Life Cycle Inventory and Assessment

of Selected Low Slope Roofing Systems in North America

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TEGNOS Research, Inc

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EXECUTIVE SUMMARY

This study provides an overview of Life Cycle Assessment (LCA) as applied to selected low slope roofing systems used widely throughout North America. LCA is a scientific approach to evaluating the environmental impact of a product or system throughout its life cycle. The objective of the study was to establish up-to-date life cycle impact data based on a critical review of previous LCA studies and new life cycle inventory data acquired from industry and public sources. The study examined roofing systems employing a variety of roofing membranes, including EPDM, TPO, PVC and SBS modified bitumen. In addition, the study examined a number of common roof system attachment methods, including ballasted, fully adhered and mechanically attached applications. The scope of the life cycle assessment included all inputs associated with the extraction, manufacture and installation of these roofing systems. Outputs measured included all key impacts identified by the US Environmental Protection Agency in its TRACI impact assessment tool.

The study findings suggest that Global Warming Potential (GWP) may be one of the most meaningful measures for comparing the relative environmental impact of low slope roofing systems. GWP appears to be meaningful because significant differences in GWP were observed among the roofing systems studied. Among these roofing systems, GWP as measured in Carbon Dioxide (CO^2) equivalents varied from a low of 22.4 kilograms to a high of 81.8 kilograms per square meter of roof surface, an almost 4-to-1 variation.

The findings also suggest that roof system service life may be critical to determining how effectively environmental impact may be mitigated, or spread over actual service life. As an example, to provide equivalent annual global warming impact, the systems studied would need to deliver a service life from as short as 15 years for the system generating the lowest initial GWP to as long as 54 years for the system generating the highest initial GWP.

The study findings also suggest that method of application plays a relatively minimal role in determining LCA impacts for low slope roofing systems, while product thickness and polymer characteristics may play more important roles. Membrane color may also play a role for certain types of membranes and polymer formulations.

Finally, the EPDM data used in this study, based on up-to-date product formulation, resulted in an environmental impact for EPDM significantly lower than results currently available in public databases that may not contain up-to-date EPDM formulation data. As a result, it may be prudent for building design professionals using the currently available public LCA information to be aware of the significantly reduced EPDM impact data demonstrated by this study.

STUDY BACKGROUND

The Product Life Cycle. Life Cycle Assessment (LCA) is a scientific approach to evaluating the environmental impact of a product throughout its life cycle. The life cycle of a product encompasses the major activities required during the course of the service life of a product, from its manufacture, use, maintenance, and up to its final disposal. Figure 1 illustrates the life cycle stages in a typical LCA along with the inputs and outputs to be considered:

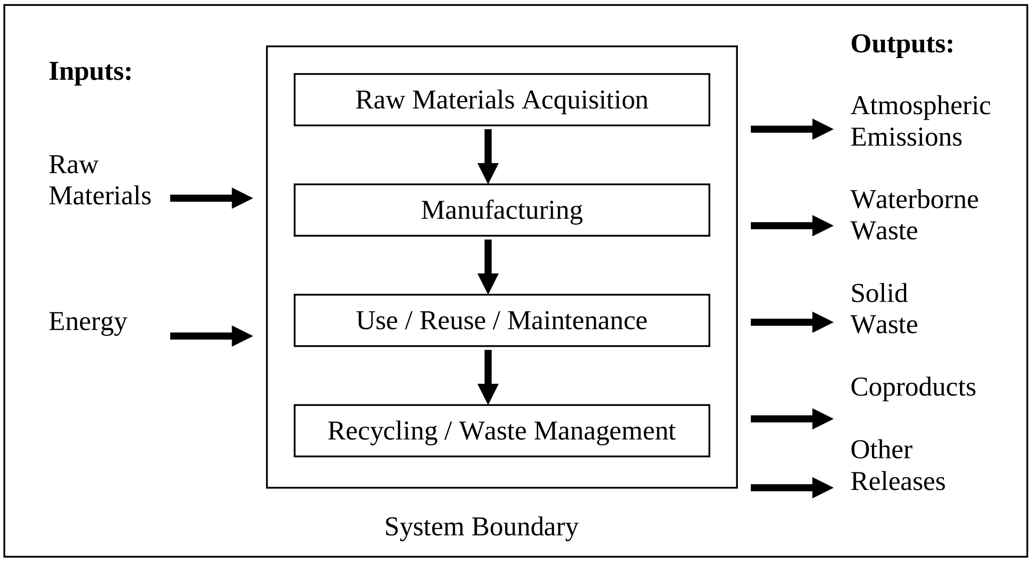

Figure 1: The Product Life Cycle
(Source: Scientific Applications International Corporation, 2006, p.1.)

Environmental impacts are the result of the inputs and outputs over a product's life cycle. Inputs such as raw materials and energy carry with them environmental impacts just as much as obvious environmental outputs such as atmospheric emissions, and solid wastes. Although the total number of different potential environmental impacts may be very large, the U.S. Environmental Protection Agency has identified the major impact categories in its widely-used TRACI (Tool for the Reduction and Assessment of Chemical and other environmental Impacts) tool. These major impact categories along with the measures employed are listed in Table 1.

Table 1: TRACI Impact Categories and Measures

TRACI Impact Category:	Impact Measure:
Global Warming Potential (GWP)	kg CO^2 Equivalent
Ozone Depletion Potential (ODP)	kg CFC Equivalent
Photochemical Oxidant Potential (PCOP)	kg NOX Equivalent
Acidification Potential	H+ Moles Equivalent
Eutrification	kg Nitrogen Equivalent
Health Toxicity (Cancer)	kg Benzene Equivalent
Health Toxicity (Non-Cancer)	kg Toluene Equivalent
Health Toxicity (Air Pollutants)	kg: DALYs Equivalent
Eco-Toxicity Potential	kg 2,4-D Equivalent

Source: Bare, Norris, Pennington, & McKone, 2003, p.55.

In addition to identifying the major threats that impact the environment and human health, the TRACI methodology also identifies specific measures for each impact. As an example, although a number of atmospheric gasses including methane and various gaseous oxides may contribute to global warming the TRACI scale measures all of these impacts in terms of their equivalency to Carbon Dioxide (CO^2), the most common "greenhouse gas." In a similar manner, the potential for depleting the earth's ozone layer is measured in terms of equivalency to the impact of CFC-11, the once-popular "Freon." refrigerant.

The LCA Process. Once relevant inputs and outputs have been identified and a measurable scale has been developed for each impact, LCA provides a methodology to apply this information to decision-making. According to the U.S. Environmental Protection Agency (Scientific Applications International Corporation, 2006), an effective LCA process may be divided into three basic steps:

1. Compiling an inventory of relevant energy and material inputs and environmental releases.
2. Evaluating the potential environmental impacts associated with identified inputs and releases.
3. Interpreting the results to help in making an informed decision.

Because the LCA process involves a final step of interpreting the results, it is employed frequently as a comparative method to make decisions among alternatives. An example of one of the first applications of LCA was a study of the environmental impact soft drink containers conducted by the Coca-Cola Company in the 1970s (Duda & Shaw, 1997). At the time, Coca-Cola was considering replacing its returnable glass bottles with disposable cans or plastic bottles. Because of emerging public concern regarding the potential environmental damage of disposable containers, the company wanted to carefully examine comparative environmental impacts before making a decision. To the surprise of many at the time, the LCA conducted by Coke demonstrated that plastic bottles were the best environmental choice because each plastic bottle consumed and emitted fewer hydrocarbons than the alternatives.

Life Cycle Inventory (LCI). The life cycle assessment of a complex system requires a process that provides for the summation of impacts associated with the individual products incorporated into the system. In the case of buildings, several tools have been developed to identify and summarize the impacts of individual building components. These tools include the BEES® tool developed by the National Institute of Science and Technology in the U.S., the Athena® EcoCalculator developed by the Athena Institute in Canada, and the GaBi software developed in Europe. Although each of these tools utilizes different methodologies and weighting protocols, all rely on the development of a comprehensive Life Cycle Inventory (LCI) database to provide the appropriate product inputs. Both NIST and the Athena Institute have developed LCI databases to support their building assessment tools, while the GaBi software is support by the Ecoinvent database. In addition, a common North American LCA database is being developed through a partnership of the National Renewable Energy Laboratory (NREL) and the Athena Institute. This database, the US LCI, is intended to serve as a common, peer-reviewed database for both the BEES® and Athena® EcoCalculator tools.

Current Status of LCA and LCI. Although interest in LCA is growing rapidly among building designers and owners, the LCI databases necessary to support expanded use of current LCA tools remain incomplete. As an example, roofing materials in the BEES® database are limited primarily to asphalt shingles. The Athena roofing database contains a larger selection of roofing materials and systems, but some of the information may be based on incorrect data and assumptions. As an example, the LCI impact data for EPDM roofing membrane is based on an assumed EPDM membrane formulation consisting of 30% carbon black, 6% clay filler and 64% EPDM polymer (Franklin Associates, 2001). In reality, EPDM membrane produced in North America contains 47% carbon black, 28% EPDM polymer, 20% process oil, and 5% other additives (TRC Environmental Corporation, 1995). This difference poses significant problems because the environmental impacts (especially energy-related impacts such as Global Warming Potential) of complex polymers are relatively high compared to many other construction materials. This difference is a result of the large amount of petroleum required to produce complex polymers, both in terms of chemical feedstocks as well as process energy. Because the Athena LCI values for EPDM were based on a polymer content over twice as large as actually used, the environmental impacts for EPDM are significantly overstated. As a consequence, the present study was commissioned in part to develop a more accurate LCA profile for EPDM roofing membrane.

STUDY OBJECTIVES

This study was commissioned to meet the following objectives:

1. Summarize the best available LCA data for selected low-slope roofing systems as relevant to North American roofing practice.
2. Update and validate previous LCA studies of low-slope roofing systems.
3. Submit updated LCA data to relevant North American LCI databases.
4. Provide a summary report to assist building designers interested in evaluating the life cycle impacts of selected low-slope roofing systems.

METHODOLOGY

Selection of Assessor. In order to assure that all LCA assessment activities conducted as part of this study reflect most recent industry best practice, the GreenTeam, Inc. of Tulsa, Oklahoma was selected as project assessor. The GreenTeam is a strategic environmental consulting firm specializing in building industry issues. Dru Meadows, AIA, FCSI, CCS and Charles E. Bell, AIA, NCARB, LEED AP, founding principals of theGreenTeam, are nationally and internationally recognized design professionals; and Mr. David Reisdorf of the GreenTeam is a Life Cycle Assessment Certified Professional (LCACP) as recognized by the American Center for Life Cycle Assessment. In addition, Ms. Meadows serves as the chair of the recently-formed ASTM Committee E-60 on Sustainability.

Roofing Systems Assessed. The LCA conducted by the GreenTeam included the following low-slope roofing membranes, thicknesses, and application methods:

- Membrane Types:
    - Non-reinforced EPDM (black & white*)
    - Reinforced EPDM (black)
    - Reinforced TPO (gray & white**)
    - Reinforced PVC (gray & white**)
    - SBS modified bitumen (unsurfaced)

        *white top layer over black bottom layer
        **white top layer over gray bottom layer

- Membrane Thicknesses:
    - 45 mil (Non-reinforced EPDM, black only)
    - 60 mil (Non-reinforced and Reinforced EPDM, Reinforced TPO and PVC)
    - 72 mil (Reinforced TPO)
    - 80 mil (Reinforced TPO and PVC)
    - 90 mil (Non-reinforced EPDM, black Only)
    - 140 mil (SBS modified bitumen)

- Application Methods:
  - Loosely laid and ballasted (EPDM, TPO, PVC)
  - Fully adhered (Non-reinforced and reinforced EPDM, reinforced TPO and PVC, SBS modified bitumen)
  - Mechanically attached (Reinforced EPDM, TPO and PVC)

In addition to the above membranes and application methods, the following ancillary materials necessary for system installation were also evaluated:

- Metal fasteners and plates (For insulation attachment and membrane securement as required for fully adhered and mechanically attached applications)
- Membrane bonding adhesive (for fully adhered applications)
- Ballast stone (for ballasted applications)

LCA System Boundaries. All LCAs were conducted on a "cradle-to-gate" (or cradle-to-building) basis, including all necessary inputs to complete the installation of the roofing membrane. Ideally the LCA would extend to the "grave" of the roofing membranes because differences in maintenance, service life and disposal have environmental implications. However, additional studies will be necessary to extend this research to include in-service and end-of-life impacts.

Input Sources. Sources of input used by the GreenTeam included:

- Previous LCA studies of low-slope roofing systems (Franklin Associates, 2001; Morrison Hershfield Ltd., 2001)
- EPDM membrane composition (TRC Environmental Corporation, 1995)
- EPDM Roofing Association (ERA) supplied information
- EPA AP-42 emission factors
- Existing LCI Databases (US LCI, Ecoinvent / SimaPro, Athena Institute)

LCI data for TPO, PVC and SBS modified bitumen was derived primarily from the Athena Institute and were based on the Franklin Associates and Morrison Hershfield LCA studies. LCI data for EPDM was derived from RMA compounding and manufacturing data provided by TRC Environmental supplemented by EPA AP-42 and existing LCI database information. LCI data for TPO was derived from a variety of resources, including Athena, RMA and other industry data. LCI data for metal fasteners and ballast stone were derived from existing LCI database information. LCI data for bonding adhesive was derived from generic adhesive formulation information provided by ERA.

Assumptions. Developing life cycle inventories necessarily involves working with approximations and sometimes incomplete data due to the complexity of most production systems. Approximations may be utilized when data reflects industry averages or conversely only a single producer. Approximations may be utilized to normalize variability in materials and emissions due to production flows, geographic differences, and continual changes in production methods (generally industrial processes improve efficiency overtime). Data may be incomplete because many materials do not have health or environmental impact studies. Data may be incomplete for materials considered to be proprietary, and for many materials that vary over a range of forms and concentrations. Assumptions are required to fill in data holes in life cycle assessments, but it is important to be aware that assumptions reduce the reliability and precision of the LCI.

This LCI/LCA used whenever possible industry average data that was U.S. or North American derived to best reflect production by ERA members. When not available, European data primarily from the Ecoinvent LCI databases were used. These assumptions included:

- The class of chemicals known as thiocarbamates were substituted for Ziram and Thiram additives in the EPDM formulations.
- White mineral oil was substituted for Sunpar process oil in the EPDM formulations.
- In the EPDM polymer, butadiene was substituted for ethylidene norbornene (ENB).
- Tetrachlorosilane was used as a proxy for the class of chemicals called amino silanes.
- Gypsum was substituted for talc (hydrated magnesium silicate) due to similarities in mining and processing related minerals.
- Traditional galvanized steel (zinc galvanized) is substituted for Galvalume steel (aluminum galvanized steel) for fasteners used in mechanical attachment.
- For PVC membrane, EPDM was used as a proxy for ethylene polypropylene (EP) rubber used as a plasticizer, and only one plasticizing compound was assumed in PVC formulations. Phthalates were not included in the PVC roofing formulations.
- Energy for EPDM is calculated from ERA supplied industry data, plus USA Input-Output (derived from U.S. Department of Commerce, Bureau of Economic Analysis) data for the synthetic rubber industry. The industry data does not capture energy consumed upstream in the extraction of raw materials and processing into inputs for roofing membrane production. The addition of the input-output data better represents the full industry demand for energy, though may double count energy consumed at EPDM roofing membrane plants.
- Energy for TPO production is modeled using USA Input-Output data for the synthetic rubber industry.
- EPDM roofing membrane adhesive formulation was provided by the EPDM Roofing Association. Material Safety Data Sheet (MSDS) data for adhesives specific to PVC and TPO membranes were used to provide a similar approximation.
- Installation energy used to lift roofing materials onto roofs is assumed relatively equal among the membranes and is not included in the inventory.

Summary of Outputs and Impacts. All outputs and impacts were calculated by the GreenTeam using SimaPro LCA software. Impacts were summarized using the categories and unit measures of the US EPA TRACI Model (See Table 1). All membranes studied were assumed to provide equal service lives, so the basic impacts were unadjusted for service life. All impacts were calculated based on one (1) square meter (M^2) of installed roofing membrane.

FINDINGS

Comparison of Widely-Used Membranes and Application Types. Because of the large overall combination of membrane, thickness and application types, this study provides a summary of the most common and widely-used low-slope roofing systems:

- Ballasted Systems
  - 60 mil Non-reinforced EPDM (Black)
- Fully Adhered Systems
  - 60 mil Non-reinforced EPDM (Black)
  - 60 mil Non-reinforced EPDM (White)
  - 60 mil Reinforced TPO (Gray)
  - 60 mil Reinforced TPO (White)
  - 60 mil Reinforced PVC (Gray)
  - 60 mil Reinforced PVC (White)
  - 140 mil SBS Modified Bitumen (Unsurfaced)

- Mechanically Attached Systems
  - 60 mil Reinforced EPDM (Black)
  - 60 mil Reinforced TPO (Gray)
  - 60 mil Reinforced TPO (White)
  - 60 mil Reinforced PVC (Gray)
  - 60 mil Reinforced PVC (White)

In order to provide an equivalent comparison, all non-asphaltic membranes (EPDM, TPO and PVC) are compared based on a common thickness of 60 mils. The SBS membrane is compared using the 140 mil thickness, which is a typical thickness of a modified bitumen top layer that would reasonably be compared to single-ply membranes of 60 mil thickness. A summary of the impacts for a square foot of each of these systems is provided in Figure 2:

			TRACI IMPACT CATEGORY								
SYSTEM DESCRIPTION			Global Warming	Acid Rain	Carcin.	Non-Carcin.	Respiratory Effects	Eutrification	Ozone Depletion	Eco-Toxicity	Smog
SYSTEM	MEMBRANE	ATTACHMENT	(kg CO2)	(H+ moles)	(kg benzene)	(Kg toluene)	(kg PM)	(Kg N)	(kg CFC-11)	(Kg 2,4-D)	(Kg NOX)
EPDM	60 mil Non-Reinf. Black	Ballasted	28.3	11.9	0.17	463	0.05	0.004	< 0.00001	3.78	0.08
	60 mil Non-Reinf. Black	Fully Adhered	29.6	12.3	0.17	514	0.06	0.005	< 0.00001	4.26	0.08
	60 mil Non-Reinf. White	Fully Adhered	22.4	8.8	0.17	528	0.04	0.003	< 0.00001	4.79	0.05
	60 mil Reinforced Black	Mech. Attached	28.7	12.0	0.17	542	0.06	0.004	< 0.00001	3.50	0.08
TPO	60 mil Reinforced Gray	Fully Adhered	30.5	19.2	0.15	419	0.06	0.004	< 0.00001	2.19	0.08
	60 mil Reinforced Gray	Mech. Attached	29.4	18.9	0.15	477	0.06	0.003	< 0.00001	1.71	0.08
	60 mil Reinforced White	Fully Adhered	30.9	19.4	0.15	424	0.06	0.004	< 0.00001	2.41	0.08
	60 mil Reinforced White	Mech. Attached	29.8	19.2	0.15	483	0.06	0.003	< 0.00001	1.93	0.08
PVC	60 mil Reinforced Gray	Fully Adhered	58.6	39.4	0.05	492	0.03	0.010	< 0.00001	6.58	0.20
	60 mil Reinforced Gray	Mech. Attached	54.2	38.4	0.04	528	0.03	0.008	< 0.00001	2.80	0.19
	60 mil Reinforced White	Fully Adhered	73.1	49.1	0.06	606	0.04	0.010	< 0.00001	8.62	0.24
	60 mil Reinforced White	Mech. Attached	67.8	47.8	0.05	650	0.03	0.011	< 0.00001	4.01	0.23
SBS	140 mil Unsurfaced	Fully Adhered	81.8	52.7	0.06	998	0.04	0.160	< 0.00001	10.9	0.31

Figure 2: TRACI Impacts for Widely-Used Low-Slope Roofing Systems
Unit of Impact per M^2 of Installed Membrane
(Source: The GreenTeam, 2009)

Magnitude & Relevance of Impact Categories. As illustrated in Figure 2, energy-related categories such as global warming appear to offer the greatest relevance. Global warming potential (GWP) as measured by kilograms of CO^2-equivalents varied from a low of 22.4 kg per square foot (fully adhered white non-reinforced EPDM) to a high of 81.8 kg per square foot (140 mil unsurfaced SBS). The relevance of the global warming category is further supported by the degree of differences exhibited by the membranes studied. As an example, the global warming potential of a white PVC or unsurfaced SBS membrane is over twice the same potential of a black EPDM or white TPO roofing membrane for all system types studied. Figure 3 provides a comparison of GWP for each of the widely-used low-slope roofing membranes and systems:

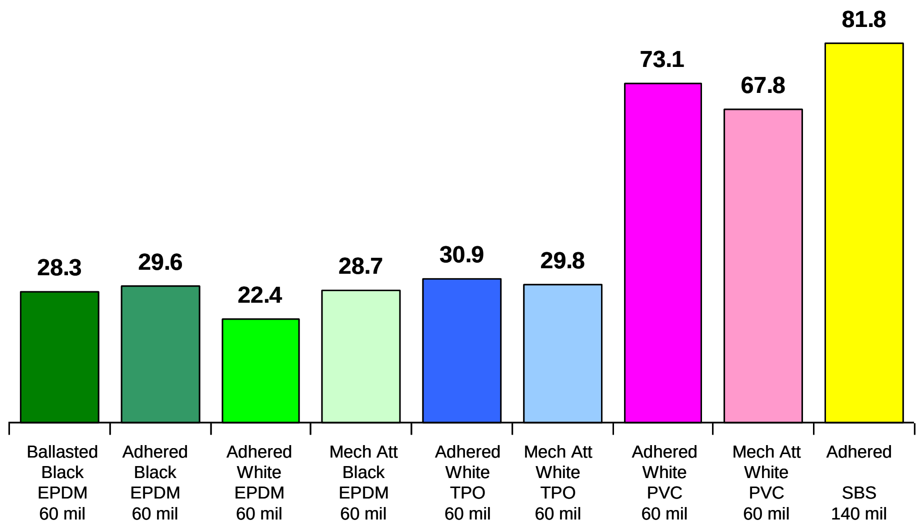

Figure 3:
Global Warming Potential (GWP) for Widely-Used Low-Slope Roofing Systems
Kg CO^2 Equivalent per $M^2$of Installed Membrane
(Source: The GreenTeam, 2009)

Many other categories, including categories related to toxicity and health effects appear to offer much lesser magnitude and relevance. As an example, the ozone-depletion potential of every membrane and system studied as measured by kilograms of CFC-equivalents was less than 0.00001 kg per square foot. Similarly, eutrification potential as measured by kilograms of nitrogen equivalents was less than 0.01 kg per M^2 for all membranes except SBS (0.16 kg).

As suggested by other studies of the environmental impact of building materials, global warming appears to be a significant differentiating factor for making informed sustainable material evaluations and selections. And because global warming potential is closely tied to the amount of energy needed to extract, manufacture, transport and install these building materials, it may remain a significant factor for many years, especially in a nation that relies heavily on fossil-based energy sources. Over time, as renewable energy replaces fossil sources for energy production, the importance of global warming potential may fade from the built environment; but at the present such a situation is likely decades into the future.

The Role of Membrane Formulation. The differences observed among the various low-slope roofing membranes, especially differences in global warming potential and energy consumption suggest a number of possible explanations. The relatively low GWP of the EPDM membranes may be attributed to the relatively high polymer effectiveness of EPDM which, in turn, allows a relatively low polymer content in the membrane formulation. In fact, this high polymer effectiveness may be an even more significant factor considering the additional energy required to cure or vulcanize a rubber material.

In contrast to the relatively high energy input required to vulcanize rubber polymers like EPDM, the TPO and PVC membranes both enjoy a lower energy input for manufacturing. However, the relatively lower GWP of TPO as compared to PVC may be attributed to the relatively higher energies required to produce a halogenated polymer like PVC as compared to a non-halogenated olefin polymer like TPO.

A comparison of the SBS membrane to the single-ply membranes studied also suggests a relationship between product thickness and GWP. SBS modified bitumen requires a lower polymer content than even EPDM, but this advantage of polymer efficiency appears to be clearly offset by the greater total thickness required. And this comparative GWP disadvantages would be further magnified since a typical SBS roof installation involves the application of an additional layer of SBS material as a base layer.

The Role of Attachment Method. One of the most interesting findings in this study is the minimal role played by attachment method in determining impact. As an example, the various attachment methods studied (ballasted, fully adhered, mechanically attached) appear to affect overall GWP by less than 4% for EPDM and TPO and less than 7% for PVC. This lack of demonstrable difference suggests that the selection of the most suitable application method should be based on other factors such as potential longevity, ease of repairability, etc.

The Role of Membrane Color. For the TPO and PVC membranes, membrane color appears to play little or no role as a differentiating factor. As an example, the GWP for a fully adhered gray 60 mil TPO membrane (30.5 kg/ft^2) is essentially identical to the GWP for a similar white 60 mil TPO membrane (30.9 kg/ft^2). For EPDM membranes, however, the difference between white and black is relatively more pronounced, with a fully adhered white 60 mil EPDM membrane exhibiting the lowest GWP of the study (22.4 kg/ft^2) as compared to a similar black 60 mil EPDM membrane (29.6 kg/ft^2). A possible explanation both for the similarity of white and gray TPO / PVC and the difference between black and white EPDM may be related to differences in the use of carbon black in these three membranes. Black EPDM has a relatively high carbon black content (47% by weight), and carbon black requires a higher level of production energy as compared to the titanium dioxide (TiO^2) and white clay typically used as substitutes for carbon black in white EPDM formulations. In contrast, the formulations of gray and white TPO and PVC are essentially identical, with only a miniscule amount of carbon black or similar pigment added to achieve a gray hue.

The Role of Service Life. As mentioned earlier in this study, the impact measurement of all membrane systems was based on an equivalent service life. The reasoning behind this assumption was based on several factors. First, published information and research on the estimated service life of low-slope roofing systems exhibits a significant level of variation that may be explained more by research assumptions rather than specific membrane characteristics (Hoff, 2009a). More importantly, the industry perception of the service life of established low-slope roofing alternatives such as EPDM, PVC and SBS appears to be converging as these systems have matured in the market. And although TPO does not have as long a track record as the other membranes studied, observed performance to date has been positive.

Although this study is "service-life neutral" in scope, one important observation related to service life may be drawn from the data. Because of the relatively high variation in LCA impacts among the membranes studied (especially GWP), the implication of these variations on long-term impact and service life should be reviewed. As an example, fully adhered white EPDM (GWP = 22.4 kg/ M^2) would require only a little over two-thirds the service life of adhered black EPDM (GWP = 29.6 kg/ M^2) to produce an equal annual distribution of the initial embodied GWP impact. In a similar manner, an adhered white PVC membrane (GWP = 73.1 kg/ M^2) would require a service life over twice as long as black EPDM to produce an equal annual distribution of initial embodied GWP impact. Figure 4 illustrates this comparison among the widely-used low-slope roofing systems in terms of the service life required to provide an equal annual distribution of GWP impact as compared to white EPDM (assuming a conservative 15-year minimum service life for white EPDM).

System	**Membrane**	**Attachment**	**Global Warming Potential (GWP)** (kg CO2 eq.)	**Minimum Service Life To Achieve Equivalency** (1) (Years)
EPDM	60 mil Non-Reinf Black	Ballasted	28.3	19.0
		Fully Adhered	29.6	19.8
	60 mil Non-Reinf White	Fully Adhered	22.4	15.0
	60 mil Reinforced Black	Mech. Attached	28.7	19.2
TPO	60 mil Reinforced Gray	Fully Adhered	30.5	20.4
		Mech. Attached	29.4	19.7
	60 Mil Reinfirced White	Fully Adhered	30.9	20.7
		Mech. Attached	29.8	20.0
PVC	60 mil Reinforced Gray	Fully Adhered	58.6	39.2
		Mech. Attached	54.2	36.3
	60 Mil Reinfirced White	Fully Adhered	73.1	49.0
		Mech. Attached	67.8	45.4
SBS	140 mil Unsurfaced	Fully Adhered	81.8	54.8

(1) Using a conservative 15 Year Service Life for the Lowest Impact System (White EPDM Fully Adhered)

Figure 4: Minimum Service Life to Distribute GWP Equally

Editor's Note: Since the publication of this report in 2010, the new data has been submitted to the Athena databases. You may view this new data at http://www.athenasmi.org/

DISCUSSION

Revision of LCI Databases. Because the EPDM data in this study based on an accurate formulation of the product produces a significantly lower overall environmental impact, it is imperative that the current Athena LCI database and Athena® EcoCalculator be revised as quickly as possible. In addition, this new LCI data should also be submitted as quickly as possible to the US LCI database for use with the BEES® and other LCA tools. In the interim, it would be prudent for building design professionals using the Athena® EcoCalculator to be aware of the significantly reduced EPDM impact data demonstrated by this study.

Importance of Service Life Estimates. The data in this study suggest that service life estimation is a critical element in the development of an accurate and dependable life cycle assessment of any building or roofing system. As a consequence, building designers should not assign an estimated service life for a building or any major building system without conducting a sensitivity analysis of the comparative consequences of that service life. As an example, if a roofing system with a relatively low initial GWP is being compared against a roofing system with a significantly higher GWP, the data in this study suggests that it would be prudent for the designer to be confident that the higher GWP system can provide a significantly longer service life in order to be considered an equivalent in terms of global warming impact.

Importance of Life Cycle Management. As stated previously, the LCA conducted for this study was based on a cradle-to-building approach. As a consequence, no impacts were identified or measured for activities that occur during the service life of the roofing system (routine maintenance and periodic repair or renovation) or at the end of service life (removal, disposal and possible recycling). Although many of the activities not addressed by this study such as routine maintenance and periodic renovation generate relatively small environmental impacts, their value in extending service life may be much more important than their incremental impact contribution. The following charts from a study presented at a recent Construction Specifications Institute (CSI) conference may help to illustrate this value. Figure 5 illustrates an all-too-common roof life cycle when little or no consideration is given to routine maintenance and periodic renovation. Well before the roofing system's potential life cycle has been achieved, the roof must be replaced, and significant environmental impacts are generated by the removal and disposal of the existing roof and the supply and installation of the new roof.

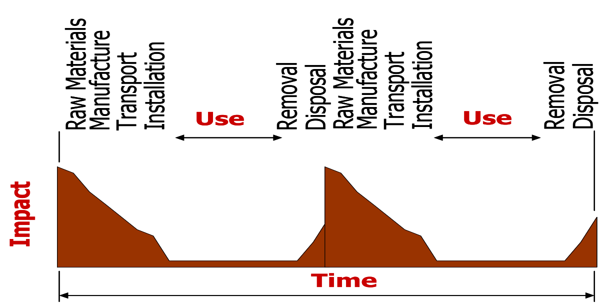

Figure 5: The All-Too-Common Roof System Life Cycle
(Source: Hoff, 2009b)

In contrast, Figure 6 illustrates a more sustainable life cycle when active planning for routine maintenance as well as planned renovation is included in the design and management of the roofing system. Instead of waiting for deterioration to occur, the roof system is maintained periodically; and in addition, a major renovation may be planned in the middle of its potential service life. As a result, the service life of the roofing system is extended significantly and the environmental impacts of the roofing materials and installation labor are spread over a much longer period.

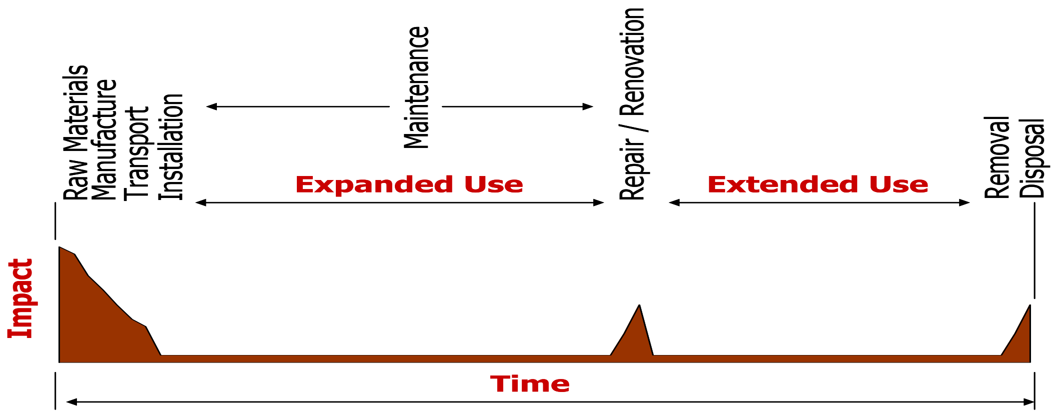

Figure 5: The Sustainable Roof System Life Cycle
(Source: Hoff, 2009b)

Although this is merely a graphic representation, it offers an important perspective, especially in view of results of the current study that indicate the initial environmental impact of low-slope roofing systems may differ significantly, especially in terms of global warming. As a consequence, roof system and design features that help support maintenance and planned renovation may provide significant value in reducing overall environmental impact.

For the roof system designer, the opportunity to reduce overall environmental impact by extending useful service life implies that material or design features that support this opportunity should receive considerable attention. Such features may include the ability to accurately predict maintenance and repair requirements, relative ease of repair of the roofing membrane, and the ability to remove and replace selected roof system components.

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