Resource Efficient Use of Mixed Wastes

Case study: Gypsum-to-Gypsum, *from Production to Recycling, a Circular Economy for the European Gypsum Industry with the Demolition and Recycling Industry*

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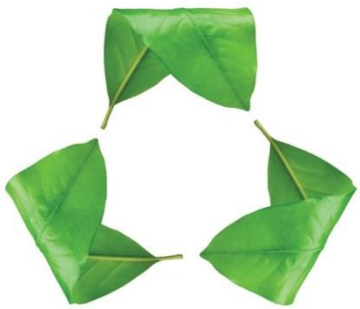

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Key findings

Gypsum-to-Gypsum (GtoG): From Production to Recycling, a Circular Economy for the European Gypsum Industry with the Demolition and Recycling Industry

Context

Construction and demolition waste (CDW) is one of the most significant waste streams in the EU. It consists of numerous materials. CDW has a high potential for recycling and re-use, and has been identified as a priority waste stream by the EU.

The Waste Framework Directive (2008/98/EC) requires that Member States shall take the necessary measures to achieve a minimum of 70% re-use, recycling or other material recovery of CDW (including gypsum-based waste) by 2020.

Although gypsum-based waste is a highly recyclable material, the recycling rate for gypsum-based waste remains low. The low recycling rate of gypsum-based waste is due to current demolition practices that result in the mixing of all CDW fractions which prevent further recycling of gypsum.

In addition, Council Decision 2003/33/EC specifying procedures and criteria for the acceptance of waste at landfills has not been correctly implemented in several Member States and this has resulted in potentially recyclable gypsum-based waste to be disposed of instead of being available for recycling.

In this context, the GtoG project was implemented, involving numerous partners (demolition companies, recycling companies, manufacturing facilities and the European federation of producers of gypsum products, universities), in order to achieve higher recycling rates thus helping to achieve a resource efficient economy.

Objectives

The ultimate objective of the project was to transform the European gypsum demolition waste market and the achievement of at least 30% reincorporation of recycled gypsum in the manufacturing process and close the loop on gypsum waste recycling.

The GtoG project was also aiming at informing the case for the establishment of end of waste status at EU (or national) level for gypsum waste.

Area: Belgium, France, Germany, Greece, Poland, Spain, the Netherlands and the UK

Key figures

Limited figures are available as the qualitative and quantitative assessment of the pilot projects and overall project is in progress.

1 150 000 tonnes of gypsum based waste was generated in in 2012.

Country	Recycling of Gypsum-based waste (%)
The Benelux[1]	40.4
The UK	21.7
France	15.2
Germany, Spain, Greece, Poland	0.0

[1] This includes Belgium, The Netherlands and Luxembourg. The data for Belgium and The Netherlands are reported together for confidentiality reasons

Description

- *Timeline: Jan 2013 – Dec 2015*
- *17 project partners: 1 Project coordinator, 5 demolition companies, 2 recycling companies, 5 manufacturing facilities, 3 universities, 1 consultant*
- *8 Countries targeted: Belgium, France, Germany, Greece, The Netherlands, Poland, Spain, The UK*
- *The project had three distinct phases:*
  - *Phase A: Establish current practices in demolition/deconstruction, recycling and production of gypsum products in Europe.*
  - *Phase B: Conduct pilot projects whereby the demolition companies would apply best practices to the deconstruction of buildings in order to maximise the quantity of gypsum available for recycling. The pilot projects aim to inform the production of codified standards in the form of best practices for the audit of a building prior to deconstruction and also best practice deconstruction techniques.*

    They also informed the development of Waste Acceptance Criteria for the accepteance of gypsum-based waste for recycling.

    They also allowed the assessment of production parameters during trials where production processes were 'business as usual' and trials where the reincorporation f recycled gypsum was increased up to 30% (or the maximum technically feasible)
  - *The final phase of the project, Phase C, consisted of a detailed qualitative and quantitative assessment of the pilot projects and overall project.*
- *Resources:*
  - *Financial: €3,566,250*

    Human Resources: approx. 55 people across all 17 project partners

Key factors of success and potential for replicability

- *A mandatory requirement for an audit of the gypsum-based waste prior to demolition of buildings where the project is above a certain threshold.*
- *A mandatory requirement to segregate gypsum waste from other CDW.*
- *The enforcement of the Council Decision 2003/33/EC must be stricter.*
- *The landfill levy for disposing of gypsum waste should be set to act as a disincentive to disposing of gypsum waste.*
- *The level of segregation of plasterboard waste from other C&D waste which can be influenced by legal requirements such as designing for deconstruction and making deconstruction a mandatory requirement.*
- *A requirement for the specific level of reincorporation of recycled gypsum in new gypsum products should be considered as part of the green procurement framework.*

Conclusion

Theproject target was to demonstrate that 30% reincorporation of recycled gypsum into new gypsum-based products is achieveable. However, while the project production trials proved the feasibility of increased levels of reincorporation of recycled gypsum, level of reincorporation was approximately 25%. That is not to say that 30% is not achievable but that there were certain limitations to the project

The successful replication of the project depends on a number of pre-conditions relating to the enforcement of current CDW legislation and also the use of policy instruments such as landfill levy, requirements for deconstruction rather than demolition.

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1. Introduction

Gypsum is a mineral used in the manufacture of construction components such as, inter alia, plasterboard and gypsum blocks.

This case study, the gypsum-to-gypsum (hereafter referred to as 'GtoG') project looked at the production of gypsum, the generation of gypsum waste and the recycling of gypsum waste in order to develop a methodology that maximised closed-loop recycling[2] of gypsum.

Increasing the level of closed-loop recycling would help to achieve resource efficiency within the construction sector and essentially demonstrate the possibility of creating a circular economy for a waste stream. The target of the GtoG project was to achieve 30% reincorporation of recycled gypsum into the manufacturing process.

The project involved key stakeholders of the value chain: demolition companies, recycling companies and production companies - so that each actor in the chain knew what was required of their output in order to optimise the quality and quantity of material available for the next step in the process.

The project targeted 8 EU countries (Belgium, France, Germany, Greece, Poland, Spain, the Netherlands and the UK) which generated 1,150,000 tonnes of gypsum based waste in 2012.

The Project Coordinator was Eurogypsum, the European federation of national associations of producers of gypsum products based in Brussels.

1.1. Context of the initiative

Gypsum is one of the few construction materials where the waste is processed and can then be used in the production process to make the same product again. It is 100% recyclable because the chemical composition of the gypsum in plasterboards and blocks always remains the same.

Despite the fact that closed-loop recycling is possible for gypsum, the reality is that much of the gypsum waste that is generated in Europe is disposed of. In the study of current practices in managing gypsum-based waste, the rate for recycling gypsum-based waste is still relatively low and there are varying practices and issues that affect this rate in different countries.

Construction and demolition waste (CDW) is one of the most significant waste streams in the EU, accounting for approximately 750 million tonnes per year. It consists of numerous materials, many of which can be recycled. Construction and demolition waste has a high potential for recycling and re-use, since some of its components have a high resource value. CDW has been identified as a priority waste stream by the European Union.

One of the objectives of the Waste Framework Directive (2008/98/EC) is to provide a framework for moving towards a European Recycling Society with a high level of resource efficiency. In particular, Article 11.2 stipulates that *Member States shall take the necessary measures designed to achieve that by 2020 a minimum of 70% (by weight) of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the List of Wastes shall be prepared for re-use, recycled or undergo other material recovery (including backfilling operations using waste to substitute other materials*). This target includes for gypsum waste.

Council Decision 2003/33/EC established criteria and procedures for the acceptance of waste at landfills and specified that non-hazardous gypsum-based materials should be disposed of only in landfills for non-hazardous waste in cells where no biodegradable waste is accepted. However, this has not been correctly

[2] Closed-loop recycling is where the waste is processed and then used in the production process to make the same product again

implemented in several Member States and this allows for potentially recyclable gypsum to be disposed of instead of being available for recycling[3]. The Decision has been fully implemented in Belgium (all three regions), Greece and the UK.

The Decision has been transposed into legislation in Germany but it has been modified such that gypsum waste can be used at landfills, under certain conditions and where it is considered to be a recovery process.

In Poland, it has been integrated into Polish law but it appears that it has not yet come into force. France has transposed the decision into national legislation but with a slight modification that states "Except for practical reasons, plaster-based wastes are stocked in cells where no biodegradable waste is accepted.". In Spain, the Decision has been integrated into Spanish legislation but this legislation has not entered into force. However, national waste legislation is prepared by the Ministry of Environment but is implemented, enforced and monitored by each of the 17 regional governments, which has the potential to complicate it's enforcement nationally. In the Netherlannds, the decision has been integrated but under certain conditions it may be landfilled where recycling is not possible.

Aside from the implementation of the Decision into national legislation, of the 8 countries in the study, only 3 have specific monocells for the disposal of gypsum waste.

The current level of data recording and reporting of CDW does not allow for an accurate estimate of total quantities generated in Europe or for its management. Gypsum waste statistics for generation and management are also difficult to estimate at European or Member State level because they are often mixed in with other inert CDW materials.

Gypsum is 100% recyclable but **the recycling rate for gypsum-based waste is low in many Member States** given that selective deconstruction is required. Further to this, gypsum-based wastes generated by demolition and renovation projects can be contaminated with other materials, such as paint, fastenings, screws, wood and insulation materials among others, which can hinder recycling. This is due to the fact that demolition practices that are typically employed result in the mixing of all fractions which does not allow further recycling of gypsum. About 4 million tonnes of gypsum waste are landfilled in Europe annually.

Some of the main barriers to the recycling of gypsum waste are:

- Lack of knowledge of demolition companies on the benefits of proper deconstruction, both in terms of costs and recycling;
- Low availability of uncontaminated gypsum-based waste for recycling;
- Lack of knowledge and/or manufacturing systems to allow for the reincorporation of recycled gypsum.

This project sought to investigate potential options for overcoming some of these barriers.

1.2. Objectives

The ultimate objective of the project was to transform the European gypsum demolition waste market and the achievement of at least 30% reincorporation of recycled gypsum in the manufacturing process. This would take a holistic, cradle-to-cradle approach, i.e. from demolition to the recycling of gypsum waste generated as part of C&D waste and also the production of gypsum construction products.

[3] DA.1: Report Inventory of current practices

Figure 1: The efficient value chain assessed under the GtoG Project

The GtoG project was also aimed at informing the case for the establishment of end of waste status at EU (or national) level for gypsum waste.

The first phase of the initiative was to **establish the current recycling practices for gypsum** in Europe. This included identifying recyclers of gypsum from C&D waste, manufacturers of gypsum products and their specifications for the acceptance of reprocessed gypsum and the reincorporation of recycled gypsum in the manufacturing process.

By establishing where **manufacturers** of gypsum-based construction products accept recycled gypsum waste from construction, the objective was to **determine the technical and chemical specifications for the quality of recycled gypsum waste** can be established. This informs the gypsum recyclers of the quality required of their recycled gypsum.

The **quality of the recycled gypsum** is determined largely by the quality and condition of the gypsum-based waste delivered to the gypsum recyclers by the demolition companies. Gypsum recyclers can therefore define **criteria for the acceptance of gypsum-based waste** from demolition companies in order to ensure that they can produce recycled gypsum of the quality required to reincorporate it into the manufacturing process.

Once the parameters have been established for each step of the cycle, the next objective was to codify the C&D practices that generate gypsum-based waste as there is a strong correlation between careful management of these wastes during demolition and a market for gypsum recycling.

To this end, the project sought to establish of the following guidance documents:

- **Best Practices for an audit of a building to carry out a qualitative and quantitative assessment of gypsum-based wastes** that will be generated during demolition;
- **Best Practices in deconstruction of gypsum-based wastes**, following the audit, to ensure the material is removed such that it can be transferred to the recyclers in the required condition.

Within this, the project sought to conduct a **financial comparison** between correct deconstruction practices and 'business as usual' demolition practices in order to illustrate the financial benefit of deconstruction over demolition.

The next objective of the project was to **process the properly deconstructed and segregated gypsum waste such that the recycled gypsum could be reincorporated into the manufacturing process for new gypsum-based construction products**. To this end, further expected outputs from this phase of the project included:

- Guidance on the criteria for acceptance of gypsum waste for recycling;
- End of waste criteria for recycled gypsum waste;
- Production process parameters for the reincorporation of gypsum waste.
- The ultimate objective for the project was **30% reincorporation of gypsum waste into manufacturing of new products** and closing the loop on gypsum waste recycling.

1.3. Results

The project was divided into three phases:

- Assessment of Current Practices
- Pilot projects
- Assessment & evaluation of pilot projects and overall project

1.3.1. Phase A - Report on current practices in demolition/deconstruction, recycling and production of gypsum products

The output of the first phase of the GtoG project was a value-chain analysis, involving an analysis and evaluation of the current practices in deconstruction & demolition, C&D waste characterization, processing of the gypsum waste for the production of recycled gypsum and its reincorporation into the manufacturing process across eight Member States: Belgium, France, Germany, Greece, Poland, Spain, The Netherlands and the United Kingdom.

The findings of the assessment of current practices are broadly grouped as follows:

- Implementation of EU Regulation
- Deconstruction Practices
- Recycling Market
- Reincorporation of recycled gypsum into the manufacture of gypsum-based construction products
- Statistics

Implementation of EU Regulation – Council Decision 2003/33/EC requires that non-hazardous gypsum-based materials should be disposed of only in landfills for non-hazardous waste in cells where no biodegradable waste is accepted. However, this has not been correctly implemented in six of the eight Member States under the study. In some of the countries where it is transposed, there are issues relating to the level of enforcement and the transposition relating to gypsum waste in particular.

Deconstruction Practices – In three of the eight countries assessed, deconstruction is not standard practice. Demolition is carried out with no segregation of gypsum-based wastes from other C&D wastes. The obstacles to deconstruction include design and construction of buildings that does not facilitate ease of deconstruction and the perception that deconstruction is a more costly practice.

The main drivers of deconstruction are:

- Environmental – where sustainable building certification standards such as BREEAM or LEED are used, deconstruction tends to be practiced;
- Image – companies will adopt an environmental approach in order to create a positive public perception of their activities;
- Economic – Deconstruction optimises costs in many countries, e.g. where landfill costs are high;
- Regulation – Some countries, i.e. Spain and France, have regulatory requirements on the segregation of C&D waste (Spain) and the auditing of materials pre-demolition in order to encourage deconstruction;
- Limitation on mixing gypsum[4] with other C&D waste – several countries[5] specify limits for gypsum content in C&D waste being used as a secondary aggregate for backfilling.

Recycling Market – The market for recycled gypsum in Europe is influenced by six main factors, which cannot be addressed by gypsum recyclers or manufacturers:

1. The share of the gypsum waste market that can be reached by the established recycling system
2. The level of segregation of gypsum-based waste from other C&D waste

[4] There is a risk that the gypsum will break down resulting in leaching and potential groundwater contamination or the production of hydrogen sulphide, a hazardous flammable gas.
[5] Belgium, France, Germany, Italy, the Netherlands and the UK

3. The cost of the gypsum recycling option compared with landfilling in a given country
4. The size of the gypsum waste market that is in compliance with the existing regulations
5. The existence of cheaper legal alternatives, aside from landfill (e.g. export, open-loop recycling).
6. Environmental considerations that influence the destination of the gypsum waste more than cost.

These results are useful in identifying what specific issues may need to be addressed in order to increase the level of recycling of gypsum waste.

Reincorporation of Recycled Gypsum – The analysis of the current practices in relation to the recycling of gypsum found that there are seven factors that drive the reincorporation of recycled gypsum into the manufacture of gypsum-based construction materials. The factors are listed by decreasing level of impact:

1. *Cost reduction (high impact)* – recycled gypsum is less expensive than natural gypsum
2. *Resource efficiency (high impact)* – the reincorporation of recycled gypsum reduces the amount of natural gypsum required to be extracted
3. *Customer request (high impact)* – where construction is influenced by Green Public Procurement or sustainable building certification standards such as BREEAM, LEED, DGNG etc.
4. *Green Public Procurement (GPP) (medium impact)* – this is a voluntary instrument whereby public authorities procure more sustainable goods, services and works than would otherwise be procured, ensuring a lower environmental impact. The Gypsum Industry published GPP criteria for wall panels, including a requirement for the percentage of recycled gypsum included.
5. *Product Marketing (medium impact)* – plasterboard products including a greater level of recycled gypsum offer a competitive edge when it comes to marketing the product against other similar products.
6. *Industry Voluntary Agreement (medium impact)* – these are voluntary agreements between the government and industry and are used as a policy tool to generate commitment to achieve certain measures.
7. *Sustainability commitments (medium impact)* – this is when the industry makes the commitment to produce more sustainable materials.

Whilst the first three drivers already have a strong impact in the industry, it is expected that one of the outcomes of this project is that Green Public Procurement and Industry Voluntary Agreements will become bigger drivers of the reincorporation of recycled gypsum in manufacturing through the reassessment of the GPP criteria for the percentage of recycled gypsum in wall panels and by generating the impetus for more countries to enter into agreements to improve the amount of C&D waste recycled.

Statistics – The lack of quality data and reliable reporting on C&D waste across the EU makes it difficult to assess the level of recycling of C&D waste and much less so for gypsum waste. From the Phase 1 inventory of current practices, the following data was gathered on the recycling of gypsum-based waste:

Country	Recycling of Gypsum-based waste (%)
The Benelux[6]	40.4
The UK	21.7
France	15.2
Germany	0.0
Spain	0.0
Greece	0.0
Poland	0.0

This table illustrates that the current level of recycling of gypsum-based waste is falling short of making a contribution towards meeting the 70% target set for 2020.

[6] This includes Belgium, The Netherlands and Luxembourg. The data for Belgium and The Netherlands are reported together for confidentiality reasons

1.3.2. Phase B - Pilot projects

Phase B of the project was the running of five pilot projects whereby the demolition companies would apply due care and attention to the deconstruction of buildings, especially with respect to gypsum, in order to maximise the quantity of gypsum available for recycling.

The requirement for this phase was a total of 100 tonnes of gypsum-based waste per pilot project was to be provided to the recyclers for processing before being sent onwards for reincorporation of recycled gypsum in the manufacture of gypsum-based construction products.

The objective of those phase of the project was to form a basis for optimising of deconstruction, recycling of gypsum-based waste and reincorporation of recycled gypsum in the manufacturing process.

The outputs of the pilot projects included a set of codified standards for pre-deconstruction audits of materials and deconstruction practice, waste acceptance criteria for recycling gypsum and specifications for recycled gypsum such that it is end of waste and production on manufacturing process paramaters.

Best Practices in Audit Prior to Deconstruction of Buildings

This document provides for a standardised set of best practices in carrying out a an audit on a building prior to its deconstruction to qualitatively and quantitavely assess:

- The waste produced by the deconstruction of the building;
- The waste arising from the use of the building, e.g. furniture, equipment, etc.;
- Residual waste not arising from the building or its fixtures and fittings.

Conducting an audit allows for waste management planning, the potential costs (e.g., transport costs, costs to dispose of waste streams that cannot be recovered, costs of outlets for recoverable materials, etc.) and possible risks (e.g. the possibility of hazardous wastes).

In tandem with this document, a database of the main categories of gypsum-based products likely to be encountered during the deconstruction of a building was produced. This document provides guidance to ensure that all gypsum-based wastes would be segregated at source and reduce errors in identifying gypsum-based waste as other wastes.

Best Practices in Deconstruction Techniques

This document provides for a standardised set of best practices for a controlled deconstruction of gypsum based systems.

It describes:

- The most common types of gypsum systems that may be encountered on a deconstruction project;
- The waste acceptance criteria of the recyclers involved in the project;
- Best practice desconstruction techniques for each gypsum-based system type.

It also describes the methodology employed to assess the economics of deconstruction compared with the economics of demolition.

The five pilot projects are described with respect to the type of gypsum-based system encountered, the description of the deconstruction works, quantities of gypsum-based waste generated and the next destination for the material.

The pilot projects allowed for the economics of deconstruction[7] and the economics of demolition[8] to be quantified and compared, with the elements that vary between the two defined. They demonstrated that savings were made by employing deconstruction techniques, as shown in the following table.

[7] Deconstruction involves the stripping out of fixtures and fittings in order to segregate the materials prior to the demolition of the building
[8] Demolition involves the destruction of the structure or elements of the structure (as in a renovation) where waste are mixed together and no segregation of materials takes place

Table 1: Deconstruction and demolition costs for plaster blocks and plasterboard

Type of Gypsum-based System	Type of Costs	Deconstruction costs (€/m^2)	Demolition costs (€/m^2)
Plaster blocks 	*Cost of demolition / deconstruction*	0.22	0.22
	Cost of storage and transportation	0.02	0.02
	Cost of outlets	0.06	0.11
	TOTAL	**0.30**	**0.35**
Plasterboard 	*Cost of demolition / deconstruction*	2.30 – 4.61	2.34 – 5.58
	Cost of storage and transportation	0.01 – 0.54	0.14 – 4.19
	Cost of outlets	0.01 – 0.16	0.88 – 13.25
	TOTAL	**2.32 – 5.00**	**7.00 – 19.00**

The economic assessment of the pilot projects illustrates that in all cases, the cost of the outlets is a major influence and that deconstruction is the more financially beneficial option. This is a very important result of the project as deconstruction has been seen as a more expensive option than demolition. Where demolition is employed, the outlet for the waste is typically landfill and so the cost of landfilling CDW will have a big role in making demolition a less attractive option in comparison with deconstruction.

The production of these two handbooks on Best Practices codifies the standards expected for deconstruction practices in order to maximise the level of gypsum available for recycling.

Waste Acceptance Criteria For Gypsum Based Waste Destined For Recycling

In order for gypsum-based waste to be recycled, it must meet criteria specified by the recyclers before it is accepted for recycling.

The purpose of this document is to provide guidance on Waste Acceptance Criteria (WAC) to increase the level of recycling of gypsum waste and consequently reduce potential risks to the environment due to bad management of gypsum waste. By detailing and comparing the WAC of three global recyclers (Gypsum Recycling International, New West Gypsum Recycling and Siniat France), the GtoG WAC can be considered best practice in ascertaining the suitability of gypsum waste for recycling. Furthermore, it is open to input from all interested stakeholders in order to further strengthen it. A list of gypsum-based wastes that are accepted and not accepted by the three recyclers has been compiled.

The production of the WAC defines to contractors the types of gypsum-based wastes that will be accepted by three global gypsum recyclers. This will help to reduce the level of contamination in gypsum-based wastes being presented for recycling and thus maximise the level of recycling of these wastes.

The production of a codified set of standards for the for the deconstruction practices themselves and for the Waste Acceptance Criteria for recyclers allows demolition companies to segregate the waste materials at source and meet the criteria for the recycling of gypsum-based waste. The recyclers involved in the project declared that they were pleased with the quality and condition of the gypsum-based waste forwarded to them by the demolition companies.

Production Process Parameters

The five manufacturing plants participating in the GtoG project collected data and provided information based on the experiences at their plants provided guidance on the key paramters affecting the reincorporation of

recycled gypsum in the manufacturing process, how the reincorporation of recycled gypsum impacted the manufacturing process and the potential to achieve the 30% reincorporation rate in plasterboard manufacturing on a wider scale.

Given that the production processes at the five plants were not identical, it was not possible to assess the impact of specific recycled gypsum characteristics on the production process parameters, some key findings were made:

- Reincorporation of recycled gypsum, up to a level of 30%,in Type A plasterboard manufacturing is feasible in practice
- Reincorporation of recycled gypsum up tp a level of 30% does not affect the basic operformance characteristics of Type A plasterboards – all samples conformed to EN 520.
- The increased percentage of reincorporated recycled gypsum may result in potential bottlenecks in the production process in terms of recipe modifications, e.g. the inclusion of additives, and production process equipment (e.g. storage, feeding conveyors, recycled gypsum preprocessing etc.) that may arise when a higher reincorporation percentage becomes standard practice in the manufacture of plasterboard.

Overall

The main qualitative result from the project was getting all of the major actors in the project together to discuss a common goal and how to achieve it. Each stage of the value chain has an important role to play and especially for demolition companies at the start of the chain[9] who were better able to understand the required quality and condition of the gypsum-based waste for recycling to be sent to the recyclers and this allowed them to demonstrate their ability to provide recyclable material to a stringent requirement.

The experiences on the pilot projects also provide a basis for recommendations to be made concerning the manufacturers of gypsum-based projects in relation to eco-design and for those planning and implementing at the construction phase in order to increase the potential level of recovery of the gypsum-based systems at the deconstruction phase.

1.3.3. Phase C - Assessment and evaluation of projects and overall project

The final phase in the project involved assessing the pilot projects quanlitatively and quantitatively in order to **develop Key Performance Indicators (KPIs) and present a set of Best Practice Indicators (BPIs)** aiming to increase the amount of gypsum waste capable of being recycled, as well as to maximise the quality and quantity of recycled gypsum that can be reincorporated in the manufacturing process. These indicators take into account the whole process from the building audit prior to deconstruction through to the reincorporation into the manufacturing process.

In addition, a **Roadmap and proposal of procedures for the implementation of a sustainable value chain** was produced by Eurogypsum. This document is based on the results achieved by all the project actions and is a general presentation of the operational environment of the GtoG project, a full assessment of the gypsum value chain, including a deep analysis of the practices and needs of all the actors that are part of the gypsum industry, and a series of recommendations proposed to the national authorities, to the European Commission and to the gypsum industry, in order to achieve a more widespread implementation of gypsum-based waste waste recycling from C&D activities.

1.3.4. Documents Produced Throughout the GtoG Project

The following are the reports produced through the three phases of the project:

- The inventory of current practices for deconstruction, recycling and reincorporation in the manufacturing process of the recycled gypsum

[9] In terms of this project, demolition companies are at the start of the chain but in theory, the product manufacturers, the architects and project managers designing and constructing systems in the first instance are the starting point

- The European handbook of best practices for controlled deconstruction of gypsum system and the European manual of best practices for the audit of building prior to deconstruction
- European guidelines on gypsum waste acceptance criteria
- Quality criteria for recycled gypsum, technical and toxicological parameters
- Techno-economic assessment of recycled gypsum incorporation into theplasterboard manufacturing process
- Report on best practices indicators for deconstruction, recycling and reincorporation practices
- Roadmap for future implementation of a sustainable value chain
- Inventory of best practices for deconstruction, recycling and re-incorporation

2. Implementation of the initiative

In this section a practical approach on the implementation of the initiative will be presented.

2.1. Planning of the initiative and actors involved

The key legislation and documents in the planning and implementation of the project are listed in section 4.

Project Inception

The project was first conceived of in 2010 by Eurogypsum as recycling had been discussed by members of the industry but not in a coordinated manner and not with any direct course of action in mind.

Eurogypsum is the Project Coordinator. It is a European federation of national associations of producers of gypsum products based in Brussels. Its role is to promote the interests of the European gypsum industry, to help move towards the sustainable growth of the market for gypsum products and solutions and maintaining and improving the image of the industry.

As Eurogypsum developed the project concept, it was decided that they should apply for funding to carry out the project under the LIFE program. In order to put together and submit the application, it was required that all project partners be identified and in place for the project.

Project Partners

The first step in identifying project partners was to speak with gypsum product manufacturers and engage with those companies willing to be involved. The manufacturers who agreed to be involved in the project were:

- Saint Gobain (two subsidiairies, Gyproc and Placo);
- Siniat (two Siniat SA in France and Siniat UK);
- Knauf.

As the manufacturers had working relationships with recyclers of gypsum waste, they were able to identify potential recyclers who may be interested in participating in the project. Of those contacted, two recyclers agreed: Gypsum Recycling International (GRI) and New West Gypsum Recycling (NWGR).

The involvement of the Technical University of Athens as a project partner to coordinate with the manufacturers was a suggestion proposed by the manufacturers. The Universidad Politécnica de Madrid (UPM) was brought on board as a partner to carry out the monitoring and evaluation of the project (they also produced the value chain analysis in terms of deconstruction methodologies, economics of logistics and recycling). The Fundación General Universidad Politécnica de Madrid was engaged for the technical and chemical assessment of gypsum samples. This testing was carried on samples of gypsum products produced with respect to 'business as usual' gypsum production and also in relation to gypsum products made with a maximised level ofo reincorporation of recycled gypsum.

RECOVERING Sarl became project partners through their working relationship with both Eurogypsum and Saint Gobain and their work on gypsum-based waste management. They were also involved with the selction and shortlisting of demolition companies (based on geographical location). Of those contacted, five companies agreed to be involved in the project. They coordinated the demolition companies through the project and produced the handbooks on best practices for the audit of buildings prior to deconstruction and best practices in deconstruction techniques.

Financial and Human Resources

The budget for the project was €3,566,250. This was determined by each of the project partners calculating their costs to participate in the project in order to determine the total project cost. 50% of the project costs (€1,783,123) were contributed by the European Commission under the Life programme funding.

In terms of human resources allocated to the project, there were approximately 55 people10 directly involved in the project:

- Eurogypsum – 3
- Universities – Approximately 6 (2 per university; 1 senior researcher and 1 junior researcher)
- Demolition companies – approximately 15 (3 per company; a senior person and 2 operatives)
- Recyclers – approximately 15 (3 per facility; 1 senior and 2 operatives)
- Manufacturers – approximately 15 (3 per facility; 1 senior and 2 operatives)
- Consulting Agency – 1

Planning

There are three main phases in the project but they were broken down into smaller, more focussed actions in order to deliver on each element of the project. The process is outlined in the table below.

Table 2: Project planning

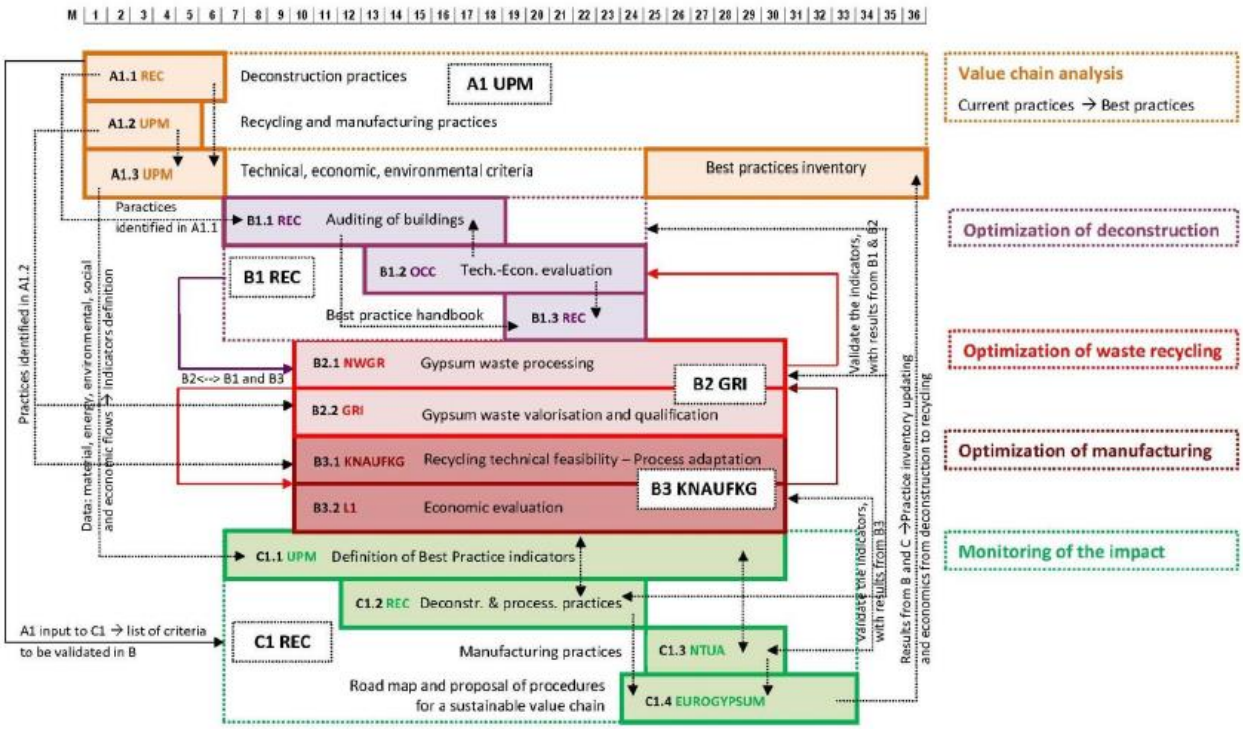
Task	Start Date	End Date
PHASE A: VALUE CHAIN ANALYSIS IN TERMS OF DECONSTRUCTION METHODOLOGIES, ECONOMICS OF LOGISTICS AND RECYCLING		
Deconstruction practices - Economics of deconstruction and logistics	01/2013	06/2013
Recycling and plasterboard manufacturing practices	01/2013	05/2013
Technical – Economic – Legislative - Environmental criteria	01/2013 01/2015	06/2013 12/2015
DELIVERABLE: Inventory Of Current Practices *(Due: 09/2013)*		
DELIVERABLE: Inventory Of Best Practices *(Due: 12/2015)*		
PHASE B.1: ECO-EFFICIENCY OF DECONSTRUCTION / SEGREGATION: TECHNICAL / ECONOMIC / MARKET FEASABILITY		
Auditing of buildings - deconstruction projects	07/2013	06/2014
Technical economic evaluation of deconstruction steps	01/2014	12/2014
Preparation of "best practices" handbooks	07/2014	12/2014
DELIVERABLE: European Handbook On Best Practices In Deconstruction Techniques *(Due: 12/2014)*		
DELIVERABLE: European Handbook On Best Practices On Audits Prior To Deconstruction Of Buildings *(Due: 12/2014)*		
PHASE B.2: VALORISATION OF DECONSTRUCTION WASTE		
Processing of gypsum waste from deconstruction	10/2013	06/2015
Valorisation and qualification of gypsum waste from deconstrution	10/2013	06/2015
DELIVERABLE: Guidance Criteria for Recycled Gypsum *(Due: 06/2015)*		
DELIVERABLE: End Of Waste Specifications for Recycled Gypsum *(Due: 06/2015)*		
PHASE B.3: TOWARDS SUSTAINABLE LIGHTWEIGHT SYSTEMS		
Technical feasibility and process adaptation of gypsum recycling	10/2013	06/2015
Economic Evaluation. Energy and raw material saving potentials	10/2013	06/2015
DELIVERABLE: Report: Production Process Parameters *(Due: 06/2015)*		
PHASE C: MONITORING OF THE IMPACT IN THE VALUE CHAIN		

[10] Estimate provided by Eurogypsum

Definition of best practices indicators	07/2013	06/2015
Monitoring of deconstruction and processing practices	01/2014	12/2014
Monitoring of manufacturing practices	01/2015	06/2015
Road map and proposal of procedures for the implementation of a sustainable value chain	12/2014	09/2015
DELIVERABLE: Report: Best Practices Indicators for Deconstruction, Decontamination, Characterisation and Recyling Practices *(Due: 12/2014)*		
DELIVERABLE: Technical Handbook And Outline Roadmap *(Due: 06/2015)*		

The project structure is illustrated in the schematic below, which outlines the elements of each phase, the duration and the coordinator for each element.

Figure 2: Project structure



2.2. Implementation of the initiative

The project officially began on 1st of January 2013 with Phase A and the deliverable for this phase of the project was the report on the current practices in the industry with respect to demolition/deconstruction, recycling and reincorporation into the manufacturing process. UPM was responsible for the delivery of this report. During the process, drafts were issued to project partners for comments. The final report was issued in September 2013.

Phase A had 4 main sections to describe current practices in the gypsum industry:

1. Gypsum properties ,characteristics of the gypsum industry and principles of sustainable construction
2. Current gypsum recycling practices
3. Current deconstruction practices
4. Drivers and barriers for recycling of gypsum-based waste

In order to ascertain the quantities of gypsum waste being generated, statistics published by Eurostat and Prodcom were collated and projections were modelled to give quantities of gypsum products on the market and estimates of gypsum-based waste generated. The industry was assessed using production and turnover data (available on Prodcom), sales data and construction output data. Environmental tools such as Life Cycle Analysis (LCA) and Environmental Products Declarations (EPDs) were used to providing relevant, verified and

comparable information about the environmental impacts of gypsum products in order to determine their role in sustainable construction. Furthermore, the use of recycled gypsum and how it would be rewarded in several sustianble construction evaluation systems, e.g. BREEAM, LEED, DGNB, etc.) was studied.

Reviewing current gypsum recycling practices involved issuing questionnaires to EU-based gypsum recyclers and collating the results from those who responded. Only countries where a minimum of 3 questionnaires were completed and returned from 3 different companies were consolidated as a separate country. The results of a survey of gypsum manufacturers carried out by Eurogypsum in 2012 were also used.

Current deconstruction practices were established through interviews of stakeholders involved in deconstruction, including demolition companies, waste management during works and.logistics of waste storage and transport.

In order to define the main drivers and barriers of recycling of gypsum-based waste, questionnaires were issued to demolition companies, project owners, project managers and consultants, The questionnaires returned from the 2012 survey of gypsum manufacturers were used to establish the drivers from a manufacturing point of view.

Phase B began in earnest in January 2014 and involved the running of the pilot projects with the ultimate deliverable of the handbooks on best practices for auditing buildings prior to deconstruction and for deconstruction techniques. RECOVERING were ultimately responsible for the coordination of this element of the project and they liaised with the demolition companies, the gypsum recyclers and the manufacturers.

In terms of the pilot projects themselves, the interaction between demolition company, recycler and manufacturer was defined by geographical location.

Table 3: Pilot projects stakeholders

Project Location	Demolition Company	Timeline	Destination of deconstructed gypsum
Levallois Perret, close to Paris	Occamat	Jan 2014 – Apr 2014	Siniat SA (France)
Paris	Pinault & Gapiax	June 2014	NWGR (Vaujours, France)
London	Cantillon Ltd	Jul 2014 – Dec 2014	NWGR (UK)
Graben, near Munich	KS Engineering GMBH	Feb 2014 – Mar 2014	GRI (Netherlands)
Brussels	Recycling Assistance	Jun 2014 – Nov 2014	NWGR (Belgium)

In order to assess the economic feasibility of deconstruction of the gypsum-based system, a methodology has been developed to calculate a cost range or an average cost of deconstruction per square meter and per ton for a given gypsum-based system and a given deconstruction or demolition technique in a given country. The tool used is Excel-based and is used to record key data for each project, including:

- Description of the site and the gypsum-based system in situ;
- The various materials the system is comprised ofand the total costs per square meter and per ton to **deconstruct** the gypsum-based system;
- The various materials the system is comprised ofand the total costs per square meter and per ton to **demolish** the gypsum-based system;
- For both deconstruction and demolition, the costs (for each waste stream generated) for storage, transportation and treatment.

The overall result was a breakdown of costs and comparison of costs incurred for deconstruction and demolition.

The following photos highlight different stages of the process:

1 - Deconstruction

2 – Sorting on Site

3 – Recycling

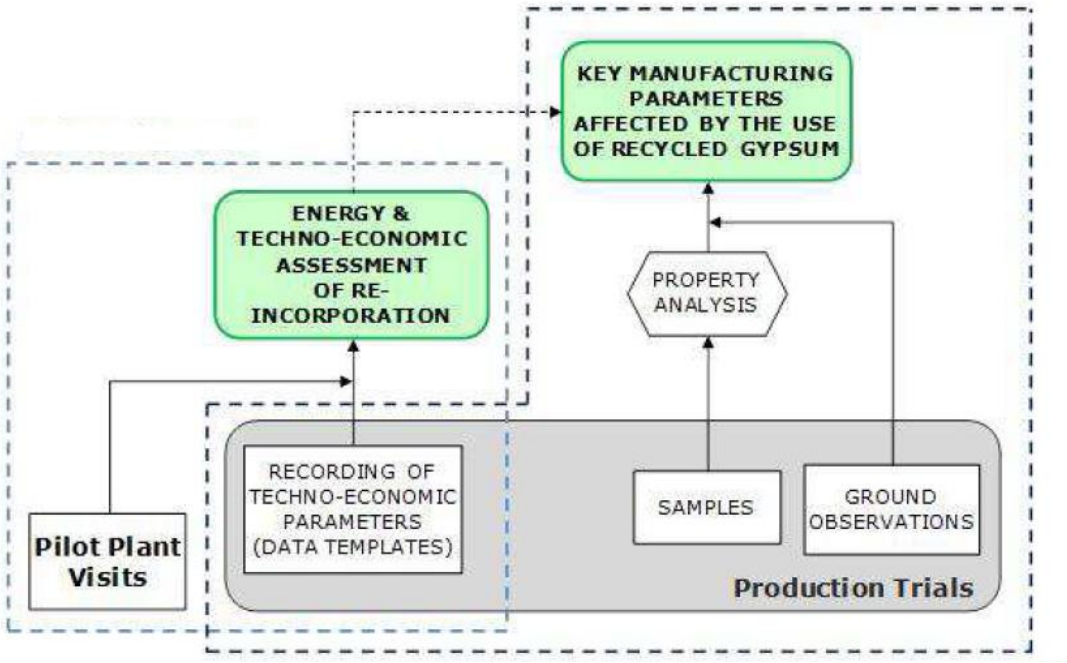
4 – Manufacturing

The five manufacturing plants participating in the project were:

- Knauf Gips
- Siniat FR
- Siniat Ltd UK
- Saint-Gobain Placoplatre
- Saint-Gobain Construction Products Belgium NV - Gyproc

All five facilities collected data for two rounds of production trials. The first round of trials referred to 'business as usual' operations including the standard percentage of recycled gypsum used by each plant in their typical manufacturing processes which would serve as a baseline. The second round of trials involved including gradually increasing quantities of recycled gypsum in the production process up to the set target of 30% or up to a technically feasible maximum, defined by product quality or process effectiveness.

Figure 3: Production trials process



Data from the trials was primarily collected through technical and chemicall analysis of both raw materials and products from each plant for both rounds of trials and from recording the key techno-economic paramters for the manufacturing process for each plant.

The outputs from Phase C were based on the findings of Phases A and B. These outputs include **Best practices in deconstruction, recycling and reincorporation practices** and a **Roadmap and proposal of procedures for the implementation of a sustainable value chain**.

2.3. Factors of success

There have been several factors that have contributed to the successful implementation of the GtoG project..

The main factor of success was the **level of cooperation** between the actors in the process. The interaction between the demolition companies, the recycling companies and the manufacturing companies allowed each to understand the challenges each faced and for each to understand what was required of them in order to make the project a success and for future potential collaborations. The project created the possibility for the industrial partners to acquire collective knowledge-experience that is beneficial for their businesses and collaboration with their commercial competitors. This is especially true for the demolition companies as it gave them an opportunity to engage proactively and prove their professionalism in meeting the requirements for waste acceptance at the recycling facilities. It is also essential for the recycling companies to understand the requirements for the reincorporation of recycled gypsum into manufacturing, with respect to parameters such as particle size and paper content.

The **EU funding** from the Life programme meant that the project could be conducted and be successful.The budget allocated for the project as a whole was deemed to be sufficient to allow for it to meet all of its objectives.

The **broad range of expertise** across each element of the value chain allowed for a comprehensive analysis and assessment of how to get from current practices to bring about a transformation in the deconstruction/demolition industry and to increase the level of reincorporation of recycled gypsum in the manufacture of gypsum products. This was supported by scientiofic expertise in assessing the chemical composition and technical specifications of gypsum products in order to demonstrate the technical integrity of products produced with a high level of recycled gypsum.

The outcomes of the specially designed and controlled production trials **allowed each manufacturer to plan the necessary industrial adaptations**, which would require further investigation.

The main obstacle encountered was where the gypsum-based construction systems installed during construction/renovation did not facilitate proper deconstruction and resulted in the disposal of the gypsum waste.

3. Lessons learned

Following the conclusion of Phase B, the project had demonstrated that the implementation of proper deconstruction practices could save money for each actor in the value chain and would also maximise the availability of suitable gypsum-based waste for recycling.

The project has produced guidance on the best practices in auditing buildings prior to deconstruction in order to qualitatively and quantitatively assess the waste to be managed and best practices in deconstruction techniques. It also allowed for the generation of Waste Acceptance Criteria for the acceptance of gypsum-based waste at recyclers.

The knowledge that the employment of proper deconstruction techniques result in economic savings for demolition companies, will help the companies to move from demolition to deconstruction practices. The Best Practice handbooks and Waste Acceptance Criteria will provide practical guidance and ensure that a larger quantity of gypsum waste available for recycling.

The experiences of the manufacturers and the results of the production trials demonstrate the technical (and chemical) integrity of gypsum products, particularly Type A plasterboard, manufactured with a high level of reincorporation of recycled gypsum, manufacturers of gypsum-based products will be more open to the use of recycled gypsum, as it was demonstrated that the use of recycled gypsum was similar in cost to virgin material.

3.1. Preconditions for application of the initiative - replicability

The project provides guidelines and data on the close loop recycling of gypsum-based waste which will facilitate replicability of the intiativie in other Member States.

However, a number of pre-conditions are required for the replicability of the GtoG initiative. These pre-conditions relate to:

- A legal requirement for an audit of the gypsum-based waste prior to demolition of buildings where the project is above a certain threshold, e.g. building area, budget, etc.
- A legal requirement to segregate gypsum-based waste from other CDW materials.
- The enforcement of the Council Decision 2003/33/EC must be stricter. In many countries, the required monocells for the disposal of gypsum-based waste do not exist. This should result in the segregation and recycling of gypsum-based waste yet it does not seem to. Greece and Poland have transposed the decision and do not have the required monocells but there is no recycling of gypsum-based waste. Enforcement will mean this waste cannot be disposed of which will result in more material being available for recycling.
- The landfill levy for disposing of gypsum waste should be set at such a level to act as a disincentive to disposing of gypsum-based waste. The competitiveness of the closed-loop recycling solution compared to legal disposal at landfills is impacted by the landfill levy which effectively determines the cost of landfilling. The landfill levy should be set to ensure that it is more cost effective for demolition companies to bring gypsum-based waste to recyclers rather than landfills.
- The Level of segregation of plasterboard waste from other C&D waste which can be influenced by legal requirements such as designing for deconstruction and making deconstruction a mandatory requirement.

The level of implementation of GPP could also be one of the factors driving the replicability of similar initiatives. For example, GPP criteria could include contractual requirements for deconstruction and recycling of gypsum-based waste in redevelopment and minimum recycled content in gypsum based products[11].

[11] European Commission. 2010. Wall Panels – Green Public Procurement Product Sheet. http://ec.europa.eu/environment/gpp/pdf/wall_panels_GPP_product_sheet.pdf

Member States with high ambition to achieve or exceed the preparing for re-use, recycling and other material recovery target for CDW in Article 11 of the WFD will also be the more amenable to a similar initiative.

As the development of a similar inititiative in other Member States requires the involment of many actors in the gypsum value chain, coordination and good lines of communication will also be essential to the success of the initiative in being replicated across Member States. It is important for demolition companies to be aware of the acceptance criteria at gypsum recycling facilities and it is also crucial for recyclers to know the specifications of the gypsum to be reincorporated, e.g. particle size, paper content, etc. Increased communbication through the value chain allows for consistent volumes and quality of recycled gypsum to be available for reincorporation.

3.2. Innovation potential

The main innovation in this project is that it established a circular economy for a whole waste stream. It has provided a workable example of a cradle-to-cradle solution by informing manufacturers, construction companies, demolition companies and recyclers so that they can work together to maximise the resource efficiency of gypsum.

Another innovative element of the project is the technical and chemical analysis on products manufactured as per current practices and those manufactured with a maximal level of reincorporation of recycled gypsum. This allowed for the comparison of chemical compositions and technical specifications in order to demonstrate the integrity of the products manufactured with a high level of recycled gypsum.

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- Telephone interview with Henrik Lund-Nielsen, CEO, Gypsum Recycling International, 20.08.2015
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