GYPSUM ASSOCIATION

LIFE-CYCLE ASSESSMENT SUMMARY

GYPSUM ASSOCIATION

The Gypsum Association (GA) is an international, not-for-profit trade association that is tax exempt under Section 501 (c) 6 of the Internal Revenue Code. The Association is based in the Washington, DC area, and was formally established in 1930 and incorporated in the State of Illinois in 1961.

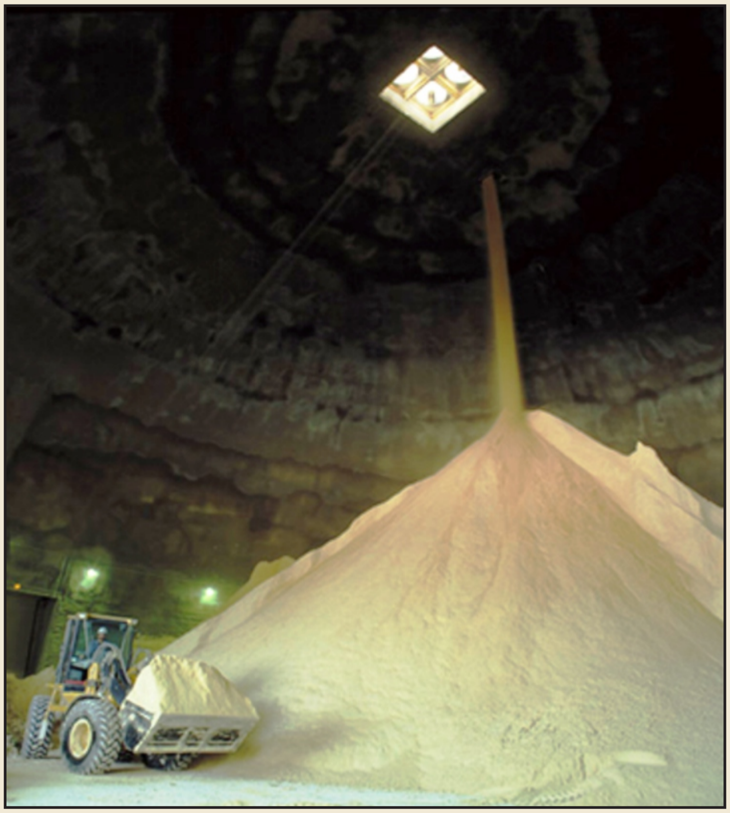
The members of the Gypsum Association ship over 99% of all the gypsum board, gypsum panels, and gypsum plaster products sold in the United States and Canada. The Association's membership includes all the active gypsum board manufacturers based in the U.S. and most of the manufacturers based in Canada. A firm or corporation must calcine gypsum and manufacture gypsum board under the provisions of ASTM Standard C 1396 to be eligible for membership in the Association.

The Association provides technical, promotional, statistical, informational, and legislative monitoring services to its members and interested parties. Technical publications and promotional materials are generated by the Association for use by its member companies and the general public.

WHAT IS GYPSUM?

In the language of chemistry, gypsum is "calcium sulfate dihydrate." It contains calcium, sulfur bound to oxygen, and water. Gypsum is a common, naturally occurring mineral that is found in various forms such as alabaster – a material used for decoration and construction as far back as ancient Egypt – and the White Sands of New Mexico, now a National Monument.

A non-toxic mineral, gypsum can be helpful to humans, animals, plant life, and the environment. While the majority of gypsum produced in North America is used to manufacture gypsum board or building plasters, gypsum is also used as a soil additive; to create surgical and orthopedic casts; as a food additive; and as the primary ingredient in toothpaste.

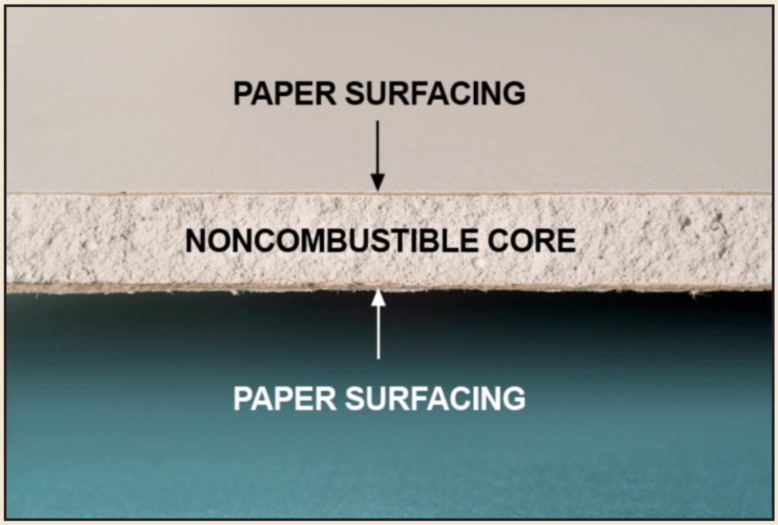


Today, almost half of all gypsum used in the United States is "FGD" gypsum, which is derived from flue-gas desulfurization. This process removes polluting gases from the stacks of fossil-fueled power plants and purifies them into a hard substance. This purified, solid material can then be manufactured into gypsum board. The production of FGD gypsum reduces the emission of harmful materials into the atmosphere and thus reduces air pollution.

Natural gypsum and FGD gypsum are calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$). The gypsum in natural and FGD gypsum is chemically identical and both are naturally fire-resistant. FGD gypsum has been used to manufacture gypsum board for over 30 years.

WHAT IS GYPSUM BOARD?

Gypsum board, also commonly known as drywall (occasionally GWB within this document), is the technical product name used by manufacturers for a specific board with a gypsum core and a paper facing.



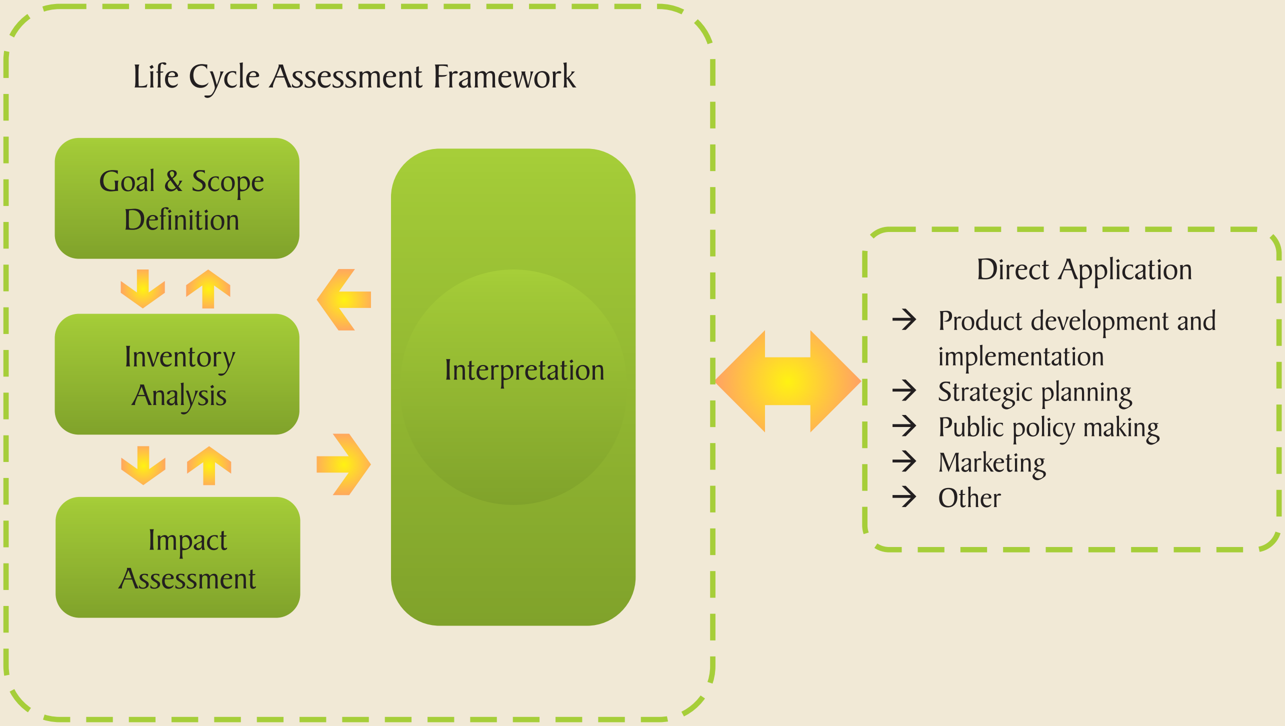
Gypsum board is the premier building material for wall, ceiling, and partition systems in residential, institutional, and commercial structures. Gypsum products are naturally fire-resistant, and provide sound control, economy, versatility, quality, and convenience.

Gypsum board covers the interior of more than 97% of the new homes constructed in the U.S. and Canada and is used to finish the interior and sheath the exterior of non-residential structures throughout the world. It is manufactured to comply with the provisions in the consensus standard, "ASTM C 1396, *Standard Specification for Gypsum Board*." This standard is referenced in building codes such as the *International Building Code, International Residential Code*, and the NFPA (National Fire Protection Association) 5000: *Building Construction and Safety Code*.

WHAT IS A LIFE CYCLE ASSESSMENT?

Life cycle assessment (LCA) is an analytical tool used to comprehensively quantify and interpret the energy and material flows to and from the environment over the life cycle of a product, process, or service. Environmental flows include emissions to air, water, and land, as well as the consumption of energy and material resources. By including these environmental impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product and a more accurate picture of the true environmental trade-offs in product selection.

Graph 1



Two international standards, ISO 14040:2006 and ISO 14044:2006[1], describe an iterative four-stage or phased methodology framework for completing an LCA, as shown in Graph 1: (1) goal and scope definition, (2) life cycle inventory, (3) life cycle impact assessment, and (4) interpretation.

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[1]Guidelines standardized by the International Organization for Standardization (ISO) as:
ISO 14040:2006. Environmental Management – Life Cycle Assessment – Principles and Framework.
ISO 14044:2006. Environmental Management – Life Cycle Assessment – Requirements and guidelines.

GOALS OF THE STUDY

In collaboration with the GA LCA working team members, the following drivers for carrying out this LCA study were identified:

- To better characterize the overall environmental performance of the membership's primary products.
- To be able to share, and respond to customer and public requests for, accurate environmental information on GA member processes and products.
- To better understand the contribution of various GWB processes within the cradle-to-gate profile of GWB products.
- To assist other organizations in understanding and communicating the environmental footprint and performance of their products when incorporating GWB products.

More specifically the goals of this study were as follows:

- Determine the cradle-to-gate environmental profile, on a production weighted average (representative) basis of 1,000 square feet of ½" Regular gypsum wallboard product, and identify key environmental inputs and outputs associated with the manufacture of this GWB product.
- Determine the cradle-to-gate environmental profile, on a production weighted average (representative) basis of 1,000 square feet of ⅝" Type X gypsum wallboard product, and identify key environmental inputs and outputs associated with the manufacture of this GWB product.

SCOPE OF THE STUDY

The GA and its members engaged the Athena Sustainable Materials Institute to conduct a representative, transparent and ISO 14040/44:2006 compliant cradle-to gate LCA of 1,000 square feet (92.9 m2) of the industry's two most common gypsum wallboard products – ½" (12.7 mm) Regular and ⅝" (15.9 mm) Type X gypsum wallboard – as produced in the U.S. in 2010. The two types of gypsum board addressed by the study annually account for over 85% of the gypsum board shipped in the U.S. and Canada.

In support of the study, primary LCI data were collected for three major gate-to-gate processes in the production of GWB: natural or crude gypsum ore extraction (six quarries and one underground mining site), gypsum paper manufacture (three plants) and GWB production (17 plants) for the reference year 2010. The GWB manufacturing plant study sample included all GA member companies and represented about 25% of all establishments producing gypsum and about 30% of all GWB produced in the U.S. To ensure representativeness, the GWB manufacturing plant study also considered the scale of operations including a mix of small, medium and large facilities, their geographical location in each U.S. census region and their source of gypsum – adjacent quarry, mine, imported gypsum ore and their use of FGD gypsum.

METHODOLOGY

The LCA study was conducted in accordance with ISO 14040:2006 and ISO 14044:2006. The study data, methods, results and report underwent an independent critical review by an external LCA expert.

A cradle-to-gate LCA assessment was conducted to evaluate the environmental performance of ½" Regular and ⅝" Type X GWB by considering the potential impacts of the selected life cycle stages, starting with extracting raw materials from the earth (the "cradle") and ending at the plant exit "gate" where the product is ready to be shipped to a distributor or user.

Within all three gate-to-gate processes (natural gypsum ore extraction, gypsum paper and GWB manufacture), "mass" was deemed the most appropriate physical parameter for allocating the total environmental load between the reference or functional product of interest and coproduct(s). Plant specific formulations for 1,000 square feet of the two products of interest were used to calculate the required input raw materials (both primary and secondary) and the ancillary materials.

To solve the "multi-functionality" of coal-fired power generation process and calculate the environmental profile of the FGD gypsum input, a co-product of the coal-fired power plant power generation process, a "system expansion" approach was used to avoid allocation.

The study supported a comprehensive set of life cycle impact assessment (LCIA) impact categories based on ISO 21930:2007 "Sustainability in Building Construction – Environmental Declaration of Building Products", and the US EPA TRACI impact assessment characterization model provided a North American context for calculating the impact category indicator results. The study's large representative sample size, reliable, up-to-date and transparent process data and its comprehensive set of supported environmental life cycle impact category indicators provide a credible LCA benchmark for the gypsum wallboard industry. Overall, the data quality underlying the study is considered "high" or "good".

Table 1. Cradle-to-Gate Environmental Profile for GWB Products (1,000 sq. ft.)

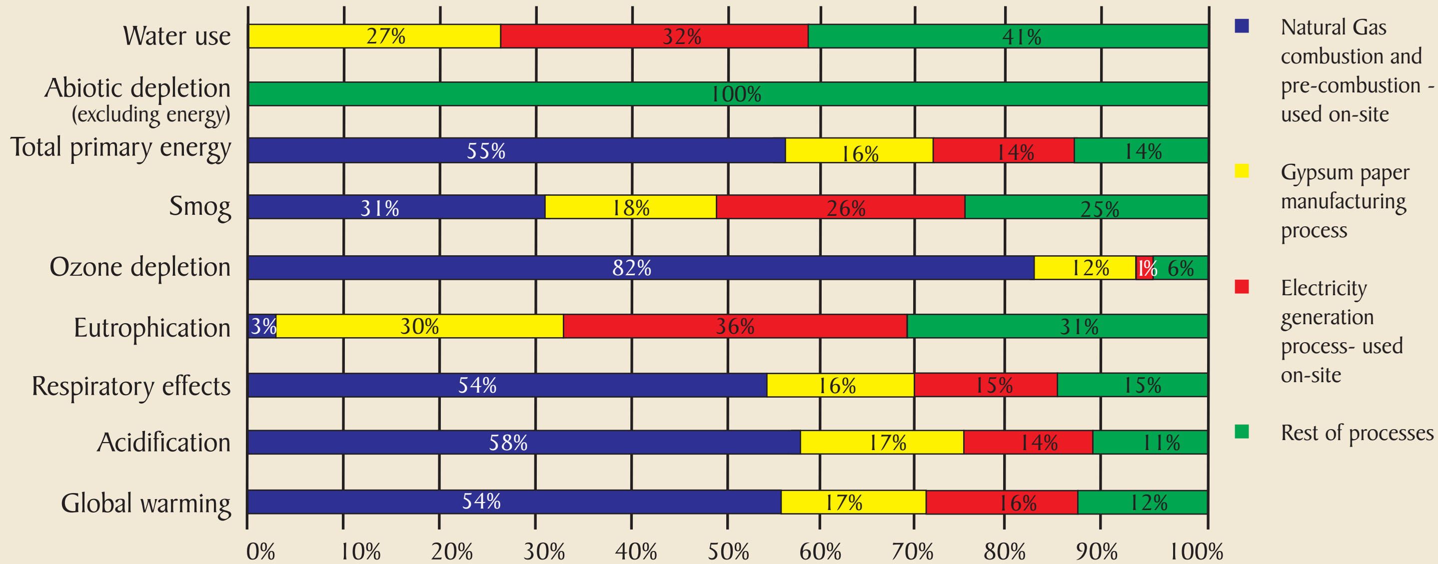
Impact Category Indicator	Unit	1/2" Regular GWB	5/8" Type X GWB
Global warming	kgCO_2eq	233.3	315.4
Acidification	H^+ moles eq	93.9	127.0
Respiratory effects	kg $PM_{2.5}$eq	0.45	0.61
Eutrophication	kg N eq	0.30	0.37
Ozone depletion	kg CFC-11 eq	1.1E-05	1.5E-05
Smog	kg NO_xeq	0.467	0.632
Total Primary Energy	MJ	4051.4	5445.1
Non-renewable, fossil	MJ	3725.7	5047.7
Non-renewable, nuclear	MJ	180.7	242.9
Non-renewable, biomass	MJ	2.4	2.6
Renewable, biomass	MJ	122.1	124.3
Renewable, wind, solar, geothermal	MJ	2.2	2.9
Renewable, water	MJ	18.3	24.7
Abiotic depletion	kg Sb eq	4.3E-03	6.2E-03
Water use	m^3	3.1	4.1

RESULTS

The cradle-to-gate weighted average environmental profile results for ½" Regular and ⅝" Type X GWB finished products are reported in Table1. The cradle-to-gate manufacture of 1,000 sq. ft. of ½" Regular and ⅝" Type X GWB embodies about 4.1 GJ and 5.5 GJ of primary energy use and emits in the order of 233 kg and 315 kg (CO2 equivalent) of greenhouse gas emissions, respectively. For both GWB products, over 90% of the total primary energy inputs were derived from non-renewable fossil fuel resources.

A dominance analysis revealed that the three main inputs of the GWB manufacturing system were, in descending order, on-site natural gas use, gypsum paper and on-site electricity use. Figures 1 and 2 illustrate the results of the dominance analysis for 1,000 sq. ft. (MSF) of ½" Regular and ⅝" Type X GWB finished products.

Figure 1. Dominance Analysis: 1/2" Regular GWB Product - % basis, per MSF



Note: Totals not equal to 100% due to rounding

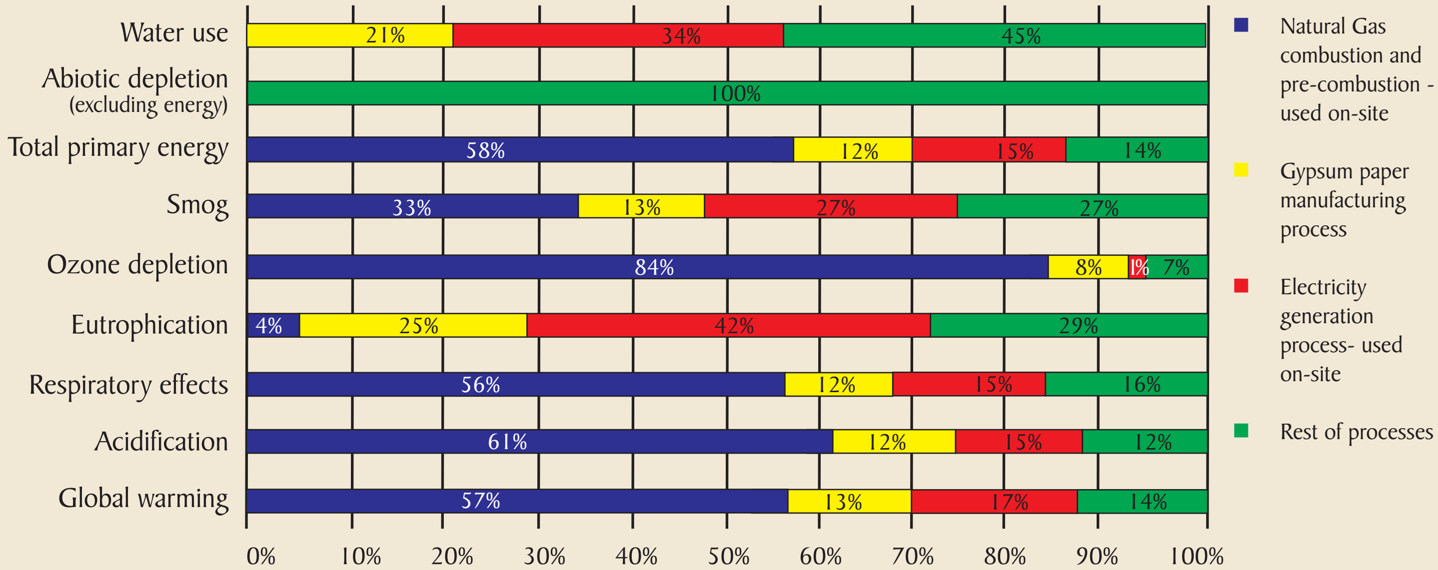
The GWB plant's energy use was the single largest contributor to the majority of the LCIA category indicator results - global warming, acidification, respiratory effects, ozone depletion, smog and total primary energy – often accounting for greater than 70% of the total impact results for the two GWB products.

The input of gypsum paper was the next most consistent and significant contributor to the majority of the LCIA category results (excluding abiotic resource depletion) and ranged from 8% to 30% of the total impact results for the two products.

Dry and wet additives in the production of GWB products accounted for 25% to 27% of the total eutrophication potential impact across the two product systems. The contribution of additives to the rest of the LCIA category results ranged from 3% to 11% for the two products.

Inbound transportation of raw and ancillary materials and the outbound transportation of wastes for treatment accounted for 32% to 33% of the smog potential, but transportation contributed no more than 8% to the other LCIA category results for the two GWB products.

Figure 2. Dominance Analysis: 5/8" Type X GWB Product - % basis, per MSF



Note: Totals not equal to 100% due to rounding

The contribution of the natural gypsum extraction system (both domestic & imported) to the depletion of abiotic resources potential was 98%. Natural gypsum's contribution to the rest of the LCIA category results ranged from 0.3% to 8% of the total impact results for the two products. The net impact of FGD synthetic gypsum use was an environmental benefit to the product system due to the diversion/avoidance of landfilling FGD gypsum. The FGD gypsum impact credit ranged from 1% to 7% across the set of LCIA category measures; except for smog formation potential, where the credit effect was closer to 30% due to avoidance of transportation to the landfill.

On average, for every 1,000 sq. ft. of GWB product manufactured about 0.4% of all material inputs end up as solid waste. Of the total solid waste, 0.04% was deemed "hazardous waste" to be incinerated – the majority of the solid waste outputs were either recycled, used as agricultural gypsum, returned to the quarry site for the purpose of land reclamation or sent to landfill.[2]

An influence analysis indicated that 78% to 82% of the total LCIA results were within the GWB plant's sphere of operational control of which plant energy use was the prime contributor. A sensitivity analysis of "on-site energy use" at the GWB plant indicated that plant energy use was also about three times more sensitive to the use of natural gas than electricity. Additional sensitivity analyses revealed that a change in the source location of natural gypsum imports (Canada or Mexico) had a minimal influence (<1%) on the overall LCIA results.

2. "Hazardous waste" is composed of items such as dry oil, oil filters, batteries, lamps, etc. sent to an incinerator or suitably disposed in accordance with regulatory requirements.

CRITICAL REVIEW

The LCA study was critically reviewed by theGreenTeam, Inc.

The reviewer conducted an ISO 14044:2006(E) *Environmental management—Life cycle assessment—Requirements and guidelines* 6.1-6.2 critical review of the Athena Institute *A Cradle-to-Gate Life Cycle Assessment of ½" Regular and ⅝" Type X Gypsum Wallboard*.

As specified in ISO 14044:2006(E), the reviewer considered the following in the critical review:

- Are the methods used to carry out the study consistent with ISO 14044:2006(E)?
- Are the methods used to carry out the study scientifically and technically valid?
- Are the data used appropriate and reasonable in relation to the goal of the study?
- Do the interpretations reflect the limitations identified and the goal of the study?
- Is the study report transparent and consistent?

The LCA documentation reviewed included the draft report *A Cradle-to-Gate Life Cycle Assessment of ½" Regular and ⅝" Type X Gypsum Wallboard*, the MS Excel worksheet "GA LCA study-Summary of 5 LCI product profiles spreadsheet-Oct, 2011," and GA comments matrix dated October 26, 2011.

CRITICAL REVIEW CONCLUSIONS

The reviewer finds the Athena Institute *A Cradle-to-Gate Life Cycle Assessment of ½" Regular and ⅝" Type X Gypsum Wallboard* appropriately applied ISO 14044:2006(E) *Environmental management—Life cycle assessment—Requirements and guidelines*. The LCA:

- Is consistent with ISO 14044:2006(E) *Environmental management — Life cycle assessment – Requirements and guidelines.*
- Uses scientifically and technically valid methods.
- Uses appropriate and reasonable data in relation to the goal of the study.
- Interpretations reflect the limitations and goals of the study.
- Report is transparent and consistent.

GYPSUM ASSOCIATION MEMBERS 2013

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