An assessment of wood product processing technology advancements between the CORRIM I and II studies

Jamie Meil
Jim Wilson*
Jennifer O'Connor
Jim Dangerfield

Abstract

With the recent release of the CORRIM II Phase I research results, a rare opportunity exists to compare and contrast the wood products industry's process advancements with that of the original CORRIM study completed three decades ago. This technical review explores the continued innovation in wood product processing technologies over the last 30 years to gauge how these advancements have served to underscore and demonstrate the environmental benefits of the industry's products in their traditional use—home building. The paper focuses on three wood products common to both studies—softwood lumber, sheathing plywood, and oriented strandboard (OSB)—and compares advances in primary wood product production in terms of wood utilization, forest-to-mill gate energy use, and thermal process energy self-sufficiency. Results of this study indicate a marked improvement in wood usage by the softwood lumber industry, while both plywood and OSB have stayed steady despite declining log size and resource quality. Finally, this review puts the last 30 years of advancements in wood product production in perspective by comparing the varying resource and energy use associated with the major structural wood components in a typical single-family home built in North America. Applied across all single-family homes built in the United States, the industry's greater resource utilization, improved energy efficiency, and declining reliance on fossil fuels result in an annual savings of about 10 million barrels of oil, 4.4 million metric tons (9,700 million lbs) of carbon dioxide emissions, and a reduced harvesting level equivalent to 15,000 ha (37,066 acres) of forest.

The wood products industry in North America has undergone continual change in the last 30 years. It has had to adapt constantly to a changing resource base, competition from both within its own industry and from other industries promoting substitutes for commodity wood products, and changes to consumer requirements in housing, the industry's prime market. Interspersed among these fundamental resource, economic, and market pressures, the industry has had to weather a multitude of movements in the form of protectionism, industry consolidation, and environmentalism, the latter posing challenges widely ranging from resource availability to indoor air quality concerns. This study reviews technological change in the industry by looking more closely at its resource use, energy use, and energy self-sufficiency across three commodity wood products and follows these resource and energy use changes through the housing market to provide an end-use context and perspective for 30 years of change in the industry.

Recently, a new set of wood products production data has been produced in the United States under a project known as CORRIM II (Bowyer et al. 2004). This is a follow-up research project to the original CORRIM study, referred to as

The authors are, respectively, President, ANJAcor Inc, Ottawa, Ontario, K1Y 0M4 Canada (jkmeil@sympatico.ca); Dept. of Wood Sci. and Engineering, Oregon State Univ., Corvallis, Oregon (jim.wilson@oregonstate.edu); and Building Industry Advisor, Vice-President, FPInnovations–Forintek Div., Vancouver, British Columbia, V6T 1W5 Canada (jennifer@van.forintek.ca, jim@van.forintek.ca). The authors would like to thank Forintek and its industry members, Natural Resources Canada, and the Provinces of British Columbia, Alberta, Quebec, Nova Scotia, New Brunswick, Saskatchewan, and Newfoundland-Labrador, for their guidance and financial support for this research. This paper was received for publication in August 2006. Article No. 10239.
*Forest Products Society Member.

Forest Prod. J. 57(7/8):83-89.

CORRIM I, which was conducted nearly 30 years ago (National Research Council 1976; Boyd et al. 1976). In 1974, with support from the National Science Foundation, the Board on Agriculture and Renewable Resources under the Commission of Natural Resources of the National Resource Council, appointed the Committee on Renewable Resources for Industrial Materials (CORRIM) to conduct a study of renewable resources in meeting the nation's future material needs. The primary impetus for the CORRIM I project was the oil crisis of 1974. At that time it was widely believed that renewable resources could be used as alternatives to materials that were currently obtained from nonrenewable resources to augment material supplies, to improve energy conservation in materials supply, and especially to relieve some of the U.S. dependence on foreign sources of energy. Thirty years later, material substitution is still a primary driver for the CORRIM II project as it expands our understanding of the relative impact of wood products and alternative materials on the environment.

The CORRIM I study confirmed that the wood products industry could have a major influence on shaping the material and energy use of the nation but that the industry needed to address a number of issues. Among these was the need to intensify research efforts focused on increasing the recovery of products from the forest resource and to prolong the longevity of wood in-service.

At the outset of the CORRIM I study, the industry's utilization of wood, while improving, was less than perfect. Charles Bingham, Vice President of Weyerhaeuser at the time, summed up the state of the industry's resource utilization in his 1975 keynote address to the Forest Products Society annual meeting (Bingham 1975):

> ". . . taking a typical old-growth Douglas-fir acre of our ownership[1] in western Oregon in 1948, its stem harvest volume of 17,920 cubic feet (507 m^3) of wood produced only 3,640 ft^3 (103 m^3) of product—lumber—in 1948. Most of the wood volume—14,280 ft^3 (404 m^3)—was burned as slash or used for fuel. An equivalent acre of our holdings in 1963, with the same harvest volume, produced 4,617 ft^3 (131 m^3) of lumber as the result of gradually improving mill utilization. It would also produce the wood equivalent of 3,842 ft^3 (109 m^3) of linerboard, and 814 ft^3 (23 m^3) was used in plywood. Thus by 1963, more than half the harvest—9,273 ft^3 (263 m^3)—was used in products (as compared to 20% in 1948). But, 8,647 ft^3 (245 m^3) of wood was still burned or wasted. Ten years later, by 1973, lumber production from that acre and stem harvest volume had increased to 5,009 ft^3 (142 m^3), and plywood production had more than doubled to 1,736 ft^3 (49 m^3). Linerboard utilization had also increased spectacularly to 5,848 ft^3 (166 m^3) of harvest. Particleboard had also moved into the utilization stream, consuming 1,520 ft^3 (43 m^3). In other words, in 1973 the acre produced 14,113 ft^3 (400 m^3) utilized in manufacture—nearly four times the 1948 level. Still 3,807 ft^3 (108 m^3) were being used as fuel or wasted, and the wood fibre volume in portions of the tree other than the stem (some 45% of the green weight on each acre) was not utilized at all."

[1] The Weyerhaeuser Company to this day remains the single largest private landowner in North America.

While Bingham's address describes but one firm's evolving resource use over a 25-year period, his historical account serves to underscore the industry's increasing level of resource and production integration as well as improved general manufacturing product recovery. Resource integration in the 1970s meant directing the raw log resource appropriately to the various conversion process—saw-logs to sawmills, veneer logs to plywood mills, and pulp logs to pulpmills.

The merchandizing of the resource today has ostensibly changed from a raw log focus to a co- or by-product orientation as improved and new product technologies have developed. For example, Canada's pulping industry was once completely dependent on processing pulpwood, but today less than 10 percent of the raw furnish to pulping operations is in the form of raw logs. Why has this happened? The industry today is much more consolidated than it once was, and therefore there is a better resource flow between a company's forestry, wood products, and pulp and paper business units. At the same time, continued improvement in processing technology as well as new product development has blurred the historical definition of what constitutes a saw-log, a veneer log, and what was once considered pulpwood; lumber mills are now processing pulpwood into lumber (and tree-tops that were once left on the forest floor), and plywood mills are now using what was originally referred to as a saw-log, leaving the pulp sector to process the by-product stream from these primary resource converters and to use recycled waste paper and linerboard. Further, with the coming of age of particleboard and medium density fiberboard (MDF) product technologies and the advent of waferboard, which, with refinement, morphed into oriented strandboard (OSB), the industry is utilizing the whole tree from previously underused hardwood and softwood species. Hence, the industry has shifted toward better all-around resource utilization: less is left on the forest floor, more of the raw furnish finds its way into various products, and the remainder is used as fuel. The balance of this review paper examines these developmental shifts in greater detail.

CORRIM I and II Reports

In many respects, the original CORRIM I report was the result of a nation trying to find ways to lessen its dependence on Third World oil. Thus, many of the methodological underpinnings of the first report were geared to determine the "theoretical" renewable resource and related energy availability of the industry. This methodological approach makes it difficult to compare and contrast the original study results with that of the newly completed CORRIM II report, which follows a lifecycle assessment protocol.

Both reports use mass-based allocation to apportion fuel and material inputs to the various products of a particular processing stream. However, while the CORRIM II study actually documented the energy use by fuel type, CORRIM I did not. Instead, the first study looked at the mass balance for various product-processing streams and determined the gross energy input required in the form of mechanical (electrical) and process heat (thermal) to determine whether the processing activity could be energy self-sufficient—a more macro approach. The CORRIM II study looked at each product process at various production stages and made allocations to various coproducts as they were produced—a more micro assessment approach. These differences in methodologies pose certain difficulties when trying to infer change. This study therefore had to delve into each approach and find commonality for reporting comparable results.

In the early 1970s the complement of wood products considered in the CORRIM I report was somewhat different from that considered by the CORRIM II project. While commodity products like lumber and plywood appear on each study's product list, in 1970 structural flakeboard (a.k.a. waferboard and what today is called OSB), laminated veneer lumber and medium-density fiberboard were not well-established products—in fact, their technologies had just been, or were only about to be, deemed economical. Other products like wet-formed hardboard and insulation board received considerable attention in the 70s, but today these two products make-up a very small portion of the industry's product mix. Therefore, this technical review limits the product comparison analysis to softwood lumber, sheathing plywood, and OSB.

CORRIM II developed its product profiles by region and followed a life cycle inventory protocol. In an effort to maintain comparability across the two studies, it was necessary to assume an equal production level between the U.S. Pacific Northwest (PNW) and the U.S. Southeast (SE) for both lumber and plywood production, thus maintaining the regional weighting assumed in CORRIM I. Today, lumber production in these two regions is very similar, with the PNW and SE producing 17.1 and 16.7 BBF, respectively in 2000. CORRIM II's analysis of OSB production was limited to the U.S. Southeast, which uses a high percentage of softwood as the raw furnish for the final board product. However, a large proportion of OSB production in the United States and most production in Canada, is based primarily on a hardwood resource (aspen). Hence, the CORRIM II results for OSB, while indicative, cannot alone be considered necessarily representative of the entire industry.

Results

Raw material balances

Softwood lumber. — The CORRIM I project, using a materials balance trajectory for the U.S. forest resource, determined that in 1970 one metric ton (t) (2,205 lbs) of logs (including bark) yielded 0.35 t of lumber, 0.29 t of pulp chips, 0.11 t of sawdust, 0.15 t of planer shavings and 0.10 t of bark. At these recovery rates it would take 2.07 ovendry t of logs to yield 1000 board feet (MBF) of nominal 2 by 6 lumber (assuming an ovendry weight of 723 kg/MBF). The CORRIM I team further postulated that over a 30-year period lumber recovery would increase 10 percent with sawdust recovery declining 3 percent and planer shavings recovery declining by 7 percent. While they provided little basis for these predicted lumber and by-product recovery figures, it would appear they had thinner kerf saws in mind for the sawdust reduction and, in general, better lumber target size control in the reduction of planer shavings. It is interesting to note that pulp chip recovery was expected to remain unchanged, which suggests they expected little change in the relative value of lumber and its coproducts of production.

The CORRIM II project determined a materials balance for two major lumber producing regions in the United States—the Pacific Northwest (PNW) and the Southeast (SE)—in 1999/2000 from detailed mill surveys. The results for the two regions combined indicated that one metric ton of logs (including bark) yielded 0.45 t of lumber, 0.31 t of pulp chips, 0.08 t of sawdust, 0.06 t of planer shavings and 0.11 t of bark. At these recovery rates, it would take 1.81 ovendry metric tons of logs to yield 1.0 MBF of 2 by 6 lumber. Surprisingly, the CORRIM I year 2000 product recovery forecast (**Table 1**) turned out to be exactly correct for lumber recovery and off by only a point or two for the other coproducts of lumber production. It should also be noted that the CORRIM II study found lumber recovery varied significantly across the PNW and SE, with the PNW averaging 0.49 t of lumber per metric ton of wood input and SE achieving 0.42 t of lumber per metric ton of raw logs processed (bark included).

Table 1. — Material balance for conversion of 1 t of logs with bark into softwood lumber (based on ovendry weight).

	CORRIM I			CORRIM II
	1970	1985[a]	2000[a]	1999/2000
Lumber	0.35	0.40	0.45	0.45
Pulp chips	0.29	0.29	0.29	0.31
Sawdust	0.11	0.08	0.08	0.07
Bark	0.10	0.10	0.10	0.11
Planer shavings	0.15	0.13	0.08	0.06
Total	1.00	1.00	1.00	1.00

[a]Values are estimated.

Thus, on average, softwood lumber recovery is about 22 percent more efficient from a resource throughput perspective than in 1970. And process improvements in chipping technology, thinner kerf saws, curve sawing, and computerized scanning and "optimization" technology have led to better recovery of higher value coproducts (i.e., lumber and pulp chips in favor of sawdust and planer shavings). With decreasing log size and quality over this 30-year period, the increased recovery of usable lumber and coproducts due to technological advances is notable.

Softwood plywood. — The CORRIM I study team developed a base year material balance for softwood sheathing plywood as shown in **Table 2**. However, they did not, make recovery projections for future years as they did for softwood lumber. At an average ovendry wood mass of 992 pounds/1000 ft^2 (Msf) 3/8-inch basis of plywood, the CORRIM I study would require one metric ton of raw logs to produce 1000 ft^2 of plywood. The recovery results recorded in the CORRIM II study indicates a log input of 0.93 t including bark, which amounts to a 7 percent improvement in plywood recovery efficiency.

The recovery gain in usable veneer is surprising given the decrease in the size and quality of logs; for example, in the PNW peeler log, diameter has decreased by at least 4 inches (100 mm) from an average of more than 18 inches (457 mm) to 14 inches (356 mm) or less over the last 30 years. Both bark and pulp chip recovery have declined in favor of particleboard furnish. Several explanations for the higher plywood recovery in spite of processing a smaller log are possible. One explanation is that while the log diameter has decreased, the wood is much sounder (less core rot) causing less "lathe spinout," which in turn translates into less pulp chips and higher peeler core recovery. The use of power drive rolls also decreases spinout, and the advent of better lathe technology (which can minimize peeler core diameter) and the use of laser enhanced clipping have aided in the recovery of usable veneer. A consequence of more peeled veneer is that less of the log goes

Table 2. — Material balance for conversion of 1 t of logs with bark into softwood sheathing plywood (based on ovendry weight).

	CORRIM I 1970	CORRIM II 2000
Sheathing plywood	0.45	0.48
Pulp chips	0.30	0.26
Sawdust	0.02	0.01
Bark	0.10	0.05
Particleboard furnish	0.08	0.15
Peeler core	0.06	0.05
Total	1.00	1.00

to the chipper, which in turn results in more particleboard furnish.

The plywood industry has also made strides in the use of adhesives. In the 1970s, the industry was using about 20 pounds (9.1 kg) of phenol-formaldehyde adhesive per Msf (3/8-inch basis). Today, with improved adhesive chemistry, application technology, adhesive extenders and new catalysts, the amount of adhesive required has dropped 15 percent to 17 pounds (7.7 kg).

Oriented strandboard (OSB). — In the original CORRIM report, flakeboard (the precursor to waferboard or oriented-strand board) was only beginning to penetrate sheathing markets in North America even though the first mill was built in 1950 in the United States. The material balance difference between the various conceptual flakeboards of CORRIM I were found to vary substantially depending on the quality (amount of rot) and type (i.e., hardwood or softwood) of raw log resource, and on flaking technology. We have elected to report the mass balance associated with flaking of the whole log (after debarking), which more closely resembles current technology (**Table 3**). To produce 1000 ft^2 (93 m^2) 3/8-inch basis of structural flakeboard required the input of 0.70 t of raw wood[2]. While the structural properties of the board product first contemplated back in the 1970s have improved dramatically, the raw material mass balance hasn't changed appreciably from what was first projected. Adhesive usage in the OSB industry has decreased, going from 60 pounds (27 kg) per Msf to 50 pounds (23 kg) in 1999 (a 17% decrease), whereas the wax content on the same basis has increased from 12 pounds (5.5 kg) to 19 pounds (8.6 kg) in 1999 (a 58% increase). The resin decrease can likely be attributed to the increased use of isocyanate-based adhesive in place of phenol-formaldehyde in OSB compared to the 1970s flakeboard, where phenol-formaldehyde was used exclusively.

Energy use and self-sufficiency

The original CORRIM I study estimated both harvesting (stump-to-roadside) and roadside-to-mill transportation, and manufacturing energy use for the product profiles. The more recent CORRIM II study not only determined energy used in stump-to-mill harvesting and transportation, but also in fertilizing and replanting of harvested areas, by site class harvested on a regional basis. To maintain comparability across the two studies, this study negates the additional energy use associated with the silviculture measures included in the CORRIM II assessment. Also, CORRIM II looked at each manufacturing process by discrete unit process, while the CORRIM I study took a more global system approach when defining energy use and allocating energy to coproducts of production that were sold (i.e., coproducts leaving the system boundary) to arrive at net energy ascribed to the primary product. **Table 4** presents each study's net energy use (exclusive of energy use allocated to coproducts) for the three products of interest by activity stage and fuel type. Harvesting includes both stump-to-roadside log preparation as well as roadside-to-mill transportation. Manufacturing includes all activities from the receiving of raw logs to the production of the finished product at the mill gate.

[2] Based on CORRIM II OSB weight of 1203 lb/Msf 3/8-inch basis of wood only.

Table 3. — Material balance for conversion of 1 t of logs with bark to structural flakeboard (CORRIM I) and OSB (CORRIM II) in the U.S. Southeast (based on ovendry weight).

	CORRIM I 1970	CORRIM II 1999
Sheathing flakeboard (OSB)	0.70	0.71
Bark	0.10	0.08
Fines (hogfuel)	0.20	0.21
Total	1.00	1.00

The CORRIM I study had limited reporting on actual fuel use beyond mechanical and process heat energy requirements. This study instead focused on determining whether each manufacturing process was capable of being energy self-sufficient by simulating the potential energy recovery in the form of electricity and steam for process heat needs from the biomass portion deemed to be fuel. All three products were found to be capable of being energy self-sufficient during manufacture. That is, each product process produced enough wood residuals to both generate its electricity and process heat needs from the exhaust steam exiting the electricity generation system. However, the actual utilization of biomass for energy at the time was not reported and remains in question.

A study by Grantham and Howard (1980), using 1970 USDA Forest Service data, estimated the manufacturing residue output from all wood products manufacturing and found that only 25 percent of all residual by-products were used within the originating plant as fuel, with another 37 percent transferred to other manufacturing facilities as raw furnish (coproducts). The remaining 38 percent went unused and was either landfilled or burned with no energy recovery as a method of disposal. Corder et al.'s (1972) Oregon survey of lumber and plywood production in 1967 determined that the portion of residue used for fuel was 25.7 percent for lumber production and 24 percent for plywood production, which serves to underscore the Grantham and Howard findings.

Another wood energy use study of the U.S. lumber and wood products industry prepared by Goetzl and Tatum (1983) indicated that lumber mills used a greater proportion of wood fuels in their energy mix than all other mill types combined. This makes sense from the standpoint of resource processed per unit of production (lumber having one of the highest). Still, in 1981, 17 percent of all sawmill residues were landfilled or otherwise disposed of. It is general practice to first burn clean dry wood (e.g., sawdust) rather than wet, dirty wood (e.g., bark) as the cost of the boiler (burner) unit is at least a third less for clean dry wood relative to the same size

Table 4. — Net energy use for lumber, plywood and flakeboard (OSB) by activity stage and fuel type (excludes energy allocated to coproducts).

		1000 BF (MBF) of Kiln-dried lumber		1000 sq. ft 3/8 inches basis (Msf) of plywood		1000 sq. ft 3/8 inches basis (Msf) of OSB	
Activity / fuel type	Unit	CORRIM I	CORRIM II	CORRIM I	CORRIM II	CORRIM I	CORRIM II
Harvesting							
Diesel	MJ	1,003	620	403	344	624	440
Manufacturing							
Electricity	MJ	271	349	26	376	151	647
Process heat	MJ	3,851	3,979	3,498	2,475	4,400	4,620
Total		5,125	4,949	3,827	3,195	5,175	5,707

Table 5. — Fossil fuel and carbon dioxide emissions savings summary.[a]

	Fossil fuel savings	Carbon dioxide savings
	MJ/unit	Kg/unit
Lumber (MBF)	2275	148
Plywood (Msf)	2905	189
OSB (Msf)	2934	191

[a]Based on an average carbon dioxide emission level of 65 g/MJ of fossil fuel

unit burning dirty wetwood. Given these resource and economic realities, it can be surmised that little to no bark was being burned for energy recovery in the early 1970s, especially given the prevalence of teepee (bee-hive) burners at the time as a method for bark and residual wood fiber disposal. Note that the Environmental Protection Agency banned teepee burners in the early 1970s.

Excluding the bark portion of the hog fuel by-product stream and known sold coproducts (e.g., pulp chips and particleboard furnish), the manufacturing process heat energy self-sufficiency for lumber, plywood, and flakeboard was potentially 100 percent, 43 percent, and 100 percent, respectively, for the CORRIM I study. While these results are unlikely to be the case, they do indicate theoretical limits based on what is deemed a coproduct for resale vs. a residual retained as a fuel.

Relative to CORRIM I, the CORRIM II harvesting and roundwood transportation activity energy use results indicate a substantial decrease in energy per unit of final production. Essentially, a combination of reduced resource requirements (higher recovery in the case of lumber) and more fuel-efficient harvesting and transportation equipment are responsible for this across-the-board decrease in harvesting and transportation energy use.

In addition, CORRIM II reports generally higher in-plant electricity usage for all three products, most likely due to the additions associated with greater labor saving automation and the use of more scanning/optimizing technology, but a decrease in process energy usage (except for OSB)[3]. In terms of manufacturing energy alone, softwood lumber production has experienced a 5 percent increase in energy use, plywood a 19 percent decrease, and OSB production a 16 percent increase in energy use. When harvesting and resource transportation are factored in the overall energy use, lumber energy has decreased by 5 percent, plywood energy has decreased by 17 percent and OSB energy is 10 percent higher than reported in the CORRIM I study. An explanation for the higher energy use reported for OSB in the CORRIM II study is the prevalent use of emission control technology such as regenerative thermal oxidizer (RTO) in Southeastern OSB plants. These plants consume approximately 43 megajoules (MJ) (41 kBTU) of electricity and 465 MJ (441 kBTU) of natural gas per Msf 3/8-inch basis of panel production to control volatile organic compound (VOC) emissions—at the time of the CORRIM II survey only half the plants had RTO emission control devices. Manufacturing process energy derived from wood hogfuel (process thermal energy self-sufficiency) in the CORRIM II study is calculated to be 76 percent, 90 percent and 81 percent for lumber, plywood, and OSB, respectively. Energy self-sufficiency, while completely attainable when all residuals are included in the calculation, is not necessarily a goal of the industry but rather a function of the prevailing market economics between various fuels and their inherent heat values (including conversion efficiency and capital investment) and

Table 6. — CORRIM II Minneapolis structural wood house design characteristics.

Characteristic	Design elements
Single-family dwelling in Minneapolis	2 story with full basement
Floor area	2062 sq. ft (192 sq.m)
Foundation (footing and slab)	3000psi (20 Mpa) concrete
Foundation walls	Concrete block
first and second floors	2 by 10 solid wood joists @ 16 inches (400 mm) o/c and 5/8 inches (15 mm) plywood decking
Above-grade exterior walls	2 by 6 wood studs @ 16 inches (400 mm) o/c with 7/16 inches OSB sheathing
Below-grade exterior wall	2 by 4 wood studs @ 24 inches (600 mm) o/c
Partition walls	2 by 4 wood studs @ 16 inches (400 mm) o/c
Roof	Light frame wood trusses with OSB sheathing

Table 7. — Wood product bill of materials for the Minneapolis home design.

Wood Product	Units	Quantity
Softwood lumber	MBF	10.4
Sheathing plywood	Msf (3/8 inches basis)	2.8
OSB	Msft (3/8 inches basis)	5.6

[3] It should be kept in mind that the OSB (flakeboard) energy use profile prepared in CORRIM I was developed from prototypical engineering studies and perhaps was not as accurate as achieved with the more established lumber and plywood product streams.

Table 8. — Thermal fossil fuel, related CO_2 and resource use savings by product for a typical single family home (192 m^2) year 2000 as compared to 1970.

		Implied fossil fuel savings		Implied CO_2 savings		Resource use savings	
Product (unit)	Product qty in house	MJ per unit of product	House total MJ	Kg per unit of product	House total kg	Kg per unit of product	House total kg
Lumber (MBF)	10.4	2275	23360	148	1524	260	2704
Plywood (Msf)	2.8	2905	8134	189	529	70	196
OSB (Msf)	5.6	2934	16430	191	1070	5	28
Total			47924		3123		2928
MJ per m^2 of house			250		16		15

the market values of the coproducts of each product process stream. It is clear that the industry has increased its use of residual wood for process heat production, with the usable residual fuel component shifted toward the greater use of bark, which has displaced some of the other wood fiber residuals (planer shavings and sawdust) that are now sold as coproducts.

The significance of relying on energy from biomass is twofold: (1) biomass is a renewable energy source, so its use delays the depletion of fossil fuel reserves; and (2) carbon dioxide emissions from the burning of biomass have been deemed environmentally neutral; hence, biomass energy use does not contribute to the global warming effect.[4]

As discussed previously, it is difficult to ascertain the degree to which the overall wood products industry has changed its use of biomass fuels when generating its process heat needs, but if we assume 25 percent of residues used as fuels as reported by Grantham and Howard for 1970 as a starting point and compare that to the CORRIM II calculated process thermal energy derived from wood residues for the three products of interest, it would appear that considerable greenhouse gas and fossil fuel use savings have occurred over the intervening years (**Table 5**). For example, over the last 30 years, the net savings in fossil fuel use and carbon dioxide emissions amount to 2,275 MJ (2,156 kBTU) and 148 kg (326 lbs), respectively, per MBF of softwood lumber produced. This analysis suggests that the industry has markedly reduced its reliance on fossil fuels for its process heat needs and consequently, has also reduced its contribution to global climate change.

Comparative results in the context of home construction

This section puts the advancements in wood product resource use, process heat energy self-sufficiency and climate change over the last 30 years in the context of the major structural components in a typical single family home built in North America. In other words, we looked at the environmental impact of the total structural wood volume in a home, comparing 1970 data to 2000 data.

Table 6 describes the component make-up of a single-family home as adapted[5] from the ATHENA Environmental Impact Estimator (EIE) software as used by the CORRIM II project (Lippke et al. 2004). **Table 7** summarizes the lumber, plywood, and OSB bill of materials for the two-story, 2,062 ft^2 (192 m^2) home. The wood bill of materials amounts reflect the three wood products of interest used in all wall, floor, and roof assemblies. **Table 8** then summarizes the net process thermal energy savings, implied carbon dioxide savings attributed to not using fossil energy for process heat, and resource use efficiency gains for the wood bill of materials based on the difference between the previously calculated mass balance results for CORRIM I (circa 1970) and those of CORRIM II (circa 2000) studies.

Overall, the thermal process energy to manufacture the structural wood products used in this house has, on average, declined by 250 MJ per square meter of house. Fossil fuel-related CO_2 emissions have decreased by 16 kg/m^2. Resource use has improved 10 percent, with a 2.8 t decline (15 kg/m^2) in the raw wood harvest necessary to manufacture the wood products used to construct the home. Almost all of the resource use improvement, however, can be ascribed to recovery advances within the lumber manufacturing industry (12%) and, to a lesser extent, the plywood industry (7%).

By projecting the energy, greenhouse gas, and resource-use savings over the total annual area of U.S. single-family housing (1.28 million units at 2,200 ft^2 per house, or a total of 2.8 billion ft^2 (260 million m^2), a more complete perspective is added to the significance of the results. The 265 MJ/m^2 fossil fuel energy savings multiplied by the total area of single-family housing results in an energy savings equivalent to about 10 million barrels of oil and a related savings of 4.4 million metric tons of carbon dioxide. This energy and carbon dioxide savings is equivalent to removing one million passenger cars from the road for a year.[6] The 15 kg/m^2 resource use savings is equivalent to not having to harvest 15,000 ha of forest (based on an average harvest level of 257 t per hectare), a land area equivalent to that of the District of Columbia.

Summary

Results of this study indicate a marked improvement in wood usage by the softwood lumber industry segment over the last 30 years, with both plywood and OSB holding their

[4] According to the International Panel on Climate Change for processes with CO_2 emissions, if (a) the emissions are from biogenic materials and (b) the materials are grown on a sustainable basis, then those emissions are considered to simply close the loop in the natural carbon cycle—that is, they return to the atmosphere CO_2 which was originally removed by photosynthesis. In this case, the CO_2 emissions are not counted. Conversely, CO_2 emissions from burning fossil fuels are counted because these emissions would not enter the cycle were it not for human activity.

[5] The original material take-off specified wood I-joists for the floor, as indicated in Table 6. As shown in the bill of materials (Table 7), the wood I-joists have been converted to solid wood joists to assist in comparison across the two technology time frames.

[6] As calculated at www.usctcgateway.net/tool/.

own despite declining log size and resource quality. The industry has shifted to a more integrated use of wood, which has a significant portion of wood fiber (as opposed to bark) either being used in the primary product itself or sold to other wood product producers as raw furnish. More and more of the biomass used as fuel is now in the form of bark as compared to the 1970s, when a significant portion of bark was burned as a means of waste disposal, with no heat recovery.

From a harvesting energy use perspective, the increased wood utilization in combination with more energy efficient and productive harvesting and transportation practices has served to lower harvesting energy use dramatically for all three products since the early 1970s. Overall manufacturing energy has also generally decreased over the last 30 years; however, mechanical electricity use is now higher while more efficient thermal energy systems have reduced process heat needs. Both lumber and plywood have seen a 5 percent and 17 percent reduction in overall energy use, respectively, and between 75 percent to 90 percent of the manufacturing process thermal energy use of the industry is now derived from burning wood (which includes bark) hogfuel, significantly lessening the industry's reliance on fossil fuels as well as reducing its impact on the globe's climate.

Literature cited

Bingham, C. 1975. The Keynote. Forest Prod. J. 25(9):9-14.

Bowyer, J., D. Briggs, B. Lippke, J. Perez-Garcia, and J. Wilson. 2004. Life cycle environmental performance of renewable materials in the context of residential building construction: Phase I Res. Rept. Consortium for Res. on Renewable Industrial Materials CORRIM Inc. Seattle Washington. 60 pp +15 chapter modules of approximately 600 pp. at www.corrim.org.

Boyd, C.W., P. Koch, H.B. McKean, C.R. Morschauser, S.B. Preston, and F.F. Wangaard. 1976. Wood for structural and architectural purposes. Committee on Renewable Resources for Industrial Resources: Panel II. Wood and Fiber 8(1):3-72.

Corder, S.E., T.L. Scroggins, W.E. Meade, and G.D. Everson. 1972. Wood and bark residues in Oregon--Trends in their use. Res. Pap. 11. Forest Res. Lab., Oregon State Univ. Corvallis, Oregon. 16 pp.

Goetzl, A. and S. Tatum. 1983. Wood energy use in the lumber and wood products industry. Forest Prod. J. 33(3):44-48.

Grantham, J.B. and J.O. Howard. 1980. Logging Residues as an Energy Source in Biomass Conversion, Vol 2. K.V. Sarkanen and D.A. Tillman, eds. Academic Press, New York.

Lippke, B., J. Wilson, J. Bowyer, J. Perez-Garcia, and J. Meil. 2004. CORRIM: Life cycle environmental performance of renewable building materials. Forest Prod. J. 54(6):8-19.

National Research. Council. 1976. Renewable Resources for Industrial Materials. National Academy of Sciences, Washington. 267 pp.