Gypsum recycling best practice indicators

A. Jiménez Rivero*, A. de Guzmán Báez, M. Rodríguez Quijano, J. García Navarro

Grupo de Investigación Sostenibilidad en la Construcción y la Industria giSCI - UPM,
Universidad Politécnica de Madrid, Spain.

Abstract

Since January 2013, the Life+ GtoG project is working for transforming the gypsum waste market. The aim is to achieve higher gypsum recycling rates in Europe and to promote best practices in deconstruction, recycling and reincorporation processes. This paper focuses on the Best Practice Indicators (BPIs) for gypsum recycling. To this end, a set of monitoring parameters have been defined and combined in the form of Key Performance Indicators (KPIs) that have been tested by the three gypsum recyclers participating in the project. As a result, a group of BPIs has been obtained, which can be used to recognize and encourage best practices associated to the recycling route, from a technical, environmental, social and economic perspective

Keywords: Gypsum recycling, Key Performance Indicators (KPIs), Best Practice Indicators (BPIs), GtoG Life+ Project.

1 Introduction

Unsustainable use of resources causes environmental damages, such as climate change, desertification, deforestation and loss of biodiversity, as well as economic risks. Circular economy has been identified as one of the six core concepts to increase resource efficiency. In a circular economy, post-consumer waste is effectively collected, recycled and used to make new products, and virgin raw materials are used only when secondary raw materials are not available (European Parliament. Committee on the Environment, Public Health and Food Safety, 2015)

There is currently a large proportion of gypsum waste that is being landfilled and backfilled worldwide ("Strategic Analysis of the European Recycled Materials and Chemicals Market in Construction Industry. M579-39," 2011), including building plaster, gypsum blocks and plasterboard, being the later the most common recyclable gypsum waste generated in Europe.

The Life+ GtoG project "From production to recycling: a circular economy for the European gypsum Industry with the demolition and recycling Industry" is working for creating a recycling culture of gypsum products, changing the way this waste is usually treated in construction, renovation and demolition works, with the aim of achieving higher gypsum recycling rates in Europe and promoting selective deconstruction practices. For this purpose, five demolition companies, one demolition consultant, two gypsum waste recyclers, five plasterboard manufacturers and three academic partners, leaded by Eurogypsum (the European association of plaster and plasterboard manufacturers), are working together in this large consortium with representation in 7 European countries.

This study aims to define an analytical framework for the gypsum recycling process, consisting of a group of best practice indicators to help the stakeholders to measure the performance and progress of gypsum waste management, to provide decision-making information, to detect possibilities of improvement and to monitor changes over time.

2 Methodology

The first part of the methodology consists on identifying key areas of influence to be measured from previous preparatory actions, where a thorough review on existing literature, questionnaires distributed among European stakeholders and the gypsum recycling business model are analysed. Such influencing areas correspond to four categories divided into each of the stages part of the recycling process: gypsum waste reception, storage, processing and transport of the recycled gypsum (Table 3). The classification enables the development of specific indicators per stage and thus precise parameters, which facilitates their use and individual evaluation in a classification breakdown for a more effective analysis.

According to this, a first approach of potential Key Performance Indicators (KPIs) and monitoring parameters is produced. Being parameters the variables that combined in an equation compose the indicator and enable the data collection, according to the recycling indicator they are addressing.

With the KPIs defined, application and interpretation of results is carried out by applying the same in five pilot projects set in five distinct national contexts: Belgium, two in France, Germany and the United Kingdom. After data collection and analysis, a set of 9 KPIs is finally selected and refined, from which a number of 7, specifically aiming to recognize and encourage best practices in the recycling process, are considered as the final Best Practice Indicators (BPIs), associated to quantitative or qualitative evaluation criteria, in order to show the degree of compliance with a minimum level of performance.

Best practice criteria couldn't be associated to two economic KPIs, as the result highly depends on the peculiarities of each country (e.g. energy cost, performance of the equipment, environmental fees etc.)

3 Results and discussion

3.1 Monitoring parameters

Tables 1 - 2 show the monitoring parameters defined according to the categories to be measured (technical, environmental and socio-economic).

TECHNICAL PARAMETERS
QUALITY CHECK DATA
Gypsum waste received - GW (t)
Gypsum waste rejected - GW_r (t)
Wet Gypsum Waste received - GW_w (t)
Slightly wet gypsum waste received (i.e. rain during transport) - GW_{Sw} (t)
Presence of plastics and foils (High/Low /None)
Presence of insulation materials (High/Low /None)
Presence of steel rails and bars (High/Low /None)
Presence of wood (High/Low /None)
Presence of other impurities (High/Low /None)
Impurities manually separated - I (t)
Reference gypsum waste density - 0.40 (t/m^3)
GYPSUM WASTE PROCESSING
Gypsum waste processed - GW_p (t)
Output of recycled gypsum - RG (t)
Output of paper fraction - P (t)
Output of metal - M (t)

Table 1. Monitoring parameters for the technical indicators

ENVIRONMENTAL AND SOCIO-ECONOMIC PARAMETERS
RECYCLING PROCESS ENERGY DATA
Electricity consumption - E_e (kWh)
Electricity cost - E_c (€/kWh)
Conversion factor, EU-27 average electricity emissions factor* - EE (kg CO_2/kWh)
Fuel consumption - E_f (l)
Fuel cost - F_c (€/l)
Conversion factor, GHG emission intensity of diesel** - EF (kg CO_2/l)
TRANSPORT FROM RECYCLING TO THE MANUFACTURING PLANT DATA
Lorry energy consumption - E_{LF} (l)
RG per roundtrip to reincorporation- RG_{rd} (t)
Distance to the plasterboard manufacturing plant*** - D_m (km)
Roundtrips to reincorporation - RT_r (No.)
Freight transportation factor**** - CF_t (g CO_2/tkm)

*Data source EEA, 2008
**Calculated from IPCC and Fuel cycle emissions NETL
***A maximum of 5 km will be considered
****Data source EEA 2011, road transportation

Table 2. Monitoring parameters for the environmental and socio-economic indicators

3.2 Performance Indicators and best practice criteria

Based on the discussion above, KPIs and BPIs are presented in Table 3. In sections 3.2.1 – 3.2.9 their description, equation and best practice criteria, when applicable, are specified.

Category	Stage	Indicators	BPIs	Best practice criteria
TECH	Storage	TECH1. Required space for storage the gypsum waste	✓	TECH1 ≥ 0.40/GW m^3
	Reception	TECH2. Quality of the gypsum waste received	✓	TECH2.1 ≤ 3%; TECH2.2 ≤ 25%
	Reception	TECH3. Gypsum waste rejected	✓	0%
	Processing	TECH 4. Output materials of the recycling process	✓	Paper output > 0%:
ENV	Processing and transport	ENV1. CO_2 emissions from the recycling process	✓	ENV1.1+ENV1.2 < 2.033 kg CO_2 eq/t
	Processing and transport	ENV2. Natural gypsum saved	✓	ENV2 > 0
SOC	Reception	SOC1. Recycler's satisfaction	✓	High
ECO	Processing	ECO1. Energy cost of the gypsum waste processing	X	-
	Transport	ECO2. Transport cost of the recycled gypsum	X	-

Table 3. KPIs, BPIs selection and criteria

3.2.1. TECH1. Required space for storage the gypsum waste

It assesses the required space for storage the gypsum waste at the recycling plant (Eq. 1). A properly dimensioned storage place should be set up in order to guarantee a constant gypsum waste feedstock. Based on this, this indicator gives a rough estimation of the required space for storage.

$$TECH1 = \frac{GW}{0.40}\ (\%) \geq 0.40 \qquad (1)$$

where *GW* is the gypsum waste received in tonnes; and 0.40 t/m^3 the reference density obtained from the GtoG pilot projects.

3.2.2. TECH2. Quality of the gypsum waste received

The compliance with the recyclers' acceptance criteria in relation to the presence of impurities and the percentage of wet gypsum waste received is evaluated. (Eq. 2 - Eq.3). The indicator is divided into “TECH2.1 Impurities” and “TECH2.2 Wet gypsum waste received”. Both sub-indicators and their related parameters must be under the limit value to comply with the overall required quality. The considered limit value of impurities is 3% and 25% for the amount of wet gypsum waste.

$$TECH2.1 = \frac{I}{GW}\ (\%)\ \leq 3 \qquad (2) \qquad TECH2.2 = \frac{GW_W + GW_{SW}}{GW}\ (\%)\ \leq 25 \qquad (3)$$

where GW is the gypsum waste received; GW_W is the wet gypsum waste received and GW_{SW} is the slightly wet gypsum waste received (e.g. rain during transport).

3.2.3. TECH3. Gypsum waste rejected

The rate of gypsum waste rejected by the recycler due to non-conformity with the relevant acceptance criteria (Eq. 4), as defined in the “Acceptance criteria per country” developed in the GtoG project (Burgy et al., 2015) is assessed. A rejection rate would mainly occur if high moisture content or presence of contaminants is found in the load.

$$TECH3 = \frac{GW_r}{GW}\ (\%)\ = 0 \qquad (4)$$

where GW_r is the gypsum waste rejected; and GW is the gypsum waste received.

3.2.4. TECH4. Output materials of the recycling process

It presents the ratio of the materials output (Eq. 5-7) after processing the gypsum waste. If paper ratio is significantly low, it can be attributed to the fact that paper hasn't been properly removed, therefore affecting the quality of the recycled gypsum output.

$$\text{TECH4.1} = \frac{RG}{GW_p}(\%) \quad (5) \qquad \text{TECH4.2} = \frac{P}{GW_p}(\%) > 0 \quad (6) \qquad \text{TECH4.3} = \frac{M}{GW_p}(\%) \quad (7)$$

where *RG* is the recycled gypsum obtained; P is the paper fraction; M is the metal fraction; and GW_p is the gypsum waste processed.

3.2.5. ENV1. CO_2 emissions from the recycling process

The emissions resulting from the waste recycling process (Eq. 9) and the transport of the recycled gypsum (Eq. 10), are quantified by this indicator (Eq. 8). The result can be compared with the extraction of natural or FGD gypsum (2,033 kg CO_2 equiv/t) which has been obtained from reference data (Ecoinvent, 2012; Rigips Saint-Gobain, 2014). The indicator is divided into "ENV1.1 Processing CO_2 emissions" and "ENV1.2 Transport CO_2 emissions".

$$ENV1.1 + ENV1.2 < 2.033 \ \ (kg\ CO_2\ equiv/t) \quad (8)$$

$$ENV1.1 = \frac{(EE\ x\ Ee) + (EF\ x\ Ef)}{GW_p}\ (kg\ CO_2\ equiv/t) \quad (9)$$

$$ENV1.2 = \frac{F_{CO2}\ xRG_{rd}\, xD_r\, xRT_r}{1000}(kg\ CO_2\ equiv/t) \quad (10)$$

where EE is the electricity emission factor; E_e is the electricity consumption; EF is the emission intensity of fuel; E_f is the fuel consumption; F_{CO2} is the freight transportation factor; RG_{rd} is the recycled gypsum transported to reincorporation per roundtrip; D_r is the distance to reincorporation; and RT_r the roundtrips to reincorporation.

3.2.6. ENV2. Natural gypsum saved

ENV2 shows the amount of recycled gypsum obtained (Eq. 11), avoiding natural resource depletion, landscape preservation and H_2S emissions from landfill disposal. It is assumed that natural gypsum saved equals to recycled gypsum obtained.

$$ENV2 = RG\ (t) > 0 \tag{11}$$

where RG is the recycled gypsum obtained.

3.2.7. SOC1. Recycler's satisfaction

It quantitatively assesses the satisfaction reported by the recycler in relation with the gypsum waste received. The evaluation method is currently under discussion.

3.2.8. ECO1. Energy cost of the gypsum waste processing

It represents the energy cost of the recycling process (Eq.12). Best practice criteria have not been associated to this performance indicator, as the result is an indicative value that depends on the electricity, fuel cost as well as on the performance of the equipment, in the country under study.

$$ECO1 = \frac{(E_e x E_c) + (E_f x F_c)}{GW_p} \ (€/t) \tag{12}$$

where E_e is the electricity consumption; E_c is the electricity cost; E_f is the fuel consumption; F_c is the fuel cost; and GW_p is the gypsum waste processed.

3.2.9. ECO2. Transport cost of the recycled gypsum

It is the transport cost from the recycling facility to the manufacturer (Eq.13). The nearest the manufacturing plant is to the recycling facility, the more profitable is for the company and the easier to achieve a closed-loop gypsum recycling. Similarly to ECO1, best practice criteria cannot be associated to ECO2, as the result depends on the peculiarities of each country.

$$ECO2 = \frac{C_f x E_{LF} x D_m x RT_m}{RG} \ (€/t) \tag{13}$$

where C_f is the fuel cost; E_{LF} is the lorry energy consumption; D_m is the distance to the plasterboard manufacturing plant; RT_m is the number of roundtrips to reincorporation; and RG is the recycled gypsum obtained.

4 Conclusion

The paper presents a set of 9 Key Performance Indicators (KPIs) and the selected 7 Best Practice Indicators (BPIs),classified in 4 categories: technical, social, economic and environmental, and per stage of the recycling process: : gypsum waste reception, storage, processing and transport of the recycled gypsum.

Best practices are implemented during the recycling process if:

- A properly dimensioned storage place is set up in order to guarantee a constant feedstock, avoiding further presence of impurities and moisture content at the same time, once received.
- Gypsum waste at the recycling plant complies with the recyclers' waste acceptance criteria (3% of impurities and 25% for the amount of wet gypsum waste) thus no gypsum waste is rejected nor sent to landfill.
- Paper is generated as an output material of the recycling process, when plasterboard is present at the waste load.
- CO_2 emissions resulting from the recycling process are lower than those due to the extraction of natural or FGD gypsum.
- The use of recycled gypsum in the manufacturing of new plasterboard saves natural gypsum from extraction.

Acknowledgement

This study was drafted with results obtained under the framework of the GtoG project, supported by the European Commission – DG Environment through the Life + programme; under contract number LIFE11 ENV/BE/001039.

References

Burgy, J.-Y., Croizer, G., De Guzman, A., Garcia Navarro, J., Jimenez-Rivero, A., Nougarol, S., & Rodríguez Quijano, M. (2015). European Handbook on Best Practices in Deconstruction Techniques. Retrieved June 5, 2015.

Ecoinvent. (2012). Ecoinvent v2.2 Life Cycle Inventory (LCI) database, Gypsum, mineral, at mine/CH S. Retrieved June 5, 2015, from http://www.ecoinvent.ch/

European Parliament. Committee on the Environment, Public Health and Food Safety. (2015). *Draft report on resource efficiency: moving towards a circular economy 2014/2208(INI)*.

Rigips Saint-Gobain. (2014). Environmental Product Declaration Gypsum plasterboard RIGIPS PRO and RIGIPS 4PRO.Strategic Analysis of the European Recycled Materials and Chemicals Market in Construction Industry. M579-39. (2011).