SCRREEN2

This project has received funding from the European

Union's Horizon 2020 research and innovation programme

under grant agreement No 958211.

Start date: 2020-11-01 Duration: 36 Months

FACTSHEETS UPDATES **BASED ON THE EU FACTSHEETS 2020**

GYPSUM

AUTHOR(S):

TABLE DES MATIÈRES

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

GYPSUM

OVERVIEW

Gypsum ($CaSO_4.2H_2O$) is an evaporite mineral formed by precipitation, commonly from lake or sea water. It can also form in hot springs or precipitate from volcanic gases. Anhydrite is a dehydrated variety of the same mineral (chemical formula: $CaSO_4$). Gypsum plaster, also called plaster of Paris is a calcined variety (heated to remove water) which is also known as a hemihydrate. This calcined gypsum is the main semi-product for further manufacturing of plaster based products. Alabaster is a fine-grained, white or lightly tinted, gypsum which has been used since ancient times for sculpture. Gypsum has a hardness of 2.0 on Mohs scale (and is used to define that point on this relative scale), is moderately water soluble and if pure will be white or colourless.

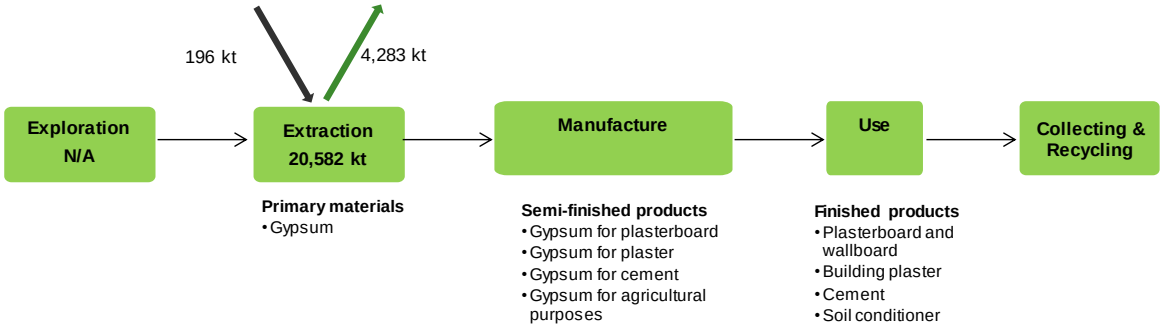

Figure 1. Simplified value chain for gypsum in the EU[1]

Table 1. Gypsum supply and demand in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
160,336,830	China 16% USA 13% Iran 9% Spain 7% Thailand 7%	24,611,358	15.3%	Morocco 54% Bosnia and Herzegovina 13% United Kingdom 8% Tunisia 7% Norway 5%	0%

Prices: The price of gypsum, especially in the main producing countries, is stimulated by the construction of homes, commercial buildings, and office spaces (USGS, 2005). As one of the largest gypsum producers, the production and demand in the United States of America has had influence on the price development. Minor prices increases and decreases are therefore often caused by natural disasters and the housing damages related to them (USGS, 2008). However, it is also important to note that the price of gypsum varies by the

[1] JRC elaboration on multiple sources (see next sections)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

country of destination: While in 2020 the average price of gypsum in China was 50$ per ton, the rice in the United Emirates laid at 11$ per ton.

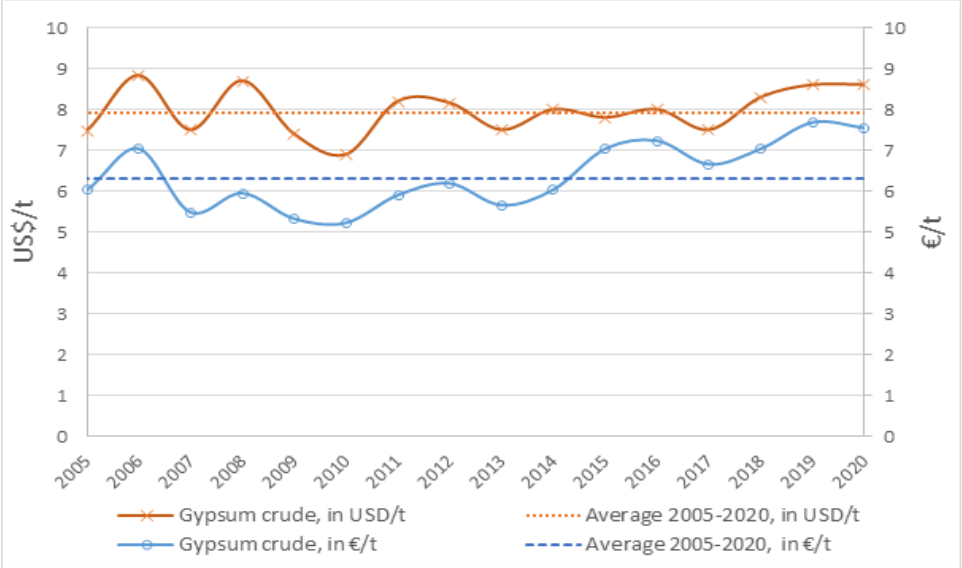

Figure 2. Annual average price of gypsum between 2000 and 2020 (USGS, 2021)[2].

Primary supply: China and USA consists the major producers, with 25 and 21.2 Mt respectively, in 2020 (WMD, since 1984). A notable gypsum production is taking place also in Iran, Spain and Thailand, with 15.1, 13.5 and 9.3 Mt, respectively. The average annual production in EU in the period 2016-2020 was 24.1 Mt. Spain (8.9 Mt), France (4.2 Mt), Germany (4 Mt) and Poland (1 Mt) are the major producers. The production in Italy dropped from a range of 3.8 to 5.9 Mt per year in the period 2012-2015 to <0.2 Mt in 2020 (Eurostat, 2021). Gypsum is a "high place – value" industrial mineral therefore most of the gypsum produced is consumed in the country of production.

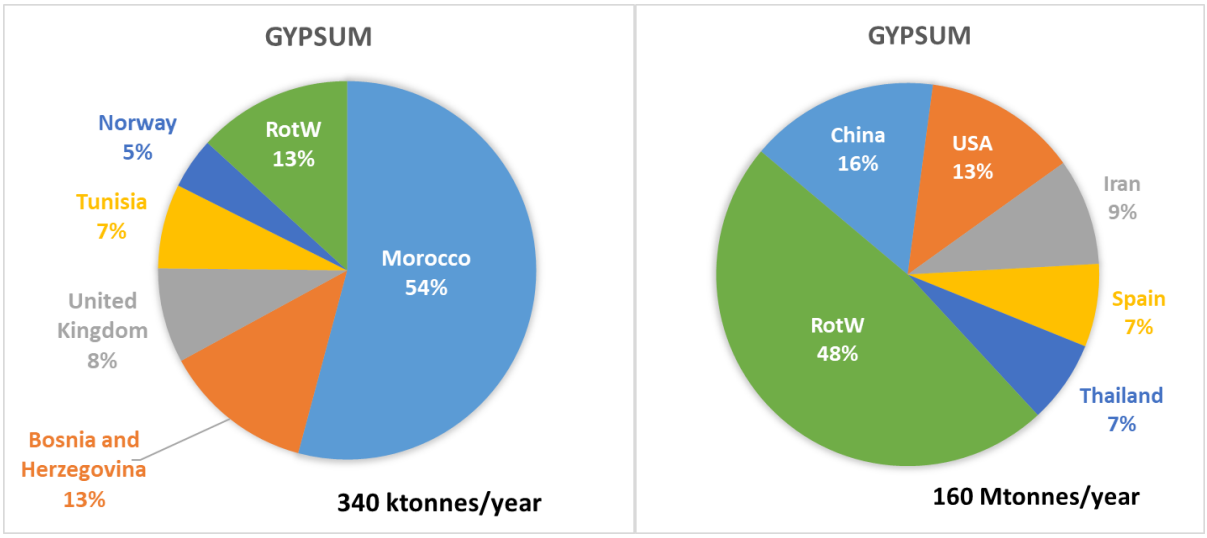

Figure 3. EU sourcing of gypsum and global mine production (2016-2020)

[2] Values in €/kg are converted from original data in US$/kg by using the annual average Euro foreign exchange reference rates from the European Central Bank (https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

Secondary supply: The EU industry does not solely rely on natural gypsum. The use of FGD gypsum, recycled gypsum and other synthetic gypsum is also important to the sector (Lee et al., 2011; Kubba, 2017). In the reported period, approximately 38% of consumption was met by FGD gypsum, 3% by recycled gypsum and 2% by other synthetic gypsum, with the remaining 57% by natural gypsum. Regarding FGD, US Environmental Protection Agency (EPA) concludes that the use of FGD in gypsum board has significant environmental and economic benefits (Eurogypsum, 2014 and 2020).

Uses: The European gypsum industry is one that is vertically integrated, comprising companies that mine gypsum and manufacture plasterboard, wallboard, plaster and other gypsum products. Gypsum is also used in cement production and in agriculture as soil conditioner.

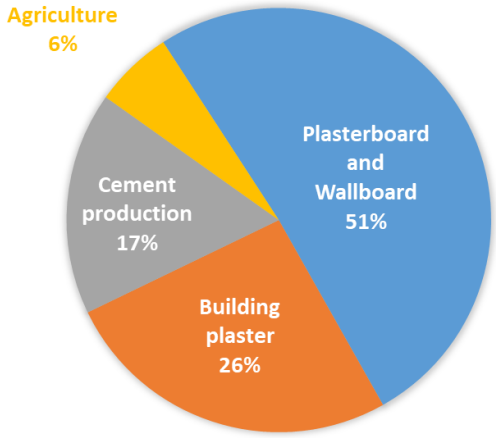

Figure 4: EU uses of gypsum

Substitution: Substitutes for gypsum used in plasterboard and wallboard include synthetic gypsum and recycled gypsum. These materials have similar properties with natural gypsum and are used in the same way. Wood based wall panels, renewable material wall panels, plastic and metal panels, brick and glass may also be used to construct wallboards. In applications such as building plaster and stucco, gypsum may be substituted by cement and lime plaster.

Table 2. Uses and possible substitutes

Use	Percentage*	Substitutes	Sub share	Cost	Performance
Plasterboard and Wallboard	51%	Synthetic gypsum	30%	Similar or lower costs	Similar
Plasterboard and Wallboard	51%	Recycled gypsum	2%	Similar or lower costs	Similar
Plasterboard and Wallboard	51%	Wood based wall panels	20%	Similar or lower costs	Similar
Plasterboard and Wallboard	51%	Renewable material wall panels	1%	Similar or lower costs	Similar
Building plaster	26%	Cement plaster	25%	Similar or lower costs	Similar
Building plaster	26%	Lime plaster	2%5	Similar or lower costs	Similar

*Estimated end use shares and sub shares of gypsum based on DG Environment, 2022; Eurogypsum, 2015; Industrial Minerals & Rocks, 2006; SCRREEN Validation Workshop (2019 and 2022)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

Other issues: The substance evaluations related to the REACH regulation, resulted in no hazardous classifications associated with either mined or by-products of gypsum. Gypsum products are not classified as dangerous according to EU CLP Regulations (GPDA 2023). Typical symptoms of prolonged exposure to gypsum may include irritation of eyes, skin, mucous membrane, upper respiratory system; cough, sneezing, rhinorrhea (discharge of thin nasal mucus) (NIOSH, 2019). Gypsum core board products normally do not entail any risk (CertainTeed, 2018). Most gypsum waste (GW) in the EU is currently landfilled. Besides the loss of valuable resources, gypsum landfilling may result in potential leaching of sulphates; moreover, hydrogen sulphide and greenhouse gases can be emitted due to degradation processes occurring in landfills.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

GLOBAL MARKET

Table 3. Gypsum supply and demand (extraction) in metric tonnes, 2016-2020 average

Global production	Global Producers	EU consumption	EU Share	EU Suppliers	Import reliance
160,336,830	China 16% USA 13% Iran 9% Spain 7% Thailand 7%	24,611,358	15.3%	Morocco 54% Bosnia and Herzegovina 13% United Kingdom 8% Tunisia 7% Norway 5%	0%

Natural Gypsum is extracted from quarries and underground mines. The estimated average global production of natural gypsum (incl. anhydrite) in the period 2016-2020 was about 160.3 Mt per year, with China, the USA and Iran being the largest producers.

Most important EU-producers (24.3 Mt average annual production) are Spain (e.g., Torralba Grupo, Knauf Gips Saint-Gobain Placo Iberica), Germany (e.g., Knauf Gips, Saint-Gobain Rigips) and France (e.g., Saint-Gobain).

In the EU, gypsum is mainly used for plasterboard and wallboard (51%), building plaster (26%), cement production (17%) and agriculture (6%). Natural gypsum had a share of about 55.4% of the worldwide gypsum consumption (310.8 Mt) in 2019, followed by synthetic gypsum (43.8%) and recycled (RC) gypsum (0.9%) (Harder 2022). Synthetic gypsum is produced in the desulphurization of flue gases (FGD gypsum) or, for example, during the production of hydrofluoric acid, phosphoric acid and titanium dioxide.

Global consumption is as setting regulator in the cement industry (53.4%) followed by the gypsum plasterboard industry (28.3%). In 2021, estimated average prices by USGS were 9.0 US$ per metric ton for crude gypsum and 37 US$ for calcined gypsum (USGS 2022). Substitution of gypsum plasterboard and wallboard by wood based or renewable material wall panels and the use of cement or lime plaster as alternatives for gypsum building plaster is possible. Analysts generally see an increase in the worldwide gypsum consumption to about 337.9 Mt per year in 2030 (+8.7% compared to 2019) (Harder 2022).

The percentage of natural gypsum on the demand is expected to decrease slightly from 55.4% to 50.8% in 2030. Top export countries for natural gypsum will be Oman and Iran that still hold extensive resources.

Although the availability of FGD gypsum will further decrease in the US and in Europe due to coal phase-out actions, global use for all synthetic gypsums is forecasted to increase to 155.7 Mt in 2030 (+13.8% compared to 2019). This is because of the rising availability of FGD gypsum in China and the rest of the world and the future use of numerous other sources of synthetic gypsum. Furthermore, the percentage of recycled gypsum is expected to increase drastically to about 11 Mt per year in 2030 (+293% compared to 2019), which will cover about 3.2% of the global demand (Harder 2022).

The global gypsum supply should be secured by 2030, as there is still enough natural gypsum in many countries. However, as most gypsum is used in the local construction industry, the decrease in FGD gypsum in Western countries needs to be compensated by the use of stored FGD gypsum and by increasing extraction

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

rates of natural gypsum rather than increasing import rates. In order to secure future demand, gypsum recycling rates and the processing of phosphogypsum need to be improved.

EU TRADE

Gypsum is assessed at the mining stage. The following table lists relevant Eurostat CN trade codes for Gypsum.

Table 4. Relevant Eurostat CN trade codes for Gypsum.

Mining	
CN trade code	**title**
25200100	Gypsum; anhydrite

The listed CN code that refer to Gypsum; anhydrite is 25201000.

Figure 5 shows the import and export trend of Gypsum over a 21-years period from 2000 to 2021. The EU is a net exporter of Gypsum. The exports from EU rose steadily from 2,715,499 tonnes in 2000 to 8,832,990 tonnes in 2021. There was only one relatively sharp reduction in exports between 2008 and 2009 during the financial crisis. The import of Gypsum; anhydrite to the EU increased slightly from 269,941 tonnes in 2000 to 896,870 tonnes in 2021.

Figure 6 illustrates the share of EU imports for gypsum; anhydrite from various countries. The main import partners of the EU are Morocco (38%), Bosnia and Herzegovina (12%), Moldova (10%), and Turkey (8%). Morocco used to be the main supplier for all years. The imports from all these countries increased between 2018 and 2021.

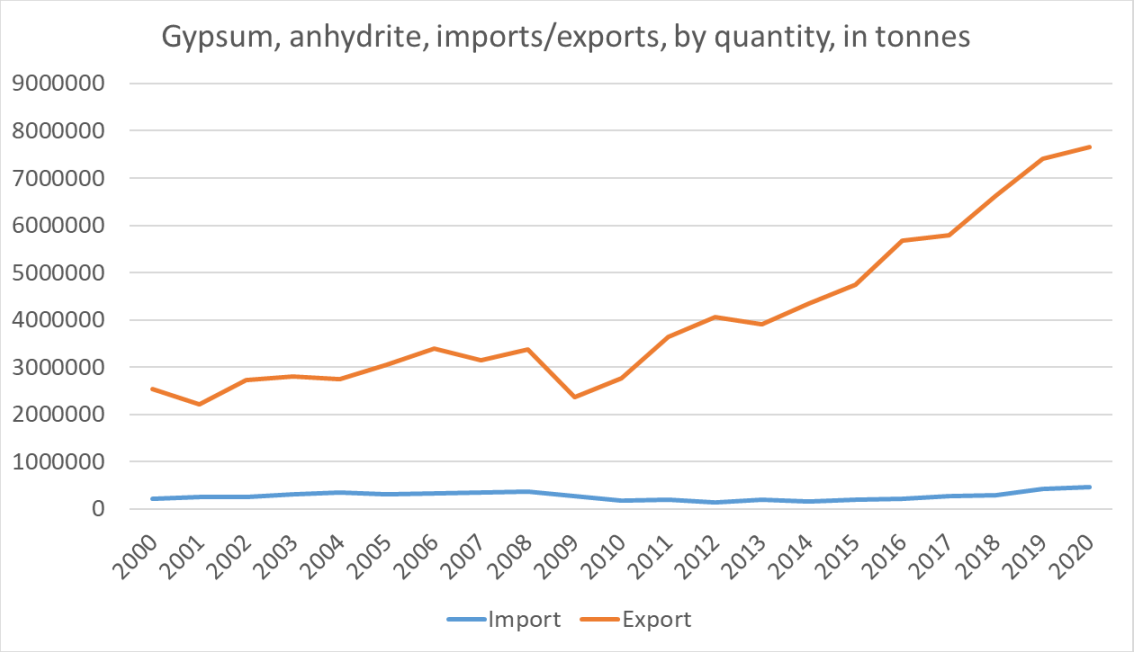

Figure 5. EU trade flows of gypsum; anhydrite (CN 25201000) from 2000 to 2021 (Eurostat, 2022)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

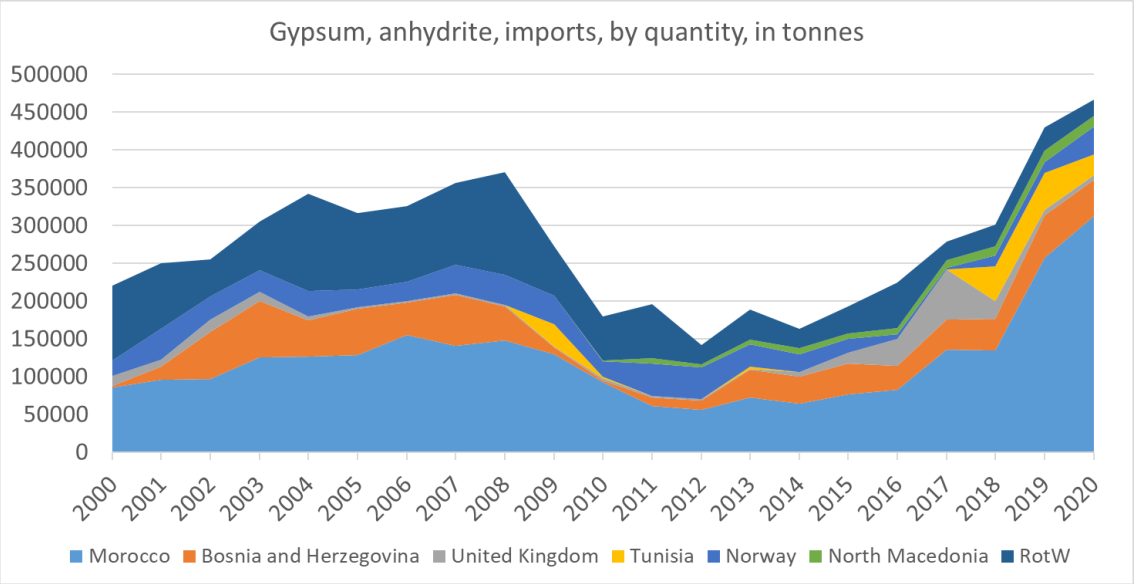

Figure 6. EU imports of gypsum; anhydrite (CN 25201000) by country from 2000 to 2021 (Eurostat, 2022)

PRICE AND PRICE VOLATILITY

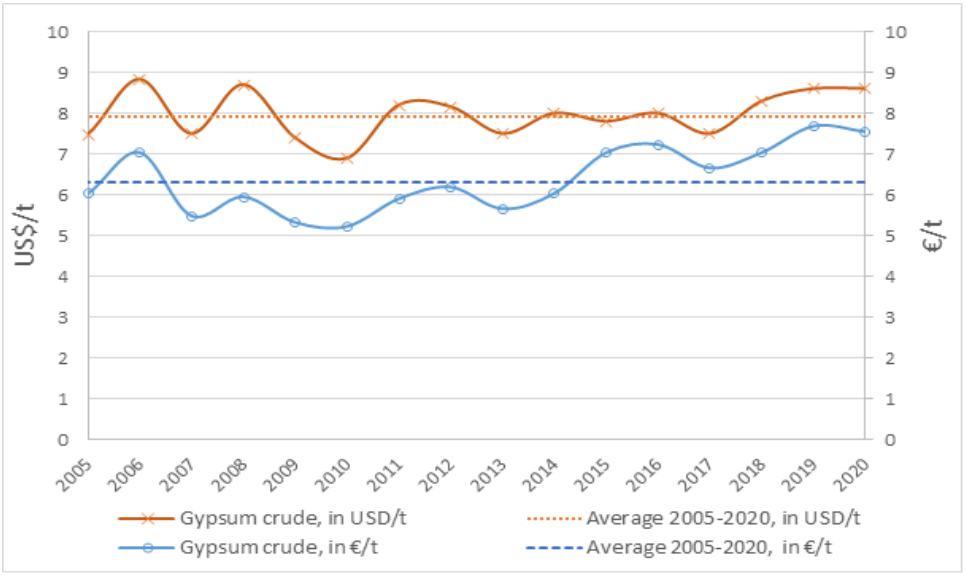

Figure 7. Annual average price of gypsum crude between 2000 and 2020, in US$/t and €/t[3]. Dash lines indicate average price for 2000-2020 (USGS, 2022)

The price of gypsum, especially in the main producing countries, is stimulated by the construction of homes, commercial buildings, and office spaces (USGS, 2005). As one of the largest gypsum producers, the production

[3] Values in €/kg are converted from original data in US$/kg by using the annual average Euro foreign exchange reference rates from the European Central Bank (https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

and demand in the United States of America has had influence on the price development. Minor prices increases and decreases are therefore often caused by natural disasters and the housing damages related to them (USGS, 2008). However, it is also important to note that the price of gypsum varies by the country of destination: While in 2020 the average price of gypsum in China was 50$ per ton, the rice in the United Emirates laid at 11$ per ton. In 2020, the most notable rate of growth in terms of prices was attained by Canada, while the other global leaders experienced more modest paces of growth (GlobalTrade, 2021).

After a slowing building sector due to the COVID pandemic, increased demand for construction materials is forecast to drive demand for gypsum (FMI - Future Market Insights, 2022).

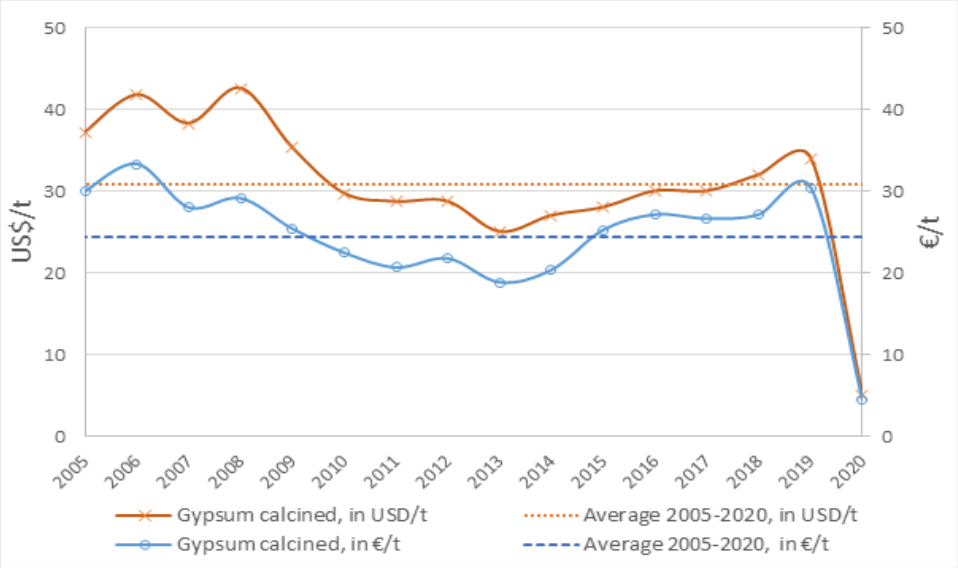

Figure 8. Annual average price of gypsum calcined between 2000 and 2020, in US$/t and €/t[4]. Dash lines indicate average price for 2000-2020 (USGS, 2022)

EU DEMAND

GLOBAL AND EU DEMAND AND CONSUMPTION

Gypsum consumption is assessed at extraction stage and for natural gypsum. Gypsum consumption consists of consumption of natural and synthetic FGD gypsum. The European apparent consumption in the period 2012 and 2016 (5-year average) was estimated at 32.3 Mt per year, of which 21.8 Mt was the domestic production of natural gypsum, 18.0 Mt tonnes was the domestic production of synthetic FGD gypsum (NERA, 2016). Consumption of FDG gypsum is expected to decline due to phasing out of coal-powered power plants. Gypsum extraction stage EU consumption is presented by HS code CN 25201000 - Gypsum; anhydrite. Import and export data is extracted from Eurostat Comext (2022). Production data is extracted from WMD (2022).

[4] Values in €/kg are converted from original data in US$/kg by using the annual average Euro foreign exchange reference rates from the European Central Bank (https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

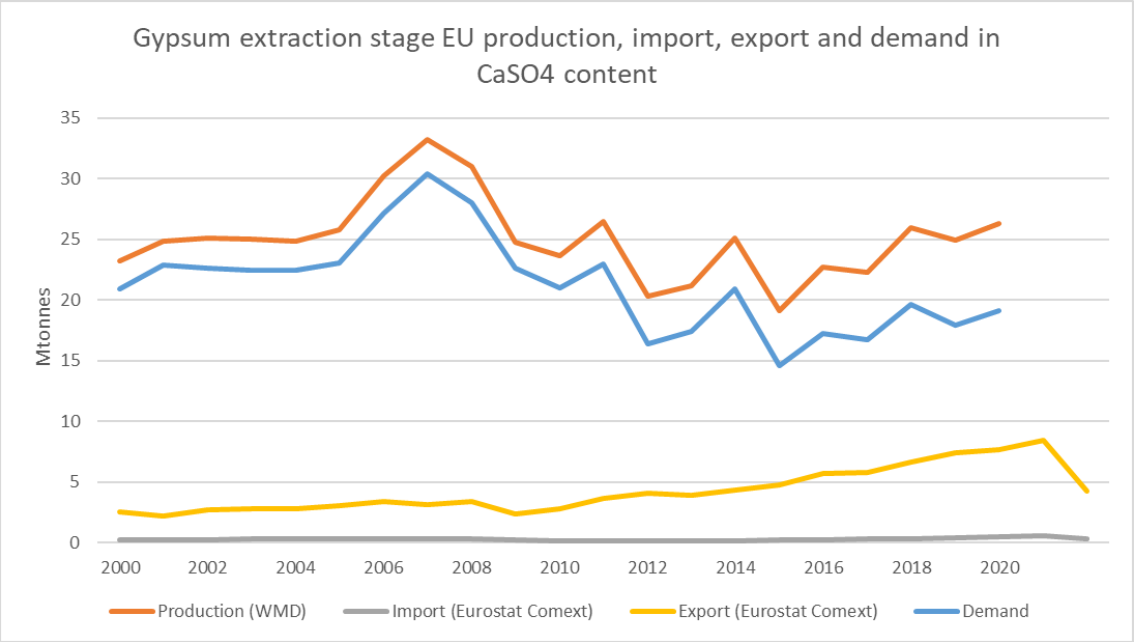

Figure 9. Gypsum (25201000) extraction stage apparent EU consumption. Production data is available from WMD (2022). Consumption is calculated in $CaSO_4$ content (EU production+import-export).

Average import reliance of gypsum at extraction stage is 0 % for 2016-2020.

EU USES AND END-USES

The European gypsum industry is one that is vertically integrated, comprising companies that mine gypsum and manufacture plasterboard, wallboard, plaster and other gypsum products.

Gypsum is also used in cement production and in agriculture as soil conditioner.

Figure 10 illustrates the end uses of Gypsum in the EU (percentages unchanged from 2020 factsheet).

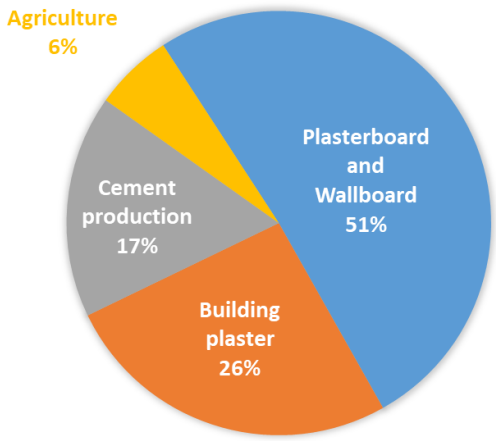

Figure 10. EU end uses of gypsum. Average 2012-2016 (Eurogypsum, 2020; validated by SCRREEN experts, 2022).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

Relevant industry sectors are described using the NACE sector codes in Table 5

Table 5. Gypsum applications, 2-digit and associated 4-digit NACE sectors, and value added per sector (Eurostat, 2021).

Applications	2-digit NACE sector	Value added of NACE 2 sector (millions €) -2019	4-digit NACE sectors
Plasterboard and Wallboard	C23 - Manufacture of other non-metallic mineral products	72,396	C2362 - Manufacture of plaster products for construction purposes
Building plaster	C23 - Manufacture of other non-metallic mineral products	72,396	C2352 - Manufacture of lime and plaster
Cement production	C23 - Manufacture of other non-metallic mineral products	72,396	C2351 - Manufacture of cement
Agriculture	C23 - Manufacture of other non-metallic mineral products	72,396	2399 Manufacture of other non-metallic mineral products n.e.c.

APPLICATIONS OF GYPSUM IN THE EU

Plasterboard, plaster blocks, ceiling tiles and gypsum fibreboard are used for partition and lining of walls, ceilings, roofs and floors. The properties of plasterboard can be modified to meet a specification or requirement.

Building plaster is commonly used for walls and ceilings, whereas decorative plaster is used to produce aesthetic effects on brick and block walls and on ceilings.

Plasterboard properties can provide several advantages to buildings, such as fire resistance, sound insulation, thermal insulation, impact resistance and humidity control (Eurogypsum, 2020).

Gypsum in cement is used to control the setting rate of cement. Circa 15 kt of gypsum are used as ornamental stones (e.g. alabaster) (SCRREEN Cgypsum workshop, 2019).

SUBSTITUTION

Substitutes with a similar functionality in comparison to gypsum are available for the applications of plasterboard, wallboard and building plaster.

Use	Percentage*	Substitutes	Sub share	Cost	Performance
Plasterboard and Wallboard	51%	Synthetic gypsum	30%	Similar or lower costs	Similar

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

Plasterboard and Wallboard	51%	Recycled gypsum	2%	Similar or lower costs	Similar
Plasterboard and Wallboard	51%	Wood based wall panels	20%	Similar or lower costs	Similar
Plasterboard and Wallboard	51%	Renewable material wall panels	1%	Similar or lower costs	Similar
Building plaster	26%	Cement plaster	25%	Similar or lower costs	Similar
Building plaster	26%	Lime plaster	2%5	Similar or lower costs	Similar

***Estimated end use shares of gypsum (DG Environment, 2022; Eurogypsum, 2015; Industrial Minerals & Rocks, 2006; outputs of SCRREEN Experts Validation Workshop (2022). Sub-shares based on hypotheses made through expert consultation (SCRREEN workshops 2019 and 2022) and literature review (e.g. Eurgypsum, 2015).**

PLASTERBOARD AND WALLBOARD

Substitutes for gypsum used in plasterboard and wallboard include synthetic gypsum and recycled gypsum.

These materials have similar properties with natural gypsum and are used in the same way.

Wood based wall panels, renewable material wall panels, plastic and metal panels, brick and glass may also be used to construct wallboards.

BUILDING PLASTER

In applications such as building plaster and stucco, gypsum may be substituted by cement and lime plaster.

AGRICULTURE

Synthetic gypsum (mainly FGD gypsum) is used as an alternative material in the production of cement and as a soil conditioner in agricultural applications.

SUPPLY

EU SUPPLY CHAIN

The average annual production in EU in the period 2016-2020 was 24.1 Mt. Spain (8.9 Mt), France (4.2 Mt), Germany (4 Mt) and Poland (1 Mt) are the major producers. The production in Italy dropped from a range of 3.8 to 5.9 Mt per year in the period 2012-2015 to <0.2 Mt in 2020 (Eurostat, 2021). Gypsum is a “high place – value” industrial mineral therefore most of the gypsum produced is consumed in the country of production. Flue gas desulfurization (FGD) gypsum EU production is estimated approximately at 18 Mt per year, thus FGD gypsum is an important input material to the European gypsum industry. The imports of gypsum is relatively low when compared to production (below 300 thousand tonnes during the period 2016-2020). Around 6.7 Mt of gypsum were annually exported to third countries between 2016 and 2020. United States, United Kingdom,

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 958211

Nigeria and Israel are the most important partners. The recycling rate is extremely low not exceeding 1% (Eurostat, 2021). There are no export restrictions, quotas or prohibitions identified that may impact on the availability of gypsum.

SUPPLY FROM PRIMARY MATERIALS

GEOLOGY, RESOURCES AND RESERVES

GEOLOGICAL OCCURRENCE:

Gypsum ($CaSO_4.2H_2O$) is an evaporite mineral formed by precipitation, commonly from lake or sea water. It can also form in hot springs or precipitate from volcanic gases. Anhydrite ($CaSO_4$) is a dehydrated variety of the same mineral. Gypsum plaster, also called plaster of Paris is a calcined variety (heated to remove water) which is also known as a hemihydrate, $CaSO_4 \cdot 0.5H_2O$. This calcined gypsum is the main semi-product for further manufacturing of plaster based products. Alabaster is a fine-grained, white or lightly tinted, gypsum which has been used since ancient times for sculpture. Gypsum has a hardness of 2 on Mohs scale (and is used to define that point on this relative scale), is moderately water soluble and if pure will be white or colourless. Natural deposits typically contain impurities and can appear grey, yellow, red or brown. Although it is often found as thick beds in sedimentary sequences, it rarely occurs as sand but White Sands National Monument in the US is a notable exception. Often gypsum is formed by the hydration of anhydrite at or near surface, which was uplifted to the near surface by geological processes. Gypsum usually passes into anhydrite below 40-50 m, although this varies according to local geological conditions.

Gypsum in nature occurs as beds or nodular masses up to a few metres thick and is formed as chemical sediments of evaporating marine or terrestrial water bodies. Common country rocks of the calcium sulphates include dolomite, saline claystone and salt rocks (e.g. halite). When the concentration of seawater increases, the calcium sulphates are precipitated after carbonate rocks and before rock salt. The primary precipitate of calcium sulphate is gypsum, only when temperature is higher than 56 to 58°C. Anhydrite is the thermodynamically stable phase. In sabkhas72 conditions of gypsum and anhydrite stability switch easily and multiple transformations are often taking place (Pohl, 2011; British Geological Survey, 2006).

GLOBAL RESOURCES AND RESERVES:

Reserves are large in major producing countries, but data for most are not available. 78 countries were thought to produce gypsum in 2021. Prior 2019 estimates of this commodity included gypsum production for China that totalled as much as 130 million tons. However, recently acquired information revealed that the vast majority of that amount was likely synthetic gypsum, which is not “mine production.” Hence, the large decrease in reported gypsum in China reflects a recategorization of gypsum material and should not be interpreted as a large decrease in the overall total world production of gypsum nor the production of gypsum in China (USGS, since 2000).

Table 6. Gypsum reserves by country in 2021 (USGS, since 2000).

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 958211

Country	Reserves in thousand tonnes
United States	700 000
Brazil	450 000
Canada	450 000
France	350 000
India	37 000
Pakistan	6 000
Thailand	1 700
Turkey	200 000
World total (rounded)	Large

EU RESOURCES AND RESERVES:

Resource data for some countries in Europe are available at Minerals4EU (2019) but cannot be summed as they are partial and they do not use the same reporting code (Table 2).

Table 7. Resource data for the EU (Minerals4EU, 2019)

Country	Reporting code	Quantity	Unit	Grade	Code Resource Type
Spain	None	60,000	Million m3	-	Resource
Greece	UGSG	70	Mt	-	Indicated
Serbia	JORC	11.89	Mt	-	Total
N. Macedonia	Ex-Yugoslavian	178,738	t	-	A
Albania	Nat. Rep. Code	1,000,000	Million m3	85%	A
Turkey	None	1,800	Mt	-	Historic Resource Estimates
Hungary	Russian Classification	?	Million m3	2.4 t/m3	-
Slovakia	None	1.127	Mt	68.4% economic	Z1
Czech Republic	Nat. Rep. Code	82,137	kt	-	Potentially economic
Ukraine	Russian Classification	56,770	kt	-	P2
Poland	Nat. Rep. Code	192.39	Mt	-	A+B+C1
Latvia	Nat. Rep. Code	47.7	Mt	-	Stock of explored deposits
Lithuania	Nat. Rep. Code	16.82	Million m3	-	Mesaured
UK	None	>2,000	Mt	-	Estimate
Ireland	None	8	Mt	78%	Historic Resource Estimates

The only country reporting reserve data on gypsum using the United Nations Framework Classification (UNFC) is Romania, which indicated 113 Mt of reserves for UNFC 111 code and 200 Mt of reserves for UNFC 121 code (Minerals4EU, 2019) (Table 3).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

Table 8. Reserve data for the EU (Minerals4EU, 2019)

Country	Reporting code	Quantity	Unit	Grade	Code Reserve Type
Spain	Other	2,645	Mt	-	Proven
Romania	UNFC	113	Mt	-	111
Croatia	Nat. Rep. Code	51.22	Mt	-	-
N. Macedonia	Ex-Yugoslavia	178,738	t	-	A
Switzerland	None	3	Mt	-	Total
Slovakia	None	1.127	Mt	68.4% economic	Z1
Czech Republic	Nat. Rep. Code	119,100	kt	-	Economic explored
Ukraine	Russian Classification	39,836	kt	Gypsum and anhydrite, total	A
Poland	Nat. Rep. Code	109.11	Mt	-	Total
UK	None	> 50	Mt	-	Total

WORLD AND EU MINE PRODUCTION

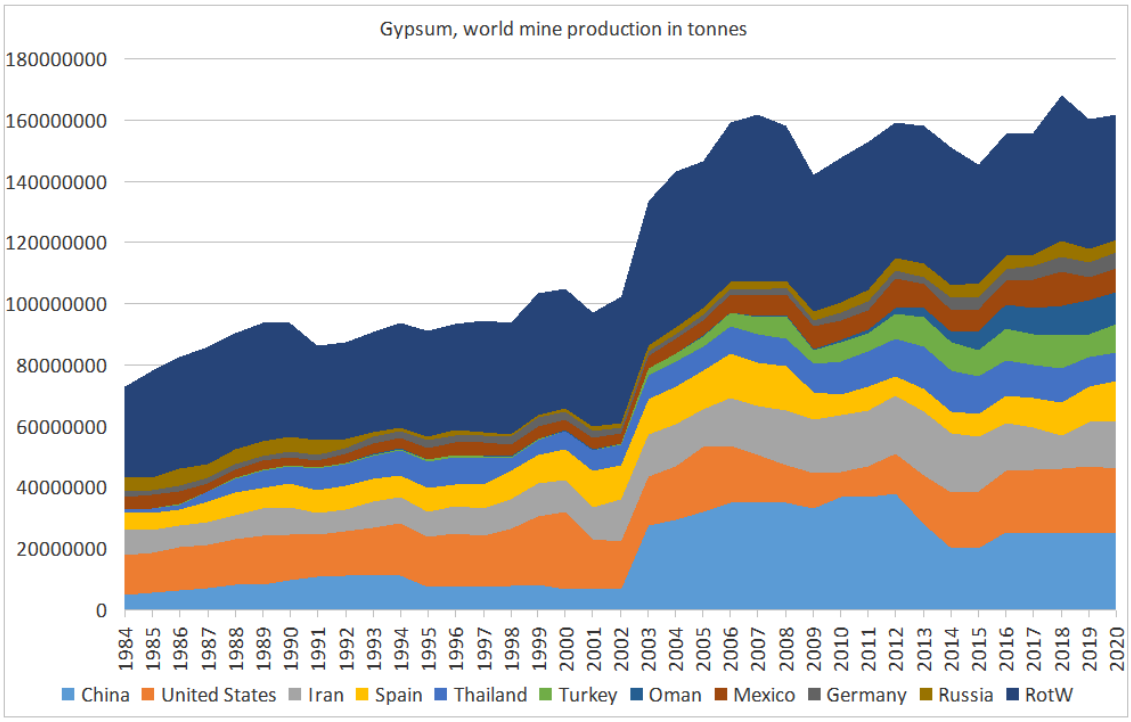

Figure 11. Global gypsum production since 1984 according to WMD (WMD, since, 1984)

Figure 11 presents the global production of gypsum according to WMD data. As it can be seen, China and USA consists the major producers, with 25 and 21.2 Mt respectively, in 2020 (WMD, since 1984). A notable gypsum

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

production is taking place also in Iran, Spain and Thailand, with 15.1, 13.5 and 9.3 Mt, respectively. Table 4 presents in detail the world production by country according to USGD data.

Similarly, Figure 12 presents the global production of gypsum according to USGS data. Both United States and Iran (besides a lump sum of other countries) consists the major producers, with 21.2 and 16.0 Mt respectively, in 2020 (USGS, since 2000). A notable gypsum production is taking place also in China, Spain and Oman with 12.6, 11.0 and 10.2 Mt, respectively. Considerable production increasing is noted in China for the period of 2007-2013. According to USGS Mineral Yearbook, this was an evidence of that country's continued and dramatic economic growth while increased use of wallboard in Asia, coupled with new gypsum product plants, spurred increased production in that region (USGS, since 2000).

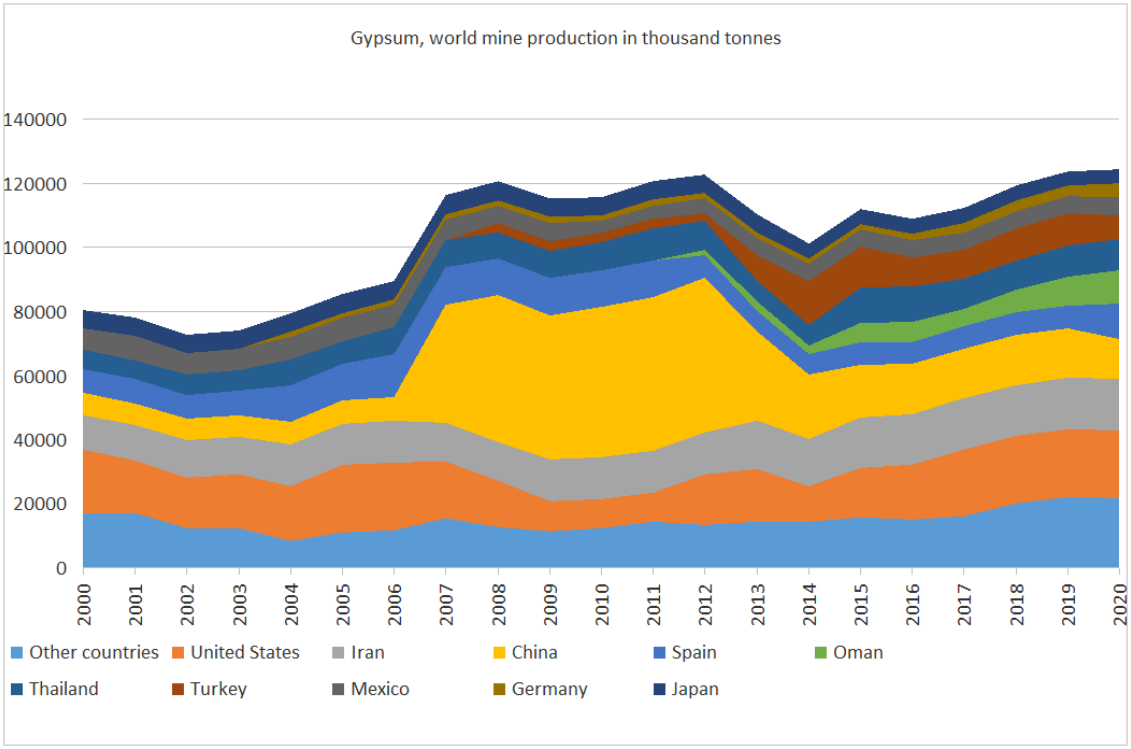

Figure 12. Global gypsum production since 2000 according to USGS (USGS, since, 2000).

EU production accounts about the 8.6% of the global production in 2020 (WMD, since 1984). Gypsum was extracted (total amount: 21.4 Mt) in 17 EU countries in this year (Eurostat, 2021). Gypsum/anhydrite are produced predominantly in Europe using open cast mining techniques (80%) and (20%) by underground mining using pillar and stall mining methods that give extraction rates of up to 75%. These mining methods do not cause subsidence and no significant waste is produced. The impact of the workings is confined to the surface facilities at the mine. Continuous mining is becoming increasingly common in underground gypsum mines too. In open cast mines, mineral to overburden/interburden ratios can be as high as 1:15. Overburden is used to reclaim the void, which may also be used for landfilling (British Geological Survey, 2006).

Table 9. World mine production (in thousand metric tonnes) by county in the period 2016-2020 according to USGS data (USGS, since 2000).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

Country	Year					
	2016	2017	2018	2019	2020	2021
United States	17 000	20 700	21 100	21 200	21 200	23 000
Algeria	2 130	2 200	2 500	2 500	2 500	2 500
Argentina	1 500	1 500	NA	NA	NA	NA
Australia	2 580	1 400	NA	NA	NA	NA
Brazil	3 400	3 400	3 200	3 000	2 000	2 000
Canada	1 630	1 700	3 000	3 000	2 400	2 900
China	15 500	15 500	15 500	15 500	12 600	13 000
Egypt	2 200	2 200	NA	NA	NA	NA
France	3 280	4 200	3 000	3 000	1 890	1 900
Germany	1 800	3 100	3 200	3 300	4 500	4 500
India	3 500	2 700	2 700	2 700	1 500	1 500
Iran	16 000	16 000	16 000	16 000	16 000	16 000
Italy	8 550	NA	NA	NA	NA	NA
Japan	4 670	4 700	4 700	4 300	4 300	4 300
Mexico	5 380	5 400	5 400	5 400	5 400	5 400
Oman	6 050	5 500	7 000	9 100	10 200	10 000
Pakistan	1 660	2 000	2 200	1 670	2 210	2 200
Russia	4 400	4 000	3 800	5 500	4 200	4 200
Saudi Arabia	1 860	3 150	3 310	3 300	3 300	3 300
Spain	7 000	7 000	7 000	7 000	11 000	11 000
Thailand	11 300	9 250	9 300	9 790	9 800	9 800
Turkey	9000	9 000	10 000	10 000	7 500	9 300
United Kingdom	1200	NA	NA	NA	NA	NA
Other countries	15000	16100	20 000	22 000	21 700	22 000

OUTLOOK FOR SUPPLY

Gypsum is a key raw material needed in large quantities in the cement industry, the gypsum plasterboard industry, for other gypsum building products, and in agriculture.

World production had fallen by -3.8 % to 166.5 Mt in 2020 due to the pandemic. A slight increase took place in 2021 by 1.3 % to 168.7 Mt. In contrast, over the years 2025 to 2030, only a smaller further increase in production quantities is expected. China leads the extraction field, with a global market share of 20.4 %, followed by the USA and Iran. The TOP 10 countries make up a market share of around 75 %. Some of the previously important countries, such as Thailand and South Africa, will continue to lose ground as the resources available there have already been largely exhausted. Oman may be able to almost double its exports from 9.3 Mt in 2019 to 16.5 Mt. Iran's exports will also increase substantially from 4.8 Mt to around 6.0 Mt. The countries with higher export rates up to 2030 will include Mexico, Canada, Turkey and Pakistan. Considerable losses are expected for Thailand. After 5.5 Mt natural gypsum exports in 2019, a maximum of 3.5 Mt are expected by 2030. Germany will also reduce its export rates, too, as less FGD gypsum is available for domestic industry and this must be offset to an extent by more natural gypsum (at-minerals, 2022).

SUPPLY FROM SECONDARY MATERIALS/RECYCLING

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

The EU industry does not solely rely on natural gypsum. The use of FGD gypsum, recycled gypsum and other synthetic gypsum is also important to the sector (Lee et al., 2011; Kubba, 2017). In the reported period, approximately 38% of consumption was met by FGD gypsum, 3% by recycled gypsum and 2% by other synthetic gypsum, with the remaining 57% by natural gypsum. Regarding FGD, US Environmental Protection Agency (EPA) concludes that the use of FGD in gypsum board has significant environmental and economic benefits (Eurogypsum, 2014 and 2020).

The global synthetic gypsum market is expected to reach 220Mt/y by 2027, from a 151 Mt/y in 2017. A modest growth in the US, a decline in Europe and growth in China is forecasted over the next 10 years. The current supply of synthetic gypsum is mostly based in these countries and has accounted for 96% of worldwide supply in 2014 (Global Gypsum, 2017).

FGD GYPSUM

FGD gypsum is a by-product of coal fired power station, while flue gas desulphurisation takes place in scrubbing towers. When flue gas comes into contact with an aqueous suspension containing limestone or slaked quicklime, SO2 present in the flue gas is oxidised to SO3 and precipitates to form finally gypsum dihydrate. The gypsum crystals are separated from the suspension with the use of centrifuges or filtering technology. FGD gypsum production in the EU is estimated approximately at 18 Mt per year. FGD gypsum, which is directly usable, is used similarly to natural gypsum in the production of plaster and plasterboard. The quantity of FGD gypsum is closely related to the sulphur content of the coal used in coal powered electricity plants and its operation time. Low sulphur coal will produce lower quantities of FGD gypsum. Eurogypsum, Ecoba and VGB Powertech have determined harmonized quality criteria and analysis methods to ensure the utilisation in the European gypsum industry.

The growth in the construction industry in Asia Pacific, North America, and Europe is anticipated to boost the global FGD gypsum market in the near future. Demand for gypsum is high in the construction industry, which accounts for 10% share of the GDP of European Union, due to wide applications in wallboard, cement, and plaster of Paris (Transparency Market Research, 2019).

The main FGD gypsum producing country is Germany due to the presence of coal fired power plants stations (around 7 million tonnes produced every year) (). Plasterboard plants in countries with no or poor natural gypsum deposits (Scandinavia, Belgium, the Netherlands, and the United Kingdom) rely up to 100% on this substitute to produce plasterboard. FGD gypsum is of higher purity than most natural gypsum. This means that lower quality gypsum can be blended with high purity FGD gypsum, allowing material that would not have been mined in the past to be exploited.

RECYCLED GYPSUM

Recycled gypsum is produced from processing of gypsum waste products, namely plasterboard waste. Three categories of gypsum waste can be differentiated based on their origin:

- Production waste (e.g. gypsum boards which do not meet specifications and waste from the manufacturing process). Production waste currently recycled is approximately 3.5-5%.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

- Waste resulting from construction sites (called construction waste). The gypsum construction waste currently recycled is estimated, at current market volumes, at ca. 7%.
- Demolition waste. The last category includes both demolition and renovation waste and is the most complex to address because it adheres to other construction materials (such as plasters, paints & screeds etc). The demolition waste does not depend on market volumes and its recycling rate is estimated at ca. 1%.

Although gypsum products are indefinitely and fully recyclable, only a small percentage of construction and demolition material is recycled in Europe76. One reason for the low amount of gypsum waste recycled from demolition activities is due to the common practice of demolishing and mixing different kinds of waste in same bins on job sites rather than deconstructing and segregating waste by nature during a deconstruction activity. This common practice also leads to potential problems of contamination with hazardous substances, which can affect the recycling efficiency. The recycling of plasterboard waste includes several activities (dismantling and separation of suitable waste, processing of plasterboard recovered and re-incorporation into new manufacturing processes) and different parties are involved to facilitate the process.

A Life Project GypsumtoGypsum77 initiative was promoted by Eurogypsum with the overall aim to achieve higher recycling and reuse rates of gypsum, thus transforming the European gypsum market in a resource efficient and circular economy. The study demonstrates feasibility of re-incorporation (up to 30% according to current state of the art technology) of recycled gypsum in manufacturing of Type A plasterboard with a face to which suitable gypsum plasters or decoration may be applied (EN-520 Standard), without noticeably affected basic performance characteristics. It highlighted potential production bottlenecks in terms of recipe modifications (e.g. in additives) and production process equipment (e.g. storage, feeding conveyors, recycled gypsum pre-processing etc.) that may arise when the increased percentage becomes standard practice in the plasterboard manufacturing. It concluded on the fact that several actions were possible to increase significantly the circularity of this industry, by favoring deconstruction versus demolition, by pushing the correct implementation of the current EU waste legislation in a harmonized way across Europe, by fostering the economic competitiveness of the recycling route compared to other currently permitted routes and by turning waste into a resource.

The recycling of gypsum is controlled by national and commercial specifications, but in reality recycling across Europe varies considerably from country to country, mainly according to local gypsum waste landfilling costs and constraints. No end-of-life criteria exist at the moment at European level that could promote gypsum recycling further. The UK is the only country, which has adopted a quality protocol for the recycling of gypsum from plasterboard waste accompanied also by a specification for the production of reprocessed gypsum (WRAP & BSI, 2013; WRAP & Environment Agency, 2011). Hence the current low production and use of recycled gypsum in Europe is not unexpected (only 3% of the total gypsum used).

Recently a new recycling facility commenced operation in Holmestrand, Norway, approximately 70km south of the capital Oslo. Construction of the building and installation of the processing equipment was completed during July 2018 and the commissioning of the new equipment was carried out in August 2018. The new recycling facility has sufficient capacity to process up to 100,000t/yr, providing sufficient capacity to service the local gypsum wallboard plants (Global Gypsum, 2018).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

OTHER SYNTHETIC GYPSUM

Several other industries produce gypsum as a by-product, but their use by the European gypsum industry is very low. Other types of synthetic gypsum include phosphogypsum, titanogypsum, citrogypsum and other (Eurogypsum, 2020).

The most important potential of other synthetic gypsums than FGD gypsum lies in the use of purified phosphogypsum, but apart from a few exceptions its radioactivity still remains a problem. There is also some potential in the use of purified titanogypsum. In the past, both the phosphoric acid and the titanium dioxide industries have systematically closed down production facilities in Europe (Eurogypsum, 2020; Gypsum Association, 2019).

PROCESSING OF GYPSUM

The raw material of gypsum powder is natural gypsum ore, and the production process of gypsum powder is mainly divided into 4 stages: crushing, screening, grinding and calcination (Beidoou, 2022) (Figure 3).

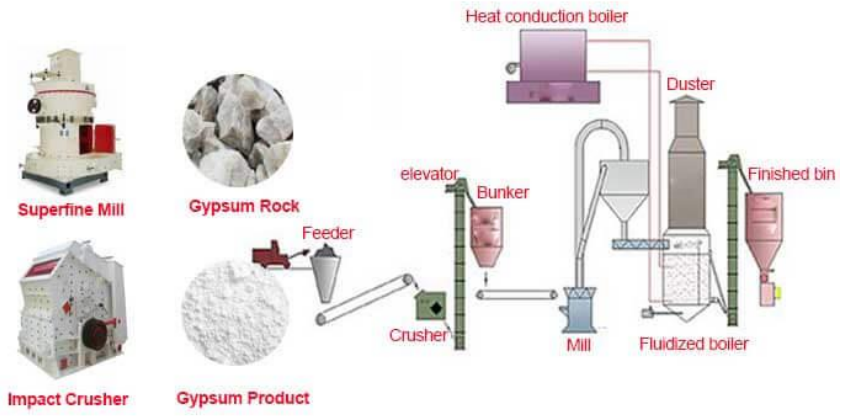

Figure 13. Gypsum Production Process (Beidoou, 2022)

1. Crushing: The mined gypsum ore raw material enters the crusher through vibrating feeder, and the crusher break the large-size gypsum ore into small particles smaller than 30mm.

2. Screening: Use a vibrating screen to separate incomplete large particles and impurities that mixed in crushed gypsum. Gypsum with suitable available size can be separated by controlling the diameter of sieve hole, which can be used as cement additive for sale.

3. Grinding: The screened gypsums are fed into the grinding mill uniformly and continuously by vibratory feeders for grinding. The ground gypsum powder is blown out by the air flow bulged by the mill blower and graded by the separator machine on the mill. The fineness qualified powder is collected by hydrocyclone and discharged through the powder outlet tube, is known as land plaster. Land plaster is sent by screw conveyor.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

4. Calcination: Calcination mainly uses the direct contact between high-temperature hot flue gas of boiling furnace and gypsum raw materials to complete the calcination and dehydration of gypsum powder. The structure and characteristics of dehydrated gypsum are also different under different heating conditions.

OTHER CONSIDERATIONS

HEALTH AND SAFETY ISSUES

The substance evaluations related to the REACH regulation, resulted in no hazardous classifications associated with either mined or by-products of gypsum. Gypsum products are not classified as dangerous according to EU CLP Regulations (GPDA 2023).

The most commonly encountered forms of dust during construction activities are associated with plaster and related plastering materials. Inhaling plaster dust can lead to respiratory complaints, including asthma and chronic obstructive pulmonary disease (COPD). In addition, serious illness can result if the plaster mix contains any silica, or if old plaster walls being sanded contain any asbestos (Azarov et al., 2016; RTVGROUP, 2022).

Typical symptoms of prolonged exposure to gypsum may include irritation of eyes, skin, mucous membrane, upper respiratory system; cough, sneezing, rhinorrhea (discharge of thin nasal mucus) (NIOSH, 2019). Gypsum core board products normally do not entail any risk (CertainTeed, 2018).

It is however underlined that companies should always use all appropriate means (personal protective equipment, workplace practices, engineering controls, continuous medical surveillance etc) to ensure that workplace exposure complies with applicable occupational exposure limits (OELs) (Brun et al., 2013). Special emphasis should be paid on monitoring and controlling exposure to respirable crystalline silica associated with all mined minerals, since this make cause autoimmune disorders, chronic renal disease, and other adverse health effects (NIOSH, 2002).

On the other hand, flue gas desulpurization (FGD) gypsum may exhibit some risk pertinent to leaching of heavy metals such as Hg (Fu et al., 2019; Hao et al., 2016). Nevertheless, no health risk has been noticed when using FGD gypsum as compared to natural gypsum (Beckert et al., 1991).

ENVIRONMENTAL ISSUES

Some life cycle assessment (LCA) studies showed the environmental benefits of recycling gypsum as input for new gypsum products. (Gypsum Association, 2011 and 2016; Pantini et al, 2019; Pedreño-Rojas et al., 2020 ; Weinmann et al, 2021).

Nevertheless, most gypsum waste (GW) in the EU is currently landfilled. Besides the loss of valuable resources, gypsum landfilling may result in potential leaching of sulphates; moreover, hydrogen sulphide and greenhouse gases can be emitted due to degradation processes occurring in landfills. Thus, efficient management systems need to be developed to minimize environmental issues and improve economics of gypsum waste management (Pantini et al., 2019).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

NORMATIVE REQUIREMENTS RELATED TO MINING/RAW MATERIAL PRODUCTION, USE AND PROCESSING OF GYPSUM

The Gypsum Association, an informal research and standard- setting group, issued, to mention few examples, construction and manufacturing standards and a set of building code requirements across the design and construction community in the United States and Canada. (Gypsum Association 2023).

RESEARCH AND DEVELOPMENT TRENDS

RESEARCH AND DEVELOPMENT TRENDS FOR LOW-CARBON AND GREEN TECHNOLOGIES

- ICEBERG[5] project: Innovative circular economy-based solutions for the building industry (EU, 2020-2024)

To embrace the European Union's circular economy strategy, the building industry must improve its waste management practices. The ICEBERG project intends to create innovative tools and technologies to advance the industry's uptake of the circular economy. It will therefore generate cross-cutting integrated smart solutions including three circular reverse logistics tools: an upgraded building information modelling-aided smart demolition tool, a novel digital end-of-life building materials (EBM) traceability platform and a radio frequency and quick response-based identification system. It will also develop advanced technologies to produce high-purity secondary raw materials through six circular case studies across Europe. These tools and technologies will be used to increase market confidence in and acceptance of recycled EBM.

OTHER RESEARCH AND DEVELOPMENT TRENDS

- GYPWORLD project - A global initiative to understand gypsum ecosystem ecology (2018 – 2022)[6]

Gypsum soils occur worldwide and represent natural laboratories of evolution and ecology. The unusual mineral content of gypsum soils is a significant barrier to the growth of most plants, and yet these soils host highly diverse endemic floras that have evolved independently on five continents. Nevertheless, these ecosystems are poorly understood compared to those of other unusual substrates. Little is known about the conservation status of gypsum floras, the potential impact of climate change on them, and their responses to mitigation and restoration. The project developers propose an integrated global study of the ecology and evolution of plant and lichen life on gypsum, including eight gypsum-rich regions from four continents that differ in geological origin, climate, and flora. The project did 1) assess the plant and lichen diversity of gypsum; 2) investigate the evolutionary origins and assembly of these floras; 3) evaluate potential adaptive mechanisms on gypsum, the functional structure of gypsum plant and lichen communities, and the processes regulating gypsum ecosystem function; 4) analyse the responses of gypsum communities to global change drivers and explore how gypsum ecosystem restoration/conservation may help mitigate the effects of global

[5] https://cordis.europa.eu/project/id/869336
[6] CORDIS EU research results, https://cordis.europa.eu/project/id/777803

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

change; 5) promote the study of gypsum ecosystems; and 6) communicate the ecological and conservation value of these ecosystems to the public.

- NanoBioS project - Nanoscale mineral-microbial interactions, associations, and biosignatures in gypsum stromatolites (2021 – 2023)[7]

Stromatolites are laminated rocky structures made by tiny, sun-loving microorganisms. They comprise the oldest undisputed evidence of fossil life on Earth, dating back more than 3.5 billion years. Lake Bakili in Ethiopia hosts atypical stromatolites made of gypsum whose challenging accessibility has left them largely unexplored. With the support of the Marie Skłodowska-Curie Actions programme, the interdisciplinary NanoBioS project will study the microbiology and mineralogy of these newly discovered stromatolites. Scientists are looking for evidence of mineral-microbial interactions and potential remnants of living organisms in the stromatolites to better understand mineral-microbial synergy and shed light on how to distinguish inorganic biomorphs from real fossils in gypsiferous deposits.

- Experimental investigation of composite gypsum board integrated with phase change material for improved thermal energy storage (Kumar et al. 2023)

The building overheating problem is one of the most important problems facing all over the world. To overcome this problem the thermal energy storage capacity of the building elements must be increased. Therefore, this study shows indoor thermal behaviour of composite gypsum board prepared through Shape Stabilized Phase Change Material (SSPCM) […]. Real outdoor testing was conducted for four consecutive days. G-SSPCM shows 3.0 °C for roof and 4.54 °C for south wall in comparison with G-0. For roof maximum time delay of 200 min on day one was recorded for G-SSPCM-5 and for south wall it is 180 min by G-SSPCM-10. Integrating PCM in the gypsum board has improved the indoor temperature profile of the building.

REFERENCES

At-minerals, (2022), Gypsum – a scarce raw material?, available at: https://www.at-minerals.com/en/artikel/at_gypsum_a_scarce_raw_material_-3752853.html, accessed on February 2023.

Azarov et al (2016), Environmental and working area dust emission from the gypsum warehouse, https://www.sciencedirect.com/science/article/pii/S1877705816315594, accessed on February 2023

Beckert et al (1991), Comparison of natural gypsum and FGD gypsum, VGB Kraftwerkstechnik 1/1991, accessed on February 2023

Beidoou, (2022), How Gypsum is Processed. Accessed at: https://www.beidoou.com/materials/what-is-gypsum-how-is-gypsum-processed.html

BGS (2019), World Mineral Production 2013-2017. British Geological Survey, available at: https://www.bgs.ac.uk/mineralsuk/statistics/worldStatistics.html

[7] CORDIS EU research results, https://cordis.europa.eu/project/id/101031812

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

British Geological Survey (2006), Gypsum - Mineral Planning Factsheet [online], available at: http://www.bgs.ac.uk/mineralsuk/planning/mineralPlanningFactsheets.html

Brun et al (2013), Buried under gypsum powder – A rare respiratory complication, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3920347/, accessed on February 2023

CertainTeed (2018), Safety data sheet for gypsum core board products

Cgypsum experts (2022), SCRREEN Experts Workshop on Platinum Group Metals. Brussels: 22.09.2022

DG Environment (2010), Green Public Procurement. Wall Panels Technical Background Report., https://ec.europa.eu/environment/gpp/pdf/thermal_insulation_GPP_%20background_report.pdf, accessed on February 2023

Eurogypsum (2015), Eurogypsum (2015) Position letter Re: Assessment of FGD gypsum as a separate raw material in the list of raw materials to be evaluated as critical by the Commission in 2016

Eurogypsum (2014), https://gypsum.org/press-roomfgd-gypsum-board/ (accessed Aug. 6, 2019)

Eurogypsum (2020), https://www.eurogypsum.org

Eurostat (2021), Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E), https://ec.europa.eu/eurostat/en/web/products-datasets/-/SBS_NA_IND_R2 , accessed on February 2023

Eurostat Comext (2022), Eurostat database. EU trade since 1988 by HS2-4-6 and CN8 (DS-045409).

Eurostat Comext (2022), Eurostat database. EU trade since 1988 by HS2-4-6 and CN8 (DS-045409). , http://epp.eurostat.ec.europa.eu/newxtweb/ , accessed on December 2022

Eurostat, (2021), Comext International Trade [Online], available at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do

Fu et al (2019), Characteristics and speciation of heavy metals in fly ash and FGD gypsum from Chinese coal-fired power plants, https://www.sciencedirect.com/science/article/pii/S0016236119306106, accessed on February 2023

Future Market Insights (2022), REP-GB-12417, https://www.futuremarketinsights.com/, accessed on December 2022

Global Gypsum (2017), https://www.globalgypsum.com/news/itemlist/tag/synthetic%20gypsum (28-3-2017)

Global Gypsum (2018), https://www.globalgypsum.com/magazine/articles/762-new-west-gypsum-recycling-commissions-norwegian-plant (1 Sep. 2018)

Global Gypsum Magazine (2018), https://www.eiif.org/sites/default/files/inline-files/eGGSept2018ns.pdfGypsumtoGypsum (2016). Gto G Project - EU Life programme. [online], available at: http://gypsumtogypsum.org/

Global Trade (2021), Global Gypsum and Anhydrite Imports Shrink with Declined Purchases from the U.S. and India, https://www.globaltrademag.com/global-gypsum-and-anhydrite-imports-shrink-with-declined-purchases-from-the-u-s-and-india/, accessed on December 2022

GPDA (2023), Health & Safety, https://gpda.com/health-safety/#:~:text=There%20are%20no%20long%20term,or%20irritate%20the%20respiratory%20system, accessed on February 2023

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

Gypsum Association (2011), A Cradle-to-Gate Life Cycle Assessment of ½" Regular and 5 /8" Type X Gypsum Wallboard, https://gypsum.org/wp-content/uploads/2019/05/15_Gypsum_Wallboard-1_2-in-Regular-5_8-in-Type-X.pdf, accessed on February 2023

Gypsum Association (2016), An Industry Average Cradle-to-Gate Life Cycle Assessment of Glass Mat Gypsum Panels for the USA and Canadian Markets, https://gypsum.org/wp-content/uploads/2019/05/GMGP_LCA-Report-Final_Athena-8.30.2016_GA-3.pdf, accessed on February 2023

Gypsum Association (2023), Standards, https://gypsum.org/construction-standards/ , accessed on February 2023

Hao et al (2016), Characterization and leaching toxicities of mercury in flue gas desulfurization gypsum from coal-fired power plants in China, https://www.sciencedirect.com/science/article/pii/S0016236116300266, accessed on February 2023

Industrial Minerals & Rocks (2006), Industrial Minerals & Rocks: Commodities, Markets, and Uses, https://books.google.it/books/about/Industrial_Minerals_Rocks.html?id=zNicdkuulE4C&redir_esc=y, accessed on February 2023

Kumar et al (2023), Experimental investigation of composite gypsum board integrated with phase change material for improved thermal energy storage, https://www.sciencedirect.com/science/article/pii/S221478532300487X, accessed on February 2023

Lee, J.C., Bradshaw, S.L., Edil, T.B., Benson C.H. (2011), Quantifying the benefits of flue gas desulphurization gypsum in sustainable wallboard production, World of Coal Ash (WOCA) Conference, May 9-12, 2011, Denver, CO, USA, http://www.flyash.info/2011/068-Bradshaw-2011.pdf

Lushnikova, N., Dvorkin, L. (2016), Sustainability of gypsum products as a construction material, in Sustainability of Construction Materials (Second Edition), Woodhead Publishing, ISBN 978-0-08-100995-6, https://doi.org/10.1016/C2014-0-02849-3

Minerals4EU (2019), European Minerals Yearbook. [online] Available at: http://minerals4eu.brgm-rec.fr/m4eu-yearbook/theme_selection.html National Institute for Occupational Safety and Health (NIOSH, 2019), https://www.cdc.gov/niosh/npg/npgd0308.htm

NERA (2016), The access to gypsum raw material by 2050: challenges, obstacles and levers. Report prepared for Eurogypsum.

NIOSH (2002), Health effects of occupational exposure to respirable crystalline silica., https://www.cdc.gov/niosh/docs/2002-129/pdfs/2002-129.pdf?id=10.26616/NIOSHPUB2002129., accessed on February 2023

NIOSH (2019), Pocket guide to chemical hazards. Gypsum, https://www.cdc.gov/niosh/npg/npgd0308.html, accessed on February 2023

Pantini et al (2019), A LCA study to investigate resource-efficient strategies for managing post-consumer gypsum waste in Lombardy region (Italy), https://www.sciencedirect.com/science/article/pii/S092134491930182X, accessed on February 2023

Pedreño-Rojas et al (2020), Life cycle assessment of natural and recycled gypsum production in the Spanish context, https://www.sciencedirect.com/science/article/pii/S0959652620301037, accessed on February 2023

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958211

RTVGROUP (2022), Managing Dust: Plaster and Plasterboard, https://s3.eu-west-1.amazonaws.com/rvt-group/downloads/plaster-and-plasterboard-dust/RVT-Group-Whitepaper-Dust-Control-Hazards-of-Plasterboarding-Whitepaper-2022.pdf, accessed on February 2023

Transparency Market Research (2019), FGD Gypsum Market - Global Industry Analysis, Size, Share, Growth, Trends, and Forecast 2017 – 2025, https://www.transparencymarketresearch.com/fgd-gypsum-market.html (accessed July 25, 2019).

USGS (2022), Gypsum Statistics and Information, https://www.usgs.gov/centers/national-minerals-information-center/gypsum-statistics-and-information, accessed on December 2022

USGS (Since 2000), Mineral Commodity Summaries, U.S. Department of the Interior, U.S. Geological Survey

Weinmann et al (2021), Environmental Evaluation of Gypsum Plasterboard Recycling, https://www.mdpi.com/2075-163X/11/2/101 , accessed on February 2023

WMD (2022), World mining data, Federal Ministry of Agriculture, Regions and Tourism of Austria (Ed.): World Mining Data (since 1984).

WRAP and BSI (2013), PAS 109:2013. Specification of the production of reprocessed gypsum from waste plasterboard. [online] Available at: http://www.wrap.org.uk/sites/files/wrap/PAS109%20(2013).pdf.

WRAP and Environment Agency (2011), Recycled gypsum from waste plasterboard. End of waste criteria for the production and use of recycled gypsum from waste plasterboard. [online] Available at: http://www.wrap.org.uk/sites/files/wrap/Gypsum_Quality_Protocol_0.pdf ZKG (2019). EU gypsum industry is part of “European Minerals Day” 2019, https://www.zkg.de/en/news/eu-gypsum-industry-is-part-of-european-minerals-day-2019_3412665.html (accessed 20 Aug. 2019).

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 958211