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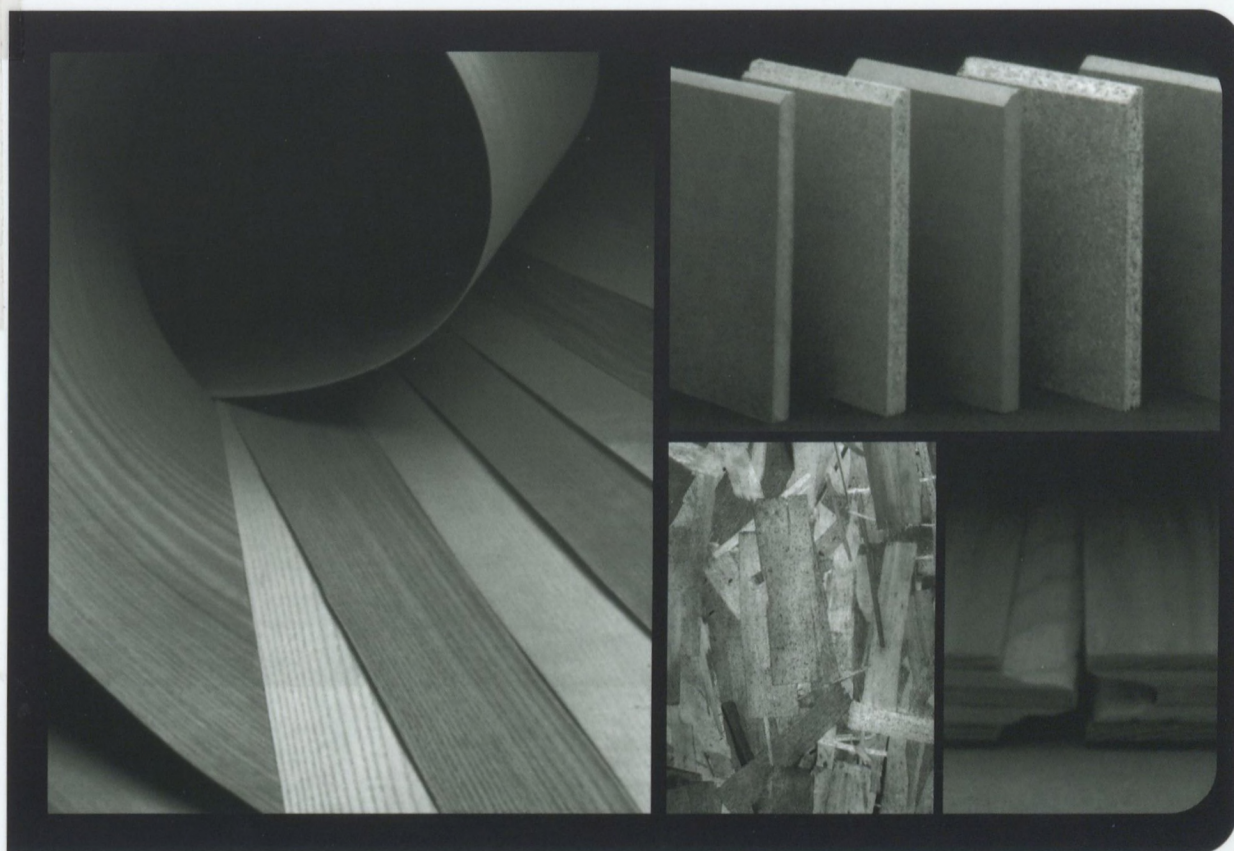
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>> Wood-Based Panel Products

SPECIAL REPORT

Canada

WOOD-BASED PANEL PRODUCTS

TECHNOLOGY ROADMAP

Industry Canada
Library - Queen

MAR - 8 2012

Industrie Canada
Bibliothèque - Queen

Canadian Cataloguing in Publication Data

Main entry under title:

Wood-based panel products: special report

(Technology roadmap, ISSN 0381-7733)

Issued also in French under title: Panneaux dérivés du bois.

Includes bibliographical references.

ISBN 0-86488-531-8

1. Plywood industry–Canada. 2. Particle board industry–Canada.
3. Fiberboard industry–Canada. 4. Veneer industry–Canada. 5. Plywood industry–
Technological innovations–Canada. 6. Particle board industry–Technological innovations–
Canada. 7. Fiberboard industry–Technological innovations–Canada. 8. Veneer industry–
Technological innovations–Canada. 9. Forest products industry–Environmental aspects–
Canada. I. Forintek Canada Corp. II. Series.

HD9764.C32W66 1998

338.4'767483'0971

C98-901155-0

For additional copies of the *Wood-Based Panel Products Technology Roadmap*,
please fax your request to us at (613) 954-6436, E-mail us at publications@ic.gc.ca or call 1-800-328-6189.

This publication is also available electronically on the World Wide Web at the following address:
<http://strategis.ic.gc.ca/trm>

To obtain additional information about this publication, please call the Forest Industries and Building
Products Branch of Industry Canada at (613) 954-3039, or

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Aussi disponible en français sous le titre : Panneaux dérivés du bois, collection Carte routière technologique.

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October 1998



PRINTED IN CANADA
on recycled paper

ACKNOWLEDGEMENTS

Industry Canada and Forintek Canada Corp. wish to acknowledge the contribution and support of the individuals who made this report possible.

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FOREWORD

The remarkable growth of the wood composite panel sector constitutes one of the success stories of the Canadian wood industry in the second half of the twentieth century — a success story that can be maintained well into the twenty-first century if we begin to prepare for it now.

In recent years, the Canadian panel industry has experienced a higher growth rate than either the forestry sector as a whole, or the overall manufacturing sector. It has become a significant contributor to Canada's net trade balance. It has also helped to diversify the wood resource and contributed to the economy of rural areas in most of our provinces.

This Technology Roadmap demonstrates that the sector's success has been driven by technology which has broadened the range of usable raw materials, reduced manufacturing costs and increased product quality. Today, as the industry's confidence is somewhat tempered by concerns over wood supplies or over-capacity, it is appropriate to analyze the situation and determine what knowledge will most likely help the industry meet its challenges. Building on the collective knowledge of the industry and its partners, the Roadmap provides this type of analysis. It also provides many elements for the development of a strategic plan that will deliver the required knowledge through a coordinated research and development effort and technology transfer program involving all of the industry's stakeholders.

The development of this Roadmap involved the cooperation of Forintek Canada Corp. and Industry Canada. In addition, the writers relied heavily on the advice and direction provided by representatives of the wood panel industry across Canada. We thank them for their input.

Canadian wood panel manufacturers will need to be more aggressive in their search for raw materials, new markets, lower costs and smarter environmental protection. They will need better methods to study market opportunities, and they will need to become more flexible to take advantage of these opportunities. This means more and better research and development.


We firmly believe that technological excellence and leadership are the key to the Canadian composite wood panel industry's prosperity as it prepares to enter the first decade of the new millennium. We also believe that the network approach recommended in the Roadmap is the most appropriate to address the industry's needs.

We also believe that the development of Technology Roadmap initiatives, such as this report, will help to identify and to develop new, critical technologies required by specific sectors to meet future market demands in the knowledge-based economy. Improving Canada's innovation performance will assist in increasing Canada's share of global trade and help in improving conditions for investment. We consider that this report affirms our desire to foster a growing, competitive, knowledge-based Canadian economy that provides more and better-paying jobs and that supports stronger business growth and innovation.

We trust, therefore, that you will review this report carefully, and that you will find it to be a useful guide for both the development of a strategic plan for your company and to advance the overall growth of the sector.



Kevin G. Lynch
Deputy Minister
Industry Canada



Ian de la Roche
President and CEO
Forintek Canada Corp.

EXECUTIVE SUMMARY

The Canadian wood-based composite panel industry has experienced dramatic growth over the past 50 years, and its current contribution to net exports makes it a significant component of Canada's economic success. It also represents a substantial factor in this country's rural economy.

This remarkable development results from a unique combination of forest resources and technological innovation giving birth to a variety of products which responded to the requirements of major markets, especially in North America, Europe and Japan. As markets become more demanding, global competition more aggressive and traditional wood resources less abundant, only technological innovation will allow the Canadian composite panel industry to maintain and improve its position.

The Roadmap, developed by Forintek Canada Corp., in consultation with the wood composite panel industry and its major partners, is designed to offer the industry and its stakeholders various technology-related targets to guide its continuing progress over the next 10 to 15 years.

In addition to Forintek specialists, industry consultants, equipment and resin manufacturers, and Industry Canada sector officers, the consultative process involved representatives of panel producing companies and the trade associations representing the main sectors of the industry. The trade associations which participated in the process included the Canadian Plywood Association (CanPly), the Structural Board Association (SBA), the Composite Panel Association (CPA), and the Canadian Hardwood Plywood and Veneer Association (CHPVA).

The Roadmap establishes the importance of innovation to the major sectors of the panel industry and identifies new and promising technologies along with suggestions on priorities for the future. It also lays out some recommendations related to infrastructure and organization that may help the various sectors of the industry to shift into high gear and move out into the fast lane.

The Roadmap is divided into nine chapters which provide a perspective of the entire panel industry, followed by detailed reviews of the five major sectors of the industry: softwood plywood, oriented strandboard (OSB), particleboard, medium-density fibreboard (MDF) and hardwood veneer and plywood. For each sector, a vision is set out, which represents how the sector sees itself developing over the next 10 to 15 years, and sets out realistic goals and parameters to assist in the selection of priority technologies and recommendations. For each panel sector, the information includes a brief description of existing processes and technologies, the identification of key opportunities for incremental technological innovation and, where relevant, opportunities for potentially breakthrough technological innovation.

Industry goals (and technology priorities) are also shaped by a set of driving forces which fall into one of five categories: fibre supply, manufacturing costs, product attributes and performance, new products and the environment. These may be interrelated and may also encompass other related factors. Corporate requirements for profitability, international competitiveness and market growth, for example, are reflected in the need for cost reduction and new and improved product development. Public sentiment and government regulations give rise to environmental requirements. The relative impact of these driving forces varies from one sector to another.

For each panel sector, the information includes a brief description of existing processes and technologies, the identification of key opportunities for incremental technological innovation and, where relevant, opportunities for potentially breakthrough technological innovation.

Incremental technological innovation may take the form of modifications or refinements to existing processes or product characteristics, or it may advance the commercialization and implementation phases

of innovation. This category of innovation is often relatively low cost and can yield proportionately high benefits without substantial risk. Examples of incremental innovation have been identified that would extend the raw material supply, reduce production costs, diversify market applications, and increase profitability through higher product value.

Breakthrough innovation, on the other hand, suggests technological leaps that would significantly affect the economics of the panel industry or individual sectors. The R&D effort involved to achieve the identified breakthroughs may be heavy, and undoubtedly the risk is high, but so is the potential payoff.

Environmental issues are important in today's world. The panel industry is very much aware of this, and it has shown itself to be environmentally responsible. As regulations became increasingly stringent, the industry has responded with the application of appropriate technologies, as detailed in Appendix I. Future developments in this area will include adapting techniques originating from other industries, and integrating environmental protection into every single step of the manufacturing process to minimize production costs.

Technological innovation has the potential to revolutionize traditional products and manufacturing processes in the panel industry, just as it has done in the past. The degree of success will depend, however, on choices that are made now, and on the commitment of the industry and its allies to innovation through medium and long term R&D. In some cases, it will depend on the stakeholders' willingness to support the more fundamental and painstaking search for knowledge, which so often lays the base for technological innovation.

The demand for panels is forecast to increase well into the next century as quality logs for traditional products become scarcer, and as designers and consumers gain experience with positive product attributes and new applications. Composite panels will also substitute for metals and plastics. However, for the Canadian wood composite panel industry to turn this potential demand into real profits, it must set out for itself technological goals that are consistent with market opportunities and customer requirements. It must also ensure that technological innovation takes place within a broader strategy that will ensure its delivery.

Recommendations are set out as a basis for the development of a strategic plan for the panel industry. They cover such areas as the acquisition and transfer of technical and scientific knowledge, the setting of priorities for the industry's R&D program, the acquisition of market knowledge, the development of value-added opportunities, and the efforts required in training and education. Recommendations apply to all stakeholders including industry, government and research organizations; they are intended to benefit both the panel industry and Canadian suppliers of equipment, adhesive, software or services.

The Roadmap is written for a broadly based audience ranging from sector specialists and industry executives, to researchers and equipment suppliers, to government policy makers and educators. It is intended to assist organizations in their planning, in setting priorities and in crystallizing direction. In addition to providing some guidance on important strategic decisions, it is intended to provoke continuing discussion among the industry's stakeholders; and the broad consultation undertaken to develop this Roadmap has already proved very successful in this regard.

Technological innovation has proven to be the prime vehicle for the remarkable development of the wood composite panel industry in Canada over the last half century. This trend has accelerated in recent years with the proliferation of new products and new process technologies. The challenge for the future is to maintain the pace and to make appropriate choices in setting the direction of technological innovation. It must be consistent with market opportunities and customer requirements. It must ensure optimal benefits to the panel industry and the Canadian economy.

The Roadmap is intended to help the industry meet this challenge. It does not lay out rigid milestones and a single route forward. That may be presumptive at this stage and suggest an inflexibility that would not be consistent with the dynamics of this industry. Rather, this Roadmap establishes the importance of innovation to the major sectors in the panel industry and identifies new and promising technologies along with suggestions on priorities for the future. It also lays out some recommendations related to infrastructure and organization that may help the various sectors of the industry to shift into high gear and move out into the fast lane.

The Roadmap is written for a broadly based audience from sector specialists and industry executives to researchers and equipment suppliers to government policy makers and educators. It is intended to assist organizations in their planning, in setting priorities and in crystallizing direction. It will not be a success unless it provokes discussion and debate and provides guidance on important strategic decisions.

Much of the material in the Roadmap comes from Forintek specialists. A series of brain storming sessions were conducted with the scientists and industrial advisors of both eastern and western divisions. This was supplemented by discussions with individual consultants, panel industry and equipment supplier representatives, and by a review of the relevant literature.

The consultative process with industry representatives was performed through a survey. To that end, a questionnaire was developed in consultation with each panel sector association. The Canadian Plywood Association (CanPly), the Structural Board Association (SBA), and the Composite Panel Association (CPA) were all asked to provide up to six industry representative names from their industrial membership to participate in the survey. Most of these participants were contacted by telephone, while some others were interviewed at mill sites. With respect to equipment suppliers, the more significant companies were contacted in an attempt to cover each processing centre to the extent possible. As with many projects of this sort, the consultative process itself was beneficial.

The panel types included in this Roadmap are: softwood plywood, oriented strand board (OSB), particleboard and medium density fibreboard (MDF). Hardwood plywood, which is similar in production to softwood plywood, is covered in less detail. Composite wood panels have expanded into hybrid products which combine two or more panels, or panels with other materials, into a single product.

Composite wood panel products are made from wood-based materials bonded together with a synthetic adhesive using heat and pressure. The materials include veneer, strands, particles and fibres. The nature of the wood raw material and the adhesive essentially determine the differentiated characteristics of the products. These include mechanical properties, water resistance, dimensional stability, surface quality and machinability.

Wood-based panel products have become increasingly specialized in recent years and are used in wide ranging applications. The demand for panels is forecast to increase well into the next century as quality logs for traditional products become increasingly scarce and as designers and consumers gain experience with positive product attributes and new applications. Composite panels will also substitute for metals and plastics.

The Roadmap is divided into nine chapters. Chapter II sets panels in perspective. It looks at their relative economic performance and overall contribution to the Canadian economy. It compares product characteristics, markets and variable costs, setting the stage for subsequent chapters on existing and future technologies.

Each of the Chapters III to VII assesses a specific panel sector. The products are described. A vision is set out for each sector 10 to 15 years down the road. This is how the sector sees itself developing under favourable circumstances but within limits of what is practical. In this way, the vision statements for each sector set out realistic goals and parameters to assist in the selection of priority technologies and recommendations. A review of the economic contribution of each sector and an outlook fifteen years ahead to 2012 provides additional background information.

Driving forces are then assessed for each sector. These are trends and factors that will impact on technological innovation of the future. In short, they are the forces which drive technology. They may also be interpreted as objectives. Their relative importance may vary with the individual sector. One or more driving forces can be related to each technological opportunity, and an understanding of their relative significance also helps in selecting priorities and recommendations.

There are five categories of driving forces impacting on panel technologies: fibre supply, manufacturing costs, product attributes and performance, new products and the environment. These may be interrelated and may also encompass other related factors. Corporate requirements for profitability, international competitiveness and market growth, for example, are manifested in the need for cost reduction and new and improved product development. Public sentiment and government regulations give rise to environmental requirements.

The need for cost reduction has always been important to this industry. In fact, new technologies have made a dramatic impact in lowering costs of panel production, thereby maintaining and lowering selling prices and expanding markets. This will continue.

Similarly, the need for appropriate and cost efficient fibre supply will continue to drive technological innovation. Over the years, the quality of logs for plywood manufacture has gone down steadily and costs have risen dramatically. This has given impetus to innovation responsible for the development of newer panel products, which in turn require ongoing innovation to deal with their changing raw material circumstances. Wood costs are relatively high for all panels, ranging from 23 per cent of total variable costs for particleboard to 56 per cent for softwood plywood.¹

There are substantial opportunities for growth in all panel sectors from new and improved product development. For several of the sectors, this is the way of the future for both expansion and survival. Innovation will be required not only for products but also for related processing technologies.

The panel industry is environmentally responsible. Nonetheless, regulations have become increasingly stringent and the industry has responded with the application of appropriate technologies. New environmental technologies developed for other industries will have to be adapted to the panel industry, but with minimal cost impact.

¹ Source: Resource Information Systems Inc. (RISI).

The main components of the panel sector chapters focus on technology, describing some of the newer technologies now being used as well as future technologies. Information in these sections is set out for each stage of manufacture or for important elements affecting the overall manufacturing process, such as emission control and new product development. The information includes a brief description of existing processes and technologies, the identification of key opportunities for incremental technological innovation and, where relevant, opportunities for potentially breakthrough technological innovation.

Incremental technological innovation may take the form of modifications or refinements to existing processes or product characteristics, or it may advance the commercialization and implementation phases of innovation. This category of innovation is often relatively low cost and can yield proportionately high benefits without substantial risk.

Breakthrough innovation, on the other hand, suggests technological leaps that would significantly affect the economics of the panel industry or individual sectors. The R&D effort involved to achieve the identified breakthroughs may be heavy, and undoubtedly the risk is high, but so is the potential payoff. Chapter VIII describes in greater detail the more promising breakthrough technologies identified in previous chapters. These may apply to all or a few panel sectors. They are bold innovations that may well be within reach over the coming decade if sufficient resources are allocated to the pertinent R&D programs. Pursuit of these technologies nevertheless requires close attention to market objectives and economics.

Recommendations are set out in Chapter IX. As with the previous two chapters, they relate to the panel industry as a whole, with specific sector references as appropriate. The recommendations respond to the goals implicit in the driving forces and the vision statements. They also consider mechanisms that will help bring about the full benefits of technological innovation. Examples include training, technology transfer and co-operation at all levels. Recommendations apply to all stakeholders including industry, government and research organizations, and are intended to benefit both the panel industry and Canadian equipment suppliers.

Appendix I looks at environmental considerations and sets out the most promising technologies for future application to the panel industry. Environmental issues are very important in today's world. They affect operating and investment decisions as well as a company's reputation in the market place. Environmental equipment is critical to the manufacturing process. An understanding of promising new environmental technologies and their potential will help ensure long term viability.

Technological innovation has the potential to revolutionize traditional products and manufacturing processes in the panel industry, just as it has done in the past. Technology is the vehicle and R&D provides the acceleration to assure the growth and prosperity of the Canadian panel industry.

The degree of success will depend, however, on choices that are made now and on the commitment of the industry and its allies to innovation through medium and long term R&D. In some cases, it will depend on the stakeholders' willingness to support the more fundamental and painstaking search for knowledge, which so often lays the base for technological innovation.

Economic Contribution

Table 1
Statistics on wood-based Panels for 1996

Sector	Number of Plants	Number of Employees in Total Activity	Manufacturing Activity (millions of dollars)			Exports (millions of dollars)
			Value of Shipments	Value Added	Wages	
Hardwood Plywood ⁱ	42	3,981	574	264	126	412
Softwood Plywood ⁱⁱ	27	4,047	1,128	457	217	335
OSB ⁱⁱⁱ	15	2,406	1,090	526	123	940
Particleboard	28	2,219	694	303	101	262
Fibreboard including MDF	8 ^{iv}	920	226	131	38	138
Totals	120	13,573	3,712	1,681	604	2,087
% Forest Industry	3.4	6.1	7.0	6.7	6.5	
% Total Manufacturing	0.37	1.1	0.9	1.14	1.4	

Source: Statistics Canada.

Table 1 summarizes principal statistics for wood-based panels for 1996. About 120 establishments employed 13,500 people and shipped \$3.7 billion worth of product. The panel industry had 6.1 per cent of total forest industry employees and 1 per cent of total manufacturing employees.

The largest panel sectors are OSB and softwood plywood; each of which shipped product worth \$1 billion in 1996. The hardwood plywood and particleboard sectors each shipped slightly more than half of that. The fibreboard sector, which includes MDF, is relatively smaller, but MDF has grown rapidly since 1995 and continues to grow.

The wood-based panel industry added \$1.7 billion of value to the Canadian economy in 1996 compared to its total shipments of \$3.7 billion. This value added, which represents about 50 per cent of the total value of panel industry shipments, was generated directly by this industry through salaries, wages, depreciation and other operating, administrative and marketing expenses, as opposed to purchased inputs manufactured by other sectors such as raw materials and supplies. This is significantly higher than the average of 40 per cent for all manufacturing industries in Canada.

ⁱ Includes veneer – Source: Resource Information Systems Inc. (RISI), Wood Products Review, July 1997.

ⁱⁱ Includes veneer – Source: Resource Information Systems Inc. (RISI), Wood Products Review, July 1997.

ⁱⁱⁱ Several new plants have been built since 1995. See OSB section.

^{iv} Includes overlay operations.

The panel industry paid salaries and wages of \$0.6 billion to all employees and of this, \$0.48 billion to its manufacturing employees. This represents 16 per cent of its value of shipments compared to 13 per cent for total manufacturing. One-half billion dollars in wages represents 5 per cent of that paid to the entire Canadian forest industry.

The panel industry has outperformed both the forest industry and total manufacturing in growth from 1990 to 1996. The value of panel shipments increased by a factor of three, for an annual growth rate of close to 23 per cent over that period, reflecting both significant price increases for all panels and substantial capacity increases in the OSB and MDF sectors. Panel production growth was accomplished with little change in the number of employees.

The panel industry is a very significant export earner for Canada, and exports are growing not only for the US but also for offshore markets. In 1996, the industry exported \$2.1 billion of products, which represented 56 per cent of its revenues. US markets accounted for 80 per cent, Japan 12 per cent; and countries in Western Europe 5 per cent. The net trade balance in panels reached \$1.6 billion as imports, mostly from the U.S., were limited to \$421 million. This compared to 1996 net trade balances of \$32.7 billion for all forest products, and \$34.5 billion for all Canadian manufactured products.

Capital expenditures in the panel industry in 1995 were significantly higher than those expected for 1996 and 1997 although this varies substantially with panel sector. While precise figures are not available, estimates from broader aggregates suggest 1996 expenditures for equipment and plants approaching \$1 billion, which represents nearly 20 per cent of the total for the forest industry and 6 per cent of that for total manufacturing. This relatively high level of capital expenditures should result in future growth of output, much of which will be absorbed by export markets, and improved competitiveness through production efficiencies.

It should be noted as well that the panel industry is located in all provinces of Canada except Newfoundland and Prince Edward Island, and it is a significant supporter of rural economies. It is based on Canada's renewable forest resource and, along with other forest industries, is a major contributor to sustainable development in the Canadian economy. The Canadian panel industry represents a bigger share of the national economy than does its US counterpart.

Variable Manufacturing Costs

Table 2
1997 Variable Costs in the Panel Industry
(Canadian dollars per m³)

	Softwood Plywood BC		Oriented Strand Board Que., Ont.		Particleboard Eastern Canada		Medium Density Fibreboard *	
	\$	%	\$	%	\$	%	\$	%
Net wood cost del'd	151	49	58	41	28	24	40	29
Adhesive	17	5	23	16	35	30	36	27
Wax	0	0	4	2	3	2	4	3
Total Materials	168	55	85	60	66	56	80	59
Labour	103	33	29	20	22	18	20	15
Electricity	11	3	8	5	10	8	14	10
Supplies & Misc.	22	7	18	12	17	14	22	16
Total Variable Costs	305	100	140	100	116	100	136	100

Source: Resource information Systems Inc. (RISI), Wood Products Review, July 1997.

* Forintek Canada Corp. estimate, based on RISI data for the US.

The purpose of this table is to illustrate critical cost factors for the various panels, and where technological innovation may have the most impact. The numbers will not reflect actual costs in all mills. While variable costs have been presented for the four panel sectors above, they are not directly comparable. For example, they relate to quite different products, with different characteristics and with different, but often, overlapping end use markets and prices. Plywood manufacture generates significant revenues from residues, which helps to offset high variable costs. Furthermore, fixed costs such as depreciation are excluded and these vary between sectors. Sectoral cost data relate to specific locations, and in some cases regional cost factors apply. In fact, the only information available for MDF was from the western US.

Despite these limitations, the comparisons help to understand each sector and its relative competitiveness, and to focus on the potential for new technologies. The need for cost reduction has always been an important driving force for technological innovation.

At \$151 per m³, wood costs for softwood plywood are three to four times those for OSB and MDF and five times those for particleboard. Plywood labour costs are much higher than in other sectors, suggesting potential for higher levels of automation. On the other hand, plywood adhesive costs are relatively low, particularly in comparison to MDF and particleboard.

OSB, which competes in some of the same structural markets as softwood plywood, has significantly lower variable costs. Similarly particleboard, which competes in some of the same furniture markets as MDF has substantially lower costs than MDF.

Panel Characteristics

Table 3 is also designed to provide an overview of panel characteristics and critical inputs, rather than direct comparisons.

Table 3
Key Panel Characteristics

	Softwood Plywood	Hardwood Plywood	Oriented Strand Board	Particleboard	Medium Density Fibreboard
Raw Material	Softwood veneer	hardwood veneer, composite wood cores	discrete strands, 12 by 150 mm (½ by 6 inches) mostly aspen	discrete wood particles less than 6 mm (¼ inch); wheat straw	discrete wood fibres and fibre bundles
Typical Adhesive	Phenol-formaldehyde	urea-formaldehyde, melamine urea-formaldehyde	phenol-formaldehyde or isocyanate or both	urea-formaldehyde, melamine, some isocyanate	urea-formaldehyde, some isocyanate
Structural versus Non Structural	Structural	mostly non structural	structural	mostly non structural	non structural
Surface Smoothness	Smooth when sanded	smooth when sanded	smooth when sanded	very smooth fines on face	exceptionally smooth
Edge Machinability	Limited	limited	very limited	good	excellent
Typical Applications	roof, floor, wall sheathing, single-layer floor, siding, floor underlayment, preserved wood foundations	decorative wall panelling, furniture, cabinetry	roof, floor, wall sheathing, floor underlayment	furniture, cabinetry, floor underlay, stair treads, counter tops, subflooring in manufactured housing	furniture, cabinetry, moulding, millwork
Special Applications	Industrial, laminated veneer lumber, concrete forms, marine plywood	multiple applications, decorative flooring	industrial, hybrid products, siding, l-beam web stock	high density, moisture resistant, fire retardant	high density, moisture resistant, exterior grade
Typical Thickness mm (inches)	6 to 31.5 (¼ to 1 1/4)	6 to 19 (¼ to ¾)	6 to 32 (¼ to 1 1/8)	6 to 38, max. 57 (1/4 to 1 ½, max. 2 ¼)	5 to 38, max. 76 (3/16 to 1 ½ max. 3)
Typical Density kg/m³ (lb/ft³)	450 to 500 (28 to 31)	400 to 880 (25 to 55)	580 to 700 (36 to 44)	640 to 800 (40 to 50) door core 450 (28)	640 to 800 (40 to 50)
Recovery (vol. product/vol. raw mat.)	0.5	0.5	0.65	0.88*	0.9*

Sources: C. C. Publications, NGM International, FCC.

* Based on Residue as Raw Material.

Description

Softwood plywood is manufactured to meet stringent requirements for exterior applications. Exterior plywood is an engineered panel built up of veneer plies. The thickness and orientation of the plies determine the performance of the panel. The veneer sheets are united under high temperature and pressure with phenol-formaldehyde adhesive, a waterproof adhesive, making the plywood suitable for exposed conditions.

Softwood plywood uses logs, preferably of good quality, as its raw material. These are put on a lathe and peeled into veneer. A range of coniferous species is used in manufacture, and each has special characteristics that may affect the performance level of the final product. Veneer of different species can be combined. Douglas-fir plywood, for example, must be faced with Douglas-fir veneer but 12 other species may be used as inner plies. Canadian softwood plywood allows 13 species for face veneer and 20 species for the inner plies.

Panels are manufactured in standard and modified constructions. Modified construction varies from standard lay-up in regard to the grain direction of the plies, the number of plies or the thickness of the individual plies. Plywood is also manufactured with adhesive-fibre overlays and specialty plywood may be textured with decorative patterns for display purposes. Panels are normally manufactured as 1,220 x 2,440 mm (4 x 8 foot) panels in 12 thickness types from 6 to 31.5 mm ($\frac{1}{4}$ to 1- $\frac{1}{4}$ inches). They are also regularly manufactured in several other sizes for export markets, e.g., 1,200 x 2,400 mm, 1,820 x 2,500 mm, 1250 x 2,500 mm, 310 x 1,820 mm, and 1,220 x 2,275 mm.

Because of plywood's combination of mechanical and physical properties, including dimensional stability, it is a material of choice for a wide range of applications, such as roof and floor sheathing for residential and commercial construction, underlay for vinyl flooring and for concrete forms.

Plywood is used extensively in the fabrication of engineered building components such as wood I-beams, preserved wood foundations, concrete forms and stress skin panels. Industrial applications include crating, pallets, bins, furniture, display racks, store fixtures and exterior signs.

Vision

Plywood is the oldest of the panel sectors. With nearly a century of industrial history, it is by many standards a mature sector. While softwood plywood still dominates North American structural markets, its share, particularly in Canada, is diminishing due primarily to substitution by OSB, and increasing difficulties in getting suitable, low cost raw material. Total output for this sector has been stable for a number of years.

This sector will continue to evolve rapidly into a producer of specialized products, which will take advantage of the unique qualities and high performance characteristics of softwood veneer and plywood. Performance of existing products will be enhanced and new products will be developed particularly for structural and engineering applications. These will include hybrid products, that is veneer combined with other panels and even non-wood materials. Many of the structural products will be incorporated into new building systems for use in residential and expanding commercial construction.

Marketing will be at the cutting edge, as this scenario depends not only on product development but also on new markets for existing, enhanced and new products. The early identification of market opportunities, both in North America and offshore, will be stressed. Similarly, product promotion with good supporting technical information will be emphasized. In short, both the companies and the sector will strengthen their marketing effort.

On the basis of RISI analyses, we expect that, in ten years hence the plywood sector will be about the same size or perhaps a little smaller. It may also be more focused. High cost mills will be out of business or forced to modernize. With concentration on value added, the price spread with OSB should increase and the industry should be profitable.

There is, however, a major caveat to this vision. As most of Canada's softwood plywood is produced in BC, its future must be viewed primarily within the context of developments in that province, particularly with respect to its forest industry. Many in the sector believe that high stumpage rates represent a major risk to maintaining long term corporate profitability and even viability for the sector as a whole.

Technological innovation will focus on new and improved product development in response to identified opportunities, particularly in niche and export markets. There will also be innovation in the development of, or modification to, manufacturing processes related to product enhancement. Machinery will become more flexible to shift rapidly between an increasing number of product lines. Automation will continue to take place to achieve cost reduction, but this will tend to be incremental on individual pieces of equipment rather than on an integrated, large-scale basis.

On the environmental front, there are no insurmountable issues foreseen over the next decade. As with other panel sectors, the softwood plywood sector is responsible, and is seen as such by the public. Companies will continue to respond to changing environmental regulations with the installation of appropriate technologies. In some cases, innovation will be applied to the disposal or utilization of wood residue.

Economics

Contribution

The Canadian softwood plywood sector is mature, displaying relatively little change in output over the last decade.

Value of shipments in 1995 was close to \$1.1 billion with value added representing about 40 per cent of that. This reflects the relatively high cost of materials, notably peeler logs for manufacture into veneer. Value of shipments in 1990 was \$0.7 billion for a five-year annual growth rate of about 10 per cent. All of this is attributed to price increases over the period; there was virtually no change in levels of production. The number of plywood and veneer producing establishments declined from 31 to 27.

Province	# of plywood mills (1997)	Production capacity Million m ³ (BSF)*		% capacity
British Columbia	12	1.634	(1.850)	85
Alberta	1	0.226	(0.200)	9
Saskatchewan	1	0.102	(0.090)	4
New Brunswick	1	0.023	(0.020)	1
Total	15	1.985	(2.160)	100

* BSF = billion square feet (3/8-inch basis).

Employees in 1996 numbered about 4,047. This represents a value of shipments of \$278,000 per employee, which is significantly less than the more capital intensive, larger scale OSB sector, but about the same level as the particleboard sector. The number of employees has been declining steadily, as the sector becomes more automated in response to a need for cost reduction and competitiveness.

Exports in 1996 were \$335 million, representing approximately one third of total softwood plywood shipments and 16 per cent of total panel exports. Imports were \$65 million, most of that from the US, leaving net exports of \$270 million. Exports to Japan were about \$180 million and to the rest of the world, notably the US and Western Europe, about \$153 million.

It is worth noting that in five years the softwood plywood sector has grown from a marginal net exporter to a significant net exporter. With respect to the US, it has reversed a net importing position in 1990 to net exports of \$88 million in 1996. However, much of this volume is green veneer, rather than plywood. Exports to the US are expected to grow as a percentage of total exports.

Canadian softwood plywood capacity is about 2 million m³ with close to 90 per cent of that located in BC plants outside that province are located in Alberta and Saskatchewan, with a very small plant in New Brunswick.

Outlook

The outlook for the Canadian softwood plywood sector to the year 2012 is premised on information provided by Resource Information Systems Inc. (RISI). These forecasts have been undertaken using rigorous and detailed analysis of supply and demand factors and econometric modelling using aggregate statistics and best assumptions of economic trends.

Their forecast for this sector, both in Canada and the US, is not optimistic. Total North American consumption, for example, is projected to decline from 19 million m³ in 1996 to 12.5 in 2012, a decline of 2.5 per cent annually.

Demand for Canadian softwood plywood in 1996, including exports, approximated 2 million m³. This is forecast to decline to 1.5 by 2012, an average annual decline of almost 2 per cent, largely because of further substitution by OSB, and rising wood costs particularly in BC where this sector is centred. Current production levels should remain flat to 2000 before declining.

Demand is expected to fall off in each of the major end use categories except industrial markets, where it will increase slightly but steadily over the sixteen years. In 2012, these markets will represent over 60 per cent of total demand compared to less than 40 per cent in 1996. The most significant declines will be experienced in construction. Canadian plywood used in single family homes in 2012, for example, will be scarcely one-third of today's levels. Most of this loss will take place within the next 5 years.

In 1996 Canadian plywood accounted for 31 per cent of total structural panel demand in Canada, compared to 69 per cent for OSB. In 2012, RISI forecasts that comparable ratios will be 12 per cent and 88 per cent, a big gain for OSB. RISI also suggests that much will depend on performance levels of the respective panels.

Total variable costs in the Canadian sector, already higher than in the US, are expected to rise by \$125 per m³, representing more than a 2-per-cent annual increase over the 16-year period. Wood costs will represent a major portion of this increase and, in fact, will account for two thirds of total variable costs by 2012. Adhesive and maintenance costs will also increase but labour costs will decline slightly, because of automation. As a result, the industry will accelerate its shift toward specialty products.

Prices for both Canadian softwood plywood and Douglas-fir plywood are expected to remain static to the year 2000 and then rise steadily at less than 2 per cent annually. Operating rates will decline from current levels of about 94 per cent to 90 per cent by the end of the next decade as operating capacity is reduced in response to declining demand.

Driving Forces

The need for quality, improved, *differentiated and specialty products* is the most important driver impacting future technological innovation, as it is the key to long term economic survival. Opportunities will, of course, depend on *market demand along with prices*, particularly in niche and export markets. An example is the export to Japan of roof panels to Japanese sizes and specifications. Key aspects include aggressive marketing and high value.

Flexible manufacturing processes are required to supply these new products at competitive prices and will therefore also drive technological innovation.

Competition from other products like OSB is important as it is forcing the industry into new products and niche markets. Such competition, therefore, has perhaps less impact on technological innovation for improved operational efficiency than on innovation required for new and enhanced products and related processes.

Cost reduction is always important, as it relates to competitiveness, profitability and survival. The real driving force for the plywood sector of the future, however, is the more broadly based need for *value enhancement*. This encompasses the need to maximize the value per unit of wood rather than simply cost reduction. Veneer sheets, for example, could be graded for alternative uses, such as the manufacture of laminated veneer lumber (LVL). Conversion of veneer into finished products, as opposed to export, also constitutes a form of value enhancement.

The need for *production efficiency* as opposed to straight cost reduction is another important driving force as it also relates to product quality and consistency. Increased efficiency reduces variability in the system allowing products to be sold for maximum value. Standard plywood, for example, currently tends to be treated as a commodity.

The *changing raw material base* will continue to force innovation in lathe technology. Logs are increasingly smaller, lower in quality with considerable variation in a number of characteristics including moisture content, e.g. subalpine fir replacing spruce. They also represent the major cost item. Although there are technologies to deal with the changing raw material, others need to be developed to not only address costs but also get more value out of the wood.

Environmental considerations are important to this sector but perhaps not a major driver of technological innovation. Environmental concerns are not of the same magnitude as those facing many other industrial sectors. Most of the technologies have already been developed and are, in fact, now in place. In some cases, new environmental standards follow the development of related technologies. In general, the environmental issues are being addressed but vigilance is important, as is any necessary technological response.

Periodic over-capacity can be a problem in this sector, but technology is not necessarily the primary and most obvious solution. Innovation that results in new products and diversified growing markets, and overall cost reduction would, however, assist the sector in minimizing cyclical impacts.

More than other panel sectors; *government regulations* will impact technological innovation in this sector in a myriad of ways. Quite apart from the need to meet future environmental regulations, high stumpage rates will restrict cash flows and therefore available funds to support R&D. In addition,

Workman's Compensation Board regulations may well force higher levels of automation to reduce risk of injury.

Existing and Future Technologies

Softwood plywood manufacture has undergone significant technological change in recent years.

Automation in plywood mills has occurred mainly in veneer production and panel lay-up. Pretreatment of the veneer blocks has enhanced veneer quality and the amount of veneer produced. Technological advances include mechanisms to load and centre logs on the veneer lathe, ultrasonic veneer block scanning; powered back up rolls; powered nose bars; and linearly positioned lathe knife carriages to speed up veneer production.

Automated lay-up lines have increased panel production rates. A recent development is the veneer-composer, which joins narrow width veneer strips into full sized sheets to facilitate their use on automated lay-up lines. These advances have reduced labour costs and improved veneer product quality.

Significant advances have been made in adhesives for plywood. Modern adhesives are faster curing and more tolerant of moisture variations in the veneer. Mills modify adhesive formulations for summer and winter conditions.

A wide variety of equipment is manufactured in North America, and equipment from Germany, Sweden, Finland and Japan is becoming increasingly common. Improvements in modern communications have led to exchanges in knowledge of new developments, particularly for specialized products and applications.

Through better scheduling of maintenance operations, the plants are able to reduce unscheduled downtime. They are incorporating preventative maintenance programs which include regular vibration analysis of all rotating equipment in order to trend bearing vibrations and predict failures. Plants are also targeting equipment requiring the longest maintenance periods in order to modify or replace them in minimum maintenance periods.

Raw Material

Existing Technologies

The plywood industry uses a variety of wood species. Production of veneer requires relatively high quality logs to maintain levels of recovery and quality of product.

Typical reductions in log quality that affect plywood production are: low log moisture content, crooked logs, presence of core rot, large numbers and sizes of knots and the presence of compression grain resulting from trees growing on steep mountain slopes. These defects reduce the number of full high grade veneer sheets from each log and lower production efficiency. The number of knots and their sizes restrict the grade of the final product to lower valued applications such as sheathing and shop grade panels where the competition from other panel products is the most intense.

The industry is not overly dependent on one specific wood species. A number of different species are permitted in core material and there is flexibility in manufacturing processes. Each species however does have its own characteristics, which may affect the characteristics and quality of the final product, and which may require adjustments and innovation in manufacturing. For example, Douglas-fir plywood exhibits the highest strength and stiffness because of the wood's high density. Other species such as

subalpine fir have much greater moisture content. Some species self prune more than others resulting in clearer wood and better recovery of quality veneer.

These variations have particular implications for lathe technologies but also for adhesives, drying, pressing and finishing. A particular technological challenge is to use new and different species in an optimal way and at the same time maintain or improve product quality and production costs.

Incremental Technological Innovation

1. *Optimization of species mix according to their characteristics and properties to achieve desired product performance.* The determination of properties for each wood species under varying conditions such as moisture, age and region will allow better use of the inherent properties of the wood and more reliable product performance.
2. *Internal log analysis.* If the exact nature of the inside of a log can be determined, by X-ray scanning, for example, then the log can be processed in the most appropriate and cost effective manner.

Preparing the Logs

Existing Technologies

Log preparation begins with the debarker, a mechanical device that strips the bark from the incoming logs. The bark is generally burnt as hog fuel to generate heat and power for plant operations. The debarked logs are cut into blocks approximately 2.5 m (8 feet) long.

A mill will select the type of debarker best suited to its needs in terms of maximum and minimum log diameter and production rate. Technology has centred on increasing throughput with minimal damage to the wood surface of the peeler logs.

In most mills, the blocks are softened prior to peeling. This may be done using steam vats, by soaking the blocks in hot water, or by subjecting them to a water spray, depending on the space requirement for such a system and that available at the mill site. When logs are carefully prepared, they can be peeled more smoothly. A smooth peel produces more veneer of higher quality and this could also result in adhesive savings. Availability of steam, throughput of the conditioning system and its efficiency in terms of log heating and energy usage are important considerations.

Veneer quality is also affected by peeler log temperature. Research has shown that higher quality veneer can be achieved using peeler log temperatures in the 32-38°C (90-100°F) range for spruce-pine-subalpine fir (SPF) species compared to 55°C (130°F) commonly used by the plywood industry. The trend is to use lower conditioning temperatures. Computer models have been developed to predict the temperature profile of logs during conditioning in order to optimize temperatures for peeling.

Incremental Technological Innovation

3. *Improved scanning and pre-sorting of logs by diameter class and species to accommodate different conditioning requirements and to optimize log handling.*
4. *Advanced computer programs to optimize yard management and log conditioning.* The benefit will be more efficient log yard utilization, more efficient log conditioning and higher quality veneer.
5. *Two-step log conditioning, i.e. conditioning log core after round up.* Removing extraneous surface layers would speed up log conditioning rates and reduce energy consumption.

6. *Further developments in computer modelling for temperature optimization of peeler logs.* This would lead to more efficient use of log conditioning systems and energy savings.

Peeling

Existing Technologies

A conveyor moves the prepared blocks to the veneer lathe where the charger grasps each log and centres it on the lathe spindles. When the block is centred, chucks lock into each end.

As the spindles rotate the block, the peeler blade cuts a thin sheet of veneer off in a continuous piece. A big peeler block can yield up to two kilometres of veneer at speeds as high as 365 m (1,000 feet) per minute. As the block rotates, its diameter decreases. To keep a constant peeling speed, the block rotates faster as the blade gets closer to the middle of the block. As well, the position of the cutting blade adjusts to the changing diameter of the block. Hydraulic guides adjust the angle of the blade to compensate for the decreasing diameter.

Veneer lathes are precision machines. They operate at extremely high speeds to produce veneer at thicknesses accurate to 0.03 mm. All manufacturers will modify and upgrade existing lathes according to needs.

Evolution of peeling has centred on technology to increase peeling speed and adjustments to knife settings during peeling to maintain quality. With the trend towards smaller diameter logs, improvements made to peeling speed are of major importance. Lathe speeds have increased from 90 to 365 m per minute (300 to 1,200 feet per minute) and X-Y chargers have been developed to improve loading of logs into the lathe and minimize the centring and roundup time. Core sizes have been reduced to 6.4 cm (2.5 inches).

Pressuring the log in the lathe was formerly accomplished with a solid nose bar, which resulted in high quality veneer but slow peeling speeds. Big bars (large diameter driven roller bars) currently predominate as they allow the fastest peeling speeds with less maintenance and down time.

Changes have occurred in knife settings for optimal veneer quality. Powered back rolls aid in the positioning of the log during peeling and prevent log movement. These technologies help to produce reasonably good quality veneer at the much higher production speeds needed today.

The industry has significantly improved its quality of veneer through the use of new lathe technology. Veneer quality has an important influence on plywood properties. If the veneer has high roughness, improper adhesive application will cause bonding problems during pressing. If the veneer exhibits a high thickness variation, excessively low or high pressure at the glueline during pressing can cause bonding problems. These conditions can result in plywood with lower mechanical strength and durability properties.

Incremental Technological Innovation

7. *Advanced computer models to help with new lathe designs.* Computer simulation of the peeling process can be used to visualize the events occurring at the knife-edge and aid in the development of new lathe controls.
8. *Further developments for incising veneer on the lathe.* Advantages would include fewer spin-outs during peeling, flatter veneer, faster drying and improvements in pressing and preservation. Incising has been shown to produce an increase in veneer yield in pilot plant studies.

9. *More advanced log loading systems.* Peeling models have shown the need for high accuracy in log centring by automated loading systems. More accurate loading systems will improve veneer recovery.
10. *Improvements in thickness control and surface roughness.* New lathes have mechanical improvements such as automated knife pitch controls. Older mills could benefit from lathe upgrades.

Breakthrough Technological Innovation

- A. *Adaptive process control.* There is significant scope for improvement in the area of adaptive process control systems and modelling of the peeling process. Installation of sensors on the lathe to detect veneer roughness, knife vibration and knife wear would allow on-line adjustments of the peeling process and would improve recovery.

Veneer Clipping

Existing Technologies

The ribbon of veneer is cut into pieces as it passes under the clipper knife. The clipper is guided by an electronic eye that scans the veneer ribbon for defects and determines where the knife should make each cut to get the maximum value from the veneer. The reciprocating knife has been generally replaced by the rotary clipper, which clips at higher feed rates. Cuts are usually made at 1.25 or 0.64-m (50 or 25-inch) intervals, except when a narrower, blemish-free piece of veneer can be produced. The clear pieces can later be upgraded for use in higher quality plywood. Waste pieces are chipped.

Incremental Technological Innovation

11. Scanning systems to automate the clipping procedure and maximize veneer yield at modern high speeds. Camera systems coupled with computer software to detect veneer defects are in development stages. Further advances and mill installation can improve yield.

Veneer Drying and Grading

Existing Technologies

Clipped veneer is separated according to moisture content. Sapwood contains more moisture than heartwood, so it must be dried for a longer time.

Workers or automatic machines feed veneer from two, three or four moisture content groups into dryers. Steam or gas heated jet dryers blow hot air onto the passing sheets. The dryers reduce the moisture content from as high as 100 per cent or more to as little as 3 per cent, on an oven-dry basis, to permit a strong, permanent adhesive bond.

The dried veneer sheets are graded according to how they can be best used in making plywood. Face pieces are used on the outside surfaces. Cross-bands and centres are used for inside layers. Face sheets without holes or cracks go directly to the glue spreader. Those with oversize defects are sent to the repair section. They can be trimmed, patched and assembled by taping or edge gluing into sheets large enough to make plywood panels.

The industry now uses multi level dryers with independently controlled multiple zones for fast production and lower risk of overheating the wood surface. A number of mills use direct fired jet dryers which impinge the flow of high temperature combustion product directly on the wood surface. All commercial dryers are equipped with moisture sensors. In some cases, an internal control system measures the temperature drop due to moisture evaporation, and then adjusts the rate at which veneer move through the dryer.

Uniformity of veneer moisture content is important for the bonding process. Regions with high moisture pockets can cause blows during the pressing process. Thus dried veneer with highly variable moisture regions will result in plywood with lower mechanical strength and durability properties. At the other extreme, over-drying of veneer will cause poor bonding and defective plywood. Technology is evolving to reduce moisture content variations in the veneer, and, simultaneously, to make the process more tolerant of such variations.

The trend is to sort veneer into strength and appearance classes for high quality and strength veneer-based products. The machine stress rated (MSR) grading of veneer is important for LVL manufacture.

Incremental Technological Innovation

12. *The use of ultrasonic stress grading.* By sorting, it would be possible to increase the value of veneer incorporated in engineered plywood panels or LVL used in specific building systems.
13. *Improved moisture sorting of veneer prior to drying.* With improvements such as better moisture content sensors, batches of veneer passing through the dryer would be consistent in moisture content and would facilitate more uniform moisture content veneer.
14. *Adoption of radio-frequency (RF) veneer drying.* While slower and more energy intensive than conventional drying, the RF unit (used in combination with a conventional dryer) can be used to dry "re-dry veneer" to produce more uniform levels of moisture content.
15. *Improvements to dryer operating efficiency and instrumentation.* Dryers could be equipped with sensors to monitor moisture content of veneer sheets and openings to release these sheets at desired levels of moisture.
16. *Veneer grading, defect cutting and assembly before drying.* Veneer dryer throughput would be improved and energy would not be wasted in drying defect veneer.
17. *Platen drying* may have the potential to provide shorter drying times, smoother and flatter surfaces, less tangential shrinkage and more uniform moisture content. It could be combined with a conventional dryer towards the end of the normal drying cycle where it would selectively apply more heating energy to wet pockets to further improve the uniformity of moisture content.

Lay-up and Gluing

Existing Technologies

When the veneer sheets are ready for assembly, workers place a face piece on a lay-up table. The cross bands are run through a machine that coats veneer with a thin uniform layer of phenol-formaldehyde adhesive. The pieces are then assembled using face pieces, cross bands and centre materials. Usually three or more sheets of veneer are used. A five-ply panel, for example, would be constructed using a face veneer, a cross band, a sheet of core veneer, another cross band and then a face veneer. Each layer is placed with the grain running at right angles to the adjacent veneer.

Some of the automated line systems apply adhesive with roller applicators but the majority of mills have switched to curtain-coater or spray lines. One mill uses foam application. The spray line is currently the most common. New developments such as the Hashimoto lay-up line from Japan have become popular with mills that have limited space available and full sheet 1,220 x 2,440-mm (4 x 8-foot) veneer. Operations that lack adequate quantities of full sheet veneer can use veneer composers which edge glue small sections into full sheets.

Changes in the gluing system such as gluing veneer of high moisture content and foaming the adhesive have reduced the amount of adhesive and lowered production costs. The development and use of phenol-formaldehyde adhesives for use with veneer at moisture contents of 10 per cent or more instead of 3 to 4 per cent is a major breakthrough. This has increased productivity in the dryer and the press; lowered adhesive spreads and improved bondability; and achieved better pre-pressing and assembly line tolerances. Costs for adhesive, drying and pressing have all been reduced.

Sufficient phenol-formaldehyde adhesive must be applied to the veneer to ensure a continuous film. Adhesive application rates range from 145 to 158 g of adhesive per m² of glue line (30 to 33 pounds per thousand square feet), with levels being increased for very rough veneer or in hot dry weather.

Gluing high moisture content veneer (up to 15 per cent) results in a product closer to the equilibrium value in actual use, reducing warp and dimensional changes. To do this and successfully retain product quality, however, a plant must operate under strict process controls.

Incremental Technological Innovation

18. *On-line adhesive spread measurement.* Continuous on-line measurement could permit automated monitoring and process control.

Breakthrough Technological Innovation

- B. *New adhesives for faster setting, better bonding, higher moisture content tolerance and lower temperatures.* Savings in drying and pressing energy could be substantial. Volatile organic compound (VOC) emissions would be reduced. Improved adhesives now on the market are expensive and application presents problems.
- C. *Intelligent system to monitor adhesive application.* An intelligent system could continuously adjust adhesive spread according to veneer roughness or other factors.

Pressing

Existing Technologies

At the end of the assembly line, the veneer assemblies are stacked and sent to the presses. In most mills, pressing has three phases.

In the first phase, the assemblies are squeezed in a cold press. This phase helps the adhesive transfer to adjacent veneer, prevents air from drying the adhesive and makes the assembly easier to handle with automated equipment.

In the second phase, the assemblies are fed onto individual caul plates or directly onto platens in the hot press. When the hot press is loaded, hydraulic pressure is applied to squeeze the assemblies at pressures of up to 1,400 kilopascals (about 200 pounds per in²). At the same time, the plywood assembly is heated at 150°C (300°F) over a period sufficient to fully cure the phenol-formaldehyde adhesive.

Adequate pressure, temperature and time are required to ensure the phenol-formaldehyde adhesive has fully cured and produced a durable adhesive-wood bond. Overlooking one of these variables can lead to lower plywood qualities.

The final phase occurs when the plywood panels exit the hot press. They are trimmed on the sides and ends to finished dimensions. Common trim sizes are 1.2 x 2.4 m for export to countries requiring metric sizes and 4 x 8 feet for domestic use.

The main advance in plywood pressing has been in the loading and unloading systems to speed up these phases and allow nearly continuous operation of the press. Modern hot presses generally use oil as the heating medium.

The plywood industry is moving towards production of thicker panels or specialized panels, which will require continual process improvements to reduce press times and ensure economical production rates.

Incremental Technological Innovation

19. *Further development of steam injection and in-situ steam technology in pressing.* This combined with incising technology has the potential to substantially reduce press times. It can also be used as a retrofit technology.

Breakthrough Technological Innovation

- D. *Continuous pressing.* This is now used successfully in other panel sectors and also in the production of LVL. Application to the plywood sector would improve production efficiency and flexibility.
- E. *Self-generated steam pressing.* Experiments are being performed in the laboratory on pressing high-moisture content veneer in a sealed environment, to create conditions similar to those obtained with steam injection, but without the related capital cost.
- F. *Other high-energy adhesive curing methods.* Energy forms other than convection heat (e.g. RF and microwave heating) may have the potential to cure adhesives extremely fast if combined with the right adhesives systems.

Patching

Existing Technologies

Veneer is very rarely found without splits, knotholes or other flaws. These flaws must be repaired neatly and efficiently to enhance value.

Three methods of patching are used in North America. The oldest form is a boat shaped wooden slab which is punched into veneer (replacing a defect) before the veneer is used for plywood manufacture. The process is environmentally friendly but slow and labour intensive. The industry has adopted two liquid slurry applications to patch finished panels with acceptable speed. Putty-patching is water based and fairly inexpensive but is only acceptable on openings of 25-mm (1-inch) size or less. Synthetic patching is a two component system using natural oils and fillers with isocyanate to produce a polyurethane patch for superior durability and defects up to 75 mm (3 inches) in size. Both material cost and wastage are higher. The components are reactive and the equipment needs periodic cleaning.

Incremental Technological Innovation

20. *Automation of defect detection and repair.* This technology is available in Europe but has not yet been adopted in North America.
21. *Development of new patching compounds.* New compounds behaving more wood like in their response to heat, moisture and pressure would allow for overlays on patched panels.

Trimming, Sanding, Grading and Storage

Existing Technologies

Generally, only plywood intended for printed end-uses, such as high grade Douglas-fir, is sanded to achieve a smooth, attractive finish. Modern methods produce fine finishes with fast wide belt sanders. After sanding, the plywood is graded and prepared for storage or shipping.

Grading and sorting will become particularly important for this sector to optimize the use of veneer sheets and maximize end-product value. Sheathing applications, for example, do not necessarily warrant a high-grade veneer.

Plywood may be treated or overlaid with other materials for specialized use.

Following the final grading, plywood is piled in standard quantity units called lifts, about 75 cm (30 inches) high. The lifts are securely bound with steel strapping for protection and ease of handling. They are labelled for type, grade and size of panel. The lifts are delivered to the warehouse for storage or shipment.

Incremental Technological Innovation

22. *New grading systems with improved accuracy.* A combination of technologies (ultrasound, RF, microwave, camera, X-ray) can be used to grade according to density, slope of grain, visual appearance and moisture content. New stress-grading equipment is being commercially developed, which can measure the mechanical properties (parallel and perpendicular) of the panels on-line.
23. *Value-added products can be produced for specialty applications.* In addition to tongue-and-grooved panels, which are increasingly common for subfloor applications, plywood mills can take advantage of niche markets for cut-to-size panels, overlaid panels, specially finished surfaces, etc.

Environmental Control

Existing Technologies

Softwood plywood is relatively environmentally friendly. Manufacturers recognize the importance of sustainable development to the public. For the plywood sector, which sources virtually all of its raw material from the forest, this means forest management and wood harvesting as well as manufacturing, where there are some similarities with other panels.

The plywood sector does generate wood residues in debarking, peeling, veneer clipping, sanding and trimming. Traditionally, this residue has been disposed of in beehive burners, but for the most part these are no longer acceptable particularly in populated areas. In some areas, wood residue has been

used as a low cost fuel, but the consumers are also facing restrictions. The use of high temperature burning, with fewer emissions, is costly. Recycling is used where possible.

Emissions from plywood manufactures are mainly from the drying process where steam and airborne particulate are common. This results in a blue haze and is a source of complaint in high population areas. Emissions from hot pressing such as VOCs and adhesive odours are normally at a minimum since phenol-formaldehyde adhesives emit very little formaldehyde when fully cured.

Environmental control is treated in greater detail in Appendix I.

Incremental Technological Innovation

24. *Addition of borax to veneer before drying to reduce VOCs.* Borax can react with wood extractives, reducing the quantity of emissions of VOCs during the drying phase.
25. *Development and utilization of processes such as RF or superheated steam/vacuum.* This would improve veneer drying at lower temperatures and reduce blue haze. These processes are available for lumber but could be optimized for drying veneer.
26. *Adoption of appropriate environmental technologies now available in other panel sectors.* Some environmental technologies available in other panel sectors (e.g. use of exhaust air as combustion air) could allow plywood plants to meet emission restrictions near highly populated areas.
27. *Development of equipment capable of operating at lower noise levels* would improve health and safety conditions in the plants.
28. *Development of new applications for bark and other residues* to reduce environmental pressure and increase revenues. Opportunities might include power, co-generation, agricultural uses, pulping and other composite products. The whole wood industry is beginning to show interest in solving a bark disposal problem, and is exploring the potential of bark as a raw material for profitable new products, including resins and moulded products.
29. *Integration of emission control and environmental friendliness into all phases of the manufacturing process,* combined with measures to improve the efficiency of the manufacturing process and reduce costs. Efforts need to be made to gradually integrate environmental factors in all production parameter optimization models.

Process Control and Quality Assurance

Existing Technologies

Automation in plywood operations has been increased substantially to reduce overall costs and to improve the consistency of product quality. Sensors and on-line measurement devices are increasingly used to control processes and product quality. The level of automation, however, is not as advanced as in other panel sectors, and the cost of retrofitting automatic controls is a major constraint. Nonetheless, greater use of computers and integrated automatic controls with feedback to make immediate process adjustments may have application in this sector.

Some plants have used computerized simulation models to assist decision making in operations and equipment purchases with good success. These tools can be applied across the operation and back into resource allocation.

Many of the process monitoring functions required by certification programs are currently being performed in mills; however these functions are frequently done manually. Automated process controls

will allow for continual monitoring of quality parameters, such as moisture content, adhesive spread, press time and temperature and sample test data. These process controls can be further adapted to alter any phase of the process, in response to feedback, and allow for much greater mill automation. All collected data can be collated and stored for quality control certification records.

Incremental Technological Innovation

30. *Adaptation of controls used in other panel sectors to the softwood plywood sector.* Benefits would include reduced labour costs, improved productivity and product quality.
31. *Automation for flexible production of non-commodity highly specialized products.* Many value-added products have small markets. Automating manufacturing processes could make them more flexible by allowing rapid changes in production lines and making non-commodity products economically viable. In the past, automation has often been synonymous with reduced flexibility; however, advanced process control techniques exist, which can successfully combine high productivity and flexibility.
32. *Refinement and further application of on-line monitoring systems.* This could include moisture content detection in dryers to more rapidly adjust drying parameters and monitoring veneer roughness to adjust adhesive application, and in-line stress grading of panels.

Breakthrough Technology Innovation

- G. *Fully integrated, automatic process control.* Such innovation would go to a more advanced level of technology than that suggested above, and would apply to the total production process as a fully integrated system.

Product Development and Improvement

Existing Technologies

New and improved products represent this sector's route to a successful future. In fact, most plants are attempting to shift production to higher value products leaving much of the sheathing market to lower cost competitors. There are myriad opportunities in structural and engineering as well as industrial applications.

Amongst the panel products, softwood plywood has unique combinations of mechanical and physical properties resulting in superior strength, stiffness and dimensional stability that make it the panel of choice for many applications.

The major challenge will be to find niche market opportunities that best suit the special characteristics of softwood plywood, including those of particular species, and then enhance existing or develop new products to exploit those opportunities. New applications will need to be identified. This also has significant implications for production technologies.

LVL used as a substitute for traditional lumber, particularly for demanding structural requirements, is a good example. LVL is manufactured with veneer using processes similar to plywood except that veneer sheets are aligned in the same direction to produce long panels which are ripped into strips for joists, beams and other structural members. LVL has also been used for millwork. High frequency curing of the glue line helps to reduce press times that tend to be long using traditional processes because LVL is at least 38 mm (1.5 inches) thick.

Incremental Technological Innovation

33. *Expand specialized species in standard and new products.* Numerous species are used in the production of softwood plywood and this is a result of historical practice and availability. Some widely available species have limited use to date in plywood production and might present future opportunities.
34. *Continued development of new products.* As discussed above, existing properties of plywood (e.g. fire performance, weather resistance, surface characteristics, assembly procedures) can be modified to address the specific requirements of niche markets. The replacement of core veneer with lower cost substitutes (e.g. OSB) may also be a consideration.

Breakthrough Technological Innovation

- H. *Development of innovative products for entirely new applications.* The objective is to design radically new products on the basis of existing veneer production and pressing technology. Such new products should aim at responding to end-user needs, particularly in new applications related to the construction, industrial and architectural markets. Another target should be non-panel structural applications. New performance characteristics can be obtained through modification of the veneer, or combination with other materials.

Summary

The plywood industry is a mature but nevertheless evolving industrial sector which currently faces two major challenges: 1) intense competition from OSB panels, and 2) escalating wood costs. The road to survival and financial success goes through the extraction of maximum value from available logs, more cost/value effective manufacturing processes, and the identification of new markets which make use of the products unique characteristics.

A number of incremental technology innovations have been listed in this chapter, which would help the industry along in this direction. Every one of them represents potential gains for the plywood sector, but it should be remembered that the manufacturing process operates as a system: every time an operating parameter is modified, the whole process needs to be re-visited, including impact on costs and market. A few bolder “breakthrough” technologies have also been identified. If they can be successfully developed, they will allow the industry to make a significant leap towards its goal; these are described in greater detail in Chapter VIII.

Description

Oriented strand board (OSB) is a structural panel product made from wood strands, flakes or wafers bonded with exterior-grade adhesives such as phenol-formaldehyde or isocyanate, under intense heat and pressure.

Having evolved from waferboard, OSB entered the structural panel market in the early 1980s and has evolved through ongoing research and development in composite wood technology. The OSB industry is now well established in North America and growing rapidly.

OSB panels are generally manufactured from aspen poplar in the northern part of North America, and southern yellow pine in the south, however other hardwood and softwood species, alone or in combinations, may also be used. The product is manufactured in three or more layers with the strands of both surface layers aligned in the longitudinal panel direction, while those of the core layer are aligned perpendicular to the length of the panel. The alignment of strands gives OSB panels improved mechanical properties (strength and stiffness) and physical properties (dimensional stability) in the direction of alignment.

The physical and mechanical properties of OSB make it suitable for a wide range of structural and non-structural applications. It is widely used in residential construction and gaining recognition in the commercial construction industry. Applications include subflooring, underlayment, roof sheathing, wall sheathing and exterior siding.

OSB is increasingly used in engineered components such as the webs of wood I-beams, as components for floor trusses, for stressed skin panels and structural foam core panels. It is also suitable for applications such as crating, pallets, bins, furniture frames, display racks and store fixtures.

Vision

This sector is having a very successful decade. It has experienced exceptional growth rates in new capacity, shipments and exports in the first half of the nineties and this is expected to continue. Both the product and the overall manufacturing capability of OSB plants have improved. There has been significant technological innovation and the sector is contributing substantially to the Canadian economy, particularly with its exports.

The vision of this sector is premised somewhat on these past successes. Despite current over-capacity, there is a sense of optimism and growth. There is the self confident belief that manufacturers have the capability to design and build a product that gives good value at economical cost.

The vision is centred both on technology and on markets. Despite the tremendous growth in capacity now taking place most are convinced that a continually enhanced product from technically advanced manufacturing processes will make it much easier for world markets to absorb the surge of Canadian OSB panels and related structural products.

OSB production is expected to keep on growing, albeit at a slower rate than in the past. Plants will be larger but fewer in number as the older, less competitive operations are forced to adapt to niche markets, or shut down in periods of excess capacity and very low prices. OSB will dominate sheathing markets and

will become a significant player in offshore markets. Raw material will become more expensive as the sector is forced to compete with other sectors for this material.

Those in the sector see technological innovation giving the markets essentially what they want: lighter weight, smoother surfaces, higher durability, insect proofing and moisture resistance. The availability of design values will allow OSB to move beyond residential construction into more complex structures and other end uses. OSB may be used in such diverse products as concrete forming, furniture, shelving and decorative panelling.

Manufacturing technology will continue to change towards increased levels of automatic control and meeting more stringent environmental standards. For example, the manufacturing process will have much improved press lines supported by advanced flakers with the ability to manufacture quality strands from a variety of fibre species, and more effective dryers that will give precise control over strand moisture content.

Economics

Contribution

The OSB sector shipped \$1.1 billion worth of product in 1996. This compares to less than \$300 million in 1990, representing an average annual growth rate of 24 per cent. The average growth of Canadian manufacturing shipments from 1990 to 1996 was about 5 per cent.

Over the same period, employment in the OSB sector increased from about 1,500 to 2,400 for an average growth rate of 10 per cent. Exports exceeded \$940 million in 1996, representing 85 per cent of shipments. Canadian exports are 92 per cent to the US, 7 per cent to Japan, and 1 per cent elsewhere. Imports from the US are small.

From 1990 to 1996, shipments per employee increased from \$175,000 to \$453,000, a 17-per-cent annual increase. This reflects substantial improvement in mechanization, productivity, and technological change. Value added per employee was even more impressive, increasing over 35 per cent in the same period.

The Canadian OSB sector has grown more quickly and makes a much greater relative contribution to its own economy than does its US counterpart. The US industry is larger in absolute terms with a capacity of about 8.8 million m³ (10 billion square feet [BSF] 3/8-inch basis) compared to about 6.2 million m³ (7 BSF) in Canada.

From 1988 to 1996, the total capital stock (new fixed assets less discarded assets) in the OSB sector expanded from \$1.1 to \$1.6 billion for an annual growth rate of about 5 per cent. Annual capital investment (80 per cent machinery and equipment; 20 per cent buildings) ranged respectively between \$160 million and \$220 million in those years.

OSB is a relatively small but significant player in the Canadian economy. It has major contributions in export earnings with almost 2 per cent of total Canadian manufacturing net exports. Its capital to labour ratios are almost twice that of the Canadian manufacturing average. Its plants are distributed across the country supporting regional development and rural economies. It is a growth sector, which utilizes species of raw material that, a decade ago, were considered non commercial.

In 1997, Canada had 22 OSB mills with a total capacity of 6.86 million m³ (7.8 BSF). Its regional distribution is set out in the following table:

Province	# of OSB mills (1997)	Capacity Million m ³ (BSF, 3/8")	% capacity
British Columbia	3	1.03 (1.175)	15
Alberta	5	1.70 (1.935)	24
Saskatchewan	1	0.18 (0.210)	2
Manitoba	1	0.44 (0.500)	6
Ontario	5	1.40 (1.595)	20
Quebec	6	1.85 (2.100)	26
New Brunswick	1	0.26 (0.300)	3
Total	22	6.86 (7.800)	100

Sources: SBA and Resource Information Systems Inc. (RISI), Wood Products Review, July 1997.

OSB is manufactured in seven provinces. Quebec is currently the largest producer followed by Alberta and Ontario. Together these three provinces account for 70 per cent of Canada's production. Several new mills were announced in 1997, which, if built, will add 1 million m³ (1.7 BSF) of capacity.

Prices of OSB declined somewhat in 1996 with the surge of new capacity that came onto the market. Substantial growth in North American consumption continued in 1997, and is expected to continue as well in 1998, but at a lower rate.

Outlook

Based on in-depth analyses of various end use markets in Canada and the US and competitive aspects such as costs and product substitution, RISI has forecast that total demand for Canadian OSB will exceed 7 million m³ (8 BSF) in the year 2000 and exceed 13 million m³ (15 BSF) by 2012. This compares to 4.6 million m³ (5.2 BSF) in the base year of 1996. Based on these figures, the average annual growth in demand for the first decade of the millennium exceeds 5 per cent.

This demand growth presupposes a significant rate of substitution of OSB for softwood plywood within the structural panel markets, particularly in housing, but to a lesser extent in non-residential and industrial markets. The OSB share of the structural panel market was 69 per cent in 1996. This is expected to increase to 79 per cent in 2000 and to 90 per cent in 2012.

Exports, primarily to the US, will continue to dominate this sector. In 1996, 82 per cent of demand was represented by export markets. RISI believes that this balance between export and domestic markets will remain essentially as is with a slight increase in favour of domestic demand to 2000 and a longer term shift slightly towards export markets to the end of the first decade.

The large export component, however, adds to the difficulties of making meaningful demand forecasts. As RISI points out, the rate of product acceptance in both US and offshore markets, prevailing exchange rates, the overall health of the world economy and relative shortages of US timber will all affect demand for Canadian OSB.

Canadian capacity is projected to climb 85 per cent in the period 2000 to 2012 in response to demand. Operating rates will range from 83 to 96 per cent as the sector goes through its supply demand cycles. Prices should recover to peaks of 1994 by the second half of the next decade. Any significant delays or surges in new capacity combined with unexpected demand cycles, however, could substantially alter this scenario.

Driving Forces

Before assessing the factors that will impact on future technological innovation, it is useful to review briefly the historical development of this sector. The first mills came into operation around 25 years ago. Both the mills and the products of today bear little resemblance to those in the early years. Physical and mechanical properties have improved whilst manufacturing costs and density have been reduced substantially. There have been major gains in fibre recovery, strand orientation and adhesive efficiency. The manufacturing process has evolved to accept new types of wood furnish and to yield panels with different properties. In fact, the ability of this sector to research and implement new technologies combined with its flexibility of manufacture is largely responsible for its high degree of success. The sector itself continues to be driven by technological innovation and by market opportunities and growth.

It is this technologically attuned mentality, established knowledge base, expectation of positive change and faith in this sector to develop appropriate technologies that will help drive innovation in coming years. Five categories of driving forces which will also impact future technological innovation are set out below. These are cost reduction, improved products, new products, raw material situation and environmental concerns.

The need to *maintain low manufacturing costs* is an important driving force for this sector. Highly competitive pricing made possible by low costs will be necessary to maintain and develop growing markets necessary to absorb the very large volumes of new OSB capacity. In periods of overcapacity with severe reductions in price, as experienced by the sector in the mid to late nineties, low costs are necessary to retain corporate viability, particularly for older facilities.

The new markets required for the future relate not only to continued product substitution and to offshore export, but also to competition with highly efficient US producers in their home market. This is the dominant market by far and particularly vital for Canadian producers, but they may be placed at a disadvantage from time to time by unexpected swings in factors affecting international trade and economics including exchange rate variations and protectionism. In short, low costs are the key to survival and growth in this sector.

Innovation in cost reduction will relate to the entire manufacturing process but particularly to high cost components such as wood, adhesives and energy required for flaking, drying and pressing operations. Low cost productivity improvements through incremental technological innovation will be particularly important for ongoing cost reduction.

As with the softwood plywood producers, there is an added dimension to cost performance. When OSB expands into non commodity, higher value markets, where quality and product differentiation are especially important, then product attributes that will command a high price become more significant than simply low operating costs. In these cases, *contribution to profit margins* is a more important driving force impacting on technological innovation than cost reduction.

Also related to growth and viability is the *need to improve existing products* to meet customer expectations and changing requirements and to increase market share. Better dimensional stability is most important, but durability, uniformity, smoothness, workability and aesthetics are also considerations.

Finished panels leave the plant with a 2 to 5 per cent moisture content. As they become exposed to the elements, they pick up varying amounts of moisture affecting dimensional stability. The building industry would prefer a panel with a moisture content closer to service conditions. Reduced panel density would also improve longer term dimensional stability.

There are also substantial opportunities in *new product development* that will help maintain future growth. These may be new applications for existing or modified OSB or they may be OSB combined with other materials for new structural products. Specialty products tend to have higher margins than commodities.

The *raw material situation* for the Canadian OSB sector, particularly for certain producers within it, may be changing. Traditionally the Canadian sector has used aspen which is well suited to its manufacture and which has been in abundant supply at relatively low costs. Aspen is fast growing with high yields and represents a significant portion of Canada's hardwood forest inventory.

However, as sector raw material requirements expand, as other sectors increasingly use this resource for their products, and as the most readily accessible aspen is harvested, rising costs and reducing availability may force some operations to examine other options including different species, softwood sawmill slabs and possibly the use of recycled OSB. Technologies are available and processes are flexible to enable these changes to be made whilst maintaining levels of product performance. In fact, plants in the southern US and in Europe use pine species as their raw material. The challenge for innovation in the Canadian sector is to make the necessary changes throughout the processes at reasonable costs and with beneficial impact on product quality.

With the possibility of a scarcer raw material supply, there is also the prospect of overall rising raw material costs which to date has been one of the key competitive advantages of the OSB sector. Technological innovation may be required to address this concern.

The rapid growth of the industry has also created a *shortage of available skills*, and some mills have experienced high turnover as a result. The solution to this problem rests with the ability of industry and education institutions to expand training opportunities.

Traditionally, the sector has experienced relatively few problems with *environmental impact*. It uses little process water and relies on phenolic adhesives, which release little formaldehyde when fully cured. Nonetheless, with an increasing public awareness of environmental issues and more stringent environmental regulations especially in urban areas, producers have been adapting technologies to reduce environmental impact. New technologies and enhanced control systems have been developed by equipment suppliers to reduce capital, operating and maintenance costs of environmental systems.

This evolution will continue, and it will impact the industry as follows:

- in the forest - logging methods
- at the log yard - management of water run-off
- in the mill - bark disposal or utilization, burner stack emissions, dust and noise control, VOC emissions during drying and pressing, waste recycling.

Existing and Future Technologies

With the assistance of research, OSB manufacturing technology has progressed steadily over the past ten years. Drying costs have been reduced and strand quality improved through proper wood yard management. Production efficiency has improved through the use of optimization systems in the pressing and processing operations. Board density has been reduced through the use of longer strands in panel face layers. Press times have been reduced through faster adhesives and higher mat face-layer moisture contents.

The degree of strand alignment has been improved through control of mat forming parameters based on a number of technical advancements. OSB is now produced faster and at a lower density without sacrificing quality.

As a result the OSB sector is well positioned for incremental technological innovation in both panel quality and manufacturing processes with good potential returns but without excessive costs. Manufacturers are no longer limited to such costly options as high adhesive content and excessively long press time.

Through better scheduling of maintenance operations, the plants are able to reduce unscheduled downtime. They are incorporating preventative maintenance programs which include regular vibration analysis of all rotating equipment in order to trend bearing vibrations and predict failures. Plants are also targeting equipment requiring the longest maintenance periods in order to modify or replace them in order to shorten maintenance periods.

Raw Material Handling and Storage

Existing Technologies

OSB production currently relies on round wood. Until recently, OSB manufacturing used only 2.5 m (8 foot) logs. More wood is now supplied to mills as tree-length stems, as harvesting methods have changed and flaker capabilities have improved.

In addition, there is more use of portal or circular type cranes in log storage and handling systems of new plants to increase capacity of storage areas and to reduce manpower and maintenance costs for mobile equipment.

The OSB industry is under pressure to use wood species which do not always have the same characteristics as aspen. So far, the inclusion of denser species has been incremental, and the producers have been able to incorporate the less desirable furnish through relatively minor modifications to the process. High quality OSB panels are currently being produced using up to 50 per cent dense hardwoods as the raw material furnish in the core layer. OSB panels have also been made successfully from sawmill softwood slabs in the laboratory.

Incremental Technological Innovation

1. *New research-based techniques to improve log yard management, to limit wood deterioration and to control log moisture content before processing.* The acquisition of computer programs and other tools to monitor log moisture content in the yard will make it easier to optimize rotations and to improve fibre recovery and flake quality.
2. *Handling systems to accommodate new sources of raw material while maintaining productivity and controlling waste and down-time.* Diversification of raw materials supply requires that the mills be able to handle smaller, more fragile or crooked logs.

Breakthrough Technological Innovation

- A. *New and modified machinery to accommodate variations in wood species and new shape infeed material with different geometry.* Different shape material (e.g. slabs) will require major changes to the manufacturing process. Most challenging of all perhaps is the possibility that some mills may need enough process flexibility to handle a variety of furnish types.

Log Pre-conditioning

Existing Technologies

A log pond is used to thaw out the logs in cold climates and to ensure adequate log temperature and moisture content for the debarking and stranding operations. The optimum temperature of the log pond is determined according to wood supply characteristics (e.g. log diameter, species, log moisture content) and climatic conditions (e.g. air temperature, wind). In practice however, the soaking time is frequently controlled by the capacity of the log pond, and optimal log conditioning is not always possible.

Incremental Technological Innovation

3. *Computer models to optimize conditioning time and energy usage according to locally prevailing conditions and other production parameters.* Research will be required to specify relationships between log conditioning time and temperature and key process parameters such as flaking quality, drying efficiency and adhesive activity. The same models will also be used to simulate the conditioning process, evaluate log sorting scenarios, and optimize pond design.
4. *Determination of optimal conditioning parameters as new species are added to the wood supply.* Once the above described models are in place, they will need to be calibrated for other species. Simulations will be used to simulate the processing of species mixes, and determine optimum parameters.

Debarking

Existing Technologies

Bark is low in density and strength. It often traps dirt and other foreign matters and is removed to ensure panel quality and to protect flaker knives from damage. The most common debarker used in OSB mills is the cambium ring debarker. Drum debarkers are increasingly considered as an alternative to ring debarkers because of their ability to maximize fibre recovery from lower quality logs. Ring debarking may have to be supplemented with a rotor type drum debarker (e.g. Fuji King) to prevent breakage of smaller logs.

Incremental Technological Innovation

5. *Ring debarkers with higher speed and more sophisticated controls,* where tool pressure and ring speed are varied automatically to accommodate varying log types and diameters. This is particularly significant for maple and birch where debarking efficiency in typical ring debarkers is lower than that for aspen. Emphasis on enhanced debarker maintenance will support improved debarking efficiency.
6. *Tandem ring debarkers to deal with long stringy bark.* This is being tested by debarker manufacturers. The first ring has splitter knives to slice the bark and the second has regular knives to remove it.
7. *Debarking systems designed for frozen wood* could remove bark before log conditioning, thereby facilitating the conditioning operation, and improving strand quality and wood recovery.

Flaking

Existing Technologies

Disc and ring type flakers are most commonly used in the OSB industry. Both types produce very satisfactory strands up to 15 cm (6 inches). However, the ring type flaker is more suitable for producing very long strands, up to 30 cm (12 inches).

Strand geometry is one of the most important factors determining the properties and appearance of OSB. In general, longer and thinner strands improve properties by providing more actual contact area and better stress transfer. They yield a higher degree of permanent set after densification at elevated temperatures and significantly decrease thickness swelling and linear expansion.

Incremental Technological Innovation

8. *New flaker designs.* One new development being introduced is a ring flaker with a ring that travels in a vertical direction (upwards) as opposed to the traditional horizontal direction. As log bundles are typically in the range of 45 cm (1.5 feet) high and 1.5 m (5 feet) wide, a vertical travelling ring has approximately one third the distance to travel, hence providing a higher capacity.
9. *Disposable flaker knives to provide more consistent knife run-out.*
10. *Optimization of flaker knives and flaker settings* for improved consistency in flake geometry, higher recovery and enhanced adhesive efficiency. Research into this area of opportunity needs to continue in combination with pre-conditioning studies. It should also consider the new types of hardwoods entering the furnish, since the latter tend to produce more brittle strands which affect fibre recovery.
11. *Panels with longer, thinner strands.* R&D findings have shown that reducing strand thickness closer to 0.3 - 0.5 mm (0.015 - 0.020 inch) and increasing strand length to 15 cm (6 inches), or even 30 cm (12 inches) will improve most board properties. Although thin strands (below 0.3 mm) can result in lower density and more stable panels, producers have not yet been able to take advantage of this knowledge because of reduced recovery. Strand thickness also needs to be optimized for specific strand lengths. It is expected that, with optimization of conditioning and flaking, the production of long, thin strands will become feasible.
12. *Reduced flake curl.* Curl inhibits proper adhesive distribution on the inside surface of the flake. This is of particular concern with wider flakes and some of the denser species.

Drying

Existing Technologies

Three-pass rotary dryers have been the most popular type with the OSB industry. However, single-pass dryers are more common in new plants. A conveyor type dryer has been introduced into the OSB industry for drying long strands at lower temperatures.

Because of their lower temperatures and smoother operation, conveyor dryers lead to much reduced VOC emissions during drying, and they reduce the risk of fires. By avoiding the tumbling action of rotary dryers, conveyor dryers treat the strands much more gently, reduce breakage and dust formation, and generally handle thin and long strands more efficiently.

Moisture control is critical for manufacturing consistent board quality. Current technology requires that the infrared moisture analyzer be mounted above a consistent level of flakes to obtain a consistent moisture level reading. This is difficult with the close coupling of modern processing, e.g. dryer primary cyclones close coupled with dry flake screens.

Incremental Technological Innovation

13. *Refinements in the use of conveyor drying for OSB.* For example, existing conveyor dryers experience some problems with the deposition of fine particles in the conveyor itself, and this problem needs to be resolved.
14. *Adaptation to new species, especially dense hardwoods, and to mixed species,* in order to maintain strand quality, fibre recovery, and to achieve the desired moisture contents. The industry's drying technology has been developed mostly for aspen.
15. *Further reduction and elimination of any volatile compounds emitted during drying.* This will require identification and quantification of the various species involved. Progress in this direction will also come from lower drying temperatures and higher target moisture contents.
16. *New moisture analyzing technology that can monitor moisture content at the most appropriate locations,* i.e. close to dryer inlet and outlet. Combined with more flexible hardware, this technology will make it easier to narrow the range of final strand moisture contents.

Screening

Existing Technologies

Rotary screens are the predominant screening equipment used in the OSB industry. Inclined vibrating conveyors with screened sections are also being used successfully, particularly for the core layer streams as increasing amounts of hardwoods are being added to the wood furnish. Because hardwood flakes are more brittle than softwood flakes, the gentle handling characteristics of vibrating conveyors result in less breakage than rotary screens. The use of these conveyor screens may increase if the trend continues toward the use of longer and thinner flakes, as the tumbling action of rotary screens may result in unacceptable breakage levels.

Incremental Technological Innovation

17. *Re-screening fines from rotary screens.* Due to the tumbling action of rotary screens, a small portion of acceptable strands always passes through the screens and gets carried away as fines, resulting in process losses.

Blending and Resination

Existing Technologies

The industry has traditionally used powdered phenolic adhesives, but liquid phenolic adhesives applied in large diameter drum blenders with spinning disc are becoming more popular. The trend is to convert to liquid phenolic adhesive or to add the ability of using liquid adhesive. Liquid adhesives adhere better to the flake surface, and make it easier to increase adhesive application rates with the denser woods, or when special properties are desired. For example, the web stock for wood I-joists must be

stronger and denser and therefore requires more adhesive. Liquid phenolics are cheaper to produce than powders; they can include additives, and they avoid some of the dust problems associated with the powder adhesive. On the other hand, powders are much cheaper and easier to transport, store and apply.

A few plants use isocyanate adhesives, primarily for the core layer, where their fast reaction time is most useful. Isocyanates are more commonly used with specialty boards. Their use is growing as lower volumes are required and higher moisture contents are possible with this type of adhesive. This means less energy and greater dimensional stability. On the other hand, isocyanates are more expensive and more hazardous to handle than phenolic adhesives. With continuing R&D efforts, the balance of advantages between the various systems keeps changing. Isocyanates are also preferred when customers insist on a light-colour board (e.g. in Japan).

Relatively small amounts of adhesive (typically 2 to 3 per cent) are used in the process, and uniformity of distribution is more important than total adhesive coverage. While increasing adhesive content is the easiest way to improve panel performance and compensate for weaknesses in other manufacturing parameters such as poor quality furnish and low density, it is relatively high cost. Adhesive represents 15 to 20 per cent of production costs. Attempts at further reducing adhesive usage have failed using existing adhesive applicators. Specialty products are being manufactured with higher adhesive levels (up to 10 per cent) for increased stability.

Incremental Technological Innovation

18. *Integration of fines into the mat.* While a number of plants currently feed some of their fines into the core portion of the mat, they are limited by the negative effect of fines on board properties. Improving technology will allow them to increase these amounts.
19. *Better powder adhesive blending systems including electrostatic blending.* Recent research suggests that powder adhesive distribution and retention are limiting panel performance and adhesive efficiency.
20. *Development of more economical and effective liquid adhesive applicators.* Spin discs are expensive to buy and a combination of discs and spray nozzles may be superior. Maintenance of spray nozzles also requires attention.
21. *On-line systems for monitoring adhesive distribution and relating it to other production parameters.*
22. *More reactive adhesives, through new formulations or the use of catalysts, to reduce press times without creating pre-cure problems.*
23. *Improvements in the properties of adhesives to reduce caking and adhesive build-up in blenders.*
24. *More economical adhesives (e.g. by incorporating extenders, such as lignin or soy bean based derivatives).*
25. *More moisture-tolerant adhesives.* Higher furnish moisture contents reduce drying requirements and related emissions. They also facilitate consolidation of the panel and promote dimensional stability.
26. *Adhesive formulations better adapted to broader mixes of furnish types, including dense hardwoods, such as birch and maple.*
27. *Adhesives that help reduce the emissions of VOCs emitted during the pressing operation, and from the finished product.*
28. *New adhesive formulations appropriate for steam-injection technology.*

29. *Optimization of blending technology* to better adapt it to the combined distribution of liquid and powder resins.

Breakthrough Technological Innovation

- B. *New adhesives for faster setting, better bonding, higher moisture content tolerance, higher species tolerance and lower temperatures.* Savings in drying and pressing energy could be substantial. VOC emissions would be reduced significantly. The identification of such systems will require a better understanding of the bonding process, as well as a better knowledge of polymers not commonly associated with wood.
- C. *New distribution systems need to be developed to improve the distribution of powder adhesives.* As discussed above, distribution problems limit the use of advanced powder adhesives. Radically new designs, possibly adapted from other industries, would allow optimum use of new high performance adhesives.

Wax and Additives

Existing Technologies

Because it represents a relatively low cost component in OSB production, wax has not received much attention from the industry or from the scientific community. Even though it can enhance moisture resistance and dimensional stability, potential gains are limited because additional wax rapidly interferes with the bonding process. The presence of high levels of wax also makes OSB more flammable.

Incremental Technological Innovation

30. *Integration of wax and adhesive research to bring out potential synergies* and to clarify the role of wax in various adhesive formulations with respect to wood characteristics, moisture content and other parameters.
31. *Addition of chemicals such as borates at the blending stage.* Preliminary research has shown that there would be no negative impact on properties but improvement in insect resistance, including that against termites, and fire resistance. This could open up markets in Japan and other Pacific Rim countries.

Breakthrough Technological Innovation

- D. *Evaluation of other additives as they might relate to the bonding process and to new product development.* Additives may be used to enhance the bonding process, to engineer specific panel properties (e.g. insect or weather resistance, machinability), or to improve board appearance.

Mat Forming

Existing Technologies

Disk type orienters are the most common device to align strands along the length of the mat, and star-type orienters are typically used to align strands perpendicular to the length of the mat.

Mat uniformity is the key to consistent panel properties. Density variations increase production costs by forcing the mills to run to higher average targets. Formers provide a high level of flexibility in

tailoring plant operations to the material being furnished for the mat. The introduction of the 3.65-m (12-foot) wide forming line allows the line to operate more slowly for a given capacity. Moreover, formers can be made to produce more than the conventional side trim to accommodate problems such as those created by longer flakes.

Over the years, manufacturers of forming equipment have continuously improved their technology and made great strides in reducing density variations and improving strand orientation.

Incremental Technological Innovation

32. *Reduction in panel density variations*, particularly when denser hardwoods are used. This is particularly important when improved dimensional stability is required. It is also an essential factor in reducing manufacturing costs.
33. *Application of image analysis and modelling work now underway to represent the forming process*. Once adapted to the plant environment, models will provide a better understanding of the factors affecting strand distribution during the mat forming process, and allow line operators to change parameters in order to optimize mat properties for various panel thicknesses, and for specialty products.
34. *Image analysis and advanced process control* can also be used in the development of on-line, real-time methods to measure and control forming and orientation.

Breakthrough Technological Innovation

- E. *New handling and forming concepts for preparing mats with longer strands (up to 30 cm)*. Laboratory tests have shown that strands in lengths from 15 to 30 cm (6 to 12 inches) can provide considerably better properties than the current 10- to 15-cm (4- to 6-inch) strands. Unfortunately, long strands are difficult to handle using existing methods and to form into a uniform mat. The use of artificial vision to analyze the forming process, combined with models under development may help identify such new concepts.

Pressing

Existing Technologies

Multi-opening presses are the most commonly used in OSB production because of their high capacity and the limited concern over thickness variation in OSB panels. The introduction of 3.65-m (12-foot) wide presses has resulted in higher capacities, less trim waste and panels in 91 or 122-cm (3 or 4-foot) wide increments.

Many factors influence the consolidation of the OSB panel in the press: press temperature, mat moisture content and its distribution, wood species, strand geometry, adhesive type, the profile of thickness change during hot pressing, mat temperature, press time, press closing speed and press pressure. The manipulation of the above factors can change the density profile of the board, the heat transfer rate, and thus the board properties and production rate.

Increases in press temperature and time improve the bonding strength in the core layer and therefore the board quality and stability. With excessively short press times, the adhesive is likely to be slightly under-cured, and significant spring-back occurs at the end of the press cycle.

The density profile of OSB is also governed by the consolidation rate of the mat which in turn is affected by the press closing time. Fast press closing times cause higher surface-layer density and higher moduli of elasticity and rupture but lower internal bonding.

The OSB industry is beginning to adopt continuous presses. Their capacity has traditionally been lower than that of multi-opening presses, but the development of the 3.05 m (10 foot) wide continuous press and the increases in press length permitting faster line speeds, press capacity is now given less consideration when comparing the two types.

Continuous presses result in better panel thickness control, improved control over board density and across the board density profiles and lower trim losses than multi-opening presses. In addition, the continuous board lends itself well to custom cut-to-size applications, where the demand exists.

Continuous presses have higher capital costs, but these can be justified by the reductions in trim waste, sanding loss (when applicable), and building costs for smaller press foundations and lower buildings. As these presses are more difficult to interrupt, compared to multi-opening presses, the reliability of the downstream board handling system is critical.

Incremental Technological Innovation

35. *Further development and use of continuous presses for OSB production.* Currently it is difficult to justify the higher costs based on existing advantages of the continuous press. Thickness tolerances are not as critical for OSB as for MDF and particleboard. Also, in order to provide an imprint on the finished boards, a flexible screen would have to be run between the top stainless steel belt and the mat. This could limit the life of the top belt.
36. *Further development in pressing cycles,* particularly with changes in other production parameters such as wood species, panel density, adhesive type. Some research has been done to optimize the various phases of the pressing cycle (closing, holding, venting), and a model is available to represent the effects of relevant production parameters.
37. *Production of lower density panels through a better understanding of the panel consolidation process* in order to reduce wood usage and enhance panel stability while reducing production costs.
38. *Further development in the use of steam-injection pressing.* The technology has been demonstrated under laboratory and pilot plant conditions. Initiatives are under way to apply the concept to industrial multi-opening presses. Once such presses are operating on a regular basis, work will be needed to optimize operating parameters for shorter press cycles and enhanced panel properties.

Breakthrough Technological Innovation

- F. *Development of steam-injection technology for continuous presses.* Ways have to be devised to equip continuous presses with steam injection capability, thus combining the benefits of the two methods.
- G. *Self-generated steam pressing.* Experiments are being performed in the laboratory on pressing high-moisture content veneer in a sealed environment, to create conditions similar to that obtained with steam injection, but without the related capital cost. Similar conditions could be applied to OSB, with similar benefits.
- H. *Other high-energy adhesive curing methods should be investigated.* Energy forms other than convection heat (e.g. RF and microwave heating) may have the potential to cure adhesives extremely fast if combined with the right adhesives systems.

Trimming, Sanding, Grading and Storage

Existing Technologies

Panel trimming and cutting is normally done immediately after pressing, since OSB does not need to be cooled. A grader checks the panel surfaces visually for imperfections using an oblique light and a reflecting mirror. The panels are then sorted by grades, and stacked with an automatic system. Sanding is only performed on some of the production, (e.g. subfloor panels) to reduce thickness variations, and it takes place off-line.

Rejecting boards with defects and delamination can be done automatically with in-line detectors. Totally automated saw positioning systems, with servomotors controlling the blade position, can change the saw position often, to produce a variety of panel sizes.

Camera systems are available to view the top, bottom and edge surfaces for conditions such as surface blisters, edge and trimming defects.

Incremental Technological Innovation

39. *Development of fully automated systems for trimming and grading.* A combination of technologies (ultrasound, RF, microwave, camera, X-ray) can be used to detect internal and surface defects. New stress-grading equipment is being commercially developed, which can measure the mechanical properties (parallel and perpendicular) of the panels on-line.
40. *Development of automated stack storage retrieval systems.*
41. *Value-added products can be produced for specialty applications.* In addition to tongue-and-grooved panels, which are increasingly common for subfloor applications, OSB mills can take advantage of niche markets for cut-to-size panels, overlaid panels, specially finished surfaces, etc.

Post-treatment

Existing Technologies

In the majority of mills, post-treatment of OSB is limited to the period of hot stacking designed to complete the curing cycle of the adhesive (thus compensating for shorter press times) and to further stabilize the panels.

Incremental Technological Innovation

42. *Application of conditioning post-treatment to increase the moisture content of the panels prior to shipping,* thereby improving their dimensional stability. At least one European mill is using this practice but it has not yet been emulated in North America. It may be advantageous for certain specialty applications where dimensional stability is critical. Methods other than simple conditioning are required to increase the efficiency of the operation, thereby reducing its cost.
43. *Application of other post treatments for specific opportunities in product added value and diversification.* This could include surface impregnation with polymers, or even chemical modification of the surface wood. As for additives, the list of potential treatments is endless, but they may present more limitations than advantages. Their main attraction is that they can

be performed off-line on any fraction of the total production, without interfering with the production process, therefore facilitating cost and emission control.

Quality Assurance and Process Control

Existing Technologies

On the process control side, current plant designs include advanced programmable logic controllers (PLCs) which control the processes in the plant and may be connected to a plant-wide network. Data acquisition for shift reports, on-line data analysis, statistical process control (SPC) and database generation can be a part of modern PLC and plant computing network design. This plant wide PLC network is interconnected to the local area network (LAN) which links all the PCs in the plant providing access to process data by operators, managers and others.

On the quality assurance side, on-line equipment is currently available to measure continuously mat thickness and density, strand orientation, and moisture content, finished board thickness and internal bond; to detect delamination; and to monitor edge and surface quality of each board. There is a growing acceptance of on-line devices to continuously monitor board quality as opposed to random board analysis.

Incremental Technological Innovation

44. *Integration of individual measurement/detection systems on a plant wide basis to provide better data analysis capabilities.* Such equipment will permit plants to optimize material consumption and productivity and place the mill in a substantially more competitive position to meet future market challenges.
45. *Equipment to measure on-line the stiffness in both directions of each board.* As seen above, such equipment is in the later stages of commercialization and should be available soon. It will enable non-destructive evaluation of every single panel as it emerges from the production line. It can also be used to grade panels into performance level categories, thus providing producers with additional quality assurance and an opportunity to tap into new markets for design-rated panels at relatively little cost.
46. *Artificial intelligence for monitoring, optimizing and troubleshooting mill operations.*

Breakthrough Technological Innovation

1. *Fully integrated, automatic process control.* Such innovation would go to a more advanced level of technology than that suggested above and would apply to the total production process as a fully integrated system. On-line monitoring and automatic feedback and control would be incorporated throughout the manufacturing process and would enable automatic change of process parameters to optimize board quality and reduce unit costs.

Environment Control

Existing Technologies

OSB is relatively environmentally friendly. Manufacturers recognize the importance of sustainable development to the public. As for the plywood sector, OSB sources virtually all of its raw

material from the forest, and this means forest management and wood harvesting as well as manufacturing, where there are some similarities with other panels.

The OSB sector does generate wood residues in debarking and trimming. Traditionally, this residue has been burnt for energy.

Emissions from OSB manufactures are mainly from the drying process where steam volatile compounds and airborne particulate are common. This results in a source of complaint in high population areas. Emissions from hot pressing such as VOCs and adhesive odours are normally at a minimum since phenol-formaldehyde adhesives emit very little formaldehyde when fully cured.

With the ever increasing emphasis on air pollution control from plant drying and heat energy systems, the complexity and cost (both conceptual and operating) of add-on pollution controls is increasing. A trend is emerging to meet the new targets through basic modifications of the systems rather than acquisition of add-on technology.

Environmental control is treated in greater detail in Appendix I.

Incremental Technological Innovation

47. *Adoption of appropriate environmental control technologies.* Some environmental control technologies available in other panel sectors (e.g. use of exhaust air as combustion air) could allow OSB plants to further reduce particulate emissions in areas where restrictions are tighter.
48. *Development of equipment capable of operating at lower noise levels* would improve health and safety conditions in the plants.
49. *Development of new applications for bark and other residues* would reduce environmental pressure and increase revenues. Opportunities might include power co-generation, agricultural uses, pulping and other composite products. The whole wood industry is beginning to show interest in solving a bark disposal problem, and is exploring the potential of bark as a raw material for profitable new products, including resins and moulded products.
50. *Integration of emission control and environmental friendliness into all phases of the manufacturing process*, combined with measures to improve the efficiency of the manufacturing process and reduce costs. Efforts need to be made to gradually integrate environmental factors in all production parameter optimization models.

By-products

Existing Technologies

Since OSB mills re-cycle their fines and trim directly into the main process, unusable wood residues constitute a relatively small, and decreasing, portion of the incoming log. Of this portion, bark represents the most important part.

Incremental Technological Innovation

51. *New uses for bark, including innovative products, panels, chemicals and even useful additives for the OSB manufacturing process.* Research in this area is not limited to OSB; the whole wood industry is beginning to show interest in solving a bark disposal problem, and in exploring the potential of bark as a raw material for profitable new products. The development of adhesives from bark may be particularly attractive to OSB industry, however, as it might satisfy some of the requirements examined in the adhesive section.

Existing Technologies

New and improved products have been this sector's mainstay. Such developments are largely responsible for its rapid growth and large volumes of production that allow for manufacturing economies of scale. OSB has continued to substitute for conventional products including traditional wood products, notably softwood plywood used as structural panels in housing and other construction.

Because of the reduced availability of large sections, and increasing lumber costs, engineered wood products that include OSB are replacing conventional lumber products. I-joists, for example, meet the requirements of many structural applications yet do not require the size or quality of raw material needed for structural lumber. OSB panels are also being combined with other materials, such as foams and overlays to broaden the product's range of applications.

Incremental Technological Innovation

52. *Many new products can be derived from OSB.* Owing to their inherent flexibility, OSB products have the potential to meet the requirements of many demanding applications, either alone or in combination with other materials (e.g. overlays).

Breakthrough Technological Innovation

- J. *Development of OSB products with significantly modified properties.* New and improved OSB products are required to increase market penetration in roofing, flooring, and siding markets. These would include panels that are fire and insect retardant, weather resistant, lighter weight, smoother and more workable, more durable, and engineered in different combinations with other materials. New applications responding to market needs should be identified, together with the related product characteristics.

Summary

The OSB industry has known extraordinary growth over the past years. Production capacity has increased at such a pace that one of the main challenges facing the industry is internal competition. For this sector, the road to continued success goes through the identification of new applications, new markets and new products, so that market expansion may keep up with capacity. Wood supply diversification will also be critical as pressure increases on traditional sources. Cost control will be critical, especially in times of overcapacity.

A number of incremental technology innovations have been listed in this chapter, which would help the industry along in this direction. Every one of them represents potential gains for the OSB sector, but it should be remembered that the manufacturing process operates as a system: every time an operating parameter is modified, the whole process needs to be re-visited, including impact on costs and market. A few bolder "breakthrough" technologies have also been identified. If they can be successfully developed, they will allow the industry to make a significant leap towards its goal; these are described in greater detail in Chapter VIII.

Description

In North America, particleboard is essentially a non-structural wood-based product made from wood particles of various sizes that are bonded together with a synthetic adhesive under heat and pressure. Raw material currently used in the manufacture of particleboard comprises primarily sawdust, planer shavings, edgings, and other wood residues. Particleboard is manufactured using a hot platen mat-formed process with larger particles concentrated in the core and smaller sized furnish on both faces.

Particleboard can be manufactured in different sizes, thicknesses, densities and grades for a variety of end uses. It has relatively homogenous properties making it an excellent core material for furniture manufacturing. Over the years, the industry has concentrated its effort on improving board surface smoothness for improved finishing and laminating purposes. Today, Canadian particleboard provides an excellent substrate for the application of decorative overlays such as veneer and melamine. Particleboard applications include furniture, cabinets, floor underlayment, subflooring in manufactured housing, door cores, and many other non-structural industrial applications.

Particleboard was first produced industrially in the 1940's in Germany and the US. Since 1960, particleboard production has sustained a substantial market growth. Due to its relatively low production costs and flexible manufacturing process, particleboard is still the major non-structural panel produced in North America.

Vision

This sector is considered mature and successful. It has experienced steady growth, and the trend is expected to be maintained over the coming years. One of the industry's major challenges has been the formaldehyde issue, but the industry responded with changes in adhesive technology and improved manufacturing controls and testing programs and managed to protect its business.

Few new plants are planned in the near future, but existing Canadian manufacturers look at the future with confidence. Their vision is centred on modernizing existing facilities and serving niche markets. To remain competitive, they need to improve control of the manufacturing process while diversifying the sources of raw materials for their furnish. Process control will permit smaller production runs of specialized products. They also need to expand their ability to produce a wide variety of finish characteristics.

Value-added products are most frequently obtained by adding overlays to particleboard. This trend is more pronounced in Canada than in the US, and it constitutes a strategy for Canadian mills to remain competitive despite their smaller size. This approach will likely continue in the future.

Industry concerns relate to restrictive provincial and federal legislation on formaldehyde emissions from the board and from the plant. Restrictive legislation in major market areas, especially in the US, could also have a dramatic impact on sales. At the same time, however, the particleboard industry recognizes the need to co-operate with governments on environmental issues.

Competition from other wood panels is not perceived as a major threat, mostly because particleboard enjoys a significant cost advantage. On the other hand, the appearance of new types of

particleboard manufactured from bark, straw, hemp or other low-cost renewable fibres may have more impact, negative for some, positive for others.

Economics

Contribution

The particleboard sector had a value of shipments in 1996 of \$694 million. This compares to just over \$300 million in 1990, representing an average annual growth rate of 15 per cent. This is double the growth rate of shipments of all Canadian manufactured products over the same period. From 1990 to 1996, employment increased from 1,900 to over 2,100 for an average growth rate of 2.5 per cent.

In 1996, exports were over \$262 million, representing over 38 per cent of shipments. Canadian exports are 96 per cent to the US and 4 per cent to the rest of the world. Annual growth in exports from 1990 to 1996 was over 30 per cent. Imports in 1996 were \$48 million and net exports, \$214 million.

From 1990 to 1995, shipments per employee increased from \$170,000 to \$275,000, a 10-per-cent annual increase. This reflects some improvement in mechanization, productivity, and technological change. Value added per employee was more positive, increasing over 13 per cent annually in the same period.

The US industry is about five times the size of that in Canada but the Canadian sector has proportionately greater contribution to the domestic economy. Its exports, at 0.6 per cent of total export activity in the domestic manufacturing sector, are significantly higher in relative terms, and in fact the US has a substantial deficit in particleboard trade.

Particleboard is a small but significant player in the Canadian economy. Its capital to labour ratios is higher than that of the Canadian manufacturing average. Its plants are distributed across the country supporting regional development and local economies. It utilizes waste raw material that comes as a by-product from other wood operations. It also uses low grade wood from forest operations and has the potential to use more recycled material and alternative fibres such as straw waste.

In 1997, Canada had 13 particleboard mills with a total capacity of 2.309 million m³ (1.312 billion square feet (BSF) ¾ inch basis). Its regional distribution is set out in the following table:

Province	# of mills (1997)	Capacity		% capacity
		million m ³	BSF	
British Columbia	3	0.354	0.201	15.3
Manitoba	1	0.053	0.030	2.3
Ontario	5	0.818	0.465	35.4
Quebec	3	0.905	0.514	39.2
New Brunswick	1	0.180	0.102	7.8
Total	13	2.309	1.312	100.0

Source: Resource information Systems Inc. (RISI), Wood Products Review, July 1997.

Particleboard is manufactured in five provinces. Although Quebec has fewer mills than Ontario, it is the largest producer followed by Ontario and British Columbia. Together these three provinces account

for about 90 per cent of Canada's production. Three new mills, all based on wheat straw were either under construction or announced in 1997. These will be located in Manitoba and Alberta and will contribute another 0.5 million m³ (0.3 BSF) of capacity.

Outlook

Based on in-depth analyses of various end use markets in Canada and the US and competitive aspects such as costs, exports and product substitution from MDF, RISI has forecast that total demand for Canadian particleboard will reach close to 2.6 million m³ (1.5 BSF) in the year 2000 and about 3.9 million m³ (2.2 BSF) by 2012. This compares to 2.1 million m³ (1.2 BSF) in the base year of 1996. Based on these figures, the average annual growth in demand for the first decade of the millennium is in the range of 3 to 4 per cent.

Estimates for growth in domestic markets are based mostly on steadily rising furniture production and the increased use of particleboard in major end-use markets. The construction market, which has always been a small user of particleboard, will retain about 5 per cent of total demand after 2000. Repair and remodelling will decline slightly to consume about 8 per cent over the decade while furniture will consume about 36 per cent. Exports, mostly to the US, will account for over 50 per cent of total Canadian production in the new decade.

Export markets, therefore, will remain the dominant demand factor for Canadian shipments with 2.1 million m³ (1.2 BSF) anticipated by the year 2012. Export growth will remain flat to the end of this decade as Canadian demand strengthens vis-à-vis that in the US but will recover in the first decade of the new millennium as overall North American markets pick up. Increasingly tight fibre supplies in the US will further encourage particleboard imports from Canada.

Imports from the US are expected to double from 1996 to 2012 to exceed 0.4 million m³ (0.2 BSF) at the end of that period, representing about 20 per cent of Canadian domestic shipments.

Average mill operating rates will tend to be more stable in the next decade compared to this one and will range from 83 to 94 per cent. Costs will rise steadily (primarily from higher adhesive and electricity prices) but moderately, as will prices. Canadian prices, however, are expected to remain below those in the US over the next decade.

Driving Forces

For a mature commodity like particleboard, *manufacturing cost* is one of the most important factors affecting the industry. This is particularly true as MDF prices have been depressed by over-capacity in that sector, and pressure from MDF competition is being felt in some traditional markets, like furniture and cabinetry. The industry is highly dependant on exports to the US market, and the need to meet the competitive challenge of US manufacturers will most likely dominate the Canadian scene over the coming years.

Competition from other panels may force particleboard manufacturers to modify some of their product characteristics, e.g. surface smoothness, machinability, dimensional stability. As Canadian mills are led to specialize in niche markets, they opt for value-added products, particularly overlays. Another driving force for the industry will therefore be *technological developments in the field of overlaying*.

New technology will also be required to help the industry accommodate a broader variety of wood types in its furnish. The product's price advantage is largely predicated on lower wood costs than is the case for most of its competitors. Another challenge for the industry will be to *further diversify its raw*

material supplies while maintaining full control over the manufacturing process and attached costs. Technological change is expected to come gradually, but it will have an impact over the industry, especially in the domain of process control.

Formaldehyde emissions represent a driving force on several accounts. More than most other wood composite panel products, particleboard has been under scrutiny by environment protection groups and governments, and pressures continue to be applied for further reductions in permitted emission levels, both in the plant and from the board in service. Significantly lower levels, either in Canada or in the US, would force manufacturers to make major changes to their process, particularly as concerns the adhesive system. Since known substitute adhesives are more costly than the current urea-formaldehyde, some mills would probably close down.

Existing and Future Technologies

The particleboard sector has not experienced the same rapid growth in new plant and construction as other panel sectors, and therefore the introduction of new technologies into process equipment has been less dramatic. However, plants have been steadily improving the quality of their products while adopting new technologies which use lower grade raw materials, increase production, and maximize the recovery of fibres.

Particleboard is used primarily in high grade industrial markets, mostly in furniture. As a result of competition, particleboard now uses finer particles for boards that have better surfaces and may be edge profiled. Plants have upgraded production processes for tighter control of variances. New or additional screening, refining equipment, blenders, forming equipment and presses have been added. Many plants now have continuous on-line monitoring systems for moisture measurement, delamination and blow detection, thickness measurement and density profile measurement.

Through better scheduling of maintenance operations, the plants are able to reduce unscheduled downtime. They are incorporating preventative maintenance programs which include regular vibration analysis of all rotating equipment in order to trend bearing vibrations and predict failures. Plants are also targeting equipment requiring the longest maintenance periods in order to modify or replace them, thereby shortening maintenance periods.

Raw Material Preparation

Existing Technologies

The basic raw material typically consists of sawmill residues, including sawdust and planer shavings, as well as some low quality logs from a variety of softwood species. There is a trend towards increased use of recycled wood. However, this requires removal of contaminants (metal, plastics, etc.) and the material, which is drier, must be thoroughly blended with conventional furnish for homogeneity.

Air density separators are increasingly used to remove grit and minimize equipment wear. Some plants use individual separators for the surface and core layer furnishes for better cleaning. Others use air density separators added to the wood infeed systems.

Sawdust and shavings are typically processed through dry refiners to size the furnish for both surface and core layers. Recent innovations include the addition of screens upstream of refiners to permit material sized for the surface layer to bypass the refiners, thereby increasing their capacity.

The use of wheat straw as raw material is a very recent innovation. A few plants in North America are now in operation, and more are planned.

Incremental Technological Innovation

1. *More efficient cleaning systems for all furnishes.* Fast analysis of the furnish, and elimination of grit and other contaminants from particleboard furnish will facilitate the inclusion of more recycled fibres, and reduce wear throughout the manufacturing process. It will also go a long way in increasing machinability of the end product.
2. *Better segregation of incoming raw material by species, moisture content, grit and contaminant content* will allow optimization of the various process parameters and of the end product.
3. *Optimization of wet particle geometry criteria according to desired panel properties and process requirements.*
4. *Improvements in the processing of agricultural fibres such as straw* will broaden the raw material supply.
5. *Increased use of multiple roll type screens with knurled surfaces and adjustable gaps* will provide better screening of wet material and lower power requirements.

Drying

Existing Technologies

Triple-pass, direct fired dryers now predominate. However, single-pass, direct fired dryers require less air and therefore need smaller air treatment systems for dryer emissions. Their use will increase.

Accuracy of measurement and consistency in moisture content of final material is required to produce higher quality industrial grade particleboard. To that end, some plants are adding devices to measure mass flow and moisture content of material entering the dryer, and are incorporating statistical process controls (SPC) with the dryer controls. To reduce maintenance, some plants are replacing the primary cyclone/multiclone arrangement with single or dual high efficiency cyclones which can attain the same efficiencies for removing particulate emissions but require less frequent cleaning.

Incremental Technological Innovation

6. *Further improvements in controlling moisture content of final material.* Closer control of moisture contents, combined with more flexible drying techniques, will narrow down moisture content variations in the furnish entering the blender. This, in turn, will enhance adhesive and pressing efficiency.
7. *Further recycling of dryer exhaust* will reduce VOC emissions and produce energy savings.

Breakthrough Technological Innovation

- A. *New types of dryers are required to lower drying temperatures.* Lower drying temperatures would significantly reduce emissions. They would also contribute greatly to a reduction in the risks of fires in particleboard plants.

Existing Technologies

Effective screening of dry surface and core layer material is critical to the production of high quality industrial grade particleboard. As the industry moves to boards with smoother surfaces and better edge profiling properties, accurate control over the sizing of the furnish must be maintained.

Oscillating, multi-deck type screens, which separate material into three fractions (oversized, accepts and fines), predominate. Screen decks on the finer mesh screens are equipped with cleaning ball decks to reduce blinding of the screen mesh surfaces.

Trends in screening include: 1) very large screens to ensure there is sufficient screen surface area to permit the entire material flow to be in contact with the screen mesh surface at least once before exiting and 2) rectangular or slotted openings in the screen meshes which maximize fibre recovery and remove cubic particles from the surface layer stream and thick flakes from the core layer stream.

A recent innovation in plants where surface and core layer materials are dried together uses screens to separate the material into five fractions: oversized, core layer, surface layer coarse, surface layer fine and fines which are used for fuel.

Incremental Technological Innovation

8. *Optimization of dry particle geometry criteria according to desired panel properties and process requirements.*

Blending and Resination

Existing Technologies

Manufacturers strive to make blenders which minimize the use of adhesive, which are gentler on the furnish to prevent degradation of the particles, and which ensure that sufficient mixing occurs between particles and adhesive to prevent the formation of blows and spots on the boards.

The paddle type short retention time blender predominates. Adhesive is applied by air or airless spray guns, and can either be added to the furnish as it enters the blender, or delivered into the blender through a rapidly rotating hollow rotor shaft.

Two-stage blending, employed primarily on surface layer material, provides a longer retention time than a single blender. This can also result in a significant reduction in adhesive consumption as the fines, which get heavily sanded in the finishing, enter the secondary blender and absorb less adhesive.

Blender infeed continuous weigh scales measure both the mass and volumetric flows of material to the blender. They provide accurate, continuous readings to the adhesive dosing system thus optimizing adhesive usage.

Incremental Technological Innovation

9. *Development of improved handling systems for more uniform distribution of wax and additives, to avoid spotting and to improve emission control.*
10. *On-line systems for monitoring adhesive distribution and relating it to other production parameters.*

11. *More reactive adhesives, through new formulations or the use of catalysts, to reduce press times without creating pre-cure problems.*
12. *More economical adhesives.*
13. *More moisture-tolerant adhesives.* Higher furnish moisture contents reduce drying requirements and related emissions. They also facilitate consolidation of the panel and promote dimensional stability. New adhesives should also be able to perform well in a broader range of moisture contents.
14. *Adhesive formulations better adapted to broader mixes of furnish types.* Straw fibres, for example, may require different adhesives from those traditionally used in the particleboard industry.
15. *Adhesives that help reduce the emissions of VOCs emitted during the pressing operation.*
16. *New adhesive formulations appropriate for steam-injection technology.*

Breakthrough Technological Innovation

- B. *New adhesives for faster setting, better bonding, higher moisture content tolerance, higher species tolerance and lower temperatures.* Savings in drying and pressing energy could be substantial. VOC emissions would be reduced significantly. The identification of such systems will require a better understanding of the bonding process, as well as a better knowledge of polymers not commonly associated with wood.
- C. *New distribution systems need to be developed to improve the distribution of adhesives.* Radically new designs, possibly adapted from other industries, would allow optimum use of new, high performance adhesives.

Wax and Additives

Existing Technologies

Because it represents a relatively low cost component in particleboard production, wax has not received much attention from the industry or from the scientific community. Even though it can enhance moisture resistance and dimensional stability, potential gains are limited because additional wax rapidly interferes with the bonding process.

Incremental Technological Innovation

17. *Integration of wax, catalyst, pH buffer and adhesive research to bring out potential synergies and to clarify the role of these ingredients in various adhesive formulations with respect to wood characteristics, moisture content and other parameters.*

Breakthrough Technological Innovation

- D. *Evaluation of other additives as they might relate to the bonding process and to new product development.* Additives may be used to enhance the bonding process, to engineer specific panel properties (e.g. insect or weather resistance, machinability), or to improve board appearance.

Mat Forming

Existing Technologies

Wind formers predominate, but they are gradually being replaced with diamond roll formers, which present the following advantages:

- significantly less power consumption
- improved mat forming accuracy, crosswise and lengthwise
- oversized particles, dust balls and adhesive lumps can be removed during forming
- less drying of furnish
- not affected by variations in ambient air conditions.

Better forming accuracy improves surface quality, allowing thinner overlay papers and less surface defects. Also, less surface furnish is required to produce a smooth surface, reducing the overall usage of furnish and adhesive. Mat uniformity is also the key to consistent panel properties. Density variations increase production costs by forcing the mills to run to higher average targets. Formers provide a high level of flexibility in tailoring plant operations to the material being furnished for the mat.

Incremental Technological Innovation

18. *Use of mechanical formers which have picker rolls close to the forming belt to better distribute the particle furnish and to better segregate and position particles in the mat, which will result in panels with reduced density variations, improved surface quality and stability, and better edge quality.*
19. *Application of image analysis and modelling work now underway to represent the forming process. Once adapted to the plant environment, models will provide a better understanding of the factors affecting particle distribution during the mat forming process, thereby making it easier to improve process control and reduce costs.*

Pressing

Existing Technologies

The functions of hot pressing are to consolidate the mat to a desirable panel density and thickness, to cure the adhesive so that furnish can be bonded together, and to heat-stabilize the panel so that it will remain at the target thickness and target density.

The hot press is the most expensive single piece of equipment and its performance has a direct impact on the production rate and product quality. Modern plants use single-opening, multi-opening or continuous presses. The trend for new and upgraded plants is toward continuous presses.

Prior to continuous presses, single-opening presses were used for their superior thickness control compared to multi-opening presses. Multi-opening presses have been used occasionally because of their higher capacity. However, with the development of the 305 cm (10 foot) wide continuous press and the increases in press length permitting faster line speeds, press capacity is now given little consideration when comparing the two types.

Continuous presses result in better panel thickness control, improved control over board density and across the board density profiles and lower losses in sanding and trimming than multi-opening presses.

As well, the continuous board lends itself well to custom cut-to-size applications, where the demand exists.

Continuous presses have higher capital costs, but these can be justified by the reductions in trim waste, sanding loss, and building costs for smaller press foundations and lower buildings. As these presses are more difficult to interrupt compared to multi-opening presses, the reliability of the downstream board handling system is critical, and some new plants are building in redundancies such as two flying cut-off saws, two stackers and two coolers.

Factors which influence the outcome of hot pressing include: press temperature, mat moisture and its distribution, press closing speed, the profile of the thickness change during pressing, press pressure and press time. In general, the use of a high closing speed, a high press temperature or a high mat surface moisture content yields sharp density profiles from the panel surface to centre.

The preferred density profile (through the thickness) depends upon use. For most applications, a higher density in surface layers for sanding and coating and a very uniform density between top and bottom layers for edge machining is ideal. This can be attained by using a press cycle with a fast initial press closing followed by a much slower closing to the target thickness.

Experimental work has been performed with steam injection. Steam is injected directly into the mat to provide a forced heat-convection method of heat transfer and thus raise the temperature in the mat quickly and uniformly resulting in shorter pressing times, improved dimensional stability and higher internal bond. Very thick panels could benefit most from steam injection technology.

Incremental Technological Innovation

20. *Further research on understanding and controlling pressing cycles*, particularly with respect to changes in other production parameters such as wood species, panel density, adhesive type. Some research has been done to optimize the various phases of the pressing cycle (closing, holding, venting), and a model is under development to represent the effects of relevant production parameters.
21. *Production of lower density panels through a better understanding of the panel consolidation process* in order to reduce wood usage and enhance panel stability while reducing production costs and maintaining critical properties.
22. *Application of steam-injection pressing.* The technology has been demonstrated under laboratory and pilot plant conditions. Initiatives are under way to apply the concept to industrial multi-opening presses in Canada. A few of these presses are in operation in US. Work will be needed to optimize operating parameters for shorter press cycles and enhanced panel properties.
23. *Reduction of density variations with wider presses.*

Breakthrough Technological Innovation

- E. *Development of steam-injection technology for continuous presses.* Ways have to be devised to equip continuous presses with steam injection capability, thus combining the benefits of the two methods.
- F. *Self-generated steam pressing.* Experiments are being performed in the laboratory on pressing high-moisture content veneer in a sealed environment, to create conditions similar to that obtained with steam injection, but without the related capital cost. Similar conditions could be applied to the production of particleboard in single-opening presses, with similar benefits.

- G. *One-step lamination.* The ability of overlaying panels directly in the press would represent a major step forward for the industry by eliminating additional handling, sanding and resination.
- H. *Other high-energy adhesive curing methods should be investigated.* Energy forms other than convection heat (e.g. RF and microwave heating) may have the potential to cure adhesives extremely fast if combined with the right adhesives systems.

Trimming, Sanding, Grading and Storage

Existing Technologies

Panel trimming and cutting is done either before or after. However, sanding must not be carried out until adequate cooling is attained so that the panel surfaces will not be “torn out”. After the panels leave the sander, a grader checks the panel surfaces visually for imperfections using an oblique light and a reflecting mirror. The panels are then sorted by grades, and stacked with an automatic system.

The trend is to totally automated systems, but most plants still use at least one person to visually grade panel surfaces. Rejecting boards with blows and delamination can be done automatically with in-line blow detectors. Totally automated saw positioning systems, with servomotors controlling the blade position, can change the saw position often, to produce a variety of panel sizes.

Camera systems are available to view the top, bottom and edge surfaces for conditions such as:

- burns, water, oil or adhesive stains
- surface blisters
- surface defects such as press belt marks, indentation, pitted areas, burnished areas, non-sanded areas or discoloration
- edge and trimming defects.

Automatic stack storage retrieval systems between the press and the sander in lieu of forklifts have been used in Europe for some time now but are relatively new in North America. Similar systems are available for warehouse management.

Incremental Technological Innovation

- 24. *Development of fully automated systems for trimming and grading.* A combination of technologies (ultrasound, RF, microwave, camera, X-ray) can be used to detect internal and surface defects. New stress-grading equipment is being commercially developed, which can measure the mechanical properties (parallel and perpendicular) of the panels on-line. Computer systems can also be adapted to limiting trim losses with custom sizes.
- 25. *Reduction in sanding requirements through better thickness control.* This will also improve process efficiency, reduce particulate emissions, and enhance surface quality.
- 26. *Value-added products can be produced for specialty applications.* Particleboard mills can take advantage of niche markets for cut-to-size panels, overlaid panels, specially finished surfaces, pre-drilling, edge-banding, shaping, machining, etc.

Post-treatment

Existing Technologies

Post-treatment is not commonly used in particleboard mills, but it may provide opportunities for adding value to regular production.

Incremental Technological Innovation

27. *Application of conditioning post-treatment to increase the moisture content of the panels prior to shipping, thereby improving their dimensional stability.*
28. *Application of other post-treatments for specific opportunities in product added value and diversification.* This could include surface impregnation with polymers, or even chemical modification of the surface wood. As for additives, the list of potential treatments is endless, but they may present more limitations than advantages. Their main attraction is that they can be performed off-line on any fraction of the total production, without interfering with the production process, therefore facilitating cost and emission control.

Process Control and Quality Assurance

Existing Technologies

The particleboard sector has been slow to apply new technologies in this area. The trend, however, is to use on-line devices which continuously monitor board quality as opposed to random board analysis.

New plant designs include advanced programmable logic controllers (PLCs) to control manufacturing processes and to be connected to a plant-wide network. This includes data acquisition for shift reports, on-line data analysis, statistical process control (SPC) and database generation. This PLC network can then be interconnected to the local area network (LAN) which links all the PCs in the plant providing access to process data by operators, managers and others.

On the quality assurance side, equipment is currently available to provide on-line, continuous measurement of mat thickness and moisture content, finished board thickness and internal bond; to detect on-line delamination; and to monitor board edge and surface quality of each board.

Process control and quality assurance offer perhaps the greatest opportunity for technological innovation, which would optimize materials consumption and productivity and place the mill in a more competitive position. Process control should also help Canadian mills produce smaller runs of specialty products, thereby giving them a competitive advantage over US producers.

Incremental Technological Innovation

29. *Integration of individual measurement/detection systems on a plant wide basis to provide better data analysis capabilities.* Such equipment will permit plants to optimize material consumption and productivity and place the mill in a substantially more competitive position to meet future market challenges.
30. *Equipment to measure on-line stiffness in both directions of each board.* As seen above, such equipment is in the later stages of commercialization and should be available soon. It will enable non-destructive evaluation of every single panel as it emerges from the production line. It can also be used to grade panels into performance level categories, thus providing producers

with additional quality assurance and an opportunity to tap into some structural markets at relatively little cost.

31. *Artificial intelligence* for monitoring, optimizing and troubleshooting mill operations.

Breakthrough Technological Innovation

- I. *Fully integrated, automatic process control.* Such innovation would go to a more advanced level of technology than that suggested above and would apply to the total production process as a fully integrated system. On-line monitoring and automatic feedback and control would be incorporated throughout the manufacturing process and would enable automatic change of process parameters to optimize board quality and reduce unit costs.

Environmental Control

Existing Technologies

Pollutants emanating from the manufacture of various wood panels are similar and occur from the following processes: wood waste and product handling, drying, pressing, secondary finishing and thermal energy production. Particleboard tends to have greater particulate emission than other wood-based panels in the drying process because of the smaller particles. Pollutants include: nitrogen oxides, sulfur oxides, carbon monoxide, formaldehyde and other VOCs.

Recently installed technologies for dryers include partial press enclosures to capture emissions and using exhaust air for combustion in the boiler plant. Particulate in the finishing areas are picked up by conventional dust collection equipment. Other conventional technologies include primary and secondary cyclones, multiclones wet dust collectors, dry and wet electrostatic precipitators, baghouses and electrostatic filter beds. These are described in Appendix I.

Incremental Technological Innovation

32. *Development of technology to significantly reduce formaldehyde emissions from finished products.*
33. *Development of technology to cost effectively reduce VOCs from manufacturing processes and recycling as much drying exhaust as possible.*
34. *Further refinement and implementation in the particleboard sector of promising new, environmental technologies including bio-filtration. See Appendix I.*
35. *Development of equipment capable of operating at lower noise levels would improve health and safety conditions in the plants.*
36. *Integration of emission control and environmental friendliness into all phases of the manufacturing process, combined with measures to improve the efficiency of the manufacturing process and reduce costs. Efforts need to be made to gradually integrate environmental factors in all production parameter optimization models.*

Breakthrough Technological Innovation

- J. *Complete system approach to environmental control, particularly for new plants.* The closed loop gasification and the closed steam loop system show good promise.

Existing Technologies

The end use markets for particleboard in Canada and the US have shifted over the last few years to higher quality industrial applications such as furniture and cabinetry. This has required product improvements necessitating significant change in production processes. While MDF has captured portions of those markets, even in low-cost applications, because of superior product characteristics and reduced processing requirements (e.g. no edge banding), continuing to upgrade product quality of particleboard, where practical and economic, will help maintain a competitive edge in established markets.

Incremental Technological Innovation

37. *Ongoing improvements to product quality* particularly with respect to workability and dimensional stability but also resistance to moisture (for underlayment, laminated flooring, kitchen cabinets, etc.). This will require a better understanding of basic parameters affecting thickness swelling and linear expansion.
38. *Improvements to operational flexibility when changing product runs* in order to produce economically smaller quantities of higher-value products.
39. *Formaldehyde free particleboard panels may represent a niche market opportunity.* Current technology to produce this type of panel is mostly based on isocyanate adhesives. Isocyanates, however, are more costly than regular urea-formaldehyde. Along a separate strategy, the adhesive and particleboard industries are searching for very efficient scavengers to neutralize all the free formaldehyde in the board.

Breakthrough Technological Innovation

- K. *Development of particleboard products with significantly modified properties.* New and improved particleboard products are required to diversify the industry's markets. These would include panels that are more resistant to moisture, of lighter weight, of lighter colour, smoother and more workable. New applications responding to radically different market needs should be identified, together with the related product characteristics.

Summary

The Canadian particleboard industry has been successful for many years, and, with the assistance of technology and market development, it can still have a bright future. For this sector, the road to continued success goes through product and process improvements which will help the industry counter the pressure from competing panels, while presenting a more environment-friendly profile and maintaining its cost advantage. Identification of new applications, new markets and new products will also play a significant role in the economics of older mills. Wood supply diversification, with increased use of recycled wood and agricultural fibres will reinforce the industry's position.

A number of incremental technology innovations have been listed in this chapter, which would help the industry along in this direction. Every one of them represents potential gains for the particleboard sector, but it should be remembered that the manufacturing process operates as a system: every time an operating parameter is modified, the whole process needs to be re-visited, including impact on costs and market. A few bolder "breakthrough" technologies have also been identified. If they can be successfully developed, they will allow the industry to make a significant leap towards its goal; these are described in greater detail in Chapter VIII.

Description

Medium density fibreboard (MDF) is a non-structural panel made of wood fibres bound together with adhesives under heat and pressure. It can be made from a variety of natural fibres, yet wood is by far the most important because of its relative abundance and year-round availability. Mill residues and chips are the common feed stocks in existing fibreboard plants.

Wood is mechanically refined, and the panels are formed through a dry process. This uses less water than the wet process used for high density fibreboard (hardboard), with obvious environmental advantages, and it allows the production of thicker panels, as the wet process is limited to 12.5-mm (½-inch) thick panels.

MDF has a substantially homogeneous consistency resulting from the uniform distribution of the wood fibres throughout the board. Different characteristics can be produced to meet end use requirements. Smooth and solid edges can be easily machined and finished, and the uniform surface provides an excellent substrate for painting or applying decorative overlays.

This advantage has secured MDF's solid position in the furniture market. It has been successfully used in shelves, flush doors, television cabinets, wrapped mouldings, cupboards, drawer fronts, table tops, pool tables, office furniture, plaques and shields, game boards, toys, picture frames, mirror surroundings, pedestals for tables, bedroom furniture and bathroom accessories. Thick MDF is penetrating markets for millwork applications such as door frames, window frames, window sills, stiles, casings and turnings, as a substitute for solid wood.

Vision

The MDF sector in Canada is very new, with most of its capacity coming on stream in the last few years, and the earliest production facilities a decade old. Most producers are therefore preoccupied with start up and establishing their market base. Moreover, the sudden surge of new capacity is far in excess of what can easily be absorbed by the existing market, and this presents a formidable hurdle to corporate profitability over the near term. In short, there has been little time for this sector to focus on a fifteen year horizon.

This sector, as much or perhaps even more than the other panel sectors, is technology based. It was established by technological innovation and most of its facilities, being new, have incorporated many of the most advanced processing and environmental technologies. Its product has evolved very rapidly as a result of innovation, and this has been largely responsible for the considerable market penetration it has achieved in a short period.

It is not surprising therefore, that as one gets beyond the short term challenges, the vision focuses on technological innovation as the centrepiece. The sector recognizes that, as in the past, longer term growth will depend on improving the performance characteristics of existing products and developing new ones. Both the nature of the product and the range of opportunities to expand markets provide considerable scope for innovation. The sector also recognizes that the rate of product substitution will depend on price competitiveness and that innovation is the key to reduced costs.

Given its growth prospects and its record of rapid and successful innovation, the MDF sector is well positioned to develop and commercialize innovative technologies in both incremental and breakthrough categories. These relate to both process and product.

As with other sectors in the early stages of their life cycles, this sector is optimistic about its future. It sees MDF continuing to substitute for other wood products in a variety of non-structural applications particularly related to furniture and cabinetry, but also to millwork and flooring. It sees itself achieving a much better balance of supply and demand with higher and more stable operating rates well within a decade. It will be a much larger and profitable sector. It will expand into new raw material sources and will be able to blend an increasing range of materials for cost and product advantage. It will utilize promising new technologies to improve environmental performance over the longer term. And finally it will continue to rely heavily on exports to the US as its major market.

Economics

Contribution

This sector is small but growing very rapidly. Its current contribution to the Canadian economy is therefore far less at this point than that from other wood panel sectors.

The first two mills were installed in 1986 and 1987, and, even by 1995, there were only three mills operating in Canada. Unfortunately, Statistics Canada does not yet provide separate principal statistics for this sector. It is estimated from broader aggregates, however, that in 1995 the MDF value of shipments from the three operating mills was over \$100 million and value added represented about 60 per cent of that, which is higher than all other panel sectors except OSB, and suggests relatively high levels of automation. Total employees numbered about 600. Exports to the US were less than 40 per cent of shipments.

With four mills operating in 1996, the value of shipments increased; exports also increased but not proportionately.

In 1997, Canada had six MDF mills with a total operating capacity of 1.042 million m³ (592 million square feet(MSF) ¾-inch basis). Its regional distribution is set out in the following table:

Province	# of mills (1997)	Capacity		% capacity
		million m ³	MSF	
British Columbia	1	0.194	110	16.9
Alberta	1	0.176	100	18.6
Ontario	2	0.458	260	43.9
Quebec	1	0.124	71	12.0
New Brunswick	1	0.090	51	8.6
Total	6	1.042	592	100.0

Source: Resource information Systems Inc. (RISI), Wood Products Review, July 1997.

MDF is manufactured in five provinces. Ontario is the largest producer followed by British Columbia and Alberta. Together these three provinces account for about 80 per cent of Canada's

production. A second plant in Quebec, with a capacity of about 0.220 million m³ (125 MSF), is in the final stages of construction and will begin commercial production in early 1998.

Outlook

Based on in-depth analyses of various end use markets in Canada and the US and competitive aspects such as costs and product substitution, RISI forecasts show that total demand for Canadian MDF will reach close to 1.2 million m³ (0.7 BSF, ¾ inch basis) in the year 2000 and 1.6 million m³ (0.9 BSF) by 2012. This compares to 0.352 million m³ (0.2 BSF) in the base year of 1996.

While growth in overall demand in the 16 years to 2012 will average almost 10 per cent annually, the exceptionally rapid growth expected in the mid to late 1990s will taper off significantly in the next decade. Average annual rates will exceed 30 per cent from 1996 to 2000, taper to about 10 per cent from 2000 to 2005 and decline further to less than 2 per cent from 2005 to 2010.

The very rapid growth rate in the mid to late 1990s is premised on opportunities for MDF substitution, particularly for lumber and particleboard used primarily in household furniture but also cabinetry, millwork, flooring and mouldings. Demand growth will follow from the surge of new capacity which will accelerate this substitution through significant price discounting and promotion.

In 1996, Canadian end use demand comprised 5 per cent residential, 6 per cent repair and remodelling, 50 per cent industrial (Canadian) and 40 per cent export which is also largely industrial. RISI suggests that the balance will not be significantly altered in 2012. The sheer size of the industrial market, both in Canada and the US will account for most of the increase over that period.

Exports, almost totally to the US, account largely for the spectacular growth in demand anticipated in the mid to late 1990s when exports will account for up to 60 per cent of total demand. In absolute terms, exports will peak at about 0.7 million m³ (0.4 BSF) in the middle of the next decade and are expected to decline slightly thereafter. Canadian industrial markets, on the other hand, show more consistent yearly growth and will surpass export demand in 2008, the first time since 1996.

RISI points out that the heavy dependence of Canadian MDF producers on export markets will expose them to both the vagaries of currency exchange rates and the competition from new producers in Asia and Europe, representing the major risk for the Canadian MDF demand forecast.

Despite healthy growth rates in Canadian consumption and exports to the US, capacity expansion has outrun demand. As a result, operating rates, prices and profitability are plummeting to the lowest levels seen in the sector. Canadian capacity utilization of 61 per cent in 1996 will climb slowly reaching the more reasonable level of 90 per cent in the middle of the next decade. Prices will increase steadily.

Driving Forces

New products and markets with substantial opportunity for growth have driven technological innovation in this sector since its inception. This will continue. There is a pressing need for new product development and for *new and improved product characteristics* for the industry to gain access to new markets and to maintain growth momentum. This is absolutely critical for the Canadian MDF sector because of its rapid percentage capacity increase over the last few years.

A focus on cost efficiencies possible through new technologies will help plants retain viability in periods of excessive over capacity. It will also help establish MDF as a substitute for traditional commodity lumber and panel products.

Canadian producers must also compete against an efficient US industry with location advantages in its home market. The Canadian sector will have to export substantial volumes of MDF to achieve even minimal operating rates over the difficult period anticipated to the year 2000. The financial strength of mill owners will definitely come into play in the years ahead.

As with the softwood plywood producers, there is an added dimension to cost performance. When MDF expands into non commodity, higher value markets, where quality and product differentiation are especially important, then product attributes that will command a high price become more significant than simply low operating costs. In these cases *contribution to profit margins* is a more important driving force impacting on technological innovation than cost reduction.

New emission control technologies have been introduced to this sector in recent years, and some have been incorporated into the newer mills. Increased public awareness and *environmental regulation* will force adoption of new technologies, and impose challenges on equipment designers and manufacturers. Major objectives will be reliability and cost efficiency.

With the tremendous increase in MDF capacity and the increasing limitations being placed on the traditional sources of *raw material* for MDF manufacture, the sector is cognizant of the need for future diversification of its raw material base. The increased use of sawdust is a case in point. Improved refining has made this once undesirable raw material a primary source for the industry. However, substantial technological innovation will be required to ensure competitive and quality products from an increasingly diverse and less desirable raw material base.

Rapid growth has also created a shortage of *available skills*. The MDF industry is having some difficulty finding good technicians, engineers and scientists, and keeping them. For some Canadian companies, the loss of key employees is a major issue which needs to be addressed.

Existing and Future Technologies

Many new MDF plants have been constructed over the last few years and the technology for producing MDF has improved substantially in a relatively short time. The product itself has improved in quality with a greater range of performance characteristics and market applications.

MDF has adapted to changes in raw material supply using furnish such as sawdust, shavings and recycled wood previously thought unsuitable. This has necessitated changes in both refiner and adhesive technology. Refiners, in fact, have become much more efficient and lower cost, and new designs continue to be offered.

Other trends include: better control of temperature and moisture of resinated fibres to improve the quality control of the finished board; and the use of continuous presses to more accurately control board thickness and reduce sanding and trim waste.

Through better scheduling of maintenance operations, the plants are able to reduce unscheduled downtime. They are incorporating preventative maintenance programs which include regular vibration analysis of all rotating equipment in order to trend bearing vibrations and predict failures. Plants are also targeting equipment requiring the longest maintenance periods in order to modify or replace them in order to shorten maintenance periods.

Raw Material Preparation

Existing Technologies

An MDF plant can handle a variety of raw materials. A typical supply consists primarily of chips combined with sawdust in a ratio of 9 to 1, but the trend is to the use of sawdust with the inclusion of at least 10 per cent shavings to help control moisture content and fibre size distribution. The blending of chips, sawdust and shavings is ratio controlled in the wood yard to achieve consistent refining results.

MDF can tolerate variations in species mix better than particleboard. Advances in adhesive technology have helped considerably, but there are still some difficulties in designing appropriate adhesive systems where there are significant chemical differences between species. Control of species chemistry is needed to ensure consistent panel quality.

Substitution of one raw material for another or significant shifts in species mix can cause large variations in mechanical properties of the product, requiring modifications and adjustments to manufacturing processes. In the longer term, recycled wood construction materials are an option, as are other types of fibres such as bagasse and other agricultural products. With the introduction of new sources of material, control of contaminants will become a major issue.

Raw material must be well prepared and managed as it is important to product quality and manufacturing costs. Monitoring and quality control are important. Oversize particles must be re-chipped and fines screened out.

Debris and grit, which abrade refiner discs and machine tools, must be removed. In some mills, washing systems are used on chips. The effluent must be treated, with the water recycled to the extent possible. Air density separators remove dirt particles from sawdust and shavings to minimize equipment wear.

Incremental Technological Innovation

1. *More efficient cleaning systems for all types of furnish.* This is particularly important to eliminate all traces of grit, and maintain a high level of machinability and edge quality.
2. *Expansion and diversification of raw material, including multi species mix, within the fibre mix,* while maintaining operating costs, reducing material costs and improving panel quality. This will include straw and other agricultural fibres.
3. *Effective particle cleaning and segregating technology* would give the MDF industry access to huge quantities of waste fibres (e.g. demolition wood, used pallets, newspapers, cardboard boxes). The proportions of different species in a given furnish must stay within narrow limits to avoid problems with adhesive adherence caused by pH variations. R&D needs to focus on developing low cost processes to segregate usable fibres from contaminants, and new adhesives capable of greater tolerance to pH variations.

Refining

Existing Technologies

Feed stock is forced through the narrow gap between two profiled discs that combine the action of mechanical shearing, cutting, squeezing and abrading to separate fibres. The quality of refined fibres depends on many factors including species, size and distribution, pre-treatment steam pressure, retention

time in the digester, applied power, geometry of refining plates, refining intensity, disc speed, and dwell time within the plate zone.

To facilitate refining, chips or particles are steam conditioned at an elevated pressure, usually 10 bars in a digester (steam vessel) that is connected directly to the refiner. The vertically, as opposed to horizontally, positioned pre-heaters use plug screw feeders for steam sealing and are most commonly used.

Refiners have been improved over the years, with more efficient fibre production at lower cost. Larger refiners have increased yield substantially. Due to greater throughput of material and ease of operation, virtually all MDF plants now use single revolving disc refiners with the single rotating disc holding special refining plates and a fixed disc with matching plates.

Small pieces of wood particles called shives tend to escape from the refining zone without being refined due to the high centrifugal force induced by the operating speed of the refining discs. There are a number of ways to reduce shive content by varying refining process parameters.

Recent trends include: 1) the use of larger diameter discs and more power, and 2) two-stage refining to improve fibre quality and to handle more effectively a range of sizes within the material furnish.

Incremental Technological Innovation

4. *Addition of dilution water to raw material furnish.* Early tests suggest reduced power requirements and longer plate life.
5. *Further improvements in refiner efficiency* particularly with respect to shives and accommodating an expanding range of raw material types and sizes.
6. *Reduction in energy requirements* through digester treatment or new designs for refiner plates. With more sawdust and shavings in MDF furnish, greater energy is applied to produce good quality fibres in the refiner process. Specific energy requirements for sawdust and shavings tend to be higher than those used in Europe.

Breakthrough Technological Innovation

- A. *Improvements in digesting capabilities including the use of high-pressure steam/heat treatment.* The objectives for increasing pressures up to 17 bars are: a) to reduce refining energy, and b) to obtain improved fibre quality for better bonding. With proper pre-treatment, it appears feasible to manufacture MDF panels without adhesive, therefore without added formaldehyde.
- B. *Addition of chemicals to enhance the digestion process.* Chemicals are used routinely in the paper industry. Research needs to devise ways of adapting this technology to MDF production within the cost constraints peculiar to this industry.

Blending and Resination

Existing Technologies

The blowlines from the refiners to the dryers are used for blending adhesive with the fibres. To prevent the blowline pipe from building-up with adhesive and wood, a concentric sleeve jackets the pipe and provides an air gap around it. Fresh air is introduced through the jacket to cool the surface of the blowline. The injection point is a 6-mm (¼-inch) pipe fitting welded to the blowline. At the adhesive

entrance point, the fibres are moving at very high velocity with great turbulence, and thus the adhesive is instantly atomized as it enters the blowline. The adhesive may enter at a single point or at multiple points along the blowline, and the entrance may be angled at 45 or 90 degrees.

Urea-formaldehyde adhesives are most commonly used for MDF. To avoid pre-cure, many plants do not add catalysts to the adhesive prior to injection. In fact, the adhesive is often diluted to prevent pre-curing in the dryer.

Incremental Technological Innovation

7. *Improvements to the mechanical process* to promote homogeneous adhesive distribution, with continuing emphasis on emission control. Better adhesive distribution will allow reduced consumption as well as lower formaldehyde and other VOC emissions.
8. *On-line systems for monitoring adhesive distribution* and relating it to other production parameters.
9. *Improved understanding of the factors affecting blowline blending* in order to optimize the process.
10. *Improved understanding of the effect of drying on the adhesive.* MDF is the only wood composite in which the adhesive is applied prior to drying, and the impact of this practice should be better understood so that lessons may be drawn both for the drying process and the adhesive formulation.
11. *More reactive adhesives, through new formulations or the use of different catalysts, to reduce press times without creating pre-cure problems.*
12. *More economical adhesives.*
13. *More moisture-tolerant adhesives.* Higher furnish moisture contents reduce drying requirements and related emissions. *They also facilitate consolidation of the panel and promote dimensional stability. New adhesives should also be able to perform well in a broader range of moisture contents.*
14. *Adhesive formulations better adapted to broader mixes of furnish types.*
15. *Adhesives that help significantly reduce the emissions of VOCs including formaldehyde emitted during the pressing operation.*
16. *New adhesive formulations appropriate for steam-injection technology.*

Breakthrough Technological Innovation

- C. *New adhesives for faster setting, better bonding, higher moisture content tolerance, higher species tolerance and lower temperatures.* Savings in drying and pressing energy could be substantial. Formaldehyde and other VOC emissions would be reduced significantly. The identification of such systems will require a better understanding of the bonding process, as well as a better knowledge of polymers not commonly associated with wood.

Wax and Additives

Existing Technologies

Because it represents a relatively low cost component in MDF production, wax has not received much attention from the industry or from the scientific community. Even though it can enhance moisture

resistance and dimensional stability, potential gains are limited because additional wax rapidly interferes with the bonding process.

Incremental Technological Innovation

17. *Integration of wax, catalyst, pH buffer and adhesive research to bring out potential synergies and to clarify the role of these ingredients in various adhesive formulations with respect to wood characteristics, moisture content and other parameters.*

Breakthrough Technological Innovation

- D. *Evaluation of other additives as they might relate to the bonding process and to new product development.* Additives may be used to enhance the bonding process, or to engineer specific panel properties.

Drying

Existing Technologies

Drying is performed through tube type dryers with lengths ranging from 90 to 100 m (300 to 350 feet) with a minimum of 30 m (100 feet) of straight tube after the blowline injection but before the first bend, because of potential fibre and adhesive build-up. Air velocity is typically 30 m (100 feet) per second. Both vertical and horizontal configurations work well. Tube dryers also have the advantage of being less apt to "ball" fibres into clumps, which makes them easier to control as far as fires are concerned.

High temperatures formerly used in drying have been lowered to below 180°C (350°F) at the inlet. This has reduced fire hazard, VOCs and smoke. The discharge temperature in the cyclone typically ranges from 50 to 70°C (120°F to 160°F).

The main functions of the dryer system are to keep moisture in the vapour phase, and to separate steam from the wood. The dwell time is short. The fibres travel through a dryer tube in 3 to 5 seconds, and the dryer cyclone in 3 to 4 seconds. The energy required for drying is in the order of 4,200 to 4,600 kJ per kilogramme of water evaporated (1,800 2,000 BTUs per pound), depending on whether the wood is dried to 10 to 11 per cent or to 3 to 5 per cent moisture content.

Incremental Technological Innovation

18. *Improvements in drying processes relating to temperature and humidity levels, VOCs and controls.*
19. *Further refinements to two- and three-stage drying as means to improve fibre quality, to obtain better control over moisture content and to reduce VOCs, thereby allowing for less expensive emission control equipment. The first stage acts as a vapour separation phase and emissions are exhausted into the plant heat energy system where VOCs are incinerated.*

Mat Forming

Existing Technologies

Vacuum assisted formers predominate. They deliver dry, resinated fibres to an enclosed area above a travelling wire screen while maintaining a negative pressure on the underside of the screen. Air travelling through the wire screen causes formation of the mat on the screen. As the mat builds up, fibres flow to thinner areas on the mat until the pressure difference between the top and bottom of the mat reaches equilibrium and mat thickness is relatively uniform across its width. Shave-off rolls further improve mat uniformity. Vacuum forming draws the fibres closer together, removing air and increasing mat density. Although some new plants are using mechanical formers without vacuum systems, their performance is not fully established.

Incremental Technological Innovation

20. *Introduction of mechanical formers*, with picker rolls close to the forming belt to distribute the particle furnish, and shave-off rollers to reduce the mat to the required thickness. Mechanical formers require significantly less power (about 1/5 of air formers), improve mat forming accuracy crosswise and lengthwise, they are not affected by variations in ambient air conditions. They also reduce the need for mat scalping and re-circulation (less than half compared to air formers), and permit incorporation of water spray systems (for use with steam injection).
21. *Combinations of mechanical and vacuum formers* would facilitate handling while maintaining the advantages of reduced mat thickness.

Pressing

Existing Technologies

After forming, the mat is pre-compressed for stiffness and strength to pass transfer points and to load into the hot press. Pre-presses have a long infeed section with a low slope and a perforated upper belt to enable the slow escape of air from the mat and the gentle compression of the loose fibre mat. Multiple compression rollers cause a repeated compression/expansion action on the mat to reduce mat spring-back.

The functions of hot pressing are to consolidate the mat to a desirable panel density and thickness, to cure the adhesive so that the furnish can be bonded together, and to heat-stabilize the panel so that it will remain at the target thickness and target density under normal service conditions.

The hot press is the most expensive single piece of equipment, and its performance has a direct impact on the production rate and product quality. Modern plants use multi-opening or continuous presses. The trend is to continuous presses.

Multi-opening presses used to be preferred over continuous presses because of their higher capacity. However, with the development of the 305-cm (10-foot) wide continuous press and the increases in press length permitting faster line speeds, press capacity is now given little consideration when comparing the two types.

Continuous presses result in better panel thickness control, improved control over board density and across the board density profiles and lower losses in sanding and trimming than multi-opening presses. In addition, the continuous board lends itself well to custom cut-to-size applications.

Continuous presses have higher capital costs, but these can be justified by the reductions in trim waste, sanding loss, and building costs for smaller press foundations and lower buildings. As these presses are more difficult to interrupt, compared to multi-opening presses, the reliability of the downstream board handling system is critical.

Heat is transferred from the platens or steel belts to the mat. The moisture in the surface furnish is converted into steam which is forced inwards. The heat from the steam is sufficient to cure adhesives such as urea-formaldehyde, melamine-formaldehyde adhesives and isocyanates. After the steam dissipates, heat transfer into the dry mat is dependent on conduction and is therefore slower.

Factors which influence the outcome of hot pressing include: press temperature, mat moisture and its distribution, press closing speed, the profile of the thickness change during pressing, press pressure, and press time. In general, the use of a high closing speed, a high press temperature or a high mat surface moisture content yields sharp density profiles from panel surface to centre.

The preferred density profile (through the thickness) depends upon use. For most applications, a higher density in surface layers for sanding and coating, and a very uniform density between top and bottom layers for edge machining is ideal. This can be attained by using a press cycle with a fast initial press closing, followed by much slower closing to the target thickness.

Density is widely accepted as the most reliable indicator of both process conditions and overall properties of the final product. Frequent determination of density profiles has become a regular part of quality control in the MDF sector.

Experimental work has been performed with steam injection. Steam is injected directly into the mat to provide a forced heat-convection method of heat transfer and thus raise the temperature in the mat quickly and uniformly, resulting in shorter pressing times, improved dimensional stability and higher internal bond. Very thick panels could benefit most from steam injection technology. Steam injection produces panels with more uniform density distribution through the thickness than conventional pressing.

Incremental Technological Innovation

22. *Further research on understanding and controlling pressing cycles*, particularly with respect to changes in other production parameters such as wood species, panel density, adhesive type. Some research has been done to optimize the various phases of the pressing cycle (closing, holding, venting), and a model is under development to represent the effects of relevant production parameters.
23. *Production of lower density panels through a better understanding of the panel consolidation process* in order to reduce wood usage and enhance panel stability while reducing production costs and maintaining critical properties.
24. *Instrumentation for continuous in-line measurement of density profile and use of this information to optimize the pressing operation*. Research is needed on the development of the density profile throughout the pressing cycle, so that feedback from the line may be used to automate the press control.
25. *Application of steam injection pressing*. The technology has been demonstrated under laboratory and pilot plant conditions. Initiatives are under way to apply the concept to industrial multi-opening presses. Once such presses are operating on a regular basis, work will be needed to optimize operating parameters for shorter press cycles and enhanced panel properties.
26. *Application of RF to pre-heat the mat between the pre-press and the hot press*, to increase press productivity.

Breakthrough Technological Innovation

- E. *Development of steam injection technology for continuous presses.* Ways have to be devised to equip continuous presses with steam injection capability, thus combining the benefits of the two methods.
- F. *Self-generated steam pressing.* Experiments are being performed in the laboratory on pressing high-moisture content veneer in a sealed environment, to create conditions similar to that obtained with steam injection, but without the related capital cost. Similar conditions could be applied to MDF, with similar benefits.
- G. *One-step lamination.* The ability of overlaying panels directly in the press would represent a major step forward for the industry by eliminating additional handling, sanding and resination.
- H. *Other high-energy adhesive curing methods should be investigated.* Energy forms other than convection heat (e.g. RF and microwave heating) may have the potential to cure adhesives extremely fast if combined with the right adhesives systems.

Trimming, Sanding, Grading and Storage

Existing Technologies

Normally, panels reach their maximum properties after cooling down. Panel trimming and cutting are performed either before or after cooling or hot-stacking. However, sanding must not be carried out until adequate cooling is attained so that the panel surfaces will not be "torn out". After the panels leave the sander, a grader checks the panel surfaces visually for imperfections using an oblique light and a reflecting mirror. The panels are then sorted by grades, and stacked with an automatic system.

The trend is to totally automated systems, but most plants still use at least one person to visually grade panel surfaces. Rejecting defective boards can be done automatically with in-line blow detectors. Totally automated saw positioning systems, with servomotors controlling the blade position, can change the saw position often, to produce a variety of panel sizes.

Camera systems are available to view the top, bottom and edge surfaces for conditions such as:

- burns, water, oil or adhesive stains
- surface blisters
- surface defects such as press belt marks, indentation, pitted areas, burnished areas, non-sanded areas or discoloration
- edge and trimming defects.

Automatic stack storage retrieval systems between the press and the sander in lieu of forklifts have been used in Europe for some time now but are relatively new in North America. Similar systems are available for warehouse management.

Incremental Technological Innovation

- 27. *Development of fully automated systems for trimming and grading.* A combination of technologies (ultrasound, RF, microwave, camera, X-ray) can be used to detect internal and surface defects. New stress-grading equipment is being commercially developed, which can measure the mechanical properties (parallel and perpendicular) of the panels on-line. Computer systems can also be adapted to limiting trim losses with custom sizes.

28. *Reduction in sanding requirements through better thickness control.* This will also improve process efficiency, reduce particulate emissions, and enhance surface quality.
29. *Value-added products can be produced for specialty applications.* MDF mills can take advantage of niche markets for cut-to-size panels, overlaid panels, specially finished surfaces, pre-drilling, shaping, machining, etc.

Post-treatment

Existing Technologies

Post-treatment is not commonly used in MDF plants, but it could be introduced to impart specific properties to regular panels.

Incremental Technological Innovation

30. *Application of conditioning post-treatment to increase the moisture content of the panels prior to shipping,* thereby improving their dimensional stability.
31. *Application of other post-treatments for specific opportunities in product added value and diversification.* This could include surface impregnation with polymers, or even chemical modification of the surface wood. As for additives, the list of potential treatments is endless, but they may present more limitations than advantages. Their main attraction is that they can be performed off-line on any fraction of the total production, without interfering with the production process, therefore facilitating cost and emission control.

Process Control and Quality Assurance

Existing Technologies

New plant designs include advanced programmable logic controllers (PLCs) to control manufacturing processes and to be connected to a plant-wide network. This includes data acquisition for shift reports, on-line data analysis, statistical process control (SPC) and database generation. This PLC network can then be interconnected to the local area network (LAN) which links all the PCs in the plant providing access to process data by operators, managers and others.

On the quality assurance side, equipment is currently available to provide on-line continuous measurement of mat thickness and moisture content, finished board thickness and internal bond; to detect on-line delamination; and to monitor board edge and surface quality of each board.

Process control and quality assurance offer perhaps the greatest opportunity for technological innovation, which would optimize materials consumption and productivity and place the mill in a more competitive position. Process control should also help Canadian mills produce smaller runs of specialty products, thereby giving them a competitive advantage over US producers.

Incremental Technological Innovation

32. *Integration of individual measurement/detection systems on a plant wide basis to provide better data analysis capabilities.* Such equipment will permit plants to optimize material consumption and productivity and place the mill in a substantially more competitive position to meet future market challenges.

33. *Equipment to measure on-line the stiffness in both directions of each board.* Such equipment is in the later stages of commercialization and should be available soon. It will enable non-destructive evaluation of every single panel as it emerges from the production line. It can also be used to grade panels into performance level categories, thus providing producers with additional quality assurance and an opportunity to tap into some structural markets at relatively little cost.
34. *Artificial intelligence for monitoring, optimizing and troubleshooting mill operations.*

Breakthrough Technological Innovation

- I. *Fully integrated automatic process control.* Such innovation would go to a more advanced level of technology than that suggested above and would apply to the total production process as a fully integrated system. On-line monitoring and automatic feedback and control would be incorporated throughout the manufacturing process and would enable automatic change of process parameters to optimize board quality and reduce unit costs.

Environmental Control

Existing Technologies

Pollutants emanating from the manufacture of various wood panels are similar and occur from the following processes: wood waste and product handling, drying, pressing, secondary finishing and thermal energy production. MDF tends to have greater particulate emission than some other wood-based panels in the drying process because of the smaller particles. Pollutants include: nitrogen oxides, sulfur oxides, carbon monoxide and VOCs.

Recently installed technologies for dryers include partial press enclosures to capture emissions and using exhaust air for combustion in the boiler plant. Particulate in the finishing areas are picked up by conventional dust collection equipment. Other conventional technologies include primary and secondary cyclones, multiclones wet dust collectors, dry and wet electrostatic precipitators, baghouses and electrostatic filter beds. These are described in Appendix I.

Incremental Technological Innovation

35. *Development of technology to significantly reduce formaldehyde emissions from finished products and in manufacturing facilities.*
36. *Continuing development of regenerative thermal oxidation (RTO) and regenerative catalytic oxidation (RCO).*
37. *Further refinement and implementation in the MDF sector of promising new, environmental technologies including bio-filtration. See Appendix I.*
38. *Development of equipment capable of operating at lower noise levels would improve health and safety conditions in the plants.*
39. *Integration of emission control and environmental friendliness into all phases of the manufacturing process, combined with measures to improve the efficiency of the manufacturing process and reduce costs. Efforts need to be made to gradually integrate environmental factors in all production parameter optimization models.*

Breakthrough Technological Innovation

- J. *Complete systems approach to environmental control, particularly for new plants.* The closed loop gasification and the closed steam loop system show good promise.

Product Development and Improvement

Existing Technologies

Both the quality and variations in product characteristics of MDF have improved substantially over the last decade and this has greatly assisted market acceptance and product substitution. Improvements in appearance and machinability have been particularly important. Both ultra thin and very thick panels have expanded product use. This has been made possible by technological changes to processes such as raw material preparation, resination, drying and pressing.

MDF will continue to substitute for such products as plywood, particleboard and particularly non-structural lumber. Such a range of product applications require different panel characteristics such as board strength, durability, stability and surface density. This calls for varying strategies relating to drying, pressing as well as raw material adhesive adjustment. For example, moisture resistant MDF has been developed that is suitable for exterior uses such as signs, billboards and other applications exposed to extreme moisture levels.

The most significant product attributes include: panel stability, fastening performance, high density for hardness, low density for reduced weight, paintability and colour.

Incremental Technological Innovation

40. *Ongoing improvements to product quality* particularly with respect to workability and dimensional stability, but also resistance to moisture (for kitchen cabinets, etc.). This will require a better understanding of basic parameters affecting thickness swelling and linear expansion. Low density MDF with good screw holding capacity could replace solid wood in some semi-structural applications such as window and door stiles and rails.
41. *Improvements to operational flexibility when changing product runs* in order to produce economically smaller quantities of higher-value products.
42. *Formaldehyde free MDF panels may represent a niche market opportunity.* Current technology to produce this type of panel is mostly based on isocyanate adhesives. Isocyanates, however, are more costly than regular urea-formaldehyde. Along a separate strategy, the adhesive and MDF industries are searching for very efficient scavengers to neutralize all the free formaldehyde in the board.

Breakthrough Technological Innovation

- K. *Development of MDF products with significantly modified properties for new market opportunities.* New MDF products are required to diversify the industry's markets. These would include panels that are more resistant to moisture, of lighter weight, of lighter colour, smoother and more workable. Examples include moulded and customer mouldable panels, very low density products, weather resistant products. New applications responding to radically different market needs should be identified, together with the related product characteristics (e.g. structural panels with aligned fibres).

Summary

The Canadian MDF industry is the most recent of all panel sectors discussed in this report, but it has experienced very rapid growth, supported by technological innovation. For this sector, the road to continued success goes through continuing product and process improvements which will help the industry expand its markets and improve its competitive position. Identification of new applications, new markets and new products will also play a significant role in helping manufacturers weather the effects of overcapacity in the coming years. Wood supply diversification, with increased use of recycled wood and agricultural fibres will reinforce the industry's position.

A number of incremental technology innovations have been listed in this chapter, which would help the industry along in this direction. Every one of them represents potential gains for the MDF sector, but it should be remembered that the manufacturing process operates as a system: every time an operating parameter is modified, the whole process needs to be re-visited, including impact on costs and market. A few bolder "breakthrough" technologies have also been identified. If they can be successfully developed, they will allow the industry to make a significant leap towards its goal; these are described in greater detail in Chapter VIII.

Description

The hardwood veneer and plywood sector shares many features with its softwood counterpart, but it is very different from it. Panel properties are quite different. Hardwood panels are generally used for decorative rather than structural purposes. There are also differences in equipment settings and requirements for adhesives. Because they are used mostly in protected applications, hardwood plywood traditionally uses urea-formaldehyde adhesives. The industry is extremely fragmented. On the other hand, of all the panel sectors studied in this report, it is the most experienced in value-added products.

In the hardwood sector, there is a major emphasis on the appearance and value of the final product, and the quality of the face veneer. The hardwood sector manufactures veneer which are often thinner than for softwood. Veneer slicing may be used as an alternative to rotary peeling, and peeling speeds are typically lower than in the softwood sector.

Hardwood veneer and plywood operations are generally smaller and located in separate plants. Log availability and quality are problems for both sectors, but this issue is perhaps more serious in the case of hardwoods. The industry also imports significant volumes of wood as logs, flitches and veneer.

Both plywood sectors use aspen for core veneer although the hardwood sector uses it more extensively. Hardwood plywood has a greater density range, and softwood is generally produced in a greater range of thicknesses. Decorative plywood is usually manufactured in 1,220 x 2,440-mm (4 x 8-foot) panels, whereas all-aspen plywood is produced in 1,220 x 1,220-mm (4 x 4-foot) and 1,220 x 2,440-mm (4 x 8-foot) sizes. All-aspen plywood panels represent only a small percentage of the total hardwood production. Although they are bonded with urea-formaldehyde, much of their technology is similar to that discussed for softwood plywood, and this section will focus on decorative panels.

This sector produces veneer and plywood comprising a varying number of veneer layers. Hybrid panels with hardwood veneer overlaid on other panels such as MDF are also manufactured. Cores made up entirely of thin veneer require more adhesive and more production processing; they tend to be restricted to applications where their unique properties are required (e.g. moulded plywood, hockey sticks).

Hardwood cores compete with other wood-based panels, and hardwood face veneers compete with various types of overlay. However, because of unique product characteristics, this sector has firmly established niche markets in furniture, cabinetry and architectural millwork. Hardwood veneer and plywood have advantages in quality and appearance and as a result enjoy greater product values than many competing products.

Vision

The future of this sector will depend to a large degree on availability of raw material. If this can be mitigated, possibly through innovation on process and product, the industry should continue to grow. This is not a sunset sector; however, incorporation of state-of-the-art equipment and methods available in other panel sectors would have a major impact on the industry's efficiency.

Technological innovation will focus on the development of, or modification to, manufacturing processes related to improved productivity. Mills will become more highly automated, producing high

quality face veneer for overlaying on aspen cores or composite panels like MDF. Mills using veneer cores will need to improve the quality of their core material when using thinner face veneer.

On the environmental front, the industry will continue to reduce formaldehyde emissions from its products and its manufacturing facilities. As with other panel sectors, the hardwood plywood sector is responsible, and is seen as such by the public. Companies will continue to respond to changing environmental regulations with the installation of appropriate technologies. In some cases, innovation will be applied to the disposal or utilization of wood residue.

Economics

In 1995, the Canadian sector had 46 plants involved in hardwood veneer, veneer-splicing or hardwood plywood manufacturing; they were located mostly in eastern and central Canada. Shipments exceeded \$500 million, and the number of employees exceeded 4,000. Plants, on average, are much smaller and generally less automated than in the softwood sector. The sector's growth is constrained by raw material supply.

About \$400 million of product was exported in 1995, representing about 70 per cent of the value of shipments. According to Statistics Canada, the value of hardwood veneer exports had increased on average by 25 per cent per year since 1991. More than half of the exports were veneer, with the remainder plywood and veneered panels. In 1995, imports were about \$150 million, leaving a net export balance of \$250 million.

Driving Forces

Availability of suitable hardwood logs is the most significant driving force that will affect this sector. Wood is the highest cost element and relates significantly to recovery, product value and product quality. Log supply will determine the future viability of this sector. Availability of suitable Canadian hardwood logs has long been in decline, and efforts in forest management will not yield results for several decades. Technological innovation will be required to help the industry make use of a larger portion of available logs.

Because of the shortage of logs, and because of consumer demand for species not available in Canada, Canadian producers of rotary cut veneer buy large volumes of their raw material requirements in the US and elsewhere at high prices. *Reliance on imports* makes them dependant on world markets and currency fluctuations. Canadian log slicing operations process tropical woods in addition to temperate species. The lumber slicing operations, generally the smallest volume producers, buy their raw material (e.g. cherry, oak, maple) from local or US sawmills.

New and improved product development is also an important driver as it provides opportunity for enhancing overall product value, and this is a sector that depends on high values for profitability. The development of hybrid panels with new core materials is a case in point.

Cost reduction is always an important driving force but perhaps less so than with other panel sectors because hardwood plywood is such a high value product. Enhancing profitability is more relevant.

Environmental factors represent a significant driving force for this sector. Formaldehyde emissions, both from the mill and from the product, and wood dust are major concerns. Formaldehyde emissions from manufacturing facilities are becoming more of an issue, although mills are currently well below permitted levels. Other lesser issues are VOCs, particulate emissions from drying and residual water from the conditioning ponds. Sustainable forest management is an emerging issue as some European customers are demanding that the products be made from forests certified as managed on a sustainable basis.

Competition is another driving force. Wood imitation synthetic overlays, which are cheaper and produced in quantity with numerous designs, are putting increased emphasis on cost reduction in the hardwood plywood sector. For veneer core producers, there is also competition from MDF as a core substrate. Competition is forcing flexibility in manufacturing processes and the development of new products to target niche markets.

Existing and Future Technologies

To respond to its challenges, the hardwood plywood industry can call on a wide array of equipment, materials and processes already available or being adopted in other panel sectors, particularly softwood plywood.

Automation will assist with veneer production and panel lay-up. Pretreatment of the veneer blocks enhances veneer quality and the amount of veneer produced. Technological advances include mechanisms to load and centre logs on the veneer lathe, ultrasonic veneer block scanning, powered back up rolls, powered nose bars and linearly positioned lathe knife carriages to speed up veneer production.

Automated lay-up lines can increase panel production rates. A recent development is the veneer-composer, which joins narrow width veneer strips into full sized sheets to facilitate their use on automated lay-up lines. These advances can reduce labour costs and increase yield.

A wide variety of equipment is manufactured in North America, and equipment from Germany, Italy, Sweden, Finland and Japan is becoming increasingly common. Improvements in modern communications have led to exchanges in knowledge of new developments, particularly for specialized products and applications.

Through better scheduling of maintenance operations, the plants are able to reduce unscheduled downtime. They are incorporating preventative maintenance programs which include regular vibration analysis of all rotating equipment in order to trend bearing vibrations and predict failures.

For the hardwood plywood industry, it is particularly important that technological innovation should focus on means of reducing costs, increasing yields and improving quality from the existing wood resource base.

Raw Material

Existing Technologies

The hardwood plywood industry uses a variety of wood species, some native, some imported. Production of veneer requires relatively high quality logs to maintain levels of recovery and quality of product.

Typical reductions in log quality that affect plywood production are: low log moisture content, crooked logs, presence of core rot, large numbers and sizes of knots and the presence of compression grain resulting from trees growing on steep slopes. These defects reduce the number of full high grade veneer sheets from each log and lower production efficiency. Face veneer needs to be free of stains and other blemishes.

Contrary to other panel sectors, the hardwood plywood industry is very species oriented, at least for face veneer, as purchasers of decorative plywood specify species. For core veneer, there is much more flexibility, and substitutes to veneer cores are available from other panels sectors.

Incremental Technological Innovation

1. *Internal log analysis.* If the exact nature of the inside of a log can be determined by X-ray scanning, for example, then the log can be processed to yield its full potential in veneer quality.
2. *Longer lasting end coating material.* To reduce end splits, decay and stains, logs may be end-coated at time of cutting with a non-toxic wax base material. Longer lasting end coating material is required for logs that are stored for several months.

Preparing the Logs

Existing Technologies

Log preparation begins with the debarker, a mechanical device that strips the bark from the incoming logs. The bark is generally burnt as hog fuel to generate heat and power for plant operations. The debarked logs are cut into blocks approximately 2.5 m (8 foot) long.

A mill will select the type of debarker best suited to its needs in terms of maximum and minimum log diameter, and production rate. Technology has centred on increasing throughput with minimal damage to the wood surface of the peeler logs.

In all mills, the blocks are softened prior to peeling or slicing. This may be achieved by water spray, steam spray or water immersion, depending on the space requirement for such a system and that available at the mill site. Immersion of the blocks in hot water may take up to several days for some species. When logs are carefully prepared, they can be peeled or sliced more smoothly. A smooth cut produces more veneer of higher quality and this could also result in adhesive savings.

Veneer quality is also affected by log temperature. Computer models have been developed to predict the temperature profile of logs during conditioning, and they can be used to optimize temperatures for peeling or slicing.

Incremental Technological Innovation

3. *Improved scanning and pre-sorting of logs by diameter class and species* to accommodate different conditioning requirements and to optimize veneer recovery. Optimization systems using scanners to sort and cut peeling logs at the mill entrance would result in fibre gain; cutting for optimal length; sorting for conditioning purposes; and sorting for appearance of surface veneer, core veneer or for sawing.
4. *Advanced computer programs to optimize yard management and log conditioning.* The benefit will be more efficient log yard utilization, more efficient log conditioning and higher quality veneer.
5. *Log temperature monitoring.* Mill studies show that only 30 per cent of the wood is in the recommended temperature range during peeling. A system to maintain uniform temperatures in the bolts could increase production, yield and quality.
6. *Further developments in computer modelling for temperature optimization of peeler logs.* This would lead to more efficient use of log conditioning systems and energy savings.

Peeling and Slicing

Existing Technologies

A conveyor moves the prepared blocks to the log cleaning station, then to the veneer lathe, where it centres it on the lathe spindles. When the block is centred, chucks lock into each end. As the spindles rotate the block, the peeler blade cuts a thin sheet of veneer off in a continuous piece. A big peeler block can yield up to 500 m of veneer at speeds as high as 365 m per minute, although actual operating speeds are usually lower for higher veneer quality. Veneer thickness can be as low as 0.03 mm. As the block rotates, its diameter decreases. To keep a constant peeling speed, the block rotates faster as the blade gets closer to the middle of the block. The position of the cutting blade changes with the remaining diameter of the block so as to maintain a constant angle.

Changes have occurred in knife settings for optimal veneer quality. Powered back rolls aid in the positioning of the log during peeling and prevent log movement. These technologies help to produce reasonably good quality veneer at the much higher production speeds needed today.

Slicing veneer accounts for approximately 5 per cent of veneer production, and it is used mainly to produce radially oriented, fine figured hardwood veneer for furniture or wall panelling face plies.

Incremental Technological Innovation

7. *Advanced computer models to help with new lathe designs.* Computer simulation of the peeling process can be used to visualize the events occurring at the knife-edge and aid in the development of new lathe controls.
8. *Adaptation of softwood plywood technology to allow peeling veneer to a smaller core for increased yield.* Chucks could be used for the first part of the peeling operation, and a chuck-less system for the latter part. This would allow for increased production of core veneer from the existing log supply.
9. *More advanced log loading systems.* Peeling models have shown the need for high accuracy in log centring by automated loading systems. More accurate loading systems will improve veneer recovery.
10. *Peeling technology for shorter bolts.* While 2.5-m (8-foot) logs are in short supply, there is an abundance of high quality 1.2-m (4-foot) hardwood logs which cannot be used because they are too costly to peel with existing systems, which have been developed for longer logs.

Breakthrough Technological Innovation

- A. *Adaptive process control.* There is significant scope for improvement in the area of adaptive process control systems and modelling of the peeling process. Installation of sensors on the lathe to detect veneer roughness, knife vibration and knife wear would allow on-line adjustments of the peeling process and would improve recovery and veneer quality.

Veneer Clipping

Existing Technologies

The ribbon of veneer is cut into pieces as it passes under the clipper knife. For core veneer, the clipper is guided by an electronic eye that scans the veneer ribbon for defects and determines where the knife should make each cut to get the maximum value from the veneer. The reciprocating knife has been

generally replaced by the rotary clipper, which clips at higher feed rates. Cuts are usually made at 1.25 or 0.64-m (50 or 25-inch) intervals, except when a narrower, blemish-free piece of veneer can be produced. The clear pieces can later be spliced off line for use in higher quality plywood. Waste pieces are chipped. For high quality face veneer, matching is done manually as it relates to art much more than to industrial processes.

Incremental Technological Innovation

11. Scanning systems to automate the clipping procedure and maximize veneer yield at modern high speeds. Camera systems coupled with computer software to detect veneer defects are in development stages. Further advances and mill installation can improve yield. Advanced scanning systems could be used for matching grain and colours.

Veneer Drying and Grading

Existing Technologies

Core veneer is separated according to moisture content, while face veneer is sorted according to appearance. Sapwood contains more moisture than heartwood, so it must be dried for a longer time.

Workers or automatic machines feed veneer from two, three or four moisture content groups into dryers. Steam or gas heated jet dryers blow hot air onto the passing sheets. The dryers reduce the moisture content from as high as 100 per cent or more to as little as 3 per cent, on an oven-dry basis, to permit a strong, permanent adhesive bond.

The dried veneer sheets are graded according to how they can best be used in making plywood. Face pieces are used on the outside surfaces. Cross-bands and centres are used for inside layers. Face sheets without holes or cracks go directly to the glue spreader. Those with oversize defects are sent to the repair section. They can be trimmed, patched and assembled by taping or edge gluing into sheets large enough to make plywood panels.

The industry now uses multi level dryers with independently controlled multiple zones for fast production and lower risk of overheating the wood surface. A number of mills use direct fired jet dryers which impinge the flow of high temperature combustion product directly on the wood surface. All commercial dryers are equipped with moisture sensors. In some cases, an internal control system measures the temperature drop due to moisture evaporation, and then adjusts the rate at which veneer sheets move through the dryer.

Uniformity of veneer moisture content is important for the bonding process. Regions with high moisture pockets can cause blisters during the pressing process. Thus dried veneer with highly variable moisture regions will result in less stable and durable plywood. At the other extreme, over-drying of veneer will cause poor bonding.

Incremental Technological Innovation

12. *Improved moisture sorting of veneer prior to drying.* With improvements such as better moisture content sensors, batches of veneer passing through the dryer would be consistent in moisture contents and would facilitate the production of veneer with more uniform moisture content.
13. *Veneer incising* would also help produce uniform moisture contents, especially with aspen used in core layers, where appearance is not an issue. The technique developed for softwood veneer for incising at the lathe cannot be used here, but other methods could be adapted.

14. *Adoption of RF veneer drying.* While slower and more energy intensive than conventional drying, the RF unit (used in combination with a conventional dryer) can be used to dry "re-dry veneer" to produce more uniform levels of moisture content.
15. *Improvements to dryer operating efficiency and instrumentation.* Dryers could be equipped with sensors to monitor moisture content of veneer sheets and openings to release these sheets at desired levels of moisture.
16. *Veneer grading, defect cutting and assembly before drying.* Veneer dryer throughput and material handling would be improved, and energy savings realized by not drying defective veneer.
17. *Platen drying* may have the potential to provide shorter drying times, smoother and flatter surfaces, less tangential shrinkage and more uniform moisture content. It could be combined with a conventional dryer towards the end of the normal drying cycle where it would selectively apply more heating energy to wet pockets to further improve moisture content distribution.

Patching

Existing Technologies

Veneer is very rarely found without splits, knot-holes or other flaws. These flaws must be repaired neatly and efficiently.

Three methods of patching are used in North America. The oldest form is a boat shaped wooden slab which is punched into veneer (replacing a defect) before the veneer is used for plywood manufacture. The process is environmentally friendly. It has traditionally been slow and labour intensive, but equipment is being introduced for automatic defect detection and repair. The industry has adopted two liquid slurry applications to patch finished panels with acceptable speed. Putty-patching is water based and fairly inexpensive, but is only acceptable on openings of 25-mm (1-inch) size or less. Synthetic patching is a two component system using natural oils and fillers with isocyanate to produce a polyurethane patch for superior durability and defects up to 75 mm (3 inches) in size. Both material cost and wastage are higher. The components are reactive and the equipment needs periodic cleaning.

Incremental Technological Innovation

18. *Development of new patching compounds.* Current compounds tend to telegraph through thin face veneer, and sanding is costly. There is a need for new, stable compounds, compatible with the adhesive, which do not require sanding. New compounds that would be more wood-like in their response to heat, moisture and pressure would allow for overlays on patched panels.

Lay-up and Gluing

Existing Technologies

When the veneer sheets are ready for assembly, workers place a face piece on a lay-up table. The cross bands are run through a machine that coats veneer with a thin uniform layer of urea-formaldehyde adhesive. The pieces are then assembled using face pieces, cross bands and centre materials. Usually three to seven layers of veneer are used. A five-ply panel, for example, would be

constructed using a face veneer, a cross band, a sheet of core veneer, another cross band and then a face veneer. Each layer is placed with the grain running at right angles to the adjacent veneer.

Changes in the gluing system, such as gluing veneer of high moisture content and foaming the adhesive, have reduced the amount of adhesive and lowered production costs. The development and use of adhesives for use with veneer at moisture contents of 10 per cent or more instead of 3 to 4 per cent is a major breakthrough. This has increased productivity in the dryer and the press; lowered adhesive spreads and improved bondability; and achieved better pre-pressing and assembly line tolerances. Costs for adhesive, drying and pressing have all been reduced.

Sufficient adhesive must be applied to the veneer to ensure a continuous film. Adhesive application rates range from 145 to 158 g of adhesive per m² of glue line (30 to 33 pounds per thousand square feet), with higher levels for very rough veneer or in hot dry weather.

Incremental Technological Innovation

19. *On-line adhesive spread measurement.* Continuous on-line measurement could permit automated monitoring and process control.
20. *Elimination of resin spots on panel surfaces.* Resin spots appear on panel surfaces from the accumulation of adhesive on the press platens. Modifications to the adhesive or to platen surfaces would alleviate the problem.

Breakthrough Technological Innovation

- B. *New adhesives for faster setting, better bonding, easier sanding, higher moisture content tolerance and lower temperatures.* Savings in drying and pressing energy could be substantial. VOC emissions would be reduced. Improved adhesives now on the market are expensive and application presents problems.

Pressing

Existing Technologies

At the end of the assembly line, the veneer assemblies are stacked and sent to the presses. In most mills, pressing has three phases.

In the first phase, the assemblies are squeezed in a cold press. This phase helps the adhesive transfer to adjacent veneer, prevents air from drying the adhesive and makes the assembly easier to handle with automated equipment.

In the second phase, the assemblies are fed onto individual caul plates or directly onto platens in the hot press. When the hot press is loaded, hydraulic pressure is applied to squeeze the assemblies at pressures of up to 1,400 kilopascals (about 200 pounds per square inch). At the same time, the plywood assembly is heated at 150°C (300°F) over a period sufficient to fully cure the adhesive.

Adequate pressure, temperature and time are required to ensure that the adhesive has fully cured and produced a permanent bond. Overlooking one of these variables can lead to lower plywood qualities.

The final phase occurs when the plywood panels exit the hot press. They are trimmed on the sides and ends to finished dimensions. Common trim sizes are 1,220 x 2,440 mm (4 x 8 feet) or whatever the customers want, within the limitations of the plant.

Incremental Technological Innovation

21. *Further development of steam injection and in-situ steam technology in pressing.* This, combined with incising technology, has the potential to substantially reduce press times.

Breakthrough Technological Innovation

- C. *Continuous pressing.* This is now used successfully in other panel sectors and also in the production of LVL. Application to the plywood sector would improve the production of panels with uniform thickness.
- D. *Self-generated steam pressing.* Experiments are being performed in the laboratory on pressing high-moisture content veneer in a sealed environment, to create conditions similar to those obtained with steam injection, but without the accompanying capital cost.

Trimming, Sanding, Grading and Storage

Existing Technologies

Generally, only the best plywood is sanded to achieve a smooth, attractive finish. Modern methods produce fine finishes with fast wide belt sanders. After sanding, the plywood is graded and prepared for storage or shipping.

Grading and sorting will become particularly important for this sector to optimize the use of veneer sheets and maximize end product value.

Plywood may be treated or overlaid with other materials for specialized use.

Following the final grading, plywood is piled in standard quantity units called lifts, about 1.2 m (4 feet) high. The lifts are securely bound with steel strapping for protection and ease of handling. They are labelled for type, grade and size of panel. The lifts are delivered to the warehouse for storage or shipment.

Incremental Technological Innovation

22. *New scanning and grading systems with improved accuracy.* A combination of technologies (ultrasound, RF, microwave, camera, X-ray) can be used to grade according to visual appearance, including colour.
23. *Value-added products can be produced for specialty applications.* Hardwood plywood mills can take advantage of niche markets for cut-to-size panels, specially overlaid panels, specially finished surfaces, etc.

Environmental Control

Existing Technologies

Hardwood plywood manufacturers recognize the importance of sustainable development to the public. As the industry sector sources virtually all of its raw material from the forest, this applies to forest management and wood harvesting as well as manufacturing, where there are some similarities with other panels.

The hardwood plywood sector does generate wood residues in debarking, peeling or slicing, veneer clipping, sanding and trimming. Traditionally, this residue has been disposed of in beehive burners, but for the most part these are no longer acceptable particularly in populated areas. The use of high temperature burning, with fewer emissions, is costly. Recycling is used where possible.

Emissions from plywood manufacture are mainly from the drying process where steam and airborne particulate are common. The industry has made great efforts to reduce VOCs, and particularly formaldehyde emissions from its products and manufacturing operations.

Environmental control is treated in greater detail in Appendix I.

Incremental Technological Innovation

24. *Addition of borax to veneer before drying to reduce VOCs.* Borax can react with wood extractives reducing the quantity of emissions of VOCs during the drying phase.
25. *Development and utilization of processes such as RF or superheated steam/vacuum drying.* This would improve veneer drying at lower temperatures and reduce emissions. These processes are available for lumber but could be optimized for drying veneer.
26. *Adoption of appropriate environmental technologies now available in other panel sectors.* Some environmental technologies available in other panel sectors (e.g. use of exhaust air as combustion air) could allow plywood plants to meet emission restrictions near highly populated areas.
27. *Development of equipment capable of operating at lower noise levels* would improve health and safety conditions in the plants.
28. *Development of new applications for bark and other residues* would reduce environmental pressure and increase revenues. Opportunities might include power co-generation, agricultural uses, pulping and other composite products. The whole wood industry is beginning to show interest in solving a bark disposal problem, and is exploring the potential of bark as a raw material for profitable new products, including resins and moulded products.
29. *Integration of emission control and environmental friendliness into all phases of the manufacturing process,* combined with measures to improve the efficiency of the manufacturing process and reduce costs. Efforts need to be made to gradually integrate environmental factors in all production parameter optimization models.

Process Control and Quality Assurance

Existing Technologies

The level of automation in hardwood veneer and plywood plants is not as advanced as in other panel sectors. Many mills are old and small, and both cost and the required financial justification of retrofitting automatic controls are constraints. Nonetheless, greater use of computers and integrated automatic controls with feedback to make immediate process adjustments may have application in this sector.

Some plants have used computerized simulation models to assist decision making in operations and equipment purchases with good success. These tools can be applied across the operation and back into resource allocation. Automated process controls will allow for continual monitoring of quality parameters such as moisture content, adhesive spread, press time and temperature and sample test data.

These process controls can be further adapted to alter any phase of the process, in response to feedback, and allow for much greater mill automation.

Incremental Technological Innovation

30. *Adaptation of controls used in other panel sectors to the hardwood plywood sector.* Benefits would include reduced labour costs, improved productivity and product quality.
31. *Automation for flexible production of highly specialized products.* Many value-added products have small markets. Automating manufacturing processes would make them more flexible, to allow rapid changes in production lines and make non-commodity products economically viable.
32. *Refinement and further application of on-line monitoring systems.* This could include moisture content detection in dryers to more rapidly adjust drying parameters and monitoring veneer roughness to adjust adhesive application, and appearance grading of panels.

Breakthrough Technology Innovation

- E. *Fully integrated automatic process control.* Such innovation would go to a more advanced level of technology than that suggested above, and would apply to the total production process as a fully integrated system.

Product Development and Improvement

Existing Technologies

New and improved products represent a major opportunity for growth and expansion, as they maximize the value of the resource. New products with improved surface quality can be obtained through specialized sanding and finishing procedures. Moreover, there is opportunity for innovation to expand the range of overlay materials and product applications. One company is producing a flooring material in which a hardwood veneer serves as face material, while a foam back provides noise control.

Incremental Technological Innovation

33. *Expand specialized species utilization in standard and new products.* Some species have limited use to date in plywood production and might present future opportunities. Concrete forms have been suggested as a possible application.
34. *Continued development of new products.* Existing properties of plywood (e.g. fire performance, weather resistance, surface characteristics, assembly procedures) can be modified to address the specific requirements of niche markets. The replacement of core veneer with lower cost wood or other substitutes may also be a consideration.

Breakthrough Technological Innovation

- F. *Development of innovative products* for entirely new applications. The objective is to design radically new products for industrial and architectural end uses, and particularly in decorative applications. New performance characteristics can be obtained through modification of wood properties, or combination with other materials.

Summary

The hardwood plywood industry is a mature industrial sector with a major challenge: the scarcity of suitable hardwood logs for peeling or slicing. The road to survival and financial success for this sector goes through the extraction of maximum value from available logs, efficient manufacturing processes, and the identification of new products and markets which create maximum value for face veneer while reducing the cost of cores. Because a number of producers are smaller than the average for the wood panel industry, technologies available may not always be directly usable, and this is a challenge of its own.

A number of incremental technology innovations have been listed in this chapter, which would help the industry along in this direction. Every one of them represents potential gains for the hardwood plywood sector, but it should be remembered that the manufacturing process operates as a system: every time an operating parameter is modified, the whole process needs to be re-visited, including impact on costs and market. A few bolder "breakthrough" technologies have also been identified. If they can be successfully developed, they will allow the industry to make a significant leap towards its goal; these are described in greater detail in Chapter VIII.

There are exciting areas of innovation on the horizon. They offer significant opportunities for substantial and long-term benefit. They are consistent with the driving forces and vision statements set out earlier in this Roadmap. However, the costs and the risks of failure may be high, and success will require a commitment from the panel industry and its partners on R&D priorities and a sustained effort over the longer term.

This chapter presents a sampling of potentially breakthrough, technological innovation in the panel industry. The examples provided would apply in most cases to a number of the panel sectors but one sector may be a leading candidate. The list is not exhaustive nor does it imply priorities.

Research institutions may be expected to play a leading role in the development of these technologies, but success, as measured by the impact of the technology on the industry's bottom line, requires collaboration of all parties (research institutions, panel producers, equipment manufacturers, adhesive suppliers and engineering consultants) within the framework of a continuing partnership.

It should also be remembered that every manufacturing centre in a plant is inter-dependent with other centres, and that any change affecting one centre invites a complete re-examination of the whole process, with due consideration for the environment, health and safety, cost and product quality. Indeed, innovation should not be seen as just providing one solution to one problem.

In the new economy, flexibility will be a major asset, and the technology of the future should be more concerned with providing a range of solutions corresponding to a range of input conditions. With this in mind, it is clear that the computer models being developed in the industry's research laboratories to describe relationships between production parameters will be of paramount importance to the industry, not only for process control, but also as decision-assistance tools, especially when they can be integrated into holistic models for the complete process, and linked to cost and market attributes models.

The future of the Canadian wood composite panel industry will also be influenced by its ability to develop new types of products. Much of this will be incremental, but opportunities abound for the development of products and systems with significantly improved (and different) properties. It should be remembered, however, that such products will only be successful and pay dividends to the wood panel industry if they **respond** to genuine markets needs. In other words, the market opportunity needs to be identified before substantial resources are invested on product development.

1. *New machinery to accommodate new types of wood supply (OSB)*

All wood composite panel sectors need to diversify their wood supply. In the case of OSB, there is an opportunity to obtain high quality strands by processing lower quality logs that may have been rejected as substandard in the past because they were crooked, too thin, and by using plantation thinnings or even some sawmill residues such as slabs.

These new sources of wood will have an effect on the whole mill, and they may require a total redesign of the green end. Different types of debarkers will be required. Alternatively, mills may consider methods to separate bark from wood. Most challenging of all perhaps is the possibility that some mills may need enough process flexibility to handle a variety of furnish types. In addition to debarkers, handling systems, conditioning ponds and flakers will require major modifications.

In terms of product quality, diversification of the raw material supply will require more effective monitoring of strand quality to ensure uniformity, and broader tolerance to variations throughout the process (e.g. drying, adhesive, additives, forming, pressing).

2. *Adaptive process control for veneer peeling (softwood and hardwood plywood)*

Plywood mills, whether they process softwood or hardwood, need to maximize the use of their logs by producing the greatest amount of high quality veneer out of every log.

There is significant scope for improvement in the area of adaptive process control systems and modelling of the peeling process. Installation of sensors on the lathe to detect veneer roughness, knife vibration and knife wear would allow on-line adjustments of the peeling process and would improve recovery. For example, a computer system could change knife pressure, knife angle and veneer thickness on the fly. Knives could also be changed automatically. The integration of adaptive process control with other innovations in lathe technology, with feed-back signals from other systems monitoring the resulting veneer, and with graphical interfaces, would yield substantial benefits in cost reduction, recovery and product quality. Adaptive process control could also be used to position the knife so that it follows the taper of the log, rather than its axis, thereby reducing slope-of-grain problems.

With hardwood veneer, the ability to adjust the horizontal gap for wood density, and to adjust knife angle for slope of grain would provide better thickness control and higher quality surfaces.

3. *New types of dryers (particleboard)*

Particleboard plants would benefit from dryers capable of operating at lower temperatures in order to reduce VOC emissions from the furnish, of providing more uniform moisture contents throughout the furnish and of handling the particles in such a way as to reduce dust formation. In addition to improving environment control in particleboard plants, the new dryers would enhance furnish quality and greatly reduce the risks of fire. Lower temperatures would also reduce deactivation of the wood surface, thereby increasing adhesive efficiency.

Conveyor dryers such as used by some OSB plants may offer solutions, but the industry should also investigate drying equipment used in other industries.

4. *Improved digestive capability for MDF digesters*

Refining is a critical operation in the MDF manufacturing process, in that it is key to any further diversification of the raw material supply. It is a major cost factor due to high power consumption, and it has great impact on end product characteristics.

Preliminary laboratory research and the experience of the pulp and paper industry suggest that the use of high-pressure steam (up to 17 bars) would help soften the bond between fibres with minimum degradation of the fibres themselves. This would reduce the energy required to refine the wood, as well as provide cleaner material and improved quality for fibre bonding. The technique needs to be thoroughly re-examined for adaptation to MDF manufacturing.

Also worthy of consideration is the addition of chemicals to enhance the digestion process. As with high-pressure steam treatment, the pulp and paper industry has used chemicals successfully for this purpose. Research is needed to devise ways of adapting this technology to MDF production within the cost constraints peculiar to this industry.

Through steam and heat treatment in the digester, MDF panels can be produced without the assistance of adhesives. Apart from eliminating the cost of the adhesive and the VOC emissions related to it, the resulting panels would have greater resistance to moisture. This technology deserves to be explored in the framework of product development.

5. *New adhesive systems (all panels)*

The Canadian wood composite panel industry has been relying on phenol-formaldehyde adhesives for "exterior" (i.e. structural) applications, and urea-formaldehyde for "interior" applications. Isocyanates have also been employed in both types of applications, mostly because of their ability to react fast, and to tolerate a relatively broad range of moisture contents. While research is being conducted by adhesive suppliers and the wood industry's research laboratories on ways to improve existing resins, mostly to make them more reactive (for shorter press times), cheaper (for lower production costs), more environmentally acceptable (less free formaldehyde and VOC emissions), and more tolerant of variations in the wood furnish (to accommodate a broader range of raw materials), it is suggested that radically different systems should be explored and developed to respond to the industry's needs.

The development of alternative systems needs to be based on a better understanding of the fundamentals of the bonding process and on sound economics. It needs to take into account other processing parameters (wood pH, surface characteristics, moisture content and density variations, etc.) as well as the industry's primary objective of enhanced performance at lower costs. It should also integrate research on additives and adhesive distribution systems.

Adhesives will clearly be an important factor in the development of new and improved panel products.

6. *Additives (particleboard, OSB, MDF)*

Catalysts have been used to facilitate the polymerization reaction of urea-formaldehyde adhesives, and they are being considered for use with phenol-formaldehyde. As scientific information develops on the principles of wood bonding, new additives should be identified, that could play a role in the wood-to-wood or in the polymer-to-wood bond.

Wax has been used in the manufacture of OSB, particleboard and MDF, because it improves the moisture resistance of the panels, and because it promotes adhesive flow when used with powder phenolics. Wax has the distinct advantage of being cheap, but once its role in the process has been more clearly identified, substitutes should be sought to enhance that role while improving other properties such as VOC emissions.

Other families of additives need to be investigated to engineer specific panel properties, including insect and weather resistance, fire performance, dimensional stability, machinability, surface smoothness, punch-through resistance or creep performance. Swelling, for example, could be reduced or eliminated through the development of cross-links between cell wall hydroxyl groups and specific chemical reagents. This has been demonstrated successfully under laboratory conditions, but not confirmed under industrial conditions.

Additives are also likely to play a role in combination with adhesives in the design of new panels, particularly those with significantly lower densities. In the case of OSB, for example, they could help maintain panel appearance and integrity when the compaction ratio drops to 1/1 or below, as desirable with denser species.

7. *New adhesive distribution systems (OSB, MDF and particleboard)*

For OSB, MDF and particleboard panels, distribution of the adhesive is currently a limiting factor to their performance, and a major effort is required in this respect, especially with adhesives that need to be applied at very low levels. Electrostatic distribution of both liquid and powder adhesives has been pursued with some success in the laboratory, and it may lead to a new industrial process. Research on distribution needs to be closely associated with research on adhesives, drying and wood surface characteristics.

A breakthrough is required in the development of highly efficient systems for the distribution of powder adhesives such as used in the OSB manufacture. Powder adhesives have been intimately associated with the success of the Canadian OSB industry thanks to their high performance and ease of transportation, and they constitute a technological success for the Canadian resin industry. However, producers have been switching to liquid adhesives, which are cheaper and can be more evenly distributed over strands with spinning discs. Significant improvements in powder resin distribution would again allow the industry to benefit from lower transportation and storage costs.

8. *Intelligent system to monitor adhesive application (all panels)*

Research is under way to apply artificial vision and image analysis techniques to the monitoring and measurement of resin distribution on veneer, strands or particles. A breakthrough in this domain would consist in devising systems capable of recording and analyzing the characteristics of the wood (e.g. veneer roughness in the case of plywood, strand or particle geometry for OSB and particleboard) and adjusting resin distribution according to these characteristics. The implementation of technology of this type would allow optimization of adhesive consumption and product quality.

9. *New strand handling and forming concepts (OSB)*

Laboratory tests have long established that the mechanical properties of OSB are a function of strand length. Long strands, up to 30 cm (12 inches) in length, have shown excellent promise in experimental work; unfortunately, long strands are notoriously difficult to handle with existing methods, and even harder to form into a uniform mat.

The use of artificial vision to analyze the OSB forming process in combination with computer models under development may help identify such new concepts.

10. *Continuous pressing (softwood and hardwood plywood)*

Continuous presses have been used successfully in particleboard and MDF production, and they are being introduced into the OSB industry. They provide better thickness control, hence lower sanding requirements. They also produce a continuous board which gives better flexibility on sizes offered to the customer. Continuous presses are also used in the manufacture of LVL, the other major product made from veneer.

For the plywood industry to benefit from these characteristics, the production line concept needs to be totally overhauled, with integration of veneer clipping, sorting, composing, drying, lay-up and resination into a totally automated and continuous operation. Re-defining the veneer preparation process should lead to the development of innovative equipment. It may also open opportunities for the production of innovative products in which the veneer arrangement might be different to suit new application requirements.

11. *Steam injection technology for continuous pressing (all panels)*

The injection of superheated steam through perforations in press platens provides a forced heat-convection method to raise mat temperatures quickly and uniformly, thereby reducing press time. Dimensional stability is also improved as a result of wood plasticization and enhanced resin cure. The technique is particularly promising for thick panels, which normally require extremely long press times. Experimental and pilot plant results have been conclusive with OSB, particleboard and MDF, and press manufacturers are considering the inclusion of this feature into their new multi-opening presses.

In the case of plywood, early results were less exciting, because of insufficient permeability of the veneer to steam. However, the recent introduction of veneer incising has created a window of opportunity

for plywood producers to reduce costs, particularly for thicker panels. It has been estimated that press times could be reduced by up to 30 per cent for a 38-mm (1-1/2 inch) thirteen-ply CSP panel.

There is every reason to believe that the same advantages could be transferred to continuous presses if innovative methods were devised to inject the steam into the mat or veneer.

12. *Self-generated steam pressing (all panels)*

Experiments have been performed in the laboratory on pressing high moisture content veneer to create conditions similar to those obtained with steam injection. Combined with veneer incising, the technique could reduce press times in the same manner, while reducing drying requirements. It would also eliminate the capital costs related to superheated steam injection.

The same technique could undoubtedly be applied to other panels. Its development requires a complete reassessment of some of the major manufacturing parameters, i.e. drying time and temperature, adhesive and additive types, pressing time and temperature.

13. *Other high-energy adhesive curing systems (all panels)*

RF and microwave energy are relatively recent developments as industrial heating methods. They rely on the establishment of alternating electromagnetic fields to induce a vibration and therefore heat in dipole compounds (such as water) in a material. They are capable of rapidly elevating internal temperatures to the boiling point of water to facilitate drying or the curing of an adhesive. The technology is widely used in industrial and home applications, but not in the wood panel industry.

RF and microwave energy travels through a panel independently of its conductive characteristics, and it is most effective in high moisture areas. At current energy cost levels, RF and microwave heating are considered uneconomical for most panel production operations. The breakthrough will therefore consist in designing new systems capable of significantly lower production costs.

14. *One-step lamination (all panels)*

With panel lamination identified as one of the major instruments for diversification and the creation of value-added products, integration of the operation into the main manufacturing process becomes very attractive, since it would eliminate the need to overlay the panels off-line.

The difficulty in implementing on-line lamination does not reside in the application of the overlay, but rather in the need to produce a perfect panel from the point of view of thickness and surface quality, with no recourse to sanding. Consequently, the feasibility of one-step lamination depends on the industry's ability to form a high-quality mat or to prepare the surface of face veneer (patching) in the case of plywood.

15. *Fully integrated, automatic process control (all panels)*

In panel manufacturing processes, raw material properties change constantly. This requires alteration of processing parameters to produce consistent products and maintain wood recovery and product quality. The objective of using process control techniques is to detect property variations, and to alter processing parameters accordingly. In a similar manner, process control can be used to modify processing parameters in order to obtain different product characteristics.

Once relationships between input parameters, manufacturing parameters and end-product characteristics (including market value) are well understood and represented in computer models, it becomes possible to integrate process control in order to obtain the most desirable set of product characteristics at the lowest possible cost.

A combination of computer models and integrated process controls will also make it possible for manufacturers to simulate the effect of parameter changes on product cost or characteristics. In addition, it will allow for increased flexibility in production, meaning shorter runs of specialty products and possibly custom production.

16. *Systems approach to environmental control (all panels)*

Environmental control has developed gradually, with manufacturers and equipment suppliers solving problems as the need was arising. The solution, in most cases, consisted in installing more pollution-control equipment, which, of course, added to capital costs and sometimes detracted from processing efficiency. In more recent years, however, the industry and its suppliers started looking at ways of reducing emissions at source by modifying processes. Lower drying temperatures are a good example of this trend. Another approach consists in collecting dust- and VOC-laden air (from the dryer or the press) and using it as combustion air: the particleboard industry has made great steps in that direction.

The next step in environmental control will be to design wood composite panel plants in such a manner that all environmental factors are considered at every step of the manufacturing process, and that environmental control measures are fully integrated among themselves and with other manufacturing parameters. The true challenge is to achieve this while reducing production costs, and a good place to start is in the laboratories, where research on drying, adhesives and pressing must include environment impact as a full-fledged production and product characteristic.

17. *New products and systems (all panels)*

All sectors of the wood composite panel industry have been looking at new products, either to diversify their production when commodities suffer from intense competition and resulting low prices, or to add value to existing product lines by accessing niche markets. While veneer-based panels may be considering alternative core materials and overlays, non-veneer product development is being addressed in the context of mat-forming, resin development and finishing, with the objectives of reducing panel weight, increasing dimensional stability and, in the cases of OSB and particleboard, enhancing surface characteristics and machinability. "Formaldehyde-free" particleboard, MDF and hardwood plywood are distinct goals for the specific market of the hyper-sensitive.

Breakthroughs in this domain will come from radical modifications of product properties through chemical alteration of the wood and the adhesive. Research has already suggested ways of achieving changes by means of impregnation, radical grafting and similar processes. Panels have been produced in the laboratories, which can be moulded by the end-user, thus opening new markets for architectural mouldings and moulded door skins. Promising results have also been obtained with treatments that make wood resistant to UV degradation and weathering. Improvements in fire performance can similarly be obtained.

Breakthroughs will also derive from the combination of wood with other materials to produce hybrid products. Such hybrids could incorporate cement or other inorganic materials (for weather, insect and fire resistance) or plastics (for mouldability, machining, water resistance, etc.). They could also incorporate metal, glass or carbon fibres for superior mechanical performance.

The technical development of such hybrids represents a challenge, but success can only come from the identification of new applications (e.g. building systems components, furniture components, automotive parts) where such innovative panels could be used to advantage and provide a healthy return to the wood composite panel industry. In some cases, development of the product should be only one aspect in the development of a complete innovative system aimed at a novel application.

In Conclusion . . .

Much can be done to provide the Canadian wood composite panel industry with the technological tools it needs to continue as a high performer in the national economy. Some gains will be small, others may drastically alter one sector or another. But resources available for technology development are limited, and the industry's R&D effort needs to be planned through a comprehensive program serving the following goals:

- Diversification of raw materials (all sectors)
- Reduction in panel densities (particleboard, OSB, MDF)
- Reduction in formaldehyde and other VOC emissions from plant and product (all sectors)
- Reduction in manufacturing costs (all sectors)
- Improvements in panel characteristics (all sectors)
- Diversification of panel characteristics (all sectors)
- Major improvements in integrated process control and manufacturing flexibility (all sectors)
- Integration of cost in all process figuration models (all sectors)
- Identification and development of new products (all sectors)
- Intensification of market research to identify new applications.

Canada has traditionally enjoyed a relative abundance of raw materials, which it has used to develop its enviable export capacity. Canadian wood composites panel manufacturers have generally kept up to date on new technology, and in some sectors they have developed into world leaders. The big challenge for this industry, as it is for so many other Canadian exporters, is to maintain its advantage in the face of a deteriorating wood supply situation and increasing foreign competition. The industry must become even more competitive in manufacturing commodity products, while acquiring new skills with respect to market specialization and production flexibility.

As we have seen in our technology assessment, not all sectors have the same opportunities or challenges. Some products are more mature than others, and they need to follow different roads to remain successful over the next ten or fifteen years. Yet they have much in common in terms of processing technology. They may compete for raw materials and for markets, but they can also be complementary, making efficient use of a broad range of raw materials, and covering an even broader range of applications. This kind of rationalization of the industry should be facilitated by the fact that the major companies involved in wood composite panel production are active in more than one sector, and therefore more likely to take the long-term view.

The following recommendations extend beyond technical issues, because technology alone cannot guarantee the industry's success. In addition to ensuring that the industry remains cost competitive, it has to be integrated into clear longer-term strategies which include human and material resources, an inspired grasp of market expectations, and a sensitivity to predominant social factors in both producing and consuming regions.

Each set of recommendations is meant to be self-supporting. As all recommendations necessarily overlap to form a coherent strategy, this implies a degree of repetition for which we apologize.

STRATEGY PLANNING

1. *Develop long-term R&D programs for all wood panel sectors*

The R&D program needs to be the next step in the Roadmap. It should be set out in broad terms initially and designed to achieve the industry's medium- and long-term priorities. Research programs already supported by industry, the Canadian federal government and several provincial governments constitute an excellent starting point. Much is already being done in universities and industry's research institutions, and the aim should be to reinforce and streamline this effort rather than duplicate it.

A number of breakthrough technologies have been identified in this report. By definition, these are high-risk, high pay-off undertakings which would go a long way in ensuring the industry's success. They should be further evaluated, prioritized, and translated into a series of manageable R&D goals.

Incremental technology innovation may be more dependant on equipment or adhesive manufacturers than on R&D institutions, but the latter have a role to play in providing the basic information that evolving technology is using, and integrating all processing and marketing centres into a coherent system.

Fundamental research on wood characteristics, drying, bonding, forming and pressing should also form part of the program. Neglecting it might jeopardize the industry's ability to pursue process optimization and control.

The R&D program should also be linked intimately to a market development plan (see below) in an interactive fashion, and support the delivery of short-term gains at the same time that it pursues its more ambitious objectives.

*Responsibility: Industry, Industry associations, Industry suppliers,
Research institutions, Governments*

2. Reinforce existing industry advisory committees to guide implementation of the industry's R&D program

Existing industry advisory committees play a critical role in ensuring that the R&D programs serve industry's interests, and in facilitating implementation of these programs. While R&D institutions and universities have no monopoly over innovation, they are in the most favourable position to provide the basic knowledge without which progress can only be empirical and slow. They can assist with the development and implementation of incremental technologies, and they are best equipped to explore and test breakthrough technologies.

The research program needs the guidance of the wood panel industry it is serving, but it also needs input from adhesive and equipment suppliers, engineering consultants and all other stakeholders. Mechanisms need to be found to give these partners a voice on advisory committees without disrupting existing arrangements. A technology watch also needs to be instituted over technical developments in industries other than wood, to identify techniques which could be adapted to this industry.

Federal and provincial government agencies need to participate actively with industry on advisory committees to ensure that the program serves provincial and national objectives in the most coherent manner and that stable funding is available to support it.

Shared risk/shared profit has proved a successful formula in existing R&D efforts. However, current programs fail to provide adequate means to demonstrate innovative technology on an industrial or pre-industrial scale, and the stakeholders should consider whether the shared risk/shared profit philosophy could be extended to this essential phase in technology implementation.

Appropriate business analysis techniques should be identified for long- and medium-term R&D projects, and applied to the industry's research initiatives in order to facilitate prioritization decisions.

*Responsibility: Industry, Industry associations, Industry suppliers,
Research institutions, Governments*

3. Continue supporting industry's R&D efforts

In order to develop the technology that industry requires for its continuing success, and to help it become a world leader as a provider of high-value products, research institutions, industry laboratories, research institutions and universities need long-term commitments to direct and indirect funding from industry and governments. This is essential to attracting and retaining the highly specialized skills necessary to carry out the research and transfer its results to industry.

Technology development and applied research need to be sustained by an understanding of principles involved, and this understanding comes only through fundamental research. Current trends, which see universities and research institutions neglect fundamental research in favour of more profitable

activities, may be dictated by economic necessity, but they represent a threat to continuing R&D and, indirectly, to the Canadian wood industry.

Government funding of research is more likely to serve national and industry goals if the various government programs are crafted to be complementary, and if the funds are primarily used to support coordinated multi-partner programs supported by industry. Government supported networks such as the network of centres of excellence would constitute an ideal framework for such university-industry-research institutions partnerships, and would therefore contribute substantially to the industry's technological advancement and success. Tax incentives, research grants and other similar forms of assistance should continue to be available to foster innovation.

Responsibility: Industry, Governments

NETWORK

4. *Create a science and technology network to support development of the breakthrough technologies identified in the program, and accelerate technology transfer*

A high degree of collaboration already exists between the industry, its research institutions, universities and adhesive or equipment manufacturers. This should be reinforced and expanded, especially with equipment manufacturers and engineering firms, because innovations issuing from laboratories frequently need to be demonstrated at pilot plant level, and integrated into existing or new machinery before panel producers can benefit from them. The network also needs to include specialists from non-traditional disciplines (computer science, mathematics, materials science, polymer science, civil engineering, mechanical engineering, etc.) as well as economics, business and market experts.

A broad network of this nature would facilitate the adoption of a holistic but realistic approach to research and development, and guarantee success in the implementation of an R&D program firmly anchored on innovation, yet committed to market relevance and continuing profitability for the industry.

Responsibility: Industry, Research institutions, Universities

5. *Adopt advanced mechanisms for the collection of intelligence on market opportunities*

Given the high priority assigned by the wood composite panel industry to market diversification, value-added and niche marketing, the marketing tools traditionally used for commodities will no longer be sufficient. The industry will be looking for market intelligence of the type more commonly associated with consumer goods, and market research methods will be borrowed from that sector to predict desirable product attributes on the basis of trends in economics, consumer preferences and government legislation.

A systematic search should be initiated for non-conventional applications which could be pursued by the industry and its research organizations (i.e. applications for which new products or systems could be developed and manufactured on the general basis of the industry's technology). One objective of this search for innovative applications should be to reduce inter industry competition and maximize penetration of new markets.

Responsibility: Industry associations, Research institutions, Universities, Governments

6. *Provide market feedback to industry and research groups*

There appears to be a need to better integrate market research, product and systems development and the industry's marketing initiatives so that all stakeholders may push (and pull) in the same direction.

The most efficient way to achieve such an integration might be to extend the science and technology network described in Section 2 above to market research, and to obtain participation of industry's marketing experts on the advisory committees discussed in Section 3.

Responsibility: Industry, Industry associations, Research institutions, Universities, Governments

7. *Encourage industry/government co-operation on environmental issues*

For a number of reasons, industry/government relationships on environmental issues have frequently been strained, and occasionally antagonistic. With a better understanding of manufacturing processes, there exists a distinct possibility that more environment-friendly processes will also be more efficient. The technological push proposed in this Roadmap recognizes this by recommending complete integration of environmental criteria in the industry's R&D program. This, however, will not happen overnight. The wood composite panel industry and governments need to establish a protocol for co-operation on the environment agenda, and progress on environment issues should, as much as possible, be linked to technology advancement.

As demonstrated in Appendix I to the present report, environment regulations can be complex, and they vary widely between Canadian provinces. Naturally, they also vary from one country to another. This chaotic situation is a source of major difficulties for an industry which operates and sells across dozens of borders, and governments should treat harmonization of environmental regulations as a high priority. Similarly, significant efforts need to be expended at both the international standard level and the political level to foster increased international harmonization.

Responsibility: Industry, Industry associations, Research institutions, Governments

8. *Encourage the growth of Canadian equipment, adhesive, software and service suppliers*

It is obvious that, if the Canadian wood composite industry is to be and remain a technology leader, its research institutions have to demonstrate technology leadership. It is equally obvious that it needs to be supported by suppliers who are, themselves, technology leaders. As new technology gets developed in this country, steps should be taken to ensure that a) Canadian suppliers (or would-be suppliers) have a fair chance to turn R&D results into profitable business ventures, b) the Canadian wood composite industry benefits by having priority access to innovative equipment, adhesives, software or services, and c) Canada positions itself to become a major exporter of technology, equipment, software, adhesives and services.

Government and industry initiatives to facilitate the transfer of technology from the laboratory to the industrial stage (e.g. pilot plant demonstration) are very helpful in this regard, but they remain far too limited. Consideration should also be given to the development of clusters of complementary companies, which combine their skills to implement new technology, and pursue world markets.

Close relationships between industry suppliers, manufacturers and research scientists are essential, and, as suggested earlier, suppliers should form part of the network supporting the industry's research and development program.

Responsibility: Industry, Industry suppliers, Research institutions, Governments

MARKET SUPPORT

9. *Make active use of R&D results to support Canadian wood products and systems world wide, and eliminate discrimination against them*

The Canadian wood composite panel industry is largely dependant on exports, and future growth will mostly be predicated on increased demand from external markets. Any long-term marketing program therefore needs to include provisions for market access such as determined by national or regional codes and standards. By participating in the development of international standards (e.g. ISO, RILEM), Canadian scientists get a chance to earn the respect of their peers for their research, and to shape standards in ways compatible with Canadian preferences. Occasionally, internationally prestigious scientists even receive invitations to contribute to the development of foreign national codes and standards.

The provision of scientific support to codes and standard development in Canada, in the US and in other major markets needs to continue as a high priority activity in the R&D program of the composite panel industry, and adequate funds need to be made available for this activity.

Responsibility: Industry, Industry associations, Research institutions, Governments

VALUE-ADDED

10. *Encourage resource production and allocation for increased product value and sustainable development*

All sectors of the Canadian wood composite panel industry express some degree of concern over future access to sufficient quantities of adequate wood supplies. For the veneer and plywood sector, procurement is already problematic. In this context, government measures to allocate the resource with priority given to those capable of converting it into the highest value products seems likely to provide an extra incentive for technology-based growth, with related positive impact on quality employment in rural areas.

Over the longer term, industry access to adequate wood supplies will be determined by today's forest management policies and practices. Research programs elucidating relationships between silvicultural operations and future product characteristics will help foresters make the right decisions, but this research has only recently been receiving the attention it deserved, and the task ahead is enormous. Identification of relatively short-term benefits may help convince the major stakeholders that additional investments in this domain could be warranted.

The National Standard for Sustainable Forest Management represents another tool to ensure adequate wood supplies over the longer term, and companies relying directly on forest resources should be encouraged to seek certification under that standard.

Responsibility: Industry, Research institutions, Governments

11. *Encourage further manufacturing, and production of specialty and value-added products*

Even if panel producers successfully diversify their production and create new lines of products to expand their markets, large plants will continue to be constrained in terms of flexibility and response time. However, the industry's efforts can be greatly amplified by a vibrant secondary manufacturing sector, capable of absorbing part of the primary production, and creating opportunities for added value, innovation and employment. Several government programs were recently initiated to support expansion of secondary

manufacturing through the transfer of technology. Other programs provide assistance with market studies and business plans.

Given that secondary manufacturing companies tend to be small and isolated, they will not be in a position to support expensive R&D on an individual basis, and formulae should be devised to allow them continuing access to advanced R&D services once current programs come to an end.

Responsibility: Industry, Industry associations, Research institutions, Governments

EDUCATION AND TRAINING

12. *Pursue the reinforcement of ties between the industry, its research institutions, universities and colleges to attract more high-calibre students*

The performance of the Canadian wood composite panel industry's R&D program and its implementation will require sets of skills (process control, computer science, materials science, mathematics, business analysis, polymer chemistry, market research, etc.) which students do not immediately associate with the wood industry. Traditionally, industry management has not always put much stock either in attracting students with such backgrounds.

To change this, co-op programs need to be set up to encourage universities and colleges to offer programs adapted to the wood industry (beyond wood science), and to encourage industry to evaluate the potential benefits of hiring college and university graduates. Emphasis on advanced technology will also attract high-calibre students to research institutions and the supplying industries (e.g. equipment, software and adhesives).

Because they specialize in applied research, the industry's R&D institutions should continue playing a key role as intermediaries between educational institutions and industry.

Responsibility: Industry, Research institutions, Universities and Colleges

13. *Reinforce training programs*

The Roadmap suggested in this report emphasizes reliance on technology as the key to continuing industry prosperity. This conjures up images of advanced automation, and automation is undeniably part of the plan, but even automated plants need people to operate, and the rapid introduction of a technology culture requires support from employees and management. To foster positive attitudes to technology, industry should develop programs involving employees in technological advancement (e.g. team building, employee support, empowerment and innovation incentives). Training and upgrading courses for the acquisition of skills in computerized process control, process simulation, etc., should be offered through apprenticeship programs or other forms of certification. Employees and management should also be encouraged to adopt modern industry values with respect to product quality and environment control.

Training will be facilitated by the development of computer tools which can be used to simulate processes, test the impact of various decisions on cost, quality, etc., and demonstrate the benefits of new technology.

Finally, training and education will only be effective if educators themselves remain state-of-the-art. The wood industry's trade associations can play a key role in transferring technology to educational institutions with an emphasis on updating the knowledge of the educators.

Responsibility: Industry, Industry associations, Research institutions, Colleges

14. *Encourage transfer of state-of-the-art technology to specifiers and end-users*

New product attributes will not provide marketing benefits and serve the industry's goals if they are not efficiently communicated by industry to decision makers and the public at large. This has been part of the trade associations' mandate, and they will require expanded resources as product lines diversify, and product characteristics become more complex.

Consensus codes and standards are typically forums where manufacturers, end-users and scientists work together. They constitute good opportunities for mutual education, and participation by industry and research staff should be firmly encouraged.

Involvement of some categories of specifiers and end-users in the proposed network would also help keep them up-to-date on new developments, at the same time as it would give them an opportunity for precious feedback.

Responsibility: Industry, Industry associations, Research institutions

In Conclusion . . .

One objective of this report was to encourage discussions within the Canadian wood composite panel industry and its stakeholders, namely its suppliers, its research institutions, its trade associations, universities, and governments. The process followed in the preparation of the report has already created increased awareness of issues affecting the future of the industry. Once the report is published, it should be used as a base for continuing discussions and for the development of a consensus for a plan of action.

Updates to this report should also be considered by all stakeholders, as a means of monitoring progress, adjusting objectives, and defining new goals.

Appendix I

Environmental Technologies

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1. BACKGROUND

1.1 *General*

In the early days of the industry, environmental issues represented a very small component of any decision to build and operate a wood composite plant. However, in today's highly sensitive environmental climate, these issues have come to represent a significant initial and operating investment by the owner. In some cases, environmental issues can make or break a project. Environmental permitting has become one of the single greatest challenges facing the industry this decade, and it will continue to pose a challenge as environmental regulations become more stringent in the future. It is therefore, extremely important that all stakeholders in the industry understand these challenges and the existing and future remedial solutions available.

Compliance with environmental standards requires a complete organizational commitment. Environmental equipment has become as important as any other plant process equipment, and must be treated as such to ensure that long-term compliance is maintained. Failure to comply with regulations can result in costly litigation, fines or even the closure of the plant. Any case of environmental non-compliance, regardless of how small, can irreparably damage a company's reputation and make permitting very difficult at the existing plant or for future plants.

Other more intensive reports dealing with environmental emission control issues for the Canadian forest industry have been undertaken by Environment Canada. It is not the intent of this appendix to repeat or add to these studies. The following pages will only attempt to present an overview of existing technologies employed world-wide to help panel manufacturing plants reduce emissions and meet regulations.

1.2 *Environmental Impact and Occupational Health*

As previously discussed environmental consideration and permitting play a major role in construction of a new facility. In attempting to address the most obvious sources of emissions, other environmental considerations can sometimes be overlooked or underestimated. It is extremely important that the complete overall environmental impact of a new plant be properly assessed and reviewed in the initial planning stages of the facility. Good public relations in the community is of vital importance in the early stage of a project.

Initial siting of a plant is a key factor in minimizing future problems. A reconstituted wood plant or any industrial plant sited next to any type of residential community will be an easy target for future complaints. Regardless of the most diligent environmental controls, reconstituted wood plants by nature will impact the community to some degree. Intangibles such as noise, odour, fugitive emissions, vehicle and truck traffic must all be taken into consideration when siting the plant. Care must be taken in the initial siting and design of the plant to minimize these types of non-descriptive environmental emissions.

Proper noise abatement systems or equipment enclosure should be considered for especially noisy equipment such as hogs, saws, flakers, refiners to name a few. Fugitive dust emissions should be minimized during both construction and operation. Proper watering of dirt roadways is a must to reduce fugitives. Paving or concreting of especially prone areas with high traffic volumes should be considered. Other dust emissions such as wood dust need to be properly collected and stored/consumed on site. Good housekeeping to collect any wood dust that may get airborne should be standard practice. Odour emissions are somewhat harder to eliminate but should still be taken into consideration in the design. Minimizing emission points and good environmental controls on dryer and press emissions will assist in minimizing fugitive odours. Earthy or musty odours from bark piles composting, log ponds or log storage yards are unfortunately a natural and difficult to control by-product of this type of operation. The impact of additional vehicle and log truck traffic is an important consideration in the selection of a site and should not be overlooked.

Log trucks rambling by a school ten times an hour would not be well received in a community. Routes to the plant should be analyzed and planned to minimize the impact on the local community if at all possible.

The Occupational Health and Safety of the plant employees is paramount to proper operation of the facility. The design of the plant should be in accordance to the most recent safety standards, and employees should all be properly trained in all safety procedures and in the proper operation of the equipment. Employees exposed for long periods to any environmental emission or substances adversely affecting health should utilize appropriate safety equipment at all times. This may take the form of ear protection, dust masks, protective coverings and breathing apparatus, to name a few. In any case, hazardous environments should at all cost be minimized during the equipment selection and design phases of the project.

2. ENVIRONMENTAL REGULATIONS

2.1 *Provincial Requirements*

Ambient air quality limits are based on the contaminant's time-averaged concentration in ambient air at ground level. Table 1 contains information on ambient air quality criteria in different provinces. The point of impingement limit is calculated using atmospheric dispersion algorithms to predict the theoretical maximum ground level concentration. Point of impingement limits are used only by Newfoundland and Ontario.

Stack emission limits are usually determined on a case-by-case basis, and based on the type of control technology used. Stack emission limits are controlled in a company's operating permit. Ambient air quality limits are typically contained in the province's environment act/regulation, but may also be added to a company's permit for a particular substance if deemed necessary. Table 2 contains limits taken from actual composite board plant approvals and provincial guidelines.

Newfoundland's Air Pollution Control Regulation sets both acceptable air quality criteria and point of impingement limits for pollutants. Dispersion modelling is required to verify compliance with the point of impingement limits.

Newfoundland requires construction approval for all new or modernized equipment. The approval may contain ambient air limits, stack emission limits and monitoring requirements. Public advertising of approval application is not required.

New Brunswick's Department of the Environment sets industry-specific stack emission limits and maximum permissible ground level concentrations in a facility's operating permit on a case-by-case basis. Ground level concentrations are also contained in the Air Quality Regulation. Certificates of approval to construct and operate are required. The certificate of approval to operate may be valid for up to five years. Public advertising of approval application is required, with provisions for public comment. The approval may contain ambient air limits, stack emission limits and monitoring requirements.

Quebec's Quality of the Atmosphere Regulation does contain ambient air quality standards that pertain specifically to the composite board industry, specifically formaldehyde. Ambient air quality standards are also regulated and enforced by the Environment Department of the Montreal Urban Community. Most pollutants are controlled based on stack emission limits. Quebec requires an approval to discharge contaminants to the environment for both new and modified sources. Each emission source requires approval. The approval does not contain stack emission limits or monitoring requirements. No public advertising for approval application is required.

Table 1
Provincial Ambient Air Quality Criteria on a 24 Hour Averaging Period ($\mu\text{g}/\text{m}^3$)

	NS	NB	PEI	NFLD	Quebec	MUC ¹	Ontario	Manitoba (Guidelines)	SK	AB	BC
Carbon Monoxide (1 hour)	34 600		35 000	5 000	34 000	35 000	36 200	35 000	15 000	15 000	
Formaldehyde (1 hour)				65	37 (15 min.)	12	65				60 (action level)
Hydrogen Sulphide	8	5	5	30 (1 h)	14 (1 h)	5	30 (1 h)	5	5	4	
Nitrogen Dioxide	400 (1 h)	200	900 (1 h)	400 (1 h)	207		200	200	400 (1 h)	200	
Sulphur Dioxide	300	300	300		288	260	275	300	150	150	160
Total Suspended Particulate	120	120	120	80 (1 h)	150		120	120	120	100	150
PM10											50

1. Montréal Urban Community

Source: NGM International, 1998

Table 2
Actual Stack Emission Limits

	Nova Scotia ¹	New Brunswick ²		Quebec ³	Ontario ⁴	Manitoba ⁵		
		Waste Wood Stack	Press Vents			Dryer RTO	Press RTO	Thermal Oil ESP
Particulate (g/s)	145 mg/m ³	200 mg/m ³		50 mg/m ³	90 mg/m ³	5.14	2.1	2.18
Formaldehyde (g/s)		20 mg/m ³	20 mg/m ³			0.085	0.08	
Carbon Monoxide (g/s)		100 mg/m ³			100 ppm			
Nitrogen Oxides (g/s)		20 mg/m ³				6.5	0.9	5.3
Sulphur Dioxide (g/s)		100 mg/m ³						
Total Hydrocarbons (g/s) (as methane)					100 ppm (as methane)			
Total Non Methane Hydrocarbons (g/s)			75 mg/m ³					
Phenol (g/s)						0.05	0.7	
Hydrogen Cyanide (g/s)						0.4		
VOC (g/s)						1.1	0.28	
Benzene (g/s)						0.008	0.0003	0.0066
MDI (g/s)							0.0141	2.18

Notes:

1. Standard Air Quality Terms and Conditions for New Solid Fuel Fired Power Plants.
2. OSB Certificate of Approval.
3. Quality of the Atmosphere Regulation.
4. OSB Certificate of Approval
5. OSB Licence

Table 2 (Continued)
Actual Stack Emission Limits

	Alberta						BC			
	MDF Approval			OSB Approval			MDF Permit			Provincial
	Dryer Cyclone	Press Exhaust Stack	Thermal Oil Stack	Dryer Cyclones & EFB	Press Exhaust Stack	Thermal Oil Stack	Two Dryer Cyclones Combined	Press Exhaust Stack	Board Cooler Vent	MDF Emission Guideline
Particulate (g/s)			0.2 g/kg	0.10 g/kg		1.10 g/kg	5.7	0.42		120 mg/m ³
Formaldehyde (g/s)	25 ppm	25 ppm		100 mg/m ³	40 mg/m ³		1.7	1.7	0.07	300 g/t product
Carbon Monoxide (g/s)										
Nitrogen Oxides (g/s)										
Sulphur Dioxide (g/s)										
Total Hydrocarbons (g/s)(as methane)										
Total Non Methane Hydrocarbons (g/s)										
Phenol (g/s)										
Hydrogen Cyanide (g/s)										
VOC (g/s)										
Benzene (g/s)				25 mg/m ³						
MDI (g/s)										

Source: NGM International, 1998

In Ontario, a certificate of approval is required for each piece of equipment that may discharge a pollutant into the environment. A new or amended approval may be required for changes in production rate, process or equipment. Emission limits are not usually part of an approval, but equipment must meet its design specifications. Approvals are not renewed on a regular basis, but are usually valid until the equipment is modified or replaced. Approvals are advertised in a public registry for 30 days, with provision for public comment. Dispersion modelling is used by the Ministry of Environment and Energy as part of the permitting process. The applicant must use dispersion modelling to prove that a facility will comply with the Air Pollution Regulation.

Manitoba Environment's licence requirements are developed on a case-by-case basis. Stack emission limits are addressed within the operating license. Ambient air quality limits are addressed in the Air Quality Objectives and Guidelines document and additional limits may also be placed in the operating permit. Under Manitoba's Classes of Development Regulation, particle wood plants fall under a class 1 development. The director may elevate a proposed class 1 development to a class 2 if deemed necessary. The director may also require an environmental protection and management plan for a new facility and for alterations to an existing facility. The minister may require that public hearings be held. Licences do not have a time limit; they are valid until alterations intended to the licensed facility have the potential to change environmental impact.

Saskatchewan Environment and Resource Management's Clean Air Act requires a permit for all sources of air emissions and industrial waste water. The permit may also include monitoring requirements. Permits control emissions on the basis of control technology, not stack emission limits. Public review and comment is available for a 30-day period. Permits have been issued from the Ministry of Environment's head office, but they are to be decentralized in the near future.

Alberta's Environmental Protection and Enhancement Act provides for the development of guidelines and ambient environment quality objectives. The Ambient Air Quality Guidelines set the ambient air quality criteria that are used in the permitting process to determine permit requirements. Stack emission limits are dependent on the control technology being used and the location of the facility. Permits can be valid for up to 10 years. A permit may need to be amended due to changes in the production rate, the equipment or the process. Air, waste water, waste management, soil, groundwater and reclamation fall under the umbrella of the operating permit. The operating permit may contain monitoring requirements, stack emission limits, and operating requirements. Risk assessment is also used by Alberta Environmental Protection to determine the short- and long-term effects of emissions on the environment.

British Columbia's Ministry of Environment, Lands and Parks has been decentralized into a head office and regional offices. The head office develops the regulations, guidelines and policies for the Ministry. The regional offices manage the regulations and the permits. Permits are required for both water and air. Changes in production rate, equipment, or modifications to the process may require an amendment to the Permit. Permit applications are advertised in local newspapers. Permits can be appealed by the company or by the public. The ministry has produced Emission Guidelines for Medium Density Fibreboard (MDF) Plants. Control technology must satisfy the province's Best Available Control Technology (BACT). This guideline would be used as a basis for an MDF plant, and most likely, any composite board plant's operating permit. As of January 1995, final air quality objectives have been selected for formaldehyde and interim air objectives for PM10 in British Columbia. The operating permit may contain monitoring requirements, stack emission and ambient limits, and operating requirements as well as upgrading requirements.

2.2 Requirements in Three US States

Three American states with composite board industries (Maine, Texas and Washington) were selected for an examination of the types of permit requirements in the United States. Specified emission values for the three states are presented in Table 3.

Table 3
Actual Stack Emission Limits

	Texas ¹		Maine ²			Washington ³
	Press RTO	Heat Energy System	Press RTO	Dryer RTO & WESP	Heat Energy System	
Particulate (g/s)	0.14	0.72	1.55	1.97	0.93	0.23 g/m ³
Formaldehyde (g/s)	0.07	0.06	0.04	0.54		
Carbon Monoxide (g/s)	0.94	3.45	1.04	12.57		
Nitrogen Oxides (g/s)	0.05	6.48	2.57	3.34	0.25	
Sulphur Dioxide (g/s)	0.001	0.50	0.06	0.09/2.6	0.06	1000 ppm
Total Hydrocarbons (g/s) (as methane)						
Total Non Methane Hydrocarbons (g/s)						
Phenol (g/s)	0.004		0.02	0.03		
Hydrogen Cyanide (g/s)						
VOC (g/s)	0.95	2.31	0.22	0.71	0.62	
Benzene (g/s)						
MDI (g/s)			0.01			

Notes:

1. OSB Permit
2. OSB Permit
3. Washington's 173-400 General Regulations for Air Pollution Sources

Source: NGM International, 1998

Maine's Department of Environmental Protection licensing requirements are dependent on the air quality region where the facility is located. Best practised treatment is required by the state to meet the region's ambient air quality standards. For a new facility or changes to an existing facility, air dispersion modelling is required to show that the region's ambient air quality standards will be met. Collection of on-site meteorological data may be required.

Texas' Natural Resource Conservation Commission (TNRCC) has developed a manual specifically for oriented strandboard mills to help streamline the permitting process. TNRCC requires that BACT be applied to all facilities that must obtain a permit. The BACT required is determined on a case-by-case basis. All manufacturer data on any abatement device used to control emissions must be submitted with the permit application.

Washington State's Department of Ecology's permit requirements are dependent on the type and location of the facility proposed and the amount and type of emissions. Emission limits are imposed as part of the BACT determination. The BACT approach for permitting is used rather than specifying immutable emission concentration limits, because it allows for imposing the highest realistic control on a source-by-source basis. In the permit, the source is required to install and maintain/operate the BACT in accordance with manufacturer's specifications.

2.3 *Emission Sources and Constituents*

The pollutants emanating from composite wood products plants are generally very similar in nature, and they typically occur from the following sources: wood, wood waste and product handling, drying, pressing, secondary finishing and thermal energy production. The major pollutant by-products generated are: nitrogen oxides, sulfur oxides, carbon monoxide, VOCs and particulate.

The concentration of pollutants from composite board plants can be quite variable, and it is dependent on a number of factors involved in the production of the final product. These factors can be such items as site location, source and type of wood, wood processing equipment, types of dryers and dryer temperatures, type of press, press temperature and pressure, heat energy system arrangements, finishing steps as well as type and quantity of product produced, to name a few.

This study will not attempt to quantify the level of pollutants generated from the countless possible operating scenarios, but only to provide an overview of the types of pollutants that can be generated in a board plant. Following is a general description of the typical pollutants found in the major manufacturing steps previously identified.

3. EMISSION SOURCES AND CONSTITUENTS

3.1 *Wood, Process Wood Waste and Product Handling*

Pollutants generated from this operation generally consist of particulate matter in the form of wood dust. This particulate matter is typically generated from the wood handling, slashing, debarking, refining, flaking, screening, sanding and hogging operations. It is generally fugitive in nature, but can be minimized and controlled with point collection, appropriate enclosures, good housekeeping and good engineering design. The maximum allowable emission rates for this operation will greatly depend on site location. In rural areas, the density of industrial plants is lower and the physical area belonging to the plants tends to be larger than in urban sites, hence emission allowances tend to be higher.

3.2 **Drying**

In the drying process the veneer, wood flakes, particles or sawdust are typically dried in large dryers (i.e. conveyor dryers, triple pass or single pass dryers or flash tube dryers) which use heated air to drive the moisture out of the wood.

The drying process is typically a large source of pollutants in the form of nitrogen oxides (NO_x), carbon monoxide (CO), particulate, volatile organic compounds (VOC) particularly formaldehyde (HCHO) and condensable phenolics. The quantity of these pollutants will vary greatly depending on the source and type of wood used, dryer temperatures and production speed. Higher dryer temperatures tend to produce higher amounts of VOCs as more hydrocarbons are produced at the higher temperatures. Particulate matter quantities will vary greatly between plywood, OSB, MDF and particleboard, and are also dependent on wood species and quality.

Emissions vary from one species to another as a result of varying characteristics relative to thermal breakdown of the wood. Typically, a majority of the pollutants are in the form of fly ash, wood fibres and VOCs. Fly ash and wood fibres are relatively easy to collect in dry collection systems such as cyclones or baghouses. VOCs, however, are somewhat more difficult to collect due to their gaseous nature. VOCs are driven out of the wood in the drying process. Because of the moisture and temperature of the flue gas the majority of VOCs tend to condense to form droplets resulting in a very fine aerosol. This aerosol is responsible for the blue haze associated with dryers in the past. At this point, these sub-micron particles are difficult to capture by mechanical filtration, and other technologies such as electrostatic or incineration must be employed. Also, due to the moisture content in the flue gas and the resinous nature of VOCs, fouling of control equipment is a continuing source of trouble.

In recent years, a number of new technologies have emerged on the market which greatly reduce the emissions from the drying process. Some of these new technologies include the following:

- Regenerative Thermal Oxidation (RTO)
- Regenerative Catalytic Oxidizer (RCO)
- Bio Filtration
- Scrubbers
- Wet Electrostatic Precipitators (WESPs)
- Electrostatic Filter Beds (EFB).

In addition, utilization of a rotary kiln gasifying heat energy system and/or conveyor drying process equipment will reduce pollutants emitted from the drying process which have to be collected by the above noted technologies. These technologies will be further discussed in the next section.

3.3 **Pressing**

Pressing emissions can be classified as continuous or non-continuous depending on the type of press being employed. Historically, press emissions were essentially uncontrolled. Presses were vented directly to the outside with the use of large ventilators or up-blast exhaust fans. Typical emissions from the press include such pollutants as NO_x, CO, particulate and VOCs in the form of formaldehyde and phenols. The quality and quantity of these pollutants will vary depending on such factors as wood species, type and quantity of resin, press temperature and time as well as line speed. VOCs and formaldehyde represent the largest quantity of pollutants generated from the press, and are generally attributable to the wood type and the type of resins used in the binding process. Changing the resin type can effect a reduction in emissions but may have a detrimental effect on the product. This option is seldom a practical solution.

The recent advent of more stringent environmental regulations such as the 1991 Clean Air Act and future emissions regulations will make the unrestricted exhausting of press emissions a thing of the past.

Recent years have seen the installation of full or partial press enclosures to contain and capture press emissions for treatment. Typical air flows from press exhausts are in the range of 1,700 to 3,400 m³ per minute (60,000 to 120,000 cubic feet per minute [CFM]). Emissions are drawn off the press by large fans and then sent to the control device. The control technology can take the form of RTOs, RCOs or WESPs, and the choice of the optimum technology to adopt depends on the exact quantity and characteristics of the pollutants and the capital and long-term operating cost of the technology. One form of control offered by certain manufacturers and installed recently makes use of the press exhaust air for combustion in the boiler plant. The VOCs are then incinerated in the boiler. The boiler exhaust gases are mixed with fresh air in the dryer and then cleaned at the back end of the dryers by the emissions control system. This type of system is best suited to a continuous press where pollutants are generated on a continuous basis and exhaust air volumes are fairly low.

Bio-filtration is also a technology that is showing good promise for press emissions clean-up.

3.4 Secondary Finishing

Secondary finishing relates to all steps involved in the finishing and packaging of the product once it leaves the press. These steps may include such items as cutting, sanding, grooving, stencilling, sealing. The primary emissions from these operations tend to be particulate and VOCs. The majority of the particulate is generally localized to the cutting and sanding operations. Most of the particulate from these operations are picked up and treated by conventional dust collecting equipment. VOCs are typically generated at the edge sealing and paint booths and to some degree at the sanding operations. The amount of VOCs generated are typically fugitive in nature in these operations and generally require the application of good engineering, equipment enclosure, and enclosure/area ventilation to minimize work place concentrations.

3.5 Heat Energy Systems

Heat energy systems typically produce hot thermal oil for the press and in some cases hot air for the dryers. These systems tend to use wood residues as the primary fuel and natural gas/fuel oil as a secondary backup fuel. Products of combustion are those normally found in the combustion of these fossil fuel sources such as: SO₂, NO_x, particulate, CO. Control of emissions from the heat energy system tends to be centred around more conventional technologies such as multiclones, ESPs, WESPs, baghouses and in some cases scrubbers. Low NO_x burners have also been used to minimize the formation of NO_x.

4. BEST AVAILABLE CONTROL TECHNOLOGIES (BACT)

A number of different control technologies are currently being applied in the board industry. Some of these technologies have been around for many years, while some have only recently come to the forefront with the advent of more stringent environmental regulations.

As previously discussed, the quantity and quality of emissions can vary depending on a number of factors. Therefore, the selection of any environmental equipment must be carefully tailored to each individual source to achieve the maximum attainable destruction removable efficiency. Some of the conventional technologies that will be reviewed are as follows:

- Primary and Secondary Cyclones
- Wet Electrostatic Precipitators (WESPs)
- Electrostatic Filter Beds (EFB)
- Regenerative Thermal Oxidizer (RTO)
- Regenerative Catalytic Oxidizer (RCO)
- Bio Filtration
- Dry Electrostatic Precipitators
- Baghouses
- Conveyor Drying
- Closed Loop Gasifying
- Scrubbers.

Table 4 provides a quick reference as to the application of these technologies for the prevention, reduction or removal of the various emissions found in board plants.

4.1 *Primary and Secondary Cyclones*

Cyclone technology has been around for many years. Primary and secondary cyclones have been used on dryer outlet to separate the dried wood product from the air stream and then remove any residual particulate from the air stream prior to discharging to the stack. Cyclones are also commonly used on dust collection systems where particulate are essentially the only emission. These devices are very efficient for particulate collection but they have no capability of reducing NO_x, SO₂, CO or VOC emissions. Therefore, in today's environmental climate, cyclones alone are usually not sufficient, and they must be paired with additional environmental equipment to provide the required reductions in emissions.

4.2 *Wet Dust Collectors*

Wet dust collectors are very similar in nature to the dry cyclones except that water is added to assist in the capture of the dust particles. The centrifugal action of the collector removes the water and dust particle. These collectors are very efficient at collecting particulate, and they will capture some condensable hydrocarbons. These collectors, however, may be troublesome in colder climates, and they result in additional waste water which must be treated.

4.3 *Dry Electrostatic Precipitators (ESP)*

ESPs are generally considered particulate control devices. Typical ESPs use an electrified wire to charge the particles, which are then attracted to the collection plates. A rapper system is used to dislodge the collected particulate from the collection plates. ESPs provides high particulate collection efficiencies and will collect VOCs in their aerosol form. However, because of the resinous nature of the particulate and VOCs in the dryer gas, ESP collection plates will foul quickly and cause a shutdown of the collector for cleaning. As a result, they are not normally used on dryer exhaust gases. They are commonly used to control emissions on heat energy systems where no VOCs are present, and the particulate and gases are in a dry state.

4.4 *Baghouses*

Used interchangeably with dry ESPs, baghouses provide for removal of particulate matter only. They are commonly used to remove particulate where no VOCs are present. Gas is passed across a series of nomex bags which collect the particulate matter. A reverse air or pulse air system removes the particulate from the bags. Baghouses provide a lower operating cost option than dry ESPs, however they are not as effective at removing small particulate. This is because particulate

Table 4
Emission Control Technology Summary

	Removal Capabilities						VOCs		Process Experience			Typical Costs	
	SO ₂	No _x	CO	PM	PM10	VOC	HCOH	Phenols	Vendor Availability (3 or More)	Commercial Operation	Demo.	Capital \$/MSF	Operating Cost
1. Primary & Secondary Cyclones				E	F				Yes	Yes		0.75	L
2. Wet Cyclones				E	G	P	P	P	Yes	Yes		1	L
3. Dry ESP's				E	E	P	P	P	Yes	Yes		4	M
4. Baghouses				E	G	P	P	P	Yes	Yes		3	L
5. WESP				E	G	G	G	G	Yes	Yes		4.5	M
6. Electrostatic Filter Beds				E	G	G	G	G	No	Yes		5	M
7. RTO			G	F	F	E	E	E	Yes	Yes		6	H
8. RCO			G	F	F	E	E	E	Yes		Yes	6.5	H
9. Bio-filtration				G	G	G	G	G	No		Yes	5.5	L
10. Scrubbers	E	P	P	G	F	F	F	F	Yes	Yes		3	M

L = Low
M = Medium
H = High

E = Excellent
G = Good
F = Fair
P = Poor

Source: NGM International, 1998

size removal in baghouses is limited by the size of openings in the bag media, while ESPs impart electrical charges to all particles. Again, as was the case for ESPs, baghouses are not used on moist and resinous dryer gases because of fouling and blinding of the bags. They are used on dry gas only. Filter bags must be replaced periodically.

4.5 *Wet Electrostatic Precipitators (WESP)*

WESPs have been used successfully in recent years on dryer outlet to control particulate matter and condensable hydrocarbons (VOCs).

The WESP uses a high intensity ionization electrode to attract the charged particles. Water is used as a quench medium to saturate and entrain the condensable hydrocarbons as well as to flush the collection area. WESPs are efficient collectors of particulate and condensable VOCs. As previously discussed, the majority of VOCs are condensed into a fine aerosol and therefore can be efficiently collected by electrostatic means. WESPs, however, require additional water treatment and can be troublesome in more northern climates.

WESPs and electrostatic filter beds (see below) will continue as a leading technology for dryer emission controls in the industry. Recent developments such as the E-tube from GeoEnergy will continue WESP dominance of the market. This system involves a refinement of the WESP technology in that the ionization electrode configuration is a suspended mast with disc electrodes within a collection tube. This results in an intense electrostatic field that is up to two times higher than conventional wire-in-tube arrangements, hence a higher particulate collection efficiency and a smaller precipitator.

4.6 *Electrostatic Filter Beds (EFB)*

EFBs are more commonly referred to as Electrostatic Gravel Filters. EFBs are a proven technology in the removal of particulate and condensable VOCs. Specifically designed for difficult to clean dryer exhaust gases, EFBs employ a proprietary technology to remove particulate and condensable VOCs. Developed by MIT scientists in the 1970s, EFBs have become commonplace in the reconstituted wood industry.

Electrostatic gravel filters employ an electrostatic principle to impart a charge to the gravel bed which collects the particulate and the aerosol VOCs. The gravel is continually removed from the bed and cleaned of the collected pollutants. The cleaned gravel is returned to the bed and the pollutants are captured in dry form in a collector for disposal. The EFB achieves a high collection efficiency by virtue of the tremendous collection surface area available in the gravel bed. Because of the dry nature of the process and the specialized gravel cleaning process, fouling of the collector is seldom a problem. This technology is a completely dry system which makes it widely suitable for cold climates. Over a dozen systems have been installed in Canada on dryers and thermal oil heaters, and they perform very well.

4.7 *Regenerative Thermal Oxidation (RTO)*

RTO technology has been around for many years but has only recently been adapted to meet the needs of the wood industry. RTOs have recently been installed on dryer outlets and on press enclosures to destroy VOCs, CO and organic particulate. RTOs rely on thermal oxidation to destroy these emissions. The dryer or press gases are sent to the RTO where the VOCs, CO and organic particulate are incinerated at temperatures of about 800°C (1,500°F). To increase the thermal efficiency of the system, ceramic beds are used to preheat the inlet air prior to combustion. This technology is very effective in the destruction of VOCs, CO and organic particulate. However, RTOs are ineffective at removing inorganic particulate and do generate some NO_x from the combustion of natural gas to generate the required temperatures. RTOs are fairly expensive to operate and require a source of fossil fuel. Inorganic particulate may cause bed fouling. The RTO

operates at or close to the melting point of some of these inorganic particulate. Once melted, these by-products can permanently adhere to the ceramic bed and cause premature bed failure. Occasional bed burn-out is required to clear the bed of inorganic particulate and reduce pressure drops. Additional inorganic particulate devices may be required upstream of the RTO.

Future RTO systems will be equipped with novel features to reduce plugging by inorganic particulate. Their combustion system will also be improved so that NO_x emissions may be reduced. Concentrators are likely to be used to reduce the volume of conveying air from the contaminated air stream.

4.8 *Regenerative Catalytic Oxidation (RCO)*

RCOs are similar in nature to RTOs except that a catalyst is employed to oxidize the VOCs. They operate at a lower temperature (300-400°C / 570-750°F), thus providing operational savings by burning less natural gas. Destruction efficiency is similar to that of RTO systems, but they produce less NO_x because of the reduced natural gas consumption. The catalyst will however lose its effectiveness over time. Higher maintenance cost and high replacement cost of the catalyst may offset any savings over the conventional RTO technology. Additional inorganic particulate control upstream of the RCO may also be required to meet emission requirements and prevent ceramic bed fouling. To date, only three RCOs are known to be operating in the US and none in Canada.

4.9 *Selective Catalytic Reduction (SCR)*

The selective catalytic reduction system is designed to destroy nitrogen oxide (NO_x) in a variety of process streams. SCR is highly effective and can eliminate up to 95 per cent of nitrogen oxides present. The catalyst used to convert the NO_x into nitrogen and water is specially designed to operate at temperatures between 290 and 590°C (550 and 1,100°F).

4.10 *Bio-filtration*

Bio-filtration is a recent technology used for the capture and destruction of particulate and VOCs. Typically better suited for controlling press emission, bio-filtration offers an alternative to RTOs and RCOs. Mesophilic micro-organisms are well suited for the destruction of easily degradable VOCs such as formaldehyde, phenols, urea, methanol, ethanol as well as pinenes, limonenes, camphene, MDI and ketones. Bio-filtration technology does not require natural gas to pyrolyze the VOCs, therefore offering a substantial saving over RTOs and RCOs. Since no natural gas is burnt, bio-filtration does contribute to NO_x emissions.

Exhaust gases from the press are sent to the bio-filtration unit where water is sprayed into the gas for cooling and to remove particulate. This gas is then passed through filter beds which house the micro-organisms. Here, VOCs and further particulate are captured and degraded by the micro-organisms. The degradation process is aerobic and complete. End products are carbon dioxide, water, mineral salts and biomass. A number of different filter beds have been tested such as wood bark, shavings and chips. The filter of choice appears to be activated carbon. Though more expensive, it provides for longer bed life without compaction. Bed temperatures need to be kept fairly constant for greatest efficiency and to prevent harm to the micro-organisms. The system requires a fairly large area for the beds.

A number of pilot tests have been carried out for this type of technology and one OSB plant in Michigan treats the press hood exhaust stream using the bio-filtration concept. Ongoing development of this technology will result in greater acceptance due to improvements in efficiency and reliability.

4.11 Rotary Concentrator Adsorption (RCA)

The RCA uses rotating adsorption zeolite or activated carbon beds to trap the VOCs before venting the clean air into the atmosphere. This system increases the fuel value of VOC-laden gas streams and the fuel economy of the oxidizer by raising the concentration of VOCs in the inlet gases. Savings vary based on the nature of the emission flow and operating conditions.

4.12 Conveyor Drying

Conveyor drying is a fairly recent technology in the board industry. The first installation took place in late 1992. A number of additional systems have since been sold and started.

Conveyor drying, as the name implies, utilizes a series of enclosed conveyors with hot air circulation to dry the flakes. It is not an emission treatment system but a refinement of the drying process which results in reduced emissions, and therefore pollution prevention. This type of drying replaces rotary drum dryers and is mainly suited to long strand or OSB production. One of the production benefits of this type of drying is a reduction in the degradation of the strands since they are not tumbled as in conventional drum dryer.

Environmentally, conveyor drying offers a number of benefits over the conventional drying systems. It has long been known that drying at lower temperature results in a reduction in the emission concentrations of certain pollutants in the exhaust air stream. The majority of the reduction is in the form of VOC production. Less VOCs are driven off at the lower drying temperatures. Temperatures of 400°C (750°F) or greater are typical for drum dryers, whereas conveyor dryer temperatures are usually around 200°C (400°F).

Unlike drum dryers, conveyor dryers allow greater flexibility in the drying process. Drying can take place in stages with varying degrees of conveyor speeds and drying air temperatures. In tests done on a number of wood species, it has been observed that certain species emit VOCs at different stages of the drying process. Southern yellow pine, for example, releases the majority of its VOCs in the first third of the drying process. On the other hand, northern hardwoods tend to release the majority of their VOCs in the last third of the drying cycle. This characteristic allows designers to target only certain stages of the dryer process for additional emission control at greatly reduced air flows. In an ideal situation, the air from the high VOC stage of the dryer is used as make-up combustion air for the plant heat energy system, thus pyrolyzing the VOCs. If using the air from this stage for combustion air is impractical, other abatement technologies, such as an RTO, can be employed. Since only a portion of the dryer air stream is being treated for VOCs, the equipment can be downsized. The remaining stages need only minor treatment for removing particulate.

An additional benefit of conveyor drying is a reduction in particulate production due to the gentler nature of the process. Conveyor drying holds great promise for the industry, but as any new technology, some problems must still be overcome. Conveyor dryers require greater maintenance than conventional dryers. Fines accumulation in the conveyors continues to be a problem. This accumulation poses a fire hazard and requires regular weekly cleaning. However, these problems are currently being assessed and subsequent conveyor dryer designs should address them.

4.13 Closed Loop Gasification

Closed loop systems are typically directed at the drying process for most plants. They generally re-circulate dryer exhaust air back to the heat energy system to be used as combustion make-up air and thus combusting the VOCs and particulate, therefore controlling emissions. Two types of such systems have recently been installed: closed loop gasification and closed steam loop systems.

The closed steam loop system is currently being offered by Swiss Combi as the EcoDry system. Wood dust, oil or gas is burnt in the heat energy system, a gas-to-gas heat exchanger transfers energy to the dryer gas stream. This closed loop gas stream is re-circulated around from the dryer to the

heat exchanger. About one third of the dryer air stream is bled off and used as combustion air in the heat energy system. Here the VOCs and particulate captured in the dryer are burnt off at high temperature.

Closed loop gasification is a system offered by Callidus Technologies. Originally employed for the incineration of hazardous waste and sludge, the system burns wood waste in a reduced oxygen atmosphere in a kiln. Exhaust gases from the kiln pass to a secondary combustion chamber (SCC) where additional air is provided to complete combustion. The gases then flow through a gas-air heat exchanger, thermal oil coil, baghouse and then exhaust into the stack. Fresh air is heated in the gas-air heat exchanger and sent to the rotary drum dryers. The hot air returning from the dryers, now containing VOCs and particulate, is then sent to the inlet of the kiln and the SCC as make-up combustion air. This completes the closed loop cycle. Because of the temperatures and the travel times in the SCC and the kiln, the organic particulate and VOCs are completely incinerated.

With this closed loop combustion process, the exhaust gas stream passing to the baghouse contains only inorganic particulate.

Only one system has been installed on a new OSB facility in the southern US. Report to date indicates that the system is operating up to expectation.

4.14 Scrubbers

Scrubbers have been employed in a number of industries to control SO₂ emissions, condensable hydrocarbons and particulate. When SO₂ capture is required, a reagent is typically used in the process. Dryer exhaust air flows through a water spray tower. Here, the gas is cooled to adiabatic saturation which permits condensation of hydrocarbons. Particulate are captured by the fine water molecules in the scrubber sprays. Water falls to the bottom of the scrubber where it is re-circulated to the sprays. A small bleed stream is drawn off the sump to remove the condensed hydrocarbons and particulate. A mist eliminator section prevents water vapour carry-over out of the scrubber and up the stack. Depending on the location of the plant, the stack gases may need to be re-heated to reduce plume opacity and prevent plume inversions. Scrubbers are efficient removers of particulate, and to some degree condensable hydro carbons. However, condensed hydrocarbons tend to be in the form of a very fine aerosol making capture in the scrubber quite difficult. Scrubbers have been mostly replaced recently by WESPs or EFBs which capture these fine condensable compounds with greater efficiency. Scrubbers require additional water treatment and may require frost protection in colder climates.

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