Recycled Plastic Lumber

A Strategic Assessment of its Production, Use and Future Prospects

A study sponsored by: the Environment and Plastics Industry Council (EPIC) and Corporations Supporting Recycling (CSR)

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Abstract

During the 1990s, a number of technologies emerged to utilize recycled plastics in products designed to replace dimensional wood lumber. Since that time, recycled plastic lumber (RPL) products have proven to be effective alternatives for many applications, offering high durability and requiring little maintenance. Plastic lumber products are resilient, weather-resistant, and impervious to rot, mildew, and termites. They do not require painting or staining. While RPL is widely employed in the construction of outdoor decks, plastic lumber is also being used to fabricate moldings, doorjambs, window casings, playground equipment, railway ties, pilings, posts and fencing products. The development and commercialization of new high-throughput, low-cost processing technologies will afford the opportunity to further close the recycling loop for the PE film and other plastics collected in industrial, commercial and municipal programs

This report details the properties and application of RPL and woodfibre-plastic composites (WPCs), charts the growth in the plastic lumber industry, describes the capabilities of the various production processes and additives, and profiles the major players. It also addresses the need for product standards and building code amendments to support the future growth of markets for plastic lumber. Finally, the report describes a series of three hypothetical processing facilities: a line manufacturing woodfibre composite deck boards from recycled PE film, one manufacturing pure polymer plastic deck boards from recycled HDPE milk jugs, and a new flow mold system designed to produce large dimension plastic timber products from a variety of mixed and contaminated plastics. The report provides a comparative analysis of the three commercially-available production processes, in terms of their cost, operation, and capacity to utilize recycled plastic feedstocks.

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List of Acronyms

ABS	acrylonitrile butadiene styrene
ASTM	formerly the American Society for Testing and Materials (ASTM is now the official name)
CCA	chromated copper arsenate
CPIA	Canadian Plastics Industry Association
CSR	Corporations Supporting Recycling
EPA	U.S. Environmental Protection Agency
EPIC	Environment & Plastics Industry Council
HDPE	high density polyethylene
LDPE	low density polyethylene
PE	polyethylene
PS	polystyrene
PVC	polyvinyl chloride
RPL	recycled plastic lumber
WPC	woodfibre-plastic composite

Executive Summary

During the 1990s, a number of technologies emerged to utilize recycled plastics in products designed to replace dimensional wood lumber. Since that time, the sale of recycled plastic lumber (RPL), including pure polymer extrusions and woodfibre-plastic composites (WPCs), have grown to capture a significant share of the deck board and deck railing market. While the largest market growth has been in the sale of exterior deck boards, plastic lumber is also being used to fabricate moldings, doorjambs, window casings, playground equipment, railway ties, pilings, posts and fencing products

Woodfibre-plastic composites (WPCs) represent the largest and fastest growing segment of the plastic lumber market. They also help close the recycling loop as a strategically important consumer of recycled polyethylene (PE) films, such as stretch wrap from the industrial, commercial and institutional (IC&I) sectors, PE bags from store depot collection programs, or PE bags and films gathered through municipal curbside collection programs across Canada.

Growth in the plastic lumber industry was very rapid in the 1990s, with growth rates of up to 50 percent per year and suppliers often unable to meet consumer demand for plastic lumber products. This period of growth has been followed by a year of consolidation, concurrent with the general economic slow down in 2001. The major industry players, the Trex Company and U.S. Plastic Lumber (along with others), had to idle equipment due to soft demand and high inventories. In spite of this, the long-term outlook for the industry is for high growth. Most of the market growth for plastic lumber has been in the North American residential deck market, which is valued at $5.2 billion (US) per year. Of this, sales of treated substructure components are worth some $1.8 billion (US) annually, while deck boards and railings account for $3.4 billion (US). By the year 2001, plastic lumber accounted for nearly 12 percent of the deck boards and railings sold, with total sales of $395 million (US). Its share of the market is expected to more than double by 2005, to $845 million (US).

The recent agreement between the U.S. Environmental Protection Agency and the U.S lumber industry to phase out arsenic compounds from pressure treated wood is expected to support the continued growth of plastic lumber for decking applications. In addition, new products, such as siding, roofing shingles, and exterior door and window casings made from WPCs, are expected to add to the overall growth potential.

Plastic lumber products can be worked with conventional carpentry tools and have a number of advantages over wood products. They resist rot, mildew and termites; they do not require regular painting or staining; and they are, otherwise, low maintenance materials. Many plastic lumber products are highly attractive and can be manufactured to meet a wide variety of design and appearance specifications. When wood or some other natural fibre source is incorporated into the material, many plastic lumber products can be painted or stained.

A recent trend in the production of woodfibre-plastic composites is the use of virgin polymers in place of recycled plastics. Polypropylene (PP) and polystyrene (PS) offer both a higher flex modulus (a measure of board stiffness) and a higher flexural strength (resistance to breaking) than polyethylene. The use of virgin polymers may also offer a wider variety of aesthetic options, including pigmenting choices and reproducible patterns. However, the higher cost of virgin polymer plastic lumber products may limit their market share. The all-recycled-content board stock, such as that produced by the Trex Company Inc. (with plants in Winchester, Virginia, and Fernley, Nevada), will continue to have a major raw material cost advantage compared to either pure polymer extrusions or composites made with virgin polymers. In the future, the plastic lumber market may segment as consumers weigh the properties of virgin polymer against the lower cost of recycled PE woodfibre products.

With growing markets for its products, the plastic lumber industry is actively researching new products, applications and production processes. This has lead to the development of a number of new products offering improved properties. A good example is a woodfibre-polypropylene composite that is oriented following extrusion and cooling. It results in an open porous structure that looks a lot like wood, and offers a flex modulus that is close to wood and a flexural strength about double that of wood.

A key issue facing the plastic lumber industry in the early 1990s was the lack of engineering standards for the products it produced. This gap is being addressed by the Plastic Lumber Trade Association, which has worked to establish a set of ASTM standards that apply to plastic lumber made (primarily) from high density polyethylene (HDPE). The polyethylene wood-fibre composite industry is also working on ASTM standards that would address the properties of composites. The development of appropriate standards that address the properties of plastic lumber will support future growth in non-structural applications, such as deck boards, siding etc. However, building codes in Canada and the U.S. have not been revised to allow for the use of plastic lumber in any coded applications. Some suppliers are currently working to address this problem.

Many of the new companies that have started up in the last two years to manufacture high quality deck systems use virgin polymers. The largest of the woodfibre-plastic lumber manufacturers in Canada are Composite Building Products International Inc. (Barrie, Ontario), Brite Manufacturing (Bolton, Ontario), GSW Thermoplastics (Barrie, Ontario), and Nexwood Industries Ltd. (Brampton, Ontario). Together with Royal Plastics (Woodbridge, Ontario), which produces a vinyl deck board system, these companies have the dominant share of the decking systems being manufactured in Canada and sold in major retail outlets. All of these manufacturers (except one) use virgin polymers for their products and are not major purchasers of post-consumer recycled content (and certainly not curbside collected film).

Canadian municipalities, retailers and companies that collect or generate used PE film and other plastic wastes continue to be dependent on large U.S. producers of composite plastic lumber, such as AERT (Springdale, Arkansas) and the Trex Company. However, a new processing system designed by a Canadian company may provide a large and growing market for curbside collected film and mixed plastics currently being landfilled. SPS Inc. (Tilsonburg, Ontario) has developed a high productivity flow mold process that has made it cost-effective and practical to manufacture large cross section-plastic composite timbers for use as railway ties and marine bumpers and pilings. The large diameter molds permit the use of mixed plastics or plastic films with higher levels of contamination at much lower processing costs. The new flow mold process also can accommodate sophisticated composites that utilize glass fibre, nylon fibre, woodfibre or rubber in mixtures that use about 50 percent PE film to achieve the structural properties needed for demanding applications. The process has been successfully used to manufacture plastic composite railway ties that are now approved for use by North American railways.

Strategic Assessment Highlights

1. The manufacture of recycled plastic lumber (RPL) and woodfibre–plastic composites (WPCs) grew rapidly through the 1990s and have captured nearly 12 percent of the North American deck board market. These materials are low maintenance, do not require painting or staining, and are impervious to rot and wood-eating insects, which makes them attractive to consumers.
2. Strong growth of RPL and WPCs should continue and the market is expected to double by 2005, in part, driven by the phase-out of arsenic compounds from pressure treated lumber.
3. The development of ASTM standards for plastic lumber products will support their use by consumers. The industry is currently working to amend building codes to permit the use of plastic lumber in coded projects.
4. A number of WPC lumber operations have been launched in Canada over the past two years. While the focus of these new operations has been on use of virgin polymers (such as polypropylene, polystyrene and high density polyethylene), one product utilizes recycled HDPE. Several large U.S. producers of plastic lumber are currently the major consumers of PE film and other recycled feedstocks collected in Canada.
5. The high growth rate in plastic lumber sales has stimulated significant research in new production technologies and manufacturing techniques, new additives that support wider product applications, and new products.
6. An oriented polypropylene-woodfibre composite developed in Canada has demonstrated flex strength superior to wood with a comparable flex modulus. This new product may open up a number of new applications.
7. A new, Canadian-designed flow-mold process for the production of large cross-section, plastic or plastic composite timbers can utilize PE films collected from curbside, mixed plastics and carpet waste. The process (and the products produced) can tolerate higher levels of contamination than other plastic lumber applications and may provide a large and viable market for these materials

1.0 Properties of Plastic Lumber

In general, plastic lumber products are durable, stable, resilient and weather-resistant. They are impervious to rot, mildew, termites and other wood-eating organisms, and do not require high maintenance or regular repainting or staining. Many plastic lumber products are highly attractive and can be manufactured to meet a wide variety of design and appearance specifications. When wood or some other natural fibre source is incorporated into the material, many plastic lumber products can be painted or stained.

The polymer chosen to formulate a woodfibre-plastic composite, as well as the amount of fibre added, will affect the properties (and potential applications) of the end products produced. For example, a Massachusetts study measured the effect of plastic type on the strength and stiffness of three commodity thermoplastics (polystyrene, polypropylene, and HDPE) with different woodfibre loading levels. Figure 1 shows the effect of increasing woodfibre content on tensile strength of each polymer, while Figure 2 illustrates the effect of woodfibre content on stiffness or flexural modulus. This data also shows why some manufacturers of WPCs are choosing to use virgin polypropylene or polystyrene as a means of increasing the stiffness and tensile strength of their finished products. In addition, increasing the amount of woodfibre can reduce the degree of creep exhibited by a plastic composite

Figure 1
Tensile Strength of WPCs

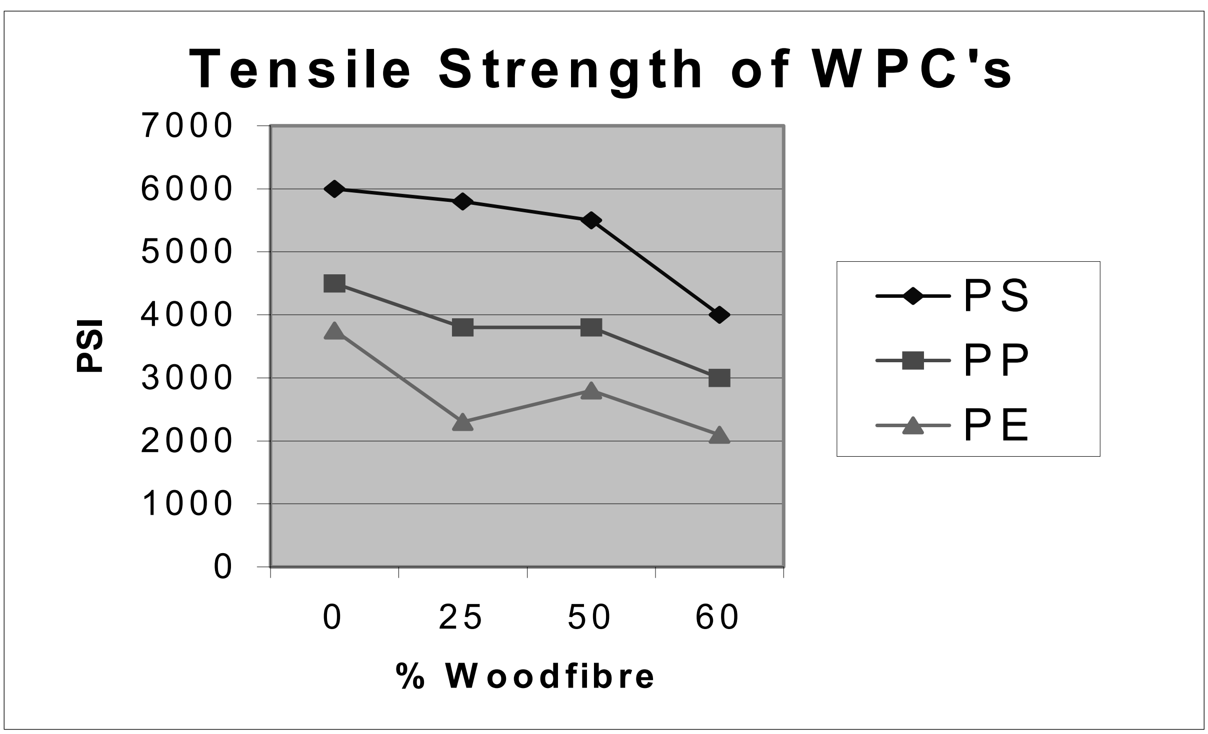


Figure 2
Bending Stiffness

A critical issue with plastic lumber is its low stiffness and low flexural strength when compared with natural wood. This may have limited the use of plastic lumber or woodfibre-plastic composites for structural applications, such as deck joists. To date, most of the extruded plastic or WPC boards produced have been used for deck surfaces where flex modulus is less critical. The new oriented wood-polymer composites may be able to reverse that situation. Table 1.1 compares the strength and stiffness of dried pine with a conventional WPC, a 30% wood-polypropylene WPC, and an oriented 30% wood-polypropylene WPC. As can be seen, conventional WPCs have relatively low flexural strength and stiffness compared to pine. However, the oriented woodfibre- polypropylene composite offers stiffness that is up to 82 percent of the flex modulus of the pine, while more than doubling the flexural strength.

Table 1.1
Comparison of the Strength and Stiffness of WPCs and Pine

Material	**% Wood**	**Relative density**	**Flexural strength** (psi)	**Flexural modulus** (psi)
Pine	100	0.37	8,000	887,500
Conventional WPC	50	0.97	1,900	169,000
Polypropylene WPC	30	0.52	6,000	215,000
Oriented PP WPC	30	0.98	17,000	733,000

Reference: Second Generation Woodfibre-Polymer Composites, W.R. Newson, Frank W. Maine. Presented at the 2002 Conference: Progress in Wood-Fibre Plastic Composites

2.0 Processing Technologies & Product Types

During the 1990s, a number of technologies emerged to utilize recycled plastics in products designed to replace dimensional wood lumber. While the largest market growth has been in the production of exterior deck boards, recycled plastic lumber (RPL) is also being used to fabricate moldings, doorjambs, window casings, playground equipment, railway ties, pilings, posts and fencing products. Despite a temporary slowdown in demand in 2000-2001, due to generally depressed economic conditions and the accumulation of high inventories by suppliers, the plastic lumber industry remains a growing force in the construction and building sector. Some of the traditional wood lumber companies are investing in new facilities to produce polyethylene wood composites. In addition, a number of Canadian companies have launched plastic lumber products in the past two years (although, for the most part, these recent start-ups have focused on the use of virgin polymers, rather than recycled plastics). Recently, an Ontario firm has updated an earlier extrusion flow molding technology, which had only limited application, to create a low-cost, high-output system that should provide new options for using recycled plastic, including sources that are heavily contaminated, to make railway ties and other large cross-section timbers.

This section briefly reviews the major production systems that are being used to make recycled plastic lumber -- including single polymer systems, extrusion flow molding systems, fiberglass-reinforced RPL, PVC extrusion profiles, woodfibre-plastic composites, oriented woodfibre-polymer composites, and polymer-polymer products. This section also assesses the capacities of the various production technologies to utilize recycled plastics in an effective and economic manner, and investigates the opportunities that might arise through the use of the new extrusion flow mold system developed by SPS Inc. (Tilsonburg, Ontario).

2.1 Single Polymer Systems

These systems, which use (primarily) continuously-extruded, structurally-foamed high density polyethylene, represent a significant part of the deck board market. The producers tend to use natural HDPE from milk jugs that can be pigmented to produce attractive deck colours. U.S. Plastic Lumber (Boca Raton, Florida) has been the largest and fastest growing company making this product.

2.2 Extrusion Flow Molding

One of the first processes to be utilized to manufacture plastic lumber with technology developed in Europe, these systems can utilize mixed polymers with lower raw material costs. However, the earlier versions of the process suffered from low productivity and produced parts of low quality, which resulted in low growth for this process. Recently, an Ontario company (SPS Inc.) has developed a new flow mold system that appears to have overcome the shortcomings of the earlier models (see sidebar “Ontario firm revolutionizes flow mold technology”). The high throughput SPS system readily produces low-cost, high-quality railway ties, marine timbers and other profiles with large cross-sections. The system can handle a wide range of recycled plastics, even those that may be heavily contaminated with “non-melts” to produce plastic lumber products that meet all the standard requirements for wooden products.

Ontario firm revolutionizes flow mold technology

SPS Inc. of Tilsonburg, Ontario, has developed a new flow mold system designed to produce large dimension plastic timber products at high throughput. The new design reduces shrinkage and voiding and can produce parts with reproducible dimensions. The system employs a unique mold design that maintains pressure in the cavity during cooling to eliminate large voids, and surface shrinkage. High productivity is achieved by use of a unique filling station that that employs a diverter valve system to fill and switch molds without interrupting the melt flow from the extruder. The valve design eliminates extruder back-pressure swings during the mold fill and switch cycle. The molds are transferred to a cooling bath by an automated carriage system that moves them sequentially through the cooling process. The system utilizes multiple molds to achieve very high throughputs. An automated line to produce railway ties is run by a single operator.

SPS also offers processing equipment to convert baled film plastic to densified feedstock. The large cross-section timber produced can tolerate higher levels of contamination in the finished product and this reduces the level of cleaning required, which (in turn) reduces the capital needed to process the recycled polymers. The process can produce parts with simple blends of mixed plastic with up to 50 percent “non-melts”, or can be used to produce complex composites with more demanding structural requirements, such as railway ties.

An automated line to produce railway ties can mold up to one tie per minute. Throughputs of 5,000 pounds per hour are attainable when producing large timber cross-sections. It is worth noting that thick cross-sections of molten polymer take very long times to cool and crystallize. Cooling cycles could be well over one hour for a 12” x 12” cross-section. A continuous extrusion process would require a water spray cooling line measured in kilometers to achieve the cooling necessary for dimensional stability. Once a plastic profile increases beyond two inches in thickness, this new flow mold system is most likely the process of choice.

Tie Tek (Houston, Texas) and U.S. Plastic Lumber (Ocala, Florida) have qualified railway ties made on the SPS system through extensive testing at the Railway Test Center in Pueblo, Colorado. Plastic ties meet all the requirements for wood ties, but do not require the use of toxic preservatives and are expected to have at least double the lifespan. It is estimated that 18 million railway ties are replaced each year in North America. SPS Inc. is also the equipment supplier to Nova Plastics Products Inc. in Newfoundland, which produces large timbers for marine applications.

2.3 Fibreglass-Reinforced RPL Production

This technology can be used to produce structural components and has a growing list of applications, including: deck joists; marine break walls, bulkheads and pilings; railway ties; and more demanding structural components. U.S Plastic Lumber is the largest producer of this type of material and some is produced under license from Rutgers University. It may be advantageous to place the glass fibre in the outer region of an extruded profiler to maximize stiffness and maintain toughness. A demonstration project (designed by M. G. Maclaren Engineering, for the New York Department of Economic Development) uses fiberglass-reinforced RPL in an arched bridge. The bridge constructed in New Baltimore N.Y. has met the design criteria for load; the tests included driving a heavy truck onto the structure and measuring deflection under load.

A polypropylene-composite sheet, manufactured by Elf Products Inc. (Euclid, Arizona), has successfully replaced marine plywood in new boat manufacture. The product is a compression-molded composite composed of polypropylene, glass fibre and cellulose fibre (that is a combination of wood, long fibre flax and kenaf). This new product, under the brand name *All-A-Board*, is being used by SEA RAY in the manufacture of fibreglass boats. It resists rot better than marine plywood and bonds well to fibreglass. It can be used for bulkheads, transoms, decks and backing plates.

2.4 PVC Extrusion Profiles

These profiles are being used in railing and deck board markets. The American Architectural Manufacturers Association is working with ASTM on standards that cover PVC products. At least 14 companies extrude PVC deck boards and railing components. Royal Plastics (Woodbridge, Ontario) offers a complete line of vinyl decking systems in Canada. If fire retardancy is required, then PVC extrusion profiles have an advantage over other plastics (that might require heavy doses of flame retardant to meet flammability requirements).

2.5 Woodfibre–Plastic Composites

WPCs are the largest and fastest growing segment of the recycled plastic lumber market. In the early 1990s, products were commercialized using mixtures of polyethylene and wood to manufacture deck boards and other wood replacement products. They were manufactured with mixtures of 50 to 70 percent woodfibre and 30 to 50 percent polyethylene, either high or low density PE or mixtures of the two polymers. The extruded deck boards and profiles exhibit higher modulus than pure polymer products (such as those made from HDPE) and can be painted and stained as wood. They are offered in natural colours that age to a gray shade similar to aged cedar, but can also be manufactured with blue, gray or red pigments that simulate the popular wood deck stains. The major manufacturers in this sector are the Trex Company and AERT. In recent years, a series of new composite products have been developed that use a wider range of polymers including polypropylene polystyrene, ABS, and PVC. Other natural fibres have been used, in addition to woodfibre, including rice hulls, flax and even straw.

The most widely used raw materials for these composites continue to be polyethylene bags and films, including high and low density polyethylene and waste woodfibre. The cost of these raw materials has tended to be lower than the cost of virgin HDPE, providing a manufacturing cost advantage to the composite board stock over the pure polymer extrusions. Despite the cost disadvantage, some companies are opting to use virgin polymers of higher modulus (including PP, PS, and ABS) to meet certain property and appearance specifications. The higher polymer costs are offset, to some degree, by designing engineered profiles that reduce weight while maintaining board stiffness.

2.6 Oriented Woodfibre-Polymer Composites

Dramatic improvements in flexural strength and flexural modulus have been demonstrated by cold drawing extruded polypropylene-wood composite. The flexural modulus of an oriented polypropylene composite with 30 percent woodfibre can achieve 82.5 percent of the flex modulus of dried pine. The same material had a flexural strength that was more than double that of pine. While not yet produced on a commercial basis, this new class of woodfibre-polymer composites shows great promise by offering a dramatic improvement in performance.

2.7 Polymer/Polymer Systems

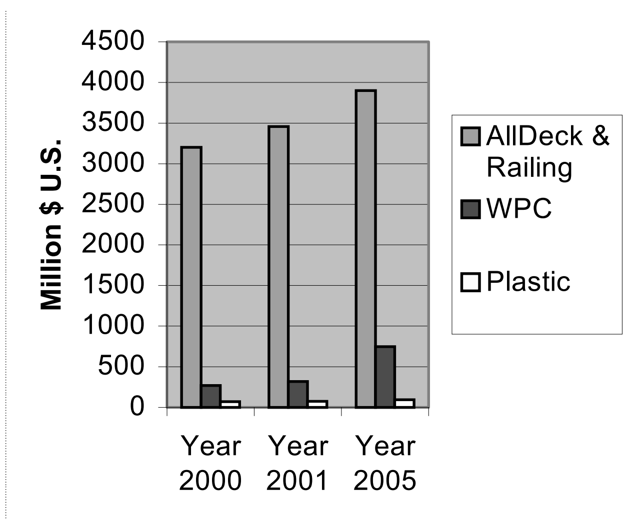
This is an interesting new technology developed by Rutgers University, which discovered that specific blends of polymers, normally thought to be incompatible (such as polyethylene and polystyrene), can form composites with properties that dramatically exceed the expected performance of the blend. Under the right conditions of mixing and component levels, an inter-penetrating network of the polymer can achieve a better balance of modulus and impact strength. This discovery is being successfully applied to the manufacture of railway ties by Polywood, a New Jersey manufacturer of composite RPL.

3.0 Current Markets And Growth Potential For RPL And WPC

It has been forecast that the growth in WPCs will continue at a rate that would double current market size by 2005. This would take market share of WPC from more than 11 percent up to 22 percent of the total North American decking market, with a total value of $750 million (US). This growth will be driven, in part, by the phase-out of chromated copper arsenate (CCA) from pressure treated lumber. At the same time the pure polymer portion of the plastic lumber market is expected to experience slower growth increasing to $95 million (US).

The Plastic Lumber Trade Association has tracked the markets for the pure polymer plastic lumber manufacturers in its annual *State of the Plastic Lumber Industry* reports. Data from these reports are shown in Table 2 below. While the 2001 report had not yet been issued when this report was prepared, indications are that sales in 2001 were flat at about $80 million (US). It is interesting to note that sales of railway ties were in the range of $2-4 million (US) and doubled each of the three years reported.

Figure 3.1
North American Residential Deck Markets, 2000-2005



After a decade of strong growth, the economic slow-down in 2001 resulted in the first cutbacks in production by the industry leaders. Trex and U.S. Plastic Lumber both shut down or suspended capacity to reduce inventory. AERT reported a 20 percent sales increase in 2001 (to $33.2 million US) and a profit of $312,000. Meanwhile, Trex Co. has reported 1st quarter 2002 sales of $52 million (US), up 23 percent from 1st quarter 2000, with a net income of $6.4 million for the quarter. Trex has also reduced finished goods inventory by 50 percent from the beginning of the year (the company had cut production by as much as 60 percent in order to reduce inventory).

Table 3.2
North American Markets for Recycled Plastic Lumber, 1998-2001

	1998	**1999**	**2000**	**2001**
Total sales ($millions US)	$50-70	$60-80	$70-90	$80
Market segment				
Parks & recreation	40-60%	30-40%	20-30%	--
Decking	20-30%	30-40%	30-40%	--
Agricultural/industrial	20-30%	20-25%	20-25%	--
Marine	5-15%	5-15%	5-15%	--
Materials handling	2-5%	2-3%	1-2%	--
Fencing	1-5%	1-5%	1-2%	--
Railroad ties	0-1%	1-2%	2-4%	--

Reference: table lists data presented in Annual State of the Plastic Lumber Industry reports for 1998,1999 and 2000; the 2001 estimate is based on data discussed at the 2002 annual meeting of the Plastic Lumber Trade Association

4.0 Opportunities in Canada

4.1 Existing Canadian Manufacturers & Products

The penetration of plastic lumber or WPCs in the Canadian deck market is still in its early stages. It has been reported that plastic lumber has captured just two percent of the Canadian market (*Canadian Plastics*, May 2002), as compared with more than 11 percent of the U.S. market. In the past two years, however, there have been a number of start-ups of Canadian plastic lumber and wood-fibre plastic composite operations in Canada. The main focus has been on the production of deck board and railing systems, with some manufacture of fence systems. The current trend in Canada has been to manufacture woodfibre composites with virgin polymers, using HDPE, polypropylene, polystyrene, and vinyl. A variety of engineered profiles are employed to reduce weight (and polymer cost), and to hide screw fasteners.

4.2 Key Canadian Suppliers

Alternative Plastic Product Manufacturing of Red Deer, Alberta, manufactures fence posts and 4x4s using the flow mold process. Raw material is primarily HDPE bottles and smaller amounts of PE film.

Amity Plastics Ltd. of Clyde, Alberta, manufactures posts and parking curbs using cleaned flake from recycled HDPE herbicide and oil bottles in a unique molding process.

Boise Cascade of Seattle manufactures polyethylene-wood composite siding by continuous extrusion. They use PE film plastic purchased in the Northwest U.S. and Western Canada from a combination of curbside collected PE film, IC&I film (stretch wrap) and store depot HDPE & LDPE films. This is a large new start-up in the plastic-wood composite industry and is likely to have a major impact on recycling PE films in Western Canada. PE film purchases and the start-up of film recycling programs are handled by Marathon Recovery. They have been successful in starting up curbside collection of PE films in Seattle.

Brite Manufacturing Inc. of Bolton, Ontario, manufactures deck boards and railing systems under the trade mark *Life Long Decking*. They extrude profiles using virgin HDPE and polypropylene in combination with woodfibre.

Canadian Plastic Lumber of Lindsay, Ontario, manufactures plastic lumber board stock using a flow mold process. They utilize film plastic and HDPE

Composite Building Products International Inc. (CPBI) of Barrie, Ontario, manufactures deck boards and railing systems under the trade name *Xtendex*. Their composite contains rice husks as the natural fibre and virgin HDPE. *Xtendex* is sold at Home Hardware, Rona, and Lansing Build-all stores.

CPI Plastics Group Ltd. of Mississauga, Ontario, offers a complete decking system under the trade name *Eon*. The product is a composite of virgin polystyrene and wood extruded in profiles.

ELB Construction of Frankford, Ontario, manufactures a line of products using recycled plastic lumber. These include channel spacers for signs, portable road signs, mail box support bases, composters, bird feeders, etc.. Plastic board stock is purchased from companies such as Canadian Plastic Lumber.

Envi Technologies Inc. of Langley, BC, manufactures plastic lumber using the Superwood flow mould process. They use mixed plastic, including HDPE and PE film plastic.

Everwood Agricultural Products of Tilsonburg, Ontario, manufactures agricultural fence posts using HDPE recovered from herbicide containers.

GSW Thermoplastics Co. of Barrie, Ontario, manufactures a line of vinyl railing systems and fence systems under the trade name *Yardcrafters*.

Impact Products / Xpotential Products in Regina and Winnipeg manufacture composite landscape timbers, parking curbs and posts using a novel mixture of 75 percent auto-shredder residue and 25 percent recycled polyethylene, including film plastic.

Nexwood Industries Ltd. of Brampton, Ontario, manufactures a line of deck boards and railing systems under the trade name *Nexwood*. The company extrudes profiles using natural recycled HDPE and woodfibre. They purchase recycled natural HDPE that has been washed, dried, remelted and filtered.

Nova Plastic Products Inc. of Corner Brook, Newfoundland, manufactures large cross-section plastic timbers for ferry bumpers and other marine applications using the SPS flow mold process. While not highly automated, Nova is an important consumer of PE film and mixed plastic in the Maritime provinces.

Royal Plastics Inc. of Woodbridge, Ontario, offers a deck and railing system under the trade name *Royal Deck*. Their systems are made from compounded extruded vinyl profiles. Royal manufactures a range of building products that include woodfibre-plastic composites in window and door casings and roofing shingles.

Syntal Products Ltd of Victoria and Saanichtin, BC, manufactures plastic lumber, under the trade name *Altwood*, using the flow mold process supplied by JET in Belgium. They use mixed plastic, including HDPE and PE film.

The **Trex Company** of Virginia has opened a PE-wood composite manufacturing operation in Nevada and are now purchasing in Western Canada. This operation does not have a wash process and will likely purchase mainly store depot collected PE films and IC&I films, such as stretch wrap. The Virginia operation of Trex is currently starting up a wash process and this should allow them to purchase curbside collected films from Eastern Canada.

5.0 Product Standards

5.1 ASTM Standards

Over the past five years, a number of ASTM standards have been issued to define test procedures and assist engineers in the design of structures that utilize recycled plastic lumber. The currently issued ASTM plastic lumber standards were developed, primarily, by the Plastic Lumber Trade Association and focus on single polymer RPL. Standards under development will address the properties of polyethylene woodfibre composites, along with structural RPL that uses fibreglass reinforcement.

Table 5.1
Recycled Plastic Lumber (RPL) Engineering Standards

ASTM Plastic Lumber Test Methods:

- D6108-97 Compressive Properties
- D6109-97 Flexural Properties
- D6111-97 Bulk Density & Specific Gravity
- D6112-97 Compressive & Flexural Creep
- D6117-97 Mechanical Fasteners
- D 6341-98 Coefficient Of Thermal Expansion
- D6435-99 Shear Of Boards & Shapes
- E108 Residential Decking Flammability

ASTM Standards In Development:

- X-20-18 Polyolefin Plastic Lumber Deck Boards
- X20-28 Guide For Testing Plastic Lumber
- X20-39 Guide: Plastic Lumber Deck Construction
- X20-43 Specs. For Plastic Lumber Joists
- X20-44 Specs. For PVC Decking
- X20-41a Flexural Properties Of Polymeric Piles
- X20-48 Radial Compression Of Polymeric Piles
- X20-49 Specs For Plastic Lumber In Bulk Head Systems
- X20-51a Specs For Polymeric Piles For Marine Fendering

5.2 Building Codes

While ASTM has begun the task of establishing test methods and engineering standards for recycled plastic lumber and wood-plastic composites, the various building codes in Canada and the U.S. have not begun to address the use of these materials.

In Canada, the federal government sets and maintains the following codes: the National Building Code, the National Fire Code, the National Plumbing Code, the National Housing Code, the National Farm Building Code, and the National Model Energy Codes. The provinces are responsible for enforcement of these standards through municipalities. It is clear that full acceptance of new plastic lumber building materials will require some coordinated action on the part of manufacturers and industry organizations to address building code amendments.

The Canadian Construction Materials Centre (CCMC) in Ottawa, Ontario, is part of the National Research Council. It offers evaluation services for non-standard products not covered by existing building codes. The CCMC is currently evaluating woodfibre-plastic composites for some manufacturers. The CCMC approach is to develop a series of tests that are required to show equivalency to code requirements and to provide these to the client. The client has a product tested and the CCMC evaluates the results. If the client is satisfied with the results, the product is registered as having been evaluated.

5.3 Railway Ties

The North American rail companies use a common test facility in Pueblo, Colorado. Plastic composite railway ties have undergone extensive testing since 1996 and the proprietary compositions offered by two current suppliers -- U.S. Plastic Lumber and Tie Tek -- have been approved as replacements for standard treated hardwood ties. Plastic ties meet the load bearing and curve holding characteristics of wood ties, and have adequate spike holding capability. The plastic composite ties are expected to have double the service life of conventional wood ties. Data and performance reports generated at the Pueblo test facility are shared by all of the major rail companies and the approved plastic railway ties are accepted by, essentially, the entire North American rail industry. The Union Pacific Railway has approved plastic composite ties and is a major buyer. In Canada, both CN and CP have apparently tried composite ties, but do not use them because of the high freight costs associated with shipping the ties from the southern U.S. manufacturers.

6.0 Additives

6.1 Impact of Additives on Long-Term Performance

The pure polymer extruded profiles have performance characteristics that reflect the properties of the polymer used in its fabrication. Stiffness of recycled HDPE is lower than that of a polyethylene-woodfibre composite. The performance issues associated with pure polymer systems center around the colour fastness and UV resistance of the surface of the board stock. A number of studies have shown that UV stabilizers and antioxidants improve performance. It is important to select metal-based pigments for long-term color stability. The organic pigments appear to be less stable during long-term exposure to the sun. The cross-section of extruded profiles is so massive that any UV degradation affects the surface of the extrusion, but has little effect on the bulk properties of the board.

With the woodfibre-polymer composites, there are a number of properties being studied to determine long-term serviceability. Surface degradation effects, selection of pigments and use of UV stabilizers and antioxidants are similar in their effect on performance as they are when added to pure polymer extrusions. Moisture uptake in composite boards is being studied extensively. Absorption of moisture occurs slowly over time. Equilibrium moisture content may take years to achieve. In water immersion tests, the use of maleic anhydride bonding agents appears to reduce moisture uptake.

Finally, the addition of up to 20 percent glass fibre reinforcement will increase modulus significantly. Fibreglass-reinforced polyolefins are currently offered as structural grade components for deck building.

6.2 Categories of Additives

6.2.1 Foaming Agents

These additives are widely used in pure polymer extrusions to reduce the weight of the board stock and to impart a uniform cell or pore structure. Foaming can be accomplished by injecting a gas or by using a chemical that decomposes at the melt extrusion temperature of the polymer. In either approach, the gas must be dispersed and dissolved in the polymer under pressure in the extruder.

Physical foaming agents include isobutane, cyclopentane, isopentane, HCFC-22, HCFC-142b, HFC-134a, nitrogen, and carbon dioxide. By dissolving in the melt during processing, these foaming agents reduce the viscosity of the melt allowing lower processing temperature. When the melt exits the die the pressure drops and the gas expands in the melt creating a cellular structure.

Exothermic chemical foaming agents include azodicarbamide (ADC), modified ADC, 4,4-oxybis(benzinesulfonylhydrazide) (OBSH), 5-phenyltetrazole (5-PT), p-toluenesulfonyl-semicarbazide (TSS), and p-toluenesulfonyl-hydrazide(TSH) . These compounds decompose and produce additional heat that requires additional intense cooling to remove.

Endothermic chemical foaming agents include sodium bicarbonate and citric acid. These compounds require heat from the process to sustain the reaction. At approximately 120 C the evolution of gas begins. The evolution is slow and homogeneous and stops if the temperature drops below 120 C.

The most commonly used foaming agent is azodicarbamide. While primarily used in pure polymer extrusion, it is increasingly being used or evaluated for use in wood polymer composites.

6.2.2 Coupling Agents

Recent studies show that properties of woodfibre-polyolefin composites can be improved by the addition of coupling agents. The most widely used coupling agents are maleic anhydride (MA) and acrylic anhydride (AA), with MA being the preferred additive. Addition of polyethylene-MA concentrates increases tensile strength, flexural strength and impact strength significantly. Water absorption is reduced by up to 50 percent and properties after moisture aging are improved. Modulus or stiffness does not improve with the use of coupling agents.

6.2.3 Extrusion Aids

Extrusion aids have proven to be very beneficial in woodfibre-plastic composites. To minimize burning and discoloration of the woodfibre, extrusion temperatures must be kept as low as possible. Polyolefins are typically extruded above 200 C, but in the case of WFP composites, extrusion temperatures are best kept well below this level. At these lower temperatures, extruder throughput is compromised. Use of an effective lubricant will increase throughput and reduce zone temperatures and also reduce melt fracture that can result in surface defects. Most commonly used extrusion aids are metallic stearates and waxes, such as zinc stearate and Acrawax or combinations of the two. The use of foaming agents will also reduce temperature and improve throughput.

6.2.4 Anti-oxidants

All of the polymers used in recycled plastic lumber or woodfibre-plastic lumber undergo thermal degradation at the elevated temperatures used to extrude profiles. All of these polymers are supplied with anti-oxidants to improve thermal stability. When recycled polymers are used, the antioxidants will be somewhat depleted compared to virgin polymers. Two classes of antioxidants -- hindered phenols and organo-phospates -- are commonly used in combination to stabilize polyolefins. Additive packages are available to boost depleted levels in recycled polymers from Ciba Geigy. The most widely used combination is a mixture of Ciba Geigy's Irganox 1010 and Irgaphos 168. Specially formulated blends of these antioxidants in pellet concentrate form are available from concentrate compounding suppliers. Testing of raw materials and the selected formulation can be done to determine whether addition of anti-oxidants will help final product properties.

6.2.5 UV Stabilizers

Exposure to ultraviolet (UV) light will cause changes in colour and surface gloss in recycled plastic lumber or woodfibre-plastics composites but does not appear to affect the overall properties of extruded profiles (because of their massive cross-sections). Some products are allowed to age naturally to take on the natural color of the wood fraction of the composite. The use of commercial UV stabilizers (that have been used extensively by the plastics industry for outdoor applications) are effective in retaining gloss and colour with the common blue and red pigments used in deck boards to simulate popular deck stains. It is also important to use inorganic pigments that are light stable compared to organic or synthetic pigments. Ciba Giegy is the largest supplier of UV stabilizers and they are readily available as concentrates from a number of concentrate suppliers.

6.2.6 Flame Retardants

Most recycled plastic lumber or woodfibre-plastic composites are sold without the addition of a fire retardant. The residential deck market does not appear to incorporate flame retardants in current products. Where a flame retardant is required in a window or door casing, PVC-based composites may have an inherent advantage. California has raised the fire issue with plastic lumber decks due to the wild fire problems in that state. This has revived interest in flame retardant packages for plastic lumber or composites. Flame retardant additives have been developed for a range of plastic products and can be formulated and adopted for the plastic lumber products if required. Commonly used flame retardants include chlorine and bromine retardants, halogen-antimony synergistic systems, phosphorus-based retardants, and inorganic flame retardants.

7.0 Manufacturing and Facility Costs

In the early 1990s, the plastic lumber industry in North America was based on the use of recycled plastics. Today, the industry is divided between those companies extruding foamed HDPE profiles and those manufacturing woodfibre-polyethylene composites. The plastic-wood composite products make up about 80 percent of the plastic lumber produced, while the pure polymer sector is responsible for about 20 percent (which includes the smaller niche products such as railway ties and marine applications.

In this section, a series of hypothetical process flow sheets and capital/operating budgets are presented in order to describe the two primary plastic lumber processing systems -- the manufacture of woodfibre composite deck boards from recycled PE film, and the manufacture of pure polymer plastic deck boards from recycled HDPE milk jugs -- as well as a new flow mold system designed to produce large dimension plastic timber products from curbside collected film, whole carpet, and mixed or contaminated rigid plastics. In addition, the first two manufacturing systems each incorporate a pre-wash system for preparing the feedstock, which is also described, followed by the continuous extrusion of the finished product. This section concludes with a comparison of the capital and operating costs associated with each of the three systems.

7.1 Woodfibre-Plastic Composites

In this section, a hypothetical process flow sheet is outlined for the manufacture of woodfibre composite deck boards from recycled film plastic collected from curbside sources in Canada. The process includes a baled PE film wash process followed by continuous extrusion of finished product.

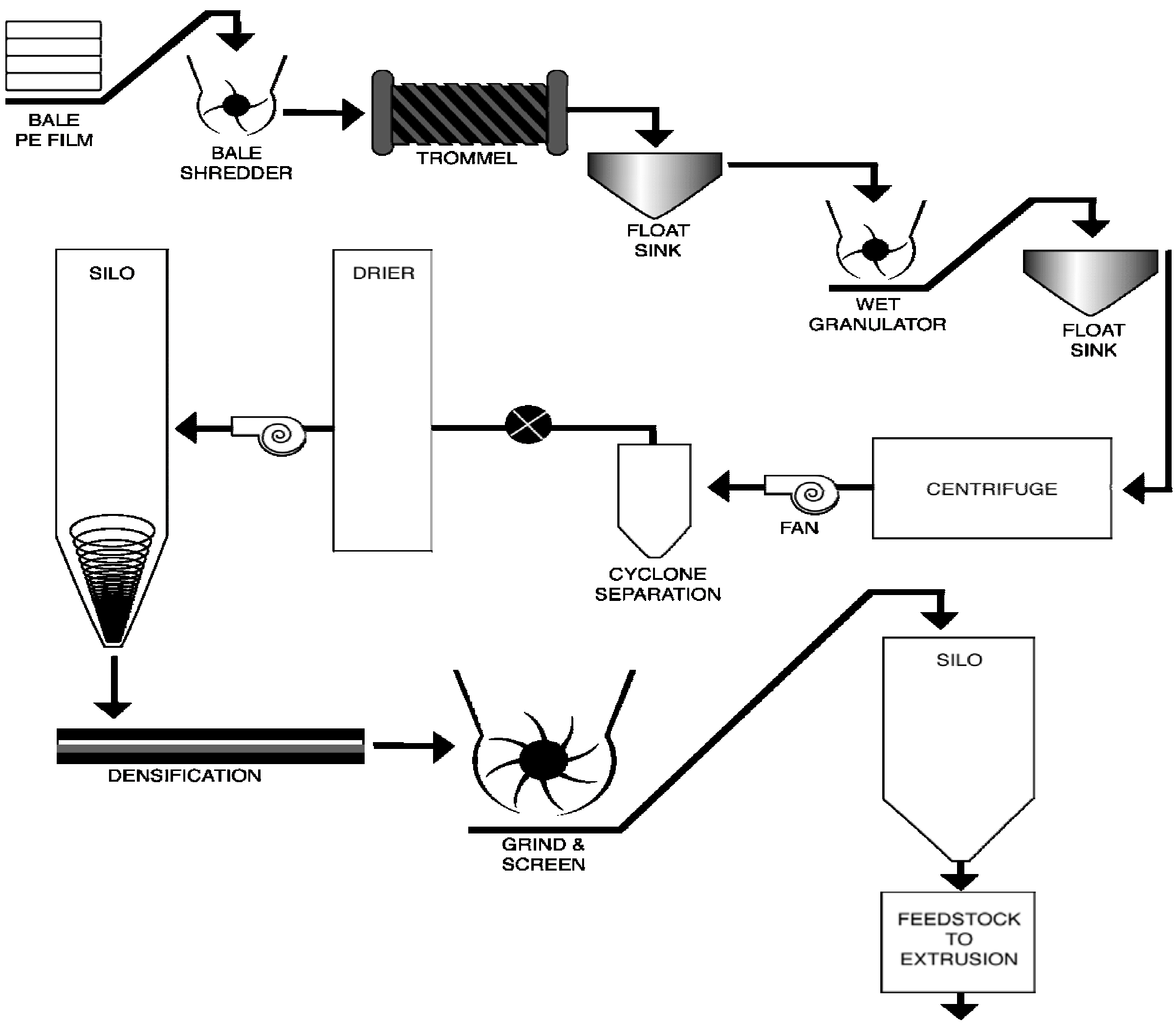
Polyethylene film, either high density or low density polyethylene or mixtures of the two types, is the major raw material used in woodfibre-polyethylene composites. Grocery store carryout sacs, collected in store depot recycling programs, have been widely used for woodfibre-plastic composites. Finding a use for recycled PE bags was the main driver for the development of PE-wood composites by Mobil in the early 1990s. The Mobil operation later became the Trex Company.

Another major source of polyethylene is stretch wrap recovered from pallet wrapping and unwrapping at distribution centres. Both sources can be used in the manufacture of composites without washing, provided they are kept reasonably clean when they are captured and provided the main contaminant is limited to paper. Clean polyethylene film can be fed into the composite process directly or densified prior to extrusion with wood flour.

7.1.1. PE Recycling and Wash Processing

As the supply of clean PE film sources are depleted, more contaminated streams of recycled plastic bags are being used in PE–woodfibre composites. In Canada, curbside plastic bag recycling is being practiced by communities in Ontario, Quebec and the Maritimes. In the past, these streams could be used in the composites process if care was taken to keep the contamination level low during collection. Wash processing of PE film should allow a wider range of plastic bags and films to be recovered as the cleaner sources are consumed. A typical wash recycling process is described below, along with the estimated construction and operating costs. The process is also capable of recovering agricultural film and other contaminated streams. The use of low-cost woodfibre and low-cost PE film has given the composite plastic lumber manufacturers a cost advantage over the recycled HDPE foamed plastic lumber producers.

Figure 7.1
PE Film Wash Process



A typical PE film wash recycling process would begin with a bale conveyor feeding a bale shredder. The cost estimates shown below are based on data supplied by a recycling systems supplier. A generous capital cost has been added for water treatment and this may vary depending on location and local regulation. Film recycling systems are available from full system suppliers or may be assembled by selecting unit operating equipment from the suppliers listed in Appendix II of this report. These estimates are intended as a general guide. Any individual or company interested in the design and installation of a similar system should work directly with suppliers and experienced designers who can assure delivery of the desired productivity, product quality and costs to meet their particular needs.

Table 7.1
Generic PE Film Recycling Process to Produce Feedstock

Unit Operations	**Purpose**
Feed belt	Load bales to feed process
Bale shredder	Cut bales into free flowing blocks; open material for contaminant removal
Trommel	Separate and loosen material; provide continuous flow to system
Float/sink tank	Separate heavy materials, such as wire, glass, stones and metal
Wet granulator	Cut material to allow for further separation; scrub plastic surfaces to aid in separation of fibre
Auger feeder	Material feed downstream
2nd Float/sink tank	Separate heavy contaminants, including PVC, PET
Horizontal centrifuge	Separate water from plastics; separate fine particles of fibre, etc.
Feed to cyclone	Transport plastic to cyclone and separate plastic from air stream
Rotary air lock	Meter plastic to next stage
Screw press	Dewater with mechanical force
Auger feeder	Transport plastic to drier
Rotary air lock & fan	Meter material to drier
Rotary air drier & fan	Dry recovered plastic film
Silo & screw feeder	Provide surge between unit operations & feed agglomerator
Continuous densifier	Densifiy dried film
Melt grinder	Cut material to desired size
Fan to silo	Convey, cool and store densified film

Table 7.2
Capital Costs of Film Recycling Process
(Cdn $ 000)

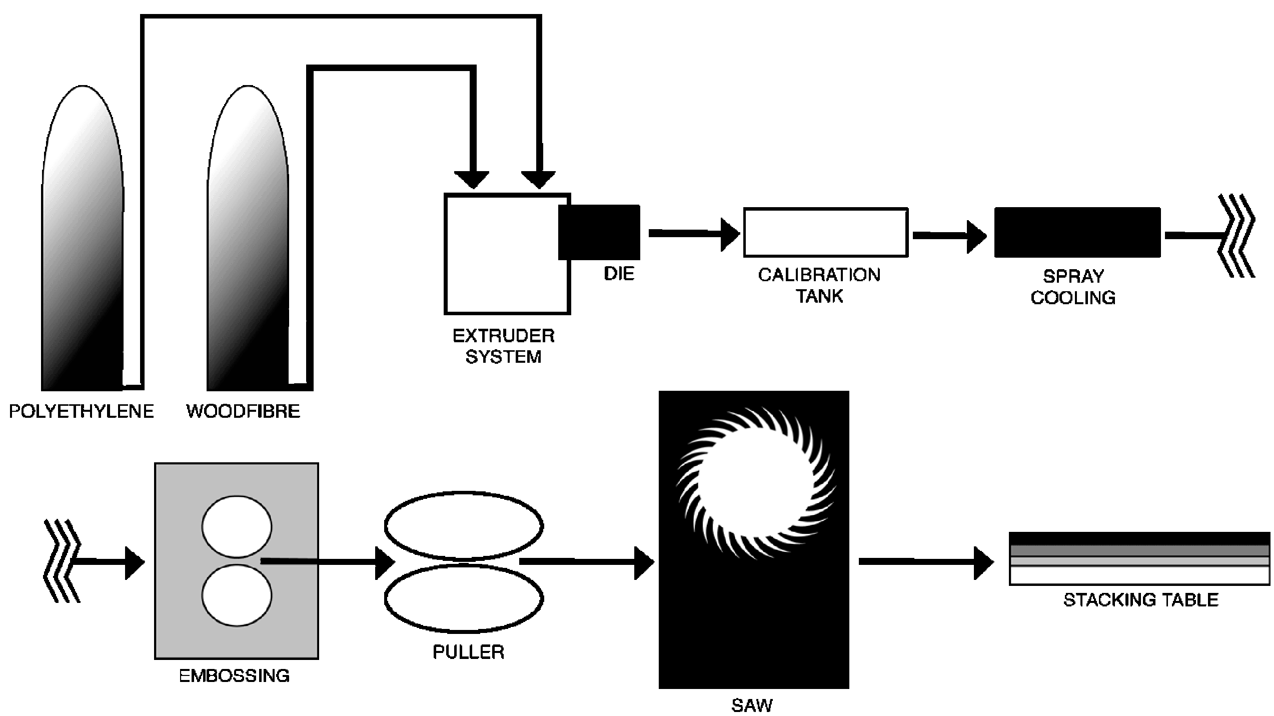
	900 kg/hr capacity	**3000 kg/hr capacity**
Equipment cost	3,680	7,288
Freight/duties	405	800
Installation	800	960
Wastewater treatment	2,400	3,200
Auxiliary equipment	1,280	1,600
Contingency (10%)	960	1,280
Total capital cost	9,525	15,128
Annualized capacity (tonnes @ 80% utility)	6,000	20,000

Table 7.3
Operating Costs of Film Recycling Process
(per kg)

	6,000 tonne/yr	20,000 tonne/yr
Total staff	12	20
Cost of staff (@ $35,000)	0.07	0.035
Electrical cost ($0.06/kwh)	0.053	0.056
Water usage	0.01	0.01
Landfill	0.013	0.013
Maintenance	0.05	0.023
Building (5$/ft)	0.004	0.004
Depreciation over 10 years	0.158	0.076
Operating cost ($ /kg)	0.358	0.217

Suggested selling price fob composite manufacturer $0.50-0.60/kg (Cdn.)

Figure 7.2
Typical Engineered Composite Process System Production Line

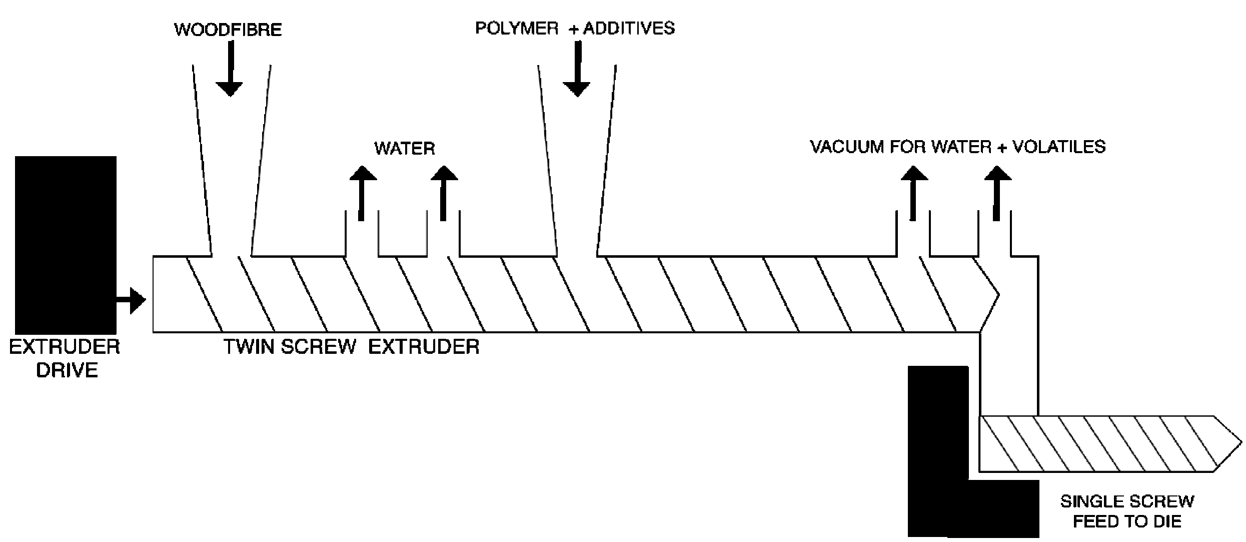


7.1.2 Woodfibre-Polyethylene Composite Extrusion Process

Wood-plastic composites are being manufactured on many different types of extruders including single screw, twin screw, parallel and conical, counter and co-rotating and tandem extruders. The process configuration is specifically designed to compound the woodfibre and provide sufficient mixing to disperse it effectively and uniformly in the polymer. A key issue is the drying of the woodfibre to eliminate moisture and volatiles from the final mixture. The wood flour is generally pre-dried, but some of the process configurations have an extruder section for drying woodfibre before introducing the polymer. Even if the woodfibre is pre-dried to one percent, a venting and pulling vacuum is required to eliminate surface defects and roughness. The major extrusion system suppliers now offer complete extrusion systems for woodfibre-plastic composites. See Appendix II for a list of extrusion suppliers

A typical extrusion process would incorporate in-line drying for woodfibre that then feeds the compounding section of the process. The process has two extruders, a twin screw for drying and compounding and a single screw for pumping. The twin screw extruder has two functions. The first operation is to dry the fibre material, typically wood flour, down to an acceptable moisture level to effectively compound polymers with organic materials. The second portion of the processing section will melt and completely homogenize the polymer, wood flour, and additives. Complete encapsulation and infusion of the cellulose material occurs in the second operation in the process section of the twin screw extruder. The compounded material is gravity dropped to a pumping device. A single screw extruder is used to create even, consistent pressure and material flow to the profile die. The combination of these operations, twin screw compounding leading to the single screw pump, can process a wide range of formulations containing up to 65 percent wood flour.

Figure 7.3
Typical Woodfibre-PE Composite Extrusion Process



This processing technique takes advantage of twin screw technology in two distinct functions. Mechanical energy is induced into the cellulose material and separates moisture from woodfibre. Two atmospheric vents are used to expel moisture. The second process completes compounding of the primary polymer and the dried cellulose material using co-rotating twin screws that provide a homogeneous mixture to the melt pump. A vacuum is used to remove further moisture and volatiles from the compounding section and the transition between the compounding and pumping extruders.

This woodfibre-PE composite production line begins with wood flour fed either from bulk bags directly to the extruder or, in the case of the larger throughput lines, a silo feed system. The extruder dries the wood flour and feeds it forward to a mixing section. The densified or pellet plastic feedstock would also have a storage silo and feed system. Both the wood flour and plastic pellets are fed through a weigh blend system for accurate control of composition by weight. At the exit of the die, the board stock passes through a calibration tank to a spray cooling section. An embossing station may be added to improve product appearance. The haul-off station continuously pulls finished board stock and feeds it to a cut-off table, which is followed by a stacking table.

Table 7.4
Cost Of Composite Manufacturing Process

Throughput rate	Budget Price: Extrusion System	Budget Price: (Feed system, silo, die, cooling haul-off, cutter system, stacking table)	Total
540 kg/hr	$990,000	$1,400,000	$2,390,000
900 kg/hr	$1,270,000	$2,000,000	$3,270,000
1800 kg/hr	$1,750,000	$2,000,000	$3,750,000

Table 7.5
Capital Cost Of Manufacturing Woodfibre-PE Composite Deck Boards
(Cdn. $000)

	Capacity 1540 kg/hr	Capacity 6000 kg/hr
PE Film Recycling		
900 kg/hr	$9,525	--
3000 kg/hr	--	$15,128
2 Extrusion systems (770 kg/hr each)	$10,400	--
8 Extrusion systems (770 kg/hr)	--	$41,600
Annual capacity	9,253 t/yr	37,013 t/yr
	13,600,000 ft/yr	54,400,000 ft/yr
Total capital costs	**$19,925**	**$56,728**

Table 7.6
Operating Costs of Woodfibre Composite Manufacturing
(1x5 hollow deck boards)

Capacity (ft per year)	**13,600,000**	**56,728,000**
PE baled film (50%) ($/kg)	0.03	0.03
Recycling cost PE film (50%) ($/kg)	0.18	0.11
Additives	0.09	0.09
Cost of woodfibre (50%) ($/kg)	0.21	0.21
Depreciation on extrusion	0.11	0.11
Electrical cost extrusion	0.08	0.08
Operators (8/extruder @$35,000)	0.06	0.06
Maintenance	0.06	0.06
Building	0.01	0.01
Cost per kg ($)	0.83	0.76
Product unit weight (kg/ft)	0.68	0.68
Cost of deck board ($/ft)	0.56	0.52

7.2 Manufacturing Process For Pure Polymer Plastic Lumber

In this section, a hypothetical process flow sheet is outlined for the manufacture of pure polymer plastic deck boards from recycled HDPE milk jugs from curbside collection or deposit programs in Canada. The process includes a baled PE bottle wash process, followed by continuous extrusion of finished product.

HDPE is the material most widely used in single polymer extrusion. The most common source of recycled HDPE is natural milk bottles. These can be processed by a multi stage process that grinds sorted bottles, followed by washing, drying, re-extrusion and filtration. This provides a consistent source of natural high density polyethylene that can be pigmented and coloured to provide excellent esthetics in the recycled plastic lumber produced.

A typical HDPE recycling system for natural milk jugs begins with manual bale breaking, followed by final manual sorting to remove coloured bottles. The loosened material is fed past a metal detector. The material then passes through a wet granulator that generates a flake of specific size and assists in cleaning and the separation of adhered materials. The flake is fed to a friction washer followed by a float/sink tank. A mechanical dryer removes most of the water and the flake is then further dried using heated air. The flake can then be melt extruded, filtered and pelletized. If the source of bottles is relatively clean, it may be possible to extrude plastic lumber using cleaned flake without re-extrusion. See Appendix II for suppliers of plastic recycling equipment.

Figure 7.4
HDPE Wash Recycling Process

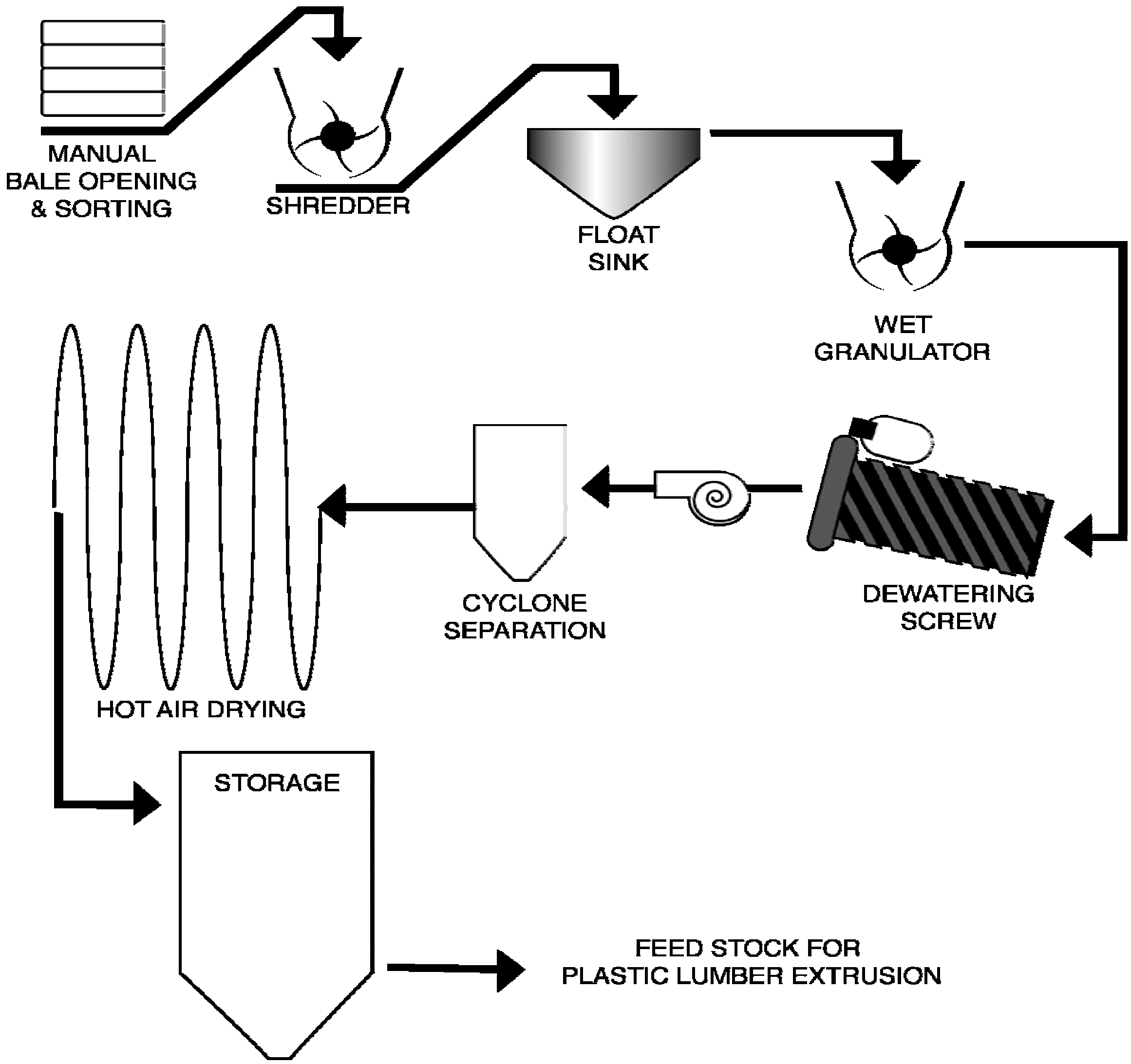


Table 7.7
Capital Costs of HDPE Wash Process
($ Cdn)

Item 1	1 Inclined conveyor belt	19,477
Item 2	1 Metal detector	14,595
Item 3	1 Granulator	80,748
Item 4	1 Blower system	14,007
Item 5	1 Pre-separation screw	44,097
Item 6	1 Intensive washer	63,916
Item 7	1 Blower system	25,182
Item 8	1 Separation tank	123,294
Item 9	1 Mechanical dryer	63,916

Item 10	1 Blower system	25,321
Item 11	1 Thermal heater	91,817
Item 12	1 Blower type	8,081
Item 13	1 Electric control cabinet,	78,234
Item 14	Steel construction, piping and channels.	15,967
Total machinery price		668,795
Item 15	Installation package	35,917
Item 16	Freight	24,489
Wastewater treatment		375,000
Total Capital Cost		1,104,200

Technical features of the system

Installed power:	285 kW
Installed thermal heating:	3 x 30 kW
Estimated power usage (approx.)	80% of the installed power
Water usage (approx.)	2-3 m^3/h
Required service air (approx.)	200–300 L/h
Pressure of the service air	6 bar
Required area (approx.)	30 x 10 m
Final purity	> 99% of cold water solvent contaminants.

Table 7.8
Operating Costs of HDPE Wash Recycling Process
(per kg in $ Cdn.)

System capacity	6,000 tonne/yr
Total staff	16
Cost of staff (@ $35,000)	0.09
Electrical cost ($0.06/Kwh)	0.013
Water usage	0.01
Landfill	0.013
Maintenance	0.03
Building (5$/ft)	0.004
Depreciation over 10 years	0.02
Operating cost ($/kg)	0.18

A typical manufacturing facility for HDPE plastic lumber would utilize the process layout shown below in Figure 7.5.

The HDPE flake produced in the wash process would be fed from a silo to a weigh blend system that would add foaming agents, pigment and any other additives required. The blended components would be hopper fed to a single screw extruder capable of mixing the colours and other additives and feeding the melt through a die. The extruded profile would pass through a calibration tank and a spray cooling section, followed by an embosser. The profile is moved through the system by a puller that passes it through a cut-off saw and stacking table.

Figure 7.5
Typical HDPE Plastic Lumber Extrusion System

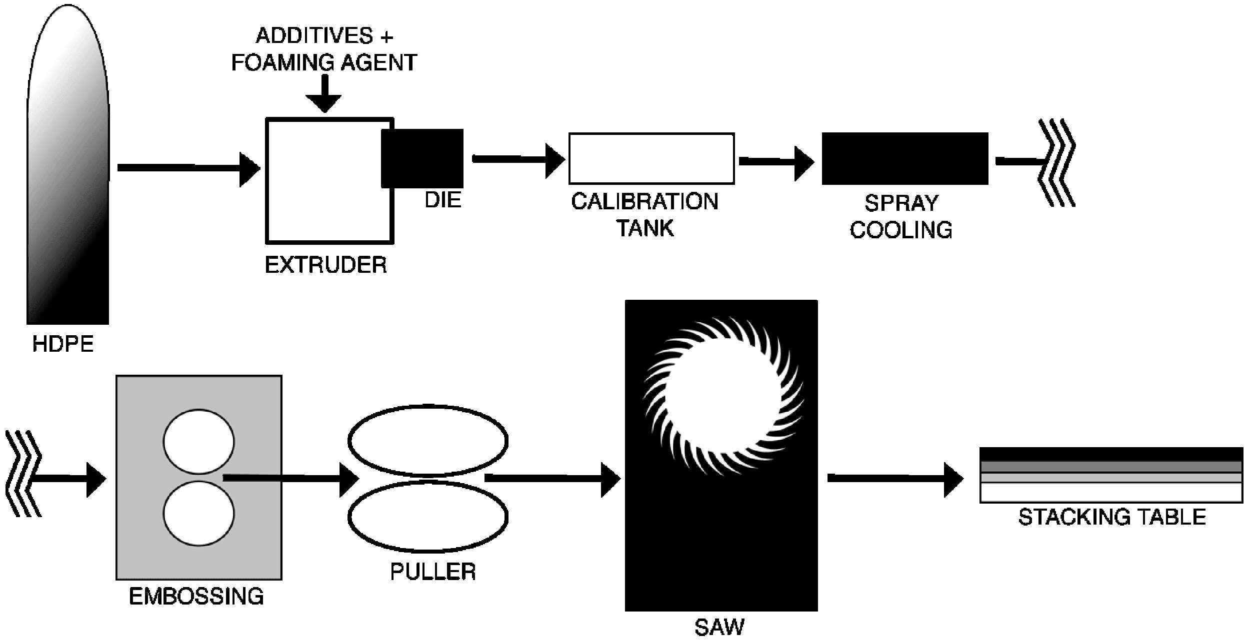


Table 7.9
Budget Prices for HDPE Plastic Extrusion System
(for 1000 kg per hour)

Budget Price Extrusion System (1000 kg/hr)	Budget Price: (Feed system, silo, die cooling haul-off, cutter system, stacking table)	Total
$600,000	$1,500,000	$2,100,000

Table 7.10
Capital Costs of Integrated HDPE Plastic Lumber Manufacturing

System capacity	1000 kg/hr
HDPE recycling system	$1,104,200
Extrusion process	$2,100,000
Total capital	$3,204,200
Annual capacity	6,000,000 kg/yr
	8.820,000 ft/ yr

Table 7.11
Operating Costs of HDPE Plastic Lumber Manufacturing
($ Cdn.)

Baled HDPE bottles ($/kg)	0.40
Wash processing ($/kg)	0.18
Cost of additives ($/kg)	0.02
Depreciation on extrusion system	0.035
Operators for extrusion (8 @ $35,000)	0.056
Electrical cost of extrusion	0.05
Building	0.01
Total ($/kg)	0.751
Cost per foot	0.51

The integrated manufacturing system, with a cost of $0.51 per foot would appear to be an attractive rate and is lower than the cost of manufacturing composite deck boards. This is due to the higher capital and operating cost of the film wash process versus HDPE bottle washing.

7.3 Flow Mold Process for Railway Ties

SPS Inc. of Tilsonburg, Ontario, has developed a new flow mold system designed to produce large dimension plastic timber products. A process description is presented in this report along with estimated capital and operating costs, because the technology offers the potential to recycle curbside collected film, whole carpet, and mixed or contaminated rigid plastics. These plastics currently have very limited markets. If this new version of the flow mold process is successful, it could rapidly increase the recycling rate of mixed or contaminated plastics.

This process layout is typical of the unit operations needed to manufacture railway ties or a range of large diameter plastic composite timbers for landscaping or marine applications. The process can accommodate a range of feedstocks, including baled PE film from curbside collection, mixed plastic bottles, injection grade rigid plastics, and carpet (including the bonded backing materials).

The flowsheet includes a line to process film plastic and/or carpet, as well as a second line for rigid plastics. The PE film/carpet line begins with a bale in-feed conveyor to a bale breaker. This is followed by a single shaft shredder that grinds material to the correct particle size and consistency, and facilitates the separation of contaminants. The ground fluff is accumulated in a storage system that meters material to a pellet mill densifier. This densified material is transferred to a storage silo that supplies one component of feedstock to the extrusion molding process.

A second line accepts baled bottles or injection grade plastics on a conveyor that feeds a bale breaker. The opened free flowing material passes through a pre-shredder. This large

Figure 7.6

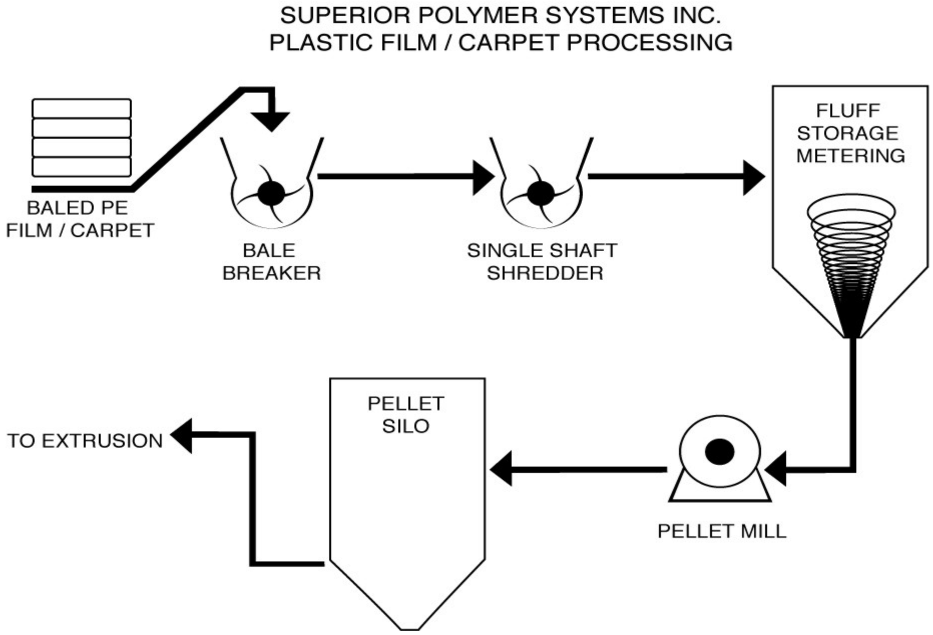


Figure 7.7

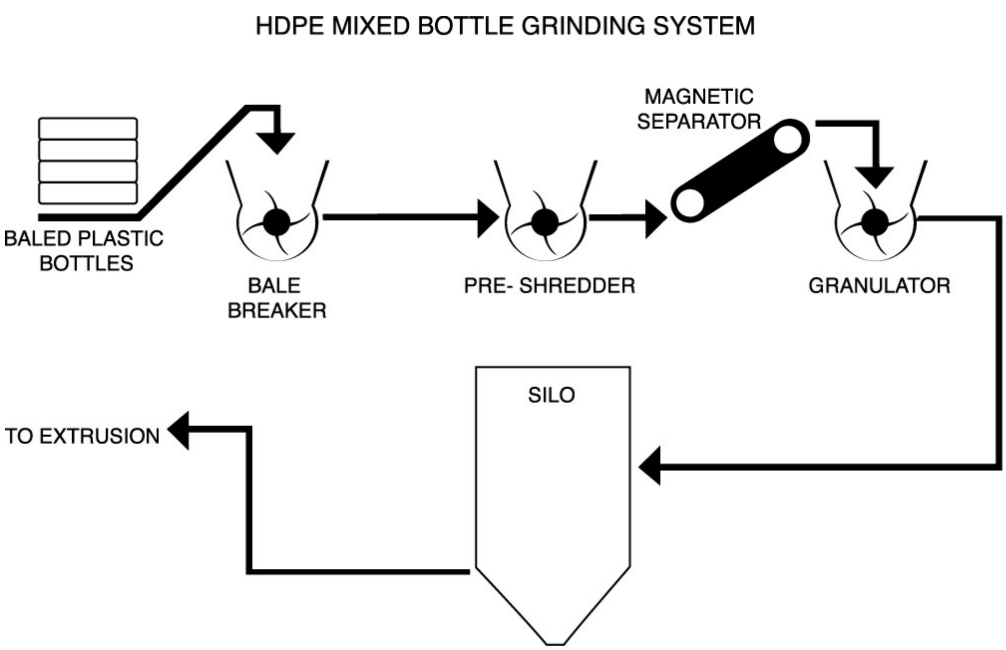
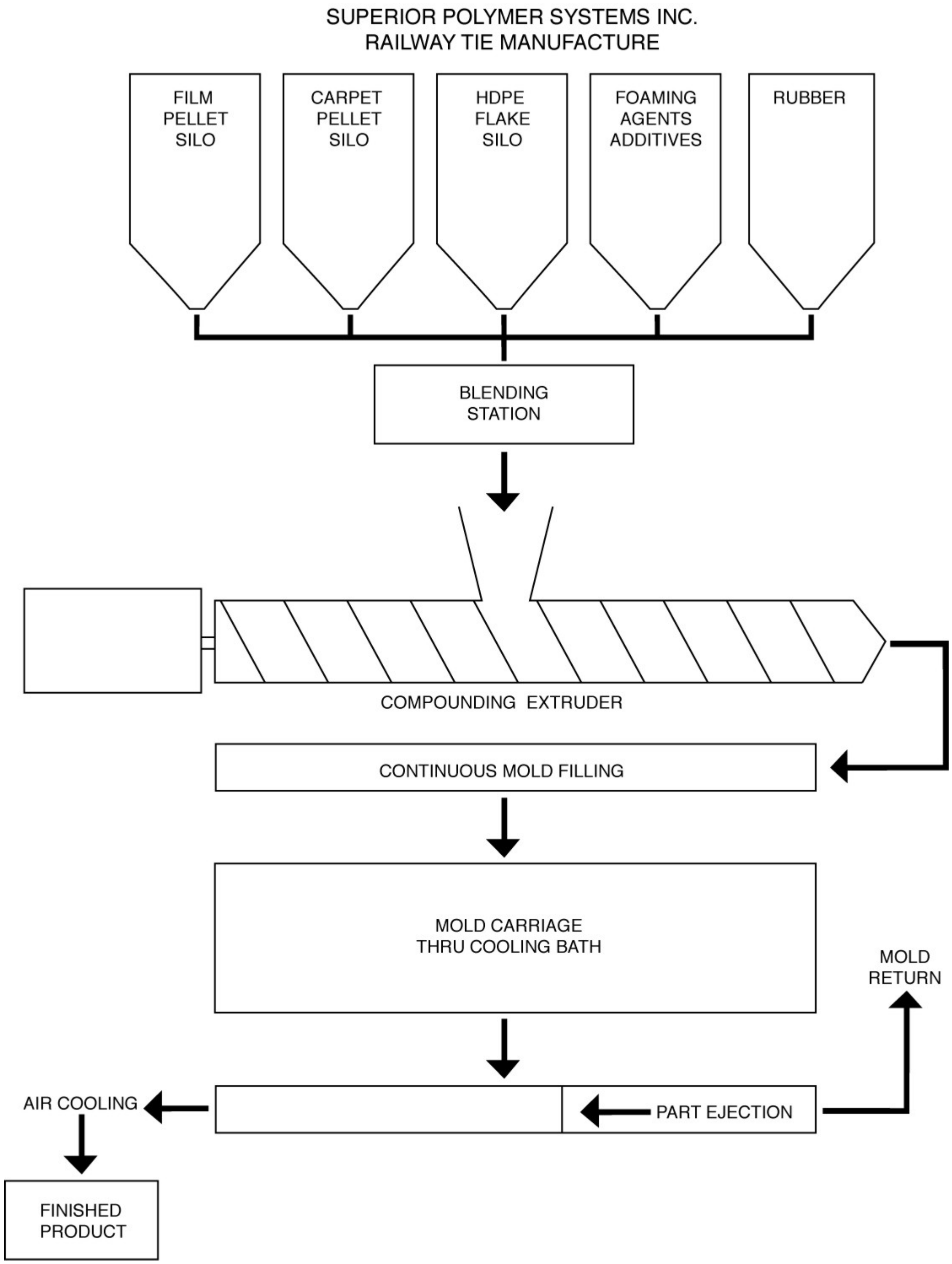


Figure 7.8
Flow Mold Process Flow Diagram



particle material is passed through magnetic separation system and then to a granulator that reduces the rigid plastic to a free flowing flake. Flake is then transferred to a storage silo.

The molding process begins by pre-blending a mixture of densified film plastic or carpet fibre that has been pelletized with film plastic, flaked rigid plastic, foaming agents, additives, and (possibly) ground rubber. The system permits customized blends of a range of materials for different products and specifications. Railway ties would be made with a patented blend of materials (that includes rubber and film plastic or other materials that meet the demanding specifications required by the railways). For products with less demanding performance specifications, such as landscape timbers, the blend would be selected based on a mix of cost and aesthetic factors.

The pre-blended mixture is fed to a compounding extruder that feeds the continuous mold filling station. The extruder is set to run at a constant rate while the polymer mixture is injected in a large single mold through a filling station. The fill station has an automated switching valve that diverts polymer flow from the filled mold to the waiting mold. This is accomplished without altering fill rate and without causing pressure surges in the extruder. The molds are equipped with a compression system that maintains finished part dimension without massive internal voiding. Once filled, the automated carriage system disengages the mold and moves it sequentially through a water cooling bath, which is sized to permit a large number of molds to be held in cooling and accommodate the part solidification/crystallization time that may exceed one hour.

The automated filing and mold carriage will permit molding railway ties at up to one per minute. At the end of the cooling cycle, the parts are ejected from the molds, which are then transferred back to the automated filing station. The parts are further air cooled and rotated to prevent any distortion.

As can be seen from the following tables, a fully automated line to produce railway ties or other heavy plastic composite timbers with a capacity of 15,000 tonnes per year has a capital cost of $5,000,000. The operating cost is just over 23 cents per kg. The current selling prices for railway ties suggest that this should be a very profitable enterprise. It is interesting to note that the operating cost for this finished product is about the same as the cost of the large-scale PE wash process described earlier in this report (with an operating cost of 22 cents per kilogram to clean film plastic for use in wood composites).

Table 7.12
Capital Cost of Flow Mold Process
(to Manufacture Railway Ties & Other Heavy Timbers)
(Capacity of 2500 kg/hr or 15,000 tonnes/yr)

Feedstock Equipment	**Cost ($ Cdn.)**
Film/Carpet Processing: (including bale feed conveyor, bale breaker, single shaft shredder, fluff storage, pellet mill densifier, and silo)	$800,000
Bottle/Injection Grade Processing: (including bale feed conveyor, bale breaker, preshredder, magnetic separation, granulator, and silo)	$700,000
Automated Flow Molding Equipment: (including feed system from silos, weigh blending for polymers & additives, compounding extruder, continuous pressure mold fill system, automated molding carriage, cooling bath, mould extraction & return, and post mold cooling & part turning)	$2,500,000
Installation, Services & Start-Up	$1,000,000
Total Capital	$5,000,000

Table 7.13
Operating Costs of Flow Mold Process
(Capacity of 15,000 tonnes/yr)

Total staff	20
Cost of staff (@ $35000 each)	0.047
Electrical cost (@ $0.06/kwh)	0.05
Landfill cost	0.013
Maintenance	0.02
Building (at $5/ft)	0.01
Depreciation (over 10 years)	0.033
Raw materials (@ $50/tonne & 80% yield)	0.06
Operating cost ($/kg)	0.233
Railway tie (@ 110-120 kg)	$26.00-28.00

Notes: current purchase price of wood railway ties is $55.00-70.00 (Cdn.); current selling price of plastic composite ties is $110.00–150.00 (Cdn.); plastic ties have at least double the lifespan of wooden ties; installation cost of replacement tie is $150.00 (Cdn.)

7.4 Comparative Cost Analysis

As can be seen in Table 7.14 below, the manufacture of plastic lumber or plastic lumber composites can be very capital intensive. It is also clear that flow mold processing is a very cost-effective process to manufacture plastic composite products, such as railway ties. Much of the savings in terms of capital and operating costs are due to the fact that the process can tolerate higher levels of contamination without affecting product properties. There is, in effect, much less investment required in cleaning and recycling systems for preparing the feedstock.

Table 7.14
Comparative Costs for RPL & WPC Processing
($ Cdn.)

Process	Capacity (kg/hr)	Capital Cost	Operating Cost ($/kg)
PE Film Wash Process	900	9,525,000	0.36
	3000	15,128,000	0.22
HDPE Wash Process	1000	1,104,000	0.18
Woodfibre-PE Composite (Integrated Process)	1540	19,925,000	0.83
	6000	56,728,000	0.76
HDPE Plastic Lumber (Integrated Process)	1000	3,204,000	0.75
Flow-Mold Railway Ties (Integrated Process)	2500	5,000,000	0.23

Notes: these estimates are approximate and are for comparison purposes only; the estimates could vary substantially based on equipment selection and site-specific requirements; integrated process estimates for operating costs include the raw material purchase price.

8.0 Conclusions

1. The manufacture of recycled plastic lumber (RPL) and woodfibre–plastic composites (WPCs) grew rapidly through the 1990s and have captured nearly 12 percent of the North American deck board market. These materials are low maintenance, do not require painting or staining, and are impervious to rot and wood-eating insects, which makes them attractive to consumers.
2. Strong growth of RPL and WPCs should continue and the market is expected to double by 2005, in part, driven by the phase-out of arsenic compounds from pressure treated lumber.
3. The development of ASTM standards for plastic lumber products will support their use by consumers. The industry is currently working to amend building codes to permit the use of plastic lumber in coded projects.
4. A number of WPC lumber operations have been launched in Canada over the past two years. While the focus of these new operations has been on use of virgin polymers (such as polypropylene, polystyrene and high density polyethylene), one product utilizes recycled HDPE. Several large U.S. producers of plastic lumber are currently the major consumers of PE film and other recycled feedstocks collected in Canada.
5. The high growth rate in plastic lumber sales has stimulated significant research in new production technologies and manufacturing techniques, new additives that support wider product applications, and new products.
6. An oriented polypropylene-woodfibre composite developed in Canada has demonstrated flex strength superior to wood with a comparable flex modulus. This new product may open up a number of new applications.
7. A new, Canadian-designed flow-mold process for the production of large cross-section, plastic or plastic composite timbers can utilize PE films collected from curbside, mixed plastics and carpet waste. The process (and the products produced) can tolerate higher levels of contamination than other plastic lumber applications and may provide a large and viable market for these materials

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Appendix I
Manufacturers of Pure Polymer and Composite Plastic Lumber

Canadian Producers

Alternative Plastic Product Manufacturing	Red Deer, AB	403 329 1713
Amity Plastics Ltd.	Clyde, AB	780 348 5355
Awax Manufacturing, Ltd.	Calgary, AB	403 203 0302
Brite Manufacturing Inc.	Bolton, ON	905 857 6021
Canadian Plastic Lumber	Lindsay, ON	705 878 5700
Cascades Re-Plast Inc.	Montreal, PQ	514 284 9850
Composite Building Products International Inc. (CBPI)	Barrie, ON	705 728 3498
CPI Plastics Group Ltd.	Mississauga, ON	416 798 9333
Dura Products International	Etobicoke, ON	416 679 0556
D.W. Gill Supply Co. Ltd.	Calgary, AB	403 255 1622
Eco Wood Products Ltd	Concord, ON	905 669 4340
ELB Construction	Frankford, ON	613 969 0990
Envi Technologies Inc.	Langley, BC	604 888 1355
Everwood Agricultural Products	Tilsonburg, ON	519 688 5141
GSW Thermoplastics Co.	Barrie, ON	705 728 7141
Impact Products / Xpotential Products	Regina, SA	306 949 6472
Intertape Polymer Group Ltd	Truro, NS	902 895 1686
Innovative Plastics Marketing Ltd.	Edmonton, AB	403 454 8162
Island Plastics Inc.	Stratford, PE	902 894-7527
PEI Inc.	Charlottetown, PE	902 892-8383
Marathon Recovery (PE FILM Recycling)	Seattle, WA	253 872 0779
Nexwood Industries Ltd.	Brampton, ON	888-763-9966
Nova Plastic Products Inc.	Corner Brook, NFLD	709 634 5055
Northern Plastic Lumber International Inc.	Lindsay, ON	705 878 5700
PSA INC.	Guelph, ON	519 823 1465
Royal Plastics Inc.	Woodbridge, ON	905 761 8829
Royal Eco Products Co.	Concord, ON	905 761 6406
Re-Source Edmonton, Ltd.	Edmonton, AB	780 463 5978
Syntal Products Ltd.	Saanitchtin, BC	250 544 1676
ZCL Composites Inc.	Edmonton, AB	780 466 6648

Pure Polymer Producers, U.S.

U.S. Northeast

Aeolian Enterprises Inc.	Latrobe, PA
American Eco-Board Inc	Farmingdale, NY
Engineering Mechanics Corp.	Columbus, OH

E.S.I. Extrusion Services Inc.	Akron, OH
Empire State Developments	Albany, NY
Industrial Pallet & Packaging C. Inc.	Beachwood, OH
Jomarico Inc.	Toledo, OH
M.G. McClaren, P.C.,	West Nyack, NY
Otsuka Chemical Co.	New York, NY
Turtle Plastics	Loraine, OH
Plastic Lumber Co., Inc.	Akron, OH
Phoenix Color	Sandusky OH
Phoenix Recycled Plastics	Ambler, PA

U.S. Midwest

3M Center	St. Paul, MN
Bedford Technology	Worthington, MN
Certain Teed	Jackson, MI
Dain Bosworth Inc	Minnesota, MN
Electro-Voice Inc.	Buchanan, MI
Extrutech Plastics	Manitowoc, WI
MBX Packaging	Wausau, WI
N.E.W. Plastics Corp.	Luxemburg, WI
North Wood Plastics	Sheboygan, WI
Recletech, Inc.	Coopersville, MI
Viking Engineering,	Fridley, MN
Earth Technology Group	Ionia, MI

U.S. West

A.S.A.P.	Greenacres, WA
Aloha Plastics Recycling Inc.	Puuene, HI
American Plastic Lumber Distributors	Cameron Park, CA
American Premier Recycling	Carlsbad, CA
BioLumber Inc.	Orinda, CA
Boise Cascade	Boise, ID
Enviro-Tech Resources Corp.	Encino, CA
RADCO	Long Beach, CA
KEPT, Inc.	Portland, OR
Land Use Economics	Norco, CA
Metro Plastics, Inc.	Tacoma, WA
The Green Group	Seattle, WA
Re-Sourcing Associates	Seattle, WA
CWC	Seattle, WA

U.S. South

21 Century Alternatives	Baytown, TX
BTW Industries, Inc.	Hollywood, FL
Chaswood Industries Corp.	Flower Mound, TX
Demer Corp.	Covington, LA

Environmental Building Products	Highlands Ranch, CO
Extrudewood North America Inc.	Tequesta, FL
Osmose	Griffin, GA
Panamerican International, Inc.	Laredo, TX
Recycled Plastic Man	Venice, FL
Wonderwood Industries	Leeds, A
MEA Engineers	Sarasota, FL

U.S. East Coast

Azdel, Inc.	Shelby, NC
BBB Plastic Lumber	South Amboy, NJ
Criterion Recycling	Providence, R.I.
Gates Formed Fibre Products	Auburn, ME
Manner Resins	Annapolis, MD
Mid-Atlantic Plastics Systems, Inc.	Roselle, NJ
Obex, Inc.	Stamford, CT
Polywood, Inc.	Edison, NJ
U.S. Plastic Lumber Ltd	Auburn, MA
Tex America, Inc.	Charlotte, NC
The Plastics & Composites Group, Inc.	Piscataway, NJ

Wood-Plastics Composite Manufacturers, U.S.

Trex	Trex
TimberTech	TimberTech
U.S. Plastic Lumber	SmartDeck
AERT	ChoiceDeck
Louisianna-Pacific	WeatherBest
Certain-Teed	Boardwalk
Correct Building Products	CorrectDeck

Appendix II
Polyethylene Recycling Equipment & Process Suppliers

Cleaning Systems

Blowmolding parts & Systems	905 738 5540
Erema North America	978 887 0040
Frontier Recycling Systems Inc.	773 626 0050
Gala Industries, Inc.	540 884 2589
Gneuss, Inc.	704 841 7251
Govoni Sim Bianca, Inc.	888 346 8664
Herbold – Crowther Machinery Inc., Dorval	514 636 1166
Leda SAS	+39 0321 806789
M.A. Industries, Inc.	800 241 8250
Mid Atlantic Plastic Systems	908 241 9333
PRT America, Inc.	941774 7936
Plastic Oil Products	805 937 3050
Sorema Division of Previero	914 774 3355
Tex America Inc.	704 552 5404

Densifiers

Berlyn Extruders Inc.	800 423 7596
Blowmolding Parts & Systems	905 738 5540
Cal- Siera Machine	909 627 9807
Chicago Transpacker Corp.	800 635 5745
Erema North America	978 887 0040
Hudnut Industries Inc.	503 722 2938
Kohlman Engineering Corp.	888 566 7224
Leda SAS	+39 0321 806789
MIXACO/American Barmag Corp.	800 345 1630
Mid Atlantic Plastic Systems Inc.	908 241 9333
PRT America, Inc.	941 774 7936
Precision Machinery Systems Inc.	800 851 7891
Processall Inc.	513 771 2266
Scanrec Inc.	800 577 3766
Sebright Products	800 253 0532
Sorema Division of Previero	914 774 3355
Tex America Inc.	704 552 5404

Granilators

AEC Nelmor	508 278 5584
Advanced Manufacturing	800 329 6888
American Pulverizor Co.	314 781 6100
Blowmolding Parts & Systems	905 738 5540
Blue Tech Inc.	908 464 7134
Bruce Mooney Associates Inc.	800 454 2686

Franklin Miller Inc.	973 535 9200
Gabriel International Group	812 537 5400
Gensco America Inc.	800 268 6797
Granutech-Saturn Systems	877 582 7800
Hosokawa Polymer Systems	860 828 0541
Konar Industries Inc.	614 836 2366
M.A. Industries, Inc.	800 241 8250
Marathon Equipment Co.	800 633 8974
Mid Atlantic Plastic Systems Inc	908 241 9333
MIXACO/American Barmag Corp.	800 345 1630
Nordfab Systems	800 222 4436
PRT America, Inc.	941 774 7936
Rapid Granulator Inc.	888 495 5900
ReTech Industries Inc.	336 886 6070
Rotochopper	608 452 3651
Sorema Division of Previero	914 774 3355
Sweed Machinery Inc.	800 888 1352
Tex America Inc.	704 552 5404
Triple/S Dynamics	800 527 2116
Williams Patent Crusher	314 621 3348

Plastic Lumber / Plastic Composite Manufacturing Equipment & Systems

Superior Polymer Systems Inc., Tilsonburg, ON.	519 688 0555
Coperion Corp., Ramsey, New Jersey	201 327 6300
Davis Standard Corporation Pawcatuck, Ct	860 599 1010
Extrusion Systems Inc. Mississauga, ON	905 474 1896