Fire-Resistant Gypsum Board

Knauf Ltd. & Partner

ENVIRONMENTAL PRODUCT DECLARATION

ISO 14025:2006 and ISO 21930:2017

Knauf Company is pleased to present this Environmental Product Declaration (EPD) for their Fire - Resistant Gypsum Board. This EPD was developed in compliance with ISO 14025 and ISO 21930 and has been verified by Lindita Bushi, Ph.D., from ATHENA Institute.

The LCA and the EPD were prepared by Vertima Inc. The EPD includes cradle-to-gate life cycle assessment (LCA) results.

For more information about Knauf Company, visit https://knauf.com/ar-EG

For any explanatory material regarding this EPD, please contact the program operator.

1. GENERAL INFORMATION

PCR GENERAL INFORMATION			
Reference PCR	Smart EPD® Part A Product Category Rules for Construction Products and Services, Standard 1000, v1.2, March 14, 2025. Smart EPD® Part B Product Category Rules for Gypsum Panels, Standard 1000-004m, version 2, February 24, 2025.		
The PCR Part A review was conducted by:	*Jack Geibig (Chair)* *Ecoform* *jgeibig@ecoform.com*	*Terrie Boguski* *Harmony Environmental* *tboguski@harmonyenviro.com*	*Hugues Imbeault-Tétrault* *Groupe AGECO* *hugues.itetreault@groupeageco.ca*
The PCR Part B review was conducted by:	*Jack Geibig (Chair)* *Ecoform* *jgeibig@ecoform.com*	*Michael Gardner* *Independent Consultant* *michael@mgardnerservices.com*	*Gaurav Das* *Independent Consultant* *gd30gcc@gmail.com*

EPD GENERAL INFORMATION		
Program Operator	ASTM Program Operator for Product Category Rules (PCR) and Environmental Product Declarations (EPDs), General Program Instructions, Version: 8.0, Revised 04/29/20. 100 Barr Harbor Drive, West Conshohocken (PA) 19428-2959 USA www.astm.org	
Declared Product	**Fire-Resistant Gypsum Board**	
EPD Registration Number **1098**	**EPD Date of Issue** March 2026	**EPD Period of Validity** March 2026 - March 2031
EPD Recipient Organization	Knauf Company Cairo Festival City, Podium 1, PO6, 4th Floor, 4730006, New Cairo /knauf.com/ar-EG	KNAUF

EPD Type/Scope and Declared Unit	**Year of Reported Manufacturer Primary Data**
Product-specific cradle-to-gate EPD with declared unit of 92.9 m^2 (1000 ft^2) of manufactured and packaged Fire -Resistant Gypsum Board.	2021

Geographical Scope	**LCA Software**	**LCI Databases**	**LCIA Methodology**
Global	OpenLCA v.1.11.0	Ecoinvent 3.9.1	IPCC 2021 and CML v4.8 2016

This LCA and EPD were prepared by:	Vertima Inc. www.vertima.ca
This EPD and LCA were independently verified in accordance with ISO 14025:2006, ISO 14040:2006 and ISO 14044:2006, Smart EPD PCR in Part A and Part B as well as the ISO 21930:2017. ☐ Internal ☒ External	Lindita Bushi Lindita Bushi, Ph.D. Athena Sustainable Materials Institute

The owner of the declaration shall be liable for the information and evidence herein; ASTM, or its affiliates, shall not be liable with respect to manufacturer information, life cycle assessment data, and evidence.

LIMITATIONS

Environmental declarations from different programs (ISO 14025) may not be comparable. EPDs are comparable only if they comply with ISO 21930, use the same sub-category PCR where applicable, include all relevant information modules, and are based on equivalent scenarios with respect to the context of construction works.

2 PRODUCT DEFINITION AND INFORMATION

2.1 COMPANY DESCRIPTION

Founded in 1932, Knauf Egypt began as a family company and over the years has grown into a global enterprise spanning 90 countries, incorporating multiple brands, and delivering world-class construction materials and solutions via 40,000 employees worldwide. Knauf Egypt is one of the world's leading manufacturers of building products for interior design, insulation, and acoustic design ceilings. Knauf operates plants globally, producing state-of-the-art drywall systems, gypsum plasters, and insulating materials, as well as external thermal insulation composite systems. In addition, they offer a wide range of paints, flowing screeds, and flooring systems.

In the context of the growing popularity of sustainable building and LEED V4.1 Rating Systems, developing Type III Environmental Product Declarations (EPDs) would allow Knauf to increase visibility for its products.

Knauf therefore retained the services of Vertima Inc. to carry out a life cycle assessment and develop an EPD for Fire-resistant Gypsum Board manufactured at the site located at Al Semad, Attaka, Suez Governorate 8132540, Egypt. The headquarter of Knauf Egypt is located at Cairo Festival City, Podium 1, PO6, 4th Floor, 4730006, New Cairo.

2.2 PRODUCT DESCRIPTION

Knauf Fire-resistant Gypsum Boards are gypsum wallboards specially designed to offer superior fire resistance performance when used in drywall partitions, shaft walls, ceilings and lining systems. The product is manufactured in 1200 mm widths, lengths between 2400 mm to 3000 mm and three different thicknesses (6.5 mm, 9.5 mm, 12.5 mm and 15 mm). The weight for the board with 12.5 mm thickness is approximately 9.76 kg/m^2. Figure **1** shows Knauf product images. The primary United Nations Standard Products and Services Code (UNSPSC) code for gypsum board products is 30161509 and the Construction Specifications Institute (CSI) code for gypsum board products is 09 29 00. Based on information provided by the manufacturer, the core type is regular and the face type is paper. There is no recycled gypsum core or recycled glass in the product. According to the manufacturer, there is no recycled paper content in the facing paper.

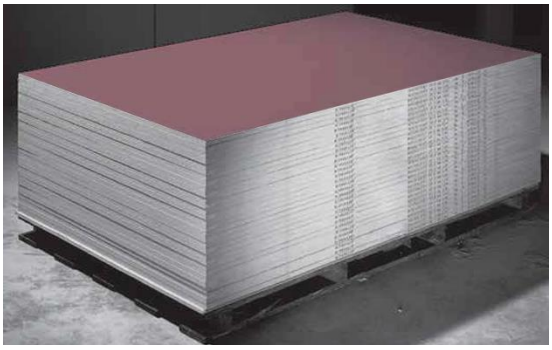

Figure 1: Representation of Knauf Fire-resistant Gypsum Board.

2.2.1 Product Average

The weighted profile of each product is calculated based on the 2021 annual production data (in square meter/square foot). Based on ISO 21930 section 5.3 on the average EPDs for groups of similar products, the EPDs developed in this analysis do not represent the average EPDs.

2.2.1.1 *Product-Specific EPD*

In the context of the growing popularity of sustainable building and LEED v4 and v4.1 Rating Systems, developing Type III Environmental Product Declarations (EPDs) would allow Knauf to increase visibility for its Fire-resistant Gypsum Board products. The EPD for the moisture-resistance gypsum board products has been conducted according to Smart EPD Part A and Part B PCR, developed in accordance with the ISO 21930 – 2017, ISO 14025, ISO 14040 and ISO 14044 [1, 2, 3, 4, 5 ,6]. The LCA follows an attributional approach and EPDs comply with the ASTM Program Operator Rules, version 8.0 revised 04/29/20 [7].

2.3 APPLICATION

Knauf Fire-resistant Gypsum Boards are gypsum wallboards specially designed to offer superior fire resistance performance when used in drywall partitions, shaft walls, ceilings and lining systems.

2.4 DECLARATION OF METHODOLOGICAL FRAMEWORK

This LCA is a cradle-to-gate study. For this analysis, the attributional approach was followed and impacts of infrastructure have been excluded.

The life cycle stage included in the analysis is the production stage. According to the Smart EPD PCR Part B [2], this includes A1) Extraction and upstream production, A2) Raw materials transportation to the manufacturing site, and A3) Manufacturing.

According to the ISO 21930-2017 allocation procedure, mass should be used as the primary basis for co-product allocation. OpenLCA software v1.11 [8], an open-source software, was used to calculate the inventory and to assess potential environmental impacts associated with the inventoried emissions.

2.5 TECHNICAL DATA AND STANDARD TESTS

For specific properties and performance data for Knauf products, please consult the following link: https://knauf.com/en [7].Table 1 presents the technical data and standard tests for the products under study.

Table 1:Technical Details

Product	Declared Units	Unit
Fire-resistant Gypsum Board	92.9 (1000)	m^2 (ft^2)
Thickness	12.5	mm
Weight	9.76	Kg/m^2
Width	1,200	mm
Length	2,400 – 3,000	mm

Product	Declared Units	Unit
Moisture Content	12.34	%
Products	**Standard Tests**	**Description**
	DIN EN 520	Definitions, requirements and test methods (includes Amendment A1:2009
	ASTM E1414	Standard Test Method for Airborne Sound Attenuation Between Rooms Sharing a Common Ceiling Plenum
	ASTM E413	Classification for Rating Sound Insulation
	ASTM E90	Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements
	ASTM C11	Standard Terminology Relating to Gypsum and Related Building Materials and Systems
	ASTM C1396	Standard Specification for Gypsum Board
Fire-resistant Gypsum Board	GA-254-2017	Fire-resistant Gypsum Sheathing

2.6 PRODUCT COMPOSITION AND INPUT MATERIALS

The composition of Fire-resistant Gypsum Board products is presented in Table 2 below. Based on mass balance, manufacturing losses represent 5% of the materials input.

Table 2: Material composition for Fire-resistant Gypsum Board product

Components	Amount (%)
Gypsum	64.07%
Water	32.03%
Cardboard	2.54%
Starch	0.06%
Sugar crystal	0.04%
Liquifier	0.15%
Retarder	0.15%
Edge glue	0.15%
Foam	0.15%
Ink and cleaning	0.15%
Fiber glass	0.42%
Total	100.00%

2.7 MANUFACTURING

Fire-resistant Gypsum Board is manufactured using plaster of Paris as its main raw material. Plaster of Paris is prepared through the controlled heating of natural gypsum rocks. The plaster is melted with different additives based on the desired properties. The mixture is distributed on cardboard paper to form a gypsum board. Lastly, the edge of the gypsum board is glued and the board is cut into different sizes based on the customer's request. Quality control at each step of the process is critical to ensuring that the final product meets standard requirements and customer expectations. Figure 2 shows the flow diagram for the manufacturing stage.

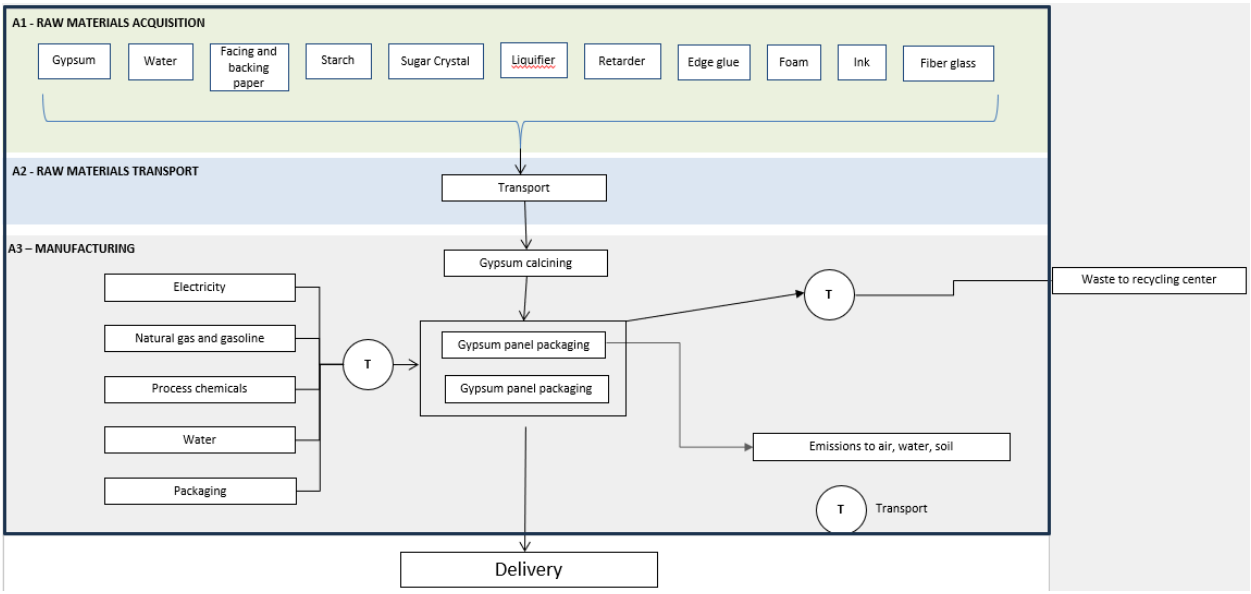

Figure 2: Flow diagram for Knauf Fire-resistant Gypsum Board manufacturing process.

2.8 PACKAGING

The Fire-resistant Gypsum Board products are packaged with stretch film, polypropylene strapping and end tape to prepare them for delivery. Packaging materials are the same type and amount for all products involved in the study. The materials used are presented in Table 3.

Table 3: Packaging materials used per each DU of Fire-resistant Gypsum Board products.

Materials	Fire-resistant Gypsum Board	Units
Stretch Film	4.01E+00	kg
Polypropylene strap	8.82E+00	kg
End tape	2.13E+04	cm

2.9 USE CONDITIONS

After installation of Knauf Fire-resistant Gypsum Board products, the manufacturer does not provide specific recommendations concerning use conditions except those indicated on the TDS sheet.

2.10 REFERENCE SERVICE LIFE AND ESTIMATED BUILDING SERVICE LIFE

According to ISO 21930-2017, the reference service life (RSL) is not accounted for as the used stage is not included in the analysis [3].

2.11 REUSE, RECYCLING, AND ENERGY RECOVERY

There is no re-use or energy recovery in the Fire-resistant Gypsum Board manufacturing process.

2.12 DISPOSAL

This LCA study assumes that 100% of waste materials are recycled. Waste materials include metal, cardboard, plastic, steel, wood pallets and used oil. There are no hazardous wastes generated in the process. Waste transportation to the recycling center was accounted for in the inventory.

2.13 FURTHER INFORMATION

Further information about Fire-resistant Gypsum Board products is available at https://knauf.com/ar-EG

3 LIFE CYCLE ASSESSMENT CALCULATION RULES

3.1 DECLARED UNIT

The declared unit (DU) analyzed is 92.9 m^2 (1000 ft^2) of manufactured and packaged Fire-resistant Gypsum Board.

3.2 SYSTEM BOUNDARIES

According to ISO 21930-2017, the LCA is cradle-to-gate. The life cycle stage included in the analysis is the Production stage. Construction, Use and End-of-Life stages are not included in the system boundary. The production stage includes the following modules: A1) Extraction and upstream production, A2) Raw materials transportation to the manufacturing site, and A3) Manufacturing (**Figure 3**).

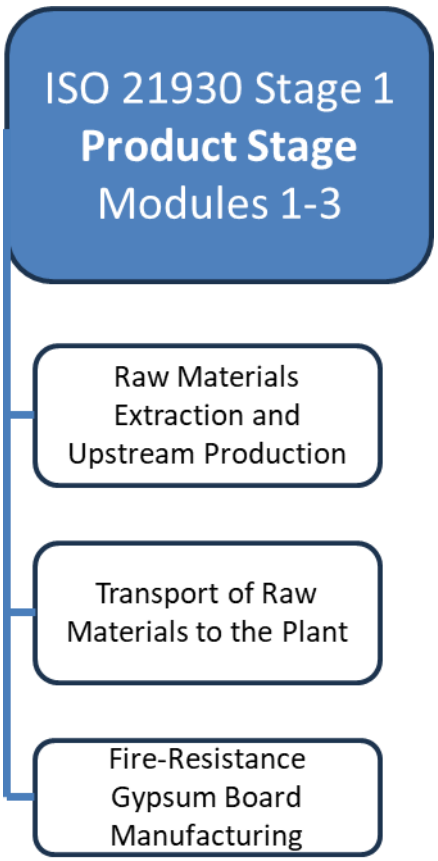

Figure 3: Presents the life cycle stages, and their modules, included in the system boundaries [1]

Extraction and upstream production (module A1): This stage includes the extraction and manufacturing of raw materials needed to produce Fire-resistant Gypsum Board products.

Raw materials transportation to manufacturing site (module A2): This stage includes the transportation of raw materials from suppliers to Knauf's manufacturing site at Al Semad, Attaka, Suez Governorate 8132540, Egypt.

Manufacturing (module A3): This stage includes water and energy (electricity, gasoline and natural gas) consumption for the manufacturing processes. No renewable electricity is used in this EPD. Chemicals include those used in the process as well as their transport to the site. Hazardous and non-hazardous waste treatment has been counted as well. Finally, packaging materials to make products ready for shipment are covered by this stage. This includes their extraction, manufacturing and transportation to the factory.

3.3 CUT-OFF CRITERIA

According to section 6.3.3 of ISO 21930 [3], if a mass flow or energy flow represents less than 1% of the cumulative mass or energy flows of the system, it may be excluded from the system boundaries. However, these flows should not have a relevant environmental contribution. In addition, at least 95% of the total energy and mass flows shall be included, and the cumulative mass or environmental impacts of the excluded flows shall not exceed 5% of the total mass and energy flows or potential environmental impacts.

In the present study, no primary data (input material, energy consumption) was excluded from the system boundaries. Water consumption includes the water used for cleaning and water consumption by employees. No primary data on the construction, maintenance or dismantling of the company's capital assets was included in the model. Also, primary data from daily transport of the employees, office work, business trips and other employee activities was not included in the model. See Table 4 below.

Table 4 Data Source of Fire-resistant Gypsum Board

Material / Process Category	Module	Material/Process Name	Inventory Dataset Name	Dataset Source	Dataset Geographic Region	Data Reference Year
Raw Material	A1	Gypsum	gypsum quarry operation | gypsum, mineral | Cutoff, U - RoW	Ecoinvent dataset 3.9.1	RoW	2022
		Water	tap water production, artificial recharged wells | tap water | Cutoff, U - RoW	Ecoinvent dataset 3.9.1	RoW	2022
		Cardboard	kraft paper production | kraft paper | Cutoff, U - RoW	Ecoinvent dataset 3.9.1	RoW	2022
		Starch	maize starch production | maize starch | Cutoff, U - RoW	Ecoinvent dataset 3.9.1	RoW	2022
		Sugar crystal	sugarcane production | sugarcane | Cutoff, U - RoW	Ecoinvent dataset 3.9.1	RoW	2022
		Liquifier	-	-	-	-
		Retarder	polyethylene production, low density, granulate | polyethylene, low density, granulate | Cutoff, U - RoW	Ecoinvent dataset 3.9.1	RoW	2022
		Edge glue	polyurethane adhesive production | polyurethane adhesive | Cutoff, U - GLO	Ecoinvent dataset 3.9.1	GLO	2022
		Foam	polyurethane production, flexible foam, TDI-based, flame retardant | polyurethane, flexible foam, flame retardant | Cutoff, U - RoW	Ecoinvent dataset 3.9.1	RoW	2022
		Ink and Cleaning	deinking emulsion production, in paper production | deinking emulsion, in paper production | Cutoff, U - RoW	Ecoinvent dataset 3.9.1	RoW	2022
		Fiber Glass	glass fibre production | glass fibre | Cutoff, U - RoW	Ecoinvent dataset 3.9.1	RoW	2022
Transport	A2	Truck	transport, freight, lorry >32 metric ton, EURO6 | transport, freight, lorry >32 metric ton, EURO6 | Cutoff, U - RER	Ecoinvent dataset 3.9.1	RER	2022
		Boat	transport, freight, sea, container ship | transport, freight, container ship | Cutoff, U - GLO	Ecoinvent dataset 3.9.1	GLO	2022
Energy	A3	Electricity	market for electricity, medium voltage | electricity, medium voltage | Cutoff, U - EG	Ecoinvent dataset 3.9.1	EG	2022
		Natural gaz	natural gas, burned in micro gas turbine, 100kWe | heat, central or small-scale, natural gas | Cutoff, U - RoW	Ecoinvent dataset 3.9.1	RoW	2022
		Gasoline	Gasoline, combusted in equipment - RNA	USLCI	RNA	2002

As mentioned in ISO 21930-2017, clause 6.2.7.2 a, cut-off rules were not applied for hazardous wastes. They were accounted for.

3.4 DATA SOURCES

Inventory data were collected from the manufacturing site located at Al Semad, Attaka, Suez Governorate 8132540, Egypt using a life cycle inventory (LCI) questionnaire. Data was collected via the Technical Manager and the manufacturing team. The Technical Manager and Production Manager were responsible for filling out the questionnaire. Further telephone, email and meeting discussions allowed us to further detail aspects of the questionnaire, to collect additional information, or to seek clarifications.

When primary data was not available, datasets were selected either from the *ecoinvent* v3.9.1 - cut-off database, the most comprehensive LCI database currently available that is more representative globally.

3.5 DATA QUALITY

Data Quality Parameter	Data Quality Discussion
Source of manufacturing data: Description sources of data	Manufacturing data was collected from the Knauf manufacturing site located at Al Semad, Attaka, Suez Governorate 8132540, Egypt. Data included the total annual units in kg and total production mass of products under study; raw materials entering the production of the products under study; materials losses; transport modes and distance of materials; energy consumption; water consumption; emissions to the environment at the manufacturing plant; waste treatment; packaging material; and Fire-resistant Gypsum Board product distribution.
Source of secondary data: Description sources of raw material, energy source, transport, waste and packaging data	When appropriate, the grid mix was changed for the grid mix of the province or country where the process takes place. Otherwise, ecoinvent datasets representative of the global market or "rest-of-the-world" were mainly selected as proxies.
Geographical representativeness	The manufacturing site is located at Al Semad, Attaka, Suez Governorate 8132540, Egypt; hence electricity consumption is based on the Egypt grid mix. Geographical correlation of the material supply and the selected datasets are representative of each specific area or a larger area.
Temporal representativeness	Primary data were collected to be representative of the 2021 production year, while this is not always the case for ecoinvent datasets. Nevertheless, ecoinvent v 3.9.1 remains the reference LCI database used in this study.
Technological representativeness	Primary data, obtained from the manufacturer, are representative of the current technologies and materials used by the company.
Completeness	All relevant process steps were considered and modelled to satisfy the goal and scope. Cut-off criteria were respected.

3.6 PERIOD UNDER REVIEW

The period under review is the 2021 production year.

3.7 ALLOCATION

According to ISO 21930-2017, the allocation approach used as the primary basis for co-product allocation is mass allocation. In this study, mass allocation was used for the manufacturing input and output flow and the yearly production mass of each product under study was used as a basis. Data related to material and energy consumption were provided for all co-products by the manufacturer.

Materials undergoing recycling/reuse/incineration (with energy recovery for other product systems) processes are excluded from the system boundary. A cut-off approach was used because recycled/reused/incineration material is part of raw material preparation for another product system.

No burdens are allocated across the system boundary with secondary material, secondary fuel or recovered energy flows arising from waste.

4 LIFE CYCLE ASSESSMENT RESULTS

4.1 RESULTS TABLES

The life cycle assessment results are presented per DU. According to the standard requirements, results presented derive from the life cycle impact assessment (LCIA) and the life cycle inventory (LCI).

LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

According to Smart EPD PCR part A for building and construction products and services and part B for gypsum panels, the life cycle impact assessment shall, at a minimum, report the set of impact categories. These six impact categories are globally deemed mature enough to be included in Type III environmental declarations. Other categories are being developed and defined and LCA should continue making advances in their development. However, EPD users shall not use additional measures for comparative purposes.

The LCA results are presented from Table 5 for Knauf Fire-resistant Gypsum Board products.

Table 5: Fire-resistant Gypsum Board Life Cycle Impact Assessment Results per DU 92.9 (1000) m^2 (ft^2)

Indicators	Units	Production stage			Total
		A1	A2	A3	
Global Warming Potential-Total (GWP-total), IPCC 2021 (AR6)	kg CO2 eq	7.17E+01	1.18E+01	3.87E+02	4.71E+02
Global Warming Potential-Biogenic (GWP-biogenic), IPCC 2021 (AR6)	kg CO2 eq	1.12E+00	3.48E-03	1.74E-01	1.30E+00
Global Warming Potential-Fossil (GWP-fossil), IPCC 2021 (AR6)	kg CO2 eq	6.97E+01	1.18E+01	3.87E+02	4.69E+02
Global Warming Potential-Land Use and Land Use Change (GWP-luluc), IPCC 2021 (AR6)	kg CO2 eq	9.48E-01	5.99E-03	1.37E-01	1.09E+00
Ozone depletion potential (ODP)	kg CFC-11-Eq	1.78E-06	2.14E-07	6.29E-06	8.29E-06
Eutrophication potential (EP)	kg PO4-Eq	3.23E-01	7.69E-03	2.11E-01	5.42E-01
Acidification potential (AP)	kg SO2-Eq	3.71E-01	4.10E-02	6.59E-01	1.07E+00
Photochemical oxidant creation potential (POCP)	kg ethylene-Eq	3.27E-02	3.11E-03	7.01E-02	1.06E-01
Abiotic depletion potential (ADP): elements	kg Sb-Eq	1.86E-03	3.15E-05	1.12E-03	3.01E-03
Abiotic depletion potential (ADP): fossil fuels	MJ	6.13E+02	1.59E+02	1.47E+03	2.24E+03

According to Smart EPD part A, the life cycle inventory (LCI) shall be presented for resources used and output flows, waste categories and carbon removals and emissions.[1] The environmental parameters used for inventory analysis describe the use of renewable and non-renewable material resources, renewable and non-renewable primary energy, and water.

The LCI results are presented in Table 6 for Knauf Fire-resistant Gypsum Board products.

Table 6: Fire-resistant Gypsum Board Life Cycle Inventory Impact Results per DU of 92.9 m^2 (1000 ft^2).

Parameter	Unit	Production stage			Total
		A1	A2	A3	
RPRE(1)	MJ, LHV	9.39E+02	2.51E+00	1.12E+02	1.05E+03
RPRM(2)	MJ, LHV	4.97E+02	0.00E+00	0.00E+00	4.97E+02
PERT(3)	MJ, LHV	1.44E+03	2.51E+00	1.12E+02	1.55E+03
NRPRE(4)	MJ, LHV	6.93E+02	1.62E+02	1.03E+03	1.88E+03
NRPRM(5)	MJ, LHV	0.00E+00	0.00E+00	5.45E+02	5.45E+02
PENRT(6)	MJ, LHV	6.93E+02	1.62E+02	1.57E+03	2.42E+03
SM(7)	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RSF (8)	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NRSF(9)	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FW(10)	m^3	3.94E-01	0.00E+00	2.32E-02	4.17E-01
RE(11)	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Output Flows and Waste					
HWD(12)	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NHWD(13)	kg	0.00E+00	0.00E+00	2.00E-02	2.00E-02
HLRW(14)	m^3	4.89E-08	2.44E-09	5.57E-08	1.07E-07
ILLRW(15)	m^3	2.39E-07	1.55E-08	3.02E-07	5.56E-07
CRU(16)	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MR(17)	kg	0.00E+00	0.00E+00	2.00E-02	2.00E-02
MER(18)	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
EE (19)	MJ, LHV	0.00E+00	0.00E+00	0.00E+00	0.00E+00

*In the calculation of RPR_M and $NRPR_M$, packaging materials were included.
(1): RPR_E = RPRT - RPR_M, where RPRT(3) is equal to the value for renewable energy obtained using the CED LHV methodology.
(2): RPR_M, is calculated by multiplying the mass (kg) of the material input (or its components) by the net calorific value (lower heating value) (MJ/kg) of this input as per ACLCA ISO 21930 Guidance [8]. In the calculation of RPR_M, packaging materials were included.
(4): $NRPR_E$ = NRPRT - $NRPR_M$, where NRPRT(6) is equal to the value for non-renewable energy obtained using the CED LHV methodology (both non-renewable energy, fossil fuel and nuclear).
(5): $NRPR_M$, is calculated by multiplying the mass (kg) of the material input (or its components) by the net calorific value (lower heating value) (MJ/kg) of this input as per ACLCA ISO 21930 Guidance [8]. In the calculation of $NRPR_M$, packaging materials were included.
(7): Calculated as per ACLCA ISO 21930 Guidance [8], 6.5 Secondary material, SM: There is no SM involved in the Knauf manufacturing process.
(8): Calculated as per ACLCA ISO 21930 Guidance [8], 6.6 Renewable secondary fuels, RSF: There is no RSF involved in the Knauf manufacturing process.
(9): Calculated as per ACLCA ISO 21930 Guidance [8], 6.7 Non-renewable secondary fuels, NRSF: There is no NRSF involved in the Knauf manufacturing process.
(10): Water used in the Knauf manufacturing process is for production and cleaning.
(11): In the Knauf process, there is no recovery energy (RE).
(12): Calculated from life cycle inventory results, based on datasets marked as "hazardous."
(13): Calculated from life cycle inventory results, based on "non-hazardous" waste.
(14): Calculated as per ACLCA ISO 21930 Guidance [8], 10.3 High-level radioactive waste, conditioned, to final repository. It should be noted that the Knauf manufacturing process does not generate any HLRW (high-level radioactive waste), e.g., when generated by electricity production, consists mostly of spent fuel from reactors. (ISO 21930:2017, clause 7.2.14).
(15): Calculated as per ACLCA ISO 21930 Guidance [8], 10.4 Intermediate- and low-level radioactive waste, conditioned, to final repository. It should be noted that the Knauf manufacturing process does not generate any ILLRW (low- and intermediate-level radioactive waste), e.g., when generated by electricity production, arise mainly from routine facility maintenance and operations (ISO 21930:2017, clause 7.2.14).
(16 to 19): Reused components (CRU), materials for energy recovery (MER), exported energy (EE) are nil and materials for recycling (MR) are accounted for in this analysis.

5 LCA: INTERPRETATION

The aim of this section is to present more details on the contribution to the impacts and resource use of the different life cycle modules of each Knauf product studied. See Figure 4 below.

The manufacturing module (A3) is the major contributor to the environmental impacts for all impact categories. The extraction and upstream manufacturing module (A1) represents the second contributor. The transportation module (A2) is the lowest contributor. The relative environmental impacts for A3 of the Fire-resistant gypsum board product are between 37% and 82% for all impact categories. The environmental impacts of module A1 are between 15% and 62% for all impact categories. The contributor of transportation module (A2) is major for ADP fossil fuel impact category (< 7%). See figure 4 below.

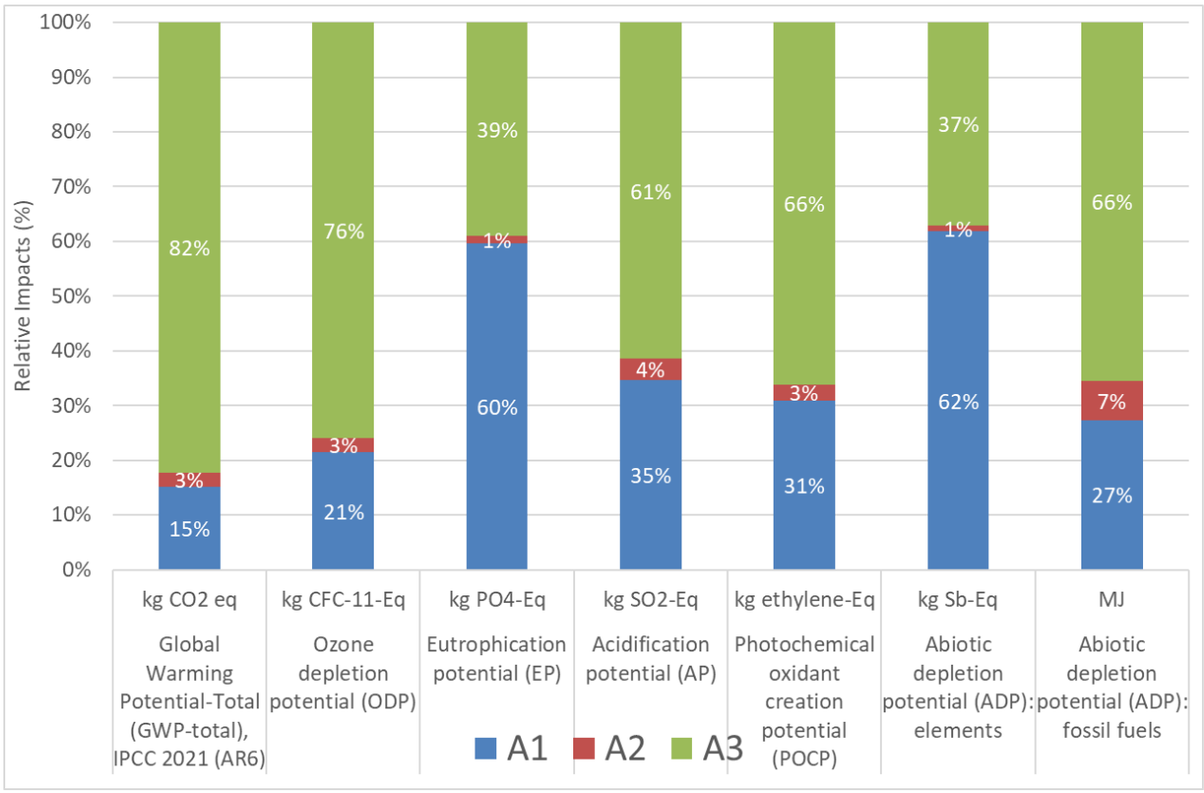

Figure 4: Contribution of each life cycle stage of Fire-resistant Gypsum Board

6 ADDITIONAL ENVIRONMENTAL INFORMATION

6.1 ENVIRONMENTAL ACTIVITIES AND CERTIFICATION

Hydrogen sulfide (H2S) formation in Municipal Solid Waste (MSW) and Construction & Demolition (C&D) landfills require a sulfate source, carbon source, anaerobic conditions, moisture, pH, and temperature. Gypsum panels are a significant contributor to H2S formation.

Problems and Solutions:

Issues in Landfill Gas (LFG) Projects: High H2S concentrations in LFG can cause engine wear and corrosion, leading to more frequent maintenance. Combustion of H2S-rich LFG emits sulfur dioxide (SO2), a regulated pollutant with strict emission limits in the U.S. Prevention Measures: Diverting gypsum panels from landfills can reduce H2S

formation. Some landfills ban drywall disposal, except in small amounts. Recycling markets for gypsum drywall (e.g., agricultural soil amendments, new drywall production) help reduce landfill deposits.

Cement and Concrete:

Gypsum is used in cement to delay setting time, providing flexibility in concrete applications. The amount of gypsum varies with other ingredients, such as limestone and clay. Portland cement, the most common type in North America, contains 3-5% gypsum by weight. Gypsum is essential in cement production, with no practical substitutes. Though recycling gypsum from new construction is acknowledged, the quantities are unknown, and it is a potential market for waste gypsum.

Land Applications:

Gypsum has been used in North American agriculture for over 250 years, providing calcium and sulfur to plants and improving soil and water quality. It benefits clay soils, reduces soil acidity and aluminum toxicity, and decreases phosphorus runoff. Clean scrap gypsum panels are preferred over demolition gypsum for agricultural use due to contamination concerns. Both formal and informal markets exist for agricultural gypsum, with transport emissions from demolition to recycling facilities being a significant consideration.

6.2 EXTRAORDINARY EFFECTS

There are no extraordinary effects for Knauf Fire-resistant Gypsum Board products.

7 REFERENCES

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