ENVIRONMENTAL PRODUCT DECLARATION

STYROFOAM™ INSULATION

DOW CHEMICAL COMPANY

STYROFOAM™ insulation products deliver continuous insulation and thermal and air barrier solutions.

Dow has a long history of leadership in sustainability and energy efficiency. Dow has sustainability goals for operations, manufacturing, and energy generation which results in mutually beneficial reduction of costs and greenhouse gas emissions. Dow products contribute to a sustainable energy future by helping to improve the efficiency of virtually every major industry, including transportation and construction.

Dow Building Solutions has over 65 years of building science expertise in the global commercial and residential construction industry and provides solutions for thermal, air and moisture management that help reduce energy costs and greenhouse gas emissions while protecting against the elements. All Dow Building Solutions insulation products continue to conserve energy through the life of the building with no additional maintenance during their use.

More information about Dow Building Solutions can be found at www.dowbuildingsolutions.com

UL CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION UL.COM/EPD

ENVIRONMENTAL PRODUCT DECLARATION

STYROFOAM™

According to ISO 14025 and ISO 21930:2007

This declaration is an environmental product declaration (EPD) in accordance with ISO 14025. EPDs rely on Life Cycle Assessment (LCA) to provide information on a number of environmental impacts of products over their life cycle. Exclusions: EPDs do not indicate that any environmental or social performance benchmarks are met, and there may be impacts that they do not encompass. LCAs do not typically address the site-specific environmental impacts of raw material extraction, nor are they meant to assess human health toxicity. EPDs can complement but cannot replace tools and certifications that are designed to address these impacts and/or set performance thresholds – e.g. Type 1 certifications, health assessments and declarations, environmental impact assessments, etc. Accuracy of Results: EPDs regularly rely on estimations of impacts, and the level of accuracy in estimation of effect differs for any particular product line and reported impact. Comparability: EPDs are not comparative assertions and are either not comparable or have limited comparability when they cover different life cycle stages, are based on different product category rules or are missing relevant environmental impacts. EPDs from different programs may not be comparable.

PROGRAM OPERATOR	UL Environment
DECLARATION HOLDER	DOW Building Solutions
DECLARATION NUMBER	4786548101.101.1
DECLARED PRODUCT	STYROFOAM™ Insulation
REFERENCE PCR	Product Category Rules for preparing an environmental product declaraiont (EPD) for Product Group: Building Envelope Thermal Insulation
DATE OF ISSUE	October 13, 2014
PERIOD OF VALIDITY	5 Years
CONTENTS OF THE DECLARATION	Product definition and information about building physics Information about basic material and the material's origin Description of the product's manufacture Indication of product processing Information about the in-use conditions Life cycle assessment results Testing results and verifications

The PCR review was conducted by:	Wayne B. Trusty (Chairperson) Wayne B. Trusty & Associates Limited epd@ulenvironment.com
This declaration was independently verified in accordance with ISO 14025 by Underwriters Laboratories ☐ INTERNAL ☒ EXTERNAL	Wade Stout, UL Environment
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:	Thomas Gloria, Life-Cycle Services, LLC

This EPD conforms with ISO 21930:2007

Product Description and Information

Product Description

Dow STYROFOAM™ insulation can be broadly categorized into two products: STYROFOAM™ and STYROFOAM™ Ultra insulation. STYROFOAM™ extruded polystyrene foam provides an R value of 5 h·ft^2·°F/Btu per inch; STYROFOAM™ Ultra uses patented carbon black materials in the foam for better thermal performance over other extruded polystyrene foam insulations. This enhanced formulation helps the foam to absorb infrared radiation, slowing transmission through the foam and lowering heat flow, and yields an R value of 5.6 h·ft^2·°F/Btu per inch. The insulation is designed to deliver energy savings, weatherization protection and other benefits in residential and commercial wall applications. STYROFOAM™ insulation is easy to install, can be applied to a variety of substrates, satisfies the applicable fire, air and water-resistive barrier requirements, and maintains a consistently high R-value throughout the lifecycle of the building.

STYROFOAM™ rigid foam boards are made in R-values ranging from R-1 to R-20 for use in North American building applications. STYROFOAM™ is manufactured in thicknesses from 0.25 in to 4 in. The functional unit of the product as defined by the PCR is 1 square meter of insulation material with a thickness that gives an average thermal resistance (R_{SI}) R_{SI}=1 m^{2}K/W (5.68h·ft^2·°F/Btu) and with a building service life of 60 years. The calculated thickness which provides the required R_{SI} value for STYROFOAM™ is 1.14 in (2.89 cm) and for STYROFOAM™ Ultra is 1.01 in (2.57 cm). As an example, STYROFOAM™ Brand Cavitymate foam insulation complies with ASTM C578 Type X, meets IBC/IRC requirements for foam plastic insulation, meets CAN/ULC S701 Type 3. The physical properties of STYROFOAM™ Brand Cavitymate are presented in Table 1. Further information on specific products and physical properties of STYROFOAM™ products can be found at:
http://building.dow.com/na/en/products/insulation/rigidfoam.htm

Table 1: Physical Properties (US) of STYROFOAM™ BRAND CAVITYMATE Extruded Polystyrene Insulation

PROPERTY AND TEST METHOD	VALUE
Thermal Resistance(1), ASTM C518, R-value, ft^2• h•°F/Btu	5.0
Compressive Strength(2), ASTM D1621, psi	15.0
Water Absorption, ASTM C272, % by volume, max.	0.3
Water Vapor Permeance, ASTM E96, perms, max	1.5
Maximum Use Temperature, °F	165
Coefficient of Linear Thermal Expansion, ASTM D696, in/in•°F	3.5*10^{-5}
Flexural Strength, ASTM C203, psi, min.	40

STYROFOAM™

According to ISO 14025

Manufacturing Locations

The Dow Chemical Company manufacturing locations are presented below.

Dalton Plant Dalton, GA 30720	Haning Rock Plant Ironton, OH 45638	La Porte Plant LaPorte, TX 77572-0685
Joliet Plant Channahon, IL 60410	Riverside Plant Pevely, Missouri 63070	Varennes Plant Varennes, Quebec J3X 1T3

Primary data from all the plants was used for the life-cycle assessment and the results are based on the weighted average of production.

Application and Uses

Application areas for STYROFOAM™ products are thermal insulation of roofs, ceilings, interior and exterior walls, floors, basements, exterior insulation finishing systems (EIFS) and composite panels. STYROFOAM™ systems are water and air barriers, in addition to thermal barriers. The applications and specific products in which the insulation boards are used are listed below:

- **Roofing:** Help control heat and moisture transfer through commercial and residential roofs and ceilings.
  STYROFOAM™ ROOFMATE™
  STYROFOAM™ ROOFMATE™ – Ribbed
  STYROFOAM™ DECKMATE™
  STYROFOAM™ DECKMATE™ Plus
  STYROFOAM™ DECKMATE™ Plus FA
  STYROFOAM™ PLAZAMATE™
- **Interior Walls:** Help manage the energy and moisture issues that can compromise the performance of residential and commercial walls.
  STYROFOAM™ CLADMATE™ XL
  STYROFOAM™ WALLMATE™
  STYROFOAM™ Z-MATE™
- **Exterior Walls:** Deliver energy savings and weatherization protection in all types of residential and commercial walls.
  STYROFOAM™ Residing Board
  STYROFOAM™ Ag Board
  STYROFOAM™ DURAMATE™ Plus
  STYROFOAM™ PERIMATE™
  STYROFOAM™ SM
  STYROFOAM™ Scoreboard

STYROFOAM™ Residential Sheathing
STYROFOAM™ Ultra SL

- **Cavity Walls:** Deliver proven performance in block-backed cavity wall construction, providing high thermal performance, moisture resistance and durability.
  STYROFOAM™ CAVITYMATE™
  STYROFOAM™ CAVITYMATE™ Plus
  STYROFOAM™ CAVITYMATE™ SC
  STYROFOAM™ CAVITYMATE Ultra
  STYROFOAM™ Scoreboard
  STYROFOAM™ PANELMATE™
  STYROFOAM™ PANELMATE™ Ultra
- **Panels/Composites:** Deliver optimal thermal efficiency, moisture resistance and panel stiffness.
  STYROFOAM™ Panel Core 20
  STYROFOAM™ Panel Core 30
  STYROFOAM™ Panel Core 40
- **Geotechnical Insulation:** Provide economical, long-term solutions for geotechnical applications.
  STYROFOAM™ HIGHLOAD 40
  STYROFOAM™ HIGHLOAD 60
  STYROFOAM™ HIGHLOAD 100
  STYROFOAM™ SM
- **Other Applications:** Provide energy-efficient performance in various types of commercial and residential applications, including attics and ceilings.
- STYROFOAM™ SM
  STYROFOAM™ Square Edge
  STYROFOAM™ Tongue and Groove
  STYROFOAM™ UTILITYFIT™ XPS 15 PSI
  STYROFOAM™ Ultra SL
  STYROSPAN™ Insulation
  STYROFOAM™ FREEZERMATE™
  STYROFOAM™ HIGHLOAD 40
  STYROFOAM™ HIGHLOAD 60
  STYROFOAM™ HIGHLOAD 100
  STYROFOAM™ RECOVERMATE CR

Installation

Dow STYROFOAM™ rigid foam products are installed with ancillary materials such as fasteners or adhesives that attach the foam to a variety of substrates. Flashing tape, foam sealant or liquid applied flashing are used to seal the joints between adjacent foam sheets and around fenestrations or penetrations. This EPD covers only the rigid foam product as there are many options for ancillary materials, depending on the wall, roof or foundation assembly requirements. Installation instructions for STYROFOAM™ products in a variety of applications can be found at: http://building.dow.com/na/en/tools/installations/

STYROFOAM™

According to ISO 14025

Production

Material Content

Material	Mass Composition STYROFOAM™	Mass Composition STYROFOAM™ Ultra	Non – renewable	Renewable	Recycled Material	Origin	Transportation Mode	Transportation Miles
Polystyrene (virgin)	60-80%	60-80%	■			North America	Rail and Truck	<1500
Polystyrene (re-manufacture)	10-30%	10-30%			■	North America		0
Blowing agents	<10%	<10%	■			North America	Truck	<2000
Flame Retardants	<1%	<1%	■			North America	Truck	<1500
Additives	<2%	<2%	■			North America	Truck	<1500
Colorant	<1%	<1%	■			North America	Truck	<200
Carbon Black		<10%	■			North America	Truck	<200

Manufacturing Process

STYROFOAM™ extruded polystyrene foam (XPS) is manufactured in a continuous extrusion process with electricity as the main energy source. Polystyrene is melted together with the additives in the extruder under high pressure. Blowing agents are injected into the melted mass and dissolved in it. The melted mass is extruded through a flat die. The drop in pressure causes the polystyrene to foam, cool down and solidify. An endless board of homogenous closed-cell polystyrene foam is produced. This is cooled further and then cut to dimension, trimmed and the surface modified if necessary. More than 99% of the XPS foam production trimmings and production waste is recycled directly back into the production facilities to manufacture XPS instead of going into the waste stream. Polystyrene is a thermoplastic material and can therefore be recycled easily and economically by melting it. The durability of XPS is as long as the lifetime of the building in which it is used.

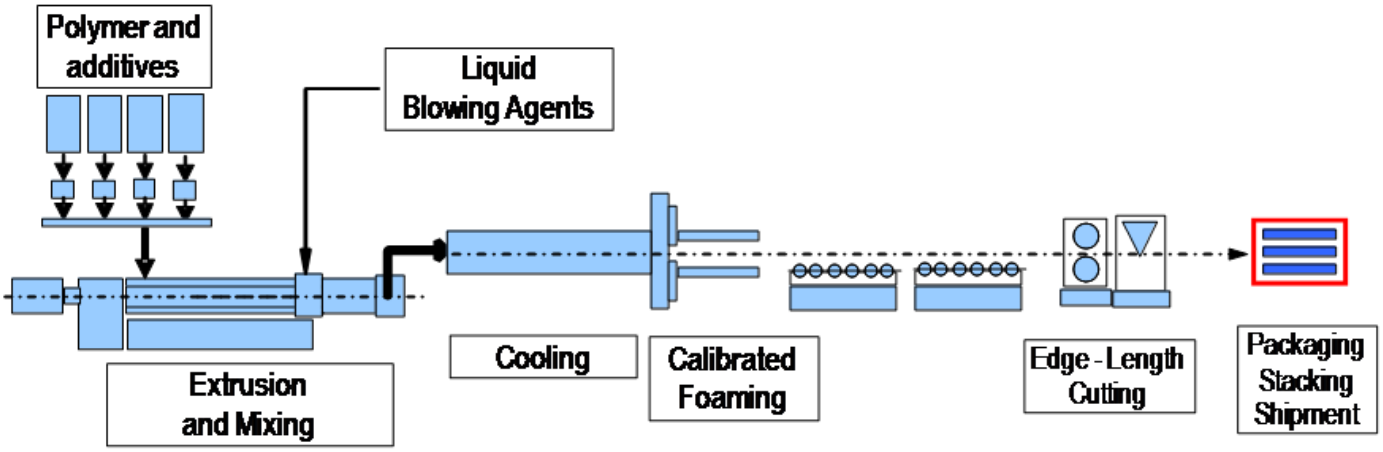


Figure 1: Process Flow of STYROFOAM™ manufacturing

Life Cycle Assessment – Product System and Modeling

Functional Unit

The functional unit of the product as defined by the PCR is 1 square meter of insulation material with a thickness that gives an average thermal resistance (R_{SI}) R_{SI}=1 m^2K/W (5.68h·ft^2·°F/Btu) and with a building service life of 60 years. The calculated thickness which provides the required R_{SI} value for STYROFOAM™ is 1.14 in (2.89 cm) and for STYROFOAM™ Ultra is 1.01 in (2.57 cm).

Life Cycle Stages Assessed

The STYROFOAM™ foam insulation study was a cradle-to-grave analysis, so the boundaries extended upstream to materials in the earth and continued to the commercial product going to landfill. The life cycle stages assessed in this study include:

- Raw material production including extraction of primary raw materials, raw material manufacturing, and disposal of key raw material production waste.
- All raw material transportation to manufacturing location.
- STYROFOAM™ production, including primary facility utilities and emissions data.
- Packaging for STYROFOAM™ shipment to distributor.
- Disposal of manufacturing waste.
- Commercial product transportation from plant to distributor.
- Commercial product transportation from distributor to building site.
- Used product transportation from building site to landfill (both from construction and end of life).
- Emissions of blowing agent during use
- Landfill of used product, including any trimming waste from installation.

System Boundaries

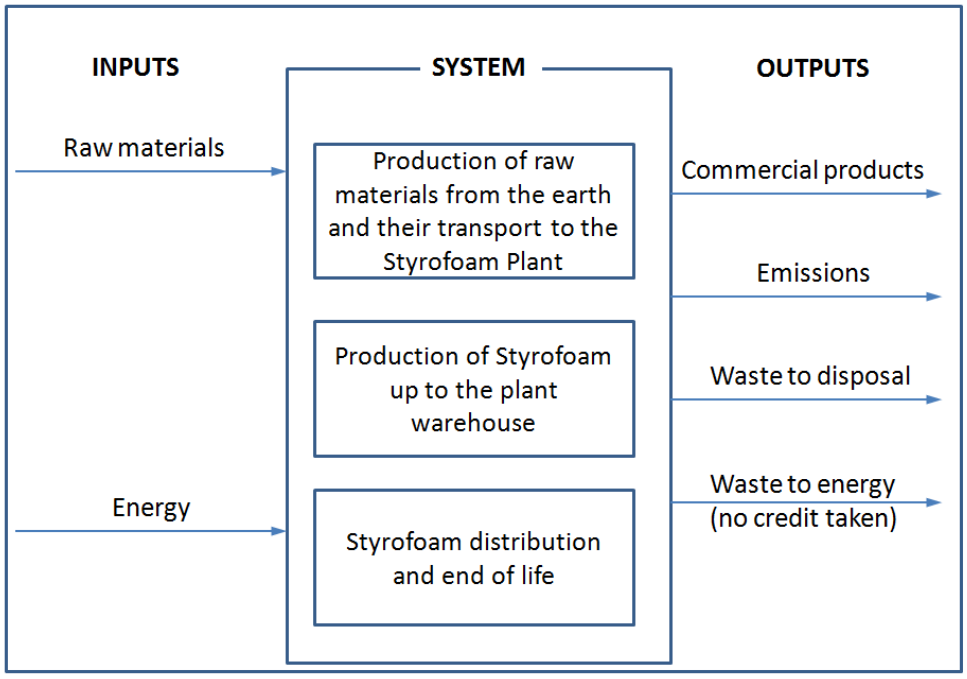


Figure 2: High level view of life cycle stages (showing only direct inputs and emissions)

Assumptions

The following assumptions were made for this life cycle assessment:

- Products are disposed of in a landfill at the end of life
- Installation requires no external energy input and no maintenance
- Blowing agent in the commercial product is released to the atmosphere during the specified 60 year study period. 45% during use and 55% at the end of life (landfill)
- Transportation of the product from the distributor to the building site is assumed to be 50 miles by truck
- Transportation of the product from the building site to landfill is assumed to be 100 miles by truck
- During its service life, insulation significantly reduces the energy use in a building, thereby reducing the impact on the environment. However, building heating and cooling is excluded during the use phase of the life cycle assessment as required by the PCR. The benefits of insulation in the reduction of building energy use is described separately in this declaration as additional information beyond the scope of the product life cycle assessment.
- Dismantling and demolition were not considered during the end of life stage.

Cut-Off Criteria

Cut-off criteria are conditions that specify how much of the data obtained in the study will be used in modeling the system. For an extremely detailed life cycle inventory, accounting for every input is likely to be impractical within reasonable time constraints; hence, cut-off criteria help guide the rationale for excluding any data. According to the PCR, a process or activity that contributes no more than 2% of the total mass and uses no more than 1% of the total energy may be omitted from the inventory analysis. An exception is that omissions of any material flows that may have a relevant contribution to the selected impact categories of the products underlying the Environmental Product Declaration will be justified, if applicable, by a sensitivity analysis. The sum of the excluded material flows must not exceed 5% of mass, energy or environmental relevance.

To provide a robust analysis, and to thereby enhance the credibility of the study, the approach taken was to include as much of the life cycle inventory data in the models as possible. All known inputs to STYROFOAM™ foam production have been included. The implicit cut-off for this data source is relevance: inputs and outputs related directly to the foam production operation are included; ancillary inputs (office supplies and travel, for example) are not included. Capital production process items (machines, equipment etc) were excluded from this study.

This EPD is in compliance with the cut-off criteria. No processes were neglected or excluded.

Transportation

Transportation was included for all inbound raw materials, shipment of commercial product to distributor, shipment from distributor to building site, and end of life product to landfill. Primary data were obtained for the transport of the major raw materials. These were a combination of rail and truck transport between 0 and 2000 miles, depending on the STYROFOAM™ product location. Transportation of the product from the distributor to the building site is assumed to be 50 miles by truck. Transportation of the product from the building site to landfill is assumed to be 100 miles by truck.

Period Under Consideration

All Dow primary data for the production used in the study were from the year of 2013.

Secondary Background Data

All Dow primary data for the energy and material inputs and emissions during production was collected internally from Dow facilities. The US EPA was the source for data on grid electricity. Ecoinvent v3 was the source for other background LCA data.

Data Quality

Overall, the data used in this study, a combination of Dow production data and Ecoinvent library data, allowed the construction of life cycle models that describe the production of foam insulation. Primary data was obtained for the most critical inputs. This is high quality data since it comes directly from Dow facilities. Secondary data, from Ecoinvent 2.2 was used for upstream process models to provide an established, documented and reasonable source of information.

Allocation

In a production process where more than one type of product is generated, it is necessary to allocate the environmental impacts (inputs and outputs) from the process to the different products in order to obtain product-based inventory data. Allocation rules should reflect the goal of the production process. For production of building envelope thermal insulation products, allocation is preferably carried out according to mass. This was used in this project to divide utilities use and emissions known on an annual basis across all production of the plant. Different specific STYROFOAM™ foam products are manufactured at the plants. All carried the same direct manufacturing burdens per unit mass.

Use

STYROFOAM™ foam insulation boards do not require any additional resources to perform its intended use as a thermal insulator. Ancilliary materials may be needed to satisfy requirements as an air, water or fire resistive assembly, but they have not been included in the analysis. During use, there are reductions in the energy consumption of a building and also the release of the blowing agent. For the purposes of this study, the blowing agent is assumed to be released 45% during the 60 year temporal analysis boundary and 55%at disposal.

End-of-Life

For the purposes of this study the end of life stage for XPS foam is disposal to a landfill. The transportation of the foam boards from building site to landfill is considered to be 100 miles.

Environmental Product Declaration

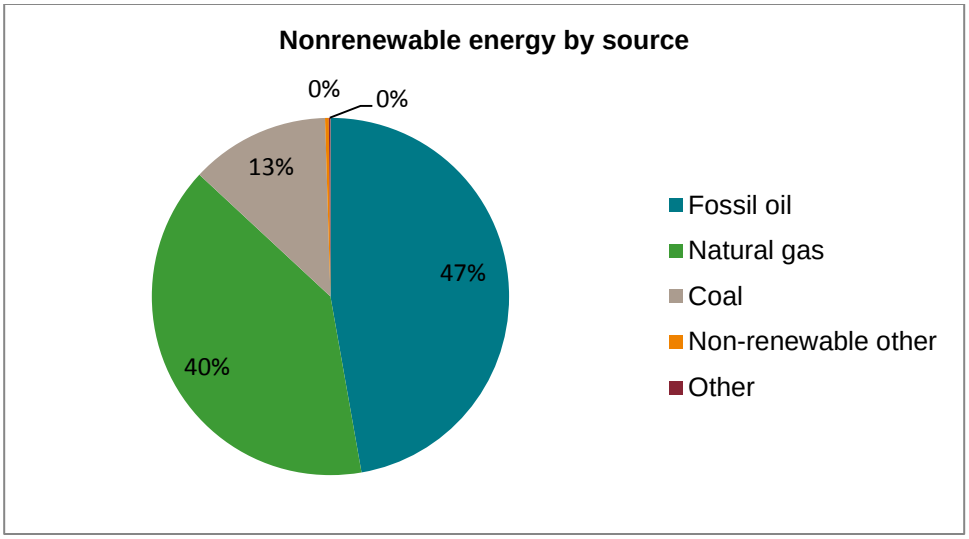
Use of Material and Energy

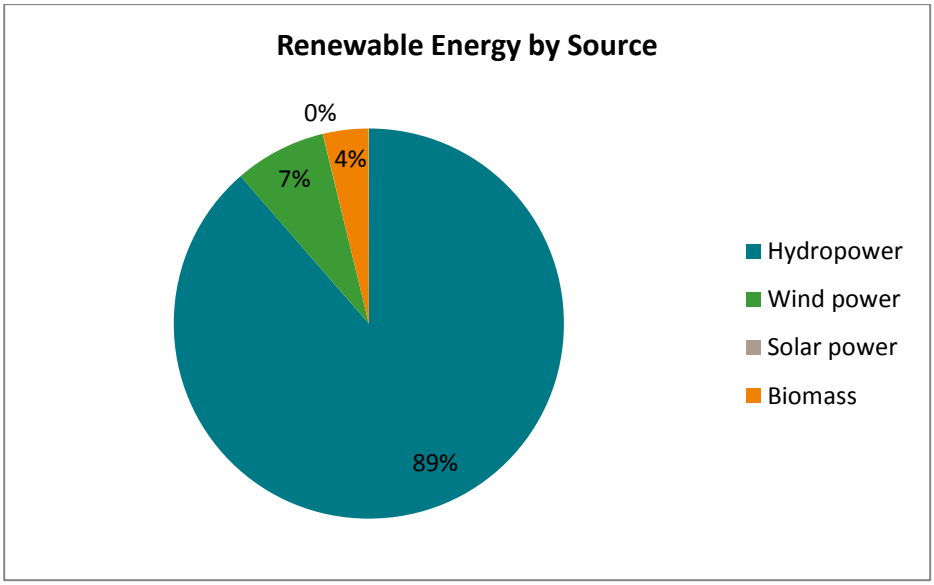
Total primary energy of the STYROFOAM™ and STYROFOAM™ Ultra foam

Primary Energy Resource Category	Energy (MJ eq)
Non-renewable, fossil	82.60
Non-renewable, nuclear	5.43
Renewable, biomass	0.03
Renewable, wind, solar, geothermal	0.06
Renewable, water	0.71
Total Primary Energy	88.8

Total primary energy of the STYROFOAM™ and STYROFOAM™ Ultra foam by source type

Non-Renewable Primary Energy Source	Energy (MJ eq)	Renewable Primary Energy Source	Energy (MJ eq)
Fossil oil	38.98	Hydropower	0.70
Natural gas	32.78	Wind power	0.06
Coal	10.39	Solar power	0.0001
Non-renewable other	0.28	Biomass	0.03
Gas, mine, off-gas, process, coal mining	0.13		



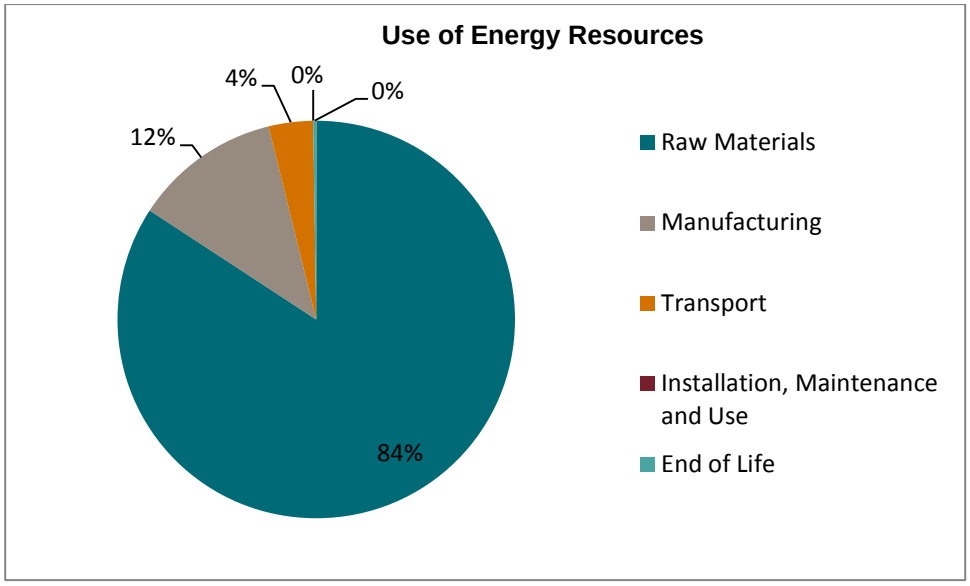


Primary Energy by Life Cycle Stages

STYROFOAM™ and STYROFOAM™ Ultra

Impact category	Unit	Total	Raw materials	Manufacturing	Transport	End of life
Primary Energy	MJ	8.88E+01	7.48E+01	1.06E+01	3.200E+00	2.20E-01

As shown in the pie chart below, the majority of the primary energy demand is attributed to the Raw Materials stage, with 84% of the contribution. Due to its function as a thermal insulator and the insulation product not requiring any energy during use, great reductions in energy consumption of a building are achieved during the use phase of the STYROFOAM™ insulation.



Life Cycle Assessment – Product

Impact category	Unit	Total	Raw materials	Manufacturing	Transport	Installation, maintenance	End of life
Ozone depletion	kg CFC-11 eq	6.71E-04	6.71E-04	0	0	0	0
Global warming	kg CO2 eq	9.53E+01	9.03E+00	2.54E+01	1.90E-01	2.72E+01	3.33E+01
Smog	kg O3 eq	1.98E-01	3.38E-01	2.30E-02	3.50E-02	0	2.00E-03
Acidification	mol H+ eq	9.98E-01	7.48E-01	1.72E-01	6.50E-02	0	3.00E-03
Eutrophication	kg N eq	2.72E-03	1.85E-03	6.70E-04	1.10E-04	0	7.00E-05
Water use	kg	5.45E+00	1.45E+00	4.00E+00	0	0	0
Non-hazardous waste	kg	7.99E-01	1.60E-02	6.00E-03	0	0	7.77E-01
Hazardous waste	kg	2.70E-03	2.70E-03	0	0	0	0
Waste to energy	kg	7.80E-05	0	7.80E-05	0	0	0
Primary Energy	MJ	8.88E+01	7.48E+01	1.06E+01	3.20E+00	0	2.20E-01

Additional Environmental Information

Other Environmental

Cradle to Cradle Silver Certification

Contributes to LEED points in the Material and Resources, Energy and Atmosphere and Indoor Environmental Quality sections.

Building Use Stage Benefits

Insulation requires no extra energy or utilities to operate over its useful life. The STYROFOAM™ insulation reduces the energy associated with heating and cooling the building, and contributes to reduction in greenhouse gas emissions.

An example presented below provides the net energy savings for average rigid STYROFOAM™ insulation in a medical office building. The net energy saved is the total energy saved minus the life cycle energy for production and disposal of STYROFOAM™ insulation.

The case study used for the analysis is a two story medical office building 21,335 square foot insulated to ASHRAE 90.1 2013 minimum R-value requirements for walls and roofs. The conditioned space within the building is 20836 sq ft. The wall insulated area is 10,003 square feet. The roof insulated area is11,493 square feet. The example includes an analysis of a mass wall frame structure and a steel wall frame structure for four locations: Dallas, TX, Nashville, TN, Saginaw, MI, Minneapolis, MN all in four different ASHRAE Zones. The modeling was performed using EnergyPlus, an hourly energy analysis simulation program. This actual medical office building is located in Saginaw, MI and the building was modeled with the appropriate HVAC equipment necessary to operate a medical office building. Due ot the nature of an office building and the HVAC equipment necessary, more energy is used compared to an office building, so the example provided below is very conservative in terms of the enrgy saved.

In comparison to the case study presented below an office building not used for medical purposes would have a faster payback due to the mechanical system needed. Additionaly, buildings insulated to ASHRAE 90.1-2010 or 2007 would also have a faster payback due to less insulation being required. This case study building has an energy savings payback ranging from 2.1 years in a cold climate (Zone 5 and 6) to 4 years in a warm climate (Zone 3).

The ratio of the energy usage used to fabricate STYROFOAM™ insulation components versus the building energy usage saved over the 60 year life of the buildings ranges between .038 to .068, this means that the energy saved is 14 to 26 times bigger than the energy used to fabricate the product.

Energy Savings		Life Cycle MJ for Insulation Used in Building	MJ Saved/ Year for Case Study Building	Net MJ Saved (First Year)	Payback Time (Years)	MJ Saved over 60 Year Use Phase
Zone 3 - Dallas, TX	Mass Wall	539,000	140,000	-399,000	3.8	7,871,000
	Steel Frame	612,000	153,000	-459,000	4.0	8,576,000
Zone 4 - Nashville, TN	Mass Wall	653,000	184,000	-468,000	3.5	10,413,000
	Steel Framed	736,000	197,000	-538,000	3.7	11,101,000
Zone 5 - Saginaw, MI	Mass Wall	683,000	331,000	-352,000	2.1	19,157,000
	Steel Framed	776,000	347,000	-428,000	2.2	20,071,000
Zone 6 - Minneapolis, MN	Mass Wall	815,000	370,000	-423,000	2.1	21,422,000

	Steel Framed	815,000	380,000	-433,000	2.1	21,986,000

References

- International Standard ISO 14040, “Environmental management – Life cycle assessment – Principles and framework”, Second edition, 01 July **2006**
- International Standard ISO 14044, “Environmental management – Life cycle assessment – Requirements and guidelines”, First edition, 01 July **2006**
- European Commission - Joint Research Centre - Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. First edition March 2010. EUR 24708 EN. Luxembourg. Publications Office of the European Union; **2010.**
- Underwriters Laboratories. “Product Category Rules for preparing an environmental product declaration (EPD) for Product Group: Building Envelope Thermal Insulation”. September 12, **2011** (valid through September 12, 2016)
- Ecoinvent v2.2, Swiss Centre for Life Cycle Inventories, **2010**