



LIFE CYCLE ANALYSIS OF ASPHALT
IMPREGNATED FIBERGLASS BUILT-UP
ROOFING FELTS

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Ottawa, Canada
March, 2001

ACKNOWLEDGEMENTS

This report was made possible through the support of Natural Resources Canada and the federal Climate Change Action Fund under its Technology Early Action Measures Program (TEAM).

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Preface

This report is an addendum to the March 2000 cradle-to-gate-life cycle inventory report on residential roofing products. It has been prepared as part of a continuing program to extend the knowledge base of the ATHENA™ Sustainable Materials Institute, a not-for-profit organization dedicated to helping the building community meet the environmental challenges of the future. The data developed in this report will be used in ATHENA™, the Institute's systems model for assessing the relative life cycle environmental implications of alternative building or assembly designs.

Institute studies and publications fall into two general categories: investigative or exploratory studies intended to further general understanding of life cycle assessment as it applies to building materials and buildings; and individual life cycle inventory studies which deal with specific industries, product groups or building life cycles stages. All studies in this latter category are firmly grounded on the principles and practices of life cycle assessment (LCA), and follow our published Research Guidelines, which define boundary or scope conditions and ensure equal treatment of all building materials and products in terms of assumptions, research decisions, estimating methods and other aspects of the work.

The integration of all the Institute's life cycle inventory data is a primary function of ATHENA™ itself, and we therefore caution that individual industry life cycle study reports may not be entirely stand-alone documents in the sense that they tell the whole story about an individual set of products. ATHENA™ also generates various composite measures that can be best described as environmental impact indicators, a step toward the ultimate LCA goal of developing true measures of impacts on human and ecosystem health.

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LIFE CYCLE ANALYSIS OF ASPHALT IMPREGNATED FIBERGLASS BUR FELTS

1.0 Introduction

This report presents cradle to gate life cycle inventory estimates for asphalt impregnated fiberglass felts used in built-up roofing (BUR). The work was commissioned by the ATHENA™¹ Sustainable Materials Institute as part of the continuing series of life cycle analyses of building materials.

The estimates presented in this report were developed by Venta, Glaser & Associates with the assistance and cooperation of the Canadian asphalt-based roofing products manufacturers. While the present LCA addresses BUR glass felts, in many respects it is an extension of the ATHENA report entitled, “Life Cycle Analysis of Residential Roofing Products”, prepared by Venta, Glaser & Associates and Jan Consultants, and issued in March 2000. The same constituents are used in production of asphalt impregnated BUR felts as in asphalt residential roofing. Therefore, the raw energy and materials inputs for the asphalt impregnated glass BUR felts were based on numbers developed for the ATHENA Residential Roofing Products study, and imported into the typical BUR felts formulas, as provided by the industry. Asphalt data used in both of these studies are from an independent study by Franklin Associates.

1.1 *Report Structure*

Section 2 of this report presents the formulations for three types of asphalt impregnated built-up roofing felts. Section 3 displays the energy used per tonne of each product. Section 4 provides tables illustrating atmospheric emissions associated with the production of roofing products. Emissions to water from asphalt roofing products are summarized in Section 5, and Section 6 presents estimates of solid wastes.

¹ ATHENA™ is a registered trademark of the ATHENA™ Sustainable Materials Institute.

2.0 Raw Materials Requirements

The asphalt impregnated BUR felts formulations for the three types of felts, as specified by the ASTM D2178-97a “Standard Specifications for Asphalt Glass Felt Used in Roofing and Waterproofing”, are shown in Table 2.1 in grams per square meter, and converted to kg/ tonne of finished product in Table 2.2.

The primary differences between the three types of felts are the size and number of openings in the felt per square foot or meter. As indicated by the formulations shown in Table 2.1, there are also differences in weight. Type IV is the dominant type in the market place, but the other two types are still used, although we have no data on the relative market shares.

For ease of comparison with the “Life Cycle Analysis of Residential Roofing Products”, applicable tables in this report show, in brackets and italics, the corresponding table number in that LCA report.

Table 2.1 (4.25): Product formulations (g/m²)

Input	Type III	Type IV	Type VI
Glass mat	73	83	93
Asphalt saturant	200	95	95
Stabilizer / filler	108	51	51
Parting agent / sand	107	156	146
Total	488	385	385

Table 2.2 (4.26): Product formulations (kg/tonne of product)

Input	Type III	Type IV	Type VI
Glass mat	149.590	215.584	241.558
Asphalt saturant	409.836	246.753	246.753
Stabilizer / filler	221.311	132.468	132.468
Parting agent / sand	219.262	405.195	379.221
Total	1000.000	1000.000	1000.000

3.0 Energy Use

The energy used per tonne of each product is shown in Tables 3.1 to 3.3. The results for each product are presented first in GJ/tonne, and then in MJ/square. The total energy includes that required to produce and transport each of the components from its source to the roofing plant, the energy used in the roofing plant, and feedstock energy.

To convert the embodied energy expressed in GJ/tonne to MJ/square — a square being 100 square feet, a unit commonly used by the roofing industry — the values from Table 3.1 have to be multiplied by a factor of 4.896 (rounded) for Type III glass BUR felt. This conversion factor was derived by multiplying the Type III product weight per m² from Table 2.1, converted to per 100 ft² basis, by 1.08 factor to take into account the overlap during the felt application. For example, the total embodied energy, including feedstock energy, can be thus estimated as—

$$28.7586 \text{ GJ/tonne} \times 0.004896 \text{ tonnes/square} \times 1000 = 140.813 \text{ MJ/square}$$

(Note: all factors are rounded here compared to spreadsheet values).

Similarly, for Type IV and Type VI glass BUR felts, the conversion factor from GJ/tonne to MJ/square is 3.863. (rounding as noted above)

The energy used in the production of Type III BUR glass felt, expressed in MJ/square, is shown in Table 3.1A, and for Types IV and VI, in Tables 3.2A and 3.3A respectively.

Total energy input to the three glass BUR felts is summarized in Tables 3.4 and 3.4A.

Table 3.1 (4.29): Type III Fiberglass BUR felt energy input, GJ/tonne

Fuel type	Components			Manufacturing	
	Process	Transport	Total	Roof plant	Total
Coal	0.0000		0.0000		0.0000
Gasoline	0.0115		0.0115		0.0115
LPG	0.0236		0.0236		0.0236
Diesel road	0.0085	0.4892	0.4977		0.4977
Diesel rail	0.0000	0.0109	0.0109		0.0109
Diesel marine	0.0000	0.0264	0.0264		0.0264
Natural Gas	6.2993		6.2993	0.1477	6.4470
Petroleum Coke	0.0000		0.0000		0.0000
Residual Oil	1.4379	0.5233	1.9612		1.9612
Other	0.0000		0.0000		0.0000
<i>Fuel energy subtotal</i>	<i>7.7808</i>	<i>1.0499</i>	<i>8.8306</i>	<i>0.1477</i>	<i>8.9784</i>
Electricity	1.5635		1.5635	0.0720	1.6355
<i>Total process energy</i>	<i>9.3443</i>	<i>1.0499</i>	<i>10.3941</i>	<i>0.2197</i>	<i>10.6139</i>
Feedstock energy	18.1447		18.1447		18.1447
Total, including feedstock energy	27.4890	1.0499	28.5389	0.2197	28.7586

Table 3.1A: Type III Fiberglass BUR felt energy input, MJ/square

Fuel type	Components			Manufacturing	
	Process	Transport	Total	Roof plant	Total
Coal	0.000000	0.000000	0.000000	0.000000	0.000000
Gasoline	0.056194	0.000000	0.056194	0.000000	0.056194
LPG	0.115386	0.000000	0.115386	0.000000	0.115386
Diesel road	0.041524	2.395430	2.436955	0.000000	2.436955
Diesel rail	0.000000	0.053542	0.053542	0.000000	0.053542
Diesel marine	0.000000	0.129433	0.129433	0.000000	0.129433
Natural Gas	30.843561	0.000000	30.843561	0.723361	31.566922
Petroleum Coke	0.000000	0.000000	0.000000	0.000000	0.000000
Residual Oil	7.040713	2.562162	9.602875	0.000000	9.602875
Other	0.000000	0.000000	0.000000	0.000000	0.000000
<i>Fuel energy subtotal</i>	<i>38.097378</i>	<i>5.140566</i>	<i>43.237944</i>	<i>0.723361</i>	<i>43.961306</i>
Electricity	7.655570	0.000000	7.655570	0.352538	8.008108
<i>Total process energy</i>	<i>45.752948</i>	<i>5.140566</i>	<i>50.893514</i>	<i>1.075899</i>	<i>51.969414</i>
Feedstock energy	88.843081	0.000000	88.843081	0.000000	88.843081
Total, including feedstock energy	134.596028	5.140566	139.736595	1.075899	140.812494

Table 3.2 (4.29): Type IV Fiberglass BUR felt energy input, GJ/tonne

Fuel type	Components			Manufacturing	
	Process	Transport	Total	Roof plant	Total
Coal	0.0000		0.0000		0.0000
Gasoline	0.0072		0.0072		0.0072
LPG	0.0142		0.0142		0.0142
Diesel road	0.0125	0.6126	0.6251		0.6251
Diesel rail	0.0000	0.0158	0.0158		0.0158
Diesel marine	0.0000	0.0264	0.0264		0.0264
Natural Gas	7.8864		7.8864	0.1472	8.0335
Petroleum Coke	0.0000		0.0000		0.0000
Residual Oil	1.7906	0.3151	2.1057		2.1057
Other	0.0000		0.0000		0.0000
<i>Fuel energy subtotal</i>	<i>9.7108</i>	<i>0.9699</i>	<i>10.6807</i>	<i>0.1472</i>	<i>10.8279</i>
Electricity	2.1757		2.1757	0.0720	2.2477
<i>Total process energy</i>	<i>11.8865</i>	<i>0.9699</i>	<i>12.8564</i>	<i>0.2192</i>	<i>13.0755</i>
Feedstock energy	10.9245		10.9245		10.9245
Total, including feedstock energy	22.8110	0.9699	23.7809	0.2192	24.0001

Table 3.2A: Type IV Fiberglass BUR felt energy input, MJ/square

Fuel type	Components			Manufacturing	
	Process	Transport	Total	Roof plant	Total
Coal	0.000000	0.000000	0.000000	0.000000	0.000000
Gasoline	0.027759	0.000000	0.027759	0.000000	0.027759
LPG	0.054808	0.000000	0.054808	0.000000	0.054808
Diesel road	0.048182	2.366539	2.414721	0.000000	2.414721
Diesel rail	0.000000	0.060876	0.060876	0.000000	0.060876
Diesel marine	0.000000	0.102114	0.102114	0.000000	0.102114
Natural Gas	30.464298	0.000000	30.464298	0.568480	31.032778
Petroleum Coke	0.000000	0.000000	0.000000	0.000000	0.000000
Residual Oil	6.916960	1.217027	8.133987	0.000000	8.133987
Other	0.000000	0.000000	0.000000	0.000000	0.000000
<i>Fuel energy subtotal</i>	<i>37.512007</i>	<i>3.746556</i>	<i>41.258563</i>	<i>0.568480</i>	<i>41.827043</i>
Electricity	8.404465	0.000000	8.404465	0.278129	8.682594
<i>Total process energy</i>	<i>45.916471</i>	<i>3.746556</i>	<i>49.663028</i>	<i>0.846609</i>	<i>50.509637</i>
Feedstock energy	42.200463	0.000000	42.200463	0.000000	42.200463
Total, including feedstock energy	88.116935	3.746556	91.863491	0.846609	92.710100

Table 3.3 (4.29): Type VI Fiberglass BUR felt energy input, GJ/tonne

Fuel type	Components			Manufacturing	
	Process	Transport	Total	Roof plant	Total
Coal	0.0000		0.0000		0.0000
Gasoline	0.0072		0.0072		0.0072
LPG	0.0142		0.0142		0.0142
Diesel road	0.0118	0.6727	0.6844		0.6844
Diesel rail	0.0000	0.0177	0.0177		0.0177
Diesel marine	0.0000	0.0159	0.0159		0.0159
Natural Gas	8.7335		8.7335	0.1472	8.8806
Petroleum Coke	0.0000		0.0000		0.0000
Residual Oil	1.9820	0.3151	2.2970		2.2970
Other	0.0000		0.0000		0.0000
<i>Fuel energy subtotal</i>	<i>10.7487</i>	<i>1.0213</i>	<i>11.7700</i>	<i>0.1472</i>	<i>11.9171</i>
Electricity	2.4252		2.4252	0.0720	2.4972
<i>Total process energy</i>	<i>13.1738</i>	<i>1.0213</i>	<i>14.1951</i>	<i>0.2192</i>	<i>14.4143</i>
Feedstock energy	10.9245		10.9245		10.9245
Total, including feedstock energy	24.0984	1.0213	25.1197	0.2192	25.3388

Table 3.3A: Type VI Fiberglass BUR felt energy input, MJ/square

Fuel type	Components			Manufacturing	
	Process	Transport	Total	Roof plant	Total
Coal	0.0000	0.0000	0.0000	0.0000	0.0000
Gasoline	0.0280	0.0000	0.0280	0.0000	0.0280
LPG	0.0548	0.0000	0.0548	0.0000	0.0548
Diesel road	0.0455	2.5984	2.6439	0.0000	2.6439
Diesel rail	0.0000	0.0682	0.0682	0.0000	0.0682
Diesel marine	0.0000	0.0615	0.0615	0.0000	0.0615
Natural Gas	33.7366	0.0000	33.7366	0.5685	34.3051
Petroleum Coke	0.0000	0.0000	0.0000	0.0000	0.0000
Residual Oil	7.6563	1.2170	8.8733	0.0000	8.8733
Other	0.0000	0.0000	0.0000	0.0000	0.0000
<i>Fuel energy subtotal</i>	<i>41.5212</i>	<i>3.9451</i>	<i>45.4663</i>	<i>0.5685</i>	<i>46.0347</i>
Electricity	9.3682	0.0000	9.3682	0.2781	9.6463
<i>Total process energy</i>	<i>50.8894</i>	<i>3.9451</i>	<i>54.8345</i>	<i>0.8466</i>	<i>55.6811</i>
Feedstock energy	42.2005	0.0000	42.2005	0.0000	42.2005
Total, including feedstock energy	93.0898	3.9451	97.0349	0.8466	97.8815

Table 3.4 (4.32): Embodied energy in asphalt impregnated fiberglass BUR felts, GJ/tonne

Energy type	Type III	Type IV	Type VI
Coal	0.0000	0.0000	0.0000
Gasoline	0.0115	0.0072	0.0072
LPG	0.0236	0.0142	0.0142
Diesel road	0.4977	0.6251	0.6844
Diesel rail	0.0109	0.0158	0.0177
Diesel marine	0.0264	0.0264	0.0159
Natural Gas	6.4470	8.0335	8.8806
Petroleum Coke	0.0000	0.0000	0.0000
Residual Oil	1.9612	2.1057	2.2970
Other	0.0000	0.0000	0.0000
<i>Fuel energy subtotal</i>	8.9784	10.8279	11.9171
Electricity	1.6355	2.2477	2.4972
<i>Total process energy</i>	10.6139	13.0755	14.4143
Feedstock energy	18.1447	10.9245	10.9245
Total, including feedstock energy	28.7586	24.0001	25.3388

Table 3.4A: Embodied energy in asphalt impregnated fiberglass BUR felts, MJ/square

Energy type	Type III	Type IV	Type VI
Coal	0.000000	0.000000	0.0000
Gasoline	0.056194	0.027759	0.0280
LPG	0.115386	0.054808	0.0548
Diesel road	2.436955	2.414721	2.6439
Diesel rail	0.053542	0.060876	0.0682
Diesel marine	0.129433	0.102114	0.0615
Natural Gas	31.566922	31.032778	34.3051
Petroleum Coke	0.000000	0.000000	0.0000
Residual Oil	9.602875	8.133987	8.8733
Other	0.000000	0.000000	0.0000
<i>Fuel energy subtotal</i>	<i>43.961306</i>	<i>41.827043</i>	<i>46.0347</i>
Electricity	8.008108	8.682594	9.6463
<i>Total process energy</i>	<i>51.969414</i>	<i>50.509637</i>	<i>55.6811</i>
Feedstock energy	88.843081	42.200463	42.2005
Total, including feedstock energy	140.812494	92.710100	97.8815

4.0 Atmospheric Emissions

Emissions to air have been calculated using the same approach as for energy use and, as in Section 3, table numbers in this section are followed by the corresponding table numbers from the residential roofing report.

Table 4.1 (5.7): Roofing plant emissions for each of the products (kg/tonne)

	Type III	Type IV	Type VI
CO ₂	7.3424	7.3140	7.3140
SO ₂	0.0000	0.0000	0.0000
NO _x	0.0087	0.0087	0.0087
VOC	0.1611	0.1607	0.1607
CO	0.0022	0.0022	0.0022
CH ₄	0.0002	0.0002	0.0002
Particulates	0.0844	0.0615	0.0615

Table 4.2 (5.8): Air emissions associated with production of roofing product components (kg/tonne)

	Type III	Type IV	Type VI
CO ₂	488.55	572.36	629.17
SO ₂	2.5919	2.3409	2.5021
NO _x	1.0005	1.0342	1.1211
VOC	6.0108	4.2211	4.3324
CO	0.4491	0.3683	0.3875
CH ₄	0.2605	0.1641	0.1655
Particulates	0.2237	0.1590	0.1578

Table 4.3 (5.9): Air emissions from transport of components to the roofing products plant (kg/tonne)

	Type III	Type IV	Type VI
CO ₂	76.04	69.70	73.30
SO ₂	0.5012	0.3398	0.3414
NO _x	0.4991	0.5722	0.6211
VOC	0.0543	0.0648	0.0663
CO	0.2251	0.2770	0.3036
CH ₄	0.0122	0.0147	0.0156

Table 4.4 (5.10): Total air emissions associated with production of roofing products (kg/tonne)

	Type III	Type IV	Type VI
CO ₂	564.59	642.05	702.47
SO ₂	3.0931	2.6807	2.8436
NO _x	1.4996	1.6064	1.7423
VOC	6.0652	4.2859	4.3987
CO	0.6742	0.6454	0.6911
CH ₄	0.2727	0.1788	0.1811
Particulates	0.2237	0.1590	0.1578

The above estimates of atmospheric emissions can be converted to grams per roofing square units using the same conversion factors as shown in Section 3.

5.0 Emissions to Water

Emissions to water have been calculated using the same approach as for energy use and, as in Section 3, table numbers in this section are followed by the corresponding table numbers from the residential roofing report.

Table 5.1 (6.2): Emissions to water from asphalt roofing products [g/tonne]

	Type III	Type IV	Type VI
Suspended solids	81.8708	66.2106	64.5975
Aluminum	0.00881	0.01075	0.01023
Phenolics	0.03738	0.02433	0.02416
Oil & Grease	55.2572	33.7322	33.6881
Nitrate, Nitrite	1.15717	1.41040	1.34235
DOC	1.27471	1.55562	1.48047
Chlorides	247.5438	243.8131	234.7764
Sulfates	163.0073	153.3173	148.0564
Sulfides	0.01467	0.01790	0.01704
Ammonia, -ium	1.07225	0.80175	0.78686
Zinc	0.05094	0.03429	0.03395

6.0 Solid Waste

Solid wastes have been estimated using the same approach as for energy use and, as in Section 3, the table number is followed by the corresponding table number from the residential roofing report.

Table 6.1 (7.1): Solid wastes (kg/tonne of product)

Type III	Type IV	Type VI
9.0000	5.4187	5.4187