

WOOD PRODUCTS AND CARBON PROTOCOLS
*CARBON STORAGE AND LOW ENERGY INTENSITY
SHOULD BE CONSIDERED*

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Introduction

In developing incentives and protocols to reduce carbon emissions and increase carbon sequestration, one glaring omission stands out. Storage of carbon within wood products has thus far been ignored by policy analysts, as has the low energy intensity (and even lower fossil fuel intensity) of wood products in general. The omission is significant since in the United States alone carbon stored within wood products is over one-third that being sequestered annually within the nation's forests. The lack of recognition of lower energy and fossil fuel intensity is even more serious because the impact of these factors on carbon flux is substantially greater than that attributable to carbon storage. The data on carbon storage in wood products and their low-energy intensity is increasingly well documented and readily available. The time is right and strong opportunities exist for carbon protocols and markets for carbon credits to recognize the carbon storage benefits of wood products.

Forest Growth and the Capture of Solar Energy

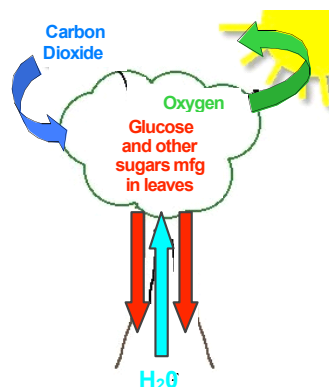
At a time when mankind is searching for ways to capture the power of the sun, it turns out that one of society's principal construction materials – wood – is produced almost entirely from solar energy. In addition, carbon dioxide that is removed from the air during tree growth is combined with water and converted to simple sugars within the leaves, conveyed downward through the branches and bole in the form of sap, and then converted into complex polymers that combine to form the structure of wood (Figure 1). In a natural process that uses freely available solar energy, an intricately structured polymeric material is created that has a higher strength-to-weight ratio than steel. This reality largely explains why the energy embodied¹ in wood products is lower than any other construction material. Lumber, in particular, requires relatively little energy to produce since only minimal processing is needed to convert the naturally produced wood to desired shapes. Wood products requiring more steps in processing need more energy to produce, but significantly less energy than non-wood materials.

Energy and Fossil Energy Efficiency of Wood Products Manufacture

Not only does production of lumber and wood products require relatively little additional energy beyond the solar energy used in tree growth and wood production, but very little of the added energy that is used for this purpose is produced from fossil fuels. Over one-half of the energy consumed in manufacturing wood products in the U.S. is bioenergy, produced from tree bark, sawdust, and by-products of pulping in papermaking processes. In some regions over two-thirds of process energy is produced in this way. In fact, the U.S. wood products industry is by far the nation's leading producer and consumer of bioenergy, accounting for about 60 percent of production (Murray et al. 2006).

¹ The term "embodied energy" refers to the quantity of energy required by all of the activities associated with a production process, including gathering, transporting, and primary processing of raw materials.

Figure 1
Photosynthesis



Large-scale production of energy from wood in North America has its origin in the oil shocks of the 1970s. In response to petroleum supply disruptions much of the nation changed energy consumption habits only briefly before returning to business as usual. The wood products industry, on the other hand, launched a concerted and sustained program of innovation and investment to convert what previously had been wastes into energy. The result was a sharp increase in energy self-sufficiency for the industry, and a corresponding decline in consumption of energy supplies from national and regional energy grids.

When one considers that (1) wood is produced using solar energy, (2) the manufacture of lumber and other wood products requires little additional energy, and (3) only one-third to one-half the energy consumed is fossil energy, then total emissions from wood products manufacture, including emissions of carbon dioxide, are typically far lower than for potential wood substitutes. Fossil energy production is the source of a large proportion of the adverse impacts of industrial activity, resulting in emissions of such compounds as sulfur dioxide, the nitrogen oxides, methane, and carbon dioxide.

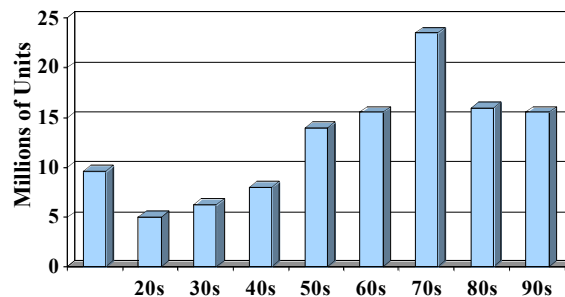
Carbon Storage in Wood and Wood Products

As noted earlier, the source of carbon contained within wood is carbon dioxide taken from the atmosphere in the process of tree growth. This carbon becomes an integral part of wood, comprising one-half its dry weight. Enormous quantities of carbon are stored (or sequestered) in the twigs, branches, boles, and roots of trees, and in the products made of wood. Additional carbon is stored in forest litter and forest soils.

There are approximately 26 billion metric tons of carbon within standing trees, forest litter, and other woody debris in domestic forests, and another 28.7 billion mt in forest soils (Birdsey and Lewis 2002). Carbon contained within wood products in use and in landfills is estimated at 3.5 billion mt. These figures suggest a relatively minor contribution of long-lived forest products to carbon sequestration.

Current rates of carbon accumulation provide a different perspective. A recent estimate places the rate of carbon sequestration in U.S. forests at 170 million mt annually, a quantity of carbon equivalent to about 10 percent of total carbon emissions nationally. The rate of carbon accumulation within wood products in use and in landfills is estimated at about 60 million mt annually (Heath and Smith 2004) – 35 percent the rate of sequestration within forests, and almost 45 percent of the annual additions to non-soil forest carbon stocks (Heath and Skog 2004). Much of the carbon contained within wood products resides in the nation's housing stock, estimated at 116 million units in 2000. Wood-framed buildings make up about 90 percent of homes in the U.S., and in all homes, whether wood framed or not, wood furniture, cabinets, flooring, and trim is dominant. Consequently, as the number of housing units grows (Figure 2), carbon storage in these houses grows as well.

Figure 2
Homebuilding Activity in the United States in
the 20th Century – Continuing Increases to the
116 Million Housing Unit Inventory



Source: Wilson (2006)

It should be noted that the quantity of carbon sequestered in wooden buildings remains only as long as the buildings do. As wood deteriorates, in a process that is chemically essentially the reverse of photosynthesis, carbon is returned to the atmosphere while oxygen is used and water re-formed. Carbon stocks will only continue to increase as long as the rate of construction of wooden structures is greater than the rate of removal from the housing stock.

Carbon Implications of High Energy Efficiency and Product Sequestration

A number of life cycle assessment studies over the past several decades have conclusively shown marked differences in energy requirements associated with different building materials and structures made from them. In every one of these studies, wood products and structures made of wood have been found to require the least energy, and in most cases by a substantial margin.

High energy efficiency and low fossil fuel consumption, combined with the fact that wood is one-half carbon by weight, means that wood and the products made from wood tend to be not only carbon neutral, but carbon *negative*. That is to say, that even when

carbon emitted in all the steps of processing is considered, the net result is carbon storage rather than emission of carbon; this is not the case for any other construction material (Table 1).

Several recent studies of energy consumption and carbon balances associated with construction of entire structures are summarized in Tables 2 through 4. Again, wood has a clear environmental advantage.

Table 1
Net Carbon (C) Emissions in Producing a Ton of Various Materials

Material	Net Carbon Emissions (kg C/metric ton) ^{a/ b/}	Net Carbon Emissions Including Carbon Storage Within Material (kg C/metric ton) ^{c/}
Framing lumber	33	-457
Medium density fiberboard (virgin fiber)	60	-382
Brick	88	88
Glass	154	154
Recycled steel (100% from scrap)	220	220
Concrete	265	265
Concrete block ^{d/}	291	291
Recycled aluminum (100% recycled content)	309	309
Steel (virgin)	694	694
Plastic	2,502	2,502
Aluminum (virgin)	4,532	4,532

^{a/} Values are based on life cycle assessment and include gathering and processing of raw materials, primary and secondary processing, and transportation.

^{b/} Source: USEPA (2006).

^{c/} A carbon content of 49% is assumed for wood.

^{d/} Derived based on EPA value for concrete and consideration of additional steps involved in making blocks.

Table 2
Total Consumption of Fossil Fuels (MJ/ft²) Associated with Two Exterior Wall Designs
in a Warm Climate Home ^{a/}

	Type of Exterior Wall	
	Lumber-Framed Wall	Concrete Wall
Structural components ^{b/}	6.27	75.89
Insulation ^{c/}	8.51	8.51
Cladding ^{d/}	22.31	8.09
Total ^{e/}	37.09	92.49

^{a/} One megajoule is equivalent to 0.27778 kilowatt hours or 947.8 Btus.

^{b/} Includes studs and plywood sheathing for the lumber-framed wall design and concrete blocks and studs (used in a furred-out wood-studs wall) for the concrete wall design.

^{c/} Includes fiberglass and six-mil polyethylene vapor barrier for both warm climate designs.

^{d/} Includes interior and exterior wall coverings. Exterior wall coverings are vinyl (lumber-framed wall design) and stucco (concrete wall design). Interior wall coverings gypsum for both warm climate designs.

^{e/} Includes subtotals from Structural, Insulation, and Cladding categories.

Source: Edmonds and Lippke 2004.

Table 3
Consumption of Fossil Fuels (MJ/ft²) Associated with Three Floor Designs^{a/ b/}

	Floor Design		
	Dimension wood joist floor	Concrete slab floor	Steel joist floor
Total	9.93	24.75	48.32

^{a/} One megajoule is equivalent to 0.27778 kilowatt hours or 947.8 Btus.

^{b/} Excludes any consideration of insulation.

Source: Edmonds and Lippke 2004.

Negative carbon emissions associated with wood products manufacture also translates to low carbon emissions when building wooden structures. In view of the fact that “wood” buildings are never built completely of wood (just as “steel” or “concrete” buildings are never built completely of steel or concrete), structures that are dominantly made of wood do result in carbon emissions, but the impact of the use of carbon negative wood results in low carbon emissions relative to other types of structures. This is illustrated in Table 4.

Table 4
Results of a Life Cycle Inventory of a Large Office Building

Construction	Total Energy Use ^{b/}	Above Grade Energy Use ^{b/}	CO ₂ Emissions ^{c/}
Wood ^{a/}	3.80	2.15	73
Steel	7.35	5.20	105
Concrete	5.50	3.70	132

^{a/} The wooden design included the use of large composite lumber (PSL) columns and beams.

^{b/} GJ x 103

^{c/} kg x 103

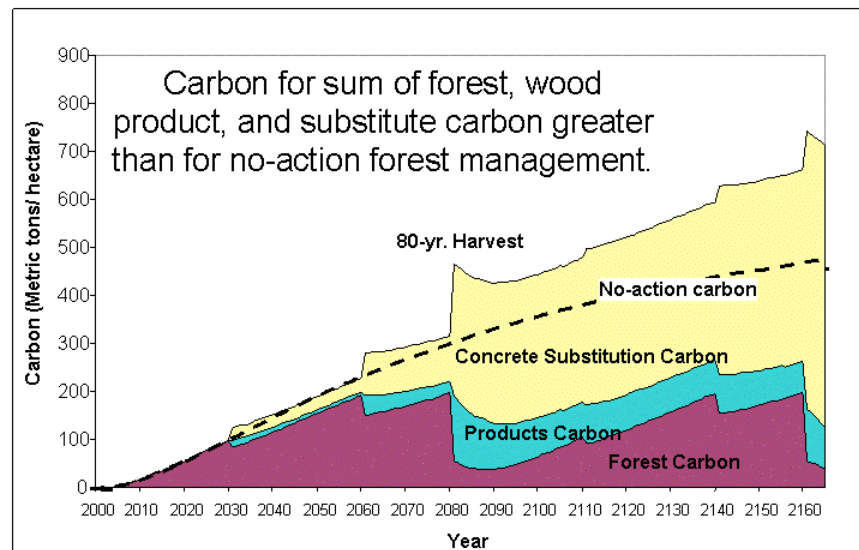
Source: Forintek Canada/Canadian Wood Council, 1997.

Avoided Carbon through Product Substitution

Because the quantity of energy consumed in producing wood products is low compared to functionally equivalent products made of other materials, energy is saved and emissions avoided each time wood is substituted for these other materials in building construction. As long as substitutions are appropriate (i.e. result in similar durability over time), and the management of forests from which wood is harvested is sustainable, there is clear environmental advantage to use of wood wherever possible.

This substitution effect is very large, as illustrated by the light yellow segment of Figure 3, and as recently underscored by Buchanan (2007). Carbon stored in products (shown in aqua) is significant relative to the carbon stored in the forest biomass and soils (shown in brown). Note that total carbon accumulation when forests are managed so as to exclude forest harvest (dashed line) is less than when periodic harvest does occur.

Figure 3
Carbon Storage Implications of Managing a Forest on an 80-Year Rotation, with Intermediate Thinnings at Years 30 and 60, and a Portion of Wood Harvested at Rotation Age Used for Long-Lived Construction Products. Substitution Comparison to Construction with Concrete.



Source: Perez-Garcia, J., B. Lippke, J. Connick, and C. Manriquez (2005); Wilson (2006).

As significant as the carbon stored in products and forest biomass and soils is, both pale in comparison to the substitution effect. As pointed out by Sathre (2007):

The substitution effect of forest product use is cumulative; i.e. carbon emissions are avoided during each rotation period due to substitution for fossil fuel and material by the harvested biomass. Thus, not harvesting the forest would cumulatively increase carbon emissions over what would otherwise be possible if forests were harvested and used on a regular rotation period. Because the substitution benefits of forest product use are cumulative, and the carbon sink in the forest biomass and soil limited, non-management and non-use of forest biomass becomes less attractive as the time horizon increases. Over the long term, active and sustainable management of forests, including their use as a source of wood products and biofuels, allows the greatest potential for reducing net carbon emissions.

International Carbon Protocols

The University of Washington in 1997 identified three approaches to reducing forest-related carbon dioxide emissions (US Forest Service 2001):

1. Allow the growing forest to absorb carbon dioxide (through photosynthesis) and store it as wood in the forest.

2. Harvest the forest before it burns or decomposes and store the carbon in less rapidly decomposing forest products.
3. Use wood products as substitutes for aluminum, steel, concrete, brick, and other products that consume much greater quantities of fossil fuels (and release more carbon) in their manufacture.

A fourth alternative would be to establish new forests on non-forested sites.

Currently, forest-related strategies available for earning carbon credits toward compliance with the Kyoto protocol (see sidebar) are limited to the fourth alternative – establishment of forests on areas previously lacking forest cover, or on lands degraded by agriculture or mining. Also under study is development of incentives for retaining forested lands as intact forests (alternative 1 above).

Despite a long history of research focused on carbon storage (Row and Phelps 1996; Schlamadinger and Marland 1996; Winjum and Brown 1998; Skog and Nichols 2000; Birdsey and Lewis 2002), there is no recognition to date by climate negotiators of the potential for storing carbon in wood products or of avoiding carbon emissions through product substitution (alternatives 2 and 3). Sedjo and Amano (2006) note that the current assumption regarding the fate of harvested wood is that once a tree is harvested, all of its carbon is released and that the net stock of carbon in long-lived wood products is unchanging. Fortunately, there is now broad recognition that this assumption is faulty, with initiatives for accounting for carbon storage within harvested wood products currently underway (Pingoud et al. 2003; Ruddell et al. 2007). The carbon storage issue is likely to be taken up within the next year as part of the United Nations Framework Convention on Climate Change (UNFCCC).²

The Kyoto Protocol

The Kyoto Protocol requires industrialized countries to implement policies and measures for reducing greenhouse gas emissions to at least 5 percent below 1990 levels by the end of 2012. A global market for carbon credits and projects has arisen largely as a result of the Kyoto Protocol and is a significant development in the marketplace for ecosystem services.

Within the Kyoto Protocol there are three “mechanisms” that create cap-and-trade models and are the basis of the mainstream carbon market. The mechanisms include Emissions Trading, Joint Implementation, and Clean Development. The Clean Development Mechanism (CDM)¹ is referenced most frequently and is distinguished by its focus on carbon credits that result from financing carbon reduction projects in developing countries. This mechanism is viewed as a key link between developed and developing countries. In 2006, CDM traded credits totaled \$5 billion (USD) and accounted for 450 million tons of reduced carbon dioxide emissions (MtCO₂e).

http://unfccc.int/kyoto_protocol/items/2830.php

² In December 2007, the Chicago Climate Exchange (CCX) Committee on Forestry approved new protocols for carbon sequestration associated with long-lived wood products and managed forests. These efforts may help inform international discussions about carbon storage in wood products. (<http://www.chicagoclimatex.com/info/advisories/2007/2007-18.pdf>)

It is not likely that a decision on the carbon storage issue will not be based on science alone. Politics are certain to play an important role. For example, in seeking to perhaps assign credit for stored carbon in a situation in which significant quantities of wood are harvested in one nation, processed in another, and consumed in yet another, to which of these nations should the carbon credits go? Which nation, moreover, should be assigned a burden or penalty when products begin to deteriorate and release carbon? These kinds of questions explain part of the reticence in dealing with the stored carbon issue. Japan, for instance, has expressed concern that it might be disadvantaged should the status quo relative to harvested wood products change (Mitchell 2003).

Although there is tentative discussion about the carbon storage issue under the UNFCCC, the outcome is far from certain. More fundamentally, there is no recognition at this point of the substitution effect, and little likelihood that an issue like this could be effectively considered by international climate negotiators given the complicating reality of competing industries in addition to sometimes conflicting national agendas. Nonetheless, continued work to call attention to the substitution factor is important, if for no other reason than that some government purchasing programs and green building programs nationally and internationally are tending to promote substitution of non-renewable, highly energy intensive products *for* wood.

Short of international agreement, there are things that could be done on a state, provincial, or national level to effectively bring about recognition of superior energy efficiency and substitution effects, and related action. One, in particular, has promise. That, very simply, is a carbon tax. Sather (2006) observed that a uniform carbon tax applied to all carbon emissions would systematically favor all highly energy efficient products (or at least those that are fossil fuel efficient), while disfavoring products with lower energy efficiency.

The Bottom Line

Considerable carbon is stored in wood products. Such products are also highly energy efficient, with their manufacture resulting in the emission of far less carbon dioxide and other greenhouse gases than non-wood materials. The differences are large, and recognition of such differences important if society is serious about reducing carbon dioxide and greenhouse gas emissions. Recognition of differences is also important in that such recognition is the first step to development of rational government purchasing and green building programs.

Aside from the potential for recognition of carbon storage within wood products in international agreements, a strong incentive for recognizing high energy and fossil fuel efficiency could be created by simply implementing a uniformly applied carbon tax. This approach is well worth considering.

References

Birdsey, R. and Lewis, G. 2002. Carbon in U.S. Forests and Wood Products, 1987-1997: State by State Estimates. USDA-Forest Service, General Technical Report GTR-NE-310. http://www.fs.fed.us/ne/newtown_square/publications/technical_reports/pdfs/2003/gtrne310.pdf

Buchanan, A. 2007. Energy and CO₂ Advantages of Wood for Sustainable Buildings. Staff Paper, Department of Civil Engineering, University of Canterbury, Christchurch, New Zealand. (<http://www.civil.canterbury.ac.nz/staff/..%5Cpubs%5CEnergy-CO2AdvantagesWoodSustainableBuildings.pdf>)

Edmonds, L. and B. Lippke. 2004. Reducing Environmental Consequences of Residential Construction through Product Selection and Design. Consortium for Research on Renewable Industrial Materials, Fact Sheet No. 4. (September)

Fernholz, K. and J. Bowyer, A. Lindburg, S. Bratkovich. 2008. Ecosystem Markets: New Mechanisms to Support Forestry. Dovetail Partners (March 26). (<http://www.dovetailinc.org/reports/pdf/DovetailEcoMkts0308dk.pdf>)

Forintek Canada Corporation/Canadian Wood Council. 1997. Comparing the Environmental Effects of Building Systems - A Comparison of Wood, Steel, and Concrete Construction in 3-Story Office Buildings. Wood the Renewable Resource Series, Case Study Number 4.

Heath, L. and J. Smith. 2004. Criterion 5, Indicator 27: Contribution of forest ecosystems to the total global carbon budget, including absorption and release of carbon. 7 p. In: Darr, D., coord. Data report: A supplement to the national report on sustainable forests—2003. FS-766A. Washington, DC: U.S. Department of Agriculture. <http://www.fs.fed.us/research/sustain/contents.htm> (8 June).

Heath, L. and K. Skog. 2004. Criterion 5, Indicator 28: Contribution of forest products to the global carbon budget. 10 p. In: Darr, D., coord. Data report: A supplement to the national report on sustainable forests—2003. FS-766A. Washington, DC: U.S. Department of Agriculture. <http://www.fs.fed.us/research/sustain/contents.htm> (8 June).

Miner, R. and A. Lucier. 2004. A Value Chain Assessment of Climate Change and Energy Issues Affecting the Global Forest-Based Industry. A Report to the WBCSD Sustainable Forest Products Industry Working Group. (<http://www.resourcesaver.org/file/toolmanager/CustomO16C45F60545.pdf>)

Mitchell, C. 2003. Estimation, Reporting and Accounting of Harvested Wood Products. United Nations Framework Convention on Climate Change reports FCCC/TP/2003/7 (<http://www.greenhouse.crc.org.au/crc/ecarbon/CoP9.pdf>)

Murray, B., R. Nicholson, M. Ross, T. Holloway, and S. Patil. 2006. Biomass Energy Consumption in the Forest Products Industry. US Department of Energy/ RTI International. (http://www.eia.doe.gov/cneaf/solar.renewables/page/biomass/rti_biomass_report_2006.pdf)

NCASI. 2006. Energy and greenhouse gas impacts of substituting wood products for non-wood alternatives in residential construction in the United States. Tech. Bulletin No. 925. National Council for Air and Stream Improvement, Inc., Res. Triangle Park, North Carolina. (<http://www.wbcsd.org/DocRoot/X1ZvkdDg4I9bOXKoXW8P/sfpi-carbon-climate.pdf>)

Perez-Garcia, J., B. Lippke, J. Comnick, and C. Manriquez. 2005. An Assessment of Carbon Pools, Storage, and Wood Products Market Substitution Using Life-Cycle Analysis Results. Wood and Fiber Science, 37 Corrim Special Issue, pp. 140-148. (<http://www.corrim.org/reports/2005/swst/140.pdf>)

Pingoud, K., A. Perala, S. Soimakallio, and A. Pussinen. 2003. Greenhouse gas impacts of harvested wood products: Evaluation and development of methods. VTT Res. Notes 2189, VTT Tech. Res. Centre of Finland, Espoo, Finland. (<http://www.vtt.fi/inf/pdf/tiedotteet/2003/T2189.pdf>)

Row, C. and B. Phelps. 1996. Wood Carbon Flows and Storage After Timber Harvest. In: Sampson, R. and D. Hair (eds). Forests and Global Change: Volume 2. Forest Management Opportunities for Mitigating Carbon Emissions. Washington D.C.: American Forests.

Ruddell, S., R. Sampson, M. Smith, R. Giffen, J. Cathcart, J. Hagan, D. Sosland, J. Godbee, J. Heissenbuttel, S. Lovett, J. Helms, W. Price, and R. Simpson. 2007. The Role for Sustainable Managed Forests in Climate Change Mitigation. Journal of Forestry 105(6):314-319. (<http://michigansaf.org/ForestInfo/Ruddell-EtAl-2007.pdf>)

Sathre, R. 2007. Life-Cycle Energy and Carbon Implications of Wood-Based Products and Construction. Mid Sweden University Doctoral Thesis 34, Ecotechnology and Environmental Science, Department of Engineering, Physics and Mathematics, Mid Sweden University. ([www.diva-portal.org/diva/getDocument?urn_nbn_se_miun_diva-50-2_fulltext\[1\].pdf](http://www.diva-portal.org/diva/getDocument?urn_nbn_se_miun_diva-50-2_fulltext[1].pdf))

Schlamadinger, B. and G. Marland. 1996. The Role of Forest and Bioenergy Strategies in the Global Carbon Cycle. Biomass and Bioenergy 10(5/6):275-300.

Sedjo, R. and M. Amano. 2006. The Role of Forest Sinks in a Post-Kyoto World. Resources, Number 162. Washington D.C.: Resources for the Future, pp. 19-22. (http://www.rff.org/Documents/RFF-Resources-162_ForestSinksPostKyoto.pdf)

Skog, K. and G. Nicholson. 2000. Carbon Sequestration in Wood and Paper Products. USDA-Forest Service, General Technical Report RMRS-GTR-59. (<http://www.fpl.fs.fed.us/documnts/pdf2000/skog00b.pdf>)

USDA-Forest Service. 2001. Forest Products Conservation and Recycling Review, vol. 13, no. 2/3. (<http://www.fpl.fs.fed.us/tmu/resources/documents/nltr/nltr0301.htm>)

- USEPA. 2006. Solid Waste Management and Greenhouse Gases--A Life Cycle Assessment of Emissions and Sinks, 3rd Ed. United States Environmental Protection Agency. Washington, D.C.
(<http://worldcat.org/wcpa/oclc/77463291?page=frame&url=http%3A%2F%2Fpurl.access.gpo.gov%2FGPO%2FLPS76916&title=&linktype=digitalObject&detail=>)
- Wilson, J. 2006. Using Wood Products to Reduce Greenhouse Gases. Seminar, Oregon State University, Department of Wood Science and Engineering, April 5.
(http://www.corrim.org/ppt/2006/Wilson_April6_OSU/index.htm)
- Winjum, J., S. Brown, and B. Schlamadinger. 1998. Forest Harvests and Wood Products – Sources and Sinks of Carbon Dioxide. Forest Science 44(2): 272-284.
(<http://www.epa.gov/wed/pages/publications/abstracts/archived/winjum98.htm>)

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