

Construction and Demolition Waste Recycling A Literature Review



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Purpose

The purpose of this literature review is to provide a comprehensive overview of current methods for reusing and recycling construction and demolition (C&D) waste materials in Europe and North America. Construction and demolition practices are also examined along with policies and legislation influencing C&D waste management. Given the diverse C&D waste materials produced at Dalhousie University, this literature review examines many of the waste materials produced by the ICI sector in Nova Scotia. A particular effort was made to describe C&D waste recycling methods which are not widely practiced in Nova Scotia.

Summary

While construction and demolition wastes are usually grouped together under the title “C&D waste”, these waste streams are produced by two different processes and the volume and type of materials produced can differ greatly. Demolition projects often produce 20-30 times as much waste material per square meter as construction projects. Construction waste normally contains more modern building materials than demolition waste since new buildings are rarely torn down. In addition, demolition waste is often contaminated with paint, adhesives and dirt and the materials can be securely fastened together making separation more difficult.

The volume of C&D waste produced in a region depends on many factors including population growth, city or regional planning, the state of the construction industry and landfill fees. In countries such as China with rapid urbanization and low landfill fees, C&D waste can account for 30-40% of total waste production (Zhao, Leefink & Rotter, 2010). Recycling rates are also dependant on a variety of factors including maturity of the local recycling industry, landfill and recycling drop-off fees, landfill bans and cost of raw materials.

In Canada, the construction industry has produced large amounts of waste for decades, and the total volume produced continues to increase in many regions (Alberta Environment, n.d.). As well, the majority of C&D waste produced in Canada continues to be sent to landfills (Recycling Council of Ontario, 2006). However, recycling rates have been increased in some regions and new recycling processes are being developed and tested. The rapid adoption of sustainable building rating systems by both the general public and the Canadian Government reflects Canadians’ increased awareness of the environmental impacts associated with the construction industry and a desire to mitigate them.

Since the demolition of buildings and infrastructure produces much more waste than construction activities, the development of processes to effectively reuse and recycle demolition materials is important for reducing landfilled C&D waste. The demolition method used also plays a significant role, as selective demolition or full deconstruction can prevent the damage of reusable components and allow materials to be separated for recycling at the demolition site. However, since these procedures require more time and labour than mechanical demolition, low landfill

fees, inexpensive raw materials and high labour costs can render them economically unviable.

Around the world, governments and municipalities are enacting legislation that encourages the reuse and recycling of C&D waste. In Europe, a Waste Framework Directive has been revised by the European Union to include a requirement that 70% of each member state's C & D waste be reused or recycled by 2020 (BIO Intelligence Service, 2011). While the revised Waste Framework Directive will most likely be the main policy driver for European C&D waste management until 2020, the techniques for achieving this target will vary across the continent since each member state must incorporate the requirements into its own legislation. Approaches to meeting the Waste Framework Directive diversion target will also differ due to the wide variation in C&D waste reuse and recycling rates across Europe. While Germany, Denmark, Ireland, the Netherlands and the United Kingdom have recycling rates which are higher than 70%, Spain, Poland and Greece currently recycle less than 20% of their C&D waste (BIO Intelligence Service, 2011).

At the national level within Europe, policies and regulations used to guide C&D waste management can be grouped into four categories. One category is that of waste policies. These policies often take the form of a national waste framework policy which will at minimum incorporate targets and directives from the European Union Waste Framework Directive. If the management of C&D waste is not specifically addressed within a national waste framework policy, a separate policy which focuses on this issue may be created (BIO Intelligence Service, 2011). A second category of legislation is that of landfill regulations. The most effective of these regulations include a tax on land filled C&D waste or an outright ban on the land filling of specific waste materials. A third type of legislation is designed to promote the use of recycled building materials in new construction, thereby developing a market for recycled C&D waste while creating a closed-loop recycling process. This method is being developed in Germany to encourage the use of recycled concrete and other aggregates in the production of new concrete. A final category of legislation is that which regulates the environmental performance of new construction (BIO Intelligence Service, 2011). While this type of legislation has not yet been implemented in Europe, it could encourage C&D waste recycling through the creation of mandatory standards for the use of recycled materials in new construction and standard recycling rates for C&D waste materials.

Canadian provincial governments have developed several regulations and agreements to improve C&D waste recycling rates. The government of Ontario established waste reduction regulations in 1994 which require contractors to create a work plan outlining strategies for recycling C&D waste materials. The regulations also require the separation of certain waste materials to facilitate recycling. The government of Alberta recently created a landmark voluntary agreement with the Canadian Home Builder's Association-Alberta and the Alberta Construction Association which commits all parties to implementing policies and procedures which will effectively increase the

percentage of C&D waste that is recycled (Daily Commercial News and Construction Record, 2008). And in Nova Scotia, the Halifax Regional Municipality has passed a bylaw banning several construction materials from its landfills and requiring a 75% diversion rate for C&D waste.

On the following page, a summary (Table 1) of current opportunities for reusing and recycling C&D waste materials in Europe and North America is presented and compared with current practices in HRM.

Table 1

A Comparison of Methods for Reusing and Recycling C&D Waste in Europe and North America with Reference to their Implementation in the Halifax Regional Municipality

Materials	Reuse	HRM *	Recycle	HRM *
Whole structures	- Occasionally moved for reuse	√		
Aggregates	- Deconstructed brick-work can often be reused	0	- Aggregates commonly recycled into fill for roads and buildings - Recycled concrete used as aggregate in production of new concrete	√ x
Asphalt Shingles	- Research ongoing	0	- Used in asphalt pavement and other road construction applications - Used as a fuel	√ √
Clean Wood	- Architectural woodwork, heavy timbers and flooring often valued for reuse	√	Used as... - fuel - mulch - compost additive - Limited possibilities in manufacturing	√ x
Contaminated Wood	- Short life-span limits the potential for this	0	- Limited use as fuel - Research into composting ongoing	√ √
Treated Wood	- Potential for reuse due to long life-span	0	- Research currently being conducted	x
Gypsum Board	- Undamaged gypsum board can often be reused	0	Can be used... - In production of new gypsum board or cement - As a soil amendment	√ x
Metals	Structural steel and aluminum products can be reused if dismantled properly	0	Most metal waste is valued as a versatile recycled material - Metal waste is often the first material targeted for recycling on construction and demolition projects	√
Plastics	PVC window and door frames as well as gutters can be easily reused	0	Recycling markets are being developed for PVC pipes, window frames & vinyl siding	x
Ceiling tiles	Can be reused	0	Can be recycled into new ceiling tiles	x
Synthetic carpeting	Undamaged carpeting can be reused	0	Synthetic carpeting can often be recycled for use in new carpet components and other synthetic products	√

* Implementation in HRM of the methods summarized is indicated in the following manner:

√ = method has been implemented to some extent, x = method has not been implemented, 0 = state of

implementation is unknown

Methods

This literature review focuses on opportunities for increasing the reuse and recycling of C&D waste in Nova Scotia based on findings found in Europe and North America. The focus was restricted to these geographic areas because they have the most similar types of government, construction methods and waste materials to Nova Scotia. Research for this literature review began with an examination of “Recycling Construction and Demolition Waste: A LEED-Based Toolkit” by G. Winkler. This guide provided a comprehensive overview of current methods and opportunities for recycling C&D waste in North America. More detailed information was then sought using on-line database searches. This research provided a useful selection of peer-reviewed journal articles and grey literature. In offering a section on policy and legislation affecting C&D waste management, the intent is not to provide the reader with a comprehensive overview of these laws within Canada or worldwide, but to showcase several contrasting examples in order to demonstrate the variety of legislation being used for C&D waste management today. Further information for this literature review was gathered from interviews and personal communication with professionals knowledgeable of C&D waste management in Europe and North America.

Introduction

The term “construction and demolition waste”, or “C&D waste” is commonly used to describe a large number of waste materials generated from the construction and demolition of buildings and civil infrastructure. While many waste materials from construction and demolition projects are the same, the quantities produced will vary greatly with demolition projects often creating 20 to 30 times as much waste as construction projects (Recycling Council of Ontario, 2006). In addition, construction waste consists primarily of off-cuts from new construction materials while many demolition waste materials are worn and have been painted, fastened together or otherwise modified from their original state.

In much of the world, it has until recently been cheapest and most convenient to landfill all C&D waste. However, within the last two decades, many regions have seen the development of several factors which combined together have made the land-filling of C&D waste less desirable. These factors include the arrival of many current landfills at full capacity, the high cost of building landfills with adequate environmental protection, public resistance to the construction of local landfills and an increased interest in reducing demand for natural resources while creating a sustainable construction industry. Together, these factors have prompted many governments and municipalities to find ways to encourage the reuse and recycling of C&D waste. Europe has led the way, with countries such as Belgium, Denmark and the Netherlands recycling more than 80% of their C&D waste by the late 1990s (Symonds & Associates, 1999). Progress has also been made recently in Canadian provinces such as Nova Scotia, where the Halifax Regional Municipality is currently diverting more than 80% of its C&D waste from storage in a landfill

(D. Chassie, personal communication, July 8, 2011).

Construction

Construction Waste Materials

Construction waste varies worldwide depending on the structure being built, materials used and construction methods employed. In Canada and the United States for instance, family homes are usually built with a wooden frame while clay bricks are used in much of Europe (Merino, Gracia & Azevedo, 2010). A US study estimated that residential construction waste consisted primarily of wood (42%), followed by gypsum wallboard (27%), brick (6%), roofing (2%) and metals (2%) (United States Environmental Protection Agency, 2003). A further 15% was made up of miscellaneous materials such as plastics. Construction waste is usually 20 to 30 times less than demolition waste and consists primarily of off-cuts and trimmings. Lower value construction materials such as gypsum board will often be used more wastefully during the construction process than high value materials. As well, in this case it is often less expensive to dispose of surplus material than provide storage space until another use can be found (James, Pell, Sweeney & St John-Cox 2006). It should be noted though that regional differences in construction methods and choice of building materials will affect the quantities and variety of construction waste produced. Trends in building techniques also alter construction waste over time. For example, expanded polystyrene (EPS) insulation and polyvinyl chloride (PVC) pipes are now used regularly in residential development resulting in increased volumes of plastic waste. The use of engineered wood products has also increased significantly during the past 60 years (McMahon, 2008).

The construction industry

The construction industry is a significant contributor to Canada's economy with total capital expenditures close to six billion in 2010 (Statistics Canada, 2011). Similarly to other western countries, the Canadian construction industry involves a large and diverse group of businesses that often specialize in a particular step of the construction process. Certain companies focus on foundation construction for example, or roofing work (James et al., 2006). As well, the size of construction companies varies hugely, ranging from several hundred employees to single-person operations (James et al., 2006). A significant feature of the construction industry is its competitiveness. Many construction contracts are awarded through a bidding process which drives down costs and often results in minimal profit margins. This system can have negative consequences for C&D waste diversion since recycling processes may be viewed as an unnecessary expense unless they are less expensive than landfill costs (James et al., 2006).

Construction and Sustainability

The construction industry has been described as conservative and slow to change (James et al.,

2006). However, a shift towards more sustainable building practices is currently taking place in Canada and much of the rest of the world (World Green building Council, 2011). Several different rating systems have been developed around the world to monitor and certify the process of constructing environmentally sustainable buildings. The most well known rating system in North America is the US Green Building Council's Leadership in Energy and Environmental Design (LEED) program. Other rating systems include BOMA Best, the International Code Council's ICC-ES SAVE program, BREEAM in the UK, and Australia's Green Star program. Since its inception in 2000 in the United States, LEED has quickly become the most frequently used rating system in North America for new construction and is administered in Canada by the Canada Green Building Council. LEED certified construction projects worldwide doubled each year between 2000 and 2009 with total registered and certified floor area surpassing 7 billion square feet before 2010 (Watson, 2009). Provincial governments and universities in Canada have taken a leading role in the shift to sustainable construction practices. Dalhousie University committed this year to attaining LEED's Gold standard for all new construction projects greater than 10,000 square feet and all new construction projects controlled by Public Works and Government Services Canada must meet LEED certification standards (Dalhousie University, 2011; Canadian Construction Association, 2011). In addition, since 2009 the government of Nova Scotia has required that all building projects receiving provincial financial assistance be designed and built to LEED Silver standards (Transportation and Infrastructure Renewal, 2010).

Demolition

Whole Building Reuse

The moving of buildings to new locations in order to reuse them has quite possibly been practiced in Nova Scotia ever since Europeans first landed and built houses in this province. It does not seem possible to move structures built of brick, stone or concrete. However, wooden framed buildings within a certain size range can be picked up and transported with trucks or custom made trailers. While the reuse of whole buildings can greatly reduce the creation of construction and demolition waste, there are currently major constraints to moving buildings in all areas of the province. These constraints include the cost of picking up and moving the building, the cost of creating a foundation for the building in its new location, and the often significant cost of moving electric, telephone and fiber optic cables out of the way (Clifford Collins, personal communication, September 19, 2011). In Nova Scotia today, single story wooden framed buildings are relatively affordable to move since they can often fit below electric and communications cables when they are transported down public roads. While the moving of multi-story wooden framed buildings is still practiced as well, more often than not the building is simply moved from one location on a property to another (Clifford Collins, personal communication, September 19, 2011). Moves which involve transport along public roads are less common due to the high added cost of removing electric and communications cables to allow the

passage of multi-story buildings. This process can cost more than the lifting and moving of the building. Moves that involve travel on busy roads and highways may require traffic control measures which can add to the total cost of the project. While wooden houses appear to be the most commonly moved buildings, community centres and churches are also occasionally moved as well. (Clifford Collins, personal communication, September 19, 2011).

Demolition Waste Materials

Although construction and demolition waste materials are often grouped together under the generic term “C&D waste”, the materials generated from these activities can be quite different. One reason for this is that construction activities make use of currently available manufacturing processes and materials while demolition activities often remove older structures. Older buildings can contain materials no longer used in the construction industry today, resulting in a different waste stream. An example of this is asbestos, which was a common insulation material forty years ago, but is now regarded as hazardous waste. Differences between construction and demolition waste are also due to the nature of each process. Demolition procedures typically remove the whole structure, resulting in 20-30 times more waste material than construction activities. Materials such as metal, which is rarely wasted during the construction process can form a significant percentage of total demolition waste when a building is torn down. Wood, concrete, brick and other masonry typically constitute more than 60% of residential and 80% of non-residential demolition waste (Recycling Council of Ontario, 2006). Finally, demolition waste is often contaminated with “paints, fasteners, adhesives, wall covering materials, insulation, and dirt” (Falk & McKeever, 2004, p. 34). The presence of these contaminants can make demolition materials difficult to recycle. As well, contrasting demolition materials have often been fastened together during the construction process and separating them can be expensive and time consuming.

Demolition Procedures

The demolition of buildings and civil infrastructure produces significantly more C&D waste than either renovation or construction. It has been estimated that renovation and demolition projects together produce approximately 90% of a nation’s C&D waste, or 9.8 kg for each m² demolished (Agamuthu, 2008). Traditionally, low tipping fees at landfills and affordable raw materials have suppressed interest in reusing or recycling building materials produced through demolition. Therefore, until recently, demolition contractors have focused on demolishing a structure as quickly and efficiently as possible with little regard for optimizing waste recycling opportunities. As interest in recycling demolition waste materials has grown, however, demolition procedures have been adapted to preserve building materials which can be reused and to allow for the separation of waste materials for recycling. Adapted demolition procedures include *selective demolition*, in which valuable materials are removed by hand for reuse or

recycling before the remains of the structure are torn down and mixed together. This procedure is sometimes expanded into complete *deconstruction* (also known as *selective dismantling*), where the entire building is taken apart piece by piece.

While selective demolition and deconstruction are often undertaken to increase the quantity of materials available for resale, the ability of these procedures to reduce landfilled C&D waste is beginning to be appreciated. The economic competitiveness of selective demolition or full deconstruction in comparison to traditional demolition is dependent on local labour costs, waste disposal costs and the productivity of the labour force employed (Dantata, Touran & Wang, 2005). Higher waste disposal costs for example, or increased worker efficiency can play a large role in the profitability of deconstruction. The local value of used building materials will also impact the cost effectiveness of deconstruction activities. Finally, the type of construction being demolished and the materials it contains play a role in the viability of each demolition process. Research by Dantata et al. (2005) suggests that deconstruction of brick structures can take considerably longer and produce more waste than the deconstruction of wooden framed structures.

Demolition and Sustainability

As noted earlier, the demolition of buildings and civil infrastructure can create significantly more waste material than construction activities. In particular, traditional demolition practices in which all building materials are mixed together create a waste stream which is difficult and costly to recycle. Local landfill fees have a strong influence on the economic viability of alternative demolition practices. In the absence of government regulations, landfill fees are the primary factor influencing demolition processes while local labour costs and the market price for used materials play a secondary role. In order to increase recycling rates, the government of Denmark has required municipalities to sort their construction and demolition waste on site since 1995 through an agreement with the Danish Contractors' Association (Waste & Resources Action Programme, 2006). While the recycling processes used to sort mixed materials and reduce contamination vary between countries and regions, it is clear that the separation of materials at the demolition site through selective demolition or other means is often the most effective way to ensure a clean, uncontaminated product (Merino, Gracia & Azevedo, 2010). However, demolition materials can sometimes be mixed together depending on the use identified for them. Concrete, bricks and ceramics for instance, are often ground up together for use as fill in road building or other construction projects. Such a use allows these materials to be mixed during the demolition process, although other materials may still need to be sorted out.

Policy and Legislation

International

Massachusetts

Massachusetts has employed landfill bans for specific C&D waste materials in order to reduce the total amount of waste landfilled in the state (Sonnevera International, 2006). The Massachusetts Department of Environmental Protection (DEP) banned the disposal of asphalt pavement, metal, brick, concrete and wood in 2006 and clean gypsum board in 2011 (J. McQuade, personal communication July 25, 2011). Through a Solid Waste Master Plan entitled Beyond 2000, the Massachusetts DEP committed the state to an 88 percent reduction in landfilled non-municipal solid waste by 2010 and the waste bans were designed to assist this process (Sonnevera International, 2006). It appears, however, that a ban on asphalt, brick and concrete has not contributed significantly to a reduction in land filled waste since the recycling rate for these materials was already high before the ban came into effect. On the other hand, the total volume of recycled materials other than those banned doubled between 2007 and 2009 (DEP, 2011). This suggests that other influences such as the development of recycling markets and the advancement of recycling processes have also played a role in increasing recycling rates.

Europe

While most legislation pertaining to C&D waste management has been developed at the national level, a revision of the European Union's Waste Framework Directive (WFD) requires 70% of each member state's C&D waste to be reused or recycled by 2020 (BIO Intelligence Service, 2011). This piece of legislation will likely be the main policy driver for European C&D waste management until 2020. However, since each member state must incorporate the requirements into its own legislation, the techniques for achieving this target will vary across the continent. This is no less true due to the wide variation in C&D waste reuse and recycling rates across Europe. While Germany, Denmark, Ireland, the Netherlands and the United Kingdom have already surpassed the Waste Framework Directive's C&D waste diversion requirements, countries such as Spain, Poland and Greece have diversion rates which are currently below 20% (BIO Intelligence Service, 2011). This means that the WFD will play a more significant role in the development of some member states' C&D waste management programs than others.

At the national level, policies and regulations used to guide C&D waste management in Europe can be grouped into four categories. An important category is that of waste policies. These policies often take the form of national waste framework policies which will as a minimum incorporate targets and directives from the WFD. If the management of C&D waste is not specifically addressed within a national waste framework policy, a separate policy which focuses on this issue may be created (BIO Intelligence Service, 2011).

A second category of legislation is that of landfill regulations which are easy to implement and

directly influence opportunities for disposing of C&D waste (BIO Intelligence Service, 2011). The most effective of these regulations include a government tax on land filled C&D waste or an outright ban on the land filling of specific waste materials (BIO Intelligence Service, 2011). Regulations which stipulate the individual disposal of waste materials (such as gypsum board and asbestos) or the construction of environmentally sensitive landfills can encourage C&D waste recycling to a lesser extent by increasing landfill fees.

A third type of legislation aims to promote the use of recycled building materials in new construction, thereby developing a market for recycled C&D waste while creating a closed-loop process. In Germany, an ordinance is being developed which will provide standards for the safe use of recycled concrete and other aggregates in the production of new concrete. A similar piece of legislation in Finland provides clear requirements for the use of recycled aggregates in various types of concrete construction (BIO Intelligence Service, 2011).

A fourth category which has so far seen little development in Europe is that of legislation regulating the environmental performance of new construction. This legislation could also encourage C&D waste recycling through the creation of mandatory standards for the use of recycled materials in new construction and standard recycling rates for waste materials. While regulations of this sort have not yet been made law in Europe, certain voluntary building standards such as the German Sustainable Building Certificate have incorporated this process into their certification system (BIO Intelligence Service, 2011). This sort of regulation has also been adopted by the LEED building standards in North America.

Canada

Alberta

The government of Alberta signed a landmark agreement on C&D waste management with the Canadian Home Builders' Association-Alberta (CHBA-A) and the Alberta Construction Association (ACA) in 2008. In the agreement, these three entities committed to implementing procedures and policies which will effectively increase the percentage of C&D waste that is recycled (Daily Commercial News and Construction Record, 2008). This agreement is noteworthy because it is the first voluntary agreement on C&D waste reduction in Canada. The government of Alberta has proposed a system where deposits are paid based on the square footage of a building. After construction has been completed, a portion or all of the deposit is given back based on the documented diversion of waste from landfills (Cryderman, 2010). As Denmark has demonstrated, voluntary agreements between the construction industry and governments can give industry a voice in the decision-making process and help ensure that waste management regulations are accepted by everyone involved in the construction industry. While

Alberta's C&D waste management agreement has the potential to bring the government of Alberta and construction industry organizations together to collaborate on diverting C&D waste from the landfill, as of August, 2010, the agreement had not yet been legislated (Cryderman, 2010).

Ontario

The government of Ontario established waste reduction regulations in 1994 as part of a Waste Reduction Action Plan (WRAP) in response to a looming waste disposal crisis. The crisis was due to the increasing difficulty of finding new landfill space and a rise in the cost of building new landfills (Sonnevera International, 2006). The regulations are known as the "3Rs" regulations and while never enforced, are noteworthy examples of a regulatory mechanism for C&D waste reduction in Canada. A main objective of Ontario's WRAP was to divert 50% of the province's total waste from landfills by the year 2000 using 1987 waste production levels as a baseline. The 3Rs regulations were the most significant component of WRAP and were designed "to stimulate reduction, reuse and recycling of waste generated by the municipal and IC&I sectors" (Sonnevera International, 2006, p. 178).

The regulations approach C&D waste diversion in the following manner. Part IV of regulation 102/94 states that contractors who are managing the construction or demolition of buildings which are at least 2,000 m² must conduct a waste audit of all waste that will be generated from the project and prepare a written report describing the audit. Following this, a written waste reduction work plan must be created outlining strategies for reducing, reusing and recycling waste generated from the construction or demolition process. Finally, the work plan must include measures for communicating the waste reduction strategies to all workers at the construction site (Sonnevera International, 2006).

C&D waste diversion is also addressed in regulation 103/94 which requires certain waste materials to be separated during the construction or demolition of buildings greater than 2,000 m² (Sonnevera International, 2006). For demolition projects these materials include Portland cement concrete, brick, steel and wood. For construction projects, cardboard and clean (unpainted) drywall were added to the list. While the separation process is termed "source separation" in regulation 103/94, materials are allowed to leave the site commingled for separation elsewhere. In this way, separation can be accomplished by a recycling facility rather than the construction or demolition contractor (Sonnevera International, 2006). When the Ontario 3Rs regulations were established in 1994, a Waste Reduction Office (WRO) existed as part of the Ontario Ministry of Environment. The WRO was put in place to help "waste generators, packagers, municipalities and recycling site operators understand and comply with the requirements contained in the regulations" (Sonnevera International, 2006, p. 181). However, the WRO was closed in the autumn of 1994 and educational information on the 3Rs regulations was afterwards unavailable.

This effectively halted progress towards compliance with these regulations. Since then, although the regulations have theoretically remained in force, the Ontario Ministry of Environment has lacked the funds to enforce them and only one fine associated with non-compliance has been recorded (Sonnevera International, 2006).

Nova Scotia

Nova Scotia has made progress during the last 15 years in the diversion of C&D waste from provincial landfills. While a significant percentage of diverted C&D waste is currently used at landfills for daily cover or road building, research is being undertaken to expand the opportunities available for the reuse and recycling of C&D waste materials across the province. The province of Nova Scotia manages C&D waste through its *Solid Waste Resource Management Regulations*. Through these regulations the province created the Resource and Recovery Fund Board (RRFB) which seeks to develop and support value-added industries that contribute to the reduction or diversion of solid waste in Nova Scotia. The RRFB also funds municipal and regional waste diversion programs. Its C&D waste program offers funding to regions and municipalities based on the volume of C&D waste diverted each year. This provides regions with an additional monetary incentive to recycle C&D waste which is particularly important in rural regions that are far from established recycled material markets.

The Halifax Regional Municipality (HRM) in particular has taken additional steps to encourage C&D waste recycling through the creation of By-Law L-200. This by-law goes beyond the provincial regulations in the following key areas: 1) A more comprehensive C&D materials ban that includes asphalt paving, porcelain and ceramic as well as the municipal solid waste materials banned by the province. 2) A stipulation that all C&D waste generated must be taken to a certified C&D Processing Facility or Transfer Station. 3) A requirement that 75% of all C&D waste material received at a processing facility must be recycled or diverted from a landfill (Dillon Consulting Ltd, 2006). These requirements along with a large population base and more significant local recycling markets allowed HRM to achieve a C&D diversion rate of at least 75% since the By-Law was introduced in 2001. However, approximately half of the material diverted was used as landfill cover in 2010 (D. Chassie, personal communication, July 8, 2011). The two C&D processing facilities operating in HRM are Halifax C&D Recycling and RDM Recycling.

Management of Construction and Demolition Waste Materials

Aggregates

The term “aggregate” is used broadly by the construction industry to refer to natural mineral materials used for various types of construction. Robinson, Menzie & Hyun (2004) describe the

term aggregate as “an industrial commodity term for sand, gravel, and crushed rock materials, in their natural or processed state, that are used to provide bulk, strength, and wear resistance in construction applications” (Barkdale, 2000, as cited in Robinson, Menzie & Hyun, 2004, p. 276). In the U.S., aggregates are primarily used in the production of portland cement concrete, asphalt pavement, and as structural fill in the construction and maintenance of roads and buildings (Tepordei, 1999). In Europe, the word “aggregate” is also used to describe recycled concrete, bricks and ceramics which are often crushed and used as fill for civil engineering projects. More recently, these recycled aggregates have begun to be used in Europe for the production of new concrete (Weil, Jeske & Schebek, 2006).

Aggregates often represent a large proportion of a region’s C&D waste stream due to their weight and predominance in modern construction techniques. If used asphalt pavement torn up during the repaving of roads is included, the total volume of waste aggregates produced is much larger. While individual houses are often constructed of wood in Canada and other northern regions such as Scandinavia, house foundations, larger public buildings and transportation infrastructure are often constructed using aggregates. In other parts of Europe and North America, aggregates are more commonly used for all types of construction and represent an even higher proportion of total C&D waste produced. For example, a Spanish national plan for C&D waste from 2001 demonstrates that aggregates made up 75% of Spain’s C&D waste at the time (Merino et al., 2010).

Aggregates have often been targeted by recycling strategies due to their abundance in C&D waste streams. In Europe and North America, recycled aggregates have most commonly been used as loose fill in the construction of roads and other infrastructure. Recently, however, there has been increased interest in substituting recycled aggregates for natural aggregates in concrete production (Weil et al., 2006). In Germany, research into this possibility has been prompted by concerns over ground water contamination from recycled aggregates used as fill. However, using recycled aggregates in the production of new cement can also reduce the use of primary mineral resources by more than 40% (Weil et al., 2006).

An important question that must be asked when conducting research on using recycled aggregates in new concrete is whether the concrete produced will have the same strength and durability as concrete made with natural aggregates. Many construction materials are made using a particular specification which is adhered to in order to ensure that the manufactured product will perform optimally. The use of recycled materials often requires an alteration in the manufacturing process which in turn requires the development of a new specification (or “spec”). While research in Germany has demonstrated that certain types of concrete can be reliably produced using recycled aggregates, Weil et al. (2006) describe several conditions that must be adhered to in order for the process to be successful. For instance, the authors state that recycled aggregates from civil engineering projects must not be used for structural engineering

applications as they can contain chloride which can affect the durability of structural concrete. Weil et al. (2006) also note that increased amounts of binding material such as cement, fly ash, or concrete plasticizers must often be used due to the rougher surface and more angular shape of recycled aggregates. If cement is chosen, the total energy consumed and air emissions produced in the manufacture of concrete can be close to 40% higher than that of concrete with primary aggregates. However, if fly ash or concrete plasticizers are used to prevent an increased use of cement, total energy use and air emissions can remain very similar to that of traditional concrete (Weil et al., 2006).

It appears that only recycled concrete and brick can be used in the production of new concrete and these aggregates must be carefully sorted from other materials in order to ensure that they are free of contaminants. Weil et al. (2006) state that current technologies for the sorting of C&D waste are unable to separate different aggregate types and that pending the development of new waste sorting technology, aggregate sorting must take place at the demolition site through selective demolition or deconstruction procedures.

Current Practices in HRM:

While recycled aggregates are used as loose fill at the Otter Lake Landfill in HRM and other landfills in Nova Scotia, they are not often used for other applications in the province. (A.Way, personal communication, August 24, 2011; Dillon Consulting Ltd, 2006). It appears that the major obstacles to recycling a greater percentage of aggregate waste in Nova Scotia are the abundant sources of aggregates in the province and inexpensive transportation costs (Dillon Consulting Ltd, 2006).

Asphalt Shingles

Due to their prevalent use as a roofing material in North America, asphalt shingles are a significant waste stream in both the United States and Canada. It is estimated that up to 1.25 million tonnes of asphalt shingle waste is currently produced in Canada each year, primarily from reroofing projects (Hannah, 2010). Fortunately, within Canada and the United States there is growing interest in recycling asphalt shingles in order to reuse the asphalt cement and mineral aggregate they contain for the production of hot-mix asphalt (HMA) pavement. The recent rise in cost of petroleum products has made virgin asphalt cement increasingly expensive and research has confirmed that used asphalt shingles can be incorporated into the production of HMA pavement. This decreases the cost of asphalt paving and makes use of a significant waste stream (Krivit, 2007).

According to Owens Corning Fiberglass Technology Inc. (2000), standard asphalt shingles are currently made up of the following materials. Limestone or fly ash is used as a coating filler and constitutes 32 – 42% of the product. Granules, which are small, painted pieces of rock or coal

slag normally make up 28 – 42% of the product. Asphalt cement constitutes 16 – 25% while “back dust” made from limestone or silica sand is usually 3 – 6%. The base of the shingle is 2 – 15% of the total and is normally made from fiberglass, paper or cotton rags. Finally, adhesives make up 0.2 – 2% of the shingle.

Asphalt shingle recycling has benefited from more than 25 years of research and development (Krivit, 2007). The majority of this research has focused on the recycling of asphalt shingle scrap from the manufacturing process. Recycled asphalt shingle (RAS) scrap produced from manufacturing has enjoyed greater acceptance from government regulators and engineers for the creation of construction materials specifications than used “tear-off” shingles from roofing projects (Krivit, 2007). This may well be because manufacturing shingle scrap is more uniform, has fewer contaminants and consists of essentially unused materials. However, overburdened landfills and rising petroleum prices are increasing the attractiveness of using tear-off RAS for road construction applications including HMA.

Specifications for the production of HMA are influenced by climate and traffic conditions and therefore vary by region (Krivit, 2007). Due to this variation, “departments of transportation [in the United States] have opted to independently test the effect that adding RAS has on pavement performance” (Krivit, 2007, p. 28). Tests of HMA mixes in the United States have found that incorporating up to 5% RAS in hot-mix asphalt does not degrade the performance of the asphalt. In fact it can create certain advantages such as increased resistance to rutting if the paper backing is included (Hanson, Foo & Lynn, 1997). However, the use of RAS at a higher percentage can affect the asphalt’s performance since the asphalt cement found in shingles is harder than that used for asphalt pavement. This problem may be resolved by using a softer grade of virgin asphalt cement in the hot-mix. Several recent research projects have focused on solving this issue (Krivit, 2007). In the Halifax Regional Municipality of Nova Scotia, Halifax C&D Recycling has developed a process for separating paper shingle backing from the other ingredients which has allowed them to offer two different products from RAS. The paper backing is sold to a local cement kiln for use as a fuel while the granules and asphalt cement are used in HMA applications. RDM Recycling also collects asphalt shingles for recycling. The shingles are sent to Halifax C&D for processing. It appears that this procedure of separating asphalt shingles into two different products is unique in North America. Halifax C&D recycling sells RAS without the paper backing to Ocean Contractors Ltd. for use in HMA. Ocean Contractors Ltd. currently uses less than 2.5% RAS in its hot-mix asphalt, or approximately 200 to 400 tons of RAS per year (E. Henneberry, personal communication, June 16, 2011).

In North America, energy recovery is the only other current high value recycling option for manufacturer or tear-off shingle scrap. Within Canada, cement kilns often utilize shingles for this purpose. Asphalt shingle scrap diverted for fuel might need less sorting than shingle scrap used for HMA since higher rates of contamination could possibly be supported in this context. Krivit

(2007) writes that cement kilns can also make use of the inorganic components of the asphalt shingles used for fuel including the surface granules, mineral filler aggregates, fiberglass, talc dust and any nails remaining in the shingles. According to Krivit (2007), these components can provide ingredients useful to the cement making process including calcium, magnesium, limestone, dolomite and silica as well as aluminum and iron from metal contamination. The value of the inorganic fraction as a mineral supplement, the organic fraction as a fuel source and the avoided landfill costs can together assign a relatively high value to RAS used for this purpose. In Europe, RAS is also being used for energy production. While this practice has seen limited development in the United States, it is currently unusual in North America (Krivit, 2007).

There are several additional uses for RAS in road construction besides HMA. While the value of RAS is often lower for these applications, there is the potential to use higher quantities of the material. Higher percentages of RAS have been used successfully in lightweight pavements for low volume applications such as driveways and parking lots (Krivit, 2007). The blending ratios used for these pavements have typically consisted of between 25% and 50% RAS (Krivit, 2007). Recycled asphalt shingles have also been used successfully as a component of road base fill. While much less controlled research has been done on using RAS as part of an asphalt road base, the practice has been used successfully by contractors in Maine and Minnesota (Krivit, 2007). In the United States, RAS is generally permitted in a road base as long as the total bitumen content stays below levels specified by each state. A Canadian study on the use of RAS in road bases found that RAS levels of 5% increased the stability of many aggregate mixtures without compromising precipitation drainage (Shrestha, 2008). RAS has also shown promise when added to gravel aggregates for the maintenance of rural roads. Multiple tests in the US have demonstrated that the addition of RAS can minimize dust and vehicle noise, prevent gravel from falling into drainage ditches and increase the life of the road surface while reducing maintenance needs (Krivit, 2007).

The use of RAS for road patching has proven to offer several advantages over traditional materials and has been used for several years in parts of the United States (Krivit, 2007). RAS is being used for the production of road patching products that can be applied cold, or “cold patches”. According to Krivit (2007), Home Depot offers a cold patch product in the US containing RAS. Many of the reported advantages of cold patches made with RAS are due to the paper or fiberglass fibers from the shingle backing. These advantages include a longer life than traditional patch materials, a lighter weight and less “clumping” during storage. It is also reported that these cold patches are easier to apply since a hole can simply be filled one inch over grade and compacted by vehicular traffic (Krivit, 2007).

Current practices in HRM:

Within the Halifax Regional Municipality of Nova Scotia, asphalt shingles that arrive at C&D processing centres are sorted from other materials and collected at Halifax C&D Recycling

where the paper backing is removed from the asphalt covered aggregate through a unique processing method. The paper backing is sold to Lefarge for use in their cement kiln in Nova Scotia while the asphalt and aggregate are reused by Ocean Contractors Limited in the production of new asphalt pavement.

Wood

Clean and contaminated wood normally constitutes a large percentage of the total C&D waste produced in North America (Dillon Consulting Ltd, 2006; Recycling Council of Ontario, 2006). As such, it is often an area of focus in C&D waste diversion strategies. When examining wood waste, it is important to distinguish between clean and contaminated wood. The term “clean wood” refers to sawn lumber to which glues, resins, plastics or other materials have not been added. “Contaminated wood”, also known as “dirty wood”, includes engineered wood products to which glues and resins have been added as well as wood products with paints or stains applied to them. Examples of engineered wood include plywood, particle board and laminated wood products. Certain additives such as formaldehyde-based resins and lead paints are highly toxic and their presence can limit the options available for recycling contaminated wood.

Treated wood products also make up a significant percentage of contaminated wood waste. Treated wood is normally infused with metals or chemicals to preserve the wood against mold and rot. The infused metals and chemicals in treated wood make it often unsuitable for recycling or reuse in other applications. Coal tar creosote and chromated copper arsenate (CCA) are the most commonly used wood preservatives in North America. Coal tar creosote is a distillate derived from coal tar which is created from the combustion of bituminous coal. Creosote treated wood is primarily used for civil infrastructure such as wharves and bridges while CCA treated wood is used most frequently for insect and rot resistance in buildings. The preservative CCA is composed of copper, chromium and arsenic. While CCA and creosote treated timbers have traditionally been disposed of in landfills, the metals and chemicals they contain can contaminate groundwater supplies. There is currently much research being done to develop a viable process for removing the toxins from this wood in order to allow for safe disposal or recycling of the materials to take place. For example, low-temperature pyrolysis has been used successfully in a semi-industrial scale prototype in France (Helsen, Van den Bulck & Hery, 1998).

Opportunities for Reuse:

Wood is a versatile material and can often be reused in new building projects if the dimensions of the timber are appropriate (Winkler, 2010). Framing lumber is often the most easily reused since the dimensions of this timber have changed little over the past century (Winkler, 2010). Timber of this sort that has remained dry and undamaged can be reused again for the same purpose. Heavy timbers are often especially valuable due to their aesthetic appeal and the work

of carefully disassembling them is usually well rewarded. Solid board sheathing is reused less frequently due to the current preference for plywood or oriented strandboard siding which can be installed more quickly. Lastly, architectural woodwork is often valued for its character and beauty making it a prime candidate for salvage and reuse. The value of such woodwork is heightened by the cost of reproducing it today, which is often prohibitive. Therefore, the cost of salvaging architectural woodwork is one of the easiest to justify during the demolition process. This is also true of well constructed interior woodwork such as cabinetry and doors.

Energy Generation and Recovery:

The use of clean waste wood as a fuel source for heat or electricity production is a well established practice in many countries including Canada, The United States and Australia (Warnkin, 2004). As the price of fossil fuels has risen, the cost competitiveness of wood has increased and a demand for clean C&D waste wood as a fuel source has arisen. Contaminated wood, however, is used less frequently or in smaller quantities due to widespread concern over its potential to produce air contaminants. Soiled wood is also of concern to fuel purchasers since dirt and grit can cause slagging in furnaces (Warnkin, 2004). In many regions, selling waste wood for fuel can be more economically viable than producing mulch or compost because of the additional processing expenses involved with the latter products. In Sydney Australia and Halifax, Nova Scotia, waste wood used for fuel is tested to ensure that contaminant levels are kept at required levels (Warnkin, 2004; D. Chassie personal communication, June 29, 2011).

Mulch and Compost

Much research has been done on using waste wood from construction and demolition projects as a mulch or ingredient in compost mixes (McMahon et al. 2008). The primary concern with these applications is the degree to which the wood used is contaminated with toxins, plastic or metal. Due to this concern, it seems that the use of contaminated wood for the production of mulch or compost has been largely limited to pilot studies (McMahon et al., 2008, Biocycle, 2007). The use of clean waste wood for mulch production is common across North America, although construction and demolition waste appears to be a less common source than land clearing, landscaping and manufacturing (Townsend, Solo-Gabriele, Tolaymatv& Stook, 2003). However, tests of mulch products have indicated that despite producers' demand for clean wood, significant percentages of contaminated wood end up in mulch products. This has been attributed to a low awareness of the adverse health and environmental effects of using contaminated wood for mulch as well as difficulties with identifying contaminated and treated wood (Townsend et al. 2003).

Recent research has demonstrated that the composting process can assist with the degradation of heavy metals and pesticides found in treated wood products. Barker and Bryson (2002) found

that composting may also convert metallic pollutants into less bioavailable species and concluded that composting has the potential to remediate contaminated materials. McMahon et al. (2008) tested the ability of a contained composting process to reduce toxins in contaminated wood products in the U.K. The toxins consisted of isocyanates and phenolurea formaldehydes used as synthetic binding agents. McMahon et al. (2008) identified significant reductions in toxicity levels during a 14 week composting process.

Other Recycling Options:

There are several other value-added uses for clean waste wood that have been developed to some extent. A significant demand for wood flour is emerging in parts of the United States. This is due to the use of wood flour as an inexpensive filler in woodfiber- plastic composite lumber, a product whose popularity is increasing. However, the production of wood flour requires a very clean wood supply and engineered wood products cannot be used for this purpose. In addition, certain tree species can be unsuitable for the production of wood flour for composite lumber (Buehlmann, 2002).

Current Practices in HRM:

In the Halifax Regional Municipality of Nova Scotia, Halifax C&D Recycling mixes clean and contaminated waste wood together to be sold as fuel. This is possible since the Nova Scotia Department of Environment allows a contamination rate in the fuel mix of up to 10% (D. Chassie personal communication, June 29, 2011). RDM Recycling currently recycles clean wood as fuel and grinds contaminated and treated wood for use as a landfill cover (A. Way, personal communication, August 24, 2011). RDM may send a larger percentage of its contaminated wood to the Otter Lake landfill for use as landfill cover in order to meet the landfill's demand since both facilities are operated by Dexter Construction Company Ltd.

Gypsum Board

Along with aggregates and wood, gypsum board constitutes a significant percentage of C&D waste in North America. In the United States, the National Association of Home Builders Research Centre has estimated that gypsum waste makes up 27% of all residential construction waste (Recycling Council of Ontario, 2005). In addition, the Waste & Resources Action Program (WRAP, n.d.) estimates that 15% of Canada's yearly production of gypsum board is disposed of as manufacturer and construction waste. Gypsum board has traditionally been disposed of in landfills in Canada. However, it has been found that under certain conditions, gypsum board co-disposed with biodegradable waste can produce hydrogen sulphide gas (H₂S) as well as sulphide leachates (WRAP, n.d.). Hydrogen sulphide gas is flammable and toxic to humans. In British Columbia, limiting gypsum board to 5% of mixed waste was found to be ineffective in

preventing the production of hydrogen sulphide gas which led to a ban in 1984 on the landfilling of gypsum board within the Greater Vancouver Regional District. This ban encouraged Canadian companies such as New West Gypsum Recycling Inc. to develop efficient processes for recycling gypsum (WRAP, n.d.). Within the last decade, it has become common for gypsum board to be segregated from organic waste when deposited at landfills in Europe in order to prevent the production of hydrogen sulphide gas (WRAP, 2006).

During the past three decades, several important uses have been identified for recycled gypsum. In many regions, the largest demand for recycled gypsum has been created through its reuse in the production of new gypsum board (James, Pell, Sweeney, & St John-Cox, 2006). This demand can vary though depending on the percentage of recycled gypsum manufacturers are willing to incorporate into new products and the price of virgin gypsum in each region. The integration of at least 20% recycled gypsum into new gypsum board is common in British Columbia, Ontario and Denmark, with percentages as high as 40% tested successfully (WRAP, 2006). In contrast, the Yoshino Gypsum Company in Japan limits the use of recycled gypsum to 10% in new products (Saotome, 2007). Recycled gypsum is also used successfully as a substitute for virgin gypsum in cement production (D. Chassie, personal communication, June 29, 2011). Finally, there is some demand for recycled gypsum as a soil additive in agriculture and composting operations. However, land applications create a smaller demand for recycled gypsum than cement and gypsum board production.

This literature review identified several circumstances that encourage gypsum board recycling within a region. WRAP (2006) indicates that ensuring landfill fees are significantly higher than recycling fees can help guarantee recyclers a steady supply of waste material. In North America, where tipping fees themselves have rarely been designed to encourage recycling, the regions best suited for gypsum recycling have been those with significant construction activity and a lack of local gypsum deposits (WRAP, n.d.). The high demand for new gypsum board and subsequent large amounts of construction waste combined with a premium price on virgin gypsum in these regions offers several advantages to gypsum recycling operations.

In order to recycle gypsum board, the gypsum must be separated from the paper facing; various processes have been developed by recyclers to accomplish this (WRAP, n.d.). This separation process is particularly important when using recycled gypsum for cement production, as the paper content must normally be kept below 1% in this case (D. Chassie, personal communication, June 29, 2011).

Current Practices in HRM:

Gypsum board that is brought to C&D processing centres as separated material or that is easily recoverable from mixed loads is processed by Halifax C&D Recycling to remove contaminants

and the paper backing from the gypsum. There are currently two companies interested in buying recycled gypsum in Atlantic Canada: Certain Teed in New Brunswick which manufactures Gypsum Board and Lafarge Canada Incorporated, which uses the material during the production of new cement at its plant in Brookfield, Nova Scotia. Certain Teed requires that the recycled gypsum it purchases is completely free of screws and nails while Lafarge has a stricter tolerance on paper contamination.

Metals

Post-consumer metals have some of the highest values of any recycled building product and the Canadian metal recycling industry is well established across the country (Fothergill, 2004). Because of this, Canadian contractors and recycling centres rarely have a problem finding buyers for well sorted metal waste. Nonferrous metals such as copper and aluminum are particularly valuable and buyers often provide containers and hauling free of charge for these materials. Metal waste from construction projects is usually quite limited due to the high cost of metal products. Common sources of nonferrous metal construction waste include copper pipe cut-offs, aluminum gutter and flashing trimmings and electric cable cut-offs (Winkler, 2010). Structural steel sections are usually created to architectural design specifications in order to minimize waste. Because of this, ferrous metal construction waste usually accumulates through cut-offs from steel studs, rebar, strapping and other framing pieces (Winkler, 2010).

Current Practices in HRM:

It appears that all metal C&D waste sent to C&D processing centres is being recycled within the Halifax Regional Municipality. The value of this material has contributed to the development of a robust recycling industry across North America which facilitates recycling processes. At RDM Recycling for example, even small pieces of metal are sorted from mixed C&D waste by hand or with magnets. The damage that metal pieces can do to processing machinery is an added incentive for thorough sorting at this facility (A. Way, personal communication, August, 24, 2011).

Glass

While glass has been used in windows for centuries, it is now commonly used to construct exterior wall panels, tiles and photovoltaic panels as well. This diversification of glass building materials has greatly increased the percentage of glass used in commercial buildings in particular. It appears that glass waste from construction projects is limited since glass windows, tiles and panelling are available in a variety of sizes. Glass is often a small percentage of current demolition waste as well since it was only frequently used in windows, mirrors and insulation products in older structures. While window glass represents the largest percentage of demolition

glass waste, there is currently little demand for single-pane windows since they do not insulate as well as newer designs. It is unclear whether the difficulty in separating window materials discourages recycling of these products as well. Glass block salvaged from deconstruction activities is reused in HRM and elsewhere (R. Rhyno, personal communication, August 23, 2011).

Large demands for recycled glass are being created through its use as a substitute for sand in cement production and as a replacement for gravel in hot-mix asphalt where it can make up 40% of the aggregate mix. Recycled glass is used to a lesser extent for water filtration systems, as a replacement for sand on golf courses and playing fields, in the production of fibreglass insulation and as a fluxing agent in the manufacture of tile and brick. More valuable uses of recycled glass are also being developed. In the United States, Vetrazzo Inc. produces glass composite counter tops made with up to 100% recycled glass (Winkler, 2010).

Current Practices in HRM:

Unsorted glass waste is currently being used in the creation of daily landfill cover at the recycling centres in HRM. Halifax C&D Recycling will recycle glass waste such as street light covers and window glass if it arrives sorted. The C&D glass waste is used to manufacture a certified aggregate used in septic systems (D. Chassie, personal communication, September 9, 2011).

Plastics

Although plastics typically represent just 1% of total construction and demolition waste, their environmental impact can be significant once they are disposed of (Assessing the Potential of Plastics Recycling in the Construction and Demolition Activities (APPRICOD), 2004). Plastics can take centuries to biodegrade, and the chemicals contained within them are serious threats to air and water quality when plastic waste is incinerated or landfilled. In addition, the use of plastics in the construction industry continues to increase.

While a wide variety of plastics are manufactured worldwide, polyvinyl chloride (PVC) is the most commonly used plastic in the construction industry today. According to APPRICOD (2004), PVC accounted for 47% of all plastics used in the construction industry in Western Europe in 2002. PVC is now commonly used for manufacturing pipes and ducts, door and window frames and vinyl flooring (APPRICOD, 2004). High density and low density polyethylene are used as well for the production of plastic piping. The plastics EPS (expanded polystyrene), XPS (extruded polystyrene) and PU (polyurethane) are also frequently used to manufacture insulation materials and made up 18% of the construction industry's plastics consumption in Western Europe in 2002 (APPRICOD, 2004).

Plastics have been used for vinyl flooring since the mid-1950s. However, many plastic building components have only captured a significant percentage of the market since the 1970s. Due to this relatively short period of use, many plastic building components in use today are not yet found in demolition waste. Too little time has elapsed to conclusively determine the lifespan of most of these materials. However, life-span estimates are currently lengthy for several PVC products including window frames (50 years) and pipes (100 years) (APPRICOD, 2004).

Since plastics make up such a small percentage of total C&D waste, recycling efforts have focused on construction materials which represent a significant percentage of total C&D plastic waste. These materials usually include vinyl siding and flooring, PVC window and door frames, PVC piping and ducts, gutters, thermoplastic roof membranes and plastic packaging. There are two primary recycling processes that can be applied to plastics: mechanical recycling and chemical recycling (APPRICOD, 2004). Due to differences in their properties and melt temperatures, different plastics must often be kept separate for manufacturing purposes resulting in a demand for separated recycled plastics. Therefore, in order to use recycled plastics for many manufacturing applications it is necessary to sort and reprocess them individually. Mechanical recycling is well suited to this task. During mechanical recycling the plastic waste is usually cleaned and shredded, then processed to remove impurities before being melted and extruded into pellets. Chemical plastic recycling involves breaking plastics down into the chemical compounds they are made up of using heat and pressure. APPRICOD (2004) states “the recovery process is unique to plastics [and] produces basic chemical substances of defined specifications and high quality” (p. 17). Chemical recycling is well suited to recycling mixed plastic waste and can reduce oil consumption in plastic manufacturing.

In some European countries, C&D plastic waste recycling is well developed. In Germany for instance, this process has been in place for almost twenty years (APPRICOD, 2004). Within Germany, manufacturers of plastic construction products have formed associations to orchestrate recycling of their products. For example, in 1993, manufacturers of PVC floor coverings established the Association for PVC Floor Covering Recycling (AgPR) which provides recycling centres across the country. Post-consumer vinyl floor coverings can be dropped off at any recycling centre free of charge if they are clean and properly sorted. Similar associations have been developed for recycling vinyl windows and thermoplastic roofing membranes. A key factor in the development of any recycling industry is the presence of a steady supply of post-consumer material. To meet this need, the European-wide PVC recycling association RECOVINYL has been established by vinyl manufacturers and converters (APPRICOD, 2004). RECOVINYL organizes international PVC waste collection efforts through a network of certified recyclers thereby increasing the reliability of the waste supply. Materials collected include pipes, window frames, vinyl siding and shutters (APPRICOD, 2004).

In Canada, strategies for recycling plastic C&D waste are only beginning to be developed. The Canadian Plastics Industry Association (CPIA) has begun pilot projects to collect plastic pipe cut-offs in Ontario and Alberta (M. Axemith, personal communication, August 22, 2011). CPIA has also produced several reports on best practices for recovering and recycling vinyl siding during demolition projects. In Ontario, several recycling companies are currently collecting vinyl from construction projects and vinyl manufacturing facilities. As well, the company Simplas has facilities in Edmonton, AB and Mississauga, ON which accept PVC and polyethylene pipe cut-offs and vinyl siding from construction and demolition sites for recycling. Simplas claims to be the only Canadian company recycling plastic piping from construction and demolition projects (P. Garceau, personal communication, August 22, 2011). Plastic C&D waste is dropped off at Simplas free of charge or collected for the company in separate bins at landfills. It appears that C&D plastic waste recycling is not yet common outside of Alberta and Ontario.

Current Practices in HRM:

There are no recycling processes currently in place for recycling plastic C&D waste in the Halifax Regional Municipality. The municipality's distance from plastic manufacturers may be a constraint to the development of a plastics recycling industry as recycled plastic would need to be transported long distances. As well, it appears that used vinyl siding must remain clean and uncontaminated in order to be recycled (Dillon Consulting Ltd, 2006). In this case, traditional demolition practices would be a constraint to the recycling of vinyl siding and selective demolition would be required.

Carpeting/ Ceiling- tiles/ Insulation

There are several building materials which despite their smaller volume are important to consider when examining C&D waste diversion. The most significant of these is carpeting, which makes up approximately 4% of Nova Scotia's C&D waste (Dillon Consulting Ltd, 2006). Although carpet recycling efforts have been increasing in the United Kingdom and the United States over the past decade, Canada has only recently taken steps to promote carpet recycling with the establishment of the Canadian Carpet Recovery Effort (CCRE) in 2010. In a similar manner to the Carpet America Recovery Effort (CARE), CCRE seeks to "facilitate industry led and market driven solutions for the diversion of post-consumer carpet from landfills and the advancement of secondary markets using recycled content" (CCRE, 2010, slide 8). There are currently several diversion opportunities for recycled carpets. Clean carpets in good condition can often be reused if care is taken with their removal. Depending on the carpet type and its condition, processing of post-consumer carpeting can produce components for new carpeting or carpet padding or plastic resins for the production of other recycled products. Alternatively, post-consumer carpeting can be used as a fuel source for industrial processes such as cement making (Bro-Tex Inc., n. d.).

Ceiling tiles are another building product for which recycling procedures have recently been developed. In the United States, Armstrong World Industries (Armstrong) was the first company in North America to begin an extensive ceiling tile recycling program in 1999 to provide a supply of recycled material for their new ceiling tile products. Since then, they have recycled over 50,000 tonnes of ceiling tiles. Armstrong currently collects used ceiling tiles in the provinces of British Columbia, Alberta and Ontario, grinds them into powder, and incorporates the recycled mineral fiber into the production of new ceiling tiles. It appears that closed-loop recycling of ceiling tiles has not yet been developed in Canada (Recycling Council of Ontario, 2005). In Nova Scotia, Thermo-Cell Industries Limited has suggested that certain types of ceiling tile could be ground and used as blown-in insulation (B. Kenney, personal communication, August 25, 2011).

A final subject which is worth our attention is insulation materials. Currently, several different types of insulation material are commonly used. The most frequently used products are polystyrene board, fiberglass and paper cellulose. Paper cellulose insulation is often itself a recycled product with approximately 80% being made from recycled newspaper (Winkler, 2010). According to Winkler (2010), old cellulose insulation can be incorporated into new insulation. This practice, however, does not appear to be widespread, perhaps due to the length of time needed to extract old cellulose insulation from wall cavities.

While the process of recycling fiberglass batts into fiberglass board products has been developed, it is not currently economically feasible. Therefore, while fiberglass batts are occasionally salvaged for reuse, most are currently sent to the landfill in North America (Winkler, 2010). Armstrong World Industries, however, does accept commercial fiberglass batting that does not have a paper cover for recycling. They also accept acoustical insulation panels for recycling if they meet certain conditions. For further information on Armstrong's conditions for accepting materials for recycling, please call their recycling centre at 1877-276-7876.

Polystyrene boards (often known as Styrofoam) are becoming more popular as an insulation material for exterior walls. Recycling opportunities for this material are unfortunately very limited at the moment. Rastra Inc. (www.rastra.com) is the only company in North America currently accepting used polystyrene boards for recycling. The company has manufacturing plants in Columbus, Ohio, and Albuquerque, New Mexico, and uses the recycled material for manufacturing insulated concrete form products (Winkler, 2010).

Current Practices in HRM:

Carpet recycling within the Halifax Regional Municipality is conducted on a limited basis by InterfaceFLOR, an international manufacturer of carpet floor tiles based in Georgia, United States. InterfaceFLOR currently recycles commercial carpeting, but is unable to recycle

household carpeting since it lacks central collection depots to stockpile this product (J. MacNeill, personal communication, August 25, 2011). A general constraint on carpet recycling is the additional cost of packing the carpet for shipment to an InterfaceFLOR recycling facility. The current cost of recycling carpeting in HRM is approximately \$.25-.50 per square foot if new InterfaceFLOR carpet tiles are installed, although the price can be higher if carpeting is removed inefficiently (J. MacNeill, personal communication, August 25, 2011).

Ceiling tiles and fiberglass insulation are not currently collected on a large scale for recycling in HRM. The reuse of these materials does occasionally occur, however, if they remain in good condition during renovations or deconstruction.

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