



A LIFE CYCLE ANALYSIS OF
SOLID WOOD AND STEEL CLADDING

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Preface

This report was commissioned as part of a continuing program to expand 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.

Our ultimate goal is to foster sustainability by encouraging building designs which will minimize life cycle environmental impacts. To achieve that goal the Institute is developing ATHENA™, a systems model for assessing the relative life cycle environmental implications of alternative building or assembly designs. Intended for use by building designers, researchers and policy analysts, ATHENA™ is a decision support tool which complements and augments other decision support tools like costing models. It provides a wealth of information to help users understand the environmental implications of different material mixes or other design changes in all or part of a building.

Two of the Institute's key objectives are to:

1. increase public awareness of the environmental impacts of buildings and the built environment; and
2. provide information and tools to help put the environment on a footing with cost and other traditional design criteria.

To help achieve these objectives and to ensure transparency of our research and data development process, we make all of our reports available to Institute members and model users.

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 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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A Life Cycle Analysis of Solid Wood and Steel Cladding

1.0 INTRODUCTION

This report summarizes cradle-to-gate life cycle inventory estimates for solid wood and steel cladding systems typically used in residential and light commercial applications. These inventory values include production activities from raw materials extraction through product manufacturing inclusive of related transportation. Additional information is also provided concerning transportation modes and distances for the distribution of finished products from manufacturing plants to the six city centre destinations contained in the ATHENA™ model. The work was conducted by the ATHENA™ Sustainable Materials Institute (ASMI) and while including new information concerning solid wood cladding material production, this study also borrows extensively on two previously completed ASMI inventory reports on wood and steel building materials.

1.1 Research Guidelines

To ensure compatibility with ATHENA™ Sustainable Materials Institute objectives and computer modeling approaches, all life cycle analysis methods and techniques employed in this report have been done in accordance with the Institute's predefined Research Guidelines.

The life cycle analysis (LCA) framework is discussed in the Institute's Summary Reports - Phase II and III. The latter document includes the most recent Research Guidelines (1997) and hence, this report does not duplicate the LCA protocol. A full explanation is provided where calculations do not conform to the Research Guidelines

1.2 Study Focus And Product Coverage

This study provides a complete life cycle inventory from cradle-to-gate as well as transportation mode and distance information for solid wood and steel cladding delivered to six major Canadian cities.

For the solid wood siding, three species of wood are studied across three different siding types in both a dry and green condition, providing eighteen separate solid wood siding options. The three species include cedar, pine and spruce and the three siding options for each species are bevel, tongue and groove (T&G), and shiplap siding. The light gauge steel cladding includes two use designations that vary by gauge or thickness - residential (30 ga.) and commercial (26 ga.).

1.3 Report Structure

The organization of this report is as follows:

- Section 2 provides general background information on solid wood siding markets, products, and industry structure.
- Section 3 is devoted to a detailed description of the cradle-to-gate LCI prepared for wood siding.
- Section 4 presents an overview of the Canadian steel cladding industry and sets out the actual products covered in the report.
- Section 5 describes the cradle-to-gate LCI prepared for steel cladding in both residential and commercial applications.
- Section 6 presents the methodology and results for the transportation of finished wood and steel cladding products, by transportation mode and distance, to the six city centres used in ATHENA™ to represent different regions.

2.0 SOLID WOOD SIDING - AN OVERVIEW

2.1 Products And Markets

Solid wood siding is an exterior cladding for low-rise structures. The wood species commonly used for siding in N. America include western red cedar, redwood, cypress, northern white cedar and eastern white pine. In Canada, a few other species, such as eastern spruce and lodgepole pine, are also gaining a foothold in the solid wood siding market. Solid wood siding production in N. America is dominated by large integrated firms; however, small specialty firms also exist and serve either a regional market or specific market niches. Solid wood siding production is not reported separately in Canada as it is aggregated with softwood lumber production. It is estimated, however, that over 180 softwood lumber mills across the country produce or have the capacity to produce wood siding.

Solid wood siding was the primary siding material prior to 1955, but since has experienced a continuous decline due to use of both alternative wood composite and other man-made materials. From a high of 43% of the market, solid wood siding has slipped to about 10% of the market.

The most common solid wood siding products include bevel lap siding, shiplap, board and batten and shingles.

2.2 Manufacture

The manufacture of solid wood siding differs very little from that of softwood lumber. In fact, solid wood siding manufacture requires only additional sawing and/or shaping depending on the final product profile to be achieved. For a complete discussion of softwood lumber manufacturing see *Raw Material, Energy Profiles and Environmental Unit Factor Estimates for Structural Wood Products* [5].

2.3 Energy And The Environment

Solid wood products are in general one of the least energy intensive building materials available to society. For instance, softwood lumber typically requires less than 6 MJ/kg of product, although energy intensiveness also varies by species, initial and final moisture content and final product specification; i.e., whether the product is kiln-dried or sold as “green”. This latter condition is especially pertinent to solid wood siding as the product can be readily purchased in both dry and green condition. In the past, the industry has paid little attention to its energy use because energy represents only a small portion of its cost structure. Rising wood and energy prices, however, have resulted in more efficient raw material use and greater use of wood by-products as a fuel source. Thus, the industry has both reduced its energy intensiveness and its reliance on fossil fuels.

3.0 LIFE CYCLE INVENTORY SOLID WOOD SIDING

This section provides an overview of the life cycle inventory (LCI) conducted for solid wood siding. The initial analysis was conducted by surveying three Canadian solid wood siding mills over the period January 1996 through June 1997. Due to the small sample and proprietary nature of specific mill information it has been necessary to aggregate and normalize the three mill's information into a weighted average. The generalized LCI profile is then disaggregated by product, species and final moisture condition of the resulting final products. The manipulation of the LCI data into a generalized profile protects individual mill information and at the same time affords a fairly typical representation of the solid wood siding industry in Canada.

In keeping with ATHENA™ Research Guidelines, the LCI has been broken into two unit processes; namely, (1) raw material extraction which includes harvesting, forest management and transportation of timber to the mill gate, and (2) manufacturing which includes all processes necessary to achieve a finished product(s) at the mill gate. Final transportation of finished products to the six regional distribution centres is covered separately in Section 6.1.

3.1 Raw Material Harvesting, Forest Management And Transportation

Typically, harvesting encompasses removal of timber from the site and delivery to roadside, forest management includes all necessary steps to regenerate the site, and transportation denotes the movement of raw fibre from roadside to the mill gate.

Each mill surveyed provided input and output information concerning their harvesting, forest management and transportation operations. We normalized the results across the three mills for the production of one oven dry tonne (odmt) of manufactured siding. When, we tested for the significance of ancillary material use, we found that hydraulic fluids, motor oils and greases combined contributed less than one percent of the mass and less than 2 percent of the energy use of the unit process. Hence these three minor inputs were not included in the final roll-up of the generalized LCI profile. The profile does, however, include empty backhauls.

Because all three mills reported the sale of all bark production, we have treated bark as a co-product for allocation purposes for this unit process, despite the fact that bark is not separated from the timber until after it enters the mill. In the manufacturing unit process, bark is treated as a by-product with all energy associated with its production (deemed to be minimal) assessed to the final siding product. We believe this allocation methodology best reflects the true environmental loadings of bark production.

Table 1. below presents the results for this unit process with transportation reported separately. Atmospheric emission quantities are calculated using figures reported in the ATHENA™ Research Guidelines. Environmental burdens associated with the use of electricity, including atmospheric emissions, are not reported here as these are calculated by the ATHENA™ Model on a regional basis. The generally higher values reported for dry siding reflect greater fibre requirements during the production of kiln-dried siding.

Table 1. Normalized Inventory Profile for one odmt of Green and Dry Siding - Resource Harvesting, Forest Management and Transportation

	per odmt of grn siding Quantity	per odmt of dry siding
ENERGY USE - MJ		
<u>Harv./For. Mngt.</u>		
Diesel	204.2	219.5
Gasoline	19.6	21.1
Electricity	27.6	29.7
<u>Transportation</u>		
Diesel	507.9	546.0
Gasoline	17.3	18.6
H.F.O. - Marine	18.9	20.3
EMISSIONS TO AIR		
<u>Harv./For. Mngt.</u>		
CO ₂ g	15770	16953
CO mg	165000	177375
CH ₄ mg	5000	5375
No _x mg	171000	183825
SO ₂ mg	21000	22575
V.O.C. mg	27000	29025
Particulates mg	0	0
<u>Transportation</u>		
CO ₂ g	54281	58352
CO mg	456000	490200
CH ₄ mg	8000	8600
No _x mg	590000	634250
SO ₂ mg	75000	80625
V.O.C. mg	85000	91375
Particulates mg	0	0
EMISSIONS TO LAND (g)		
Process waste	2200	2365

3.2 Manufacturing

This section provides an overview of the normalized LCI for the manufacture of solid wood siding in both a dry and green state. Solid wood siding manufacturing is very similar to softwood lumber manufacture with a few more finishing details. Incoming logs are debarked and cut to length and then sorted by diameter and species (some mills will also sort on the basis of initial moisture content). The logs are then fed into the sawmill for sawing into rough lumber which is then sorted by width, thickness and length. The sawmill production is then either destined for kiln drying or may bypass kiln drying and go directly to the planer mill for final sawing and shaping. Finally, the product is graded and packaged for shipment to either an in-transit finishing plant or directly to final markets.

The typical moisture content of dry siding varies between 20% and 25% while green siding is usually above 25%. Most kiln-dried siding is destined for further finishing (e.g., in transit painting or staining). However, considerable quantities of green siding are also sold (for one mill surveyed green production represented well over 70% of total siding sales) which is often painted or stained on site after installation. Cedar and white pine siding is also often left unfinished to weather to a natural silvery grey colour.

In the course of production the initial log is broken down into the final product as well as a number of co-products which include pulp chips, sawdust and planar shavings. These co-products are then sold to other forest product manufacturers (e.g., reconstituted board and panel mills as well as pulp mills). These co-products represent upwards of 55% of all solid wood processed for green siding and about 52% for kiln-dried siding. The lower percentage in the case of kiln-dried siding reflects the use of some co-products as boiler fuel providing process heat to kiln operations. The results, presented in Table 2 below reflect the allocation, on a mass basis, of environmental inputs and outputs to these co-products. It should be pointed out that the values reported in Table 2 do not include the factory application of paints or stains. This aspect of product finishing will be added in the course of conducting a detailed LCI of paints and stains by the Institute.

Table 2. Normalized Inventory Profile for one odmt of Solid Wood Siding (Green and Dry) - Manufacturing

	Green	Dry
ENERGY USE (MJ)		
Electricity	812	1083
Diesel	47	113
Gasoline	5	12
Propane	29	29
Natural Gas	--	713
Biomass	--	784
EMISSIONS TO AIR		
CO ₂ g	54000	158000
CO mg	40000	115000
CH ₄ mg	1000	8000
No _x mg	42000	171000
SO ₂ mg	5000	6000
V.O.C. mg	6000	40000
Particulates mg	-	389000
WATER USE (L)	450	520
EMISSIONS TO WATER (micro g)		
BOD	9000	9000
Suspended Solids	92000	92000
Oil & Grease	4000	4000
EMISSIONS TO LAND (g)		
Process waste	3070	3250
Boiler Ash	--	270
Inorganic	--	210

3.3 Summary Profiles By Activity Stage, Species And Product

This section presents detailed summary inventory profiles for various types of solid wood siding by species and activity stage on a square meter of wall basis. The profiles, generated by recalculating the normalized weighted average profile to reflect species and product finishes, better portray the end market use of siding.

Table 3 below sets out the product use per square meter of wall surface used to estimate the summary profiles for the three species across the three different siding types. The three species include cedar, pine and spruce and the three siding options for each species are bevel, tongue and groove (T&G) and shiplap siding for a total of nine separate solid wood siding options. Bevel siding is the typical horizontally applied siding in the market; however, both tongue and groove and shiplap siding can also be employed in a soffit application. Further, tongue and groove siding can be installed on a diagonal. These various products and species provide a fair representation of the Canadian industry.

Table 3. Product use by Species

PRODUCT USE (odkg)/ sq m of WALL SURFACE			
SIDING SPECIES	BEVEL	T&G	SHIPLAP
Cedar	4.23	6.36	6.63
Pine	5.21	7.80	8.12
Spruce	4.80	7.00	7.25

To expedite the estimation procedure and afford comparison across the various siding types, we have standardized the siding width to a nominal 6” product. (Nominal board foot production reporting still prevails within the industry, hence the “nominal” designation.) We also investigated the error associated with varying final product widths within a species on a square meter of applied siding and found that changing widths of the final product had only a minor impact (less than 3% change) on the estimated summary profile. The tabulated results below, exclude on-site waste associated with the application of the siding and again emissions associated with electricity use have not been included. Both on-site construction waste and emissions to land, air and water associated with electricity use are handled within the ATHENA™ model.

Tables 4a and 4b, 5a and 5b and 6a and 6b provide the summary profiles by activity stage for cedar, pine and spruce siding products.

Table 4a. Summary Inventory Profile for Cedar Siding Covering one square meter of Wall - Resource Harvesting, Forest Management and Transportation

	BEVEL		T & G		SHIPLAP	
	Green	Dry	Green	Dry	Green	Dry
ENERGY USE (KJ)						
<u>Harv./For. Mngt.</u>						
Diesel	863.8	928.5	1298.7	1396.1	1354.0	1455.4
Gasoline	82.9	89.1	124.7	134.0	130.0	139.7
Electricity	116.7	125.5	175.5	188.7	183.0	196.7
<u>Transportation</u>						
Diesel	2148.4	2309.5	3230.2	3472.5	3367.0	3619.9
Gasoline	73.2	78.7	110.0	118.3	115.0	123.3
H.F.O. - Marine	79.9	85.9	120.2	129.2	125.0	134.7
EMISSIONS TO AIR						
<u>Harv./For. Mngt.</u>						
CO ₂ g	66.7	71.7	100.3	107.8	104.6	112.4
CO mg	698.0	750.3	1049.4	1128.1	1094.0	1176.0
CH ₄ mg	21.2	22.7	31.8	34.2	33.2	35.6
No _x mg	723.3	777.6	1087.6	1169.1	1133.7	1218.8
SO ₂ mg	88.8	95.5	133.6	143.6	139.2	149.7
V.O.C. mg	114.2	122.8	171.7	184.6	179.0	192.4
Particulates mg	0.0	0.0	0.0	0.0	0.0	0.0
EMISSIONS TO AIR						
<u>Transportation</u>						
CO ₂ g	229.6	246.8	345.2	371.1	359.9	386.9
CO mg	1928.9	2073.5	2900.2	3117.7	3023.3	3250.0
CH ₄ mg	33.8	36.4	50.9	54.7	53.0	57.0
No _x mg	2495.7	2682.9	3752.4	4033.8	3911.7	4205.1
SO ₂ mg	317.3	341.0	477.0	512.8	497.3	534.5
V.O.C. mg	359.6	386.5	540.6	581.1	563.6	605.8
Particulates mg	0.0	0.0	0.0	0.0	0.0	0.0
EMISSIONS TO LAND (g)						
Process waste	9.3	10.0	14.0	15.0	14.6	15.7

Table 4b Summary Inventory Profile for Cedar Siding Covering one square meter of Wall - Manufacturing

	BEVEL		T & G		SHIPLAP	
	GREEN	DRY	GREEN	DRY	GREEN	DRY
ENERGY USE KJ						
Electricity	3434.8	4581.1	5164.3	6887.9	5383.6	7180.3
Diesel	198.8	478.0	298.9	718.7	311.6	749.2
Gasoline	21.2	50.8	31.8	76.3	33.2	79.6
Propane	122.7	122.7	184.4	184.4	192.3	192.3
Natural Gas	0.0	3016.0	0.0	4534.7	0.0	4727.2
Biomass	0.0	3316.3	0.0	4986.2	0.0	5197.9
EMISSIONS TO AIR						
CO ₂ g	228.4	668.3	343.4	1004.9	358.0	1047.5
CO mg	169.2	486.5	254.4	731.4	265.2	762.5
CH ₄ mg	4.2	33.8	6.4	50.9	6.6	53.0
No _x mg	177.7	723.3	267.1	1087.6	278.5	1133.7
SO ₂ mg	21.2	25.4	31.8	38.2	33.1	39.8
V.O.C. mg	25.4	169.2	38.2	254.4	39.8	265.2
Particulates mg	0.0	1645.5	0.0	2474.0	0.0	2579.1
WATER USE (L)	1.9	2.2	2.9	3.3	3.0	3.4
EMISSIONS TO WATER (µg)						
BOD	38.1	38.1	57.2	57.2	59.7	59.7
Suspended Solids	389.2	389.2	585.1	585.1	609.9	609.9
Oil & Grease	16.9	16.9	25.4	25.4	26.5	26.5
EMISSIONS TO LAND (g)						
Process waste	12.9	13.7	19.5	20.7	20.4	21.5
Boiler Ash	0.0	1.1	0.0	1.7	0.0	1.8
Inorganic	0.0	0.9	0.0	1.3	0.0	1.4

Table 5a. Summary Inventory Profile for Pine Siding Covering one square meter of Wall - Resource Harvesting, Forest Management and Transportation

	BEVEL		T & G		SHIPLAP	
	Green	Dry	Green	Dry	Green	Dry
ENERGY USE (KJ)						
<u>Harv./For. Mngt.</u>						
Diesel	1063.9	1143.7	1592.8	1712.2	1658.1	1782.5
Gasoline	102.1	109.8	152.9	164.3	159.2	171.1
Electricity	143.8	154.6	215.3	231.4	224.1	240.9
<u>Transportation</u>						
Diesel	2646.2	2844.6	3961.6	4258.7	4124.1	4433.5
Gasoline	90.1	96.9	134.9	145.1	140.5	151.0
H.F.O. - Marine	98.5	105.9	147.4	158.5	153.5	165.0
EMISSIONS TO AIR						
<u>Harv./For. Mngt.</u>						
CO ₂ g	82.2	88.3	123.0	132.2	128.1	137.7
CO mg	859.7	924.1	1287.0	1383.5	1339.8	1440.3
CH ₄ mg	26.1	28.0	39.0	41.9	40.6	43.6
No _x mg	890.9	957.7	1333.8	1433.8	1388.5	1492.7
SO ₂ mg	109.4	117.6	163.8	176.1	170.5	183.3
V.O.C. mg	140.7	151.2	210.6	226.4	219.2	235.7
Particulates mg	0.0	0.0	0.0	0.0	0.0	0.0
EMISSIONS TO AIR						
<u>Transportation</u>						
CO ₂ g	282.8	304.0	423.4	455.1	440.8	473.8
CO mg	2375.8	2553.9	3556.8	3823.6	3702.7	3980.4
CH ₄ mg	41.7	44.8	62.4	67.1	65.0	69.8
No _x mg	3073.9	3304.4	4602.0	4947.2	4790.8	5150.1
SO ₂ mg	390.8	420.1	585.0	628.9	609.0	654.7
V.O.C. mg	442.9	476.1	663.0	712.7	690.2	742.0
Particulates mg	0.0	0.0	0.0	0.0	0.0	0.0
EMISSIONS TO LAND (g)						
Process waste	11.5	12.3	17.2	18.4	17.9	19.2

Table 5b. Summary Inventory Profile for Pine Siding Covering one square meter of Wall - Manufacturing

	BEVEL		T & G		SHIPLAP	
	GREEN	DRY	GREEN	DRY	GREEN	DRY
ENERGY USE KJ						
Electricity	4230.5	5642.4	6333.6	8447.4	6593.4	8794.0
Diesel	244.9	588.7	366.6	881.4	381.6	917.6
Gasoline	26.1	62.5	39.0	93.6	40.6	97.4
Propane	151.1	151.1	226.2	226.2	235.5	235.5
Natural Gas	0.0	3714.7	0.0	5561.4	0.0	5789.6
Biomass	0.0	4084.6	0.0	6115.2	0.0	6366.1
EMISSIONS TO AIR						
CO ₂ g	281.3	823.2	421.2	1232.4	438.5	1283.0
CO mg	208.4	599.2	312.0	897.0	324.8	933.8
CH ₄ mg	5.2	41.7	7.8	62.4	8.1	65.0
No _x mg	218.8	890.9	327.6	1333.8	341.0	1388.5
SO ₂ mg	26.1	31.3	39.0	46.8	40.6	48.7
V.O.C. mg	31.3	208.4	46.8	312.0	48.7	324.8
Particulates mg	0.0	2026.7	0.0	3034.2	0.0	3158.7
WATER USE (L)	2.3	2.7	3.5	4.1	3.6	4.2
EMISSIONS TO WATER (µg)						
BOD	46.9	46.9	70.2	70.2	73.1	73.1
Suspended Solids	479.3	479.3	717.6	717.6	747.0	747.0
Oil & Grease	20.8	20.8	31.2	31.2	32.5	32.5
EMISSIONS TO LAND (g)						
Process waste	16.0	16.9	23.9	25.4	24.9	26.4
Boiler Ash	0.0	1.4	0.0	2.1	0.0	2.2
Inorganic	0.0	1.1	0.0	1.6	0.0	1.7

Table 6a. Summary Inventory Profile for Spruce Siding Covering one square meter of Wall - Resource Harvesting, Forest Management and Transportation

	BEVEL		T & G		SHIPLAP	
	Green Quantity	Dry Quantity	Green Quantity	Dry Quantity	Green Quantity	Dry Quantity
ENERGY USE (KJ)						
<u>Harv./For. Mngt.</u>						
Diesel	980.2	1053.7	1429.4	1536.6	1480.5	1591.5
Gasoline	94.1	101.1	137.2	147.5	142.1	152.8
Electricity	132.5	142.4	193.2	207.7	200.1	215.1
<u>Transportation</u>						
Diesel	2437.9	2620.8	3555.3	3821.9	3682.3	3958.4
Gasoline	83.0	89.3	121.1	130.2	125.4	134.8
H.F.O. - Marine	90.7	97.5	132.3	142.2	137.0	147.3
EMISSIONS TO AIR						
<u>Harv./For. Mngt.</u>						
CO ₂ g	75.7	81.4	110.4	118.7	114.3	122.9
CO mg	792.0	851.4	1155.0	1241.6	1196.3	1286.0
CH ₄ mg	24.0	25.8	35.0	37.6	36.3	39.0
No _x mg	820.8	882.4	1197.0	1286.8	1239.8	1332.7
SO ₂ mg	100.8	108.4	147.0	18.0	12.3	163.7
V.O.C. mg	129.6	139.3	189.0	203.2	195.8	210.4
Particulates mg	0.0	0.0	0.0	0.0	0.0	0.0
EMISSIONS TO AIR						
<u>Transportation</u>						
CO ₂ g	260.5	280.1	380.0	408.5	393.5	423.1
CO mg	2188.8	2353.0	3192.0	3431.4	3306.0	3554.0
CH ₄ mg	38.4	41.3	56.0	60.2	58.0	62.4
No _x mg	2832.0	3044.4	4130.0	4439.8	4277.5	4598.3
SO ₂ mg	360.0	387.0	525.0	564.4	543.8	584.5
V.O.C. mg	408.0	438.6	595.0	639.6	616.3	662.5
Particulates mg	0.0	0.0	0.0	0.0	0.0	0.0
EMISSIONS TO LAND (g)						
Process waste	10.6	11.4	15.4	16.6	16.0	17.1

Table 6b. Summary Inventory Profile for Spruce Siding Covering one square meter of Wall - Manufacturing

	BEVEL		T & G		SHIPLAP	
	GREEN	DRY	GREEN	DRY	GREEN	DRY
ENERGY USE KJ						
Electricity	3897.6	5198.4	5684.0	7581.0	5887.0	7851.8
Diesel	225.6	542.4	329.0	791.0	340.8	819.3
Gasoline	24.0	57.6	35.0	84.0	36.3	87.0
Propane	139.2	139.2	203.0	203.0	210.3	210.3
Natural Gas	0.0	3422.4	0.0	4991.0	0.0	5169.3
Biomass	0.0	3763.2	0.0	5488.0	0.0	5684.0
EMISSIONS TO AIR						
CO ₂ g	259.2	758.4	378.0	1106.0	391.5	1145.5
CO mg	192.0	552.0	280.0	805.0	290.0	833.8
CH ₄ mg	4.8	38.4	7.0	56.0	7.3	58.0
No _x mg	201.6	820.8	294.0	1197.0	304.5	1239.8
SO ₂ mg	24.0	28.8	35.0	42.0	36.3	43.5
V.O.C. mg	28.8	192.0	42.0	280.0	43.5	290.0
Particulates mg	0.0	1867.2	0.0	2723.0	0.0	2820.3
WATER USE (L)	2.2	2.5	3.2	3.6	3.3	3.8
EMISSIONS TO WATER (µg)						
BOD	43.2	43.2	63.0	63.0	65.3	65.3
Suspended Solids	441.6	441.6	644.0	644.0	667.0	667.0
Oil & Grease	19.2	19.2	28.0	28.0	29.0	29.0
EMISSIONS TO LAND (g)						
Landfilled	14.7	15.6	21.5	22.8	22.3	23.6
Boiler Ash	0.0	1.3	0.0	1.9	0.0	2.0
Inorganic	0.0	1.0	0.0	1.5	0.0	1.5

4.0 STEEL CLADDING INDUSTRY - AN OVERVIEW

4.1 Products And Markets

The Canadian steel industry is comprised of forty-two mills. Four of these are integrated steel plants producing approximately two-thirds of all steel in Canada. A life cycle inventory was completed for these plants by product type in 1993 for the ATHENA™ Sustainable Materials Institute. Another eleven plants are characterized as mini-mills which use an electric arc furnace technology rather than the traditional blast furnace employed by integrated mills, and rely primarily on recycled scrap as a raw material input. A life cycle inventory analysis of Canadian mini-mill plants was also conducted for the Institute in August 1994.

The remaining 27 plants produce specialty steel (e.g. stainless) in various shapes, using continuous and form casting, followed by rolling or forming and subsequent machining. These small plants produce little, if any, building materials and were not studied.

In October 1994 the Institute produced another steel report combining the results of both the integrated and mini-mill reports to achieve a weighted average life cycle inventory across various steel building materials. This last report is the primary source for the life cycle inventory of steel cladding presented here.

In Canada, two manufacturers of steel cladding systems dominate the market. The largest manufacturer and distributor of steel cladding products is Vic West Inc. headquartered in Montreal, with forming plants in each of the major urban centres considered in the ATHENA™ model. Ideal Roofing is the second largest producer and serves eastern Canada and the upper US northeast from its plant in Ottawa. Ideal Roofing provided additional information concerning final product manufacturing and product specifications. Both manufacturers use a painted galvanized sheet product produced by BAPCO in Burlington which purchases its raw galvanized sheet goods from both Stelco and Dofasco - two integrated steel producers.

Steel cladding is available in a multitude of colours and profiles for almost any residential and commercial application. However, the scope of this analysis allowed study of only two diverse gauge categories of steel cladding - residential and commercial. Residential cladding is a rapidly developing market for steel cladding systems, primarily in the form of roofing with a smaller volume in siding. Typically, the gauge is lighter in residential compared to commercial applications (e.g., 30 ga. or (0.015")) and finished product widths are narrower. That is, 36" wide galvanized sheet rolls are used in the forming operations to produce products with a final width in the range of 27"-29". Alternatively, commercial cladding is of a heavier gauge (26 ga. (0.021")) are formed out of 48" wide rolls with a final product width in the order of 38"-40".

Final product lengths are usually at the discretion of the end user and can vary considerably depending on the application.

4.2 Energy And The Environment

Both Steltech reports prepared for the Institute include background discussions of energy conservation measures adopted by the Canadian steel industry for pneumatic blast and electric arc furnace basic steel making processes as well as for rolling and finishing operations. Since 1974

the steel industry, primarily integrated mills, have increased their energy efficiency by approximately 20%. Similarly, the Canadian steel industry has directed significant resources towards achieving compliance with government mandated as well as voluntary pollution prevention targets. For instance, the control of particulate emissions has resulted in virtually zero visible emissions from an industry that was once noted for its black smoke stacks. Equally significant pollution reductions have been achieved with the industry's effluent and solid waste streams. The Steltech reports describe in detail the industry's measures to control air emissions, liquid effluents and solid wastes and the reader is referred to these earlier reports for a complete discussion of the industry's steps to conserve energy and control emissions.

5.0 LIFE CYCLE INVENTORY - STEEL CLADDING

This section provides a generalized life cycle inventory (LCI) for steel cladding using the earlier LCI work completed by Steltech (October, 1994). Galvanized steel sheet produced in integrated steel mills is the product of choice for steel cladding and therefore, we borrow heavily on Steltech's integrated mill study [4] for galvanized sheet. Relative to mini-mills, integrated mill production is more energy and virgin resource intensive.

Unlike the earlier Steltech reports, we have broken out transportation and reported it separately. The results have also been normalized to one square meter of finished steel cladding for residential and commercial applications.

The LCI profile has been segmented similar to that for wood cladding; i.e., extraction and manufacturing. Resource extraction covers the mining and quarrying associated with raw materials necessary for the production of galvanized steel sheet as well as associated transportation of raw materials to the steel mill. Manufacturing entails all transformations within the steel mill (sinter plant, coke ovens, blast furnaces, etc.) necessary to produce cladding gauge galvanized sheet. Final transportation from the mill to regional distribution centres as set out in the ATHENA™ model is accounted for separately in Section 6.2.

Not included in the earlier Steltech study or in this study is the paint used to achieve the final colour of the cladding stock. Typically, paint is applied to a thickness of 2.5 mil on the finished side of the cladding and is warranted for 20 years. In a similar vein, final forming of the painted galvanized sheet into cladding is not accounted for in this inventory. Discussions with industry personnel have led us to believe that energy use and associated emissions are relatively minor compared to the production of galvanized sheet; electricity is the primary energy input and represents less than 2% of the energy embodied in galvanized sheet and all process steel waste was said to be recycled. However, conversion factors have been calculated for the production efficiency of turning raw sheet into formed cladding on m² basis. The LCI profile results can be found for steel cladding extraction and manufacturing in Tables 7a and 7b respectively

Table 7a. Summary Inventory Profile for one square meter of finished Steel Cladding
- Resource Exploration, Extraction and Transportation

	RESIDENTIAL	COMMERCIAL
	30 ga. 0.015"	26 ga. 0.021"
ENERGY USE (KJ)		
<u>Extraction</u>		
Diesel	2945	3960
Gasoline	12	16
Electricity	2779	3737
Natural Gas	2663	3541
<u>Transportation</u>		
Diesel	838	1127
EMISSIONS TO AIR		
<u>Extraction</u>		
CO ₂ g	761	1024
CO mg	523	703
CH ₄ mg	277	372
No _x mg	1691	2274
SO ₂ mg	2218	2983
V.O.C. mg	684	920
Particulates mg	112	150
EMISSIONS TO AIR		
<u>Transportation</u>		
CO ₂ g	59	80
CO mg	373	501
CH ₄ mg	19	26
No _x mg	677	910
SO ₂ mg	85	114
V.O.C. mg	73	98
Particulates mg	--	--
EMISSIONS TO LAND (g)	n.a.	n.a.

Table 7b. Summary Inventory Profile for one square meter of finished Steel Cladding - Manufacturing

	Residential	Commercial
	30 ga. 0.015”	26 ga. 0.021”
ENERGY USE (kj)		
Electricity	6747	9072
Diesel	5082	6834
Gasoline	12	16
Natural Gas	5082	6834
Coal, Electrodes, scrap	74593	100303
EMISSIONS TO AIR		
CO ₂ g	6923	9310
CO mg	91211	122650
CH ₄ mg	50	67
No _x mg	8396	11290
SO ₂ mg	24606	33088
V.O.C. mg	12236	16454
Particulates mg	5347	7190
WATER USE (L)	468	630
EMISSIONS TO WATER (mg)		
Non-Ferrous Metals	23.4	31.5
Cyanide	28.1	37.8
Phenolics	6.6	8.8
Ammonia(um)	496.1	667.5
Non-Halogenated Org	1.3	1.8
Halogenated Organics	1.9	2.6
Sulphides	4.7	6.3
Iron	192.0	258.2
Oil & Grease	538.6	724.2
Suspended Solids	4585.1	6166.0
EMISSION TO LAND (g)		
Blast Furnace Slag	811.1	1090.7
BOF & EAF Dust	61.5	82.7

6.0 TRANSPORTATION OF FINISHED PRODUCTS TO URBAN CENTRES

This section describes mode and distance information for delivery of wood and steel cladding products to major urban centres considered in the ATHENA™ model. The model then calculates the energy use and air emissions associated with travel mode and distance for each product going to the various markets. Without knowing exact market shares and the locations of all plants producing the various products (especially for wood cladding) we can only calculate an average haul by mode and distance for each product. Product shipments from distributors, in the case of wood cladding, and forming plants, in the case of steel cladding, to final construction sites is handled separately in the Athena model as part of the on-site construction database.

6.1 Finished Wood Cladding Transportation

Based on information from our wood siding manufacturing participants and our general understanding of species availability within Canada, we have concluded the following:

- Western Red Cedar is by far the major specie used in siding applications and is only economically sourced from the BC Coast
- Eastern White Cedar, while an alternative to Western Red Cedar, is limited to eastern Canadian markets as a siding product
- Spruce and pine is largely available across Canada and is equally available to all six major markets defined in the ATHENA™ model. Hence, we have used similar average transportation modes and distances as previously derived for softwood lumber.

Based on the above premises we have constructed an average distance and transportation mode table as set out below:

Table 8. Final Transportation of Wood Cladding to ATHENA™ Markets

Species/ Destination	Truck km	Rail km
Western Red Cedar		
Vancouver	65	
Calgary	25	1049
Winnipeg	25	2455
Toronto	25	4537
Montreal	25	5340
Halifax	25	6301
Eastern White Cedar		
Vancouver	N/A	
Calgary	N/A	
Winnipeg	N/A	
Toronto	337	
Montreal	337	
Halifax	65	
Pine and Spruce		
Vancouver	337	
Calgary	337	
Winnipeg	337	
Toronto	337	
Montreal	337	
Halifax	65	

6.2 Finished Steel Cladding Transportation

Table 9 below presents the mode and haul distance used for finished steel cladding. The table is based on the premise that coiled galvanized steel sheet is produced and pre-painted in southern Ontario and shipped for final product forming in each of the six urban centres modeled within ATHENA™.

Table 9. Final Transportation of Steel Cladding to ATHENA™ Markets

Destination	Truck km	Rail km
Vancouver	25	4537
Calgary	25	3488
Winnipeg	25	2082
Toronto	65	
Montreal	25	805
Halifax	25	1765

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