the ATHENA™ Sustainable Materials Institute

MAINTENANCE, REPAIR AND REPLACEMENT EFFECTS FOR BUILDING ENVELOPE MATERIALS

Prepared by:

MORRISON HERSHFIELD LIMITED

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ATHENA™ Sustainable Materials Institute
28 St. John Street, P.O. Box 189
Merrickville, Ontario Canada, K0G 1N0
Tel: 613-269-3795
Fax: 613-269-3796
Email: wbtrusty@fox.nstn.ca

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1. INTRODUCTION

The ATHENA[1] Institute commissioned this report in 2001, contracting Morrison Hershfield to undertake research into maintenance, repair and replacement effects of various building envelope materials utilized in North America. This report provides the results of the Morrison Hershfield analysis.

1.1 Terms of Reference

Morrison Hershfield was asked to review the types of systems and effects shown in Table 1.1 for the full range of building types indicated in the table.

Maintenance and repair effects of building materials include the following:

- material usage, including quantity take-offs on a square meter basis for maintenance and repair products and components;
- typical frequency of maintenance and repairs for each of the urban centres given in the ATHENA software;
- energy use for maintenance and repair;
- transportation mode and distance from the distributor to the site of the above components; and
- on-site waste of maintenance and repair components and its disposition.

Replacement effects of building materials include the following:

- typical life expectancy of each material;
- mass of waste materials and its disposition.

Previous ATHENA Institute estimates of the environmental effects of replacing the following systems were also reviewed: commercial roofing, including PVC, EPDM, modified bitumen, B.U.R., TPO, and rubberized asphalt.

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

Table 1.1 Building Systems and Types Studied

System	Maintenance & Repair Effects	Replacement Effects
Wood cladding[1]	x	x
Traditional stucco[2]	x	x
PVC siding, typical for low-rise applications	x	x
Split-faced concrete block siding	x	x
Steel cladding	x	x
Brick cladding	x	x
Concrete block siding	x	x
Curtain wall system	x	x
Window systems[3]	x	x
Residential roofing[4]	x	x
Commercial roofing[5]	x	
Gypsum board[6]	x	x

Building type		
• Single family residential	• Multi-unit high-rise residential-owner occupied	• Institutional
• Multi-unit low-rise residential	• Office-rental	• Commercial
• Multi-unit high-rise residential-rental	• Office-owner occupied	• Industrial

[1] Typical for low-rise applications, clapboard style (including related fasteners for maintenance and repair effects).
[2] With a wire mesh backing and breather type mesh backing.
[3] Including PVC, wood, aluminum, and fiberglass frames, both fixed and operable types (plus related insulation, fasteners, gaskets and caulking for maintenance and repair effects).
[4] Including organic and fiberglass-based 3-tab shingles, mineral roll roofing, and clay and concrete tiles, (including fasteners for maintenance and repair effects).
[5] Including PVC, EPDM, modified bitumen, BUR, TPO and rubberized asphalt.
[6] Externally and internally applied (including fasteners for maintenance and repair effects).

NOTES:
• Insulation materials within wall assemblies typically last the life of the building, and are excluded from this study.
• Also excluded is polyethylene sheeting used as a vapour barrier in thermally insulated wall, floor and ceiling assemblies as there are no typical maintenance and repair effects for polyethylene when used as a vapour barrier.
• Painted finishes are periodically replaced to maintain finishes and to protect exterior woods from the elements. The frequency of replacement varies dramatically depending on the material on which it is placed and the environment in which it is placed. Accordingly, the data associated with paint replacement is given in the repair sections of each of the elements which are typically painted.
• Glass fibre-framed windows are typically available only as extremely high-quality systems and are relatively new to North America; as a result, historical life spans are not available and further study is required.

1.2 Information Used

The durability data in this report was developed based on Morrison Hershfield experience, and with the information in CSA Standard S-478-95, "Guidelines on Durability in Buildings" and the CMHC Research Report, "Service Life of Multi-Unit Residential Building Elements and Equipment". The information was obtained or verified using Morrison Hershfield personnel from their offices in Toronto, Ottawa, Calgary, Vancouver, and Atlanta, in an effort to obtain the expected level of accuracy.

Many building types and elements are water sensitive; as a result, the service life values of these components are affected by exterior water (driving rain or ground water) and seasonal drying potential. This was taken into consideration in the estimation of the service life of buildings as a whole and the elements that are included within this report. Figure 1 below displays a decay hazard map of North America which was utilized to establish service lives.

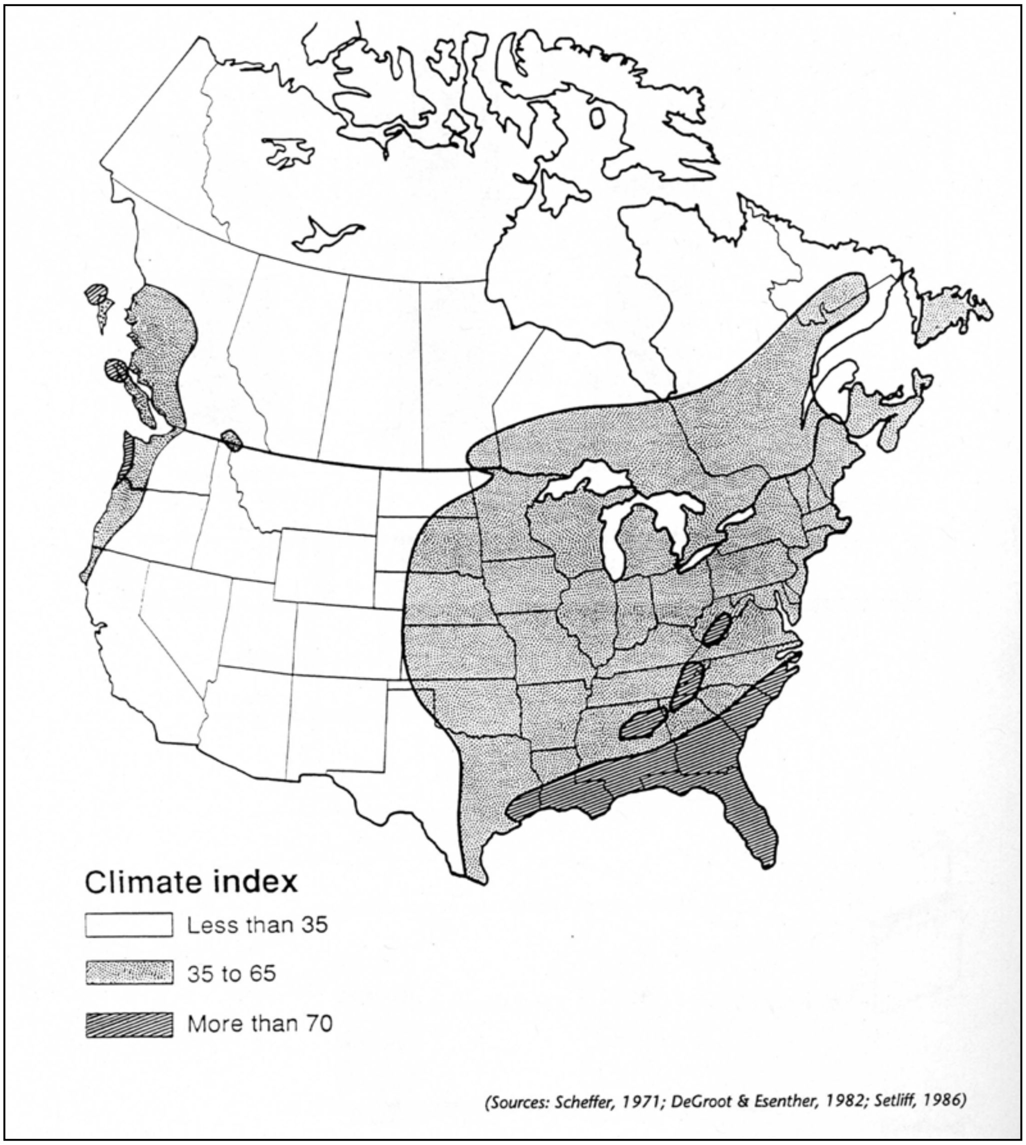

Figure 1: Decay Hazard Map for North America

Assumptions

In the development of the unit quantities for some items, it was necessary to assume typical sizes and orientations for wall assemblies. These assumptions were made based on Morrison Hershfield's professional judgment and experience. Further, many of the estimates were developed under the assumption that the elements in this report are installed on buildings no higher than ten storeys. Morrison Hershfield also recognize, and have included in their calculations, the fact that some elements are more commonly installed on low-, mid-, or high-rise buildings.

1.3 Service Life Estimation

As indicated above, the average service life of building elements was estimated for several different building types in several different locations and climates.

In many cases, however, this estimation is limited by the service life of the building, and not the particular element. For example, brick facades might be expected to last more than 50 years, while the building they are installed in might last only 40 years. Hence, the service life of the building may well be the overriding criterion determining the actual life of the component element.

Similarly, the service life of specific building elements is in some cases overridden for reasons other than durability. This is often dependent on building usage. For example, window systems in a commercial building may be replaced for aesthetic reasons as the building's tenant changes. The values in this report reflect this reality on an elemental basis for each building type.

1.4 Report Structure

Section 2 deals with elements common to many materials and systems in the construction of buildings, such as cranes and sealants. Subsequent sections deal with the various systems studied, as listed in Table 1.1 above. Each section deals first with maintenance and repair effects, then with replacement effects.

2. COMMON ELEMENTS

In the construction of buildings, many materials or systems share common elements such as cranes or tools. This section discusses the methodology behind the derivations of the impacts of several common elements.

2.1 Cranes

Cranes are available in many different sizes and configurations. Most portable or truck-mounted cranes are run by diesel engines. Tower cranes (T-style) are most often run by electricity, although this electricity is often powered by diesel-fueled generators. For the purposes of this report, we have assumed that all crane lifting is powered by diesel fuel.

We have spoken with several crane suppliers and manufacturers, and have found that for a medium-large hydraulic crane (100 Ton capacity), the fuel spent ranges from 20 to 40 litres per hour, depending on loads lifted. Accordingly, light loads such as insulation would result in the use of 200 l/day for lifting, where heavy loads such as concrete might result in 400 l/day. Under the assumption that the mass of light loads is negligible and heavy loads are lifted at 20 minute intervals to a height of 30 m, we can use regression analysis to develop the following equation for fuel use by load:

$$F = 0.000037\ M \times h + M/500 + 0.83$$

F = diesel fuel in Litres
M = mass of material lifted (kg)
h = height of material to be lifted (m)

2.2 Sealants

Sealants are utilized in many cladding materials and systems. They are common in expansion joints as a seal around penetrations such as doors or windows. For the purposes of this report, we have assumed the size of a sealant joint is approximately 12 mm square. Further, where a backer rod is utilized, we have assumed it will have a diameter of approximately 18 mm.

No sealant type was assumed for this report. A variety of sealant types is available, many of which are popular on a location (rather than end use) basis.

2.3 Mortar Mixer

Gas powered mortar mixers are commonly utilized in the application of brick, concrete block, stucco, and split faced concrete block. A typical mortar mixer utilizes an 8HP gas powered motor, which often runs continuously on the job. This mortar mixer will use approximately 1 litre of gasoline per hour.

2.4 Swing Stages and Scaffolding

Swing stages are often utilized to gain exterior access to larger buildings. Alternatively, scaffolding is used.

Scaffolding is typically set up by hand, although roof mounted cranes are occasionally used to assist in lifting. For the purposes of this report, we have assumed no on-site electricity is utilized for scaffolding.

Swing stages are powered by electric engines. Under the assumption that these engines are 75% efficient, that a no load mass of 500 kg (including two men and the swing stage) is utilized, and that the average height of material lifted is 12 m, the following equation has been developed:

$$E = 0.0222 + 0.160\ M$$

E = energy in KWH
M = mass of material lifted (kg)

3. WOOD CLADDING

Wood cladding is typically used in residential and low rise buildings that have wood frame construction. The species of wood can vary by location, but is typically either cedar or pine. Wood siding is available in a number of styles and constructions; this report, however, was limited to clapboard style wood cladding.

3.1 Maintenance and Repair Effects

Spot Repairs

In a properly designed and maintained wood wall, the siding should not require major repairs or replacement of small sections (spot replacement) in its lifetime. It is, nevertheless, common to allow for periodic spot replacement, although the area of wall replaced is typically less than 5% and replacement is performed on less than 20% of wood clad buildings. Accordingly, we have assumed the environmental costs of this task to be negligible.

Re-Painting

Re-painting and re-staining of wood siding is typically performed approximately once every five to seven years. The data for re-painting is included in Table 3-1 below.

Table 3-1 Maintenance and Repair: Re-painting Wood Siding

WOOD		Residential	
Description:			Multi-unit
Re-painting or re-staining of wood wall.		Single Family	Low-rise
Maintenance Cycle			
Calgary	years	7	7
Montreal	years	5	5
Toronto	years	5	5
Halifax	years	5	5
Vancouver	years	5	5
Winnipeg	years	7	7
Minnesota	years	7	7
Atlanta	years	5	5

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0
RAW INPUTS		
paint	L/m^2	0.172
	waste	2%

3.2 Replacement Effects

Replacement of a properly designed and maintained wood wall can vary dramatically, and in many cases replacement is not necessary for the life of the building. However, the values portrayed in Table 3-2 reflect average frequency of exterior wall replacement, including cases where the wood is simply covered over.

Table 3-2: Replacement Effects for Wood Siding

WOOD		Residential			
Description:			Multi-unit		
Removal of 100% of the wood siding.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)
Replacement Cycle					
Calgary	years	25	25	na	na
Montreal	years	25	25	na	na
Toronto	years	25	25	na	na
Halifax	years	25	25	na	na
Vancouver	years	25	25	na	na
Winnipeg	years	25	25	na	na
Minnesota	years	25	25	na	na
Atlanta	years	25	25	na	na

MASS OF MATERIALS			DISPOSITION		
Material			Landfill	Recycle	Other
wood	kg/m^2	1.60	100%		
nails	kg/m^2	0.025	100%		
Building Paper (15# Asphalt impregnated felt)	kg/m^2	2.295	100%		

4. STUCCO

4.1 Maintenance and Repair Effects

Spot Repairs

Periodically, stucco finishes become cracked and require local repairs. A description of a typical stucco repair and its environmental impact are shown in Table 4-1.

Table 4-1: Local Repair of Stucco Wall

STUCCO		Residential				ICI				
Description:			Multi-unit			Office				
Local replacement of approximately 10% of stucco wall.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	20	20	20	20	20	20	20	20	na
Montreal	years	20	20	20	20	20	20	20	20	na
Toronto	years	20	20	20	20	20	20	20	20	na
Halifax	years	15	15	12	12	12	12	12	12	na
Vancouver	years	15	15	12	12	12	12	12	12	na
Winnipeg	years	20	20	20	20	20	20	20	20	na
Minnesota	years	20	20	20	20	20	20	20	20	na
Atlanta	years	15	15	12	12	12	12	12	12	na

continued…

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0
RAW INPUTS		
Base coat	kg/m^2	3
	waste	10%
Finish coat	kg/m^2	0.6
	waste	10%
Expanded metal mesh	kg/m^2	0.1
(galvanized steel)	waste	3%
Fasteners	kg/m^2	0.003
(galvanized steel)	waste	0%

note: units are per entire wall area

Painting

Stucco finishes require periodic painting to maintain an aesthetically pleasing finish. Table 4-2 displays typical data associated with painting.

Table 4-2: Re-painting of Stucco Wall

STUCCO		Residential				ICI				
Description:			Multi-unit			Office				
Re-painting or re-staining of stucco wall.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	9	9	9	8	10	9	9	8	na
Montreal	years	7	7	7	6	8	7	7	6	na
Toronto	years	7	7	7	6	8	7	7	6	na
Halifax	years	7	7	7	6	8	7	7	6	na
Vancouver	years	7	7	7	6	8	7	7	6	na
Winnipeg	years	9	9	9	8	10	9	9	8	na
Minnesota	years	9	9	9	8	10	9	9	8	na
Atlanta	years	7	7	7	6	8	7	7	6	na

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0
RAW INPUTS		
paint	L/m^2	0.172
	waste	2%

4.2 Replacement Effects

Replacement of a properly designed and maintained stucco wall can vary dramatically, and in many cases is not necessary for the life of the building. Further, stucco is rarely replaced in its entirety, although it is commonly over-clad with a different material (such as PVC or wood). Although this may take place, for the purposes of this report we have assumed replacement consists of replacing the stucco. Table 4-3 reflects this assumption.

Table 4-3: Replacement Effects for Stucco Siding

STUCCO		Residential				ICI				
Description: Removal or overcladding of 100% of the stucco siding.			Multi-unit			Office				
		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	75	65	35	35	35	35	35	35	na
Montreal	years	75	65	35	35	35	35	35	35	na
Toronto	years	75	65	35	35	35	35	35	35	na
Halifax	years	25	20	20	20	20	20	20	20	na
Vancouver	years	25	20	20	20	20	20	20	20	na
Winnipeg	years	75	65	35	35	35	35	35	35	na
Minnesota	years	75	65	35	35	35	35	35	35	na
Atlanta	years	25	20	20	20	20	20	20	20	na

MASS OF MATERIALS			DISPOSITION		
Material			Landfill	Recycle	Other
Base coat	kg/m^2	30.0	100%		
Finish coat	kg/m^2	6.0	100%		
Expanded metal mesh	kg/m^2	1.0	100%		
Fasteners	kg/m^2	0.028	100%		
Building paper (15# asphalt impregnated felt)	kg/m^2	2.295	100%		

5. PVC SIDING

PVC siding is typically installed as cladding on residential low-rise buildings.

5.1 Maintenance and Repair Effects

PVC siding is sold as a non-maintenance exterior cladding, which typically requires very little maintenance other than cleaning, generally with normal detergents or proprietary cleaning agents. Occasional repairs of mechanical or heat damage may be required; the area of repairs is very small, however, and is assumed negligible for the purposes of this report. PVC siding is not typically re-painted.

5.2 Replacement Effects

Replacement of PVC cladding is typically driven by a loss of plasticizers (which makes the siding brittle) or by aesthetics. We have developed an average frequency of PVC cladding replacement as shown in Table 5-1.

Table 5-1: Replacement Effects of PVC Siding

PVC CLADDING		Residential	
Description:			Multi-unit
Removal of 100% of the PVC siding.		Single Family	Low-rise
Replacement Cycle			
Calgary	years	35	35
Montreal	years	35	35
Toronto	years	35	35
Halifax	years	35	35
Vancouver	years	35	35
Winnipeg	years	35	35
Minnesota	years	35	35
Atlanta	years	35	35

MASS OF MATERIALS			DISPOSITION		
Material			Landfill	Recycle	Other
PVC	kg/m^2	2.3	100%		
aluminum flashing	kg/m^2	0.12	100%		
Nails	kg/m^2	0.05	100%		
Building Paper (15# asphalt impregnated felt)	kg/m^2	2.295	100%		

6. SPLIT-FACED CONCRETE BLOCK

Split-faced concrete block is similar in material composition to standard concrete block; however, the manufacturing process results in one double-width block which is mechanically split, creating two blocks with a stone-like appearance. This material is common in high-rise and commercial buildings.

6.1 Maintenance and Repair Effects

Caulking Replacement

Caulking is periodically replaced in split-faced concrete block walls. Table 6-1 provides data relating to this task.

Table 6-1: Re-caulking of Split-faced Concrete Block Walls

SPLIT FACED CONCRETE BLOCK		Residential				ICI				
Description:			Multi-unit			Office				
Re-caulking of a split faced concrete block wall.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	15	15	15	15	15	15	15	15	20
Montreal	years	15	15	15	15	15	15	15	15	20
Toronto	years	15	15	15	15	15	15	15	15	20
Halifax	years	15	15	15	15	15	15	15	15	20
Vancouver	years	15	15	15	15	15	15	15	15	20
Winnipeg	years	15	15	15	15	15	15	15	15	20
Minnesota	years	15	15	15	15	15	15	15	15	20
Atlanta	years	12	12	12	12	12	12	12	12	15

continued…

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0
RAW INPUTS		
sealant	kg/m^2	0.053
	waste	10%
Polyurethane foam	kg/m^2	0.004
(backer rod)	waste	0%

Re-pointing

Re-pointing is also periodically performed in split-faced concrete block walls. Actual areas requiring re-pointing can vary by building type (a smaller percentage of wall areas on higher buildings requires re-pointing). For the purposes of this report, we have assumed 15% of the wall areas will be re-pointed during each re-pointing program. Table 6-2 provides data relating to this task.

Table 6-2: Re-pointing of Split-faced Concrete Block Walls

SPLIT FACED CONCRETE BLOCK		Residential				ICI				
Description:			Multi-unit			Office				
Re-pointing of a split faced concrete block wall.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	25	25	25	25	25	25	25	25	25
Montreal	years	20	20	20	20	20	20	20	20	20
Toronto	years	25	25	25	25	25	25	25	25	25
Halifax	years	20	20	20	20	20	20	20	20	20
Vancouver	years	25	25	25	25	25	25	25	25	25
Winnipeg	years	25	25	25	25	25	25	25	25	25
Minnesota	years	25	25	25	25	25	25	25	25	25
Atlanta	years	30	30	30	30	30	30	30	30	30

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0
RAW INPUTS		
mortar	kg/m^2	14.25
	waste	25%

6.2 Replacement Effects

Split-faced concrete block siding typically performs for the life of the building, after which it is usually disposed of at landfills. The mass of materials at disposal is identical to the mass of materials installed.

7. STEEL CLADDING

7.1 Maintenance and Repair Effects

Re-caulking

Caulking is periodically replaced in steel clad walls. Backer rod is not generally used for this purpose, and there is little or no on-site energy associated with re-caulking. The only effects, therefore, relate to the use of sealant, as indicated in Table 7-1.

Table 7-1: Re-caulking of Steel Clad Walls

STEEL CLADDING		Residential				ICI				
Description:			Multi-unit			Office				
Re-caulking of steel cladding		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	na	na	15	15	15	15	15	15	20
Montreal	years	na	na	15	15	15	15	15	15	20
Toronto	years	na	na	15	15	15	15	15	15	20
Halifax	years	na	na	15	15	15	15	15	15	20
Vancouver	years	na	na	15	15	15	15	15	15	20
Winnipeg	years	na	na	15	15	15	15	15	15	20
Minnesota	years	na	na	15	15	15	15	15	15	20
Atlanta	years	na	na	12	12	12	12	12	12	15

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0
RAW INPUTS		
sealant	kg/m^2	2E-05
	waste	10%

Re-painting of Metal Clad Walls

The finishes on metal walls fade and peel with age, after which they can be replaced or repainted. In most applications, the cost of quality re-painting is close to the cost of replacement. Accordingly, it is most common for metal clad walls to be simply replaced as their finish becomes unacceptable (see Table 7-2 below).

7.2 Replacement Effects

Metal cladding can often remain functional for the life of the building on which it is installed; however, as noted above, it is often replaced for aesthetic reasons at the intervals given in Table 7-2.

Table 7-2: Replacement of Steel Clad Walls

STEEL CLADDING		Residential				ICI				
Description:			Multi-unit			Office				
Removal of 100% of the steel siding.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	na	na	40	40	30	30	40	25	35
Montreal	years	na	na	40	40	30	30	40	25	35
Toronto	years	na	na	40	40	30	30	40	25	35
Halifax	years	na	na	30	30	25	25	30	20	35
Vancouver	years	na	na	30	30	25	25	30	20	35
Winnipeg	years	na	na	40	40	30	30	40	25	35
Minnesota	years	na	na	40	40	30	30	40	25	35
Atlanta	years	na	na	30	30	25	25	30	20	35

MASS OF MATERIALS			DISPOSITION		
Material			Landfill	Recycle	Other
Steel cladding	kg/m^2	10.0		100%	
Fasteners	kg/m^2	0.025	100%		
Building Paper (15# asphalt impregnated felt)	kg/m^2	2.295	100%		

8. BRICK CLADDING

8.1 Maintenance and Repair Effects

Caulking is periodically replaced and re-pointing performed in brick veneer walls, as indicated in Tables 8-1 and 8-2. Actual areas requiring re-pointing can vary by building type (a smaller percentage of wall areas on higher buildings requires re-pointing). For the purposes of this report, we have assumed that 25% of the wall areas will be re-pointed during each re-pointing program. Table 8-1 excludes the caulking around windows.

Table 8-1: Re-caulking of Brick Veneer Walls

BRICK		Residential				ICI				
Description:			Multi-unit			Office				
Re-caulking of brick veneer.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	15	15	15	15	15	15	15	15	20
Montreal	years	15	15	15	15	15	15	15	15	20
Toronto	years	15	15	15	15	15	15	15	15	20
Halifax	years	15	15	15	15	15	15	15	15	20
Vancouver	years	15	15	15	15	15	15	15	15	20
Winnipeg	years	15	15	15	15	15	15	15	15	20
Minnesota	years	15	15	15	15	15	15	15	15	20
Atlanta	years	12	12	12	12	12	12	12	12	15

continued…

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0
RAW INPUTS		
sealant	kg/m^2	0.02
	waste	10%
Polyurethane foam	kg/m^2	0.002
(backer rod)	waste	0%

Table 8-2: Re-pointing of Brick Veneer Walls

BRICK		Residential				ICI				
Description:			Multi-unit			Office				
Re-pointing of 25% of the brick veneer		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	25	25	30	30	30	30	30	30	35
Montreal	years	20	20	25	25	25	25	25	25	35
Toronto	years	25	25	30	30	30	30	30	30	35
Halifax	years	20	20	25	25	25	25	25	25	35
Vancouver	years	25	25	30	30	30	30	30	30	35
Winnipeg	years	25	25	30	30	30	30	30	30	35
Minnesota	years	25	25	30	30	30	30	30	30	35
Atlanta	years	30	30	35	35	35	35	35	35	35

continued…

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0
RAW INPUTS		
mortar	kg/m^2	7.5
	waste	25%

8.2 Replacement Effects

Brick veneer typically performs for the life of the building, after which it is generally disposed of at landfills; it often serves as liner material at landfills, however. Currently, only a small percentage of brick is recycled. The mass of materials at disposal is identical to the mass of materials installed.

9. CONCRETE BLOCK SIDING

Concrete block siding consists of concrete blocks that are filled with mortar and reinforcing steel and tied back to the studs or wall system. The mortar is placed between the blocks as well as in the block voids, which run in the vertical direction. The reinforcement steel is placed in the vertical direction within these filled voids.

When utilized as siding, concrete blocks are typically painted on the exterior. Interior finishes and constructions can vary from a simple painted (un-insulated) surface to an insulated wall assembly inside of the concrete block wall.

9.1 Maintenance and Repair Effects

Painted concrete block walls require periodic repainting to maintain an aesthetically pleasing finish, and caulking is periodically replaced in exposed concrete block walls. Tables 9-1 and 9-2 display typical data associated with these tasks, excluding caulking around windows.

Table 9-1: Re-painting of Concrete Block Wall

CONCRETE BLOCK		ICI		
Description: Re-painting of exterior of concrete block wall.		Institutional	Commercial	Industrial
Maintenance Cycle				
Calgary	years	7	7	8
Montreal	years	7	7	8
Toronto	years	7	7	8
Halifax	years	7	7	8
Vancouver	years	7	7	8
Winnipeg	years	7	7	8
Minnesota	years	7	7	8

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0
RAW INPUTS		
paint	L/m^2	0.172
	waste	2%

Table 9-2: Re-caulking of Concrete Block Wall

CONCRETE BLOCK		ICI		
Description: Re-caulking of an exposed concrete block wall.		Institutional	Commercial	Industrial
Maintenance Cycle				
Calgary	years	15	15	20
Montreal	years	15	15	20
Toronto	years	15	15	20
Halifax	years	15	15	20
Vancouver	years	15	15	20
Winnipeg	years	15	15	20
Minnesota	years	15	15	20
Atlanta	years	12	12	15

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0
RAW INPUTS		
sealant	kg/m^2	0.053
	waste	10%
Polyurethane foam	kg/m^2	0.004
(backer rod)	waste	0%

9.2 Replacement Effects

Concrete block exterior walls typically last for the life of the building. The mass of materials at disposal is identical to the mass of materials installed.

10. CURTAIN-WALL

Curtain-wall can be defined as a self-supporting grid comprising most of the exterior envelope in a wall. Typically, curtain-wall systems consist of a grid of aluminum framing with either glazed or unglazed areas enclosing the spaces of the grid. Glazed areas typically utilize double-glazed insulating glass units. Unglazed portions typically consist of insulated metal back-pans with metal or opaque glass spandrel panels.

10.1 Maintenance and Repair Effects

Re-caulking

Sealants within curtain-wall systems are not often replaced, but many terminations of the curtain-wall at roofs, other types of walls, or the base incorporate caulked joints that periodically require replacement. Table 10-1 summarizes the data associated with this task.

Table 10-1: Sealant Replacement on Curtain-wall

CURTAIN -WALL		Residential				ICI				
Description: Replacement of sealant			Multi-unit			Office				
		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	15	15	15	15	15	15	15	15	20
Montreal	years	15	15	15	15	15	15	15	15	20
Toronto	years	15	15	15	15	15	15	15	15	20
Halifax	years	15	15	15	15	15	15	15	15	20
Vancouver	years	15	15	15	15	15	15	15	15	20
Winnipeg	years	15	15	15	15	15	15	15	15	20
Minnesota	years	15	15	15	15	15	15	15	15	20
Atlanta	years	12	12	12	12	12	12	12	12	15

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0
RAW INPUTS		
Sealant	kg/m^2	0.04
	waste	10%
Polyurethane foam	kg/m^2	0.003
(backer rod)	waste	0%

Periodic Glazing Replacement

Insulating glass units typically fail between 10 and 30 years after construction. Accordingly, an average of 3% of the glazing is replaced each year. Table 10-2 summarizes the data associated with this task.

Table 10-2: Periodic Glazing Replacement in Curtain-wall

CURTAIN -WALL		Residential				ICI				
Description:			Multi-unit			Office				
Annual replacement of failed glazing units		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	1	1	1	1	1	1	1	1	1
Montreal	years	1	1	1	1	1	1	1	1	1
Toronto	years	1	1	1	1	1	1	1	1	1
Halifax	years	1	1	1	1	1	1	1	1	1
Vancouver	years	1	1	1	1	1	1	1	1	1
Winnipeg	years	1	1	1	1	1	1	1	1	1
Minnesota	years	1	1	1	1	1	1	1	1	1
Atlanta	years	1	1	1	1	1	1	1	1	1

INPUTS PER CYCLE			
On-site electricity input	KWH/m^2	9E-04	
On-site propane use	kg/m^2	0	
On-site diesel use	L/m^2	0	
RAW INPUTS			
Glass	kg/m^2	0.47	
	waste	0%	
WASTE MATERIAL			
Glass	kg/m^2	0.47	to landfill

Curtain-wall Retrofit

After approximately 30 years, most building owners perform a major curtain-wall retrofit to restore the appearance and functionality of the system. This typically includes re-finishing of the metal spandrel panels and repairs to back-pans. For the purposes of this report, we have assumed that 10% of the insulation within the system will be replaced at the same time, along with all gaskets and all spandrel panels. Table 10-3 below summarizes the data associated with this task. Note that a large percentage of the glazing is often replaced at this time as well — the data associated with glazing replacement is given in Table 10-2.

Table 10-3: Curtain-wall Retrofit

CURTAIN- WALL		Residential				ICI			
Description:			Multi-unit			Office			
Major retrofit of curtain-wall system		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial
Maintenance Cycle									
Calgary	years	na	na	35	35	35	35	35	35
Montreal	years	na	na	35	35	35	35	35	35
Toronto	years	na	na	35	35	35	35	35	35
Halifax	years	na	na	35	35	35	35	35	35
Vancouver	years	na	na	35	35	35	35	35	35
Winnipeg	years	na	na	35	35	35	35	35	35
Minnesota	years	na	na	35	35	35	35	35	35
Atlanta	years	na	na	35	35	35	35	35	35

continued…

INPUTS PER CYCLE			
On-site electricity input	KWH/m^2	0	
On-site propane use	kg/m^2	0	
On-site diesel use	L/m^2	0	
RAW INPUTS			
Glavanized Sheet	kg/m^2	2.5	
	waste	0%	
EPDM Gaskets	kg/m^2	0.16	
	waste	5%	
Fiberglass Insulation	m^2 1" thick	0.01	
	waste	5%	
WASTE MATERIAL			
Glavanized Sheet	kg/m^2	2.5	to landfill
EPDM Gaskets	kg/m^2	0.16	to landfill
Fiberglass Insulation	m^2 1" thick	0.01	to landfill

10.2 Replacement Effects

Curtain-wall framing typically lasts for the life of the building in most applications, with the remainder of the system replaced or retrofitted over time as already indicated.

11. WINDOW SYSTEMS

The scope of this project included research into several different window types and systems. These included windows utilizing aluminum, fiberglass, PVC, and wood frames, with fixed and operable widows for each frame type. The glazing was assumed to be double-glazed insulating glass units of 3 to 6 mm thickness.

The scope of work included research into a generic "operable" window, including an average of the data for vertical and horizontal sliding, casement, hopper, and awning windows.

11.1 Maintenance and Repair Effects

Maintenance and repair effects are similar for the four window types, and, unless otherwise specified, each of the items below applies to fiberglass, PVC, aluminum, PVC-clad wood, and wood-framed windows.

Window Re-caulking

Typically, most windows use little replaceable caulking within the window systems. However, the perimeter of each window incorporates caulked joints that periodically require replacement. Table 11-1 summarizes the data associated with this task.

Table 11-1: Window Re-caulking

WINDOWS		Residential				ICI				
Description:			Multi-unit			Office				
Replacement of sealant		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	10	10	15	15	15	15	15	15	20
Montreal	years	10	10	15	15	15	15	15	15	20
Toronto	years	10	10	15	15	15	15	15	15	20
Halifax	years	10	10	15	15	15	15	15	15	20
Vancouver	years	10	10	15	15	15	15	15	15	20
Winnipeg	years	10	10	15	15	15	15	15	15	20
Minnesota	years	10	10	15	15	15	15	15	15	20
Atlanta	years	8	8	12	12	12	12	12	12	20

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0
RAW INPUTS		
sealant	kg/m	0.38
	waste	10%

Periodic Glazing Replacement

Insulating glass units typically fail between 10 and 30 years after construction. Accordingly, an average of 3% of the glazing is replaced each year. Table 11-2 summarizes the data associated with this task.

Table 11-2: Periodic Glazing Replacement of Windows

WINDOWS		Residential				ICI				
Description:		Single Family	Multi-unit			Office				
Annual replacement of failed glazing units			Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	1	1	1	1	1	1	1	1	1
Montreal	years	1	1	1	1	1	1	1	1	1
Toronto	years	1	1	1	1	1	1	1	1	1
Halifax	years	1	1	1	1	1	1	1	1	1
Vancouver	years	1	1	1	1	1	1	1	1	1
Winnipeg	years	1	1	1	1	1	1	1	1	1
Minnesota	years	1	1	1	1	1	1	1	1	1
Atlanta	years	1	1	1	1	1	1	1	1	1

INPUTS PER CYCLE			
On-site electricity input	KWH/m^2	0	
On-site propane use	kg/m^2	0	
On-site diesel use	L/m^2	0	
RAW INPUTS			
Glass	kg/m^2	0.47	
	waste	0%	
WASTE MATERIAL			
Glass	kg/m^2	0.47	to landfill

Wood Window Re-painting

Re-painting or re-staining of wood windows is typically performed approximately once every five to seven years. The data for repainting is included in Table 11-3.

Table 11-3: Repainting of Wood Windows

WINDOWS		Residential	
Description:			Multi-unit
Repainting of Wood Windows		Single Family	Low-rise
Maintenance Cycle			
Calgary	years	7	7
Montreal	years	7	7
Toronto	years	7	7
Halifax	years	5	5
Vancouver	years	5	5
Winnipeg	years	7	7
Minnesota	years	7	7
Atlanta	years	6	6

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0
RAW INPUTS		
Oil based paint	L/m	0.032
	waste	5%

11.2 Replacement Effects

PVC-framed Windows

PVC-framed windows are available at different levels of quality, although the cheaper systems are the most popular in North America. These systems are typically replaced due to functional problems (binding, air/water leakage) or aesthetic concerns. Table 11-4 below includes data associated with replacement of PVC-framed window systems.

Table 11-4: Replacement of PVC Window Systems

PVC WINDOWS		Residential	
Description:			Multi-unit
Removal and replacement of window systems.		Single Family	Low-rise
Replacement Cycle			
Calgary	years	18	18
Montreal	years	18	18
Toronto	years	18	18
Halifax	years	19	19
Vancouver	years	19	19
Winnipeg	years	17	17
Minnesota	years	17	17
Atlanta	years	19	19

continued…

MASS OF MATERIALS				DISPOSITION		
Material	Fixed		Operables	Landfill	Recycle	Other
FRAME AND SCREEN	0	0.00	0.00	100%		
wood	BDFT/m	0.00	0.00	100%		
PVC	kg/m	6.13	7.30	100%		
aluminum	kg/m	0.00	0.50	10%	90%	
steel	kg/m	0.33	0.34	100%		
Fiberglass	kg/m	0.00	0.00	100%		
Hardware	kg/m	0.00	0.36	100%		
Glass	kg/m2	15.60	15.60	100%		
polyurethane (spray in place)	m3/m	0.00	0.00	100%		
EPDM	kg/m	0.38	0.38	100%		
Sealant	kg/m	0.34	0.34	100%		
fiberglass insulation	m3/m	0.02	0.02	100%		

Wood-framed Windows

Wood-framed windows can survive the life of the building if properly maintained. However, it is far more common for a lapse in maintenance to result in a need for wood window replacement. Table 11-5 below includes data associated with replacement of wood-framed window systems.

PVC-clad wood windows offer slightly better resistance to weathering, but also limit the drying potential of the wood frames, thus increasing the likelihood of rot. Accordingly, the data in Table 11-5 is also relevant for PVC-clad wood windows.

Table 11-5: Replacement of Wood Window Systems

WOOD WINDOWS		Residential	
Description:			Multi-unit
Removal and replacement of window systems.		Single Family	Low-rise
Replacement Cycle			
Calgary	years	16	16
Montreal	years	16	16
Toronto	years	16	16
Halifax	years	15	15
Vancouver	years	15	15
Winnipeg	years	16	16
Minnesota	years	16	16
Atlanta	years	16	16

MASS OF MATERIALS				DISPOSITION		
Material	Fixed		Operables	Landfill	Recycle	Other
FRAME AND SCREEN	0	0.00	0.00	100%		
wood	BDFT/m	5.52	7.76	100%		
PVC	kg/m	0.00	0.00	100%		
aluminum	kg/m	0.73	1.37	10%	90%	
steel	kg/m	0.33	0.34	100%		
Fiberglass	kg/m	0.00	0.00	100%		
Glass	kg/m2	15.60	15.60	100%		
polyurethane (spray in place)	m3/m	0.00	0.00	100%		
EPDM	kg/m	0.38	0.38	100%		
Sealant	kg/m	0.34	0.34	100%		
fiberglass insulation	m3/m	0.02	0.02	100%		

Aluminum-framed Windows

Aluminum-framed windows typically are replaced due to embrittlement of the thermal breaks or other components, difficulty in operation, or aesthetic issues. Table 11-6 includes data associated with replacement of aluminum-framed window systems.

Table 11-6: Replacement of Aluminum Window Systems

ALUMINUM WINDOWS		Residential				ICI				
Description:			Multi-unit			Office				
Removal and replacement of window systems.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	25	25	30	25	25	23	40	15	35
Montreal	years	25	25	30	25	25	23	40	15	35
Toronto	years	25	25	30	25	25	23	40	15	35
Halifax	years	25	25	25	22	22	20	40	15	35
Vancouver	years	25	25	25	22	22	20	40	15	35
Winnipeg	years	25	25	30	25	25	23	40	15	35
Minnesota	years	25	25	30	25	25	23	40	15	35
Atlanta	years	25	25	30	25	25	23	40	15	35

continued…

MASS OF MATERIALS				DISPOSITION		
Material	Fixed		Operables	Landfill	Recycle	Other
FRAME AND SCREEN	0	0.00	0.00	100%		
wood	BDFT/m	0.00	0.00	100%		
PVC	kg/m	0.00	0.00	100%		
aluminum	kg/m	5.94	9.65	10%	90%	
steel	kg/m	0.33	0.34	100%		
Fiberglass	kg/m	0.00	0.00	100%		
Glass	kg/m2	20.80	20.80	100%		
polyurethane (spray in place)	m3/m	0.02	0.02	100%		
EPDM	kg/m	0.38	0.38	100%		
Sealant	kg/m	0.34	0.34	100%		
fiberglass insulation	m3/m	0.00	0.00	100%		

12. RESIDENTIAL ROOFING

Residential roofing product reviewed as part of this report included organic and glass fibre shingles, roll roofing, clay tiles and concrete tiles. Metal roofing, recognized to be a significant component in the industry, was also included in this report.

12.1 Maintenance and Repair Effects

Most residential roofs receive very little maintenance. During the lifetime of a residential roof, some areas may be replaced due to blow-off, mechanical damage, or premature degradation. However, this maintenance occurs so infrequently and in such relatively small volumes, that it is assumed to be negligible. Accordingly, the report assumes no items under maintenance of residential roofing systems.

12.2 Replacement Effects

Shingles

Both organic and glass fibre-based shingles are available in different thicknesses, each with a different prescribed lifespan. Most shingles, however, are replaced in advance of the prescribed lifespan. Factors affecting the life of shingles include U.V. exposure, wind, traffic, and impact.

Currently, many localities have the ability to recycle asphalt shingles, using the included asphalt in roadways or other similar applications. Recycling, however, is not performed with all shingles, nor is it performed in all municipalities.

Organic Shingles. Most manufacturers provide organic-based shingles in 20, 25, and 30 year lifespans; most are replaced, however, in the 18 to 22 year period. Table 12-1 displays the information associated with replacement of organic shingles.

Table 12-1: Replacement of Organic-based Asphalt Shingles

Organic Asphalt Shingles		Residential				ICI				
Description: Replacement of 100% of an asphalt shingled roof.			Multi-unit			Office				
		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	18	18	na	na	19	18	18	18	20
Montreal	years	18	18	na	na	19	18	18	18	20
Toronto	years	20	20	na	na	21	20	20	20	22
Halifax	years	20	20	na	na	21	20	20	20	22
Vancouver	years	20	20	na	na	21	20	20	20	22
Winnipeg	years	18	18	na	na	19	18	18	18	20
Minnesota	years	18	18	na	na	19	18	18	18	20
Atlanta	years	16	16	na	na	17	16	16	16	18

MASS OF MATERIALS			DISPOSITION		
Material			Landfill	Recycle	Other
Shingles	kg/m^2	10.4	66%	37%	
galv. steel flashing	kg/m^2	0.6	80%	20%	
Nails	kg/m^2	0.067	100%		
15# felt	kg/m^2	0.5	100%		

Glass Fibre Shingles. Manufacturers provide glass fibre-based shingles in 25 and 30 year lifespans; most are replaced in the 20 to 25 year period. Table 12-2 displays the information associated with replacement of glass fibre shingles.

Table 12-2: Replacement of Fiberglass-based Asphalt Shingles

Fiberglass Asphalt Shingles		Residential				ICI				
Description:			Multi-unit			Office				
Replacement of 100% of an asphalt shingled roof.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	20	20	na	na	21	20	20	20	22
Montreal	years	20	20	na	na	21	20	20	20	22
Toronto	years	20	20	na	na	21	20	20	20	22
Halifax	years	20	20	na	na	21	20	20	20	22
Vancouver	years	20	20	na	na	21	20	20	20	22
Winnipeg	years	20	20	na	na	21	20	20	20	22
Minnesota	years	20	20	na	na	21	20	20	20	22
Atlanta	years	20	20	na	na	21	20	20	20	22

MASS OF MATERIALS			DISPOSITION		
Material			Landfill	Recycle	Other
Shingles	kg/m^2	11.5	66%	37%	
galv. steel flashing	kg/m^2	0.6	80%	20%	
Nails	kg/m^2	0.067	100%		
15# felt	kg/m^2	0.5	100%		

Clay and Concrete Tiles. Clay-tiled roofing is not used in cold climates due to its lack of freeze-thaw resistance. In warmer climates, clay-tiled roofs do not typically require replacement for 60 to 90 years. Accordingly, for the purposes of this report, we have assumed that the clay-tiled roof will remain functional for the life of the building in warmer climates. Concrete-tiled roofing is also considered a long-life roofing system, with the lifetime of the tiles generally limited by the life of the building on which they are installed, and we have assumed that the concrete-tiled roof will also remain functional for the life of the building. Factors that could affect replacement of both clay and concrete tiles include wind, impact, traffic, and U.V. exposure

Metal Roofing. Metal roofing is another relatively long-life roofing system that is affected by impact, traffic, and U.V. exposure. For the purposes of this report, however, we have assumed that the metal roof will remain functional for the life of the building.

13. COMMERCIAL ROOFING

13.1 Maintenance and Repair Effects

Single Ply Membrane Repairs

It is common for single ply membranes (PVC, TPO and EPDM membranes) to require annual repairs, as well as one larger repair, in their lifetime. Typically, annual repairs consist of spot repairs when necessary; these repairs are negligible from an environmental standpoint. However, often a larger repair is necessary at some time in their life. We believe an average of 1.5 % of the membrane is replaced per year, although this will likely occur mostly during the large repair.

For the purposes of this report, we have assumed that conventional mechanically fastened PVC roof was utilized with PVC membrane, conventional, mechanically fastened TPO roof was utilized with TPO membrane, and that conventional ballasted EPDM roof was utilized with EPDM membrane (these are common installations for these membrane types). The data for these repairs are included in Tables 13-1, -2, and -3.

Table 13-1 PVC Membrane Repairs

COMMERCIAL ROOFING		Residential				ICI				
Description:			Multi-unit			Office				
Annual repairs to PVC Roofing membrane		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	1	1	1	1	1	1	1	1	1
Montreal	years	1	1	1	1	1	1	1	1	1
Toronto	years	1	1	1	1	1	1	1	1	1
Halifax	years	1	1	1	1	1	1	1	1	1
Vancouver	years	1	1	1	1	1	1	1	1	1
Winnipeg	years	1	1	1	1	1	1	1	1	1
Minnesota	years	1	1	1	1	1	1	1	1	1
Atlanta	years	1	1	1	1	1	1	1	1	1

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0.004
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0.013
RAW INPUTS		
PVC membrane	kg/m^2	0.074
	waste	10%
Small dimension lumber	BF/sq.	0.182
	waste	10%
Plywood	$m^2_{1/2"}$/sq.	0.003
	waste	10%
Galv. Steel (misc.)	kg/sq.	0.121
	waste	5%
fiberglass insulation*	$m^2_{1"}$/sq.	0.279
	waste	5%

* It is assumed that fiberglass insulation was utilized.

Table 13-2 TPO Membrane Repairs

COMMERCIAL ROOFING		Residential				ICI				
Description:			Multi-unit			Office				
Annual repairs to TPO Roofing membrane		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	1	1	1	1	1	1	1	1	1
Montreal	years	1	1	1	1	1	1	1	1	1
Toronto	years	1	1	1	1	1	1	1	1	1
Halifax	years	1	1	1	1	1	1	1	1	1
Vancouver	years	1	1	1	1	1	1	1	1	1
Winnipeg	years	1	1	1	1	1	1	1	1	1
Minnesota	years	1	1	1	1	1	1	1	1	1
Atlanta	years	1	1	1	1	1	1	1	1	1

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0.003
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0
RAW INPUTS		
TPO membrane	kg/m^2	0.08
	waste	10%
Small dimension lumber	BF/sq.	0.182
	waste	10%
Plywood	$m^2_{1/2"}$/sq.	0.003
	waste	10%
Galv. Steel (misc.)	kg/sq.	0.271
	waste	5%
fiberglass insulation*	$m^2_{1"}$/sq.	0.279
	waste	5%

* It is assumed that fiberglass insulation was utilized.

Table 13-3 EPDM Membrane Repairs

COMMERCIAL ROOFING		Residential				ICI				
Description:			Multi-unit			Office				
Annual repairs to EPDM Roofing membrane		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	1	1	1	1	1	1	1	1	1
Montreal	years	1	1	1	1	1	1	1	1	1
Toronto	years	1	1	1	1	1	1	1	1	1
Halifax	years	1	1	1	1	1	1	1	1	1
Vancouver	years	1	1	1	1	1	1	1	1	1
Winnipeg	years	1	1	1	1	1	1	1	1	1
Minnesota	years	1	1	1	1	1	1	1	1	1
Atlanta	years	1	1	1	1	1	1	1	1	1

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0.013
RAW INPUTS		
EPDM membrane	kg/m^2	0.028
	waste	10%
Small dimension lumber	BF/sq.	8.355
	waste	10%
Plywood	$m^2_{1/2"}$/sq.	0.003
	waste	10%
Galv. Steel (misc.)	kg/sq.	0.06
	waste	5%
fiberglass insulation*	$m^2_{1"}$/sq.	0.279
	waste	5%

* It is assumed that fiberglass insulation was utilized.

B.U.R. and Modified Bitumen Membrane Repairs

It is common for bituminous multi-ply membranes to require periodic repairs, as well as one larger repair, in their lifetime. Typically, periodic repairs consist of spot repairs when necessary; the larger repair might include the replacement of membrane over wet insulation or flashing replacement. It is common in asphaltic roofs to rely upon modified bitumen membrane for repairs to both BUR and modified bitumen membrane roofs. For the purposes of this report, we have assumed that an average of 1.5 % of the membrane is replaced per year, although this will likely occur mostly during the large repair. The data for these repairs are included in Table 13-4.

Table 13-4: B.U.R. and Modified Bitumen Membrane Repairs

COMMERCIAL ROOFING		Residential				ICI				
Description:			Multi-unit			Office				
Annual repairs to BUR and Modified Bitumen Roofing membrane		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	1	1	1	1	1	1	1	1	1
Montreal	years	1	1	1	1	1	1	1	1	1
Toronto	years	1	1	1	1	1	1	1	1	1
Halifax	years	1	1	1	1	1	1	1	1	1
Vancouver	years	1	1	1	1	1	1	1	1	1
Winnipeg	years	1	1	1	1	1	1	1	1	1
Minnesota	years	1	1	1	1	1	1	1	1	1
Atlanta	years	1	1	1	1	1	1	1	1	1

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	4E-04
On-site propane use	kg/m^2	0.095
On-site diesel use	L/m^2	0
RAW INPUTS		
Mod. Bit. Base Sheet	kg/m^2	0.054
	waste	10%
Mod. Bit. Cap Sheet	kg/m^2	0.071
	waste	10%
wood fiberboard	$m^2_{1/2"}$/sq.	0.139
	waste	5%
fiberglass insulation*	$m^2_{1"}$/sq.	0.279
	waste	5%

* It is assumed that fiberglass insulation was utilized.

Rubberized Asphalt Membrane

Rubberized asphalt membranes are always installed in inverted roofing systems and are most commonly installed over parking garages or locations where the consequences of leakage have little direct impact on the users. As a result, repairs to rubberized asphalt membranes are not common; the membranes are most often replaced when leakage becomes intolerable. Accordingly, we have not included any amounts for maintenance of these types of roofing assemblies.

13.2 Replacement Effects

At the time of roofing membrane replacement, there are a number of commonly used options. In most instances, all roofing materials are simply removed and disposed of at a landfill. In some cases, however, components such as insulation or ballast are re-used in the new system. In a roof re-cover application, which occurs in approximately 15 to 20% of re-roofing applications, a new roof membrane is installed directly over the old membrane, often with a thin protection board or fiberboard. In protected membrane roofs (or inverted roofs), insulation and ballast are re-used approximately 20% of the time.

Tables 13-5 through 13-15 provide data for each of the membrane types in typical conventional and inverted applications. Note that for many inverted asphaltic membranes (modified bitumen, BUR, rubberized asphalt), the membrane is not removed at the time of membrane replacement, but is covered with a new membrane and remains on the building until the building is demolished.

Table 13-5: Replacement of Conventional PVC Roof System

PVC ROOFING - CONVENTIONAL BALLASTED		Residential				ICI				
Description:			Multi-unit			Office				
Removal and replacement of roofing systems.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	na	na	15	15	15	15	16	15	16
Montreal	years	na	na	15	15	15	15	16	15	16
Toronto	years	na	na	15	15	15	15	16	15	16
Halifax	years	na	na	16	16	16	16	17	15	16
Vancouver	years	na	na	16	16	16	16	17	15	16
Winnipeg	years	na	na	15	15	15	15	16	15	16
Minnesota	years	na	na	16	16	16	16	17	15	16
Atlanta	years	na	na	18	18	18	18	19	15	16

MASS OF MATERIALS			DISPOSITION			
Material			Landfill	Recycle	Other	
Small dimension lumber	BF/Sq.	12.1	100%			
Plywood	m^2(1/2")/sq.	0.18	100%			
steel fasteners	kg/sq.	1.02	100%			
Galv. Steel	kg/sq.	3.052	70%	30%		
polyethylene sheet	m^2/square	9.29	100%			
insulation			80%		20%	re-used
PVC membrane	m^2/square	9.29	80%		20%	re-used
stone ballast	kg/square	557	20%	20%	60%	clean fill

Table 13-6: Replacement of Inverted PCV Roof System

PVC ROOFING - INVERTED		Residential				ICI				
Description:			Multi-unit			Office				
Removal and replacement of roofing systems.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	na	na	15	15	15	15	16	15	16
Montreal	years	na	na	15	15	15	15	16	15	16
Toronto	years	na	na	15	15	15	15	16	15	16
Halifax	years	na	na	16	16	16	16	17	15	16
Vancouver	years	na	na	16	16	16	16	17	15	16
Winnipeg	years	na	na	15	15	15	15	16	15	16
Minnesota	years	na	na	16	16	16	16	17	15	16
Atlanta	years	na	na	18	18	18	18	19	15	16

MASS OF MATERIALS			DISPOSITION			
Material			Landfill	Recycle	Other	
1.5mm polyester felt	m^2/square	9.29	100%			
steel fasteners	kg/square	0.05	100%			
Galv. Steel	kg/square	3.052	70%	30%		
filter fabric	m^2/square	9.29	80%		20%	re-used
insulation			80%		20%	re-used
stone ballast	kg/square	557	20%	20%	60%	clean fill
PVC membrane	m^2/square	9.29	80%		20%	re-used

Table 13-7 Replacement of Conventional TPO Roof System

TPO ROOFING - CONVENTIONAL BALLASTED		Residential				ICI				
Description:			Multi-unit			Office				
Removal and replacement of roofing systems.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	na	na	15	15	15	15	16	15	16
Montreal	years	na	na	15	15	15	15	16	15	16
Toronto	years	na	na	15	15	15	15	16	15	16
Halifax	years	na	na	16	16	16	16	17	15	16
Vancouver	years	na	na	16	16	16	16	17	15	16
Winnipeg	years	na	na	15	15	15	15	16	15	16
Minnesota	years	na	na	16	16	16	16	17	15	16
Atlanta	years	na	na	18	18	18	18	19	15	16

MASS OF MATERIALS			DISPOSITION			
Material			Landfill	Recycle	Other	
Small dimension lumber	BF/Sq.	12.1	100%			
Plywood	m^2(1/2")/sq.	0.18	100%			
steel fasteners	kg/square	1.02	100%			
Galv. Steel	kg/square	3.052	70%	30%		
polyethylene sheet	m^2/square	9.29	100%			
insulation			80%		20%	re-used
TPO membrane	m^2/square	9.29	80%		20%	re-used
stone ballast	kg/square	557	20%	20%	60%	clean fill

Table 13-8 Replacement of Inverted TPO Roof System

TPO ROOFING - INVERTED		Residential				ICI				
Description:			Multi-unit			Office				
Removal and replacement of roofing systems.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	na	na	15	15	15	15	16	15	16
Montreal	years	na	na	15	15	15	15	16	15	16
Toronto	years	na	na	15	15	15	15	16	15	16
Halifax	years	na	na	16	16	16	16	17	15	16
Vancouver	years	na	na	16	16	16	16	17	15	16
Winnipeg	years	na	na	15	15	15	15	16	15	16
Minnesota	years	na	na	16	16	16	16	17	15	16
Atlanta	years	na	na	18	18	18	18	19	15	16

MASS OF MATERIALS			DISPOSITION			
Material			Landfill	Recycle	Other	
1.5mm polyester felt	m^2/square	9.29	100%			
steel fasteners	kg/square	0.05	100%			
Galv. Steel	kg/square	3.052	70%	30%		
filter fabric	m^2/square	9.29	80%		20%	re-used
insulation			80%		20%	re-used
stone ballast	kg/square	557	20%	20%	60%	clean fill
TPO membrane	m^2/square	9.29	80%		20%	re-used

Table 13-9 Replacement of Conventional EPDM Roof System

EPDM ROOFING - CONVENTIONAL BALLASTED		Residential				ICI				
Description:			Multi-unit			Office				
Removal and replacement of roofing systems.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	na	na	14	14	14	14	14	14	14
Montreal	years	na	na	14	14	14	14	14	14	14
Toronto	years	na	na	14	14	14	14	14	14	14
Halifax	years	na	na	15	15	15	15	15	14	14
Vancouver	years	na	na	15	15	15	15	15	14	14
Winnipeg	years	na	na	14	14	14	14	14	14	14
Minnesota	years	na	na	15	15	15	15	15	14	14
Atlanta	years	na	na	17	17	17	17	17	14	14

MASS OF MATERIALS			DISPOSITION			
Material			Landfill	Recycle	Other	
small dimension lumber	BF/square	12.1	100%			
steel fasteners	kg/square	0.96	100%			
Galv. Steel	kg/square	3.99	100%			
plywood	m^2(1/2")/sq	0.18	80%		20%	re-used
insulation			80%		20%	re-used
polyethylene sheet	m^2/square	9.29	80%		20%	re-used
EPDM membrane	m^2/square	9.29	80%		20%	re-used
stone ballast	kg/square	557	20%	20%	60%	clean fill

Table 13-10 Replacement of Inverted EPDM Roof System

EPDM ROOFING - INVERTED		Residential				ICI				
Description:			Multi-unit			Office				
Removal and replacement of roofing systems.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	na	na	15	15	15	15	16	15	16
Montreal	years	na	na	15	15	15	15	16	15	16
Toronto	years	na	na	15	15	15	15	16	15	16
Halifax	years	na	na	16	16	16	16	17	15	16
Vancouver	years	na	na	16	16	16	16	17	15	16
Winnipeg	years	na	na	15	15	15	15	16	15	16
Minnesota	years	na	na	16	16	16	16	17	15	16
Atlanta	years	na	na	18	18	18	18	19	15	16

MASS OF MATERIALS			DISPOSITION			
Material			Landfill	Recycle	Other	
1.5mm polyester felt	m^2/square	9.29	100%			
steel fasteners	kg/square	0.03	100%			
Galv. Steel	kg/square	3.99	100%			
filter fabric	m^2/square	9.29	80%		20%	re-used
insulation			80%		20%	re-used
stone ballast	kg/square	557	20%	20%	60%	clean fill
EPDM membrane	m^2/square	9.29	80%		20%	re-used

Table 13-11: Replacement of Conventional BUR Roof System

BUR ROOFING - CONVENTIONAL BALLASTED		Residential				ICI					
Description:			Multi-unit			Office					
Removal and replacement of roofing systems.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	na	na	20	18	18	19	20	16	20
Montreal	years	na	na	20	18	18	19	20	16	20
Toronto	years	na	na	20	18	18	19	20	16	20
Halifax	years	na	na	20	18	18	19	20	16	20
Vancouver	years	na	na	20	18	18	19	20	16	20
Winnipeg	years	na	na	20	18	18	19	20	16	20
Minnesota	years	na	na	20	18	18	19	20	16	20
Atlanta	years	na	na	20	18	18	19	20	16	20

MASS OF MATERIALS			DISPOSITION			
Material			Landfill	Recycle	Other	
steel fasteners	kg/square	0.5	100%			
Galv. Steel	kg/square	10.96	100%			
kraft paper	m^2/square	9.29	80%		20%	re-used
insulation			80%		20%	re-used
stone ballast	kg/square	185	100%			
organic felts	m^2/square	37.16	80%	20%		re-used
asphalt	kg/square	76.2	100%			

Table 13-12: Replacement of Inverted BUR Roof System

BUR ROOFING - INVERTED		Residential				ICI				
Description:			Multi-unit			Office				
Removal and replacement of roofing systems.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	na	na	22	20	20	21	22	18	22
Montreal	years	na	na	22	20	20	21	22	18	22
Toronto	years	na	na	22	20	20	21	22	18	22
Halifax	years	na	na	22	20	20	21	22	18	22
Vancouver	years	na	na	22	20	20	21	22	18	22
Winnipeg	years	na	na	22	20	20	21	22	18	22
Minnesota	years	na	na	22	20	20	21	22	18	22
Atlanta	years	na	na	22	20	20	21	22	18	22

MASS OF MATERIALS			DISPOSITION			
Material			Landfill	Recycle	Other	
Galv. Steel	kg/square	10.96	100%			
filter fabric	m^2/square	9.29	80%		20%	re-used
insulation			80%		20%	re-used
stone ballast	kg/square	557	20%	20%	60%	clean fill
organic felts	m^2/square	37.16	80%	20%		re-used
asphalt	kg/square	69	100%			

Table 13-13: Replacement of Conventional Modified Bitumen Roof System

MODIFIED BITUMEN ROOFING - CONVENTIONAL		Residential				ICI				
Description:			Multi-unit			Office				
Removal and replacement of roofing systems.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	na	na	21	19	19	20	21	17	21
Montreal	years	na	na	21	19	19	20	21	17	21
Toronto	years	na	na	21	19	19	20	21	17	21
Halifax	years	na	na	21	19	19	20	21	17	21
Vancouver	years	na	na	21	19	19	20	21	17	21
Winnipeg	years	na	na	21	19	19	20	21	17	21
Minnesota	years	na	na	21	19	19	20	21	17	21
Atlanta	years	na	na	21	19	19	20	21	17	21

MASS OF MATERIALS			DISPOSITION			
Material			Landfill	Recycle	Other	
steel fasteners	kg/square	0.5	100%			
Galv. Steel	kg/square	3.4	100%			
insulation			80%		20%	re-used
organic felts	m^2/square	18.58	80%	20%		re-used
asphalt	kg/square	69	100%			
Modified Bitumen Base Sheet	m^2/square	9.29	80%		20%	re-used
Modified Bitumen Cap Sheet	m^2/square	9.29	80%		20%	re-used

Table 13-14: Replacement of Inverted Modified Bitumen Roof System

MODIFIED BITUMEN ROOFING - INVERTED		Residential				ICI				
Description: Removal and replacement of roofing systems.			Multi-unit			Office				
		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	na	na	23	21	21	22	23	19	23
Montreal	years	na	na	23	21	21	22	23	19	23
Toronto	years	na	na	23	21	21	22	23	19	23
Halifax	years	na	na	23	21	21	22	23	19	23
Vancouver	years	na	na	23	21	21	22	23	19	23
Winnipeg	years	na	na	23	21	21	22	23	19	23
Minnesota	years	na	na	23	21	21	22	23	19	23
Atlanta	years	na	na	23	21	21	22	23	19	23

MASS OF MATERIALS			DISPOSITION			
Material			Landfill	Recycle	Other	
stone ballast	kg/square	557	80%		20%	re-used
Galv. Steel	kg/square	3.4	100%			
insulation			80%		20%	re-used
filter fabric	m^2/square	9.29	100%			re-used
Modified Bitumen Base Sheet	m^2/square	9.29	80%		20%	re-used
Modified Bitumen Cap Sheet	m^2/square	9.29	80%		20%	re-used

Table 13-15: Replacement of Inverted Rubberized Asphalt Roof System

RUBBERIZED ASPHALT ROOFING - INVERTED		Residential				ICI				
Description:			Multi-unit			Office				
Removal and replacement of roofing systems.		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Replacement Cycle										
Calgary	years	na	na	20	18	18	19	20	16	20
Montreal	years	na	na	20	18	18	19	20	16	20
Toronto	years	na	na	20	18	18	19	20	16	20
Halifax	years	na	na	20	18	18	19	20	16	20
Vancouver	years	na	na	20	18	18	19	20	16	20
Winnipeg	years	na	na	20	18	18	19	20	16	20
Minnesota	years	na	na	20	18	18	19	20	16	20
Atlanta	years	na	na	20	18	18	19	20	16	20

MASS OF MATERIALS			DISPOSITION			
Material			Landfill	Recycle	Other	
stone ballast	kg/square	557	80%		20%	re-used
Galv. Steel	kg/square	10.96	100%			
insulation			80%		20%	re-used
filter fabric	m^2/square	9.29	100%			re-used
polyethylene sheet	m^2/square	9.29	80%		20%	re-used
Rubberized asphalt membrane	m^2/square	9.29	80%		20%	re-used

14. GYPSUM BOARD

14.1 Maintenance and Repair Effects

Gypsum board used on the inside of exterior walls typically receives very little in the form of maintenance, and often lasts for the life of the building. Gypsum board on internal or partition walls, however, is occasionally replaced to suit office restructuring or renovation. The latter is not within the scope of this project.

Painted gypsum board exposed to interior spaces is periodically re-painted, primarily for aesthetic reasons. Table 14-1 includes data associated with this task.

Table 14-1: Re-painting of Gypsum Board

GYPSUM BOARD		Residential				ICI				
Description:			Multi-unit			Office				
Re-painting of interior of gypsum board wall		Single Family	Low-rise	High-rise (rental)	High-rise (owner-occupied)	Rental	Owner-occupied	Institutional	Commercial	Industrial
Maintenance Cycle										
Calgary	years	8	8	5	8	8	10	5	8	4
Montreal	years	8	8	5	8	8	10	5	8	4
Toronto	years	8	8	5	8	8	10	5	8	4
Halifax	years	8	8	5	8	8	10	5	8	4
Vancouver	years	8	8	5	8	8	10	5	8	4
Winnipeg	years	8	8	5	8	8	10	5	8	4
Minnesota	years	8	8	5	8	8	10	5	8	4
Atlanta	years	8	8	5	8	8	10	5	8	4

continued…

INPUTS PER CYCLE		
On-site electricity input	KWH/m^2	0
On-site propane use	kg/m^2	0
On-site diesel use	L/m^2	0
RAW INPUTS		
paint	L/m^2	0.086
	waste	2%

14.2 Replacement Effects

Gypsum board used as part of a building envelope typically lasts for the life of the building.