North American Wood Pole Coalition

TECHNICAL BULLETIN

Wood Materials Used as a Means to Reduce Greenhouse Gases (GHG): An Examination of Wooden Utility Poles

by: Roger A. Sedjo, Ph.D.

Abstract

Examination of research into pole alternatives indicates that, without exception, studies have found that total energy requirements associated with wood materials are considerably lower than those of commonly substituted materials. The substitution of high-energy-intensive materials for low-energy-using wood materials would contribute substantially to an overall increase in carbon dioxide emissions.

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Introduction

In recent years there has been growing concern over the build-up of greenhouse gases (GHG) in the atmosphere, particularly carbon dioxide, as a cause of global warming. The science underlying this concern has been compiled in the various reports of the Intergovernmental Panel on Climate Change (IPCC) including the First, Second (Brown et al. 1996) and Third Assessment Reports on Climate Change (IPCC 2001). It is well recognized that the major GHG is carbon dioxide and the major cause of human-generated carbon in the atmosphere is the burning of fossil fuels for energy. It is also well recognized that biological systems can play a significant role in the level of atmospheric carbon. Deforestation and land-use change both can contribute to increased emissions of carbon dioxide. However, this is reversible in that carbon can be sequestered in expanding biological systems, particularly forests (IPCC 2001). The process of forest growth captures carbon in the cells of the wood and the carbon is held captive in the forests. Additionally, the carbon continues to be held in the cells of wood that is used for long-lived products such as lumber and poles, thereby mitigating the build-up of atmospheric carbon dioxide (e.g., Karjalainen et al. 1999).

Approaches suggested for mitigating the build-up of carbon dioxide have consisted of attempts to identify various means to reduce emissions of GHGs, particularly through the development of power facilities that use fuels that emit less carbon dioxide or through the development of techniques that captures carbon dioxide released in power generation before it escapes to the atmosphere. These approaches include the use of nonfossil fuel energy, e.g., solar and wind power; the use of fossil fuels that emit lower levels of carbon dioxide per unit of energy, e.g., natural gas; and various technologies designed to capture carbon dioxide from power operations before it is emitted into the atmosphere. Finally, there are also attempts to sequester carbon out of the atmosphere. One approach is to sequester atmospheric carbon in expanding biological sinks (e.g., IPCC 2001) such as forests. It is also recognized that carbon can be held for a considerable period in wood products. Although much work has been done examining the forest as an actual or potential carbon sink, less research has been done on the carbon implications of carbon sequestered over the long-term in wood products.

Although relatively little attention has been given to the impact of the choice of materials used for construction and other purposes on atmospheric carbon, informed speculation has suggested that a materials approach could be substantial (IPCC 2001). The fourth chapter of the *Third Assessment Report* suggests two ways in which the choice of materials could be relevant. First, some materials, e.g. wood, embody substantial amounts of carbon even when in product form. Second, different materials require different amounts of energy in their construction. Steel, aluminum and bricks, for example, require large amounts of energy, most of which is produced by the burning of fossil fuels. Thus, production of many materials involves large carbon emissions through fossil fuel use and the requisite energy production. Additionally, cement production itself, which uses calcium carbonate, involves the release of large amounts of carbon dioxide.

Wood materials have advantages in that they have relatively small energy requirements in their production and thus carbon emissions associated with their production are modest. Even when converted to products, they continue to hold captive large volumes of carbon in their cells. Although it is recognized that wood offers the potential to generate carbon benefits vis-a-vis most alternative materials on these two accounts, the data supporting this view consists of a few disparate studies that are not well known. A purpose of this paper is to draw together the findings of recent research to demonstrate that this research, although undertaken in different countries by different researchers often using different methodologies, consistently finds evidence that wood is a much less energy intensive material than most of its substitutes and that the carbon and global warming consequences of substituting wood for other materials, such as steel, aluminum, cement or bricks, could be significant.

This paper draws from this literature to examine the relative effects of alternative materials on energy utilization and its probable impacts on global warming. As noted, there is only a modest body of literature on this issue and much of this literature comes from work related to determining the energy requirements of various materials. Most recent literature concentrates on determining the environmental implications of various materials using a “life cycle” approach. This paper first briefly reviews a number of studies in the literature on the energy use associated with the use of various building materials, including wood. The relation between energy utilization and carbon dioxide emissions into the atmosphere is also discussed. Next, a case study, which focuses on a specific product, utility poles, is presented.

The case study compares the carbon dioxide and global warming impacts of using wooden poles with the use of alternative materials, cement and steel. Finally, drawing from the findings of the existing literature on the energy and global warming effects of alternative materials, this paper develops generalizations and conclusions on the question of alternative material use and its implications for carbon dioxide emissions into the atmosphere.

Background

It is now well known that emissions of carbon dioxide into the atmosphere from fossil fuels used to produce energy are increasing the level of greenhouse gases in the atmosphere and are believed to be contributing to global warming. Reduced energy use, then, is one approach to reducing emissions of harmful carbon dioxide into the atmosphere. Energy is used extensively in the production of various materials used for construction and other purposes.

This paper focuses on the energy requirements for the production of products made from a number of materials, i.e., wood, steel and concrete. The amount of carbon emissions will depend upon the energy source used in a particular manufacturing situation. It should be noted, however, that the amount of carbon dioxide released is dependent upon both the energy used and the source of that energy. Some energy sources, e.g., nuclear and hydro, release no carbon dioxide. Globally, however, the vast majority of commercial energy is produced by fossil fuels. Among the fossil fuels, the amount of carbon dioxide released per unit of power varies. Coal releases the greatest amount of carbon dioxide per unit power and natural gas the least, with oil between. Nevertheless, globally there will be a strong correlation between the energy requirements of a material and the carbon dioxide releases.

Finally, it should be noted that concrete production involves the release of large amounts of carbon from the processing of calcium carbonate, which is a major component of concrete. The component is not considered in most of the calculations reported in this paper.

Carbon Dioxide Emission Implications of Materials Use: Some Studies of Wood and Other Materials

An early report Boyd et al. (1976) examined the energy implications of wood and alternative materials for construction purposes. Using data from the 1976 report, Koch (1992) examined the global energy and carbon dioxide emissions implications of substituting nonrenewable structural materials such as steel aluminum, concrete, brick and plastics in US residential construction to replace structural wood.

As shown in table 1, the energy equivalent of wood-based commodities is substantially less than that of nonwood commodities. Koch noted, for example, that wood studs require only 2.91 million Btu per dry ton while the net energy requirement of steel studs is 50.32 million Btu per ton. Furthermore, wood generally had substantially lower energy requirements than most other materials. However, plywood and Medium Density Fiberboard (MDF), products which require gluing and

Table 1. Net energy requirement for extraction, manufacture, and transport to building site of primary commodities.

Commodity	Net Energy Required (million Btu oil equivalent per ovendry ton)
Wood based commodities	
Softwood lumber	2.91
Wood fence post	4.00
Softwood sheathing plywood	6.00
MDF	8.49
Nonwood commodities	
Concrete slab	8.52
Concrete brick	8.77
Clay brick	9.06
Carpet and pad	37.19
Steel studs	50.32
Steel fence posts	50.32
Aluminum siding	200.47

Source: Koch 1992, Table 6.

heating, have substantially higher energy requirements than lumber, posts and poles.

Table 2 presents Koch's adjustments for the varying weights of the different materials to achieve a performance standard. For example, even adjusting for the lower weight of steel (table 2), the energy requirement for equivalent steel studding used in home construction would be 26.67 million Btu, or an energy requirement about 9 times that of wood.

Koch goes on to examine the implications of a reduction in timber harvests where wood materials are replaced by nonwood materials. He concludes that "if nonrenewable structural materials replace … structural wood… there will be significant increases in global energy consumption and in carbon dioxide added to the atmosphere…". (p. 31)

Table 2. Net Energy required per ton of lumber product or its nonwood equivalent.

Products	Lumber (million Btu oil equivalent	Nonrenewable
Studs (lumber vs. steel)	2.91	26.67
Floor surface (lumber vs. carpet)	2.91	12.27
Floor structure (joist structure vs. concrete)	4.14	86.37
Average	3.32	41.75
Penalty per ton of lumber replaced	38.43	

Source: Koch 1992, Table 9.

A second study, by Buchanan and Levine (1999), uses carbon coefficients derived by Honey and Buchanan (1992) and Buchanan and Honey (1994), together with embodied energy figures for a wide range of building materials drawn from Baird and Chan (1983). This study compares wood with other materials in terms of stored carbon and emissions of carbon dioxide from fossil fuel energy use in manufacturing products. The analysis of the typical forms of building construction common in New Zealand shows that wood buildings require much lower processed energy and result in lower carbon emission than buildings of other materials such as brick, aluminum, steel and concrete. Other studies, such as Alcorn (1998) and Baird et al 1997), show coefficients similar to those of Buchanan and Levine, with a downward trend through time in the use of processed energy for many materials.

Buchanan and Levine estimate that increased wood usage in the New Zealand building industry would result in a substantial reduction in carbon emissions from the manufacture of all building materials. They conclude that "the reduction in emissions is mainly a result of using wood in place of brick and aluminum, and to a lesser extent steel and concrete, all of which require much more process energy than wood" (p. 427).

Buchanan and Levine find that the substitution of wood for other material in construction in New Zealand could result in a substantial reduction in emissions from the manufacture of all building materials (20%). They also estimate a corresponding reduction of New Zealand's fossil fuel consumption of about 1.5 percent with a reduction in total carbon emissions of 1.5 percent.

Similar results were also found in a number of other countries and regions. For example, Suzuki, Tatsuo and Okada (1995) had similar results for Japan and Marcea and Lau (1992) for Canada.

Poles: A Case Study

In an interesting and more focused analysis (Kunniger and Richter 1995) develop a comprehensive life cycle analysis of utility poles for Switzerland. They follow-up on the earlier Erlandsson et al (1992) study that concluded treated roundwood poles have lower process energy requirements and create less air pollution and carbon dioxide emissions than do the substitute materials steel, aluminum and concrete.

The Kunniger and Richter study also extended and completed the life cycle information of treated products and their alternatives by analyzing the energy and materials flows connected with utility poles and transmission lines existing in Switzerland. (p. 73). The

Table 3. Primary Energy Consumption (MJ)

(CO_2 equivalents in kg)

	Concrete	Roundwood	Tubular Steel
Primary energy consumption	1,889.9	2,673.7	8,614.7
Primary energy based on fossil energy	1,823.7	1,132.0	8,315.9

Source: Kunniger and Richter 1995.

study evaluates the ecological consequences of wooden utility poles (CCF) impregnated roundwood with the alternatives of reinforced concrete and steel. The entire life cycle of the poles was analyzed including the following stages: extraction and processing of raw materials, energy supply, pole production and set-up, maintenance, dismounting, recycling and disposal. Transport within and between the different stages was taken into account. The study assumes that the service life of wooden poles is only one-half that of other materials, one replacement of each wooden pole was included in the analysis. Furthermore, the study assumed that more wooden poles were required per kilometer than either concrete or steel.[1] Based on data from the existing Swiss electricity transmission lines, a comprehensive inventory was established of all carbon dioxide extractions from and emissions to the environment caused by each process step.

Their findings with respect to energy consumption are presented in table 3. It will be noted that it is estimated that the roundwood energy required, based on fossil fuel energy, is considerably less than that for concrete or steel. The data indicate that tubular steel consumes 4 times as much energy as concrete and roundwood poles. Furthermore, while most energy for concrete and tubular steel is generated by fossil fuels, a large fraction of energy used for roundwood is based on regenerative resources, e.g., biofuels from logging residuals. Regenerative resources like biofuels are not viewed as contributing to carbon dioxide build-up in the atmosphere since the biological regrowth that will sequester carbon is assumed to totally offset emissions. Thus, the global warming potential for roundwood poles is further reduced since biofuels from the logging residues, rather than fossil fuels, provide a substantial fraction of the energy used in the production of the poles (see table 3 rows 1 and 2).

Table 4 gives the global warming potential as estimated in the KR study where substances that contribute to the greenhouse effect are summarized using CO_2 as a reference. The first row indicates the greenhouse effect per pole, while the second row estimates the effect for one kilometer of wiring, since the study assume that it typically requires slightly more wooden poles per kilometer. The table indicates that the global warming potential of a regular roundwood "pole" is about one-fifth that of concrete pole and about one thirtieth that of steel.

*Table 4. Global Warming Potential**

(CO_2 equivalents in kg)

Pole Type	Concrete	Roundwood	Tubular Steel
Regular Pole: 0.4kV	167.1	33.5	1,039.6
1 km distribution line: 0.4Kv	17,287.4	3,831.2	38,267.7

*Substances which contribute to the greenhouse effect are summarized as CO_2 equivalent in kg.
Source: Kunniger and Richter 1995.

[1] The study assumed 38 wood poles per kilometer for a 0.4 kV distribution line, whereas only 31 concrete or steel poles were required. Some industry specialists dispute the need for more wood poles than those of the other materials.

On a global warming potential per kilometer approach, where wooden poles are assumed to have a shorter life and where it is assumed that there are more wooden poles required per kilometer, roundwood poles still generate only one-fifth the global warming potential of concrete and one-tenth the that of steel.

It is clear from the findings of KR that wooden poles are substantially more environmentally benign than concrete or steel poles with regard to their utilization of energy and their potential to contribute to atmospheric carbon dioxide, which promotes global warming. The KR study concludes "the results show that impregnated roundwood utility poles in fact have certain environmental benefits when considered over their whole life cycle." (p. 72)

The findings of KR are consistent with the earlier results of Koch. For example, when examining poles Koch noted that a ton of wooden fence posts, butt-treated with water borne copper naphthenate, requires a net energy input of about 4.00 million Btu (oil equivalent), while an equivalent number of steel fence posts requires about 23.65 million Btu, or roughly a six-fold increase in energy utilization.

An Estimate of the Effect on the US GHG Emissions of Replacing Wooden Poles with Steel

The U.S. has about 110 million utility poles currently in use (North Pacific Group Inc. 2001). Using the figure of 38 wooden poles per kilometer of the Swiss researchers cited above, this is equivalent to about 2.895 million kilometers of poles. Using the assumption that a life cycle for steel poles is twice that of roundwood and a requirement of somewhat higher use per kilometer of wood poles than steel poles, the Swiss estimate that one kilometer of wooden poles would generate 34,436 kilograms less of CO_2 GHGs equivalents than would steel poles (table 4).[2] If all of the wooden utility poles in the U.S., roughly equivalent to 2.9 million kilometers, were replaced by steel, the GHG net emissions required for the production and substitution of steel for wooden poles would be equivalent to 100 million metric tons of CO_2, or 27.3 million metric tons of carbon[3].

Additionally, the destruction of existing poles (roughly 20 cubic meters of wood per pole), without their replacement by other wooden poles, would result in net emissions of 63 million tons of CO_2 or about 17.2 tons of carbon.[4] Total emissions of 163 million tons of CO_2 is about 2.8 percent of US annual emissions, which are estimated at about 5.9 billion tons of CO_2 annually. Thus, the conversion from wooden utility poles to steel would result in a small but significant increase in total US emissions.

Summary and Implications

This paper has summarized a number of studies that compare the total life cycle energy utilization of the use of wood products with the use of substitute materials such as steel, concrete, bricks and aluminum. These studies were undertaken by different researchers at different times in several countries in North America and Europe, as well as New Zealand. The examinations included a wide range of different construction materials as well as a detailed case study investigating the use of different materials for utility poles. Without exception all the studies found that the total energy requirements associated with wood materials are substantially lower than those of other commonly substituted materials.

The green house gases implications, as noted, will vary depending upon the type of energy used. At the one extreme nuclear and hydropower create no greenhouse gases in their direct production of energy, although the construction of nuclear and hydro facilities undoubtedly generates some GHG emissions. Additionally, emissions of carbon vary with the type of fossil fuel used. For example, natural gas emits substantially less carbon dioxide per unit of power than does coal. Nevertheless, there is no question but that in most countries, where fossil fuels provide a substantial part of the energy base, wood materials will emit significantly less carbon dioxide than would the commonly substituted materials.

The wooden poles case study used to estimate the effect of the conversion of wood to steel poles in the U.S. shows that, although the GHG emissions associated with pole conversion were modest compared to the national total, they were nevertheless a significant percent of US annual emissions. Emissions of a total of 163 million tons of CO_2 equivalent GHGs is about 2.8 percent of US annual emissions, which are estimated at about 5.28 billion tons of CO_2 annually. Thus, the conversion from wooden

[2] As noted, the Swiss assumption is skewed toward providing steel poles with a longer life advantage than may be warranted.
[3] Carbon content of carbon dioxide by weight is 27.2 percent.
[4] Using the conversion factors of Sedjo and Solomon 1989.

utility poles to steel would result in a small but significant increase in total US emissions.

More broadly, these studies provide empirical confirmation of concepts developed in the *Third Assessment Report* (IPCC 2001), whereby the substitution of high energy intensive materials for low-energy-using wood materials, contributes substantially to the overall increase of carbon dioxide emissions through their overall higher energy requirements.

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Dr. Roger Sedjo is Senior Fellow in the Energy and Natural Resources Division of Resources for the Future. He is also director of that organization's Forest Economics and Policy Program. Dr. Sedjo has been a consultant to several international agencies; his principal interests are long-term forest sustainability and environmental problems related to international forestry and global forest production. He is the author or editor of 13 books on forestry and resources. After obtaining bachelor's and master's degrees at the University of Illinois, he earned a Ph.D. in economics from the University of Washington.

North American Wood Pole Coalition

American Wood Preservers Institute
703-204-0500

Canadian Institute of Treated Wood
613-737-4337

Southern Pressure Treaters Association
703-204-0500

Western Red Cedar Pole Association
800-410-1917

Western Wood Preservers Institute
800-729-9663