the ATHENA™
Sustainable Materials Institute

LIFE CYCLE INVENTORY OF ICI ROOFING SYSTEMS: ONSITE CONSTRUCTION EFFECTS

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Preface

This report 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. For example, this report deals with on-site roof construction, while a separate report deals with the manufacture of selected roofing 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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1. INTRODUCTION

Morrison Hershfield was contracted by the Athena Sustainable Materials Institute to undertake research into the on-site environmental effects of several roofing systems utilized in Canada. This report includes sections on different roofing systems, components, and membrane types, as well as an On-Site Environmental Effects Table (Section 4).

1.1 Terms of Reference

Our terms of reference are described in detail in Appendix A. In summary, our services included review of the following types of membrane systems:

1. 4 ply built-up roof membrane with organic felts;
2. 4 ply built-up roof membrane with fiberglass felts;
3. PVC membrane;
4. EPDM membrane;
5. 2 ply standard modified bitumen membrane;
6. rubberized asphalt membrane; and
7. TPO membrane.

The following information was developed for each of the membrane types:

- locations of manufacture using information gathered from large material manufacturers;
- information relating to typical locations of distributors across Canada;
- on-site installation energy in volume of natural gas, propane, oil, etc. and electric power;
- on-site material quantities including tertiary items, i.e., fasteners, wood curbs, etc. (for these items, we assume a roofing system for each membrane type, define the materials used in this system, and provide the material breakdown of the membrane systems); and
- on-site material wastes.

Some of the information provided within this report was obtained from and/or verified by Simluc Roofing, a large roofing contractor located in Ottawa. Further, Peter Kalinger of Kalinger and Associates provided information about typical material types and manufacturers in Canada, and also reviewed the report for accuracy.

1.2 Limitations

Professional judgment was exercised in gathering and analyzing the information obtained and in the formulation of the conclusions. Like all professional persons rendering advice, we do not act as insurers of the conclusions we reach, but we commit ourselves to care and competence in reaching those conclusions. No other warranties, either expressed or implied, are made.

1.2.1 Information Used

The assessment is based, in part, on information provided by others. Unless specifically noted, we have assumed that this information is correct and have relied on it in developing our conclusions.

1.2.2 Assumptions

In the development of the unit quantities, for some items it was necessary to assume a roof size and complexity, as well as the size of some of the components in this roof. The details of this assumed roof are as follows:

- the roof is 50 m x 50 m, including a 30 m x 30 m one storey penthouse and six 2 m x 2 m mechanical units; and
- the parapet is 1 m high and 300 mm deep, and runs continuously around the main and penthouse roofs.

2. ROOFING SYSTEMS AND COMMON ELEMENTS

Different roofing systems can be utilized regardless of membrane type. Further, some elements within roofing systems are common and not dependent on the type of membrane.

2.1 Conventional Roofing Systems

A conventional roofing system is defined as a roof on which the membrane is located above the insulation. In Canada, conventional roofing systems typically require vapour barriers, and can be installed on any type of roof deck. Advantages of conventional systems include reduced loads and protection of the insulation. Disadvantages include the exposure of the membrane to temperature extremes, and the possibility of water or moisture being trapped beneath the membrane. Conventional roofing systems are more popular in Canada than protected membrane roof assemblies.

2.2 Protected Membrane Roof Assemblies

A protected membrane roof assembly (PMRA), or inverted roofing system, is defined as a roof on which the membrane is located below the insulation. In Canada, PMRA's are most often installed on concrete decks, although they are occasionally installed on steel decks as well. PMRA's typically require a great deal of ballast to reduce the likelihood of flotation or blow-off of the insulation, which is loose laid above the membrane. In PMRA's, the membrane normally also acts as the vapour barrier. Advantages of PMRA's include protection of the membrane from mechanical damage, traffic, UV light and temperature extremes. Disadvantages of PMRA's include increased cost, increased loads due to ballast, difficulties in performing maintenance, and increased membrane and insulation exposure to moisture and water.

PMRA's always utilize extruded polystyrene insulation. Typically, a woven polyethylene filter fabric weighing 84 g/m^2 is utilized above the insulation to provide UV protection for the insulation and to prevent migration of ballast.

Material and energy inputs for the system types are included within the membrane sections and table that follow. Insulation inputs are included in the insulation section.

2.3 Common Roof Components

The following roof components are common to many of the roof membrane types that follow.

2.3.1 Insulation

Typical roofing insulations utilized in Canada include high density fiberglass, high density rock wool, extruded polystyrene, expanded polystyrene, polyisocyanurate, and wood fiberboard. Insulations can be bonded to the

substrate with adhesives or asphalt, or can be mechanically fastened. In Canada, insulation thickness typically varies between 2" and 6". The exception to this is wood fiberboard, which is typically installed as a protection layer above other insulations, and is typically 12mm thick. It is also worth noting that most low-rise residential type applications do not include insulation within the roofing assembly (the insulation is provided in the attic space).

Sloped insulations are available in polyisocyanurate, wood fiberboard or expanded polystyrene, but these are not common in new construction.

A brief description of the various insulation types follows.

Expanded Polystyrene (EPS)

Expanded (molded) EPS board is formed from a plastic (polystyrene) polymer, which is supplied by several companies to regional converters. The process includes molding into blocks, processing into sheets, and applying facer materials (optional). The weight of 2" EPS is approximately 13 kg/square[1].

Extruded Polystyrene (XPS)

Extruded polystyrene board is formed from a plastic (polystyrene) polymer. Closed cells are integrally formed within the insulation materials during the expansion process. The continuous extrusion process causes a tight and complete skin (free of open cells) to form on each side of the insulation board. Boards are expanded to a specific thickness during the manufacturing process. The weight of 2" XPS is approximately 22 kg/square.

Glass Fiber

Glass fiber roof board insulation is a rigid insulation material composed of fine glass fibers, which provide the insulating properties of the product. The glass fiber reinforced asphalt and kraft paper top surface of the insulation boards provides a tough, impact resistant surface upon which the roof system may be applied. The weight of 2" fiberglass is approximately 55 kg/square.

Fiberboard

Fiberboard insulation is a preformed rigid fibrous-felted homogenous panel, composed principally of wood or cane fibers integrally treated with waterproofing additives and binders. The weight of 1/2" fiberboard is approximately 25 kg/square.

[1] A roofing "square" is equal to 100 square feet.

Polyisocyanurate

Polyisocyanurate foam board insulation is produced from a polyisocyanurate based chemical. The polyisocyanurate material is usually sandwiched between asphalt saturated organic or inorganic felt facer sheets. Glass fiber reinforcement used in some foam cores provides additional fire resistance and greater dimensional stability. The weight of 2” polyisocyanurate insulation is approximately 17 kg/square.

2.3.2 Decks

Typical roofing substrates in Canada include a steel deck (usually with gypsum board), a concrete deck, and a wood deck. The deck types are already covered within the ATHENA model. However, the gypsum board in a steel deck is not currently included. Thus, we suggest adding 1/2” gypsum board and related fasteners into the model as an option for steel decks. For this application, we suggest a 1% waste on gypsum board be assumed, and that 0.5 kg/square of fasteners should be used. The gypsum board and fasteners are included within the On-Site Environmental Effects Table (Section 4).

2.3.3 Parapets

Parapets are typically constructed of wood, steel, concrete, or concrete block. Parapet heights can vary from about 100 mm to over 3 m high. The materials used can vary dramatically, particularly for high parapets, on which lateral bracing would be necessary. However, we have assumed a parapet height of 1.0 m, which we believe represents a reasonable height for buildings in Canada. Accordingly, we suggest the following materials be input into the model for the different parapet types (per linear meter of parapet):

Wood:	3.6 bdft/m small dimension lumber
	2.8 m^2 /m plywood (1/2” equivalent)
	0.07 kg/m nails
	6.0 m^2/m of 1” thick fiberglass batt insulation
Steel Stud:	9.6 kg/m galvanized steel (studs)
	2.8 m^2 /m plywood (1/2” equivalent)
	0.07 kg/m nails
	6.0 m^2/m of 1” thick fiberglass batt insulation
Concrete:	0.208 m^3/m 15 MPa concrete
	5.47 kg/m rebar light sections
	1.0 bdft/m small dimension lumber
	0.250 m^2 /m plywood (1/2” equivalent)
	2.0 m^2/m of 1” thick XPS insulation
	0.30 m^2/m of 1” thick fiberglass insulation

Concrete block: 12.36 blocks/m concrete blocks
0.038 m^3/m mortar
3.18 kg/m rebar light sections
1.0 bdft/m small dimension lumber
0.250 m^2 /m plywood (1/2" equivalent)
2.0 m^2/m of 1" thick XPS insulation
0.30 m^2/m of 1" thick fiberglass insulation

Note that parapet materials have not been included in the On-Site Environmental Effects Table. We recommend that the ATHENA model include a parapet option with user identifiable height for all roof assemblies.

2.3.4 Metal Flashings

Metal flashings are typically present at parapets, at the base of walls where they intersect roofs (e.g., a penthouse), and around mechanical units. Metal flashings are most commonly constructed from 26 gauge galvanized steel. The amount of metal flashing is dependent on the roof type and susceptibility to UV degradation, but is not dependent on parapet construction. Accordingly, the metal flashing quantities are included within the On-Site Environmental Effects Table.

2.3.5 Asphalt

Asphalt or bitumen is used in built-up roofing (BUR) and modified bitumen roofing systems, both as an adhesive and as an integral part of the waterproofing system. Asphalt is typically purchased directly from a refinery and shipped to a processing plant, where it is oxidized. From this plant it is either cooled into cake form and delivered to distributors, or delivered directly in heated tanker trucks.

The majority of roofing projects in Canada utilize cakes of asphalt, which are delivered to a site on a flat bed truck and re-heated in propane fired kettles.

Heated tanker trucks are utilized on large jobs for both modified bitumen and BUR systems. Currently, tanker trucks serve approximately 15 to 30% of the asphalt market in Toronto, Calgary, Montreal, and Winnipeg. Some energy savings are achieved through the use of tanker trucks due to the delivery of hot (rather than cold) asphalt from the plant. However, these costs are offset by the increased volume of asphalt to heat. A roofing contractor who frequently utilizes both methods stated that the average propane usage in heating asphalt is very similar for both methods.

2.3.6 Environmental Site Effects Associated with Re-Roofing

There are some environmental effects associated with removing an existing roof prior to installing a new roof. Material waste is not included within this section; however, the mechanical removal of the existing roofing system typically results

in gasoline use of approximately 1.85 l/square for a bituminous roofing system. This figure represents the cost of mechanical removal of a roofing system, and would be applicable for entire roof membrane replacement or major repair projects. There are no appreciable costs, however, associated with the removal of a single ply membrane.

3. ROOF MEMBRANE TYPES

3.1 PVC Roofing Membranes

PVC (polyvinyl chloride) roof membranes are members of a thermoplastic group of materials. PVC polymers are produced by polymerization of vinyl chloride monomer, a gaseous substance resulting from the reaction of ethylene with oxygen and hydrochloric acid. Additives including plasticizers and stabilizers are utilized to provide a product suitable for roofing applications. Seams in PVC membranes can be welded together with heat or solvent to achieve bonds stronger than the original material.

PVC membranes currently make up less than 3% of the Canadian roofing market.

3.1.1 Roof System Descriptions

PVC roofing membranes are usually installed as PMRA's or conventional assemblies. In PMRA's, PVC membranes are typically fully adhered or loose laid with the perimeter mechanically fastening to the substrate. In conventional assemblies, PVC membranes are mechanically fastened with bars or discs, or can be ballasted with stone or concrete pavers. Most applications utilizing PVC membrane in Canada are conventional systems incorporating bar fasteners or conventional or PMRA ballasted systems. PVC roofing membranes are usually installed on steel or concrete decks. However, they would be suitable for installation on a wood deck as well (this would be similar to a steel deck installation, without the gypsum board).

3.1.2 Roof Component Details

- ***Felt underlayment***: 1.5 mm non-woven polyester felt, 236 g/m^2, assume 1% waste.
- ***Vapour barrier***: 0.25 mm thick low density polyethylene sheet, assume 2% waste.
- ***PVC membrane***: 1.2mm thick, 4.9 kg/m^2, assume 3% waste.
- ***Primer***: solvent or water based primer.

3.1.3 Manufacturers and Distributors

The largest distributor in Canada is Sarnafil Canada, which supplies the majority of PVC membrane in North America.

Sarnafil is manufactured in Kanton, Massachusetts for all of North America and delivered by truck to its distributors in Canada. The values shown in the On-Site

Environmental Effects Table represent a breakdown of the distance traveled to the distributor and to the major centres in Canada.

3.1.4 Energy Costs

Sarnafil is not a very energy intensive material to install. Some energy items required in the installation of PVC systems include:

- screwing the mechanical fasteners into place with regular electric drills;
- welding the seams with hot air welders; and
- lifting ballast to the roof top.

The amount of electrical energy required per square of roofing membrane for the different membrane systems is shown in the On-Site Environmental Effects Table.

3.2 TPO Roofing Membranes

The acronym TPO is a chemical industry accepted designation for a family of thermoplastic resins which are created from basic olefinic monomers. The TPO acronym is a true representation of the chemistry in the resin used to make a particular roofing membrane, much as 'PVC' represents a family of chlorinated vinyl resins and 'EPDM' represents a family of resins also based upon olefinic monomers.

Typically, and for the roofing industry, TPO polymers are blends or alloys of polypropylene plastic or polypropylene and ethylene propylene rubber (EPR) or ethylene propylene diene terpolymer rubber (EPDM). These alloys can be made either by mechanical mixing or by reactor blending using proprietary polymer manufacturing processes. After further mixing with other additives, these polymer alloys are then formed into roofing membranes with a variety of properties.

TPO membranes currently make up less than 5% of the Canadian roofing market, although increased use is expected in the future.

3.2.1 Roof System Descriptions

TPO roofing membranes are typically installed in very similar applications to those of PVC membranes, as noted in 3.1.1.

3.2.2 Roof Component Details

- ***Felt underlayment***: 1.5 mm non-woven polyester felt, 236 g/m^2, assume 1% waste.

- ***Vapour barrier***: 0.25mm thick low density polyethylene sheet, assume 2% waste.
- ***TPO membrane***: 1.1 to 1.5 mm thick, assume 3% waste.
- ***Primer***: solvent or water based primer.

3.2.3 Manufacturers and Distributors

The largest TPO membrane manufacturers serving Canada are Carlisle and Lexcan/JP Stevens.

Carlisle manufactures TPO in Senatopia, Mississippi and delivers it to Carlisle, Pennsylvania. From Carlisle, the membrane is shipped to all major centres in Canada. Lexcan are Canadian distributors of TPO membranes and are located in all the major centres in Canada. Their TPO membrane is manufactured in Westfield, North Carolina by JPS Elastomerics. Both manufacturers deliver their material by truck to their distributors in Canada. The values shown in the On-Site Environmental Effects Table represent an average of the distances traveled to the distributor and to the major centres in Canada.

3.2.4 Energy Costs

TPO membranes exhibit similar energy costs to PVC membrane systems, except that the rolls of TPO membrane can be slightly larger, reducing the number of heat welds. Further, the heat required to weld the seams is approximately 10% less than that for PVC membranes.

The amount of electrical energy required per square of roofing membrane for the different membrane systems is shown in the On-Site Environmental Effects Table.

3.3 EPDM Roofing Membranes

EPDM (ethylene-propylene-diene monomer) roof membranes are members of an elastomeric group of materials. EPDM membranes are compounded with polymers and ingredients such as fillers, anti-degradants, processing oils, and processing aids. EPDM contains 30-50% polymer (ethylene-propylene-diene monomer), 20-30% carbon black and 30-50% extender oil, sulfur, accelerator, and anti-oxidant. Sheets are produced by laminating two plies with or without reinforcement. Most EPDM sheets are vulcanized or cured in the factory by heating the compound with sulfur or another cross-linking agent. EPDM membranes can be provided in very long relatively narrow rolls (2-3m) when mechanically fastened or fully adhered, or in very large sheets in ballasted or fully adhered systems. Seams in EPDM roofs are created using adhesives either in the field or the factory.

EPDM membranes currently make up about 10% of the Canadian roofing market.

3.3.1 Roof System Descriptions

EPDM roofing membranes are typically installed as PMRA or conventional assemblies. EPDM membrane systems in Canada are either fully adhered with adhesives, ballasted with smooth stones or concrete pavers, or mechanically fastened with screw and plate systems. Adhered EPDM membranes are usually mechanically fastened with bars at the perimeter and large roof penetrations, and adhered at the remainder of the roof surfaces. Conventional and PMRA loose laid, fully adhered, and mechanically fastened systems are common in Canada. EPDM roofing membranes are most often installed on steel or concrete decks; however, they would be suitable for installation on a wood deck as well (this would be similar to a steel deck installation, without the gypsum board).

3.3.2 Roof Component Details

- ***Felt underlayment***: 1.5 mm non-woven polyester felt, 236 g/m^2, assume 1% waste.
- ***Vapour barrier***: 0.25mm thick low density polyethylene sheet, assume 2% waste.
- ***Splice cleaner***: solvent based.
- ***Splice cement***: solvent based contact cement.
- ***Bonding adhesive***: synthetic rubber.
- ***EPDM membrane***: 1.5 to 2.3mm thick, un-reinforced, assume 3% waste.
- ***Primer***: solvent or water based primer.

3.3.3 Manufacturers and Distributors

The largest EPDM membrane manufacturers serving Canada are Carlisle and Firestone.

Carlisle manufactures EPDM in Carlisle, Pennsylvania and Greenville, Illinois. From these locations, Carlisle delivers membranes to all major centres in Canada. Firestone manufactures EPDM in Kings Tree, South Carolina and Prescott, Nevada, delivering it to all major centres in Canada. Both manufacturers deliver their material by truck to their Canadian distributors. The values shown in the On-Site Environmental Effects Table represent an average of the distances traveled to the distributor and to the major centres in Canada.

3.3.4 Energy Costs

EPDM is not a very energy intensive material to install. Some energy items required in the installation of EPDM systems include:

- screwing the mechanical fasteners into place with regular electric drills; and
- lifting ballast and roofing materials to the roof top.

The amount of electrical energy required per square of roofing membrane for the different membrane systems is shown in the On-Site Environmental Effects Table.

3.4 Built Up Roofing Membranes

A BUR membrane typically consists of four layers of felt and asphalt and a flood coat of asphalt over the top layer. The felts can be constructed using fiberglass or organic materials. Asphalt is available in several different types which vary by viscosity, although not significantly by composition. Coal tar pitch was once a common component in BUR roofing assemblies, but is now rarely used in Canada. Asphalt is either mopped or poured over the felt layers to provide uniform and complete asphalt coverage of each layer.

BUR membranes currently make up approximately 50% of the Canadian roofing market.

3.4.1 Roof System Descriptions

BUR membranes are typically installed as PMRA or conventional assemblies. All BUR membranes are fully adhered to their substrate, although the insulation above the membrane in PMRA's is ballasted. BUR membranes can be installed on steel, wood, or concrete decks. They are common in both high and low rise construction.

3.4.2 Roof Component Details

- ***Organic Felts:*** no. 15 perforated asphalt felt.
  Unsaturated felt weight = 1.020 kg/m^2 per four felts.
  Asphalt saturant weight in felts = 1.275 kg/m^2 per four felts.
  Asphalt (interply and flood coat): 7.0 kg/m^2 per four felts.

- ***Fiberglass Felts:*** type 4 asphalt saturated glass ply sheet.
  Unsaturated felt weight = 0.372 kg/m^2 per four felts.
  Asphalt saturant weight in felts = 1.153 kg/m^2 per four felts.
  Asphalt (interply and flood coat): 7.8 kg/m^2 per four felts.

- ***Vapour barrier:*** vapour barriers in built-up roofs typically consist of either a 2-ply mopped on felts, or kraft paper. Kraft paper vapour barriers are normally composed of two layers of 30 lb. kraft paper laminated with asphalt and reinforced with glass fiber. Kraft paper weighs about 1.5kg/square. Vapour barriers are typically adhered with asphalt or adhesive.

- ***Vapour barrier adhesive***: if vapour barriers are applied directly to a steel deck, then adhesives are commonly utilized. Typical adhesives are comprised of an engineered cutback asphalt modified to improve elasticity and adhesion. The primary ingredients are asphalt and a solvent base. Other ingredients are proprietary and vary by manufacturer. Approximately 1.8 kg/square of adhesive are used in applications directly over a steel deck, with no appreciable waste.

- ***Primer:*** solvent based asphaltic primer.

In addition to the above, there is typically a gravel cover of 20 kg/m^2 applied for UV protection on conventional roofs.

3.4.3 Manufacturers and Distributors

The two largest manufacturers of felts used in BUR roofing are IKO and EMCO.

IKO manufactures felts in Brampton, Ontario and Calgary, Alberta. EMCO manufactures felts in LaSalle, Quebec and Edmonton, Alberta. Both manufacturers deliver their material by truck to their distributors in all major centres in Canada. The values shown in the On-Site Environmental Effects Table represent an average of the distances traveled to the distributor and to the major centres in Canada.

3.4.4 Energy Costs

BUR roofs are reasonably energy intensive materials to install. Some energy items required in the installation of BUR systems include:

- heating with propane of the asphalt from ambient temperature to 400°F;

- screwing the mechanical fasteners in some steel deck systems into place with regular electric drills; and

- lifting ballast to the roof top.

The amount of electrical energy required per square of roofing membrane for the different membrane systems is shown in the On-Site Environmental Effects Table.

3.5 Modified Bitumen Roofing Membranes

Modified bitumen roofing membranes are composite sheets consisting of bitumen, modifiers and reinforcements. The term "modified bitumen" encompasses a broad range of materials, with each specific material differing from the others with respect to the modifiers and reinforcements used. Modified bitumen membranes exhibit a thermoplastic quality of being softened by heat. They are typically bonded to substrates by torch application or asphalt.

Reinforcing materials consist of plastic films, polyester mats, glass fibers, felts, or fabrics. The modified bitumen membranes utilized most commonly in Canadian roofing applications, however, include polyester reinforcement mats integral to the material.

Modified bitumen membranes can be broken into two general categories: those utilizing atactic polypropylene (APP) as modifiers and those utilizing styrene butadiene (SBS) as modifiers. SBS membranes can be applied by torch or asphalt, and are far more typical in Canada. APP membranes are always applied with a propane torch and represent a small portion of the roofing market in Canada.

Modified bitumen membranes currently make up approximately 30% of the Canadian roofing market.

3.5.1 Roof System Descriptions

Modified bitumen roofing membranes typically consist of two layers — a base ply and a finishing (or cap) ply — and are commonly installed as PMRA or conventional assemblies. In PMRA's, modified bitumen membranes are fully adhered to the substrate. In conventional assemblies, modified bitumen membranes are either mechanically fastened with screws and plates, or fully bonded to the substrate. Both types of conventional assemblies, as well as PMRA's, are common in Canada. Modified bitumen roofing membrane systems are typically installed on steel or concrete decks; however, they would be suitable for installation on a wood deck as well (this would be similar to a steel deck installation, without the gypsum board).

3.5.2 Roof Component Details

Modified bitumen roofing systems are similar in construction to BUR systems, with the exception of the membrane type. Modified bitumen membranes can be installed using asphalt, or by torch welding. The two suppliers noted above stated that approximately 50% of the base sheet installation is with hot asphalt, while about 10% of the cap sheet installation is with hot asphalt. The membranes utilized in asphalt bonded systems are typically thinner; however, the total thickness of the system is comparable to a system installed by torch welding. Further, both hot asphalt and modified bitumen sheets are heated using propane.

Specific components utilized in modified bitumen membrane systems include the following.

- ***Primer:*** solvent based asphaltic primer.
- ***Vapour barrier:*** vapour barriers in built-up roofs typically consist of either a 2-ply mopped on felts, or kraft paper.
- ***Modified bitumen base sheet membrane adhered with asphalt:*** 2.2 mm, fiberglass reinforcement, assume 3% waste.
- ***Modified bitumen base sheet torch applied:*** 3 to 4 mm, polyester reinforcement, assume 3% waste.
- ***Modified bitumen cap sheet torch applied:*** 4 mm, polyester reinforcement, granule surfaced, assume 3% waste.

3.5.3 Manufacturers and Distributors

The two largest manufacturers of modified bitumen membranes are IKO and Soprema.

IKO manufactures membrane in Brampton, Ontario and Calgary, Alberta. Soprema manufactures membrane in Drummondville, Quebec and Chilliwack, British Columbia. Both manufacturers deliver their material by truck to their distributors in all major centres in Canada. The values shown in the On-Site Environmental Effects Table represent an average of the distances traveled to the distributor and to the major centres in Canada.

3.5.4 Energy Costs

Modified bitumen membrane is a reasonably energy intensive material to install. Some energy items required in the installation of these systems include:

- heating with propane of the asphalt or underside of the modified bitumen membrane;
- screwing the mechanical fasteners into place with regular electric drills; and
- lifting materials to the roof top.

The amount of electrical energy required per square of roofing membrane for the different membrane systems is shown in the On-Site Environmental Effects Table.

3.6 Hot Applied Rubberized Asphalt Membranes

Rubberized asphalt is a flexible, site applied membrane for use in waterproofing and roofing applications. It consists of proprietary blends of asphalt, mineral fillers, elastomers (natural, synthetic, or a blend of both), virgin or reclaimed oil, and a thermoplastic resin.

Rubberized asphalt is delivered to sites in keg form via truck. It is typically heated on site in large, propane fired kettles and applied by squeegee or trowel.

Rubberized asphalt is considered a relatively low cost membrane system, and currently makes up less than 5% of the Canadian roofing market. It is most commonly utilized on building roofs with concrete decks as well as podium or garage roof decks throughout Canada, although it can be installed on gypsum board or wood substrates as well.

3.6.1 Roof System Descriptions

Hot applied fluid rubberized asphalt is not UV resistant and is used in roofing applications only where it is sheltered from sunlight and traffic in protected membrane applications. Further, rubberized asphalt membranes are usually installed on concrete decks.

3.6.2 Roof Component Details

Rubberized asphalt roofing systems incorporate a primer or surface conditioner, a reinforcement layer, a protection sheet, and membrane reinforcements at flashing locations. A description of each of these components is provided below.

- ***Primer:*** solvent based asphaltic primer.
- ***Membrane:*** total thickness of two plies: 5mm, 0% waste.
- ***Membrane reinforcement:*** spun bonded polyester fabric.
- ***Protection sheet:*** 6 mil polyethylene.
- ***Flashing membrane:*** thermoset membrane made of uncured neoprene, sheet form, thickness 1.5 mm.
- ***Flashing membrane reinforcement:*** synthetic rubber, blend of butyl and EPDM; sheet form, thickness of 1.2 mm.

3.6.3 Manufacturers and Distributors

The largest manufacturer in Canada is Hydrotech Canada, supplying the majority of rubberized asphalt membrane. Hydrotech manufactures their material in

Montreal, Quebec, and delivers it by truck to distributors in all major centres in Canada.

3.6.4 Energy Costs

Rubberized asphalt is reasonably energy intensive to install. Some energy items required in the installation of this material include:

- heating with propane of the rubberized asphalt from ambient temperature to 500°F; and
- lifting materials to the roof top.

The amount of electrical energy required per square of roofing membrane for the different membrane systems is shown in the On-Site Environmental Effects Table.

3.7 Other Roofing Membranes

A detailed discussion of the following membrane types is not within the scope of this project. In time, consideration should be given to including the following roofing materials in the ATHENA model as well.

3.7.1 Spray Applied Polyurethane Foam

Spray applied polyurethane foam is somewhat different from other insulating materials in that it is not provided in board form, but is constructed on site by mixing components and spraying directly on the substrate. It forms not only the insulating layer, but also a major portion of the waterproofing layer.

Currently, this type of system is very rarely utilized in Canada. The use of polyurethane foam in roofing applications, however, will likely increase dramatically following recent approval by FM Global, effectively allowing the installation of these systems on buildings which FM Global insures.

3.7.2 Metal Roofing Systems

Metal roofing systems can be divided into two categories: architectural and structural. Architectural systems consist of metal sheeting installed and supported by a roof deck. These are common in low rise and residential applications. Structural systems are designed to resist the passage of water and have the capability to span joists without additional support; they can be installed in low slope applications.

We understand the ATHENA model can currently handle architectural metal roofing systems. However, the structural systems are relatively common in industrial applications and represent about 6% of the low slope market in Canada.

3.7.3 Cold Applied Liquid Compounds

This category of material comprises a number of different proprietary products in the market. They typically consist of emulsions and solutions of various resins or elastomers, bitumens, or modified bitumens. They typically contain volatile solvents which evaporate after installation, leaving the waterproofing layer. They can be applied by spray roller or squeegee.

These systems make up a small percentage of the roofing market.

4. ON-SITE ENVIRONMENTAL EFFECTS TABLE

The following table provides estimates of the environmental site effects of different roofing systems and membrane types. The table includes:

- average component transportation from manufacturers to distributors and from distributors to sites by region;
- energy inputs;
- material inputs; and
- typical insulation types for each roofing system.

The table is structured with one roofing system per page.

BUR
Conventional low rise with organic felts

Description: steel deck, Kraft paper vapour barrier, 2" insulation, 1/2" fiberboard, 4-ply BUR membrane - organic felts, gravel cover

TRANSPORTATION	Calgary	150
Manufacturer to Distributor (km)	Montreal	300
by truck	Toronto	280
	Halifax	1520
	Vancouver	1010
	Winnipeg	1310
TRANSPORTATION	Calgary	60
Distributor to Site (km)	Montreal	60
by truck	Toronto	60
	Halifax	60
	Vancouver	60
	Winnipeg	60
ENERGY INPUTS		
On site electricity input	KWH/square	0.0275
On site propane use	kg/square	3.45
On site diesel use	l/square	0.436
MATERIAL INPUTS		
stone ballast	kg/square	185.8
small dimension lumber	BF/square	0
	waste	5%
Plywood	m2(1/2")/square	0
	waste	5%
steel fasteners	kg/square	0.5
	waste	2%
galvanized steel misc.	kg/square	0
	waste	0%
galvanized steel flashing	kg/square	10.96
	waste	8%
gypsum board (steel deck only)	m2(1/2")/square	0
	waste	1%
organic 15# felts	m2/square	37.16
	waste	14%
fiberglass 15# felts	m2/square	0
	waste	14%
Kraft paper	m2/square	9.29
	waste	2%
asphalt	kg/square	76.2
	waste	0%
filter fabric	m2/square	0
	waste	1%
polyethylene vapour barrier	m2/square	0
	waste	2%
1.5 mm thick polyester felt	m2/square	0
	waste	1%
INSULATION		
wood fiberboard	m2(1/2")/square	9.29
	waste	1%
extruded polystyrene	see note	
expanded polystyrene	see note	
fiberglass	see note	x
rock wool	see note	x
isocyanurate	see note	x
insulation waste		2%

Note: "x" represents types of insulation typical for specific systems; quantity = 18.58 m2 of 1" thick insulation.

BUR
Conventional with fiberglass felts

Description: steel deck, 1/2" drywall, 2-ply organic felt vapour barrier, 2" insulation, 1/2" fiberboard, 4-ply BUR - fiberglass felts

TRANSPORTATION	Calgary	150
Manufacturer to Distributor (km)	Montreal	300
by truck	Toronto	280
	Halifax	1520
	Vancouver	1010
	Winnipeg	1310
TRANSPORTATION	Calgary	60
Distributor to Site (km)	Montreal	60
by truck	Toronto	60
	Halifax	60
	Vancouver	60
	Winnipeg	60
ENERGY INPUTS		
On site electricity input	KWH/square	0.0275
On site propane use	kg/square	5.68
On site diesel use	l/square	0.436
MATERIAL INPUTS		
stone ballast	kg/square	185.8
small dimension lumber	BF/square	0
	waste	5%
Plywood	m2(1/2")/square	0
	waste	5%
steel fasteners	kg/square	0.5
	waste	2%
galvanized steel misc.	kg/square	0
	waste	0%
galvanized steel flashing	kg/square	10.96
	waste	8%
gypsum board (steel deck only)	m2(1/2")/square	9.29
	waste	1%
organic 15# felts	m2/square	18.58
	waste	14%
fiberglass 15# felts	m2/square	37.16
	waste	14%
Kraft paper	m2/square	0
	waste	0%
asphalt	kg/square	125
	waste	0%
filter fabric	m2/square	0
	waste	1%
polyethylene vapour barrier	m2/square	0
	waste	2%
1.5 mm thick polyester felt	m2/square	0
	waste	1%
INSULATION		
wood fiberboard	m2(1/2")/square	9.29
	waste	1%
extruded polystyrene	see note	
expanded polystyrene	see note	
fiberglass	see note	x
rock wool	see note	x
isocyanurate	see note	x
insulation waste		2%

Note: "x" represents types of insulation typical for specific systems; quantity = 18.58 m2 of 1" thick insulation.

		BUR Inverted Description: concrete deck, 4 ply BUR membrane, 2" insulation,filter fabric, 60 kg/m2 stone ballast
TRANSPORTATION	Calgary	150
Manufacturer to Distributor (km)	Montreal	300
by truck	Toronto	280
	Halifax	1520
	Vancouver	1010
	Winnipeg	1310
TRANSPORTATION	Calgary	60
Distributor to Site (km)	Montreal	60
by truck	Toronto	60
	Halifax	60
	Vancouver	60
	Winnipeg	60
ENERGY INPUTS		
On site electricity input	KWH/square	0
On site propane use	kg/square	3.13
On site diesel use	l/square	0.872
MATERIAL INPUTS		
stone ballast	kg/square	557.4
small dimension lumber	BF/square	0
	waste	5%
Plywood	m2(1/2")/square	0
	waste	5%
steel fasteners	kg/square	0
	waste	2%
galvanized steel misc.	kg/square	0
	waste	0%
galvanized steel flashing	kg/square	10.96
	waste	8%
gypsum board (steel deck only)	m2(1/2")/square	0
	waste	0%
organic 15# felts	m2/square	37.16
	waste	14%
fiberglass 15# felts	m2/square	0
	waste	14%
Kraft paper	m2/square	0
	waste	0%
asphalt	kg/square	68.8
	waste	0%
filter fabric	m2/square	9.29
	waste	1%
polyethylene vapour barrier	m2/square	0
	waste	2%
1.5 mm thick polyester felt	m2/square	0
	waste	1%
INSULATION		
wood fiberboard	m2(1/2")/square	0
	waste	0%
extruded polystyrene	see note	x
expanded polystyrene	see note	
fiberglass	see note	
rock wool	see note	
isocyanurate	see note	
insulation waste		1%

Note: "x" represents types of insulation typical for specific systems; quantity = 18.58 m2 of 1" thick insulation.

		PVC Conventional mechanically fastened Description: steel deck, 1/2" drywall, 0.25 mm polyethylene vapour barrier, 2" insulation, PVC membrane with bars
TRANSPORTATION	Calgary	4315
Manufacturer to Distributor (km)	Montreal	529
by truck	Toronto	891
	Halifax	1072
	Vancouver	4315
	Winnipeg	4315
TRANSPORTATION	Calgary	60
Distributor to Site (km)	Montreal	60
by truck	Toronto	60
	Halifax	60
	Vancouver	60
	Winnipeg	60
ENERGY INPUTS		
On site electricity input	KWH/square	0.2415
On site propane use	kg/square	0
On site diesel use	l/square	0
MATERIAL INPUTS		
stone ballast	kg/square	0
small dimension lumber	BF/square	12.1
	waste	5%
Plywood	m2(1/2")/square	0.18
	waste	5%
steel fasteners	kg/square	1.022
	waste	2%
galvanized steel misc.	kg/square	5.922
	waste	2%
galvanized steel flashing	kg/square	2.16
	waste	2%
gypsum board (steel deck only)	m2(1/2")/square	9.29
	waste	1%
organic 15# felts	m2/square	0
	waste	14%
fiberglass 15# felts	m2/square	0
	waste	14%
Kraft paper	m2/square	0
	waste	0%
asphalt	kg/square	0
	waste	0%
filter fabric	m2/square	0
	waste	1%
polyethylene vapour barrier	m2/square	9.29
	waste	2%
1.5 mm thick polyester felt	m2/square	0
	waste	1%
INSULATION		
wood fiberboard	m2(1/2")/square	0
	waste	0%
extruded polystyrene	see note	
expanded polystyrene	see note	x
fiberglass	see note	x
rock wool	see note	x
isocyanurate	see note	x
insulation waste		2%

Note: "x" represents types of insulation typical for specific systems; quantity = 18.58 m2 of 1" thick insulation.

		PVC Conventional Ballasted Description: concrete deck, 0.25 mm polyethylene vapour barrier, 2" insulation loose laid, PVC membrane, 60 kg/m2 stone ballast
TRANSPORTATION	Calgary	4315
Manufacturer to Distributor (km)	Montreal	529
by truck	Toronto	891
	Halifax	1072
	Vancouver	4315
	Winnipeg	4315
TRANSPORTATION	Calgary	60
Distributor to Site (km)	Montreal	60
by truck	Toronto	60
	Halifax	60
	Vancouver	900
	Winnipeg	1315
ENERGY INPUTS		
On site electricity input	KWH/square	0.165+.04
On site propane use	kg/square	0
On site diesel use	l/square	0.872
MATERIAL INPUTS		
stone ballast	kg/square	557.4
small dimension lumber	BF/square	12.1
	waste	5%
Plywood	m2(1/2")/square	0.18
	waste	5%
steel fasteners	kg/square	0.1
	waste	2%
galvanized steel misc.	kg/square	0.892
	waste	2%
galvanized steel flashing	kg/square	2.16
	waste	2%
gypsum board (steel deck only)	m2(1/2")/square	0
	waste	0%
organic 15# felts	m2/square	0
	waste	14%
fiberglass 15# felts	m2/square	0
	waste	14%
Kraft paper	m2/square	0
	waste	0%
asphalt	kg/square	0
	waste	0%
filter fabric	m2/square	0
	waste	1%
polyethylene vapour barrier	m2/square	9.29
	waste	2%
1.5 mm thick polyester felt	m2/square	0
	waste	1%
INSULATION		
wood fiberboard	m2(1/2")/square	0
	waste	0%
extruded polystyrene	see note	
expanded polystyrene	see note	x
fiberglass	see note	x
rock wool	see note	x
isocyanurate	see note	x
insulation waste		2%

Note: "x" represents types of insulation typical for specific systems; quantity = 18.58 m2 of 1" thick insulation.

PVC
Inverted Ballasted

Description: concrete deck, 1.5 mm thick polyester felt, PVC membrane, 2" insulation, filter fabric, 60 kg/m2 stone ballast

TRANSPORTATION	Calgary	4315
Manufacturer to Distributor (km)	Montreal	529
by truck	Toronto	891
	Halifax	1072
	Vancouver	4315
	Winnipeg	4315
TRANSPORTATION	Calgary	60
Distributor to Site (km)	Montreal	60
by truck	Toronto	60
	Halifax	60
	Vancouver	900
	Winnipeg	1315
ENERGY INPUTS		
On site electricity input	KWH/square	0.165+.04
On site propane use	kg/square	0
On site diesel use	l/square	0.872
MATERIAL INPUTS		
stone ballast	kg/square	557.4
small dimension lumber	BF/square	0
	waste	5%
Plywood	m2(1/2")/square	0
	waste	5%
steel fasteners	kg/square	0.05
	waste	2%
galvanized steel misc.	kg/square	0.892
	waste	2%
galvanized steel flashing	kg/square	2.16
	waste	2%
gypsum board (steel deck only)	m2(1/2")/square	0
	waste	0%
organic 15# felts	m2/square	0
	waste	14%
fiberglass 15# felts	m2/square	0
	waste	14%
Kraft paper	m2/square	0
	waste	0%
asphalt	kg/square	0
	waste	0%
filter fabric	m2/square	9.29
	waste	1%
polyethylene vapour barrier	m2/square	0
	waste	2%
1.5 mm thick polyester felt	m2/square	9.29
	waste	1%
INSULATION		
wood fiberboard	m2(1/2")/square	0
	waste	0%
extruded polystyrene	see note	
expanded polystyrene	see note	x
fiberglass	see note	x
rock wool	see note	x
isocyanurate	see note	x
insulation waste		2%

Note: "x" represents types of insulation typical for specific systems; quantity = 18.58 m2 of 1" thick insulation.

		EPDM Conventional mechanically fastened Description: steel deck, drywall, 0.25 mm polyethylene vapour barrier, 2" insulation, EPDM membrane
TRANSPORTATION	Calgary	3550
Manufacturer to Distributor (km)	Montreal	1240
by truck	Toronto	1050
	Halifax	2070
	Vancouver	4270
	Winnipeg	2270
TRANSPORTATION	Calgary	60
Distributor to Site (km)	Montreal	60
by truck	Toronto	60
	Halifax	60
	Vancouver	60
	Winnipeg	60
ENERGY INPUTS		
On site electricity input	KWH/square	0.0365
On site propane use	kg/square	0
On site diesel use	l/square	0
MATERIAL INPUTS		
stone ballast	kg/square	0
small dimension lumber	BF/square	12.1
	waste	5%
Plywood	m2(1/2")/square	0.18
	waste	5%
steel fasteners	kg/square	0.956
	waste	2%
galvanized steel misc.	kg/square	3.3245
	waste	2%
galvanized steel flashing	kg/square	3.4
	waste	8%
gypsum board (steel deck only)	m2(1/2")/square	9.29
	waste	1%
organic 15# felts	m2/square	0
	waste	14%
fiberglass 15# felts	m2/square	0
	waste	14%
Kraft paper	m2/square	0
	waste	0%
asphalt	kg/square	0
	waste	0%
filter fabric	m2/square	0
	waste	1%
polyethylene vapour barrier	m2/square	9.29
	waste	2%
1.5 mm thick polyester felt	m2/square	0
	waste	1%
INSULATION		
wood fiberboard	m2(1/2")/square	0
	waste	0%
extruded polystyrene	see note	
expanded polystyrene	see note	x
fiberglass	see note	x
rock wool	see note	x
isocyanurate	see note	x
insulation waste		2%

Note: "x" represents types of insulation typical for specific systems; quantity = 18.58 m2 of 1" thick insulation.

		EPDM Conventional Ballasted Description: concrete deck, 0.25 mm polyethylene vapour barrier, 2" insulation, EPDM membrane, 60 kg/m2 stone ballast
TRANSPORTATION	Calgary	3550
Manufacturer to Distributor (km)	Montreal	1240
by truck	Toronto	1050
	Halifax	2070
	Vancouver	4270
	Winnipeg	2270
TRANSPORTATION	Calgary	60
Distributor to Site (km)	Montreal	60
by truck	Toronto	60
	Halifax	60
	Vancouver	60
	Winnipeg	60
ENERGY INPUTS		
On site electricity input	KWH/square	0
On site propane use	kg/square	0
On site diesel use	l/square	0.872
MATERIAL INPUTS		
stone ballast	kg/square	557.4
small dimension lumber	BF/square	12.1
	waste	5%
Plywood	m2(1/2")/square	0.18
	waste	5%
steel fasteners	kg/square	0.08
	waste	2%
galvanized steel misc.	kg/square	0.59
	waste	2%
galvanized steel flashing	kg/square	3.4
	waste	8%
gypsum board (steel deck only)	m2(1/2")/square	0
	waste	0%
organic 15# felts	m2/square	0
	waste	14%
fiberglass 15# felts	m2/square	0
	waste	14%
Kraft paper	m2/square	0
	waste	0%
asphalt	kg/square	0
	waste	0%
filter fabric	m2/square	0
	waste	1%
polyethylene vapour barrier	m2/square	9.29
	waste	2%
1.5 mm thick polyester felt	m2/square	0
	waste	1%
INSULATION		
wood fiberboard	m2(1/2")/square	0
	waste	0%
extruded polystyrene	see note	
expanded polystyrene	see note	x
fiberglass	see note	x
rock wool	see note	x
isocyanurate	see note	x
insulation waste		2%

Note: "x" represents types of insulation typical for specific systems; quantity = 18.58 m2 of 1" thick insulation.

EPDM
Inverted Ballasted

Description: concrete deck, 1.5 mm thick polyester felt, EPDM membrane, 2" insulation, filter fabric, 60 kg/m2 stone ballast

TRANSPORTATION	Calgary	3550
Manufacturer to Distributor (km)	Montreal	1240
by truck	Toronto	1050
	Halifax	2070
	Vancouver	4270
	Winnipeg	2270
TRANSPORTATION	Calgary	60
Distributor to Site (km)	Montreal	60
by truck	Toronto	60
	Halifax	60
	Vancouver	60
	Winnipeg	60
ENERGY INPUTS		
On site electricity input	KWH/square	0
On site propane use	kg/square	0
On site diesel use	l/square	0.872
MATERIAL INPUTS		
stone ballast	kg/square	557.4
small dimension lumber	BF/square	0
	waste	5%
Plywood	m2(1/2")/square	0
	waste	5%
steel fasteners	kg/square	0.03
	waste	2%
galvanized steel misc.	kg/square	0.59
	waste	2%
galvanized steel flashing	kg/square	3.4
	waste	8%
gypsum board (steel deck only)	m2(1/2")/square	0
	waste	0%
organic 15# felts	m2/square	0
	waste	14%
fiberglass 15# felts	m2/square	0
	waste	14%
Kraft paper	m2/square	0
	waste	0%
asphalt	kg/square	0
	waste	0%
filter fabric	m2/square	9.29
	waste	1%
polyethylene vapour barrier	m2/square	0
	waste	2%
1.5 mm thick polyester felt	m2/square	9.29
	waste	1%
INSULATION		
wood fiberboard	m2(1/2")/square	0
	waste	0%
extruded polystyrene	see note	x
expanded polystyrene	see note	
fiberglass	see note	
rock wool	see note	
isocyanurate	see note	
insulation waste		1%

Note: "x" represents types of insulation typical for specific systems; quantity = 18.58 m2 of 1" thick insulation.

		TPO Conventional mechanically fastened Description: steel deck, 1/2" drywall, 0.25 mm polyethylene vapour barrier, 2" insulation, TPO membrane with discs
TRANSPORTATION	Calgary	4550
Manufacturer to Distributor (km)	Montreal	1900
by truck	Toronto	1620
	Halifax	2740
	Vancouver	5360
	Winnipeg	3230
TRANSPORTATION	Calgary	60
Distributor to Site (km)	Montreal	60
by truck	Toronto	60
	Halifax	60
	Vancouver	60
	Winnipeg	60
ENERGY INPUTS		
On site electricity input	KWH/square	0.2265
On site propane use	kg/square	0
On site diesel use	l/square	0
MATERIAL INPUTS		
stone ballast	kg/square	0
small dimension lumber	BF/square	12.1
	waste	5%
Plywood	m2(1/2")/square	0.18
	waste	5%
steel fasteners	kg/square	1.022
	waste	2%
galvanized steel misc.	kg/square	3.76
	waste	2%
galvanized steel flashing	kg/square	2.16
	waste	2%
gypsum board (steel deck only)	m2(1/2")/square	9.29
	waste	1%
organic 15# felts	m2/square	0
	waste	14%
fiberglass 15# felts	m2/square	0
	waste	14%
Kraft paper	m2/square	0
	waste	0%
asphalt	kg/square	0
	waste	0%
filter fabric	m2/square	0
	waste	1%
polyethylene vapour barrier	m2/square	9.29
	waste	2%
1.5 mm thick polyester felt	m2/square	0
	waste	1%
INSULATION		
wood fiberboard	m2(1/2")/square	0
	waste	0%
extruded polystyrene	see note	
expanded polystyrene	see note	x
fiberglass	see note	x
rock wool	see note	x
isocyanurate	see note	x
insulation waste		2%

Note: "x" represents types of insulation typical for specific systems; quantity = 18.58 m2 of 1" thick insulation.

		TPO Conventional Ballasted Description: concrete deck, 0.25 mm polyethylene vapour barrier, 2" insulation, TPO membrane, 60 kg/m2 stone ballast
TRANSPORTATION	Calgary	4550
Manufacturer to Distributor (km)	Montreal	1900
by truck	Toronto	1620
	Halifax	2740
	Vancouver	5360
	Winnipeg	3230
TRANSPORTATION	Calgary	60
Distributor to Site (km)	Montreal	60
by truck	Toronto	60
	Halifax	60
	Vancouver	60
	Winnipeg	60
ENERGY INPUTS		
On site electricity input	KWH/square	0.15
On site propane use	kg/square	0
On site diesel use	l/square	0.872
MATERIAL INPUTS		
stone ballast	kg/square	557.4
small dimension lumber	BF/square	12.1
	waste	5%
Plywood	m2(1/2")/square	0.18
	waste	5%
steel fasteners	kg/square	0.1
	waste	2%
galvanized steel misc.	kg/square	0.892
	waste	2%
galvanized steel flashing	kg/square	2.16
	waste	2%
gypsum board (steel deck only)	m2(1/2")/square	0
	waste	0%
organic 15# felts	m2/square	0
	waste	14%
fiberglass 15# felts	m2/square	0
	waste	14%
Kraft paper	m2/square	0
	waste	0%
asphalt	kg/square	0
	waste	0%
filter fabric	m2/square	0
	waste	1%
polyethylene vapour barrier	m2/square	9.29
	waste	2%
1.5 mm thick polyester felt	m2/square	0
	waste	1%
INSULATION		
wood fiberboard	m2(1/2")/square	0
	waste	0%
extruded polystyrene	see note	
expanded polystyrene	see note	x
fiberglass	see note	x
rock wool	see note	x
isocyanurate	see note	x
insulation waste		2%

Note: "x" represents types of insulation typical for specific systems; quantity = 18.58 m2 of 1" thick insulation.

TPO
Inverted Ballasted

Description: concrete deck, 1.5 mm thick polyester felt, TPO membrane, 2" insulation, filter fabric , 60 kg/m2 stone ballast

TRANSPORTATION	Calgary	4550
Manufacturer to Distributor (km)	Montreal	1900
by truck	Toronto	1620
	Halifax	2740
	Vancouver	5360
	Winnipeg	3230
TRANSPORTATION	Calgary	60
Distributor to Site (km)	Montreal	60
by truck	Toronto	60
	Halifax	60
	Vancouver	60
	Winnipeg	60
ENERGY INPUTS		
On site electricity input	KWH/square	0.15
On site propane use	kg/square	0
On site diesel use	l/square	0.872
MATERIAL INPUTS		
stone ballast	kg/square	557.4
small dimension lumber	BF/square	0
	waste	5%
Plywood	m2(1/2")/square	0
	waste	5%
steel fasteners	kg/square	0.05
	waste	2%
galvanized steel misc.	kg/square	0.892
	waste	2%
galvanized steel flashing	kg/square	2.16
	waste	2%
gypsum board (steel deck only)	m2(1/2")/square	0
	waste	0%
organic 15# felts	m2/square	0
	waste	14%
fiberglass 15# felts	m2/square	0
	waste	14%
Kraft paper	m2/square	0
	waste	0%
asphalt	kg/square	0
	waste	0%
filter fabric	m2/square	9.29
	waste	1%
polyethylene vapour barrier	m2/square	0
	waste	2%
1.5 mm thick polyester felt	m2/square	9.29
	waste	1%
INSULATION		
wood fiberboard	m2(1/2")/square	0
	waste	0%
extruded polystyrene	see note	
expanded polystyrene	see note	x
fiberglass	see note	x
rock wool	see note	x
isocyanurate	see note	x
insulation waste		2%

Note: "x" represents types of insulation typical for specific systems; quantity = 18.58 m2 of 1" thick insulation.

		Rubberized Asphalt Inverted Description: concrete deck, reinforced RA membrane, polyethylene separation sheet, 2" insulation, filter fabric , 60 kg/m2 stone ballast
TRANSPORTATION	Calgary	3540
Manufacturer to Distributor (km)	Montreal	0
by truck	Toronto	550
	Halifax	1220
	Vancouver	4900
	Winnipeg	2210
TRANSPORTATION	Calgary	60
Distributor to Site (km)	Montreal	60
by truck	Toronto	60
	Halifax	60
	Vancouver	60
	Winnipeg	60
ENERGY INPUTS		
On site electricity input	KWH/square	0
On site propane use	kg/square	5.68
On site diesel use	l/square	0.872
MATERIAL INPUTS		
stone ballast	kg/square	557.4
small dimension lumber	BF/square	0
	waste	5%
Plywood	m2(1/2")/square	0
	waste	5%
steel fasteners	kg/square	0
	waste	2%
galvanized steel misc.	kg/square	0
	waste	0%
galvanized steel flashing	kg/square	10.96
	waste	8%
gypsum board (steel deck only)	m2(1/2")/square	0
	waste	0%
organic 15# felts	m2/square	0
	waste	14%
fiberglass 15# felts	m2/square	0
	waste	14%
Kraft paper	m2/square	0
	waste	0%
asphalt	kg/square	0
	waste	0%
filter fabric	m2/square	9.29
	waste	1%
polyethylene vapour barrier	m2/square	9.29
	waste	2%
1.5 mm thick polyester felt	m2/square	0
	waste	1%
INSULATION		
wood fiberboard	m2(1/2")/square	0
	waste	0%
extruded polystyrene	see note	x
expanded polystyrene	see note	
fiberglass	see note	
rock wool	see note	
isocyanurate	see note	
insulation waste		1%

Note: "x" represents types of insulation typical for specific systems; quantity = 18.58 m2 of 1" thick insulation.

		Modified Bitumen Conventional
		Description: steel deck with 1/2" drywall, 2 ply BUR vapour barrier, 2" insulation, 1/2" fiberboard, bottom ply bonded with asphalt, top ply torch applied mod. bit.
TRANSPORTATION	Calgary	900
Manufacturer to Distributor (km)	Montreal	90
by truck	Toronto	330
	Halifax	1220
	Vancouver	110
	Winnipeg	2215
TRANSPORTATION	Calgary	60
Distributor to Site (km)	Montreal	60
by truck	Toronto	60
	Halifax	60
	Vancouver	60
	Winnipeg	60
ENERGY INPUTS		
On site electricity input	KWH/square	0.0275
On site propane use	kg/square	6.3
On site diesel use	l/square	0
MATERIAL INPUTS		
stone ballast	kg/square	0
small dimension lumber	BF/square	0
	waste	5%
Plywood	m2(1/2")/square	0
	waste	5%
steel fasteners	kg/square	0.5
	waste	2%
galvanized steel misc.	kg/square	0
	waste	2%
galvanized steel flashing	kg/square	3.4
	waste	8%
gypsum board (steel deck only)	m2(1/2")/square	9.29
	waste	1%
organic 15# felts	m2/square	18.58
	waste	14%
fiberglass 15# felts	m2/square	0
	waste	14%
Kraft paper	m2/square	0
	waste	0%
asphalt	kg/square	68.75
	waste	0%
filter fabric	m2/square	0
	waste	1%
polyethylene vapour barrier	m2/square	0
	waste	2%
1.5 mm thick polyester felt	m2/square	0
	waste	1%
INSULATION		
wood fiberboard	m2(1/2")/square	9.29
	waste	1%
extruded polystyrene	see note	
expanded polystyrene	see note	x
fiberglass	see note	x
rock wool	see note	x
isocyanurate	see note	x
insulation waste		2%

Note: "x" represents types of insulation typical for specific systems; quantity = 18.58 m2 of 1" thick insulation.

		Modified Bitumen Inverted	Asphalt
		Description: concrete deck, 2 ply torch applied mod. bit. membrane, 2" insulation, filter fabric, 60 kg/m2 stone ballast	
TRANSPORTATION	Calgary	900	150
Manufacturer to Distributor (km)	Montreal	90	60
by truck	Toronto	330	280
	Halifax	1220	1280
	Vancouver	110	1010
	Winnipeg	2215	650
TRANSPORTATION	Calgary	60	60
Distributor to Site (km)	Montreal	60	60
by truck	Toronto	60	60
	Halifax	60	60
	Vancouver	60	60
	Winnipeg	60	60
ENERGY INPUTS			
On site electricity input	KWH/square	0	
On site propane use	kg/square	7.58	
On site diesel use	l/square	0.872	
MATERIAL INPUTS			
stone ballast	kg/square	557.4	
small dimension lumber	BF/square	0	
	waste	5%	
Plywood	m2(1/2")/square	0	
	waste	5%	
steel fasteners	kg/square	0	
	waste	2%	
galvanized steel misc.	kg/square	0	
	waste	0%	
galvanized steel flashing	kg/square	3.4	
	waste	8%	
gypsum board (steel deck only)	m2(1/2")/square	0	
	waste	0%	
organic 15# felts	m2/square	0	
	waste	14%	
fiberglass 15# felts	m2/square	0	
	waste	14%	
Kraft paper	m2/square	0	
	waste	0%	
asphalt	kg/square	0	
	waste	0%	
filter fabric	m2/square	9.29	
	waste	1%	
polyethylene vapour barrier	m2/square	0	
	waste	2%	
1.5 mm thick polyester felt	m2/square	0	
	waste	1%	
INSULATION			
wood fiberboard	m2(1/2")/square	0	
	waste	0%	
extruded polystyrene	see note	x	
expanded polystyrene	see note		
fiberglass	see note		
rock wool	see note		
isocyanurate	see note		
insulation waste		1%	

Note: "x" represents types of insulation typical for specific systems; quantity = 18.58 m2 of 1" thick insulation.

APPENDIX A: TERMS OF REFERENCE

LIFE CYCLE INVENTORY OF ICI ROOFING SYSTEMS: ONSITE CONSTRUCTION EFFECTS

1.0 Introduction

The ATHENA™ Sustainable Materials Institute is continuing to expand the coverage of building materials in ATHENA ™, our computer-based decision support tool for architects, engineers and public policy makers. We now intend to add roofing systems and related products. Your firm is invited to submit a proposal to develop the required model data. For more information concerning the Institute and its activities please visit our website where you will also be able to download a limited function demonstration version of our ATHENA ™ model and user manual.

The data used in ATHENA ™ is derived from product life cycle analyses and the ATHENA ™ Project as a whole involves life cycle analysis of buildings. All of our studies adhere to the fullest extent possible to the principles and practices of life cycle analysis as set out in ISO standards and the Canadian Standards Association Guidelines (CSA Z760-94, Life Cycle Assessment, Feb. 1994) .

1.1 Study Objective

The overall goal will be to augment existing Institute databases with the life cycle inventory (LCI) data required by ATHENA ™ to model typical industrial, commercial and institutional (ICI) roofing systems. The goal will be achieved in two parts: (1) a cradle-to-gate life cycle inventory of various roofing components manufacture; and (2), a life cycle inventory of on-site construction effects. The latter goal is the objective of this immediate study as set out below.

A fundamental underlying objective in all Institute work is that products be treated in an equitable and unbiased fashion. The task is to make a comprehensive and accurate assessment of environmental effects. It is not to select or single out certain products as being environmentally preferable, nor is it to highlight or focus on particular environmental impacts associated with specific products.

1.2 Scope of Work

The scope will encompass those products and materials which alone, or in combination with other products and materials, are typically used to construct roofs for ICI buildings.

The following roofing systems (membrane types) are to be included in your proposal:

- 4-ply built-up roof membrane using organic felts;
- 4-ply built-up roof membrane using fiberglass based felts;
- PVC membrane;
- EPDM membrane;
- 2-ply standard modified bitumen membrane

• rubberized asphalt membrane; and
• TPO membrane.

For each of the above roofing systems (membrane types) provide the following information, on a square meter (m^2) basis, assuming application over a wood deck, steel deck and concrete deck using both a conventional and inverted method, where applicable:

• all on-site material usage quantities (in kg) including tertiary items (fasteners, wood curbs, etc.);

• all on-site energy use in metric (volume) measure (e.g., natural gas (m^3), propane (L), diesel (L), electric power (Kwh or Mj), etc.;

• all on-site material wastes in kg typically removed from the site and land filled;

• other process emissions to air, water or soil (e.g., spills), if any, not directly related to fuel combustion; and

• locations of manufacture of major membrane product and transportation mode (rail, truck, water) and distance estimates (km) to the six cities used in ATHENA ™ to represent geographic regions; i.e., to Vancouver, Calgary, Winnipeg, Toronto, Montreal and Halifax.

The deliverable for this project will be a letter report describing the approach and findings of the study accompanied by tables for each membrane by deck and application method (conventional or inverted) with explanatory notes for each table.

1.3 Optional Considerations to Primary Study

While the Section 1.2 above describes the primary work to be completed, there are two additional options for which we are interested in receiving an itemized proposed cost.

OPTION 1: Add spray applied polyurethane foam roofing to the membrane list above and complete all study aspects as described in Section 1.2 above.

OPTION 2: Provide a maintenance and replacement schedule (including material, energy use and wastes) during the use phase of the life cycle for each roofing system (membrane type). The proposal should consider how to deal with varying levels of maintenance (from none to continual major rehabilitation) and the maintenance levels affect on the roof's life. The proposal should discuss whether the roof deck type (wood, steel or concrete) would have an impact on the longevity or maintenance schedule for the roof.

1.4 Proposal Submission

Please submit proposals by email to: jkmeil@fox.nstn.ca. All proposals must be received by the close of business December 20, 2000

If you have any questions regarding the work to be performed, please contact J. Meil directly at 613-722-8075.