drywall*, John Reindl, Dane County Department of Public Works, WI, 2003

- *BNPB1: Plasterboard - Industry, Product and Market Overview*, Defra Market Transformation Programme, February 2008
- *BNPB3: Plasterboard – Legislation and Policy Drivers*, Defra Market Transformation Programme, December 2007
- *Case Study: What Building Customers Want from a Waste Collection Service*, Troy Smith, October 2005
- *Development of Construction and Demolition Waste Recycling in Ontario*, Tomo Saotome, August 2007
- *Drywall Recycling*, C and D Recycling Program, CIWMB, August 2001
- *Eurogypsum Waste Policy: Building Value for Society*, Euro-Gypsum, September 2007
- *Gypsum Recycling - The Successful Scandinavian Solution*, Henrik Lund-Nielsen, Global Gypsum Conference 2003 Presentation
- *Gypsum Wallboard Recycling and Reuse Opportunities in the State of Vermont*, Emma Marvin, August 2000
- *Gypsum Waste Management: Caring for the Environment*, Knauf Drywall, 2005
- *Innovative Drywall Recycling Grant Final Report*, SCS Engineers/RW Beck, June 2003
- *PAS 109:2008 - Specification for the Production of Recycled Gypsum from Waste Plasterboard*, British Standards Institution, August 2008
- *Policy Options White Paper - Promoting Greater Recycling of Gypsum Wallboard from Construction and Demolition (C&D) Projects in the Northeast*, Northeast Waste Management Officials' Association (NEWMOA) C& D Materials Workgroup, September 2010
- *Process Know-How - Recycling of Plasterboard*, Heiner Hamm, Rolf Hüller, Jörg Demmich, May 2007
- *Recycling Gypsum from C & D Debris*, Mark Musick, Biocycle, March 1992
- *Scoping Waste in the Residential Built Environment Final Report*, Beacon Pathway Limited, September 2011
- *Successful Plasterboard Recycling in Practice: Reality Versus the Myths*, Henrik Lund-Nielsen, Global Gypsum Conference Presentation April, 2005
- *Sustainable C&D Waste Management*, Euro-Gypsum, January 2010
- *Target Zero Construction and Waste Minimisation Pilot Study Case Study Report*, Sinclair Knight Merz, August 2001
- *The Route to Zero Waste*, GRI, Construction and Demolition Debris Summit Presentation, January, 2008
- *Waste Plasterboard Composting Literature Review*, Craig Brown and Sarah Allcock, Envision NZ Ltd, September 2008

- *WRAP Ashdown Agreement Annual Report to 31 March 2010*, WRAP, September 2010
- *WRAP Demonstration of Plasterboard Recovery in Construction Projects*, David Smith, Steve Pearce and Steven Emery, September 2008
- *WRAP EJ Berry - Plasterboard Take-Back Using Reverse Logistics*, Oakdene Hollins, November 2008
- *WRAP International Practice in Plasterboard Recycling: Denmark*, WRAP, July 2006
- *WRAP Plasterboard Waste Recovery from Smaller Building Sites*, WRAP, July 2007
- *WRAP Trials for the Use of Recycled Gypsum in Cement Manufacture*, Faye Clamp, November 2008
- http://www.british-gypsum.com
- http://www.drywallrecycling.org
- http://www.environment-agency.gov.uk
- http://www.epa.gov
- http://gypsumrecycling.biz
- http://www.nwgypsum.com
- http://www.recyclingalliance.co.uk
- http://www.royhatfield.com

Given the nature of the research, which is aimed at gaining an overall impression of technological and process advancements in plasterboard recycling internationally and the implications for GR4CM from these advancements, and the informal nature of much of the material referenced, the research has not been undertaken as a formal literature review or research study. Instead, the material shown above has been analysed and synthesised to provide a working reference for the GR4CM project as to international best practice developments that may inform decision making as the project progresses into later phases.

Overall, the research indicates that technological and process advancement is focused on three key regions:

- The United Kingdom
- Europe
- North America

Due to its close proximity to New Zealand, Australia is also briefly considered in this report.

The report is organised geographically, with key trends and learnings from each region discussed in turn, and the key implications for GR4CM summarised at the conclusion of each regional section.

3.0 The United Kingdom

The Regulatory Environment: DEFRA and the UK Environment Agency

The United Kingdom's Environment Agency (UKEA) has the responsibility "to protect and improve the environment, and to promote sustainable development".

In August of 2007 the UK's Department for Environment, Food and Rural Affairs (DEFRA), which is the parent organisation for the UKEA, released a report looking at key drivers for the recycling of plasterboard in the UK in the light of the UKEA's 2005 reduction of plasterboard waste levels in landfills to 10%.

The report notes that for a plasterboard recycling industry to work, their needs to be strong economic drivers in place at every level of the supply chain. It also highlights the importance of source separation and appropriate handling in terms of maintaining the quality of recycled product. Tax incentives for transporting sorted materials to a recycling facility instead of a landfill were identified as a desirable option for consideration, as was exempting recycling equipment and land and buildings used for processing operations from sales tax. Reference was also made to the banning by British Columbia of plasterboard from landfills altogether. This was recognised as a powerful stimulating force to a recycling industry.

Ultimately, of the different drivers and possible incentives considered by DEFRA, the option of banning plasterboard from landfills prevailed.

On 1 April 2009, a regulation enacted by the UKEA meant that gypsum and plasterboard could no longer be sent to landfills mixed with biodegradable waste. The primary reason for this was research undertaken by the agency which suggested that "gypsum, when mixed with biodegradable waste, can produce hydrogen sulphide gas in landfill which is both toxic and odorous". The UKEA felt that there was insufficient data available to set a maximum allowable limit of gypsum in a landfill also containing organic waste, and so the combination was completely disallowed. Previously, 10% of waste being disposed of in landfill could be gypsum.

As a result of this ban, the UKEA has begun to work more proactively to encourage gypsum reuse and plasterboard recycling. The ban has, unsurprisingly, had a strong impact on such activities throughout the UK.

The onus to adhere to the regulations has been placed on the producers of construction and demolition waste and waste transfer facility operators. Construction projects worth more than £300,000 based in England must have a formal site waste management plan, and all producers must separate out plasterboard and other gypsum-based material so that it can be recycled. All producers must also make reasonable efforts to recycle and treat as much of their waste as possible, including source separation.

PAS 109: Specification for the Production of Recycled Gypsum from Waste Plasterboard

In late 2008, as the ban on disposing of plasterboard in landfills approached, the UK-based Waste and Resources Action Programme (WRAP) commissioned the British Standards Institution (BSI) to develop a specification for the production of recycled gypsum from waste plasterboard to support the need for these types of activities to become more effective.

The specification emphasises the importance of keeping waste plasterboard free from contamination and highlights the damage that co-mingling waste can inflict on processing machinery due to the presence of foreign matter. Contamination of the paper lining of the plasterboard also reduces the potential for earning income from this as a recycled resource. The specification also focuses on the difficulty of sorting and removing waste plasterboard after co-mingling because of size reduction of the waste.

The specification highlights the importance of mitigating dust creation, an issue that has plagued processing in New Zealand. Water spraying is specifically excluded as inappropriate due to the potential for caking the gypsum.

Further instruction is given in terms of storage of recycled product including the need to cover the gypsum, store on a hard floor such as concrete or metal and ensure the gypsum is protected from water or other contaminants. This advice echoes the learnings from storage of gypsum at the Holcim plant in Westport.

The Ashdown Agreement

The Ashdown Agreement on Plasterboard Recycling was reached between WRAP and the Gypsum Products Development Association (GPDA) which includes as members the largest plasterboard manufacturers in the UK: British Gypsum, Knauf Drywall and Lafarge Plasterboard. It was initiated in 2007 with the aim of reducing the amount of waste gypsum produced in the UK.

The agreement has aims that are generally similar to those of the GR4CM project, albeit at a much larger scale, with an ultimate objective of achieving zero waste plasterboard to landfill.

Two of the agreement's key targets are of particular interest:

- *Target 2*: *"To reduce the amount of waste being sent to landfill, both monocell and co-disposal, from UK plasterboard manufacturing operations to 5,000 tonnes by 2010."* The 2010 Ashdown Agreement Annual Report shows that the UK is making impressive progress against this target, reducing landfill disposal for the year ended 31 March 2010 to just 504 tonnes, or just 10% of the desired landfill target. The target has now been reduced to 2,000 tonnes per annum.
- *Target 3: "To increase the take back and recycling of plasterboard waste, for use in plasterboard manufacture, to 50% of new construction waste arisings by 2010."* The 2010 Ashdown Agreement Annual Report shows that 26% of new construction waste was recycled for use in plasterboard manufacture for the year ended 31 March 2010.

The 2010 Annual Report focuses highlights a number of factors that will aid ongoing viability of the plasterboard recycling industry in the UK in the coming years:

- A marked increase in the landfill tax paid. In April of 2010 this tax was increased by £8 per tonne to £48 a tonne. It will subsequently increase by £8 per tonne each year until at least 2014.
- The introduction by UKEA of mandatory site waste management plans for large construction projects.
- The ban instituted by UKEA of disposal of identifiable waste plasterboard in landfills.

The report demonstrates that as a result of these factors, amongst others, the amount of plasterboard production waste sent to landfill has reduced from just less than 70,000 tonnes per year in 2003 to about 500 tonnes per year in 2010.

Recycling of new construction waste has increased from about 3% of total waste in 2002 to 26% in 2010.

Key Player: Knauf Drywall

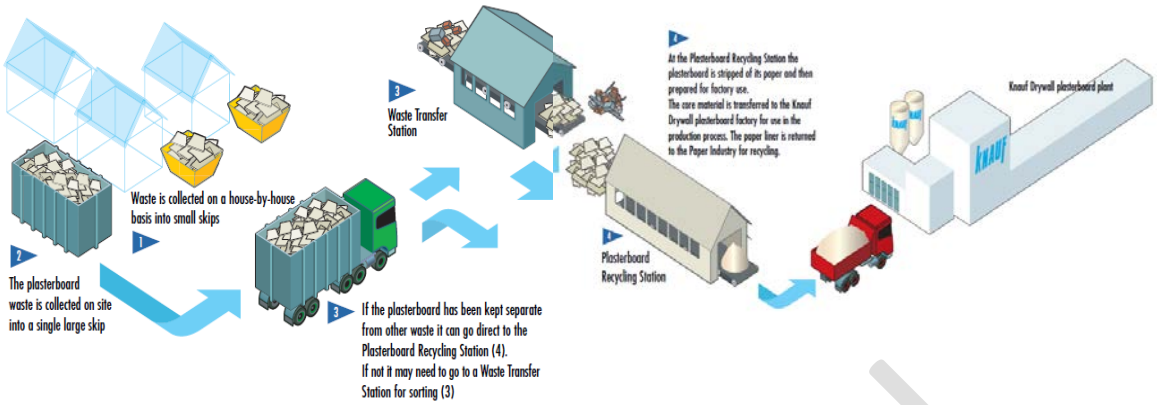
Knauf Drywall (KD) was established in the UK in 1988 and currently has manufacturing plants in Kent and Lincolnshire. As a response to the changes in UK regulations relating to plasterboard waste disposal in landfills, KD has developed a 'takeback' scheme for new construction sites.

KD use 500kg polythene bags for on-site waste plasterboard segregation. Skips and wheelie bins can also be provided for larger commercial building sites. Waste management contractors are used to collect the containers and transfer the waste plasterboard to the processing facility. Recycled gypsum is used by in the production of new plasterboard. The paper liners are recycled and supplied to "the paper industry".

As with most other collection services of this type emphasis is placed on effective on-site separation due to the limitations placed on recycling contaminated waste. It would appear that builders are charged for any waste that cannot be recycled due to co-mingling contamination.

Builders are given a dedicated phone number to request collection of full bags and to order empty replacement bags. The bags are given a unique identifier and each one is tracked and registered to the particular building site. Builders are given reports on the waste management performance of each site.

The overall process is illustrated in the diagram below:



Processing of waste plasterboard for KD is undertaken by New West Gypsum.

Key Players: New West Gypsum and Lafarge Plasterboard

New West Gypsum (NWG) is a Canadian company founded in 1986 that also operates in the UK from its base in Bristol (see the 'North America' section of this report for a full overview of NWG).

NWG works closely with a transport and waste management company called Materials Recovery Ltd (MRL), which collects and sorts waste plasterboard from building sites before delivering to NWG. Using technology developed by NWG in Canada, processing is undertaken for Lafarge and Knauf Drywall. It is estimated that NWG processes approximately 75,000 tonnes per year per site.

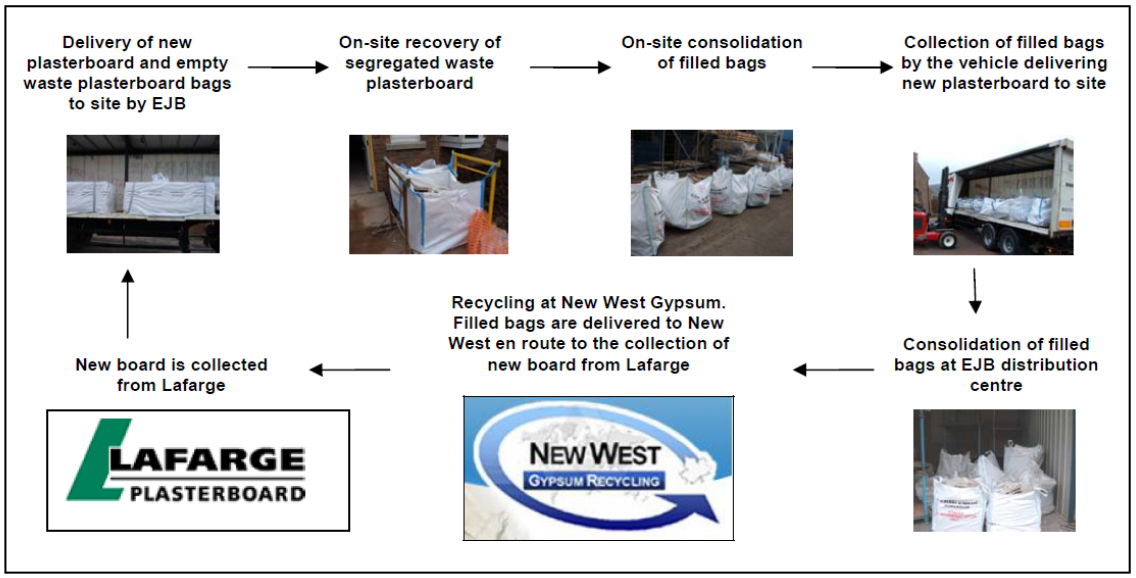
Lafarge Plasterboard Ltd (LP) has, since 2005, operated a recycling facility with NWG at the Lafarge site in Bristol. A recycling service is available to LP customers, with MRL collecting waste and delivering it either directly to NWG or "bulking stations" where it is consolidated to minimise the number of vehicle movements. The plasterboard waste is processed and re-used in the production of new plasterboard.

In June of 2007 LP and NWG partners with a plasterboard distributor called EJ Berry (EJB) to create a new take-back service for builders based on the concept of 'reverse hauling' where waste is collected and new plasterboard delivered by the same transportation company, in this case EJB. This reduces the overhead costs of waste collection and allows for the service to be offered to smaller scale building operations. The service currently collects in excess of 30 tonnes of waste plasterboard per month, and is growing in popularity.

Builders pre-pay £25 for each bag, which encourages use, and the bags are prominently branded by EJB to ensure only authorised bags are used and advertise EJB and the take-back scheme. Each bag holds approximately 280kg of waste plasterboard which equates to a cost of £89 per tonne. Analysis of the service suggests that 250kg represents the minimum volume of waste plasterboard that can be viably

collected from a single site from an economic perspective. The collection of 200kg in a £25 bag equates to £125 per tonne, as opposed to the cost of disposal using a small mixed waste skip which is approximately £86 per tonne, although this cost continues to increase annually. Because the system uses reverse hauling, which reduces costs, collection of only one bag is still considered economically viable.

The overall process is undertaken as follows:



WRAP, which prepared a case study on the service, noted that "the general consensus from the dry-lining contractors is that when compared against skips, the bag systems are less likely to be used for the disposal of other wastes since skips are more traditionally associated with mixed waste disposal. This has helped minimise contamination of the plasterboard waste bags on-site."

Prior to collecting and transporting the bags, the driver undertakes a visual inspection of the contents. Bags are not loaded until any contamination has been removed. The close working relationship between EJB and its customers means that, to date, no bags have been rejected in this manner. The bags are weighed at the collection depot and data is communicated to builders. Once sufficient waste has been gathered, a load is transported to the NWG recycling facility.

Key Player: British Gypsum

British Gypsum (BG) is a large plasterboard manufacturer with five major manufacturing plants throughout the UK. BG has developed a recycling service that takes back waste plasterboard (BG products only) from construction sites. This service has been rolled out incrementally; initially to national house-building chains, then to regionally-based companies.

The service allows the builder to use bags, skips or bins depending on volume requirements and access. BG states they can customise a receptacle solution for "any construction project". The units are picked up by a contracted waste management company at pre-agreed times and

are transported to one of a network of recycling centres throughout the UK, then to one of BG's production facilities.

The gypsum is then recycled on BG's own processing lines based on-site at their manufacturing plants and used in the production of new plasterboard. BG notes that recycled gypsum from each batch is mixed with recycled gypsum from other batches to overcome any quality consistency issues. The extracted paper is recycled and used for cattle bedding.

On-site labs test the recycled product for quality and purity, and overall the process appears to be highly automated and focused on producing a high quality recycled product. Part of the process that is not undertaken in New Zealand is heating the recycled gypsum 150 degrees Celsius to cause it to break down into a light powder and presumably remove any residual moisture.

BG states that, as a result of the efficiency and scale of their process, they are able to provide the service at a rate lower than sending the product to landfill. Price information was not able to be obtained.

Key Player: Roy Hatfield Ltd

Roy Hatfield Ltd (RH) has been in the recycling business since the 1970s. After undertaking trials in 2005, RH began processing waste plasterboard from construction and demolition sites and now process approximately 1,000 tonnes per week from around the UK and Europe at its Rotherham facility.

BH uses recycled gypsum in its own concrete admixture manufacturing process, as an ingredient in the manufacture of moisture absorbents and also for the manufacture of interior wall blocks. They also supply gypsum for plasterboard and cement manufacturing.

BH arranges collection of waste plasterboard "from all over the UK and even Ireland and mainland Europe" at a rate of between £6.00 per tonne and £20.00 per tonne depending on location.

Key Player: Gypsum Recycling UK Ltd

Gypsum Recycling UK Ltd (GRUK) is owned by the directors and shareholders of Gypsum Recycling International (GRI), a company which recycles plasterboard throughout Scandinavia, Europe and the USA (see the 'Europe' section of this report for a full overview of GRI).

GRUK utilises the process and mobile technology in use in all GRI locations. GRUK was established in 2005 and now offers a nationwide collection service with storage depots in Kent, London and Hertfordshire. GRUK takes both construction and demolition waste. As with other GRI locations, waste plasterboard is stored until sufficient quantities are collected, at which point the mobile processing equipment is despatched and the waste is processed into gypsum. Recycled gypsum is supplied to plasterboard manufacturers including Lafarge and Knauf Drywall.

WRAP Study - Trials for the Use of Recycled Gypsum in Cement Manufacture

In November 2008 WRAP undertook a study of the gypsum recycling industry with a particular focus on utilisation of gypsum for cement manufacture.

The study reported that the particular benefits of utilising recycled gypsum in cement manufacture are that:

- "the recycled content of cement will increase, which may assist cement manufacturers meeting their sustainable development objectives;
- it will support the diversion of waste plasterboard from landfill; and
- the cement industries reliance upon natural materials will be reduced."

The plasterboard recyclers considered in the study were:

Company Name	**Locations**	**Tonnage Capacity (ktpa)**
New West Gypsum	Avonmouth, Avon Immingham	60 (currently 36k) 25 (est 20-30)
Gypsum Recycling International	Halling, Kent	110
British Gypsum[16]	East Leake, Loughborough Robertsbridge, Sussex Kirkby Thor, Cumbria Sherburn-in-Elmet, Leeds	Total 100
Roy Hatfield Ltd.	Rotherham, South Yorkshire	50
Mid UK Recycling	Grantham, Lincolnshire	50
Recyclet	Brigg, Lincolnshire	65
Coast2Coast	Tollerton, Yorkshire	25
PBR UK	London	50
Total available plasterboard recycling capacity		**>535**

One of the conclusions of the study was the importance of reconsidering building demolition practices to avoid contamination of waste plasterboard. It was suggested that plasterboard be stripped out of the building before demolition and that failure to do so would mean that "plasterboard from demolition projects is not accepted at recycling facilities". This has particular bearing on the usefulness of earthquake demolition waste in Christchurch.

The study also sought to compare the costs of natural gypsum with recycled gypsum as follows:

Manufacturer	Price Per Tonne	Haulage
Recycled Gypsum from Plasterboard Natural Gypsum	£5 - £8 £8 - £12	£1.50 per mile

Source: WRAP (2007); Scoping Study for the use of Recycled Gypsum in Cement Manufacture

As is the case in New Zealand the costs of recycled gypsum and natural gypsum are very close, and transportation costs tend to impact the final price paid more than the actual resource price. This fact has resulted in cement mills in the UK being based near gypsum mines, which is not an option for New Zealand as there are no known local sources of natural gypsum.

The report also considered the various methods of waste plasterboard disposal and diversion, and the resultant costs to the waste producer from these methods. These figures are shown below:

	Take-back scheme*	Sent to plasterboard recycler	Landfill (via 10% rule)	Landfill (via monocell)
Waste container type	1 m³ bag (£19 each) On average, a bag will take 0.25 tonnes of plasterboard waste. With a chipper, this can rise to 0.35 tonnes.	Skip	Skip	Skip
Landfill tax (£/tonne)†	–	–	Included within skip costs.	Included within skip costs.
Total cost per tonne of plasterboard waste	£76 With a chipper, the cost will be ~£57**	£25–55†† The cleaner the plasterboard waste or the greater the quantities, the cheaper it will be per tonne within the range.	£50#	£133##

* Figures based on the scheme provided by British Gypsum, which requires a minimum purchase of 10 bags and a minimum collection total of six full bags.

† The annual rise in the landfill tax will be reflected in the increased cost of waste containers. With the take-back scheme, no landfill tax is paid as the waste is not going to landfill but to be recycled.

** Based on trials by Wastecycle, a chipper can provide labour cost and time savings. Manual filling was found to cost £20.15/ m^3. With the use of the chipper, this reduced to £6.46/m³ (Source: WRAP, 2007. *Capture of waste plasterboard on construction sites*; www.wrap.org.uk/document.rm?id=4740).

†† Does not include transport
# Figure sourced from Wastecycle and based on landfill costs in the East Midlands region.
See Table 1 of the WRAP Good Practice Guide.

It is important to note that the landfill cost has risen by £24 since these figures were released, and will increase by another £8 early next year. Furthermore, the 10% rule option is no longer available. Collectively these changes reinforce the economics that have been established in the UK to support waste plasterboard recycling.

Conclusions and Implications from United Kingdom Research

The regulatory environment in the United Kingdom demands that a recycling industry establish itself, and the economics of doing so are virtually unquestioned. The presence of a total ban on disposing of plasterboard in mixed landfills, significant increases in landfill taxes and the requirement for significant construction projects to have a site waste management plan all combine to establish viability for plasterboard recycling at a large scale.

Consideration needs to be given to whether any or all of these factors may be required in order to establish wide-scale plasterboard diversion from the waste stream recycling in New Zealand.

A vibrant and competitive plasterboard recycling industry exists in the UK with a number of plasterboard manufacturers and private companies providing services. Most recycling activity is undertaken by or in conjunction with a plasterboard manufacturer in partnership with a collection agency.

Key aspects to making these services work appear to be:

- Ensuring the price per tonne of collection is at the same level or lower than other avenues for disposal
- Providing a range of receptacles (bags, bins, skips) for on-site collection of waste
- Ensuring mechanisms are in place for effective on-site separation, and for checking (ideally before pick-up) that accurate separation has occurred
- Ensuring rapid and reliable pick-up as required
- Making use of 'reverse hauling' (utilising the same trucks to drop off new plasterboard and pick up waste) to minimise overhead costs and end user price

4.0 Europe

The Regulatory Environment: EU Directives

In 1999 the European Union (EU) passed Directive 31, a ten-year plan to upgrade Europe's landfills. This directive determined that all landfills would be categorised as either:

- Type 1: Inert landfills (a 'hole in the ground' for waste that does not 'interact' such as cement);
- Type 2: Non-inert, non-hazardous landfills (more expensive, with controls for leaching and air pollution and separate cells for different wastes – mainly for household and some industrial waste);
- Or Type 3: Hazardous landfills (careful storage of dangerous wastes)

The directive made the maintenance and compliance of landfills very expensive and up to 40% had ceased operation prior to the 2009 compliance deadline. The other key impact of the directive was sharply increased dumping fees. This is further compounded by the requirement in the directive that from 2009 all waste 'owners' must bear the full costs of waste disposal, including allowances for the retirement of the landfill site.

While this directive was considered stringent, it was further strengthened in 2002 by the issue of Directive 33. This directive focused on specifying what wastes could be sent to each type of landfill, and what treatments were required prior to disposal. Directive 33 determined that plasterboard waste would need to be sent to a Type 2 landfill, in a separate cell away from organic waste. Thus, from mid-2005, waste plasterboard that previously would have been sent to a Type 1 general landfill had to be sent to the considerably more expensive Type 2 landfills.

The minimum treatment required prior to disposal was determined to be sorting, effectively banning the dumping of mixed loads. This determination was considered to be a strong incentive towards on-site sorting and separation.

The impact of these directives has caused total disposal costs for waste plasterboard in Europe to increase dramatically when compared to New Zealand's costs. In Belgium and Denmark the cost is in excess of €135 per tonne, with Germany and France coming in at around €100 per tonne.

Industry Response: EuroGypsum

EuroGypsum (EG), founded in 1961, is the "European federation of national associations of gypsum products manufacturers" and speaks for the manufacturers of gypsum-based products in Europe.

As the EU introduced directives to restrict the disposal of waste plasterboard in landfills, EG worked with its members to analyse existing recycling efforts and provide guidance to promote increased recycling efforts, particularly because of the increased landfill costs.

EG noted that current collection systems for new construction waste worked well for larger organisations, but proved difficult to scale down. The two key types of collection were, as in the UK, bags and skips. EG felt that bags worked best for construction waste, particularly when reverse hauling was in place, whereas skips worked best for demolition waste, where this was an easy augmentation to existing service provision for waste contractors. As in other regions, storage space on a building or demolition site was viewed as the key restricting factor in wide-scale adoption of on-site separation.

EG felt that the use of a 'mosquito fleet' had the greatest long term potential for collection. This strategy involves the use of specialised small trucks that collect waste and deliver it directly to processors or to transfer stations. EG's report on this issues stated that this system "is more adapted to SMEs and is widely used in the US where plasterboard recycling is at a more advanced stage".

The response to the EU directives in France and Denmark has been to establish local authority waste collection centres. Over 150 operate in France alone, with access restricted to "the general public, SMEs and craftsmen". It is estimated that 55% of waste plasterboard in France is disposed of through such centres.

Despite a general acceptance of waste plasterboard recycling initiatives, it is recognised by EG that transportation costs from site to processor or waste transfer station are a barrier to adoption of the schemes. The impact of these costs has been largely offset by increased landfill costs, however, which act as a strong incentive to embrace on-site sorting and recycling.

Overall, EG states that the key success factors for recycling construction and demolition waste are:

- Clear and accurate specifications for waste to ensure it is clean, and strong enforcement of the rules
- Raising the 'consciousness' of construction personnel and pre-construction training
- On-site sorting and separate storage of plasterboard waste

The key factors influencing the economic viability of waste plasterboard recycling are considered to be:

- The availability of sorting and storage space
- The degree of waste contamination
- The costs of transportation
- The strength of existing regulations (processing, air, water, disposal, storage, etc.)
- Market availability of raw materials and demand for processed product

EG note that, in general, "new construction materials are more readily recycled than demolition or renovation wastes which are more difficult to separate, resulting in higher

contamination levels". This degree of contamination is, as shown above, a key factor in whether the recycling scheme in question will 'work' from a financial perspective.

Ultimately, according to EG, the success of the recycling industry can be summed up as follows:

"In the end, assuming there are available end-uses for the recovered materials, the immediate recycling of Gypsum debris makes economic sense if the total net financial cost of recovery is less than the cost of land-filling."

In terms of existing players within the market, EG recognise that there are two key types of industry participant: private companies with processing facilities and plasterboard manufacturers. EG notes that "nearly all the Gypsum manufacturers have internal recycling facilities. No new factory is designed without this."

Key private industry players include the UK's Roy Hatfield and Canada's New West Gypsum. Particular note is made of the mobile processing technology from Gypsum Recycling International.

Key Player: Gypsum Recycling International

Gypsum Recycling International (GRI) is a subsidiary of NKR demolition Group, the largest demolition company in Scandinavia, and is based in Naerum, Denmark. GRI is passionate about recycling waste plasterboard into gypsum for use in the manufacture of new plasterboard and even goes so far as to say "to deliver recycled gypsum powder for any other purpose than for making new gypsum products is neither logical nor the best use of the materials and the resources contained herein".

To this end, GRI supplies gypsum to the "top five plasterboard companies in the world" including USG, BPB Group, Knauf, Lafarge Gypsum and National Gypsum. GRI guarantees the quality of the powder and will take back a delivery within 24 hours if the quality is unacceptable.

Key to GRI's success has been the invention of proprietary mobile processing technology which allows it to process waste plasterboard wherever it is located, rather than transporting the waste to a central location, or to waste transfer centres for subsequent relocation.

The patented technology, launched first in Denmark in 2001, is now also being used in Sweden, Norway, the Netherlands, Ireland, the UK, the USA, Belgium, Japan and Switzerland, with new countries being regularly added to the list.

Unsurprisingly GRI has doubled in size over the past five years and is a regular placeholder on the list of Denmark's fastest growing companies.

Despite the emphasis on the mobile unit, however, GRI emphasises its 'total system approach' to recycling plasterboard, and sees this integrated system as the key to its fortunes.

The first element of this system is GRI's approach to collections.

GRI has designed containers specifically as plasterboard receptacles. GRI states that in addition to weather protection, which is viewed as critical, the 30m^3 containers are also designed to allow for easy use and collection by GRI trucks. In addition to the larger units, GRI also provides a smaller 5m^3 container.

The containers are sold or leased to waste owners and are located either at temporary sites such as construction or demolition sites (25% of containers) or at permanent sites such as municipal waste sites or waste transfer stations (75% of containers).

GRI handles waste plasterboard from manufacturing, new construction and demolition, and appears to have a high degree of tolerance for contamination in the waste. Nails or screws can be accepted within the waste, as can any kind of wall covering. Notable exclusions include plastics and foil, insulation, steel and wood.

The second element of GRI's overall system is logistics.

Waste is collected by GRI's own specialised trucks by means of a 'grabble' into an on-board storage unit. This allows a truck to make several pick-ups before returning to base. Trucks collect four to six containers' worth of waste plasterboard in one trip, minimising transportation costs. The waste collected is weighed on the truck and the data used to invoice clients. The current cost per tonne is rated at "a little less" than the landfill cost, but this differential is growing as landfill costs increase.

The waste is then transported to one of a number of warehouses for sorting prior to recycling. These are typically located close to a plasterboard manufacturing plant to keep the costs of the final product for sale as low as possible. A minimum of 2,000 tonnes of waste is stored at a warehouse before being processed over a week (based on 16 hour processing days).

The third and final element of the GRI system is the mobile recycling unit.

The 24m long, 47 ton unit, specially designed by GRI after several years of investment and research, has a capacity of 100,000 tons. It can be set up in a couple of hours and is transported from one warehouse to another as stockpiles require. This logistical optimisation substantially reduces overall costs, particularly from transportation.

A newer version of the unit, known as the XL, can handle even higher volumes, and while somewhat larger, is still able to be transported without special permits on European and US roads. All units, powered by their own diesel generator, are fully automated, create "almost no dust" and are "almost noiseless" in operation. The output is considered very high quality with very low paper contamination in the recycled gypsum.

Despite the obvious competitive advantage this technology brings, GRI consider that it is only one of several factors that must come together to create a successful recycling business model. GRI considers these factors to be:

- "Specially developed containers for easy filling and removal
- A logistic system capable of assuring an effective collection, handling and invoicing of the waste owners
- A Mobile Recycling Unit to lower transport costs by servicing more recycling plants, and capable of handling new construction waste as well as demolition waste
- Customers that can benefit directly from the recycled materials"

The first country in which GRI launched its service was its home nation of Denmark. The process by which it developed this market and created a successful business model in Denmark has been widely studied in the industry, including a case study by WRAP.

GRI has essentially cornered the waste plasterboard recycling industry in Denmark, with 90% of all public waste transfer stations providing GRI bins, and over 65% of all waste plasterboard in Denmark being recycled by GRI, the highest level for any voluntary scheme in the world. Overall 50% of the waste plasterboard recycled by GRI comes from public bins, with the remaining coming from construction companies.

GRI has been aided in developing its Danish business by the policies of the Danish Environmental Protection Agency (EPA) which include high waste taxes which make landfilling of waste plasterboard prohibitively expensive, and subsidies for green technologies, of which GRI has been a beneficiary. These factors, combined with the efficiency of GRI's system means that, on average, a waste owner will save 25% on disposal costs by sorting waste and utilising a GRI bin.

In a 2005 presentation to the Global Gypsum Conference in Prague, GRI CEO Henrik Lund-Nielsen reflected on his experiences growing GRI and attacked some of the 'myths' around

business models for recycling waste plasterboard. His key challenges to 'traditional thinking' include

- *Profitable plasterboard recycling systems can be established without a ban on landfilling of the waste*. Denmark does not ban landfilling of plasterboard, but has made it expensive to undertake. Lund-Nielsen believes the challenge is to change the behaviour of end users to encourage separation of waste at the building or demolition site. He believes that if money can be saved (25% off landfill costs in GRI's clients' case) and the process is easy enough, end users will change behaviour quickly.
- *National coverage can be economically achieved by moving the processing unit around instead of the waste*
- *Lower costs can be achieved for the end user by an effective collection and transportation system*
- *Demolition as well as construction waste can be recycled into a high quality resource.* Prior to GRI establishing its Danish operation it was widely believed that demolition waste was too contaminated to be usable, but GRI have overcome these issues with their technology and no special considerations have to be made for such waste.
- *Waste plasterboard recycling systems can be effectively established without plasterboard manufacturers having to be the initiator.* This was the prevailing thinking prior to GRI's launch, whereas GRI sees part of its value is in aiding plasterboard manufacturers to avoid the need to invest in this type of 'non-core' business.
- *Wet waste can be completely avoided.* GRI's unit can handle wet waste, but their system has been designed to avoid waste getting wet at all. As clients are charged by weight, this avoids end user cost.

Conclusions and Implications from Europe Research

As with the United Kingdom, the success of the waste plasterboard industry in Europe is apparently predicated on the economics of end user choice. There is little suggestion that builders, demolition contractors or the general public do anything other than compare pricing when determining whether to separate and recycle waste plasterboard, or simply dispose in a landfill. It is difficult to escape the fact that without the governments of European nations levying heavier and heavier taxes on landfills, waste owners would continue to choose the cheaper option and landfill their waste. As EuroGypsum succinctly states:

"In the end, assuming there are available end-uses for the recovered materials, the immediate recycling of Gypsum debris makes economic sense if the total net financial cost of recovery is less than the cost of land-filling."

Beyond this, it is evident that Europe is dominated by a number of large players including GRI that have sought not to rely simply on the basic economic transaction of recycling vs. landfilling, but rather invest in developing a system and technology that is optimised for cost savings and end user convenience.

GRI has grappled with, and overcome, a number of the issues that impact the New Zealand industry, in particular:

- Encouraging changes in on-site user behaviour by making recycling as easy as possible
- Minimising transportation costs by rationalising collection systems and making processing a mobile technology
- Lowering costs structures to offer a significant (25%) cost advantage to end users over landfilling

While New Zealand may not have the technology or level of waste to support an infrastructure as extensive as GRI's it is the focus on developing a complete system oriented around the needs of the end user that is the key learning from the approach of GRI.

5.0 North America

Unlike the UK or Europe, there is huge variation cross the United States and Canada in terms of how waste plasterboard is handled and the legislation that must be complied with. It would appear that, in general, Canada is more advanced in recycling waste plasterboard, and within the US, California and the Northeast states have undertaken the most development in this area.

British Columbia, Canada

In stark contrast to the relatively slow realisations of many other regions and countries of the concerns around hydrogen sulphide from including plasterboard in general landfills, the Greater Vancouver area banned such mixing in 1984 following a detailed study commissioned on its effects. This ban was the impetus for the creation of New West Gypsum, one of the early pioneers of plasterboard recycling.

New West Gypsum (NWG) began in Vancouver, and now has facilities in Alberta and Ontario, as well as France, Belgium, the UK and in Washington and Nevada states in the US. It currently processes over 350,000 tonnes of waste plasterboard annually, all of which is sold for plasterboard manufacture. Approximately 70% of the waste received by NWG is construction waste, with the remainder being equally split between demolition and production waste. The Vancouver facility recycles approximately 70,000 tonnes per annum, operating 16 hours a day, 6 days a week for 50 weeks a year.

NWG states that 99% of its revenues come from inwards tipping fees, where contractors pay approximately CAD75 per tonne. The recovered gypsum is sold to plasterboard manufacturers for CAD 1 a tonne (€2 – 3 a tonne in Europe), compared to CAD 19 to CAD 29 a tonne for natural gypsum.

In Europe NWG charges €15 – 20 per tonne for production waste and €50 for sorted construction and demolition waste, with an additional €15 charge if sorting is required. In Washington State, NWG charges USD50 - 55 a tonne, which is USD20 a tonne less than local landfills.

Like GRI, NWG will accept plasterboard in virtually any condition, including painted board, wallpapered, tiles or vinyl-covered board and wet board. Unlike GRI NWG also allows some contamination with plastic, small metal pieces and plastic. Only board with hazardous materials present such as asbestos is rejected. Contamination issues are largely avoided as inwards loads are charged based on quality as well as weight.

The Vancouver facility receives approximately 60 truckloads of waste per day, from up to 400kms away. Collection is split evenly from three key sources:

- Mosquito fleets (small vehicles collecting directly from construction sites)
- Larger waste management contractors
- Production waste from plasterboard manufacture

NWG maintains its own fleet of trucks to deliver recycled gypsum to plasterboard factories, then uses these to 'backhaul' production waste to NWG facilities.

Delivered loads are hand checked for metal, plastic and other contamination. The waste is then fed into a large hopper and passed under an electromagnet to remove metal fragments. The processing unit can operate in a space as small as 745m^2 and has a throughput of 25 tonnes of wet or dry waste per hour.

The gypsum produced is used at a 25% ratio with synthetic gypsum in new plasterboard manufacture to ensure quality levels are maintained. The paper liner is also recycled and sold to a local paper mill.

NWG have created a proprietary air filtration system to avoid the kind of air pollution issues which have plagued operations in New Zealand.

The founder of NWG believes that for a processing facility to be economical it will require "the supply of gypsum generated by a population of a million people, and close proximity to a gypsum wallboard manufacturer as an outlet for the recovered gypsum". He also notes that charging for inward tipping will be essential, and that high landfill costs or a ban on landfilling of waste plasterboard are highly desirable to support the economics of such a business.

A study undertaken by the British Columbia Ministry of Environment several years after instituting their ban on landfilling of waste plasterboard concluded that the barriers to entry for companies endeavouring to compete with NWG were high, due to:

- A limited supply of scrap plasterboard
- Limited end use markets
- High transportation costs

The study also ultimately concluded that the success of any recycling efforts in British Columbia depended on having a ban on landfilling of waste plasterboard in place.

Ontario, Canada

The government of Ontario has aimed to divert 60% of the state's waste from landfills annually, including a large proportion of 1.2 million tonnes per annum of waste generated by construction and demolition activities. As of 2005 only 12% of this 1.2 million tonnes was being recycled annually.

To realise this objective, two regulations were passed by the Ontario legislature:

- *Ontario Regulation 102/94* – under this regulation construction and demolition projects where the total floor area is at least 2,000m^2 require a waste audit, and owners must develop and implement waste reduction plans
- *Ontario Regulation 103/94* – under this regulation construction and demolition projects where the total floor area is at least 2,000 m^2 require source separation and recycling of waste, including plasterboard

These regulations, which have stimulated recycled efforts despite reportedly not being widely enforced, have been further augmented by increased landfill fees, although these are still only half the levels seen in Denmark. Despite increased landfill fees, however, NWG's status as the operator of the only plasterboard recycling facility in Ontario means that waste generated far from the facility tend to still be landfilled as the transportation costs are prohibitive.

A study considering the recycling of waste plasterboard from construction and demolition activities in Ontario suggests that, as in the UK and Europe, relative costs are the major factor in waste producers determining whether to landfill or recycle waste plasterboard.

The study also notes that there is little recognition of the importance of on-site sorting of waste on the construction or demolition site, and that a lack of space on sites is a major barrier to such activities, reducing the viability of recycling wastes produced.

Interestingly the author of the 2007 study noted the following:

"Some say source separation has not been implemented because it is time consuming and labour intensive, and it affects the price of recycled materials. However, it takes the same amount of time to pick up gypsum board and put it in a bin in any case. Therefore, source separation only depends on a space for bins and the environmental concern of waste generators."

Ontario, and indeed all of Canada, also operates under the Leadership in Energy and Environmental Design (LEED) Rating System, operated by the Canada Green Building Council, and analogous to the GreenStar and HomeStar programmes running in New Zealand.

LEED measures "building design and construction practices that significantly reduce or eliminate the negative impacts of buildings on the environment and occupants in five areas: water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality". Points are awarded in each category and qualifying homes given a rating of certified, silver, gold or platinum.

Part of the materials and resources score includes consideration for waste management, and requires a waste management plan and takes into account the level of waste diversion. These factors are independently verified.

Analysis of the impact of LEED suggests that it has a positive impact on waste management and that it has proved valuable to the market in that:

- "Newly constructed buildings that are LEED certified have higher occupancy than non-LEED certified
- Newly constructed buildings that are LEED certified rent for a higher dollar amount per square metre than non-LEED certified buildings
- Market demand for new buildings that are LEED-certified is higher than for non-LEED certified buildings"

These results would suggest that such rating schemes have potential impact in encouraging the recycling of waste plasterboard, but take-up tends to be sluggish internationally unless participation is compulsory, and the direct impact on plasterboard recycling is difficult to determine independently given other environmental factors such as landfill fees.

Northeast States, USA

In September 2010, with support from the Unites States Environmental Protection Agency (EPA), the Northeast Waste Management Officials' Association (NEWMOA) prepared a report considering the options for promoting greater recycling of plasterboard waste in the north-eastern states.

The report recognised that while 'clean' waste plasterboard could be recycled and used in the manufacture of new plasterboard or as a soil conditioner, the only end use that could absorb the 480,000 tonnes of new demolition and renovation waste plasterboard produced each year was replacement of virgin gypsum in cement manufacture. While this end use was deemed attractive, the recycling of all waste plasterboard in the north-eastern states would exceed the demand of regional cement manufacturers, particularly given that they operate at a theoretical limit for recycled gypsum in the cement mix of 20%.

As with nearly all other analyses of the economics of recycled gypsum, the low cost of natural gypsum and the need to encourage on-site demolition and construction separation were highlighted in the report.

In order to stimulate recycling of waste plasterboard the NEWMOA report presented the following policy options:

- *Banning landfilling of waste plasterboard*
- *Requiring recycling of waste plasterboard produced by state-financed projects*. This would be a 'lead by example' approach, and has already been adopted in Massachusetts and Maine.

- *Requiring waste management planning*. This is already happening in some states, such as Vermont and Maine, with the aim of raising awareness and generating interest in recycling options.
- *Developing and implementing extended producer responsibility*. This would involve plasterboard manufacturers, builders, government agencies, waste processors, and recyclers all assuming some responsibility for the management of plasterboard waste. This would shift part of the collection and recycling costs from the waste generator back to the producer, and make recycling more cost-effective when compared to disposal. Such schemes are already used widely for electronics waste, and several states, including Maine, are already considering this kind of regulation for plasterboard.

In response to the report, several states have already begun to implement some of the strategies identified with the most prominent being the state of Massachusetts banning plasterboard from landfills from 1 July, 2011. This ban is specifically targeted at lifting the level of waste plasterboard recycling in the state.

Florida, USA

In 2003 a team contracted to the Orange County and Seminole County local authorities produced a report to consider new technologies and opportunities in recycling plasterboard.

The team identified four key obstacles that any new plasterboard recycling programme must grapple with and endeavour to overcome:

- *Low cost of new gypsum.* The low cost of virgin gypsum makes it difficult to create a business model that can produce alternatives at a competitive price. In Florida, the average cost for new gypsum is approximately $20 per tonne.
- *Low disposal costs.* For plasterboard recycling to occur it must be cheaper to recycle than to dispose of the waste. In Florida, the average construction and demolition waste disposal tipping fee is approximately $20 per tonne.
- *Barriers to an efficient method of separation and collection.* For recycling to work on-site separation must become standard, which requires a fundamental shift in behaviour for building and demolition site operators, requiring a long lead time and significant effort. The counties that commissioned the report offered free recycling for segregated plasterboard loads as part of the project, but saw limited uptake from building and demolition contractors. Despite the limitations of off-site separation, this was still undertaken at landfill sites. The report noted that in areas where “drywall contractors” had responsibility for plasterboard waste, source segregation was much easier to implement.
- *Processing costs*. The cost and effort required to produce a consistently high quality recycled product for the end user provide a sharp challenge to the viability of waste plasterboard recycling.

California, USA

Unlike many other states and regions, recycled gypsum is significantly cheaper per tonne in California (at $20 per tonne) than natural gypsum (at $30 per tonne), which aids in stimulating the industry.

There are between forty and fifty plasterboard 'drop-off' sites in California, of which about a third are local Habitat for Humanity (HFH) chapters. Nearly all of these will only accept clean plasterboard, however, and HFH will only accept "large reusable sheets".

The local authority in San Jose, California has instituted a "deposit return system" for building contractors. Contractors must submit a waste management plan and pay a deposit before receiving a building permit. After the project, the contractor must submit evidence that the waste management plan was followed, at which point the deposit is returned.

Conclusions and Implications from North America Research

The findings from North America emphasise the trade-off between economic forces and legislation. Where market forces (albeit manipulated by government) make disposal of waste plasterboard expensive, recycling activities increase. Where new gypsum costs are low and disposal costs are low, disposal bans are deemed necessary to stimulate recycling, as seen in British Columbia and Massachusetts.

There are no stand-out technological or process innovations evident in what is being undertaken in the US and Canada, but it is clear that government support is prompting waste plasterboard recycling industries to rapidly develop in states that are typically considered more environmentally progressive.

Part of the key thinking in North America is considering more 'indirect' forms of government intervention to encourage recycling, such as the requirement for waste management plans to be prepared for larger building projects, requiring state-funded buildings to manage waste responsibly and encouraging recycling through building rating schemes.

All of the analysis undertaken in North America reinforces the findings from Europe and the UK, namely that in order for a plasterboard recycling business model to thrive it must have:

- Lower end user cost compared to new gypsum
- Lower disposal cost for building and demolition contractors when compared to landfilling
- On-site segregation/sorting
- Efficient collection mechanisms

6.0 Australia

A 2005 survey of Australian plasterboard manufacturers found that none maintained a waste plasterboard processing system, primarily because of low landfill costs and low new gypsum costs. In some states, such as South Australia, the lack of an end user for recycled product also presented a barrier to establishing a recycling market.

More recently, rising landfill costs have begun to stimulate recycling, but it would appear that many in the industry in Australia are closely watching the market develop in New Zealand to determine how to proceed.

CSR Plasterboard, based in Sydney, has begun to collect and recycle waste plasterboard utilising a fleet of three light trucks for collection. The service is currently available only to construction waste from large volume customers in the Sydney area, with approximately 100 tonnes of waste plasterboard being collected each week and processed by a contracted processor for agricultural use. The service is ostensibly provided for 'free', but the costs are actually added into the plasterboard price and 'traded off' against price discounting.

CSR reports that cement manufacture has not been considered as an end use due to the transportation costs required for remote cement plants, and the desire to avoid competition with CSR's own natural gypsum market.

Boral, another plasterboard manufacturer in Australia, also offers a plasterboard waste collection service. Builders are asked at the time of purchase if they wish to utilise a pick-up service and, if they accept, Boral charges the builder AUD120 for plasterboard waste pick up within 100km of their Melbourne factory.

Boral will only collect off-cut piles rather than providing skips that may cause waste plasterboard to become contaminated with other waste. Once a sufficient pile has been accumulated, the builder contacts Boral and a pick-up vehicle is despatched to collect the waste, which is recycled and used for agricultural purposes.

Boral considers the service to be successful and well established, but do not have records available of the volume of waste collected.

Interestingly, each of the four plasterboard manufacturers in Australia primarily sell a single length plasterboard sheet product at 6 metres long, with more than 80% of all sales being of this length. Installers simply cut the product down to fit as required. The waste on residential construction projects, which is of a greater size enabling more effective re-sure, results in waste levels of 5%, as opposed to 10 – 15% as seen in New Zealand. This is a strategy that has also been identified by Winstone Wallboards in New Zealand as offering potential construction waste reduction.

7.0 Overall Conclusions

The analysis of international trends in key regions in which waste plasterboard recycling is prominent demonstrates that the issues faced, and conclusions reached, are remarkably consistent. Many studies have been completed, and much research undertaken, and the results show that there is very little international variation in the core requirements for a successful plasterboard recycling industry.

The primary difference that presents itself is that European operators have tended to rely more on designing services that engage and satisfy the end user, whereas American services tend to be built almost solely on legislative imperative.

Overall, the following conclusions represent the key elements from the research that should be considered in building a sustainable business model for recycling waste plasterboard in Canterbury:

- *None of the markets considered thrived without high landfill costs or a ban on landfilling waste plasterboard*. Where landfilling is relatively inexpensive, and it may be argued in New Zealand that it is, creating a thriving plasterboard recycling business will prove extremely challenging. It is worth noting that landfill costs internationally are driven by the almost universal acceptance of the risks of combining waste plasterboard with organic waste and the resulting creation of hydrogen sulphide. This concern has not yet been formally addressed in New Zealand.

- *There are basic economic requirements in a successful model that appear to be virtually absolute*. The first of these is that the cost of disposing of segregated waste plasterboard must be materially lower than the costs of dumping mixed waste. The second is that the costs for an end user of obtaining recycled gypsum must be materially lower than the cost of obtaining new gypsum. All evidence suggests these decisions are made on a pure price basis.

- *Successful operations rely on on-site segregation*. This must be recognised as an extremely challenging behaviour change exercise and a successful model must work hard to understand the needs of the building or demolition contractor to make this process as easy and convenient as possible. Consideration of these needs should extend to collection processes which must align closely with the 'rhythms' of operation on the building or demolition site. Developing strong and positive working relationships between collection contractors and building or demolition contractors is vital. Other factors such as offering a range of different collection receptacles (bags, bins, skips) for different applications also assist in this endeavour. It should be noted, however, that no matter how much work is done here, site space will always be a limiting factor for on-site segregation.

- *Transportation costs can be a significant barrier to success, and transportation processes must be optimised*. Minimising transportation movements and making use of back hauling or reverse hauling where possible is important in keeping costs down. This should extend to consideration of drop-off and processing locations.

- *Pricing strategies are important.* Pricing for waste disposal based on weight alone may not be enough, and the quality and contamination level of the waste need to be considered. Checking the quality of waste before removal from the building or demolition site has strong advantages, as does passing on costs for contaminated waste.

- *Processing technology should allow for demolition waste*. The volumes required in New Zealand suggest that demolition waste must be considered but, as in most areas of the world, this provides significant challenges. It may be worth evaluating other technologies, such as that invented by GRI, which can handle the levels of contamination that may be expected in demolition waste. A higher price for receiving demolition waste would be justified.

- *The recycled product should be guaranteed.* To assist the end user in selecting recycled gypsum over natural gypsum, especially where the price differential is low, the recycled product should be guaranteed – and closely monitored – in terms of consistent quality. Product should be quickly replaced where quality is an issue.

- *Commercial and residential ratings scheme offer an additional market driver*. Providing an additional incentive for effective waste management in construction projects through ratings schemes such as Canada's LEED offers another driver in the right direction, albeit one that may be modest, especially in residential applications.

Overall the approach that Denmark's GRI has taken to the creation of a successful business model around waste plasterboard recycling is highly recommended. This approach focuses on consideration of every part of the supply chain as an overall system, with particular consideration given to the needs of the original waste owner. Strong technology or even a legislative imperative are insufficient to guarantee success, and effort must be focused on creating a compelling reason for participation in the business model at every touchpoint.

This approach resists *assuming* that suppliers and customers will participate, and instead requires that participation be virtually irresistible based on the strength of the benefits offered.

8.0 Next Steps

With a full understanding of the existing industry, combined with a strong sense of the requirements for a successful business model based on international research, the next step is to begin to consider different scenarios for scaling up plasterboard recycling in Canterbury.

This process, which will begin shortly, involves:

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

Following this process, work will begin to focus in on a preferred model and pilot trials will subsequently be initiated for this preferred model.