CHAPTER SEVEN

HIGHLIGHTS:

USING WOOD PRODUCTS TO REDUCE GLOBAL WARMING

Introduction

- Wood products can reduce significantly-increasing greenhouse gases through:
- Storing carbon in forest, building products, and landfills.
- Substituting wood for fossil fuel-intensive products like steel and concrete.
- Using wood as fuel instead of fossil fuels.

Measure of Wood Products' Performance

- Global warming potential can be measured in terms of the CO_2 equivalent amount of carbon dioxide, methane and nitrous oxide emissions released into the atmosphere.
- Carbon and global warming potential reduction can be calculated for sequestration and product and fuel substitution.

Environmental Performance of Wood Products

- Performance data for most products was documented by CORRIM.
- Building materials were studied in houses for a warm and cold climate.

The Dynamic Effects of Various Management Scenarios

- **Carbon storage in forests.** In one study, taking "no action" rather than harvesting stored more carbon.
- **Carbon storage considering forests, wood products, and concrete substitution.** Collectively a 45-year harvest cycle, wood products and substitution for non-wood products stored more carbon than the "no action" managed forest scenario.
- **Carbon storage in houses.** Wood-framed houses store more carbon than steel-framed or concrete-framed houses.
- **Carbon storage in U.S. housing stock.** Annual home construction using wood products prevent millions of metric tons of CO_2 from being in the atmosphere.

Wood Fuel Use Reduces Global Warming

- When wood is substituted for fossil fuels, less of harmful CO_2 is released.
- In the Pacific Northwest, wood generates about 43% of the total energy in the production of wood products from seedling to product.

Ways to Foster Increased Use of Wood Products and Wood Fuel

- New practices, policies, research, incentives and education are needed.
- Carbon markets are developing to trade the wood industry's greenhouse gas assets.

Summary

- Wood should be a material of choice for building green.
- Policies and practices are needed to promote the use of wood to reduce global warming.

CHAPTER SEVEN

USING WOOD PRODUCTS TO REDUCE GLOBAL WARMING

James B. Wilson

Introduction

Global warming can be attributed to two factors, those that occur naturally and those that may be human-induced. The exact contribution of each has not been determined, but it is evident that global warming has increased due to record greenhouse gases with the advent of the Industrial Revolution. If the predictions of global warming effects come true, the way many of us live will be impacted.

Greenhouse gases released to and trapped in the atmosphere cause global warming (IPCC 2001). The greatest contributors are three gases that are both naturally-occurring and human-induced: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These three are released into the atmosphere at various stages of any product's or material's life cycle. For a wood product's life cycle, the stages proceed from the planting or natural regeneration of trees, through harvesting, product manufacturing, home construction, home use and maintenance, and end-life, where wood products are landfilled, burned or recycled. Water vapor is also considered a greenhouse gas, but is not usually included in impact assessments because its contribution is not fully understood.

This chapter examines wood products as a building material for home construction, and how this appears to reduce greenhouse gases in the atmosphere, and in turn, reduce global warming. The ways that the use of wood can reduce greenhouse gases include storing carbon in forest and wood products, by substituting wood products for fossil fuel-intensive products such as steel and concrete, and by using wood as fuel instead of fossil fuels. If the dire predictions of global warming effects are true, bold action in the form of practice, policy, research and education is needed to economically address the reduction of greenhouse gases. Increased use of wood products represents a partial solution to this major concern.

Dramatic Increase of Greenhouse Gases

Measured levels of carbon dioxide, nitrous oxide, and methane in ice cores reveal that greenhouse gases are at the highest level of concentration in the past 650,000 years (Brook 2005). The last 200 years, with the onset of the Industrial Revolution, have brought a dramatic increase, and can be attributed to human activity through the combustion of fuels and related practices.

Throughout the past 650,000 years, the three significant gases have all cycled periodically, but have dramatically increased in the past 200 years. Carbon dioxide, previously cycling from about 180 ppm (parts per million) to 300 ppm, has increased to about 375 ppm. Nitrous oxide periodically cycled from 200 and 280 ppb (parts per billion), but now has increased to 320 ppb, while methane, which previously cycled from 400 to 700 ppb, has increased the most — to about 1750 ppb. The alarming trend of increasing concentrations of greenhouse gases needs to be slowed or stopped if global warming is to be abated (Flannery 2006).

Formula for Wood Products' Performance

Emissions of these three gases provide a useful, quantitative way to measure and compare the environmental performance of wood products and other materials, and their relationship to global warming. Carbon dioxide is used as a reference standard to determine the global warming potential of a gas. The heat-absorbing ability of nitrous oxide and methane are compared to the CO_2 equivalent. The Intergovernmental Panel on Climate Change (IPCC 2001) uses a 100-year horizon to estimate the atmospheric reactivity or stability of each of these gases; they can be used to establish a Global Warming Potential Index (GWPI) based on a CO_2 equivalent which is defined as:

$$\mathbf{GWPI\ (kg\ CO_2) = CO_2\ kg + (CH_4\ kg \times 23) + (N_2O\ kg \times 296)}$$

This formula can be applied to the life cycle of wood products and comparison materials, to calculate whether or not, and by how much, a given material, process or system reduces, controls or eliminates the release of carbon dioxide into the atmosphere, thus reducing the magnitude of global warming potential.

To reduce the concentration of CO_2 within the atmosphere, three approaches can be taken in consideration of the life cycle of wood products. The first, carbon sequestration, removes CO_2 from the atmosphere by storing, or sequestering, carbon in the trees, roots and soil of a forest, and by sequestering carbon in wood products — in housing stock, recycled into other products, and wood products in landfills.

The second is to use the formula for an energy accounting — evaluating the reduction of CO_2 equivalent in the atmosphere as a result of the wise selection of a product or process. For example, the life cycle of one product or material that emits less CO_2 into the atmosphere can be substituted for another.

The third is the use of biomass (wood, bark and agricultural residue) as a fuel. Fossil-origin fuels such as oil, gasoline, coal, natural gas and propane contribute CO_2 to the atmosphere, and are non-renewable and non-sustainable. The U.S. Environmental Protection Agency (EPA) considers CO_2 emissions from the combustion of biomass "impact-neutral" on global warming because of the ability of forests to recycle the CO_2 back into carbon in wood, and release oxygen to the atmosphere (EPA 2003).

Wood products sequester carbon, but that resulting decrease in carbon dioxide in the atmosphere can be offset by the use of fossil fuels in the process. For the life cycle of wood products used as building materials, coal, natural gas and oil are used to generate the electricity that powers saws. Diesel fuels trucks transport lumber. Wood and bark are burned in boilers to generate steam to dry wood. If buildings are deconstructed, fuel is used to run the equipment for the operation.

All of these factors, and many more, have to be calculated to determine the total impact of using wood products, or any products, on global warming.

Environmental Performance of Wood Products

The Consortium for Research on Renewable Industrial Materials (CORRIM) was formed in 1996 by 15 research institutions to document the environmental performance of all wood products (Bowyer *et al.,* 2004, Lippke et al. 2004b, Perez-Garcia *et al.,* 2005a). Their study covered that life cycle, from the forest resource through manufacturing, product use, and eventual product disposal or recycle.

Life cycle inventories — all the inputs and outputs to produce, use and dispose or recycle a product— were tracked through each stage. The multitude of factors included fuel use (by type and amount), electricity use (and the fuels to produce it), materials use, and CO_2, CH_4 and N_2O emissions, as well as many other types of emissions, to the air, water, and land.

The first phase of this research effort covered resource use and manufacturing of structural wood building materials in the U.S. Pacific Northwest and Southeast. Forest resource data for a variety of management scenarios were developed using inventory data, combined with growth and yield model simulations, and the Landscape Management System (Oliver 1992) to simulate inventory conditions through time (Johnson *et al.,* 2005). Data for harvesting, transportation of resources to mills, and product manufacturing inputs and outputs were collected by survey and analyzed (Johnson *et al.,* 2005, Kline 2005, Milota *et al.,* 2005, Puettmann and Wilson 2005a,b, Wilson and Dancer 2005a,b,Wilson and Sakimoto 2005).

Two U.S. building sites were selected to study the environmental impact of a house designed of various materials—a cold climate (Minneapolis) house designed to code for both wood- and steel-framed comparison, and a warm climate (Atlanta) house designed to code for both wood- and concrete-framed comparison (Perez-Garcia *et al.,* 2005a).

Life-cycle assessments were made of the various material selections for the two houses. Input data for the study was provided by the Athena Sustainable Materials Institute (ATHENA 2004) for non-wood materials and Winistorfer *et al.,* (2005) on use and maintenance for the two house designs. CORRIM (Bowyer *et al.,* 2004) provided life-cycle inventory data for forest resources, softwood lumber, softwood plywood, oriented strandboard, composite I-joist, laminated veneer lumber, and glue-laminated (glulam) beams. The analyses included life-cycle assessments comparing the use of various construction materials (wood, steel, and concrete) in terms of such factors as global warming potential, air emissions that include the greenhouse gases of CO_2, CH_4 and N_2O, and fuel use, among other impact factors (Perez-Garcia *et al.,* 2005a). Also included was a tracking of carbon through the product life cycle from the forest through construction (Perez-Garcia *et al.,* 2005b).

A Novel Approach in Modeling Carbon Storage

When carbon is sequestered in forest and wood product pools, it is not being recycled or returned to the atmosphere as CO_2. Perez-Garcia *et al.,* (2005b) modeled carbon storage in the CORRIM project looking at the carbon storage for forest and wood product pools. They took a novel approach of looking at the carbon saved as a result of differences in the CO_2 equivalent emissions when substituting the use of wood products for non-wood materials in the construction of a house.

To determine the amount of carbon stored in the forest and wood product pools, carbon conversion factors from wood mass to carbon mass (Birdsey 1992, 1996) were used. As an approximation, dry wood can be considered to be 50% carbon by mass. The model includes all mass related to storage in trees—the canopy, the stem (tree trunk and bark), roots, litter and snags, and also considers their rate of decay. Tracking carbon from the forest pool to the product pool, they again used Birdsey (1992, 1996) for mass conversion factors.

Perez-Garcia *et al.,* (2005b) took the conservative approach of converting the harvested wood into only lumber, which has a conversion efficiency of wood-into-lumber of 50% and is considered a long-term use product with an assumed service life of 80 years, the assumed service life of a house. The remaining 50% of wood in the conversion went into pulp chips, sawdust, shavings, and bark, and were all considered short-term products or wood fuel used for production of energy. Short-term products were assumed to decay over 10 years.

The Dynamic Effects of Various Management Scenarios

Perez-Garcia *et al.,* (2005b), in their example of carbon storage, examined three components: storage in the forest, storage in wood products, and the carbon difference from the use of fuels when substituting wood for some of another material such as concrete in construction of a house. The primary goal of their study was to show the dynamic affects of various management scenarios on carbon storage.

Carbon Storage in Forests

Figure 1 shows the first component of the carbon storage, the carbon stored in the forest as a result of alternative management scenarios: (a) "no-action" taken to negatively influence tree growth, whether natural or human-induced, and (b) harvesting cycles of 45, 80, and 120 years with periodic thinning. As would be predicted, the no-action scenario stores the greatest amount of carbon Of significance, the greatest rate of carbon storage occurs in the first 50 years of growth and then the rate lessens over time; although the graph shows carbon storage increasing over time, from empirical data there is little if any increase beyond 120 years (Lippke *et al.*, 2004a). Carbon storage in these forest management scenarios does not include the carbon stores of the harvested wood used in buildings and to displace fossil intensive products which are huge sources of emissions.

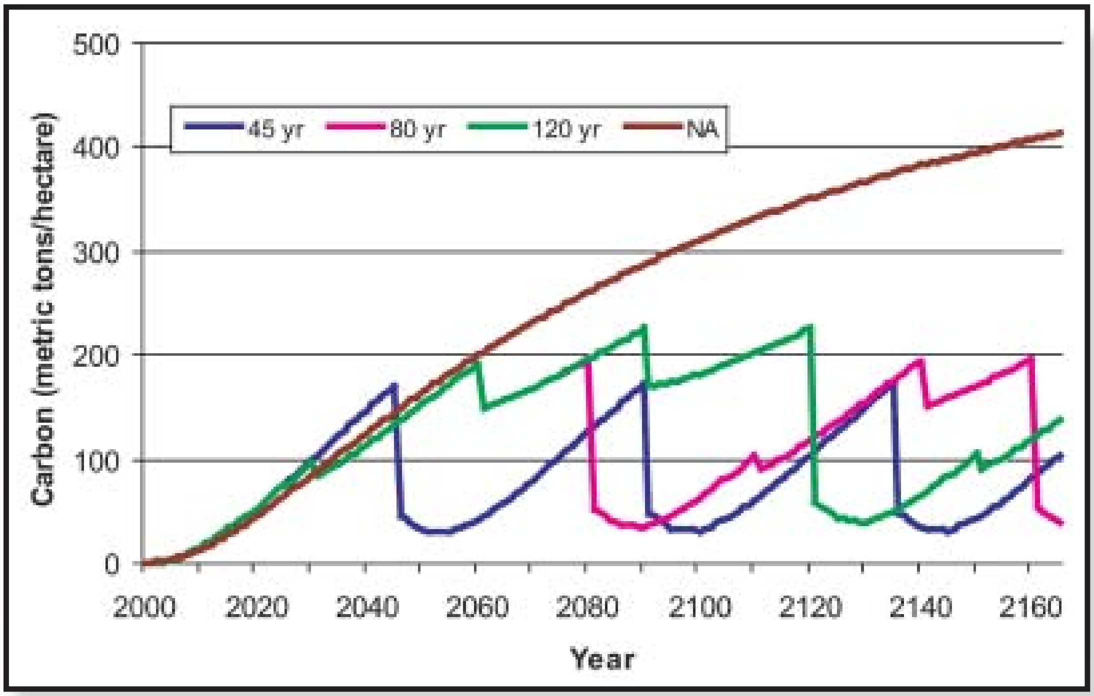

Figure 1

Carbon storage in forest pool for 45-, 80-, 120-year harvest cycles and no action (NA) taken which includes no harvesting, fires, or biological damage and should be considered a potential maximum storage (adapted from Perez-Garcia *et al.*, 2005b).

Carbon storage in Forests vs. Wood Products vs. Concrete Substitution

To analyze the three components, a house design was compared using either wood or concrete framing. Both have similar construction features, such as a concrete foundation, a wood roof truss and sheathing system. One has concrete-framed exterior walls, constructed of concrete block, wood framing, gypsum, and insulation. In the second, wood was substituted for concrete, creating wood-framed exterior walls of wood studs, gypsum, and OSB sheathing. *Figure 2* depicts the comparison of carbon storage for a 45-year harvesting cycle for all three components —the forest, wood products and substituting wood for some concrete. (Perez-Garcia *et al.*, 2005b. This figure illustrates the dramatic contribution to carbon storage as a result of substituting wood for concrete in the construction process.

Figure 3 illustrates that taking "no action" to manage a forest sequesters less carbon than when considering the management scenario of a 45-year harvest cycle, producing wood products, and substituting wood for concrete in a house construction's exterior walls

Carbon Storage in Houses

Individual houses

A significant amount of wood products go into wood-framed house construction. For example, the CORRIM cold climate house has two stories and a full basement, for a total of 192 m^2

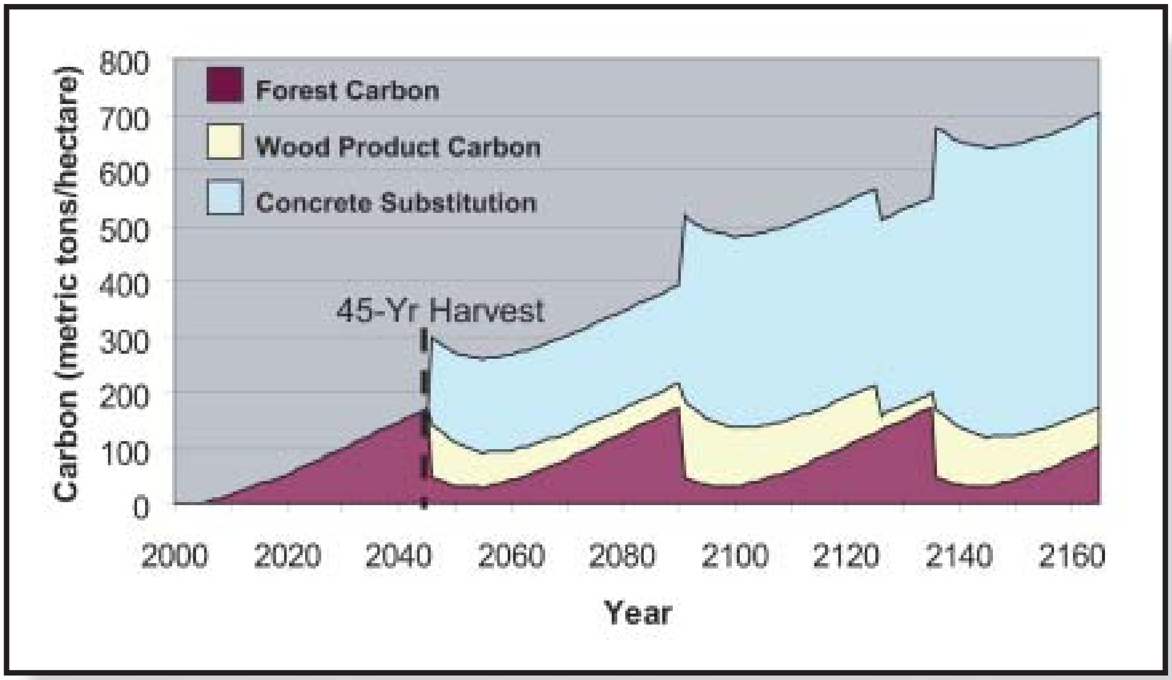

Figure 2

Carbon in the forest and product pools with concrete substitution for the 45- year harvest cycle scenario (adapted from Perez-Garcia *et al.*, 2005b).

of floor space. Its construction used 12,993 kg of wood in the form of lumber, plywood, oriented strandboard (including site construction waste), and the wood fuel to process these products. The warm climate house has a one-story concrete slab-on-grade design of 200 m^2 of floor space, and its construction took 9,811 kg of wood (Meil *et al.*, 2004).

To calculate the actual mass of wood in the two houses, the on-site waste loss and process wood fuel were subtracted from the total wood use mass. Thus, the cold climate house contains 10,411 kg of wood, while the warm climate house contains 7,078 kg. All wood products were considered to be lumber (Perez-Garcia *et al.*, 2005b).

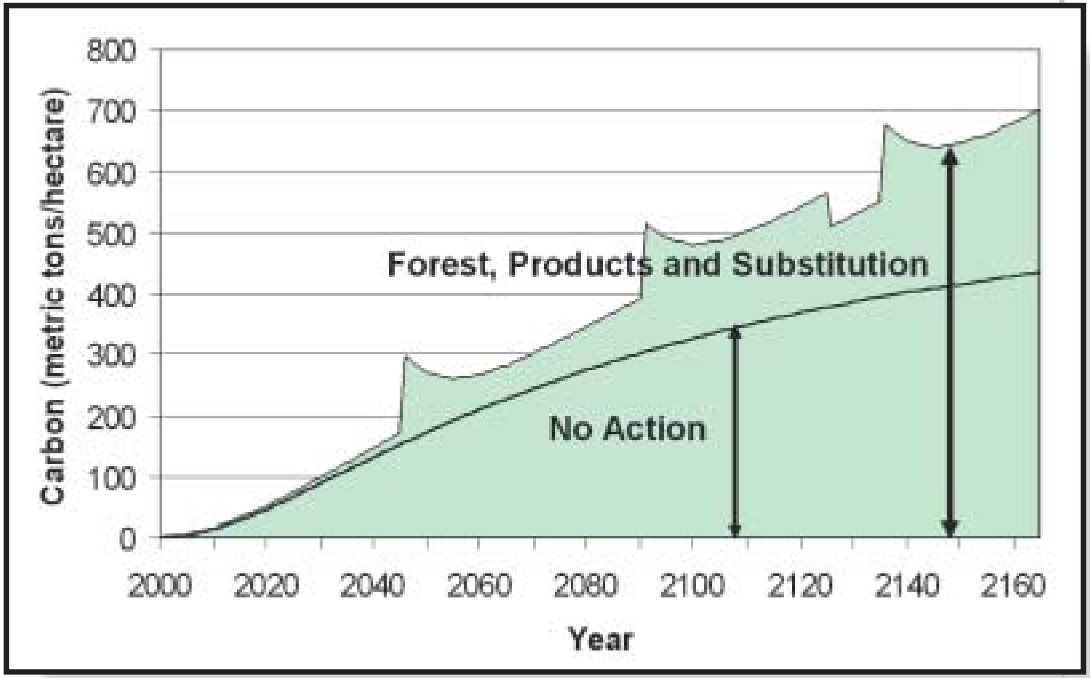

Figure 3

Total carbon over time for forest, products and concrete substitution compared to the no-action taken management scenario.

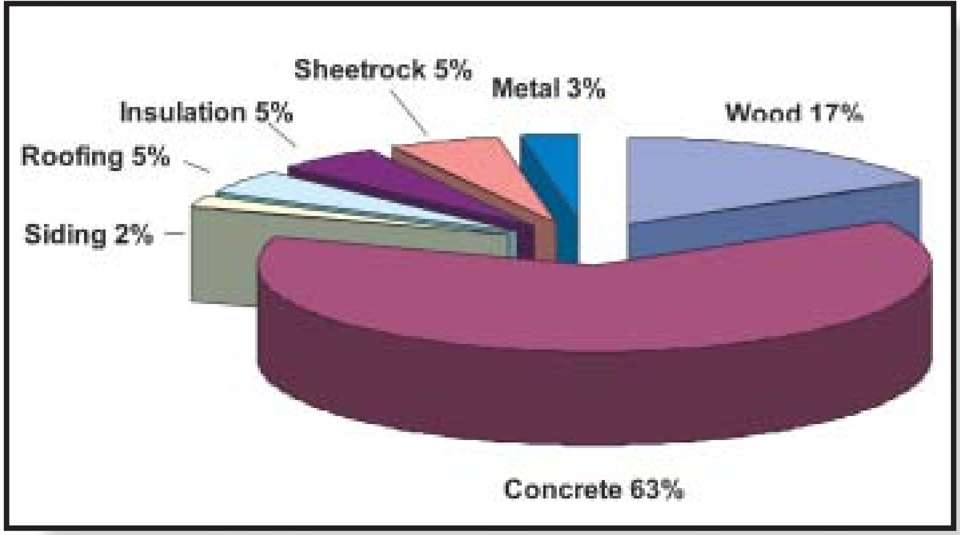

Figure 4

Cold climate wood-framed house building components by their mass.

Figure 4 shows the cold climate wood-framed house in terms of the mass of its building components. Wood represents only 17% of the total mass; concrete dominates at 63%. For the steel-framed house, the wood component drops to 8.6% and the steel component raises to 12.6%; all other components remain about the same. All house designs use a variety of common materials for their construction— wood, concrete, and steel, as well as several other materials. As with the cold climate house, it's typical that mass-wise, wood is not the largest component in a house. Normally concrete is the largest. The advantage of wood is that it can store carbon, carbon that does not occur as CO_2 in the atmosphere for at least the 80-year service life of the house, and it continues to store carbon at the end of its service life in landfills when disposed of or in products when recycled. Literature indicates that wood building products such as lumber, plywood and oriented strandboard (which excludes paper products) placed in modern landfills stay indefinitely with little or no decay, thus continuing to store carbon (Skog and Nicholson 1998).

The Global Warming Potential Index can be used to compare the environmental performance of various building materials and house designs. *Table 1* gives the GWPI for the CORRIM houses – a cold-climate design, framed in either wood or steel, and a warm-climate design, framed in either wood or concrete. CO_2 as a result of the combustion of biomass fuels is considered impact-neutral for global warming potential and is not included in the GWPI calculation. The GWPI for the steel-framed design is 26% greater than the wood-framed design, and the concrete-framed design is 31% greater than the wood-framed design.

Housing stock

Carbon in housing stock can be assessed in two ways, the carbon flow into the stock on an annual basis, also referred to as carbon flux, and the total carbon pool or store for all housing stock in the

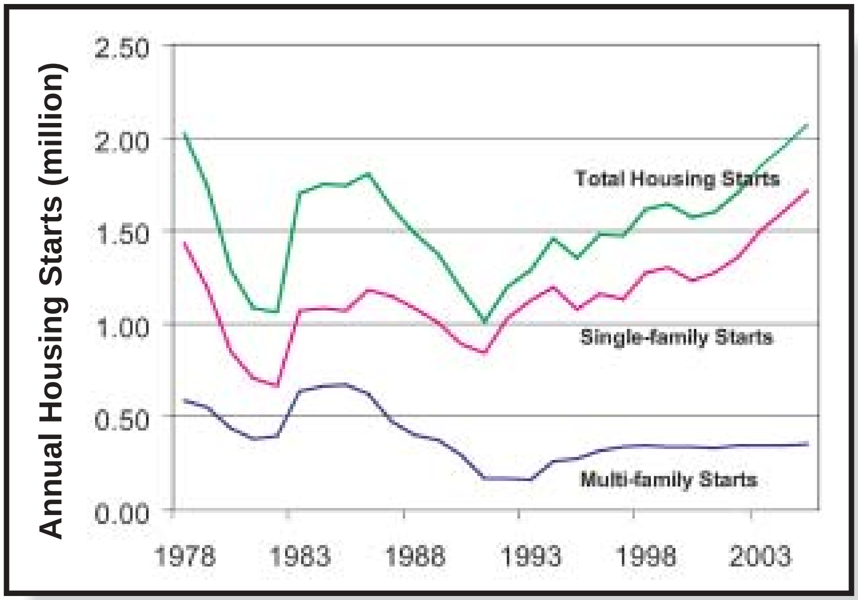

Figure 5

U.S. housing starts for 1978-2005; source NAHB (2006) based on U.S. Census Bureau data.

Table 1

RELEASE OF GREENHOUSE GASES (GHG) AND THE GLOBAL WARMING POTENTIAL INDEX (GWPI) FOR MATERIALS, TRANSPORTATION, PRODUCT MANUFACTURING AND CONSTRUCTION OF BOTH CORRIM HOUSE DESIGNS

	Cold-climate house by framing type				GWPI contribution
	Steel	Wood	Steel-Wood		wood design
GHG	**kg**	**Kg**	**kg**	**%**	**%**
CO_2 fossil	45,477	35,743	9,734		96.56
CO_2 biomass	526	1,547	-1,021		“
N_2O	0.227	0.211	0.016		0.17
CH_4	54.5	52.7	1.8		3.27
GWPI	46,797	37,017	9,780	26.4	

	Warm-climate house by framing type				GWPI contribution
	Concrete	Wood	Concrete-Wood		wood design
GHG	**kg**	**Kg**	**kg**	**%**	**%**
CO_2 fossil	27,150	20,570	6,580		96.29
CO_2 biomass	1,291	1,388	-97		“
N_2O	0.188	0.172	0.016		0.24
CH_4	33.63	32.22	1.41		3.47
GWPI	27,979	21,362	6,617	31.0	

Meil *et al.* ,2004.

U.S. Not considered in this paper, but also of importance, are remodeling applications and other uses of wood, especially those applications where the high leverage use of wood occurs when displacing steel or concrete.

For the first method, annual starts, *Figure 5* illustrates new housing stock from 1978-2005, ranging from a minimum of 1.0 to a maximum of 2.0 million based on 2006 U.S. Census Bureau data (NAHB 2006). Using an average carbon storage mass per house of 4,380 kg for the wood structure (lumber framing, plywood sheathing, oriented strandboard), *Figure 6* shows that the carbon flow for total housing starts annually ranges from about 4.5 to 9 million metric tons. The annual average over the time period is a little less than 7 million metric tons, which translates into approximately 25 million metric tons of CO_2 removed from the atmosphere annually. The actual amount of

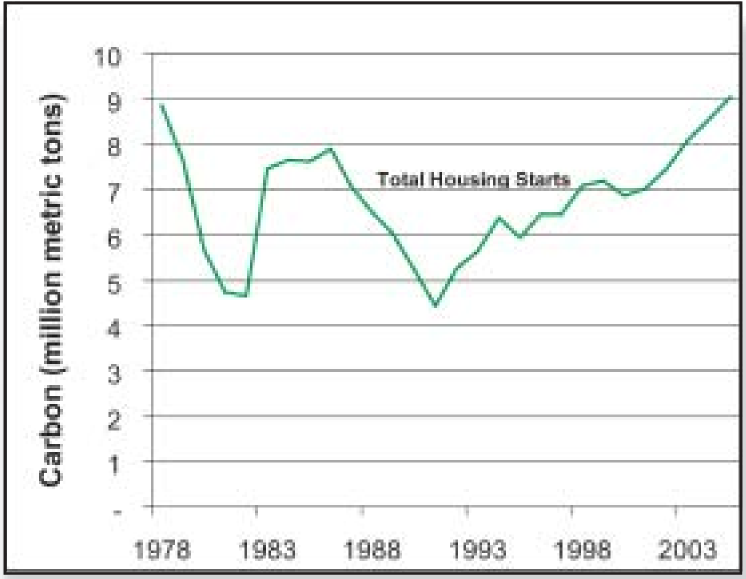

Figure 6

Annual carbon storage in U.S. housing starts 1978-2005.

Table 2

FUEL USE IN THE PRODUCTION OF PLYWOOD FOR THE PACIFIC NORTHWEST (PNW) AND SOUTHEAST (SE) U.S. (WILSON AND SAKIMOTO 2005)

Fuel	PNW on-site energy		SE on-site energy	
	MJ/m³	%	MJ/m³	%
Biomass fuel (wood)	1,400	87.3	1,990	85.6
Natural gas	150	9.4	277	11.9
Liquid petroleum gas	20	1.3	35	1.5
Diesel	34	2.1	23	1.0

Note: *Energy values were determined for the fuels using their higher heating values (HHV) in units of MJ/kg as follows: liquid petroleum gas 54.0, natural gas 54.4, diesel 44.0, and wood oven-dry 20.9.*

carbon stored in a house is much larger considering the mass of other standard wood products including doors, molding and millwork, cabinets, flooring and furniture. Offsetting some of these carbon stores are those associated with houses removed annually for any reason.

Calculations for the second method, total carbon store for all housing stock, also referred to as the cumulative stock, are based on the 2003 U.S. housing inventory estimate of 120.6 million houses (HUD 2006). The service life of a house is assumed to be 80 years, with half the houses removed prior to 80 years and the other half still in service. However, this is a conservative estimate. There are about 10 million houses still in service that were built prior to 1920, thus the actual service life is likely greater. Half of all housing stock is removed as a result of zoning changes, road widening and other factors not related to the materials' functional performance over time. Total carbon stored in the U.S. housing stock, based on 4,380 kg of carbon per house and 120.6 million houses in 2003, is 528 million metric tons. This amount is equivalent to removing 1,939 million metric tons of CO_2 from the atmosphere. The flux of carbon would be the annual change in total carbon store. The more wood products used in houses, especially where they substitute for fossil-fuel intensive products like steel, concrete and plastics, the greater the carbon store, and the lesser the impact on global warming. Wood should be a material of choice for those wanting to build green.

Wood Fuel Use Reduces Global Warming

The type of fuel used in the life cycle of a product can influence its impact on global warming. The use of wood for fuel and its release of CO_2 emissions due to combustion is seen by the U.S. Environmental Protection Agency (EPA) to be impact-neutral when it comes to global warming because the growing of trees absorbs CO_2 from the atmosphere, storing carbon in wood substance and releasing oxygen to the atmosphere (EPA 2003). Simply put, the growing of trees offsets the combustion of wood fuels—essentially a closed loop. Therefore, when wood fuel is substituted for fossil fuels, the contribution to global warming is decreased.

Wood fuel generates a significant percentage of the energy used in the production of wood building products such as lumber, plywood and oriented strandboard. *Table 2*, from the CORRIM study on the life-cycle inventory of plywood production (Wilson and Sakimoto

Table 3

FUEL USE IN THE LIFE CYCLE OF A WOOD BUILDING PRODUCT FROM THE GENERATION OF THE FOREST THROUGH PRODUCT MANUFACTURING; INCLUDES ALL FUELS AND FEEDSTOCK TO PRODUCE AND DELIVER ELECTRICITY, RESIN, WOOD AND PRODUCT (PUETTMANN AND WILSON 2005A)

	Pacific Northwest Production				Southeast Production				
Fuel Source	**Glulam %**	**Lumber %**	**LVL %**	**Plywood %**	**Glulam %**	**Lumber %**	**LVL %**	**Plywood %**	**OSB %**
Coal	3.9	2.5	4.2	3.6	13.7	10.2	13.9	12.0	11.4
Crude oil	9.9	9.7	15.1	13.4	14.7	9.7	13.2	13.4	16.9
Natural gas	36.5	39.1	33.3	24.7	32.2	8.0	35.0	27.2	34.2
Uranium	0.6	0.2	0.3	0.3	1.3	1.0	1.0	0.9	1.0
Biomass (wood)	42.1	43.0	37.2	49.5	37.5	70.8	35.8	45.5	35.5
Hydropower	7.0	5.4	9.8	8.5	0.3	0.1	0.7	0.8	0.9
Other	0.0	0.1	7.0	0.1	0.2	0.2	0.3	0.3	0.2
Total energy (MJ/m^3)	**5,367**	**3,705**	**4,684**	**3,638**	**6,244**	**3,492**	**6,156**	**5,649**	**11,145**

2005), documents that wood fuel comprises about 86% of the total on-site manufacturing facility fuels, which also include natural gas, liquid petroleum gas (LPG) and diesel. Wood fuel and natural gas are used to heat veneer dryers, hot presses, and logs prior to peeling. The LPG is used to operate fork lift trucks in the facility and the diesel is used to operate log haulers in the facility's yard. Similar percentages of wood fuel use are seen for the production of oriented strandboard (Kline 2005) and Southeast lumber (Milota *et al.,* 2005). For Pacific Northwest lumber, wood fuel use is only about 65% of total fuel use on-site (Milota *et al.,* 2005). The wood used for fuel makes use of low-valued bark and wood residuals and does not compete with higher-valued and higher-leveraged product substitutes. Economics of the high cost of fossil fuel and readily-available, low-valued wood fuels has driven its current high use. Sufficient low-valued wood residuals remain to provide additional fuel for heat and to generate electricity.

Wood fuel, or biomass energy, also represents a significant portion of the total cradle-to-gate energy needs for the production of wood products. Total energy is determined from the planting or natural regeneration of tree seedlings (referred to as the cradle), to managing the forests, harvesting, transporting logs to the production facility, and product manufacturing (referred to as the gate). The energy also includes the feedstock and fuel needed to produce and deliver the resins for the production of glulam, laminated veneer lumber, plywood, and oriented strandboard, and includes all the fuels to generate electricity and fuels, and to deliver them to the production facility.

Table 3 gives a breakdown of the cradle-to-gate fuel uses for each of the wood products produced in the Pacific Northwest and the Southeast (Puettmann and Wilson 2005a). Biomass fuel represents a significant portion of the energy needs, ranging from a low of 36% for oriented strandboard (OSB) to a high of 71% for Southeast lumber. The totals at the bottom of Table 3 show the total energy needed to produce a unit volume of product.

Table 4

Carbon dioxide (CO_2) emissions in the cradle-to-gate life cycle of a wood building product from the generation of the forest through product manufacturing (Puettmann and Wilson 2005a)

	Pacific Northwest Production				Southeast Production				
Emission	Glulam kg/m³	Lumber kg/m³	LVL kg/m³	Plywood kg/m³	Glulam kg/m³	Lumber kg/m³	LVL kg/m³	Plywood kg/m³	OSB kg/m³
CO_2 (biomass)	230	160	141	146	231	248	196	229	378
CO_2 (fossil)	126	92	87	56	199	62	170	128	294

Emissions of CO_2 by fuel source, whether for fossil or biomass sources, can also be tracked through the cradle-to-gate life cycle of a product. *Table 4* gives the CO_2 emissions for the production of various wood products (Puettmann and Wilson 2005a). CO_2 emissions from fossil fuels range from 56 to 294 kg/m³ of product. The CO_2 biomass emissions are given as a separate category since biomass fuel combustion is considered impact-neutral for global warming. Fossil fuel CO_2 emissions represent an opportunity to reduce global warming by substituting the use of wood fuel for fossil fuel at the plant site for process energy and for the generation or co-generation of electricity.

Ways to Foster Increased Use of Wood Products and Wood Fuel

Since the use of wood products and related practices can reduce greenhouse gases, which in turn reduces global warming, it would be wise to implement ways that foster their use in a manner that would be both economical and good for the environment. A strategic position should be taken that develops a pathway for new practices, policies, research, and education in order to identify preferred forest management practices, wood products, and opportunities for further product development and improved building design. There are many opportunities for increased efficiencies, and for wood products and biofuel to replace fossil-fuel intensive products and fossil fuels.

Individuals, companies, universities, government agencies, and legislators could all participate in promoting the wise use of wood. For example: identifying and implementing forest management practices that best meet a diverse set of objectives that include carbon storage, and adopting green building practices that highlight the superior environmental performance characteristics of wood building products. Other actions could include standards and guidelines for buildings that encourage the substitution of wood products for fossil-fuel-intensive products like concrete, steel and some plastics, and promoting the increased use of wood fuels.

Implementing ways to increase the favorable environmental performance of wood by modifying practices and increasing its use can be both good for the environment and cost-effective. In addition to the already competitive position of wood products, other incentives can be developed such as tax incentives for reducing emissions, improving energy efficiencies, and supporting renewable energy technologies. Another approach is to foster the trading of carbon credits that consider the benefits of using long-lived wood products as a storehouse for solar energy. The wood products industry is recognized as having greenhouse gas assets and can generally be considered as a seller of tradable CO_2 allowances. For example, the newly-started Chicago Climate Exchange trades credits at about \$4.00 per metric ton of CO_2 (CCX 2006).

This trade price would be expected to increase with marketplace maturity, considering that the more established European Climate Exchange currently trades credits at about $21.00 per metric ton of CO_2 (ECX 2006). New non-wood products or processes that emit large quantities of CO_2 from the combustion of fossil fuels could buy credits from the wood products industry which could be used to help finance process or product improvements.

Considerable data on the favorable environmental performance of wood as a building material already exist through CORRIM (Bowyer *et al.,* 2004) and the U.S. LCI Database (NREL 2006) to use as a basis for promoting its use to reduce greenhouse gas emissions. To support a strategic policy shift we should embark upon an outreach education program that promotes wood's use to the consuming public, industry, government agencies, builders, architects, engineers and legislators.

Summary

The use of wood products can reduce the amount of CO_2, a major greenhouse gas, in the atmosphere, which in turn may reduce global warming. Wood can accomplish this in several ways: storing carbon in forest and wood products, as substitution for fossil-fuel intensive products like concrete and steel in housing construction, and as biomass that replaces fossil fuels to generate process heat and electricity.

When trees absorb CO_2 from the atmosphere, carbon is stored in wood at about 50% of its mass. Trees release oxygen back to the atmosphere. The carbon remains in wood in a forest or product until it is either combusted, or chemically or biologically decomposed, returning CO_2 to the atmosphere. A significant amount of carbon is stored in the forest and in wood products for a long period of time. Carbon is stored in wood products in houses, which remain in service, on average, for at least 80 years; at the end of its service life it is stored in modern landfills for even greater duration.

Total carbon stored in wood products, or saved when wood is substituted for a material such as concrete in house framing, can be greater than the total carbon sequestered in a forest where no action is taken in terms of harvesting, fire or biological damage.

The production of wood building materials—glulam, lumber, plywood, laminated veneer lumber, and oriented strandboard —uses significant quantities of wood fuel to generate process heat, and sometimes electricity. Using wood fuel instead of fossil fuel also helps to reduce global warming, since its CO_2 emissions are considered to be impact -neutral for global warming, whereas the combustion of fossil fuels is not.

Wood presents opportunities for reducing global warming by growing more trees, managing the forest, producing wood products that are used in long-term applications, using more wood to build houses rather than fossil-intensive substitutes like steel and concrete, and substituting the use of wood fuel for fossil fuels. This can be good for the environment and still be economical when considering the high price of fossil fuels, tax incentives and carbon credits. Policies and practices are needed to further promote the use of wood for this purpose.

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