Life Cycle Analysis of Low Slope Roof Systems November 2004		
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Note: This report contains a summary of the low slope roof study carried out by the independent Swiss environmental consultant Carbotech AG. Please contact Sarnafil Inc. for a copy of the original report.		

Objective

The objective of the study was to conduct an analysis of the environmental and cost impacts of North American low slope roof systems. Although entire roofing assemblies were analyzed, the focus was on the selection of the optimal membrane due to its impact on service life and energy consumption.

The metric for comparison is eco-efficiency. Eco-efficiency expresses the ratio of the total life cycle costs to the total life cycle environmental impacts.

The low slope roof systems and the membranes analyzed (see Table 1) reflect the most commonly used products in North America.

Table 1 System description and membrane characteristics

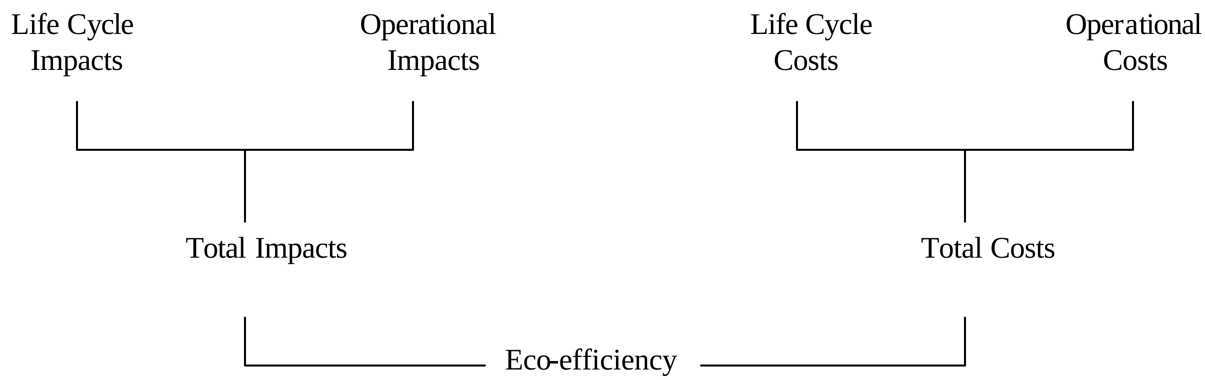
	Membrane / Insulation	Surface	Solar Reflectivity	Service life
F01	Sarnafil S327 / PIR	White exposed membrane	83 %	30 years[i]
F02	Sarnafil S327 / EPS	White exposed membrane	83 %	30 years[i]
F03	US TPO / PIR	White exposed membrane	81 %	20 years[ii]
F04	Modified bitumen / PIR	Grey granulated membrane	26 %	15.9 years[iii]
F05	EPDM / PIR	Black exposed membrane	6 %	14.2 years[iii]
F06	4 ply BUR / PIR	Grey to black aggregate/asphalt	26 %	16.7 years[iii]

PIR = Polyisocyanurate insulation
EPS = Extruded polystyrene insulation

Procedure

The two key components of eco-efficiency are environmental impacts (total life cycle impacts) and costs (total life cycle costs), both of which include life cycle and operational components. The life cycle environmental impacts were calculated on the basis of a life cycle analysis (LCA) methodology. They were aggregated for all the components into various impact categories (global warming, non-renewable primary energy, photochemical smog, acidification) using the U.S. EPA's TRACI[iv] model. Operational impacts account for the effect the various roof systems have on energy consumption The life cycle costs include the average installed roof price, maintenance and disposal costs. Operational costs include roof related energy costs for heating and cooling.

Figure 1 Eco-efficiency



All evaluations are based on a standard, single story retail facility in three different locations: Austin, TX, Los Angeles, CA and Boston, MA.

Life Cycle Impacts

Life cycle impacts of the low slope roof systems are presented in Figure 2 for the assessment criteria global warming. The impacts were calculated for the production, installation and disposal of the roof components and normalized based on the years of service life (Table 1).

The impacts depend strongly on the material consumption in the production of the roof system and on the service life of the roof. In each case, all materials are assumed to have the same service life as the membrane protecting them.

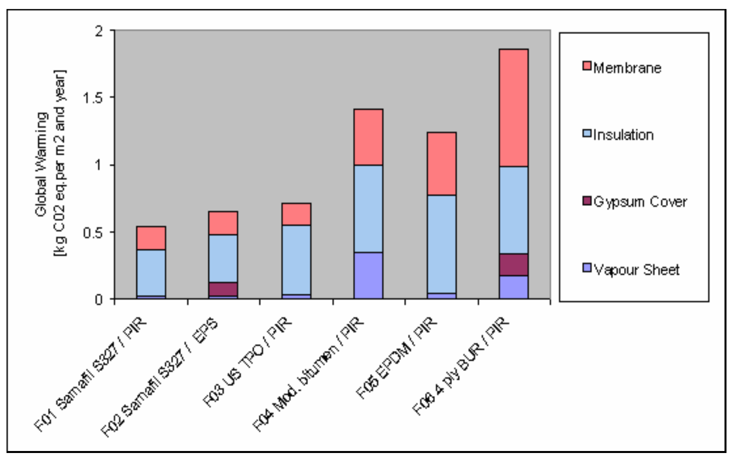


Figure 2 Life cycle impacts by low slope roof components for the assessment criteria global warming

The low slope roof systems with lightweight thermoplastic membranes and a long service life impose the lowest global warming impacts. Systems incorporating EPDM and modified bitumen membranes, with a shorter service life and/or 4-ply BUR low slope roof systems, with high material usage and short service life impose the greatest impacts.

Operational Impacts

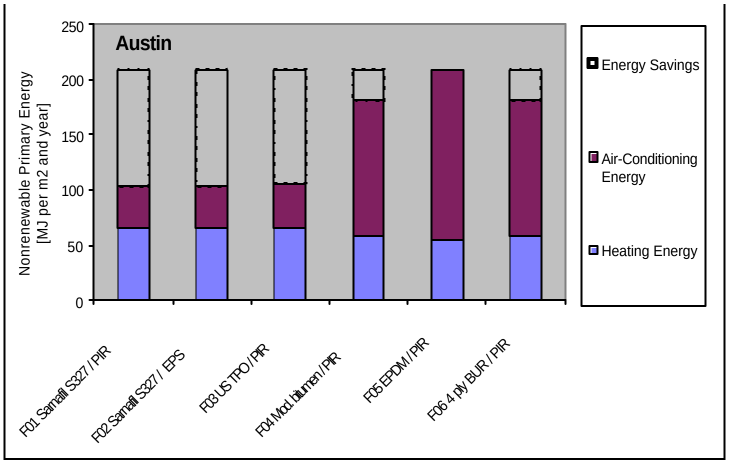


Figure 3 Energy consumption and energy savings of various low slope roof systems compared to black EPDM for Austin

Operational impacts related to air-conditioning and heating loads associated with the roof systems are illustrated in Figure 3 for the assessment criteria non-renewable primary energy. High energy consumption can result from either high air-conditioning or heating demand.

White, reflective surfaces have been shown to reduce the heat load on buildings and therefore the air-conditioning demand.

Consequently, white membranes can provide savings of up to 50% of the energy load of the roof in warm regions like Austin, TX compared to low slope roof systems with black EPDM membranes[v] (based exclusively on heat flow through the roof).

Total Impacts

Figure 4 shows the relative total impacts (life cycle and operational) calculated for all the assessment criteria.

The low slope roof systems based on Sarnafil S327 and the TPO membrane provide the best overall results due to the low life cycle impacts of these long-lasting roof systems and the low operational impacts of white reflective membranes. The relative importance of the operational impacts and their effect on the overall classification of the low slope roof systems is more relevant for warm climates such as Austin, TX.

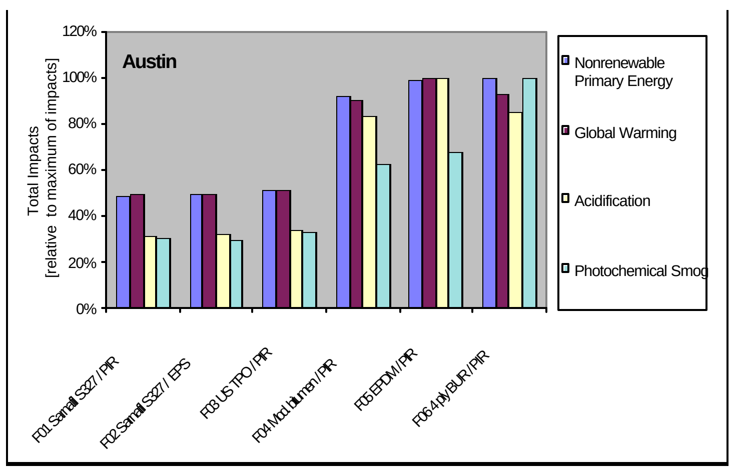


Figure 4 Total impacts in Austin relative to the maximum impact for different assessment criteria

The cool surfaces of low slope roofs with white membranes also contribute to a reduction in the urban heat-island effect, which results in a lower rate of smog formation and an improvement in ambient air quality.

Life Cycle and Operational Costs

Life cycle costs were calculated using the installation, maintenance and disposal costs of the low slope roof systems. Operational costs were calculated based on the energy costs of the air-conditioning and heating demand calculated per unit of roof area with the DOE Cool Roof Calculator. The resulting total costs are illustrated in Figure 5 for the building located in Austin, TX.

Sarnafil's S327 low slope roof system achieved the best rating based on its low life cycle costs. The low slope roof system incorporating the US TPO membrane achieved a good rating, while average ratings were found for the low slope roof systems using EPDM and modified bitumen membranes.

The operational costs and/or energy savings of white reflective low slope roofs systems are less relevant than the life cycle costs of the low slope roof systems. The relevance of operational costs depends on the cost of energy and may change with higher energy price levels.

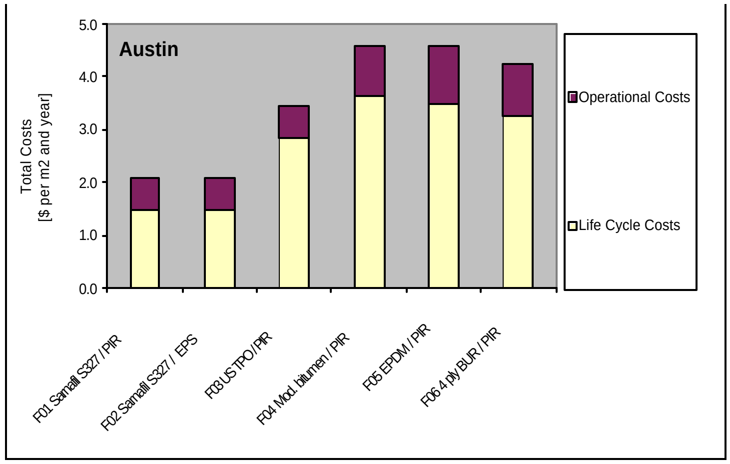


Figure 5 Total costs breakdown of life cycle and operational costs illustrated for the warm climate of Austin

Breakdown of Life Cycle Costs

Life cycle costs broken down into the three main phases of the service life are presented in Figure 6. Installation and disposal costs were normalized dividing the costs by the years of service life (Table 1).

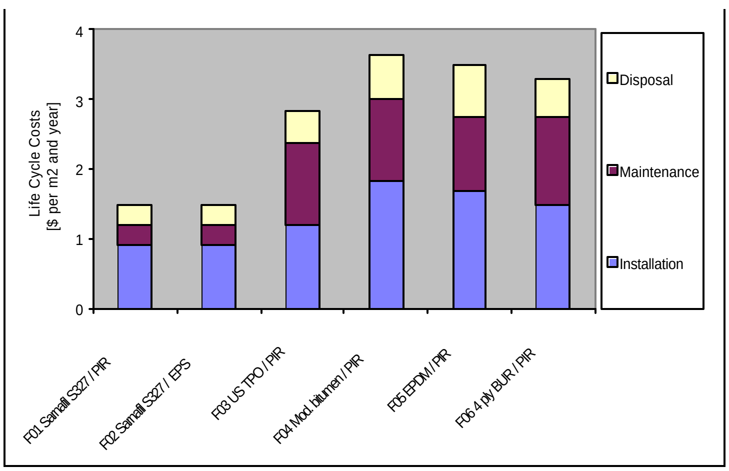


Figure 6 Portion of life cycle costs for different low slope roof systems (Sarnafil costs evaluation 2002/2003 and average costs from national survey 1996)

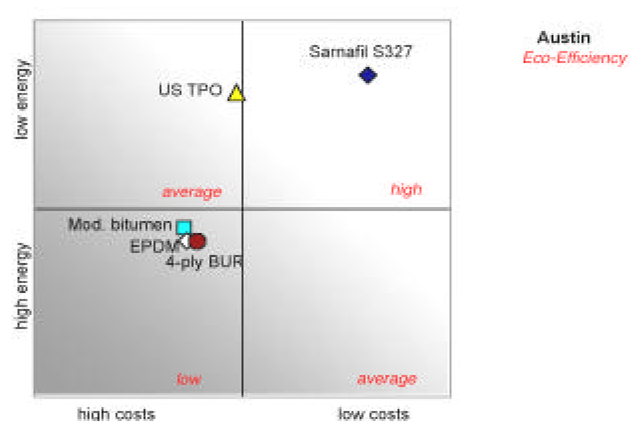
Low life cycle costs result for low slope roof systems with low maintenance requirements and long service life. Higher life cycle costs result from either higher maintenance costs and/or higher installation and disposal costs of low slope roofs with shorter service life due to the more frequent roof replacement.

The lowest life cycle costs are obtained for the Sarnafil S327 low slope roof systems as a result of the reported low maintenance requirements and the long service life.

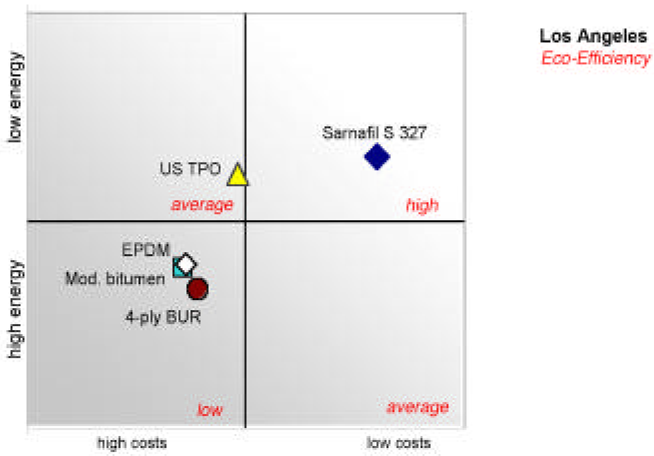
Average costs result for the assumed service life of TPO and high costs for modified bitumen, EPDM and 4-ply BUR due to their relatively short service lives.

Eco-Efficiency

Eco-efficiency expresses the ratio of the total costs to the total impacts. This ratio is useful for decision-making processes considering ecological and economic factors. The eco-efficiency of the low slope roof systems is illustrated for Austin, Los Angeles and Boston for the assessment criteria nonrenewable primary energy.



The relative eco-efficiency is represented by the shade of the occupied space in the diagram. Systems with a high eco-efficiency are found in the bright quarter on the upper right hand side and systems with a low eco-efficiency rating are in the dark quarter on the lower left hand side.

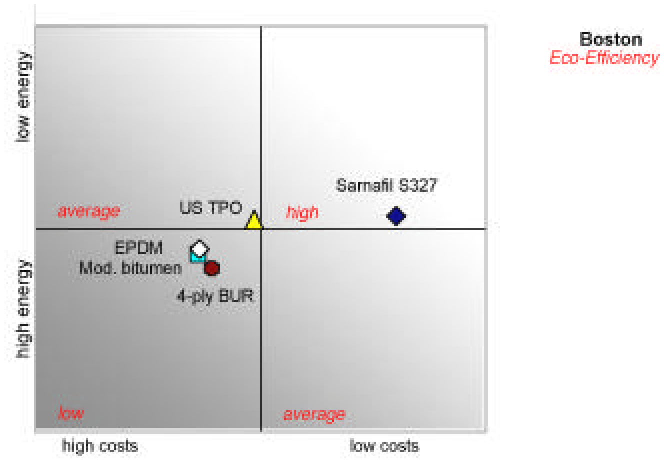


Low total impacts are the result of low slope roof systems with:

- long service life
- low energy usage
- lightweight roofs

Low total costs are the result of low slope roof systems with:

- long service life
- low maintenance requirements
- low operational energy requirements



The best results are obtained with low slope roof systems with the best ratings in both of these criteria. A high eco-efficiency rating was found for the Sarnafil S327 systems in all climatic regions as a result of low total costs and total impacts. The eco-efficiency rating for the TPO low slope roof system was average while it was low for the EPDM, 4-ply BUR and modified bitumen low slope roof systems. The relevance of the energy savings on the eco-efficiency rating due to reflective membranes depends on the climatic region. Therefore the impact is greater in warm climates than in moderate and cold climates with low air-conditioning demand.

Conclusions

On the basis of an assessment of the eco-efficiency of the chosen systems, it is recommended that low slope roof systems be selected using the following criteria, in order of priority:

- Long service life
- White reflective surface (less relevant for moderate and cold climates)
- Light weight, low material consumption
- Low maintenance requirements

Based on these criteria, white single ply, thermoplastic membranes are the best choice of the analyzed low slope roof systems with Sarnafil's S327 membrane performing best overall in this evaluation.

Selection of a low slope roof system using these criteria can reduce the total impacts and costs to the building owner and the environment.

[i] British Board of Agrement, Certificate no. 87/1849, Sarnafil PVC Roof Covering System
[ii] British Board of Agrement, Certificate no. 01/3856, Carlisle TPO
[iii] The Relative Durabilty of Low Slope Roofing, Cash, C. G., Proceeding of The Fourth International Symposium on Roofing Technology, 1996.
[iv] Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI), United States Environmental Protection Agency
[v] An insulation value of 18.9-R was applied for all low slope roof systems.

A full copy of this report can be obtained by calling Sarnafil at 800-576-2358. Visit www.sarnafilus.com for additional information about Sarnafil's roofing systems.