BASF
The Chemical Company

Submission for Verification of Eco-efficiency Analysis Under NSF Protocol P352, Part B

Walltite ECO®
Insulation Air Barrier and Vapor Barrier System
Eco-Efficiency Analysis
Final Report - November 2011

NSF®

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1. Purpose and Intent of this Submission

1.1. The purpose of this submission is to provide a written report of the methods and findings of BASF Corporation's "WALLTITE ECO®, Eco-Efficiency Analysis", with the intent of having it verified under the requirements of NSF Protocol P352, Part B: Verification of Eco-Efficiency Analysis Studies.

1.2. The WALLTITE ECO®, Eco-Efficiency Analysis was performed by BASF according to the methodology validated by NSF International under the requirements of Protocol P352. More information on BASF's methodology and the NSF validation can be obtained at http://www.nsf.org/info/eco_efficiency.

1.3. This submittal reflects an update to the original WALLTITE ECO® study which was completed and verified in February 2010. Key updates to the study include a reformulation of the WALLTITE ECO® resin, an updated eco-profile for BASF MDI production, updated compositional data for the non-spray foam alternatives and updated material pricing for all alternatives.

2. Content of this Submission

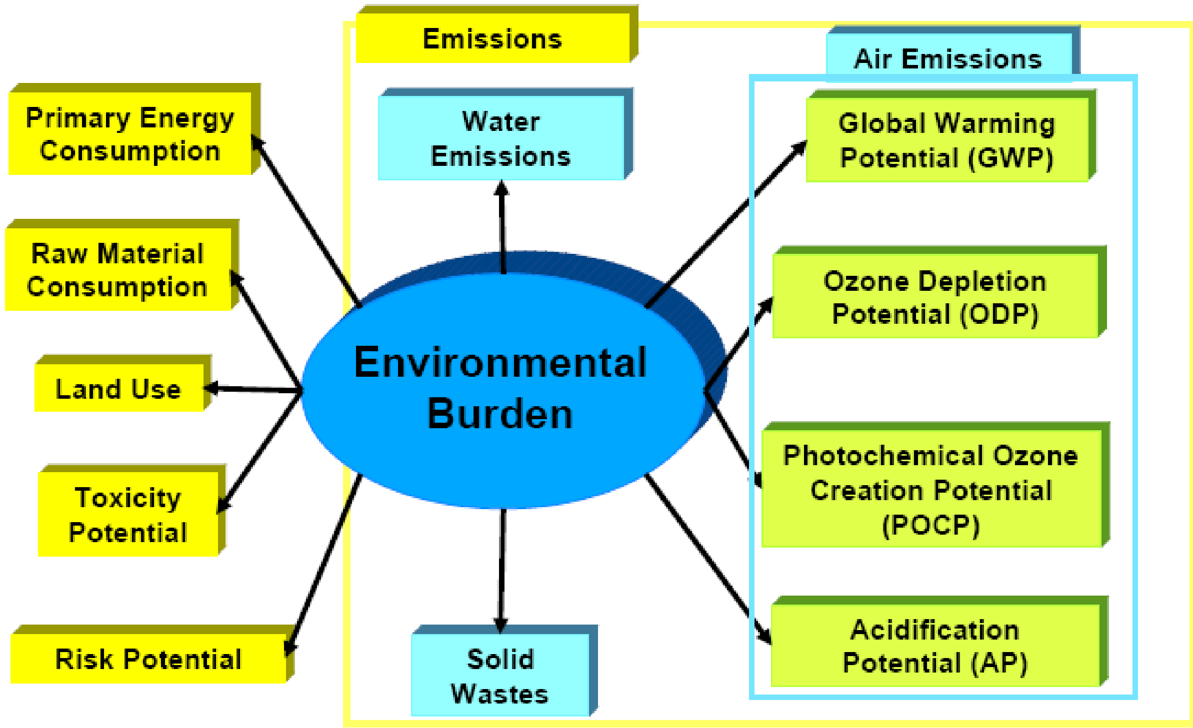
2.1. This submission outlines the study goals, procedures, and results for the WALLTITE ECO®, Eco-Efficiency Analysis (EEA) study, which was conducted in accordance with BASF Corporation's EEA (BASF EEA) methodology. This submission will provide a discussion of the basis of the eco-analysis preparation and certification work.

2.2. As required under NSF P352 Part B, along with this document, BASF is submitting the final computerized model programmed in Microsoft® Excel. The computerized model, together with this document, will aid in the final review and ensure that the data and critical review findings have been satisfactorily addressed.

3. BASF's EEA Methodology

3.1. Overview: BASF EEA involves measuring the life cycle environmental impacts and life cycle costs for product alternatives for a defined level of output. At a minimum, BASF EEA evaluates the environmental impact of the production, use, and disposal of a product or process in the areas of energy and resource consumption, emissions, toxicity and risk potential, and land use. The EEA also evaluates the life cycle costs associated with the product or process by calculating the costs related to, at a minimum, materials, labor, manufacturing, waste disposal, and energy.

3.2. Environmental Burden Metrics: For BASF EEA environmental burden is characterized using eleven categories, at a minimum, including: primary energy consumption, raw material consumption, global warming potential (GWP), ozone depletion potential (ODP), acidification potential (AP), photochemical ozone creation potential (POCP), water emissions, solid waste, emissions, toxicity potential, risk potential, and land use. These are shown below. Metrics shown in yellow represent the six main categories of environmental burden that are used to construct the environmental footprint, burdens in blue represent all elements of the emissions category, and green show air emissions.



3.3. Economic Metrics: It is the intent of the BASF EEA methodology to assess the economics of products or processes over their life cycle and to determine an overall total cost of ownership for the customer benefit ($/CB). The approaches for calculating costs vary from study to study. When chemical products of manufacturing are being compared, the sale price paid by the customer is used. When different production methods are compared, the relevant costs include the purchase and installation of capital equipment, depreciation, and operating costs. The costs incurred are summed and combined in appropriate units (e.g. dollar or EURO) without additional weighting of individual financial amounts. The BASF EEA methodology will incorporate:

- the real costs that occur in the process of creating and delivering the product to the consumer;
- the subsequent costs which may occur in the future (due to tax policy changes, for example); and
- costs having ecological aspect, such as the costs involved to treat wastewater generated during the manufacturing process.

4. Study Goals, Decision Criteria and Target Audience

4.1. *Study Goals*: The specific goal defined for the WALLTITE ECO®, Eco-Efficiency Analysis was to quantify the differences in the environmental and cost impacts over their life cycle of insulation systems for the exterior of commercial building walls in Canada, which require both an air barrier and vapor barrier system.

The intent was to parameterize the model such that all independent variables were sufficiently similar for all four alternatives, such that environmental differences could be evaluated based on specific impacts of the insulation and air barrier system. Results will be used to help a new product launch by clearly articulating the eco-efficiency of the WALLTITE ECO® system over its product life cycle. These results will be used as the basis for market differentiation between the alternatives. Additionally, the study results will be used to guide product development decisions that will result in more sustainable insulation systems. The drivers of the study include R&D decisions and marketing efforts.

4.2. *Decision Criteria*: The context of this EEA study compared the life cycle for WALLTITE ECO® closed cell, spray applied polyurethane foam insulation, extruded polystyrene insulation (XPS) with variations in the blowing agent used, expanded polystyrene insulation (EPS) and mineral fiber insulation competing in a commercial market at a regional level over the course of a life cycle. The study was both competitively and technology driven and required supplier and customer engagement. The study goals, target audience, and context for decision criteria used in this study are displayed in Figure 1.

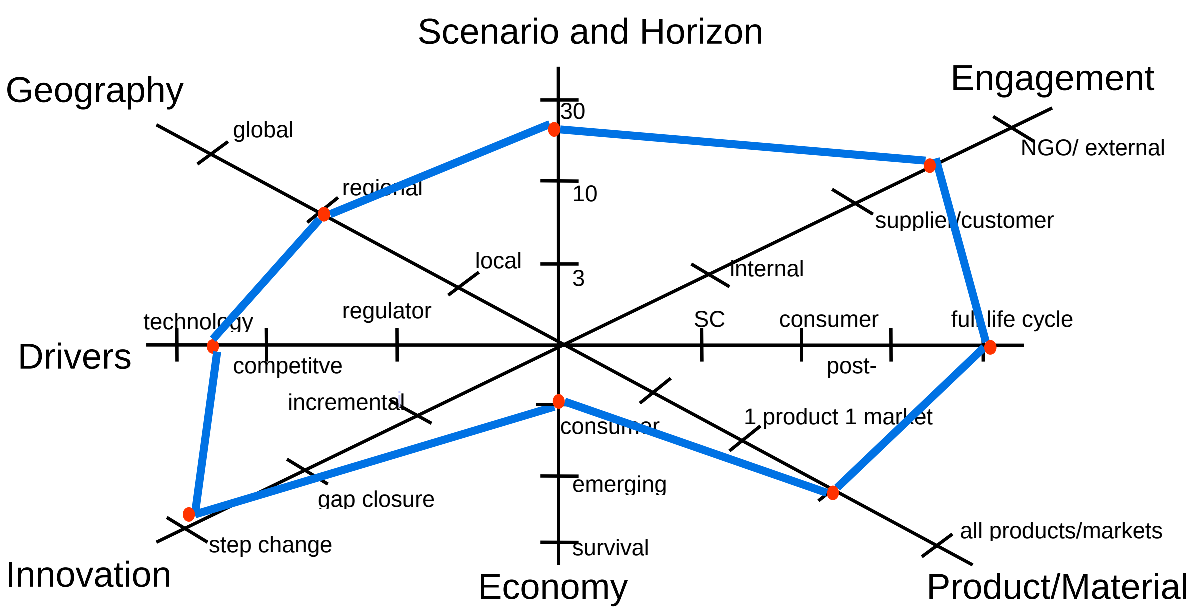


Figure 1. Diagram of study goals, target audience, and context for decision criteria for the WALLTITE ECO™ Eco-Efficiency Analysis.

4.3. *Target Audience*: The target audience for the study has been defined as architects, builders, specifiers and government regulators. It is planned to communicate study results in marketing materials and at trade conferences.

5. Customer Benefit, Alternatives and System Boundaries

5.1. *Customer Benefit*: The Customer Benefit applied to all four alternatives is defined to be the insulation of the exterior of 9 m^2 wall surface of a commercial building residing in Toronto, Canada, with one 0.6 m x 1.22 m window, an R-value of 20 ft^2*hr*F/BTU and over a period of 25 years. The wall assembly meets the National Building Code of

Canada (NBC) and WALLTITE ECO™ meets the Canadian standard for spray polyurethane, CAN/ULC-S705.1. This configuration was chosen since it represents a standard test wall configuration typically utilized by the Canadian government for measuring wall system thermal performance.

5.2. *Alternatives*: The product alternatives compared under this EEA study are summarized in Table 1, and consisted of WALLTITE ECO®, XPS, EPS and Mineral Fiber. These alternatives were selected as they represent the most commonly available technologies when selecting commercial building insulation systems, they represent the majority of the market and reflect updates in technologies (e.g. blowing agents).

Table 1: Summary of study alternatives.

Insulation	Description	Blowing Agent
WALLTITE ECO®	Spray polyurethane foam (closed cell)	Proprietary
XPS	Extruded Polystyrene	CO_2 blend
XPS	Extruded Polystyrene	Hydrofluorocarbon (HFC) blend
EPS	Expanded Polystyrene	Pentane
Mineral Fiber	Mineral wool fiber made from slag and rock	None

5.3. *System Boundaries*: The system boundaries define the specific elements of the production, use, and disposal phases that are considered as part of the analysis. The system boundaries for the four alternatives evaluated in the WALLTITE ECO®, study are shown in Figure 2. The grey boxes were not considered in the analysis because they are the same for all the alternatives. The processes/stages specifically excluded include the production of steel, concrete and masonry ties in the Production Phase of the life cycle as well as all the costs and environmental impacts associated with the Use Phase of the commercial building and the removal of the wall system prior to Disposal.

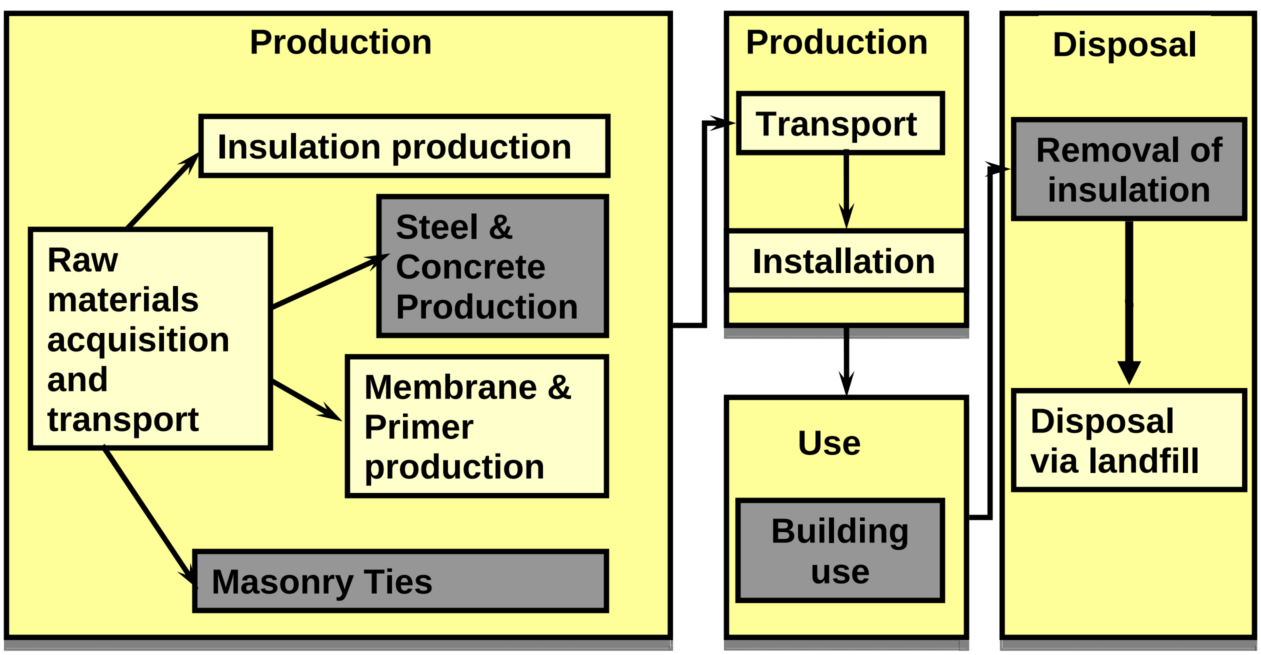


Figure 2. System boundaries

6. Input Parameters and Assumptions

6.1. *Input Parameters*: A comprehensive list of input parameters were included for this study and considered all relevant material and operational characteristics for the four insulation alternatives. The insulation formulations and parameters are given in Tables 2 and 3. Additionally, Table 4 provides parameters related to material handling and disposal. For this analysis the absolute input values associated with environmental and costs impacts were considered.

Insulation Parameters: The insulation alternatives were parameterized based on representative compositions from either company specific data, Environmental Product Declarations (EPDs) or Material Safety Data Sheets (MSDSs). Some of the formulations used for this study are confidential, but full formulations were disclosed to NSF International for the purposes of this verification. Table 2 provides general formulations for the five alternatives.

WALLTITE ECO®		XPS - HFC blend		XPS - CO2 blend		EPS		Mineral Fiber	
Component	% wt	Component	% wt	Component	% wt	Component	% wt	Component	% wt
MDI	50	Polystyrene	90	Polystyrene	90	Polystyrene	93	Mineral Fiber	95
Polyol	32	Flame Retardant (HBCD)	1	Flame Retardant (HBCD)	1	Flame Retardant (HBCD)	0.5	Binder	5
Flame Retardant	8								
Proprietary Blowing Agent	10	Blowing Agent	8	Blowing Agent	8	Blowing Agent	6.5		
		Additives	1	Additives	1				
Total	100	Total	100	Total	100	Total	100	Total	100

Table 2: General Insulation Formulations for alternatives

Construction Parameters: A sample commercial wall section was defined in order to establish the functional unit of comparison between the alternatives. For this study, the functional unit or customer benefit was defined as the insulation of the exterior of a 9 m^2 wall surface for a commercial building with one (1) 0.6 m x 1.22 m window, an R value of 20 $ft^2 * hr * {}^oF/BTU$ (3.52 $K*m^2/W$) and meeting Canadian building code This configuration is consistent with the typical Canadian government test set-up. The life cycle was set at 25 years.

WALLTITE ECO® is the only alternative which does not require the entire insulated surface (wall minus window opening) to be covered with an air/vapor barrier membrane as it has been approved by the National Research Council Canada as an approved air barrier system[8]. In addition, the other alternatives require additional membrane at each masonry tie since they are not approved as air/vapor barriers at this time. WALLTITE ECO® does require a transition or flashing membrane in order to account for building expansion and contraction at the insulation borders.

Third party testing[10] in accordance with CAN/ULC-S705.1-01 (Canadian Building Code Standard for Spray Applied Rigid Polyurethane Foam, Medium Density; Material Specification) was utilized to establish key material properties for WALLTITE ECO® such as core density and long term thermal resistance (LTTR). An approved LTTR (Long-term thermal resistance) test method was used to determine the R-value for WALLTITE ECO®. An R-value of 6.4 (at 3") yields an installed thickness to meet code requirements of 3.1 inches. Summary of the insulation study parameters are highlighted in Table 3.

Energy requirements to install and remove the insulation systems were considered equivalent for all alternatives.

	Units	WALLTITE ECO®	XPS - HFC Blend	XPS - CO2 Blend	EPS	Mineral Fiber
Assembly components						
Masonry tie	Qty/CB	36	36	36	36	36
Membrane						
Area of membrane required	m2/CB	1.2	8.3	8.3	8.3	8.3
Membrane thickness	mm	1	1	1	1	1
Density	kg/m3	1000	1000	1000	1000	1000
Membrane per CB	kg/CB	1.2	8.3	8.3	8.3	8.3
Primer						
Area to be covered	m2/CB	1.2	8.3	8.3	8.3	8.3
Thickness	mm	0.5	0.5	0.5	0.5	0.5
Density	kg/l	1	1	1	1	1
Primer per CB	kg/CB	0.6	4.2	4.2	4.2	4.2
Insulation						
Area to be covered	m2/CB	8.3	8.3	8.3	8.3	8.3
R-value per inch	ft2*h*deg F/(BTU*in)	6.4	4.7	4.1	4	4.2
Thickness	in	3.1	4.3	4.9	5	4.8
Density	kg/m3	28	35	32	20	70
Insulation per CB	kg/CB	19	31	32	21	70
Total material	**kg/CB**	**21**	**43**	**45**	**34**	**83**

Table 3: Summary of insulation study parameters.

Transportation Logistics: The environmental impacts for transporting the insulation materials to the building site as well as transporting them to the landfill during the disposal phase of the life-cycle were considered. A transportation distance of 500 km was determined appropriate for each distance for a total of 1000 km. Diesel fuel was assumed for the truck transport.

	Units	WALLTITE ECO®	XPS - HFC Blend	XPS - CO2 Blend	EPS	Mineral Fiber
Fuel consumption of truck	MJ/ton/km	2.2	2.2	2.2	2.2	2.2
Distance to construction site	km	500	500	500	500	500
Weight of materials transported to construction site	kg/CB	21	43	45	34	83
Fuel consumption to construction site	MJ/CB	23	48	49	37	91
Distance to landfill	km	500	500	500	500	500
Weight of materials transported to landfill	kg/CB	21	43	45	34	83
Fuel consumption to landfill	MJ/CB	23	48	49	37	91

Table 4: Summary of transportation and disposal information

6.2. *Costs:* The economic analysis for the WALLTITE ECO® EEA considered costs associated with materials, installation, transportation and waste disposal costs. Specifically, the analysis took into account the costs of the membrane, primer, insulation material, insulation & membrane installation, fuel required for transportation and waste disposal. Any life-cycle costs that have not been listed were assumed to be equivalent for all five alternatives and therefore were not included in the analysis. The life-cycle cost data was acquired from numerous sources. Specifically, the insulation and membrane costs were supplied by insulation contractors in Canada. Specific suppliers and contacts were supplied to NSF International. The diesel fuel price ($3.75/gallon) and the landfill disposal costs ($113/ton for non-hazardous waste) were assumed to be average values for the region of the study. It was assumed that all building materials went to landfill.

6.3. Further Assumptions: The effect blowing agents have on air emissions as they are released either during manufacturing of the foams and/or diffuse outward during the Use phase was considered for WALLTITE ECO®, XPS and EPS. Various literature sources were referenced[6] and provided to NSF International. For WALLTITE ECO®, 25% is released during manufacturing and the 1st year after installation. Thereafter, the rate of diffusion is 1.5%/year. For XPS, two different bases were established based on the alternative. For the alternative with the hydrofluorocarbon (HFC) blend blowing agent, it was assumed that 20% is released during manufacturing and 0.75%/year thereafter. For the alternative with the CO_2 blend, as the blowing agent diffusion rate through the polystyrene cell walls is very high[10], it was assumed that 100% of the CO_2 is released during manufacturing or shortly thereafter. Finally, for EPS, all of the pentane is released during manufacturing. The direct GWP of the various blowing agents as they diffuse into the environment were obtained from the 4th assessment report, Climate Change 2007 by the IPCC[11].

7. Data Sources

7.1. The environmental impacts for the production, use, and disposal of the four alternatives were calculated from eco-profiles (a.k.a. life cycle inventories) for the individual components and for fuel usage and material disposal. Life cycle inventory data for these eco-profiles were from several data sources, including BASF specific production sites, and the quality of this data was considered medium-high to high. None of the eco-profile data was considered to be of low data quality. A summary of the eco-profiles is provided in Table 5.

Table 5: Summary of eco-profiles used in this EEA.

Eco-Profile	Source, Year	Comments
WALLTITE ECO® Insulation		
MDI	BASF, 2011	Specific Manufacturing Data
Polyol Formulation	BASF/Supplier Avg., 2011	BASF and Supplier Confidential Formulation
Biobased Component	Alberdingk Boley, 2007[1]	
Flame Retardant	SRI Report US, Ullmann 2002[2,4]	
Proprietary Blowing Agent	Est. US, 2002	
Proprietary Blowing Agent	Est. US, 2010	
Primer	US, 2002	Henry Bakor Bluekskin® Technical data and MSDS
Membrane	US, 2002	Henry Bakor Bluekskin® Technical data and MSDS
Material to Landfill	BUWAL 250 Library[7], 1998	
XPS Insulation		
Polystyrene	Boustead[5],2008	Plastics Europe
HFC-134a	SRI Report US, 2002[3]	
HFC-152a	Est. US, 2010	
Hexabromocyclododecane (HBCD)	SRI Report US, Ullmann, 2002[2,4]	
Primer	US, 2002	Henry Bakor Bluekskin® Technical data and MSDS
Membrane	US, 2002	Henry Bakor Bluekskin® Technical data and MSDS
EPS Insulation		
Polystyrene	Boustead[5], 2008	Plastics Europe
Pentane	Boustead[5], 1996	
Primer	US, 2002	Henry Bakor Bluekskin® Technical data and MSDS
Membrane	US, 2002	Henry Bakor Bluekskin® Technical data and MSDS
Mineral Fiber Insulation		
Mineral Fiber	Industry Avg., 2009	
Membrane	US, 2002	Henry Bakor Bluekskin® Technical data and MSDS
Primer	US, 2002	Henry Bakor Bluekskin® Technical data and MSDS
Diesel Use – US	U.S. Avg., 1999	Most reliable profile available[5]
Solid Waste to Landfill	U.S. Avg., 2000	Most reliable profile available[5]
BASF data sources are internal data, while the others are external to BASF. Internal data is confidential to BASF; however, full disclosure was provided to NSF International for verification purposes.		

8. Eco-efficiency Analysis Results and Discussion

8.1. *Environmental Impact Results*: The environmental impact results for the WALLTITE ECO® EEA are generated as defined in Section 6 of the BASF EEA methodology.

8.1.1. *Primary energy consumption*: Energy consumption, measured over the entire life cycle, shows that WALLTITE ECO® has the lowest energy consumption, using

1,852 MJ of energy per customer benefit. Overall, it can be seen from Figure 3 that the key driver for energy consumption for each alternative is the insulation material. WALLTITE ECO® has advantages due to its heat-transfer characteristics, relatively low density and that it requires the least amount of membrane and primer. This is equivalent to an almost 50% reduction in energy consumption relative to the alternatives with the highest level of primary energy consumption, XPS, which both came in slightly above 3,820 MJ/CB. The XPS alternatives have the highest energy consumption since they use a large amount of polystyrene (high energy intensity) and require the full membrane. The WALLTITE ECO® insulation is followed by the mineral fiber alternative, which uses 2,600 MJ of energy per customer benefit over the entire life cycle.

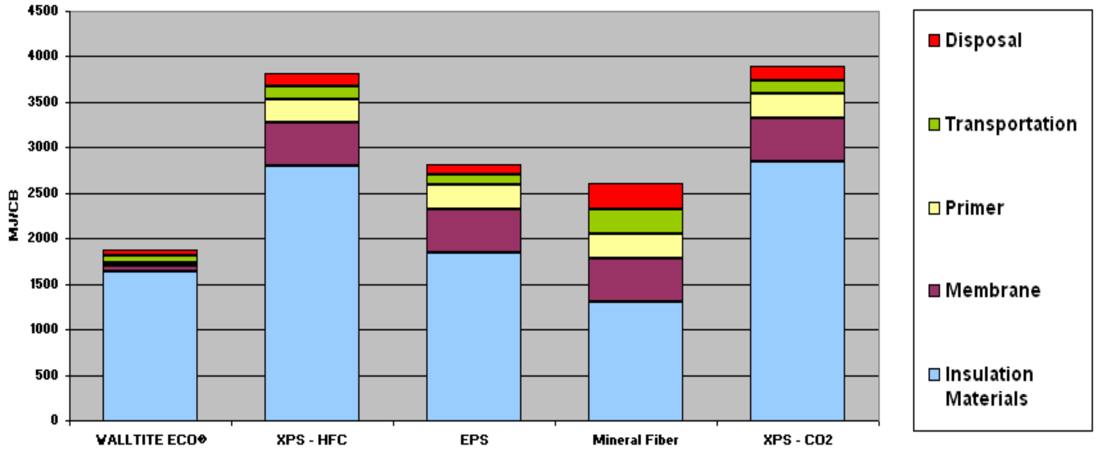


Figure 3. Primary energy consumption.

8.1.2. *Raw material consumption*: It is clear from Figures 4 and 5 that the XPS insulation alternatives consume the largest amount of raw materials, specifically fossil fuels (coal, oil, and natural gas) over the life cycle relative to the other alternatives. The largest reduction in raw material consumption compared to XPS occurs for the WALLTITE ECO® insulation, which amounts to a nearly 50% reduction in raw material consumption. WALLTITE ECO® benefits by having exceptional thermal resistance and barrier properties which enable the usage of the least amount of insulation material of all the alternatives to achieve the desired insulation value and air/vapor permeance. WALLTITE ECO® also benefits by using polyols made from recycled materials (i.e. PET plastics). The key drivers for the fossil fuel consumption are the insulation, membrane and primer materials used in the production phase of the life cycle. With regards to transportation and disposal impacts, alternatives which require more material to achieve the defined customer benefit will be impacted more heavily due to higher fuel consumption and end of life disposal requirements.

Per the BASF EEA methodology, individual raw materials are weighted according to their available reserves and current consumption profile. These weighting factors were appropriate considering the context of this study as they are determined on a global and not regional basis.

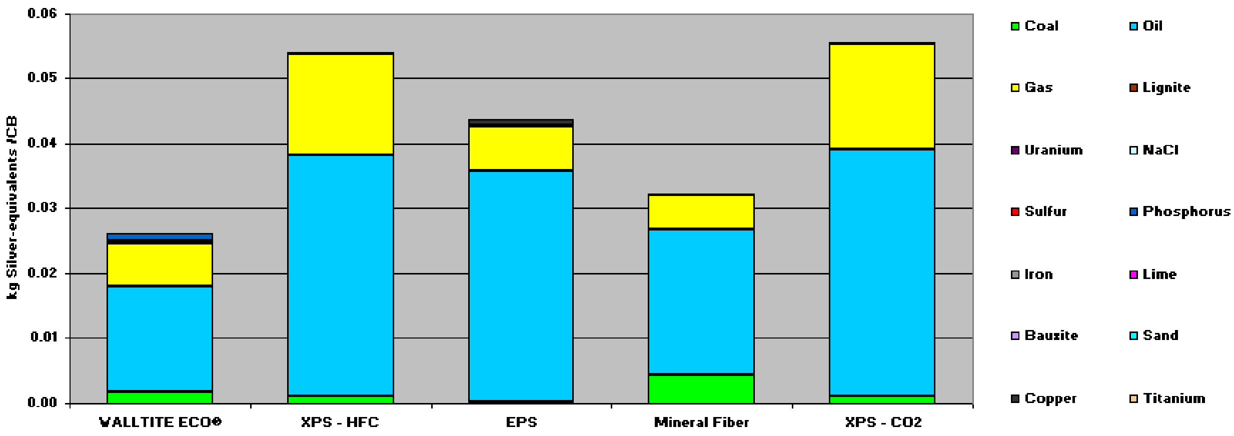


Figure 4. Raw Material consumption by type

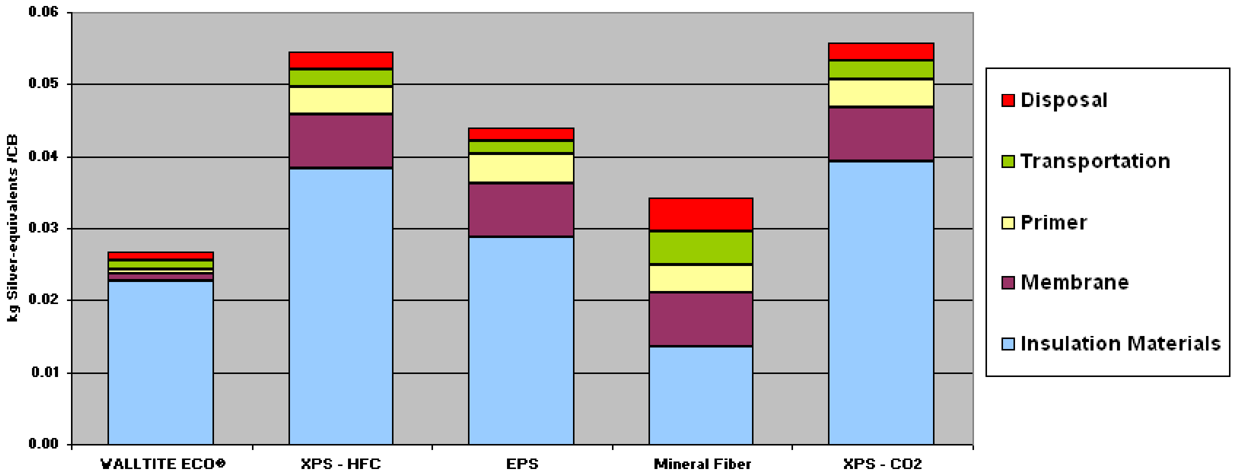


Figure 5. Raw Material consumption by module

8.1.3. *Air Emissions*:

8.1.3.1. *Global warming potential (GWP)*: The GWP of all material and energy streams over the defined life cycle were considered. This includes, for example, all raw materials required for the alternative wall systems (including the blowing agents), transportation of these materials to and from the construction site and the disposal of these materials. However, the main driver of this impact area is the inherent GWP associated with the individual blowing agents for Walltite ECO®, XPS, and EPS foams. These alternatives continue to adapt (reformulate) to accommodate more stringent regulations and pressures around blowing agents and their impact on climate change. The highest carbon footprint occurred in the WALLTITE ECO® and XPS insulation (with hydrofluorocarbon blend), with a measurement of nearly 1,700 kg of CO_2 equivalents per customer benefit. The lowest carbon footprint, with respect to the other alternatives, is for the EPS insulation, which results in the emission of 70 kg of CO_2 equivalents per customer benefit. Though sacrificing overall thermal performance which will have an impact in the amount of insulation material required, the XPS – CO_2 blend alternative was able to reduce its carbon footprint by over 90% by moving away from a hydrofluorocarbon blowing agent.

Land use changes related to the bio-based content in Walltite ECO® and its impact on the GWP for this alternative was not considered significant enough to include in this analysis.

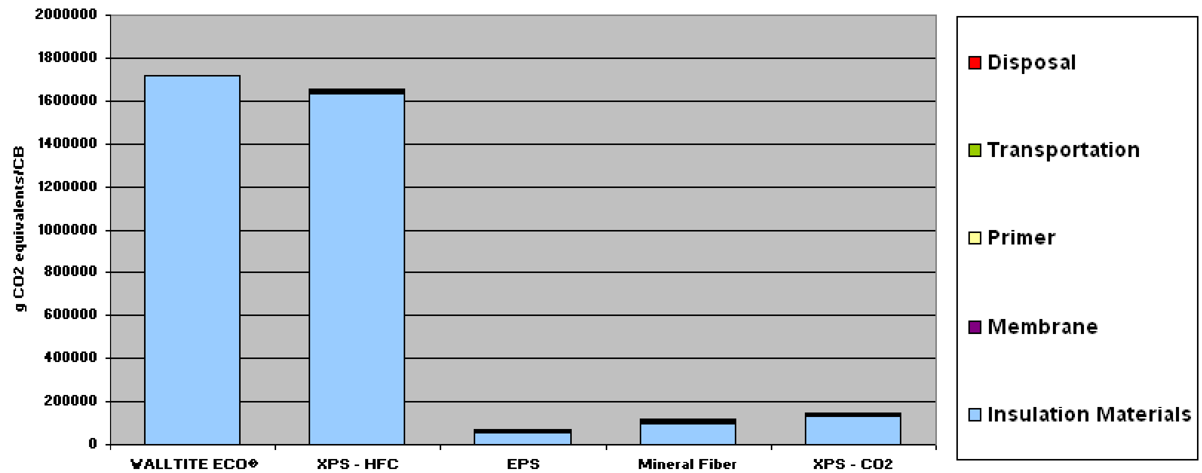


Figure 6. Global warming potential.

8.1.3.2. *Photochemical ozone creation potential (POCP, smog)*: The POCP of all material and energy streams over the defined life cycle were considered. This includes, for example, all raw materials required for the alternative wall systems (including the blowing agents), transportation of these materials to and from the construction site and the disposal of these materials. The largest photochemical ozone creation potential occurs in the EPS insulation, with a measurement of over 850 g of ethylene equivalents per customer benefit. The largest single contributor is the blowing agent for EPS, pentane. The smog potential of Pentane contributes over 60% to the life cycle POCP potential for the EPS alternative. The lowest emissions for ground level ozone formation potential occur in the WALLTITE ECO® alternative, with 84 g of ethylene equivalents emitted per customer benefit. The XPS insulation follows with emissions of slightly over 100 g of ethylene equivalents per customer benefit. The XPS alternative with the CO_2 blend has a non-halogenated VOC co-blowing agent which contributes to POCP. Excluding the blowing agents, other contributors to the POCP potential for each alternative are the CH_4 and non-methane VOCs generated during the production of the basic insulation materials and emitted during transport.

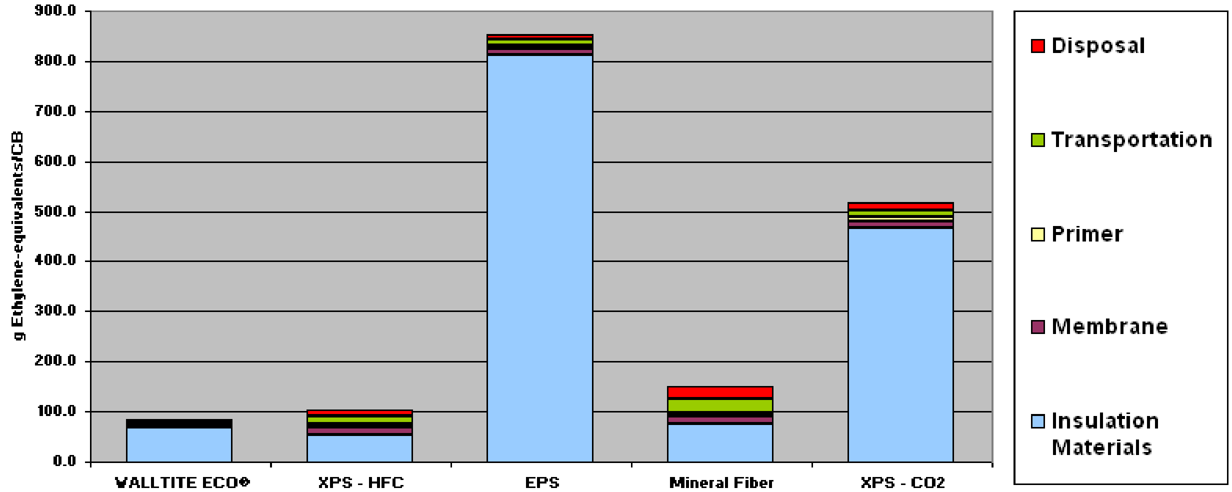


Figure 7. Photochemical ozone creation potential.

8.1.3.3. *Ozone depletion potential (ODP)*: The ODP of all material and energy streams over the defined life cycle were considered. This includes, for example, all raw materials required for the alternative wall systems (including the blowing agents), transportation of these materials to and from the construction site and the disposal of these materials. Overall, all five of the alternatives result in very minimal ozone depletion potentials, measured at 0.006-0.11 g CFC-11 equivalents per CB. None of the alternatives use ozone depleting blowing agents. The chemistries associated with the resin pre-chain manufacturing for Walltite ECO® contribute to its slightly higher impact.

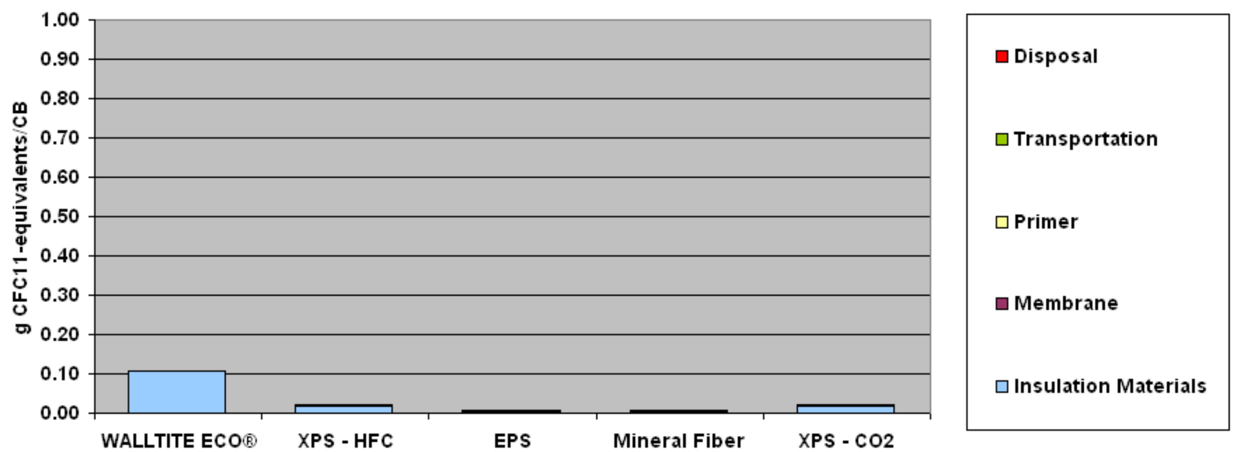


Figure 8. Ozone depletion potential.

8.1.3.4. *Acidification potential (AP)*: The acidification potential of all material and energy streams over the defined life cycle were considered for each alternative. This includes, for example, all raw materials required for the alternative wall systems (including the blowing agents), transportation of these materials to and from the construction site and the disposal of these materials. It can be seen from Figure 9 that overall, the EPS insulation has the lowest acidification potential over the entire life cycle, with emissions of around 320 g of SO_2 equivalents per customer benefit, a 75% decrease relative to the Mineral Fiber insulation, which has the highest emission potential, of over 1,400 g of SO_2 equivalent per customer benefit. Additionally, the WALLTITE ECO® has an acidification potential of 444g of SO_2 equivalents while the XPS alternatives are in a range between 520g and 540g of SO_2 equivalents respectively per customer benefit, which falls between the other alternatives. AP primarily results from NO_x, HCl, SO_x, and NH_3 generated in order to produce the insulation materials.

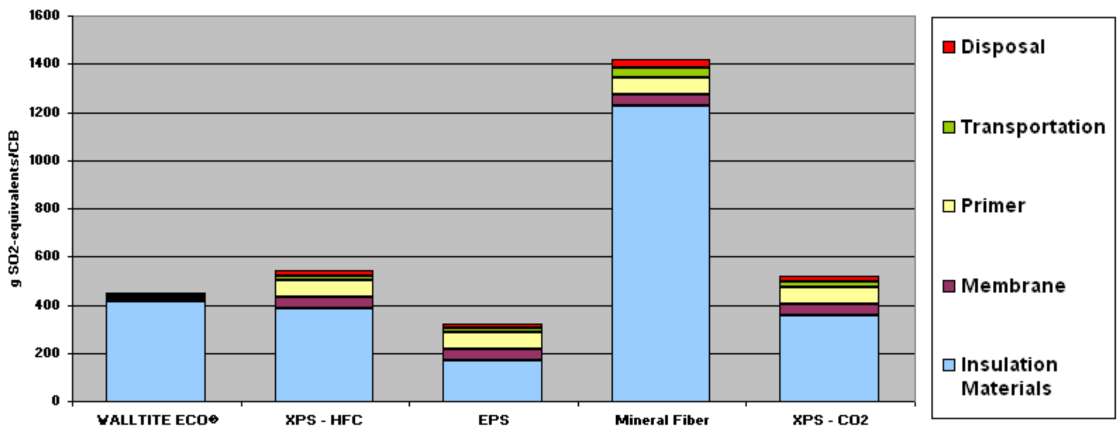


Figure 9. Acidification potential.

8.1.4. *Water emissions*: Figure 10 displays that relative to all the alternatives, the EPS insulation has the lowest critical waste water volume requirement at 2,860 L/CB, followed closely by the XPS alternatives at around 3,300 L/CB. The WALLTITE ECO® insulation has the highest water emissions, measured at around 14,224 L/CB. It is the production of the insulation materials, specifically the resin and isocyanate for Walltite ECO®, which contributes the most to the critical waste water volume, particularly through the emissions of chemical oxygen demand (COD), hydrocarbons and chlorine (Cl^-) during manufacturing.

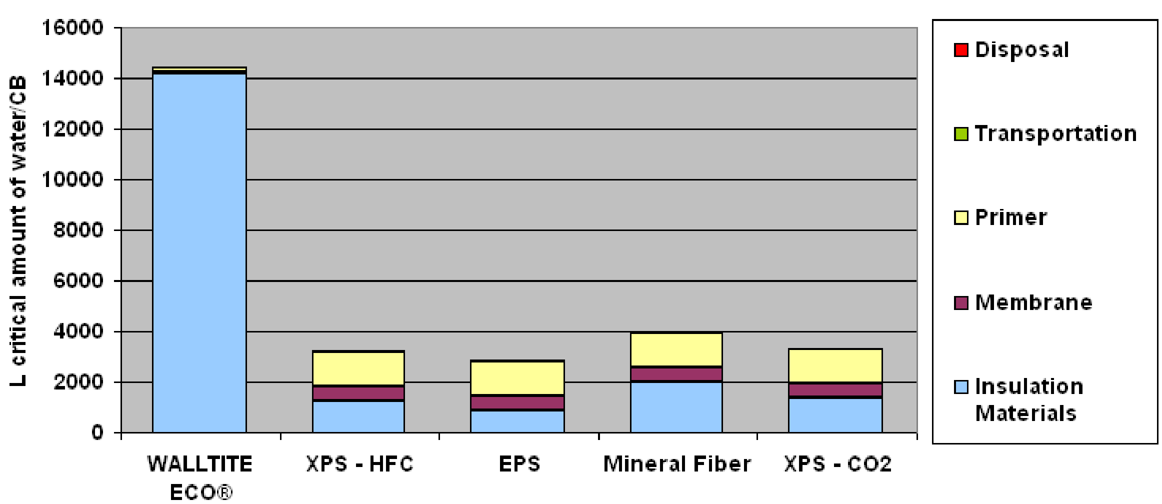


Figure 10. Water emissions.

8.1.5. *Solid waste generation*: The WALLTITE ECO® insulation generates 75% less solid waste (by weight) when compared to the Mineral Fiber insulation and 60% less (by weight) when compared to the XPS insulations. The results in Figure 11 indicate that the solid wastes sent to landfill as part of the Disposal phase of the life cycle dominate this impact category. The differences between the alternatives is directly related to the mass (weight) of material installed in order to meet the required insulation and air barrier code requirements (e.g. referencing Table 3, ~83 kg required for the mineral fiber alternative and only 21 kg required for Walltite ECO®). The category that contributes the highest amount within the waste categories is construction waste. By using recycled material, WALLTITE ECO® reduces solid waste emissions to landfill by around 5% on a weighted basis.

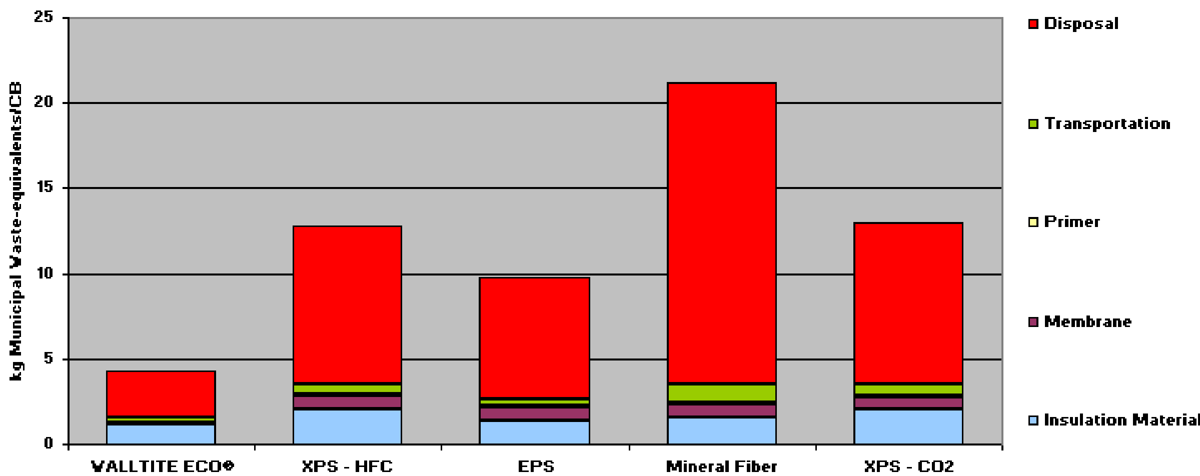


Figure 11. Solid waste generation.

8.1.6. *Land use*: As displayed in Figure 12, the WALLTITE ECO® insulation impacts the least amount of land, while the Mineral Fiber and XPS insulation alternatives impact the most amount of land over the entire life cycle. The results are primarily driven by the impacts of the transportation requirements to enable the transfer of material to the job site and eventually to its end of life disposition in a landfill. Roads required for transportation seal and split eco-systems. This severe impairment of the land is given the biggest impact weighting of all land use categories. Transportation requirements for each alternative are directly related to the mass of material that is required to be transported. Thus mineral fiber will have the highest impact as it requires the most material and Walltite ECO®, which requires the least amount of material of all alternatives, has the least impact related to transportation and overall as well. For the petroleum based insulation materials, the land use impact of the insulation materials also contributes significantly. Overall, WALLTITE ECO® uses 60% less land relative to the Mineral Fiber and XPS insulation alternatives and about 50% less when compared to the EPS alternative.

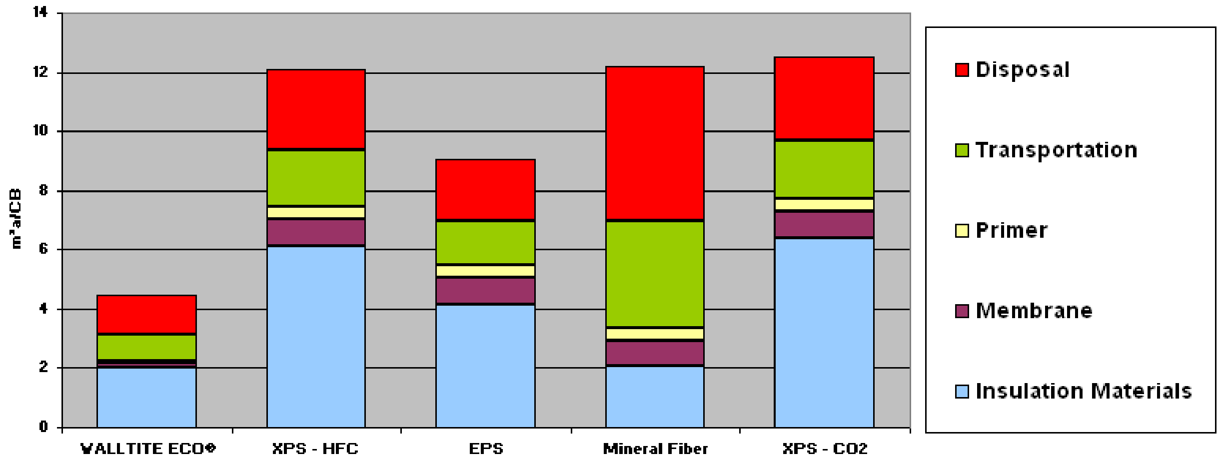


Figure 12. Land use.

8.1.7. *Toxicity potential*: The toxicity potential for the various insulation alternatives was analyzed for the production, use and disposal phases of their respective life cycles. For the production phase, not only were the final products considered but the entire pre-chain of chemicals required to manufacture the products were considered as well. An inventory of all relevant materials were quantified for the three life cycle stages. Consistent with our methodology's approach for assessing the human health impact of these materials (ref. Section 6.8 of Part A submittal), a detailed scoring table was developed for each alternative broken down per module (Figure 13) as well as life cycle stage (Figure 14). This scoring table with all relevant material quantities considered as well as their R-phrase and pre-chain toxicity potential scores were provided to NSF International as part of the EEA model which was submitted as part of this verification. As displayed in Figure 13 below, transportation and the disposal phase of the materials contributes the largest amount to the toxicity potential. The high scoring for transportation has to do with the health impacts associated with diesel fuel and emissions from fuel combustion combined with the fact that a higher weighting is applied to these scores due to the nature that they occur in an open system and thus an easier exposure route to humans. Though the production phase of the insulation materials, especially the petroleum based products, involve materials with high pre-chain toxicity scores, this is mitigated by the fact that a high safety standard of manufacturing was assumed for each of the alternatives resulting in a reduction in the exposure rate and thus a lower weighting factor was applied. No reduction in the scores based on exposure conditions was applied for the disposal phase of the materials as the potential for human contact during removal and disposal of the insulation is high. Finally, the toxicity potential weightings for the individual life cycle phases were production (20%), use (70%) and disposal (10%). These standard values were not modified for this study.

As indicated in Figures 13 and 14 below, mineral fiber has the highest toxicity. This is directly attributed to the toxicity potential of the increased fuel consumption and emissions related to the transport of a significantly higher weight of material than the other alternatives. Just considering the insulation, mineral fiber has the lowest score but when you include the entire insulation system components (insulation + membrane + primer), WALLTITE ECO® had the lowest score due to low overall material usage, less transport impacts and since impacts related to the air barrier membrane and primer were minimized as Walltite ECO® is an approved air barrier system and thus does not require a full air barrier membrane system.

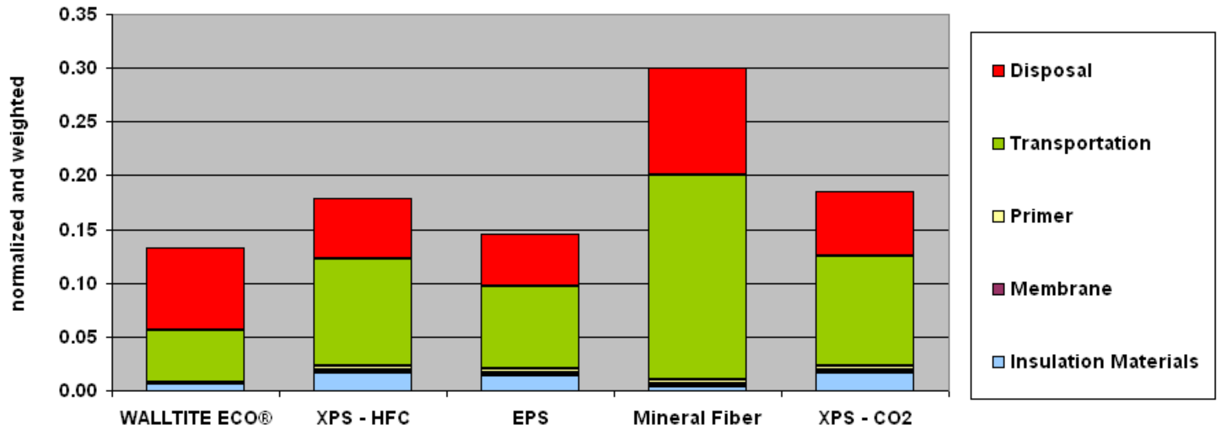


Figure 13. Toxicity Potential by Module

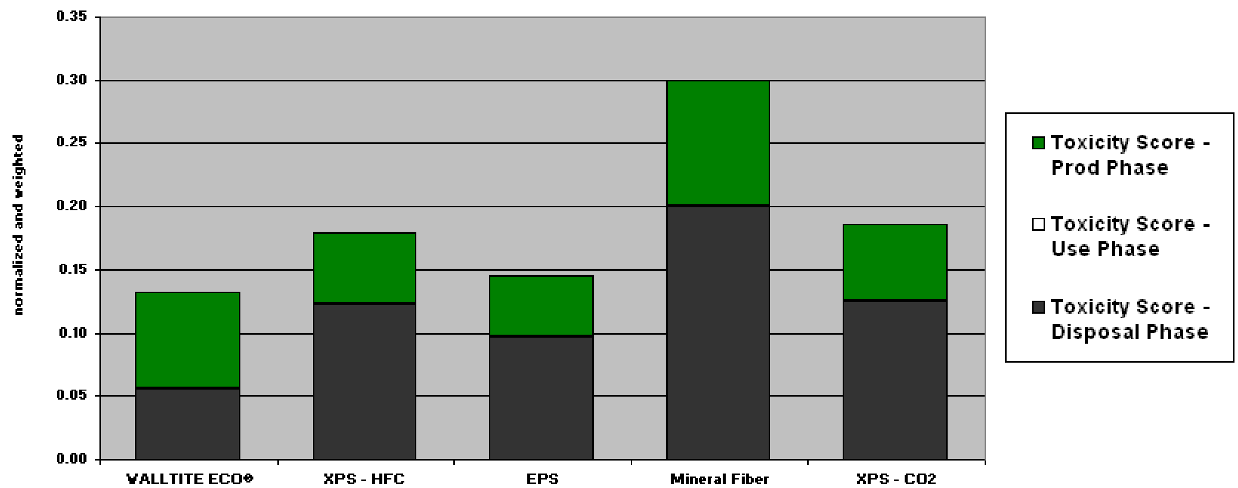


Figure 14. Toxicity Potential by Life Cycle Stage

8.1.8. *Risk potential*: All the materials and activities accounted for in the various life cycle stages were assigned specific NACE codes. NACE (Nomenclature des Activities Economiques) is a European nomenclature which is very similar to the NAICS codes in North America. The NACE codes are utilized in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the business economy and is broken down by specific industries. Specific to this impact category, the NACE codes track, among other metrics, the number of working accidents, fatalities and illnesses and diseases associated with certain industries (e.g. chemical manufacturing, agriculture, etc.) per defined unit of output. By applying these incident rates to the amount of materials required for each alternative, a quantitative assessment of risk is achieved. Similarities between the specific industries in the EU and Canada (North America) allowed for the application of this data when considering the context of this study.

For this study, an additional risk category related to the hazards related to the storage and transport of the insulation materials was considered. This study put a 10% weighting on this specific risk which was at the midpoint of the range (0-20%) that additional risk categories can have. Figure 15 shows that risks related to the production of insulation materials contribute the largest amount. The alternative with the lowest risk are the XPS alternatives, while Mineral Fiber has the highest impact. The quantity of insulation material required coupled with the risks associate with the manufacturing of mineral fiber insulation contributes to mineral fiber having the highest score. Walltite ECO®'s high score in the supplemental risk area is attributed to the over pressurization risks associated with the storage and handling of isocyanate, a key raw material.

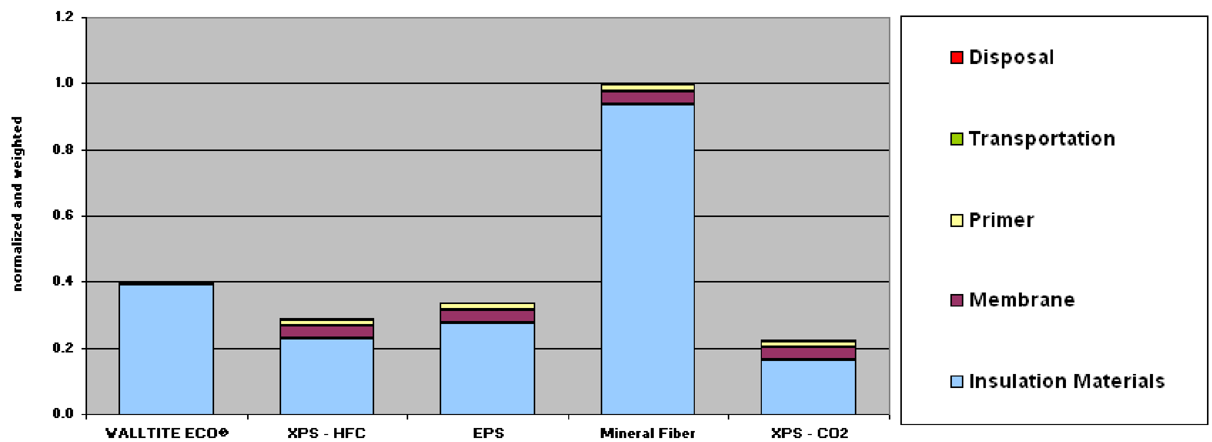


Figure 15. Risk by Module

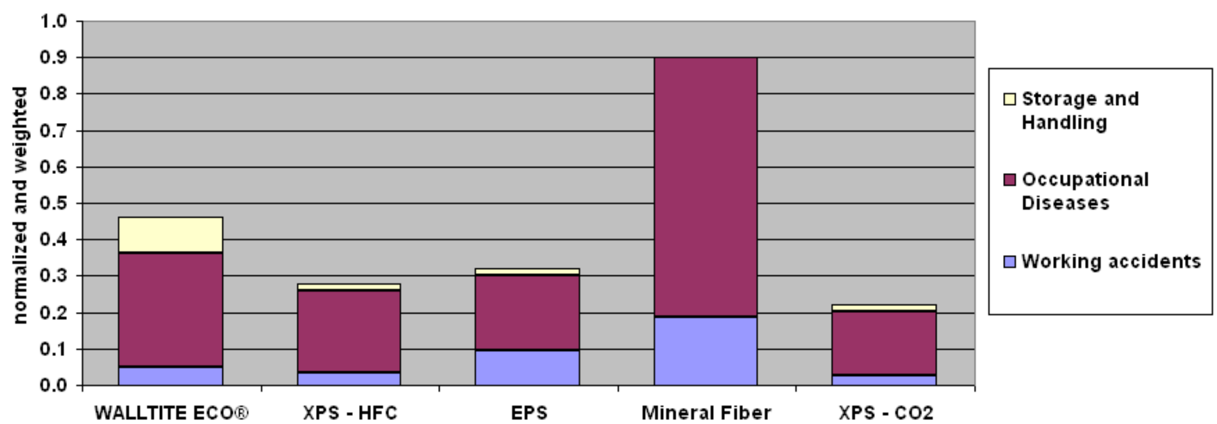


Figure 16. Risk by Impact Category

8.1.9. *Environmental Fingerprint*: Following normalization, or normalization and weighting with regards to emissions, the relative impact for all six of the environmental categories for each alternative is shown in the environmental footprint (Figure 16). WALLTITE ECO® does well in all categories except for risk and emissions, the most relevant impact category for this study. The major benefit for WALLTITE ECO® is that it requires the least amount of material to achieve the customer benefit. Walltite ECO® and the XPS – HFC alternative do not fair well in the emissions category due to the inherent GWP of their blowing agents. This effect is evident by the improved positioning of the XPS- CO_2 alternative relative to the XPS-HFC alternative in the emissions category. EPS also does well in most categories because of its low use of insulation material and its use of a low GWP blowing agent. Mineral fiber scores poorly in risk (occupational illnesses and accidents), land use and toxicity potential because of the large amount of insulation material required and the nature of its manufacturing process. XPS does not score well in most categories (energy consumption, resource consumption, land use) because of the large amount of polystyrene required during manufacturing.

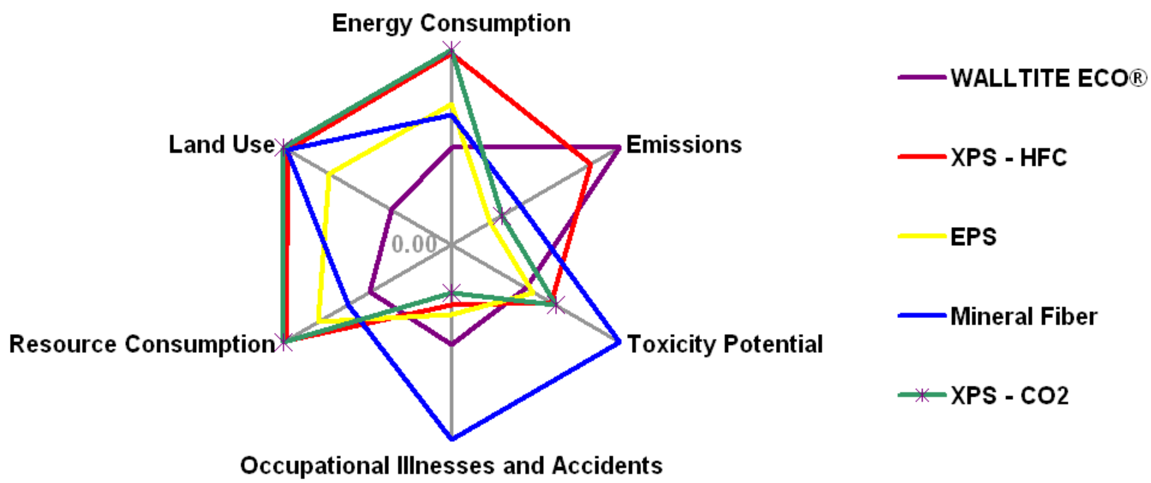


Figure 17. Environmental fingerprint.

8.2. *Economic Cost Results*: The life cycle cost data for the WALLTITE ECO® EEA are generated as defined in Section 7 of the BASF EEA methodology, which has been validated by NSF International under the requirements of Protocol P352 Part A. The results of the life cycle cost analysis found that the XPS alternatives have the highest life cycle costs and the alternative with the lowest life cycle cost is WALLTITE ECO®. From Table 6 and Figure 17, it can be clearly seen that the material costs associated with the insulation, membrane and primer are the overwhelming driver of the total cost for each alternative. The cost analysis was based on a "point in time" and was deemed appropriate for the context and scope of this study. Costs were supplied on a regional level (Toronto, Canada) by 3rd party material suppliers.

Item Costs	Units	WALLTITE ECO®	XPS - HFC Blend	XPS - CO2 Blend	EPS	Mineral Fiber
Materials and Installation						
Membrane and Primer	$/CB	29	269	269	269	269
Insulation		296	320	356	294	191
Total Material and Installation Costs	$/CB	325	590	625	563	461
Transportation						
Total Transportation Costs	$/CB	1	1	1	1	3
Waste						
Landfill Disposal Costs	$/CB	2	5	5	4	9
Total	**$/CB**	**328**	**596**	**632**	**568**	**473**

Table 6: Life cycle costs

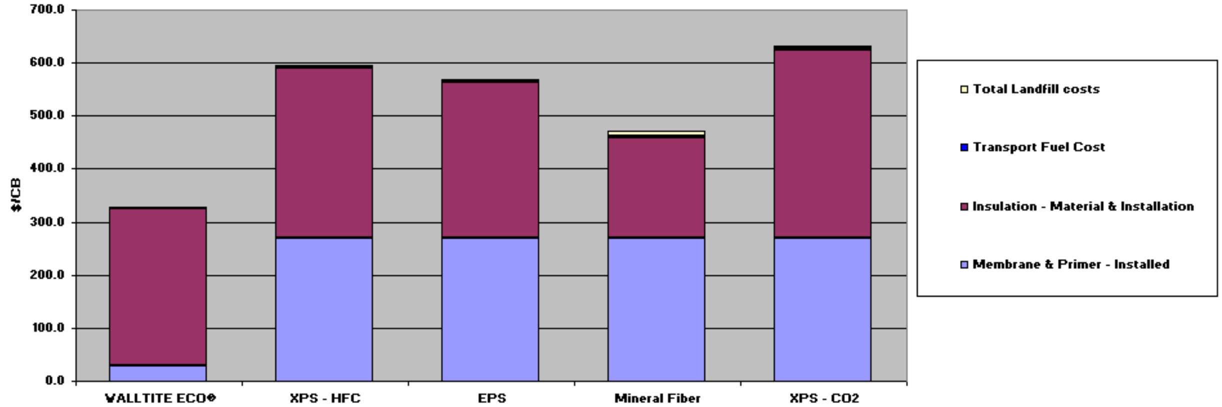


Figure 17. Life cycle costs

8.3. *Eco-Efficiency Analysis Portfolio*: The Eco-efficiency analysis portfolio for the WALLTITE ECO® EEA has been generated as defined in Section 9.5 of the BASF EEA methodology. Utilizing both environmental relevance factors and social weighting factors, study specific calculation factors were calculated and utilized in order to determine and translate for each alternative shown the fingerprint results to the position on the environmental axis. For a clearer understanding of how weighting and normalization is determined and applied please reference Section 8 of BASF's Part A submittal to Protocol P352. Specific to this study, the worksheets "Relevance" and "Evaluation" in the EEA model provided to NSF International as part of this verification process should be consulted to see the specific values utilized and how they were applied to determine the appropriate calculation factors. Specific to the choice of environmental relevance factors to this study, factors for Canada were utilized and social weighting factors applied to this study, factors for the USA were utilized. The environmental relevance values utilized were last reviewed in 2010 and the social weighting factors were recently updated in 2009 by an external, qualified 3rd party[9].

Figure 18 displays the eco-efficiency portfolio, which shows the results when all six individual environmental categories are combined into a single relative environmental impact and then combined with the life cycle cost impact. Because both environmental impact and costs are equally important, the most eco-efficient alterative is the one with the largest perpendicular distance above the diagonal line. The results from this study clearly find that WALLTITE ECO® is the most eco-efficient alternative due to its combination of low environmental burden and having the lowest life cycle cost. Mineral fiber is the next best alternative, but is almost 50% less eco-efficient than WALLTITE

ECO®. Though EPS has the lowest overall environmental impact, it is burdened with higher life cycle costs and thus is not as eco-efficient as either mineral fiber or WALLTITE ECO® but performs better overall than the two XPS alternatives. Both XPS alternatives are of comparable eco-efficiencies. XPS with the HFC blowing agents has the highest environmental impact of all alternatives. Because of its better thermal performance relative to the XPS with the CO_2 based blowing agent, The XPS-HFC alternative achieves slightly lower life cycle costs due to lower material requirements. The XPS with CO_2 blowing agent improves its environmental position by about 20% relative to XPS with HFC but has the highest life cycle cost of all the alternatives considered.

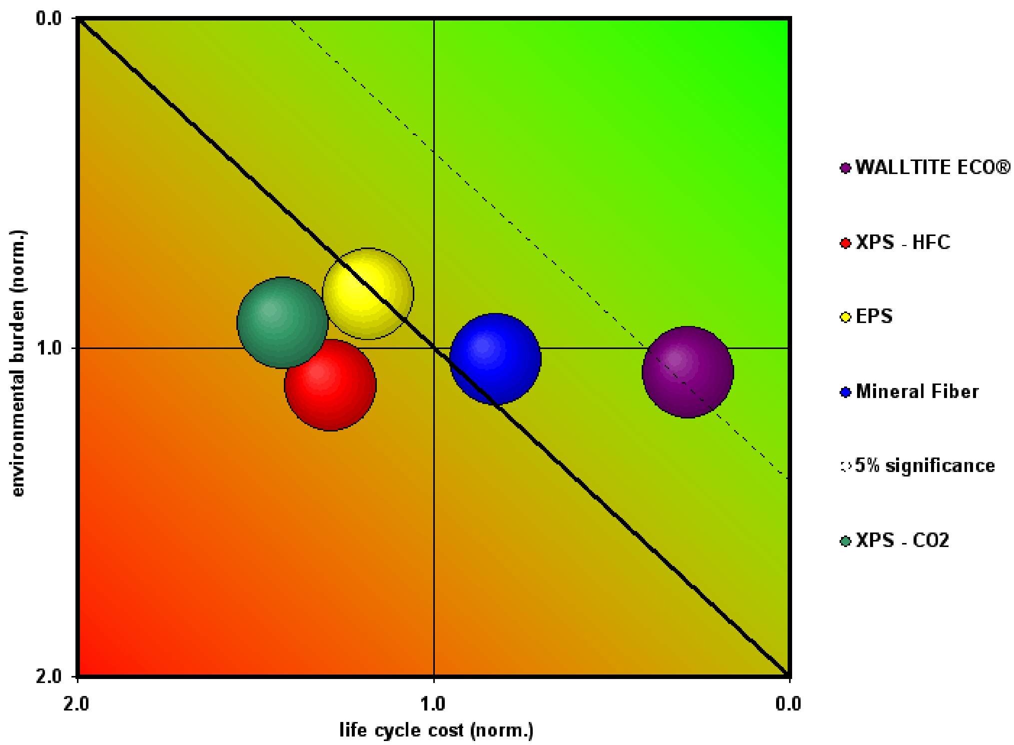


Figure 18. Eco-Efficiency portfolio. – Walltite ECO® EEA Study

9. Data Quality Assessment

9.1. *Data Quality Statement*: The data used for parameterization of the EEA was sufficient with most parameters of high data quality, which means the data was specific to this study context and goals. Moderate data is where industry average values or assumptions pre-dominate the value. No critical uncertainties or significant data gaps were identified within the parameters and assumptions that could have a significant effect on the results and conclusions. Table 7 provides a summary of the data quality for the EEA.

Table 7: Data quality evaluation for EEA parameters.

Parameter	Quality Statement	Comments
Insulation Parameters		
WALLTITE ECO® Formulation	High	Known formulation. Many eco-profiles were developed specifically for this study and are based on current technologies and supplier data.
Alternative Insulation Formulations	Moderate-High	Avg. industry data supported by recent EPDs (Environmental Product Declarations) and specific product data sheets. Assumed values are reasonable given study context and goals
Blowing Agent Formulations	Moderate-High	Assumed values are reasonable given study context and goals
Additives Formulations	Moderate-High	Assumed values are reasonable given study context and goals
R-Values	High	Measured or supplier provided data
Densities	High	Measured or supplier provided data
Blowing Agent Emissions and Air Emissions Impact	Moderate-High	Cited literature sources[6]. Assumed values are reasonable given study context and goals
Wall Assembly Design and Components	High	Standard industry/government test set-up
Air Barrier System Materials	High	Supplier information
Waste Parameters		
Disposal method	High	Assumed values are reasonable given study context and goals.
Transportation Parameters		
Distance and fuel consumption	Moderate	Assumed values are reasonable given study context and goals.
Costs		
Insulation and Membrane Material and Installation	High	Current prices for region of study. Obtained from BASF and 3rd party suppliers.
Fuel	High	Current price for region of study
Material Disposal	Moderate-High	RS Means. Building and construction cost data (specific to Toronto, Canada)

10.Sensitivity and Uncertainty Analysis

10.1. *Sensitivity and Uncertainty Considerations:*

A sensitivity analysis of the final results indicates that the economic impacts were more influential or relevant in determining the final relative eco-efficiency positions of the alternatives. This conclusion is supported by reviewing the BIP Relevance (or GDP-Relevance) factor calculated for the study. The BIP Relevance indicates for each individual study whether the environmental impacts or the economic impacts were more influential in determining the final results of the study. For this study, the BIP Relevance indicated that the economics were significantly more influential in impacting the results than the environmental impacts (reference the “Evaluation” worksheet in the Excel model for the BIP Relevance calculation) . As the data quality related to the main cost contributors (material costs) was of high quality and was specific to the Toronto area, this strengthened our confidence in the final conclusions indicated by the study.

A sensitivity analysis was also done around the environmental impacts and related study assumptions. The results indicate (reference Figure 19 below) that the impact with the highest environmental relevance was emissions. More specifically, from an air emission standpoint, global warming potential (GWP) was found to have the highest relevance on the results. These results were expected considering the context of the study and can be attributed to the quantity and specific blowing agents used. Data related to the amount of blowing agents utilized and their inherent GWP did not include any data gaps or areas of high uncertainty.

The calculation factors, which considers both the social weighting factors and the environmental relevance factors, indicate which environmental impact categories were having the largest affect on the outcome of the environmental positioning of each alternative as reflected in the portfolio. The impacts with the highest calculation factors were the same as those with the highest environmental relevance factors, which is often the case.

The calculation factors are influenced by the choice of the regional environmental relevance factors and social weighting factors utilized. Environmental relevance factors specific for Canada were utilized but established societal values for the USA were utilized and was deemed by the project team as appropriate for use in this study as values had not been specifically developed for Canada. A sensitivity analysis was conducted around this assumption. With regards to the societal views on the reduction of environmental impacts, the team felt the recent 2009 Expert Survey of the United States should provide a representative regional view (North America) in this respect and would therefore be applicable to Canada. A specific sensitivity analysis was run related to this choice. Values for Brazil, Germany, Europe, Great Britain and China were substituted for the USA values with no significant impact on the final results. Though slightly different portfolio results were obtained for each case, the relative positioning of the alternatives remained the same, with Wallite ECO® still being the more eco-efficient alternative.

Finally, the final conclusions drawn from this study are very robust and stable with the significance interval between the best alternative (Walltite ECO®) and the next best alternative, mineral fiber, determined to be > 50% (reference “Evaluation” worksheet in EEA model for calculation). A clear indication in the distinct eco-efficient advantages of Walltite ECO® as a commercial insulation system.

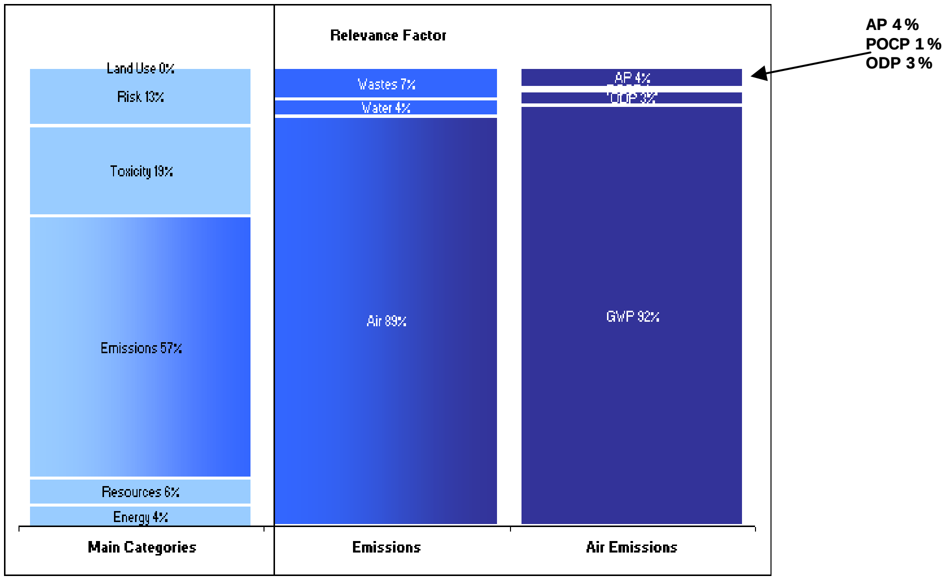


Figure 19. Environmental Relevance Factors – Walltite ECO® EEA

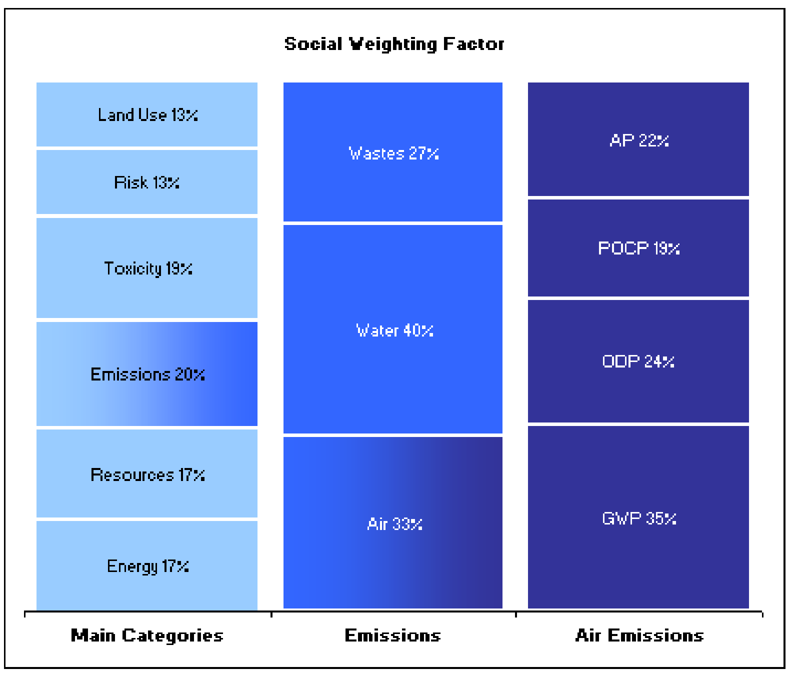


Figure 20. Societal Relevance Factors – Walltite ECO® EEA

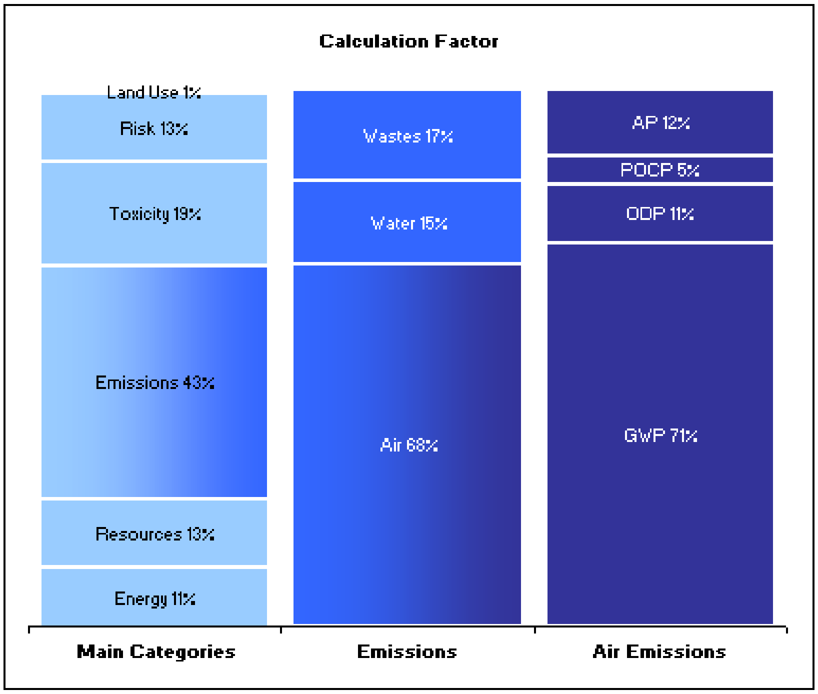


Figure 21. Calculation Factors – Walltite ECO® EEA

10.2. *Critical Uncertainties:* There were no significant critical uncertainties identified for this study that would limit the findings or interpretations of this study. The data quality, relevance and sensitivity of the study support the use of the input parameters and assumptions as appropriate and justified.

11. Limitations of EEA Study Results

11.1. *Limitations*: These Eco-efficiency analysis results and its conclusions are based on the specific comparison of the production, use, and disposal, for the described customer benefit, alternatives and system boundaries. Transfer of these results and conclusions to other production methods or products is expressly prohibited. In particular, partial results may not be communicated so as to alter the meaning, nor may arbitrary generalizations be made regarding the results and conclusions.

12. References

[1] *Alberdink-Boley GmbH Krefeld, Germany. Confidential Company Correspondence 2007*

[2] *SRI Consulting Specialty Chemicals Report Flame Retardants 2002*

[3] *SRI Market Research Report Fluorocarbons 2002*

[4] *Ullmann's Encyclopedia of Industrial Chemistry 6th edition 2002*

[5] *Boustead Consulting Ltd UK, The Boustead Model 5.1.2600.2180 LCA database*

[6] Barthelemy & Fluor. IPCC Conference. *Contribution of HFC Blowing Agents to Global Warming a Producer's View, p.6, 1999.*

Rauscher, Nadine. The Dow Chemical Company. *A comparison of CO2-Equivalent Emissions from the use of various Extruded Polystyrene Foam Insulations, p.7 , 2004.*

State of Oregon DEQ. Proposed Air Quality Permit. *Owens Corning Foam Plant.*

United States EPA. High GWP Gas Emissions 1990-2010: Inventories, Projections and Opportunities for Reductions. *Cost and Emission Reduction Analysis of HFC Emissions from Foams in the US, Chapter 9, June 2001.*

[7] BUWAL 250 Life Cycle Library, 2nd edition, Bundesamt for Umwelt, Wald und Landschaft (Swiss Agency for the Environment, Forests and Landscape)

[8] Evaluation Report CCMC (Canadian Construction Materials Centre) 13467-R Revised 2009-12-08

[9] TNS Infratest Landsberger Strasse 338 Munich Germany 80687

[10] Exova Test Report 11-06-M0257, Interim 2; Evaluation of WALLTITE ECO® v3 in accordance with CAN/ULC-S705.1-01 August 31, 2011.

[11] 2007 IPCC Fourth Assessment Report (AR4) by Working Group 1 (WG1) Chapter 2 section 2.10.2 “Direct Global Warming Potentials”.