Monitoring Progress Toward the AF&PA Climate VISION Commitment

Report on progress 2000 to 2006

Prepared by NCASI – May 2008

Introduction

The American Forest and Paper Association (AF&PA) was one of the original participants in the US government's Climate VISION program, a voluntary sector-level initiative intended achieve reductions in greenhouse gas intensity in the manufacturing sector of the economy.[1] In a January 21, 2003 letter to the Administration, Mr. Henson Moore, President and Chief Executive Officer of AF&PA, indicated that a variety of forest product industry activities were expected to "reduce our greenhouse gas intensity by 12 percent by 2012 relative to 2000." In addition, that letter indicated that "AF&PA members [would] develop a system to verify any reductions we report." The material below describes the system being used to estimate reductions made by the industry under the Climate VISION program.

Overview of the AF&PA commitment under the Climate VISION program

The AF&PA letter to the administration indicates that a number of different activities will help reduce the industry's greenhouse gas intensity. The letter specifically identifies four areas of industry activity – sequestration, research and development, recycling, and energy efficiency – and describes the role of each as follows.

"**Sequestration**: With more than 114 million acres enrolled in the program, the Sustainable Forestry Initiative® program – or SFI® – is the largest sustainable forestry program in the world. … Adherence to the SFI Standard is a condition of AF&PA membership and represents a strong commitment to enhanced forest productivity and improved forest management. We believe that one result of this commitment is significant sequestration of carbon on the nation's forestlands."

"Additionally, the industry today produces products that sequester carbon for decades or longer. Increasing demand for forest products also could increase the amount of carbon stored in products, offsetting some portion of the industry's greenhouse gas emissions."

"**Research and Development**: Research and development (R&D) through industry, academic and government partnerships will address key technology gaps. Our research partnerships with Department of Energy continue to be an effective vehicle for development of improved energy efficient processes including breakthrough technologies…."

"**Recycling**: The industry also has a strong commitment to recycling, which avoids greenhouse gas emissions from products prematurely disposed of in landfills….We expect that our recovery rate objective of at least 50 percent will also be met and lead to

[1] Greenhouse gas intensity is the amount of greenhouse gas emitted per unit of manufactured goods or services.

corresponding reductions in greenhouse gas emissions by facilitating sequestration and avoiding methane emissions from land fills…."

"**<u>Energy Efficiency</u>**: Finally, the industry will continue to derive over half of its energy requirements from renewable energy or biofuels. We recover energy from our waste stream by utilizing residual biomass as a primary energy source for our manufacturing processes. Moreover, the forest products industry leads all other manufacturing sectors in onsite electricity generation, meeting more than half of our own energy needs through highly efficient co-generation processes. At many mills, self-generated electricity goes beyond serving onsite production needs by providing supplemental electricity to the surrounding electric power grid."

<u>Quantifiable metrics for the activities outlined in the AF&PA commitment letter</u>

To monitor progress in the areas described in the AF&PA commitment letter, it is necessary to define a series of metrics that characterize the industry's performance in each area. The following material describes these metrics. Details on the calculations for each metric are contained in the Appendices to this document. Efforts will be made to use the most current information available in calculating these metrics.

Sequestration: These activities can be divided into two distinct categories – carbon sequestration in forests and carbon sequestration in forest products.

Forest Carbon Sequestration Metric: The U.S. Forest Service indicates that the net sequestration on private timberland in the United States is the equivalent of approximately 200 million metric tons of CO_2 per year. [2] Some of this land is owned by AF&PA members but much is not. Unfortunately, data are not available to determine the net sequestration accomplished on all of the land owned or managed by AF&PA members. AF&PA members, however, must certify that the lands they own are sustainably managed under the Sustainable Forestry Initiative (SFI®). The 1605b program for Voluntary Reporting of Greenhouse Gases recognizes that lands managed under SFI® are, at worst, likely to be net zero contributors to sequestration. Accordingly, although the forests belonging to AF&PA members may be sequestering carbon, for purposes of this commitment this sequestration will not be considered.

Product Carbon Sequestration Metric: The industry will calculate the annual carbon sequestration in forest products in-use using a method called "the 100-year method." This method, developed and first used by Georgia Pacific Corporation, and since endorsed by the International Council of Forest and Paper Associations (ICFPA) calculates the amount of carbon in the current year's production that is in products expected to be in use for at least 100 years. It has been adopted as one of the accepted methods under the 1605b program for Voluntary Reporting of Greenhouse Gases. Details on the calculations for the Product Carbon Sequestration Metric are contained in Appendix A.

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[2] Bickel, K. et al. 2004. *U.S. agriculture and forestry greenhouse gas inventory: 1990-2001*. Technical Bulletin No. 1907. United States Department of Agriculture, Global Change Program Office, Office of the Chief Economist.

Research and Development: Activities in this area will result in improvements in a number of different areas. For instance, research and development may yield technologies that allow the industry to substitute more biomass for fossil fuels, lowering the industry's direct greenhouse gas emissions. New technologies may also allow the industry to export more biomass-derived electricity, accomplishing overall reductions in greenhouse gas emissions by displacing fossil fuel-derived electricity on the grid. A different type of research and development may result in products that last longer and thereby increase carbon sequestration in products in-use. The impacts of activities undertaken in the "research and development" area are varied and their effects need to be captured by the metrics that address the particular type of activity involved.

Recycling: As a result of paper recycling by AF&PA members, material is kept out of municipal solid waste landfills and methane emissions from those landfills are lower than they would have been if the paper not been recycled. This metric, therefore, quantifies the avoided methane releases associated with increased paper recycling.

Avoided Methane Emissions Metric: EPA has examined the greenhouse gas and carbon implications of using various methods to manage the major components of the municipal solid waste stream. EPA's analysis can be used to specifically examine the effects of paper recycling on methane releases from municipal solid waste landfills. EPA's analysis has been used to develop emission factors representing the amounts of methane avoided per ton of paper recycled. The emission factors are then multiplied by the quantities of paper recycled by AF&PA members in any given year. The quantities of paper being recycled are determined based on data collected by AF&PA. Details on the Avoided Methane Emissions Metric calculations are contained in Appendix B.

Energy Efficiency: Improvements in energy efficiency can be expected to result in reductions in greenhouse gas intensity. More broadly, however, the greenhouse gas intensity of the industry's manufacturing operations is related not only to energy efficiency but also to fuel selection and many other factors. For this reason, the impacts of energy efficiency must be captured in more generalized metrics.

For purposes of tracking performance in the VISION program a metric will be used that characterizes the direct greenhouse gas emissions of the industry's manufacturing operations. (Direct emissions are those released from forest products manufacturing-related sources that are owned or controlled by AF&PA members.) [3]

Direct Emissions Metric: An earlier examination of emission sources determined that CO_2 emissions from stationary combustion of fossil fuels represent at least 90% of direct emissions from the U.S. forest products industry. In addition, it is these emissions that can be estimated with greatest accuracy. It is reasonable, therefore, to base this metric on direct emissions of CO_2 from stationary combustion of fossil fuel. AF&PA collects data on fossil fuel consumption at member companies and these data, along with emission factors from the WRI/WBCSD GHG

[3] The industry will also track the greenhouse gas implications of improvements that lead to reduced purchases of electricity and corresponding reductions in indirect emissions, but these reductions will not be used to measure progress against the intensity target under the VISION program. (Indirect emissions are those that are the result of AF&PA member operations but are released from sources not owned or controlled by the members.)

Protocol tools, will be used to estimate CO_2 emissions. Details on the calculation of this metric are in Appendix C.

Calculating improvements in the industry's overall greenhouse gas emissions intensity

Four metrics are being used to characterize the various activities embodied in the AF&PA Climate VISION commitment. These are;

- *Forest Carbon Sequestration Metric*
- *Product Carbon Sequestration Metric*
- *Avoided Methane Emissions Metric*
- *Direct Emissions Metric*

The calculation of intensity involves a numerator and a denominator. The numerator is a measure of emissions while the denominator is a measure of industry output. The output statistic used in the calculation is metric tons of final product.

AF&PA collects data from its members on production of pulp, paper and paperboard and the statistics developed from these data will be used in the calculations. Production statistics for wood products will also be taken from AF&PA surveys of its members. The development of a production statistic for calculating GHG intensity is discussed in detail in Appendix D. Production statistics are also used in calculating some of the individual metrics, as discussed in the appendices describing the specific metrics.

Results for 2000 through 2006

The Appendices to this report contain a more detailed explanation of the specific calculations for 2000 through 2006. The results are shown below in Tables 1, 2 and 3 [4]. Although it is good practice not to combine indirect and direct emissions, this is done in Table 2 to document that, in spite of increased electricity purchases, the industry's overall performance has improved. In Table 3, the absolute emissions are shown after correcting for the effect of the decreased production in AF&PA's membership.

[4] In some cases, the appendices contain estimates carried out to four or more significant figures, but in the summaries shown in Tables 1, 2, and 3, the estimates are rounded to three significant figures. In the opinion of the authors, the use of more than three significant figures misrepresents the accuracy expected of these estimates.

Table 1. Emissions, sequestration, avoided emissions and production data for the Climate VISION commitment

	Data for AF&PA members only			
	2000	2002	2004	2006
Pulp and paper direct emissions, metric tons CO_2	60,300,000	52,500,000	47,700,000	39,800,000
Wood products direct emissions, metric tons CO_2	880,000	1,000,000	1,000,000	740,000
Industry total direct emissions, metric tons CO_2	61,200,000	53,500,000	48,700,000	40,500,000
Pulp and paper indirect emissions*, metric tons CO_2	22,100,000	22,500,000	21,300,000	21,700,000
Wood products indirect emissions*, metric tons CO_2	4,690,000	5,460,000	4,990,000	4,100,000
Industry total indirect emissions*, metric tons CO_2	26,800,000	27,900,000	26,230,000	25,800,000
Forest carbon sequestration, metric tons CO_2 eq.	0	0	0	0
Forest products sequestration in use, metric tons CO_2 eq.	-25,970,000	-28,200,000	-25,700,000	-23,800,000
Avoided emissions due to recycling, metric tons CO_2 eq.	-24,400,000	-24,400,000	-23,300,000	-21,100,000
Pulp and paper production, metric tons	83,700,000	77,600,000	77,700,000	71,800,000
Wood product production, metric tons	35,500,000	40,200,000	35,700,000	32,300,000
Total production, metric tons	119,000,000	118,000,000	113,000,000	104,000,000

* Related to purchased electricity, net basis

Table 2. Change in emissions intensity from 2000 for AF&PA members

	2000		2002		2004		2006	
	Emissions (10^6 metric tons CO_2 eq.)	Emissions intensity (ton CO_2 eq. per ton production)	Emissions intensity (ton CO_2 eq. per ton production)	Change in emissions intensity (%)	Emissions intensity (ton CO_2 eq. per ton production)	Change in emissions intensity (%)	Emissions intensity (ton CO_2 eq. per ton production)	Change in emissions intensity (%)
Direct emissions	61.2	0.513	0.454	- 11.4%	0.429	- 16.3%	0.389	- 24.1%
Indirect emissions	26.8	0.225	0.237	5.4%	0.232	3.1%	0.248	10.2%
Direct plus indirect emissions	88.0	0.738	0.691	- 6.3%	0.661	- 10.4%	0.637	- 13.6%

Table 3. Emissions from AF&PA members, adjusted for changes in production

	Data for AF&PA members only			
	2000	2002	2004	2006
Adjusted pulp and paper direct emissions, metric tons CO_2	51,700,000	48,600,000	44,100,000	39,800,000
Adjusted wood products direct emissions, metric tons CO_2	800,000	800,000	900,000	740,000
Adjusted total industry direct emissions, metric tons CO_2	53,400,000	47,300,000	44,700,000	40,500,000
Adjusted pulp and paper indirect emissions*, metric tons CO_2	19,000,000	20,800,000	19,700,000	21,700,000
Adjusted wood products indirect emissions*, metric tons CO_2	4,270,000	4,390,000	4,510,000	4,100,000
Adjusted total industry indirect emissions*, metric tons CO_2	23,400,000	24,700,000	24,100,000	25,800,000
Pulp and paper production, metric tons	83,700,000	77,600,000	77,700,000	71,800,000
Wood product production, metric tons	35,500,000	40,200,000	35,700,000	32,300,000
Total production, metric tons	119,000,000	118,000,000	113,000,000	104,000,000

* Related to purchased electricity, net basis

APPENDIX A

CALCULATION OF THE PRODUCT CARBON SEQUESTRATION METRIC

THE 100-YEAR METHOD FOR ESTIMATING CARBON SEQUESTRATION IN PRODUCTS IN-USE

While forest products are being used, they keep carbon out of the atmosphere. A fraction of the carbon in forest products may remain in-use and sequestered from the atmosphere for so long that it becomes significant with respect to concerns about the global carbon balance and climate change.

A 100-year time horizon can be used to estimate the amounts of biomass carbon that can be expected to remain sequestered from the atmosphere in products in-use for very long periods of time. The approach has been called "the 100-year method." The 100-year method was first suggested and applied by Dr. Sergio Galeano of Georgia-Pacific Corporation [Georgia-Pacific 2002]. Dr. Galeano described its use in the context of an example of life cycle impact assessment published by the International Organization for Standardization (ISO) [ISO 2003]. It was recently accepted as a method under the 1605b program for Voluntary Reporting of Greenhouse Gases [USDOE 2006] and is described in more detail in Miner (2006).

1.0 USING THE 100-YEAR METHOD

The 100-year method involves five steps.

1. Identify the types and amounts of biomass-based products (e.g. softwood lumber) that are produced in the year of interest.[5]

2. Divide the industry's output into categories reflecting the final uses for these products. Calculate the amounts in each final use, taking into account intermediate manufacturing losses as appropriate.

3. Express annual production in terms of biomass carbon.

4. Use mathematical relationships or other time-in-use information to estimate the fraction of the carbon expected to remain in use for 100 years.

5. Multiply the amount of carbon in products by the fraction remaining at 100 years. The result is the amount of sequestered carbon attributable to this year's production.

These five steps are examined in more detail in the following discussion.

[5] When using time-in-use information for specific products, the 100-year method does not distinguish between products based on whether the inputs are virgin or recycled because this does not influence how long the *product* remains in use. If values for time-in-use are based on the length of time a *fiber* is in use, adjustments can be made to deal with the effect of recycling (as is done in the 1605b program).

1.1 Step 1: Identify the types and amounts of biomass-based products (e.g. softwood lumber, free sheet, etc.) that are produced in the year of interest.

For step 1, data on current production is obtained from AF&PA statistics.

1.2 Step 2: Divide the industry's output into categories reflecting the final uses for these products. Calculate the amounts in each final use, taking into account intermediate manufacturing losses as appropriate.

For purposes of documenting progress under the Climate VISION program, the categories for product use (except paper and paperboard) will be those identified by Skog and Nicholson (Skog 1998). For paper and paperboard, only a single category will be used in the VISION calculation. These categories, and the respective half-lives each type of use are shown in the Table A1. These were recently updated (USEPA 2008), but to provide a consistent series over time, we are continuing to use the values shown below.

Table A1. Duration of carbon sequestration in end uses of wood and paper (Skog and Nicholson 1998)

	Half-life of product (years)
Single-family homes (post-1980)	100
Multifamily homes	70
Mobile homes	20
Nonresidential construction	67
Pallets	6
Manufacturing	12
Furniture	30
Railroad ties	30
Paper (free sheet) (not used in VISION calculations)	6
Paper (all others) (not used in VISION calculations)	1
For paper and paperboard VISION calculations (not from Skog and Nicholson)	2

To account for losses that occur in intermediate stages of manufacturing (i.e. in converting primary products into final products), we are using, the factors suggested by Skog and Nicholson (Skog and Nicholson 1998). These factors indicate that 8% of solid wood is lost in intermediate processing and 5% of paper and paperboard is lost.

1.3 Step 3: Express annual production in terms of biomass carbon

The quantity of carbon in products is estimated by multiplying the quantity of product by its biomass carbon content. The carbon contents shown in Table A2 are used in the Climate VISION calculations.

Table A2. Carbon Contents used in Climate VISION calculations

(Note: The carbon contents of specific products can vary significantly. The values in the following table are felt to be reasonable considering the range encountered across the major product categories of the US forest products industry.)

Product	Carbon content %
Lumber	50
Wood Panels (structural and nonstructural)	45
Paper and paperboard	40

1.4 Step 4: Use mathematical relationships or other time-in-use information to estimate the fraction of the carbon expected to remain in use for 100 years.

The calculations for the Climate VISION program are being done using the Row and Phelps decay equations (Row and Phelps 1996). These decay equations are described by the following equations (Row and Phelps 1996).[6]

[6] The original Row and Phelps 1996 publication [Row and Phelps 1996] contained typographical errors in the equations. The equations shown here have been corrected.

Equation A1: Row and Phelps Decay Curve

\Equation A1a: *If:* *Y < HL/2*

$$FR = 1 - \left(0.4191 * \frac{Y}{HL}\right)$$

Equation A1b: *If:* *Y > HL/2 and Y < HL*

$$FR = 1 - \left(\frac{0.5}{1 + \left(2 * \ln(HL / Y)\right)}\right)$$

Equation A1c: *If:* *Y > HL*

$$FR = \left(\frac{0.5}{1 + \left(2 * \ln(Y / HL)\right)}\right)$$

Where: *FR = Fraction of carbon remaining in use in year Y*

HL = half-life (years)

Y = elapsed time (years)

In the 100-year method, only the fraction remaining in use after 100 years is of interest. The fraction remaining at 100 years can be estimated directly from product half-life using the equations above by substituting 100 years for "Y," as shown in below.

The Row and Phelps decay curve consists of three different equations. Only in cases where product half lives are greater than 100 years is it necessary to use the first or second of these equations.

Equation A2: Row and Phelps Decay Curve – Fraction remaining after 100 years

Equation A2a: *If:* *HL > 200 years*

$$FR100 = 1 - \left(0.4191 * \frac{100}{HL}\right)$$

Equation B2b: *If:* *HL = 100 to 200 years*

$$FR100 = 1 - \left(\frac{0.5}{1 + \left(2 * \ln(HL/100)\right)}\right)$$

Equation A2c: *If:* *HL is 100 years or less*

$$FR100 = \left(\frac{0.5}{1 + \left(2 * \ln(100/HL)\right)}\right)$$

Where: *FR100 = Fraction of carbon remaining in use after 100 years*

HL = half-life (years)

Table A3 shows the fraction of carbon remaining for products having a range of half-lives.

Table A3: Lookup Table for fraction remaining in use after 100 years

Half-life of product during use (years)	Row and Phelps equations (Row 1996)	Half-life of product during use (years)	Row and Phelps equations (Row 1996)
1	0.049	60	0.247
2	0.057	65	0.269
5	0.072	70	0.292
6	0.075	75	0.317
10	0.089	80	0.346
15	0.104	85	0.377
20	0.119	90	0.413
25	0.133	95	0.453
30	0.147	100	0.500
35	0.161	125	0.654
40	0.177	150	0.724
45	0.193	175	0.764
50	0.210	200	0.790
55	0.228	250	0.832

1.5 Step 5: Multiply the amount of carbon in products by the fraction remaining at 100 years

Having determined the fraction of carbon in each product that will remain in use for 100 years, the quantities of sequestered carbon are calculated by simply multiplying this fraction by the amount of carbon in product (from 1.3 above).

2.0 USING THE 100-YEAR METHOD ON 2000 THROUGH 2006 DATA FROM THE US FOREST PRODUCTS INDUSTRY

Step 1: Identify the types and amounts of biomass-based products that are produced in the year of interest.

The production statistics for AF&PA members are summarized in Table A4. In Table A5, the production statistics are converted to metric tons. The wood products production statistics are from the AF&PA Environmental, Health, and Safety (EHS) survey. The paper and paperboard production statistics are collected by AF&PA in other surveys.

Table A4: AF&PA member production statistics – 2000, 2002, 2004 and 2006

Product	2000 Production	2002 Production	2004 Production	2006 Production	Units
Lumber	1,000,000	1,200,000	960,000	951,000	Thousand cubic feet
Structural Wood Panels (3/8 inch basis)	760,000	850,000	820,000	769,000	Thousand cubic feet
Nonstructural Wood Panels (3/8 inch basis)	389,000	360,000	360,000	162,000	Thousand cubic feet
Paper and paperboard	92,300,000	85,600,000	85,700,000	79,100,000	Short tons

Table A5: AF&PA member production statistics (metric tons) – 2000, 2002, 2004 and 2006

Product	Conversion factors * from units in Table A4 to Metric Tonnes	Metric Tonnes			
		2000	2002	2004	2006
Lumber	16.35 **	16,400,000	19,600,000	15,700,000	15,600,000
Structural Wood Panels	19.43 ***	14,800,000	16,500,000	15,900,000	14,900,000
Nonstructural Wood Panels	11.36 ****	4,400,000	4,100,000	4,000,000	1,840,000
Paper and paperboard	0.907	83,700,000	77,700,000	77,700,000	71,800,000

* Conversion from AF&PA survey units to volume units based on AF&PA Environmental, Health and Safety survey conversion factors. Conversion of volume to mass based on Howard, J.. 2001. *U.S. timber production, trade, consumption, and price statistics: 1965 – 1999*. Research Paper FPL-RP-595, United States Department of Agriculture, Forest Products Laboratory, Madison WI, 2001
** Weighted average of softwood and hardwood lumber, based on 1998 production data in McKeever 2002 (73% softwood and 27% hardwood
*** Weighted average of plywood (61%) and OSB (39%), based on production data in McKeever 2002
**** Weighted average of hardwood plywood (10%), particle board including MDF (65%), hardboard (8%) and insulation board (17%), based on production data in McKeever 2002

Step 2: Divide the industry's output into categories reflecting the final uses for these products, taking into account intermediate manufacturing losses as appropriate.

The distribution of wood products among various uses was determined using information published by the U.S. Forest Service in 1998. The data are summarized in Table A6, below. Paper and paperboard do not need to be categorized according to end use because the half-life estimates being used in the calculations do not depend on end use. (See Table A1.)

Table A6. The distribution of forest products in commerce in the US

	Percent going to each use			
	Lumber*	Structural panels*	Nonstructural panels*	Paper & paperboard
Single family home	28.6%	46.8%	13.8%	0%
Multifamily home	2.7%	4.1%	2.0%	0%
Mobile homes	3.3%	4.9%	4.0%	0%
Residential upkeep	22.0%	20.9%	11.8%	0%
Non-residential construction	7.2%	8.3%	5.6%	0%
Railroad ties, etc.	1.1%	0.0%	0.0%	0%
Manufacturing - furniture	8.1%	5.4%	37.6%	0%
Manufacturing - other	4.9%	5.4%	10.0%	0%
Pallets and shipping	11.3%	1.8%	0.6%	0%
Other	10.7%	2.6%	14.7%	100%
Totals	100.0%	100.0%	100.0%	100.0%

* McKeever DB.. 2002. *Domestic market activity in solid wood products in the United States, 1950-1998*. Gen. Tech. Rep. PNW-GTR-524, Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 2002.

To determine the amounts of going to each use, the percentages in Table A6 are multiplied by the quantities A5. The results for 2000, 2002, 2004 and 2006 production are shown in Tables A7, A8, A9 and A10, respectively.

Table A7. 2000 - Quantities of products from AF&PA members by function

	Tonnes of products going to each use			
	Lumber	Structural panels	Nonstructural panels	Paper & paperboard
Single family	4,680,000	6,910,000	610,000	0
Multifamily	437,000	605,000	87,400	0
Mobile homes	536,000	717,000	175,000	0
Residential upkeep	3,600,000	3,090,000	522,000	0
Non-residential construction	1,180,000	1,220,000	247,000	0
Railroad ties, etc.	179,000	0	0	0
Manufacturing - furniture	1,330,000	795,000	1,660,000	0
Manufacturing - other	805,000	791,000	441,000	0
Pallets and shipping	1,850,000	264,000	24,400	0
Other	1,750,000	378,000	652,000	83,700,000

Table A8. 2002 - Quantities of products from AF&PA members by function

	Tonnes of products going to each use			
	Lumber	Structural panels	Nonstructural panels	Paper & paperboard
Single family	5,620,000	7,730,000	566,000	0
Multifamily	524,000	677,000	81,100	0
Mobile homes	643,000	802,000	162,000	0
Residential upkeep	4,320,000	3,450,000	484,000	0
Non-residential construction	1,410,000	1,370,000	230,000	0
Railroad ties, etc.	214,000	0	0	0
Manufacturing - furniture	1,600,000	889,000	1,540,000	0
Manufacturing - other	966,000	884,000	409,000	0
Pallets and shipping	2,220,000	295,000	22,7000	0
Other	2,110,000	7,730,000	605,000	77,60,000

Table A9. 2004 - Quantities of products from AF&PA members by function

	Tonnes of products going to each use			
	Lumber	Structural panels	Nonstructural panels	Paper & paperboard
Single family	4,500,000	7,460,000	558,000	0
Multifamily	419,000	653,000	80,000	0
Mobile homes	515,000	773,000	160,000	0
Residential upkeep	3,460,000	3,330,000	477,000	0
Non-residential construction	1,130,000	1,320,000	226,000	0
Railroad ties, etc.	172,000	0	0	0
Manufacturing - furniture	1,280,000	858,000	1,520,000	0
Manufacturing - other	773,000	853,000	404,000	0
Pallets and shipping	1,770,000	285,000	22,4700	0
Other	1,680,000	408,000	596,000	77,700,000

Table A10. 2006 - Quantities of products from AF&PA members by function

	Tonnes of products going to each use			
	Lumber	Structural panels	Nonstructural panels	Paper & paperboard
Single family	4,450,000	6,990,000	254,000	0
Multifamily	415,000	612,000	36,400	0
Mobile homes	510,000	725,000	72,900	0
Residential upkeep	3,420,000	3,120,000	217,000	0
Non-residential construction	1,120,000	1,240,000	103,000	0
Railroad ties, etc.	170,000	0	0	0
Manufacturing - furniture	1,270,000	804,000	692,000	0
Manufacturing - other	766,000	800,000	184,000	0
Pallets and shipping	1,760,000	267,000	10,200	0
Other	1,670,000	382,000	271,000	71,800,000

To account for losses in converting primary products into final products, the amounts of wood product going to each use are corrected by 8% while the paper products are corrected by 5% (Skog and Nicholson 1998). The resulting values for 2000, 2002, 2004 and 2006 are shown in Tables A11, A12, A13 and A14 respectively.

Table A11. 2000 - Quantities of products from AF&PA members by function, corrected for intermediate processing losses

	Tonnes of final product			
	Lumber	Structural panels	Nonstructural panels	Paper & paperboard
Single family	4,310,000	6,360,000	561,000	0
Multifamily	402,000	557,000	80,400	0
Mobile homes	493,000	659,000	161,000	0
Residential upkeep	3,310,000	2,840,000	480,000	0
Non-residential construction	1,080,000	1,120,000	228,000	0
Railroad ties, etc.	164,000	0	0	0
Manufacturing - furniture	1,230,000	731,000	1,530,000	0
Manufacturing - other	741,000	727,000	406,000	0
Pallets and shipping	1,700,000	243,000	22,500	0
Other	1,610,000	348,000	600,000	79,500,000

Table A12. 2002 - Quantities of products from AF&PA members by function corrected for intermediate processing losses

	Tonnes of final product			
	Lumber	Structural panels	Nonstructural panels	Paper & paperboard
Single family	5,170,000	7,110,000	520,000	0
Multifamily	482,000	623,000	74,600	0
Mobile homes	592,000	737,000	149,000	0
Residential upkeep	3,980,000	3,180,000	445,000	0
Non-residential construction	1,300,000	1,260,000	211,000	0
Railroad ties, etc.	197,000	0	0	0
Manufacturing - furniture	1,470,000	818,000	1,420,000	0
Manufacturing - other	889,000	813,000	377,000	0
Pallets and shipping	2,040,000	272,000	20,900	0
Other	1,940,000	389,000	556,000	73,800,000

Table A13. 2004 - Quantities of products from AF&PA members by function corrected for intermediate processing losses

	Tonnes of final product			
	Lumber	Structural panels	Nonstructural panels	Paper & paperboard
Single family	4,140,000	6,860,000	513,000	0
Multifamily	386,000	601,000	73,600	0
Mobile homes	473,000	711,000	147,000	0
Residential upkeep	3,180,000	3,060,000	439,000	0
Non-residential construction	1,040,000	1,210,000	208,000	0
Railroad ties, etc.	158,000	0	0	0
Manufacturing - furniture	1,180,000	789,000	1,400,000	0
Manufacturing - other	711,000	785,000	371,000	0
Pallets and shipping	1,630,000	262,000	20,600	0
Other	1,550,000	375,000	549,000	73,800,000

Table A14. 2006 - Quantities of products from AF&PA members by function corrected for intermediate processing losses

	Tonnes of final product			
	Lumber	Structural panels	Nonstructural panels	Paper & paperboard
Single family	4,097,905	6,431,917	234,000	0
Multifamily	382,281	562,921	33,500	0
Mobile homes	468,919	666,815	67,000	0
Residential upkeep	3,150,242	2,871,490	200,000	0
Non-residential construction	1,030,952	1,137,298	94,800	0
Railroad ties, etc.	156,306	0	0	0
Manufacturing - furniture	1,166,045	739,501	637,000	0
Manufacturing - other	704,495	735,550	169,000	0
Pallets and shipping	1,615,537	245,710	9,370	0
Other	1,534,928	351,579	250,000	68,200,000

Step 3:Express annual production in terms of biomass carbon.

The amounts of biomass carbon are determined by multiplying the quantities in Tables A11 to A14 by the carbon contents shown in Table A2. The results for 2000 through 2006 are shown in Tables A15 through A18, respectively.

Table A15. 2000 - Quantities of carbon from AF&PA members by function

	Tonnes of carbon			
	Lumber	Structural panels	Nonstructural panel	Paper & paperboard
Single family	2,150,000	2,860,000	252,000	0
Multifamily	201,000	250,000	36,200	0
Mobile homes	247,000	297,000	72,000	0
Residential upkeep	1,660,000	1,280,000	216,000	0
Non-residential construction	542,000	506,000	102,000	0
Railroad ties, etc.	82,200	0	0	0
Manufacturing - furniture	613,000	329,000	688,000	0
Manufacturing - other	370,000	327,000	183,000	0
Pallets and shipping	849,000	109,000	10,100	0
Other	807,000	156,000	270,000	31,800,000

Table A16. 2002 - Quantities of carbon from AF&PA members by function

	Tonnes of carbon			
	Lumber	Structural panels	Nonstructural panels	Paper & paperboard
Single family	2,590,000	3,200,000	234,000	0
Multifamily	241,000	280,000	33,600	0
Mobile homes	296,000	332,000	67,200	0
Residential upkeep	1,990,000	1,430,000	200,000	0
Non-residential construction	650,000	566,000	95,000	0
Railroad ties, etc.	98,700	0	0	0
Manufacturing - furniture	736,000	368,000	638,000	0
Manufacturing - other	444,000	366,000	169,000	0
Pallets and shipping	1,020,000	122,000	9,390	0
Other	968,000	175,000	250,000	29,500,000

Table A17. 2004 - Quantities of carbon from AF&PA members by function

	Tonnes of carbon			
	Lumber	Structural panels	Nonstructural panels	Paper & paperboard
Single family	2,070,000	3,090,000	231,000	0
Multifamily	193,000	270,000	33,100	0
Mobile homes	237,000	320,000	66,300	0
Residential upkeep	1,590,000	1,380,000	198,000	0
Non-residential construction	520,000	546,000	93,700	0
Railroad ties, etc.	78,900	0	0	0
Manufacturing - furniture	589,000	355,000	630,000	0
Manufacturing - other	356,000	353,000	167,000	0
Pallets and shipping	815,000	118,000	9,260	0
Other	775,000	169,000	247,000	29,500,000

Table A18. 2006 - Quantities of carbon from AF&PA members by function

	Tonnes of carbon			
	Lumber	Structural panels	Nonstructural panels	Paper & paperboard
Single family	2,050,000	2,890,000	105,000	0
Multifamily	191,000	253,000	15,100	0
Mobile homes	234,000	300,000	30,200	0
Residential upkeep	1,560,000	1,290,000	89,900	0
Non-residential construction	515,000	512,000	42,700	0
Railroad ties, etc.	78,200	0	0	0
Manufacturing - furniture	583,000	333,000	287,000	0
Manufacturing - other	352,000	331,000	76,000	0
Pallets and shipping	808,000	111,000	4,220	0
Other	767,000	158,000	112,000	27,300,000

Step 4: Use mathematical relationships or other time-in-use information to estimate the fraction of the carbon expected to remain in use for 100 years.

The Row and Phelps decay curves (Equation A2) and the Skog and Nicholson half-lives (Table A1) are used to estimate the carbon remaining in use for 100 years. The results are shown in Table A19.

Table A19: Fraction of carbon remaining in use for 100 years

	Values for half-life of carbon [Table B1] (years)	Fraction remaining in-use after 100 years, based on Row and Phelps decay curves (*Equation B2*)
Single-family homes (post-1980)	100	0.500
Multifamily homes	70	0.292
Mobile homes	20	0.119
Residential Upkeep	100 *	0.500
Nonresidential construction	67	0.278
Railroad ties, etc.	30	0.147
Manufacturing – furniture	30	0.147
Manufacturing – other	12	0.095
Pallets and shipping	6	0.075
Other wood products	12 **	0.095
Paper and paperboard	2	0.057

* Used half-life for single family homes
** Assume “other” uses are similar to general manufacturing uses

Step 5: Multiply the amount of carbon in products by the fraction remaining at 100 years. The result is the amount of sequestered carbon attributable to this year's production.

The fractions in Table A19 are multiplied by the quantities in Tables A20 through A23 to determine the amount of carbon expected to remain in use for at least 100 years. The results are shown in tables A24 through A27.

Table A20. 2000 - Quantities of carbon from AF&PA members remaining in use for at least 100 years

	Tonnes of carbon remaining in use for at least 100 years			
	Lumber	Structural panels	Nonstructural panel	Paper & paperboard
Single family	1,080,000	1,430,000	126,000	0
Multifamily	58,700	73,100	10,600	0
Mobile homes	29,300	35,300	8,620	0
Residential upkeep	828,000	639,000	108,000	0
Non-residential construction	151,000	141,000	28,500	0
Railroad ties, etc.	12,100	0	0	0
Manufacturing - furniture	90,100	48,400	101,000	0
Manufacturing - other	35,200	31,100	17,300	0
Pallets and shipping	63,700	8,200	759	0
Other wood products	76,700	14,900	25,600	0
Paper and paperboard	0	0	0	1,810,000
Totals	2,420,000	2,420,000	427,000	1,810,000
GRAND TOTAL FOR 2000, tonnes C				7,080,000
GRAND TOTAL FOR 2000, tonnes CO_2 eq.				26,000,000

Table A21. 2002 - Quantities of carbon from AF&PA members remaining in use for at least 100 years

	Tonnes of carbon remaining in use for at least 100 years			
	Lumber	Structural panels	Nonstructural panel	Paper & paperboard
Single family	1,290,000	1,600,000	117,000	0
Multifamily	70,400	81,800	9,810	0
Mobile homes	35,200	39,500	8,000	0
Residential upkeep	994,000	714,000	100,000	0
Non-residential construction	181,000	157,000	26,400	0
Railroad ties, etc.	14,500	0	0	0
Manufacturing - furniture	108,000	54,100	93,900	0
Manufacturing - other	42,200	34,800	16,100	0
Pallets and shipping	76,500	9,170	705	0
Other wood products	92,000	16,600	23,800	0
Paper and paperboard	0	0	0	1,680,000
Totals	2,910,000	2,710,000	396,000	1,680,000
GRAND TOTAL FOR 2002, tonnes C				7,690,000
GRAND TOTAL FOR 2002, tonnes CO_2 eq.				28,200,000

Table A22. 2004 - Quantities of carbon from AF&PA members remaining in use for at least 100 years

	Tonnes of carbon remaining in use for at least 100 years			
	Lumber	Structural panels	Nonstructural panel	Paper & paperboard
Single family	1,030,000	1,540,000	115,000	0
Multifamily	56,300	78,900	9,670	0
Mobile homes	28,200	38,100	7,890	0
Residential upkeep	795,000	689,000	98,800	0
Non-residential construction	145,000	152,000	26,100	0
Railroad ties, etc.	11,600	0	0	0
Manufacturing - furniture	86,500	52,200	92,600	0
Manufacturing - other	33,800	33,500	15,900	0
Pallets and shipping	61,100	8,850	695	0
Other wood products	73,600	16,000	23,500	0
Paper and paperboard	0	0	0	1,680,000
Totals	2,320,000	2,610,000	391,000	1,680,000
GRAND TOTAL FOR 2004, tonnes C				7,010,000
GRAND TOTAL FOR 2004, tonnes CO_2 eq.				25,700,000

Table A23. 2006 - Quantities of carbon from AF&PA members remaining in use for at least 100 years

	Tonnes of carbon remaining in use for at least 100 years			
	Lumber	Structural panels	Nonstructural panel	Paper & paperboard
Single family	1,020,000	1,450,000	52,500	0
Multifamily	55,800	74,000	4,400	0
Mobile homes	27,900	35,700	3,590	0
Residential upkeep	788,000	646,000	45,000	0
Non-residential construction	143,000	142,000	11,900	0
Railroad ties, etc.	11,500	0	0	0
Manufacturing - furniture	85,700	48,900	42,100	0
Manufacturing - other	33,500	31,400	7,220	0
Pallets and shipping	60,600	8,290	316	0
Other wood products	72,900	15,000	10,700	0
Paper and paperboard	0	0	0	1,550,000
Totals	2,300,000	2,450,000	178,000	1,550,000
GRAND TOTAL FOR 2006, tonnes C				6,480,000
GRAND TOTAL FOR 2006, tonnes CO_2 eq.				23,800,000

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APPENDIX B

CALCULATION OF THE AVOIDED METHANE EMISSIONS METRIC

Estimation of the avoided methane emissions due to paper recycling requires:

1. Definition of the baseline disposal scenario to which discarded paper would be subject if it were not recycled.

2. Evaluation of the net avoided methane emission factor for recycling versus the baseline disposal scenario.

3. Application of the net avoided methane emission factor to estimate the quantity of methane emissions avoided.

This appendix describes how each of these steps will be carried out to calculate the Avoided Methane Emissions Metric.

1. Disposal Alternatives to Paper Recycling

The disposal alternatives to paper recycling used for the Metric are landfilling (81.5%) and combustion (18.5%).

EPA (2007) presents 2006 statistics on management of municipal solid waste (MSW) in the United States that can be used to determine the fractions of paper and paperboard that are landfilled, combusted, or recycled. Figure 4 of the EPA report indicates that 55.0% of MSW is landfilled, 12.5% is combusted, and 32.5% is recovered either for recycling or composting. So, about 81.5% of unrecovered MSW is landfilled and 18.5% is combusted. About 98% of the paper in the recovered portion of MSW is recycled (AF&PA 2007).

2. Net Avoided Methane Emission Factor

When calculating *avoided* emissions, it is convenient to deal in avoided emission factors. These are equivalent, numerically, to regular emission factors except that the signs are reversed such that a negative value indicates an emission and a positive value indicates an avoided emission. The net avoided methane emission factor (NAMEF) for the Metric is the difference between the recycling avoided methane emission factor (RAMEF) and the baseline avoided methane emission factor (BAMEF):

$$NAMEF = RAMEF - BAMEF$$

The baseline avoided methane emission factor, BAMEF, is the weighted sum of the avoided emission factors for landfilling paper (LAMEF) and combusting paper (CAMEF):

$$NAMEF = RAMEF - (0.815*LAMEF + 0.185*CAMEF)$$

The various methane emission factors required for the calculation have been determined by EPA (2006) in a life-cycle assessment of emissions and sinks for greenhouse gases in solid waste management activities, including recycling, landfilling, and combustion. Of the three, only landfilling has a non-zero methane emission factor. Therefore, the calculation of the NAMEF reduces to:

NAMEF = -0.815*LAMEF

Landfill Avoided Methane Emission Factor – As the EPA (2006) analysis demonstrates, the emission factor and, therefore, the avoided emission factor, depends on the grade of paper landfilled, and the gas management practices in place at the landfill (e.g. collected & burned vs. uncontrolled). With regard to the latter factor, the Metric is based on the Year 2003 National Average gas management practices for U.S. landfills as reported by EPA (2006).

The effect of paper grade landfilled is somewhat more complex. Some grades of paper have higher emission factors (lower avoided emission factors) than others. Therefore, the overall avoided emission factor for all paper landfilled is determined by the weighted average for the mix of grades landfilled in a particular year. Moreover, the relevant avoided emission factor for the Metric is defined by the mix of grades that would be recycled if they were *not* landfilled. To determine what this mix of grades is, AF&PA recovered paper grade statistics (AF&PA 2007) are aligned with the grade-specific emission factors published by EPA (2006) to produce a grade-weighted landfill avoided methane emission factor, LAMEF. Table B1 summarizes the alignment of AF&PA and EPA grades. Where more than one EPA grade is listed for an AF&PA grade, the quantity recycled as reported by AF&PA is divided evenly among the EPA grades.

Table B1. Alignment of AF&PA and EPA Grade Descriptions

AF&PA Grades (AF&PA 2007)	EPA Grades (EPA 2006)
Mixed Grades	Magazine/Third Class Mail Phonebook Textbook Mixed Paper Broad Definition Mixed Paper Residential Definition Mixed Paper Office Paper Definition
Newspapers	Newspaper
Corrugated	Corrugated Cardboard
Pulp Substitutes	Office Paper
High Grade Deinking	Office Paper

Net Avoided Methane Emission Factor – Table B2 presents an example calculation of the grade-weighted NAMEF using data for the year 2006. The NAMEF is calculated specifically for each year.

Table B2. Calculation of LAMEF for 2006

EPA Grade	LAMEF by Grade[1], MTCE/short ton paper recycled	NAMEF by Grade[2], MTCE/short ton paper recycled	Fraction Recovered by Grade in 2006[3]	Fractional Net Avoided Methane EF, MTCE/short ton paper recycled
Corrugated	-0.32	0.26	0.575	0.150
Magazines	-0.13	0.11	0.023	0.002
Newspaper	-0.11	0.09	0.167	0.015
Office paper	-0.56	0.46	0.123	0.056
Phonebooks	-0.11	0.09	0.023	0.002
Textbooks	-0.56	0.46	0.023	0.010
Mixed Broad	-0.31	0.25	0.023	0.006
Mixed Residential	-0.29	0.24	0.023	0.005
Mixed Office	-0.30	0.24	0.023	0.006
				2006 Grade-Weighted NAMEF 0.252

[1]EPA (2006) Exhibit 6-8
[2-]0.815*LAMEF
[3]AF&PA (2007)

NAMEF 2006 = 0.252 MTCE/short ton paper recycled

Converted to CO_2 equivalents from carbon equivalents:

NAMEF 2006 = 0.924 $MTCO_2$/short ton paper recycled

Using appropriate baseline scenarios and recovered paper statistics, corresponding values for NAMEF can be calculated for 2000, 2002 and 2004.

NAMEF 2000 = 0.944 $MTCO_2$/short ton paper recycled

NAMEF 2002 = 0.925 $MTCO_2$/short ton paper recycled

NAMEF 2004 = 0.921 $MTCO_2$/short ton paper recycled

3. Application of the NAMEF

To compute the $MTCO_2$ equivalents of avoided emissions the NAMEF must be multiplied by the quantity of recovered paper recycled. The quantity used must have been subject to the same baseline scenario and have the same grade mix as was used to derive the NAMEF. AF&PA gathers statistics from its members on paper recovery and recycling every year. Table B3 summarizes the estimated emissions avoided for 2000 through 2006. The calculations will be reported for each year the avoided emissions are estimated.

Table B3. Calculating the avoided emissions in 2000 through 2006

Paper Recycled [1], million short tons				Net Avoided Methane Emission Factor (NAMEF), $MTCO_2$ avoided emissions/short ton recycled				Net Avoided Methane Emissions, million $MTCO_2$			
2000	2002	2004	2006	2000	2002	2004	2006	2000	2002	2004	2006
25.865	26.379	25.320	22.813	0.944	0.925	0.921	0.924	24.4	24.4	23.3	21.1

[1]AF&PA unpublished consumption figures for member companies in the specified year.

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APPENDIX C

CALCULATION OF DIRECT AND INDIRECT EMISSIONS

1.0 APPROACH FOR PULP AND PAPER MILLS

As part of its activities, AF&PA collects annual fuel consumption data from its members every other year. To prepare the data for use in calculating direct fossil fuel CO_2 emissions, a quality assurance/quality control (QA/QC) procedure was developed and applied to the data for the baseline year 2000. The procedure involved: comparing the AF&PA-collected data to other fuel use data gathered independently, identifying differences that were judged to be potentially significant, and verifying or correcting suspect data by contacting appropriate company personnel. AF&PA is responsible for QA/QC audits in subsequent years.

The data values are summed by fuel type and multiplied by appropriate CO_2 emission factors. Total direct CO_2 emissions are calculated by summing the total CO_2 emissions for each fossil fuel, and adjusting for the fact that fuel use data were submitted by less than 100% of the AF&PA membership. Total indirect CO_2 emissions attributed to net purchased electricity (purchased electricity minus sold electricity) are calculated and then adjusted for the fact that net purchased electricity data were submitted by less than 100% of the AF&PA membership.

1.1 QA/QC procedure details for 2000 data (baseline year)

NCASI conducted a survey of fuel consumption in 2000 for a project whose goal was to estimate SO_2 and NO_x emissions from industry combustion sources. This survey was conducted independently from the AF&PA survey; it was used to crosscheck the AF&PA data to identify values in the AF&PA data set requiring further verification. Due to the differing circumstances of the two surveys, some disagreement between the two data sets was to be expected. The intent of the QA/QC procedure was to identify and resolve differences that could materially impact the baseline CO_2 emissions estimate. Any difference between corresponding fuel use records from the two databases whose magnitude represented more than 0.1% of the nominal industry CO_2 emissions estimate (based on the original AF&PA data), were marked for further investigation with the companies involved. After investigation and resolution of these discrepancies, corrections were made as appropriate. In the 2000 data, there were 40 identified inconsistencies at 35 mills. Discrepancies at seven other mills were added to the list due to ambiguous reported information. The resulting quality-checked database was used to calculate fossil fuel-derived direct CO_2 emissions from AF&PA member pulp and paper mills.

1.2 QA/QC procedure details for 2002 and later years

Fossil fuel use data collected in 2002 and 2004 were quality checked primarily by AF&PA. In subsequent years, NCASI has had the primary responsibility for quality checking.

1.3 CO_2 Emission Factors

Emission factors used in this analysis were obtained from the WRI/WBCSD Greenhouse Gas Calculation Tools (NCASI) except as noted. The calculations used to generate emission factors are shown in Figure C1.

Many mills report use of "other fossil fuels" for fuels that are not explicitly listed in the survey. The nature of these reported "other fossil fuels" was not provided, making it difficult to determine an appropriate CO_2 emission factor. CO_2 emission factors vary depending upon the fossil fuel type as shown in Table C1. The general type of fuel listed in the "other fossil fuel" category was deduced by analyzing the reported energy conversion factor and comparing it to conversion factors of known fuel types as shown in Table C2.

Table C1. CO_2 Emission Factors for Various Fossil Fuels

Fossil Fuel	CO_2 Emission Factor (kg CO_2/GJ LHV)
Petroleum coke	99.8
Coal	92.7
Residual fuel oil	76.6
Distillate fuel oil	73.4
Kerosene	71.2
Gasoline	69.9
Liquefied propane gas (LPG)	62.5
Natural gas	55.9

Figure C1: Calculations of CO_2 Emission Factors[7]:
(Corrected for Unoxidized Carbon[8] Unless Noted Otherwise)

Coal[9]:

$$27.0908175\left(\frac{\text{GJ LHV}}{ton}\right)*1000\left(\frac{ton}{kton}\right)*92.7\left(\frac{kg\text{CO}_2}{\text{GJ LHV}}\right)=2.51E6\left(\frac{kgCO_2}{kton}\right)$$

Coke:

$$27.0908175\left(\frac{\text{GJ LHV}}{ton}\right)*1000\left(\frac{ton}{kton}\right)*99.8\left(\frac{kgCO_2}{\text{GJ LHV}}\right)=2.70E6\left(\frac{kgCO_2}{kton}\right)$$

Natural Gas:

$$0.000997\left(\frac{\text{GJ LHV}}{scf}\right)*1E6\left(\frac{scf}{MMcf}\right)*55.9\left(\frac{kgCO_2}{\text{GJ LHV}}\right)=5.57E4\left(\frac{kgCO_2}{MMcf}\right)$$

Oil: Distillate Oil:

$$1000\left(\frac{bbl}{kbbl}\right)*5.936661\left(\frac{\text{GJ LHV}}{bbl}\right)*73.4\left(\frac{kgCO_2}{\text{GJ LHV}}\right)=4.36E5\left(\frac{kgCO_2}{kbbl}\right)$$

Residual Oil:

$$1000\left(\frac{bbl}{kbbl}\right)*6.379321\left(\frac{\text{GJ LHV}}{bbl}\right)*76.6\left(\frac{kgCO_2}{\text{GJ LHV}}\right)=4.89E5\left(\frac{kgCO_2}{kbbl}\right)$$

Oil Avg.[10]: 15 % Distillate Oil, 85% Residual Oil

$$15\%*4.36E5\left(\frac{kgCO_2}{kbbl}\right)+85\%*4.89E5\left(\frac{kgCO_2}{kbbl}\right)=4.81E5\left(\frac{kgCO_2}{kbbl}\right)$$

Gasoline/Kerosene:

Kerosene:

$$1000\left(\frac{gal}{kgal}\right)*0.135313\left(\frac{\text{GJ LHV}}{gal}\right)*71.2\left(\frac{kgCO_2}{\text{GJ LHV}}\right)=9634.3\left(\frac{kgCO_2}{kgal}\right)$$

Gasoline:

$$1000\left(\frac{gal}{kgal}\right)*0.130302\left(\frac{\text{GJ LHV}}{gal}\right)*69.9\left(\frac{kgCO_2}{\text{GJ LHV}}\right)=9108.1\left(\frac{kgCO_2}{kgal}\right)$$

Gasoline/Kerosene Avg.[11]:

$$50\%*9634.3\left(\frac{kgCO_2}{kgal}\right)+50\%*9108.1\left(\frac{kgCO_2}{kgal}\right)=9370\left(\frac{kgCO_2}{kgal}\right)$$

Propane[12]:

$$1000\left(\frac{gal}{kgal}\right)*0.094266\left(\frac{\text{GJ LHV}}{gal}\right)*62.5\left(\frac{kgCO_2}{\text{GJ LHV}}\right)=5890\left(\frac{kgCO_2}{kgal}\right)$$

Tires[11]:

$$26\left(\frac{\text{BillionBTU HHV}}{kton}\right)*1.0E9\left(\frac{\text{BTU HHV}}{\text{BillionBTU HHV}}\right)*1.00225E-6\left(\frac{\text{GJ LHV}}{\text{BTU HHV}}\right)*85.78\left(\frac{kgCO_2}{\text{GJ LHV}}\right)=2.24E6\left(\frac{kgCO_2}{kton}\right)$$

[7] All conversion factors (GJ LHV per unit fuel, GJ LHV per BTU HHV, and $kgCO_2$ per GJ LHV) were obtained from WRI/WBCSD GHG calculation tools (NCASI) except for the 'Tires' (Billion BTU HHV per kton) factor. The tires conversion was provided by AF&PA and was assumed to be reported in HHV.

[8] To correct for unoxidized carbon, emission factors were multiplied by IPCC suggested values: coal = 0.98, oil and liquid fuels = 0.99, natural gas = 0.995.

[9] Conversion factors for coal were based on bituminous coal.

[10] Average was only used for comparison purposes. Individual conversion factors for residual and distillate oils were used for calculation of the preliminary 2000 CO_2 baseline estimate.

[11] Analysis on deviation of 50% gasoline – 50% kerosene was not calculated because entire gasoline and kerosene use accounts for less than 0.1% of total industry CO_2 emissions.

[12] CO_2 emission factor has not been corrected for unoxidized carbon for this fuel.

Table C2. Energy Conversion Factors for Various Fossil Fuels

Fossil Fuel	Units	Energy Conversion factor (GJ LHV/Amount Units)
Petroleum coke	ton	27.1
Residual fuel oil	bbl	6.38
Distillate fuel oil	bbl	5.94
Kerosene	gal	0.135
Gasoline	gal	0.130
Liquefied propane gas	gal	0.094
Natural gas	SCF	0.001

The following procedure was used to determine a CO_2 emission factor based upon the energy conversion factor provided for each "Other" fossil fuel:

- If the energy conversion factor was ≤ 0.05 the CO_2 emission factor for natural gas was used
- If the energy conversion factor was > 0.05 and ≤ 0.1 the CO_2 emission factor for LPG was used
- If the energy conversion factor was > 0.1 and ≤ 0.131 the CO_2 emission factor for gasoline was used
- If the energy conversion factor was > 0.131 and ≤ 0.14 the CO_2 emission factor for kerosene was used
- If the energy conversion factor was > 0.14 and ≤ 6.3 the average CO_2 emission factor of residual and distillate fuel oil was used
- If the energy conversion factor was > 6.3 and ≤ 30 the CO_2 emission factor for petroleum coke was used

The CO_2 emission factor used for calculating CO_2 emissions for purchased electricity is 177.5 kg CO_2/MMBtu. This electricity CO_2 emission factor is from the DOE Updated State-level Greenhouse Gas Emission Coefficients for Electricity Generation 1998-2000 report, and represents the three year weighted average for electrical utilities in the United States. The CO_2 emission factor for purchased electricity will remain the same throughout the reporting years to reflect the changes in electricity purchases from year to year.

1.4 2000 through 2006 CO_2 Emissions Estimates

The quality-checked fossil fuel data and purchased electricity data were used in conjunction with fuel-specific CO_2 emissions factors to estimate the baseline CO_2 emissions for 2000. Since energy data were not available for all mills that were members of AF&PA, direct and purchased electricity-related indirect CO_2 emission amounts were scaled to represent the entire AF&PA

membership for a given year. Table C3 compares the numbers of mills reporting fuel use and the pulp and paper production amounts those mills represent, to total AF&PA pulp and paper mill membership.

Table C3. Pulp and Paper Production Basis of Reported Fossil Fuel Usage

	Mills Reporting Energy Data		Total AF&PA Membership	
Year	Mills	Production (MMadmt/year)	Mills	Production (MMadmt/year)[a]
2000	277	82.4	282	83.7
2002	257	75.6	262	77.6
2004	239	76.9	241	77.7
2006	180	70.5	189	71.8

[a]from AF&PA's EHS survey database

Table C4 shows the direct CO_2 emissions from pulp and paper mills, and Table C5 shows the indirect CO_2 emissions from pulp and paper mills due to net purchased electricity. CO_2 emissions were calculated based on those mills reporting energy use data. These totals were then divided by the percentage of production represented by those mills reporting energy use data, and multiplied by 100, so that the total AF&PA direct and indirect CO_2 emission estimates shown in Table C4 and C5, respectively, represent the entire AF&PA pulp and paper membership.

Table C4. Final Pulp and Paper Sector Direct Fossil Fuel CO_2 Emissions

Year	Total AF&PA Direct CO_2 Emission (MMmt/year))
2000	60.3
2002	52.5
2004	47.7
2006	39.8

Table C5. Final Pulp and Paper Sector Indirect CO_2 Emissions related to purchased electricity, net basis

Year	Total AF&PA Indirect CO_2 Emissions (MMmt/year)
2000	22.1
2002	22.5
2004	21.3
2006	21.7

2.0 APPROACH FOR WOOD PRODUCT FACILITIES

The energy data provided to AF&PA by member companies were used to estimate direct and purchased electricity-related indirect emissions from wood products facilities. These data were found to be highly variable and confirmation of suspect values was determined to be prohibitively time-consuming. As an alternative, it was decided that the data would be analyzed statistically to develop emission factors for each of the major product categories in the wood products sector. CO_2 emissions from AF&PA members producing wood products were then determined by multiplying these emission factors by reported annual production for each product category and summing all categories. It is anticipated that this approach will also be used in future years.

Each facility providing data was first categorized by the products made: composite panels, lumber, plywood, other, or mixed production. CO_2 emissions were then calculated for each facility by multiplying the usage of each fossil fuel reported by an appropriate CO_2 emission factor (see Figure C1) and summing the results for all fossil fuels used. This total was then divided by the facility's production expressed in thousand cubic feet (MCF) wood equivalents, producing a facility-specific CO_2 emission intensity. An equivalent procedure was used for calculating indirect CO_2 emissions due to purchased electricity. The CO_2 emission factor used for calculating CO_2 emissions for purchased electricity is 177.5 kg CO_2/MMBtu. This electricity CO_2 emission factor is from the DOE Updated State-level Greenhouse Gas Emission Coefficients for Electricity Generation 1998-2000 report, and represents the three year weighted average for electrical utilities in the United States. The CO_2 emission factor for purchased electricity will remain the same throughout the reporting years to reflect the changes in electricity purchases from year to year.

Using the facility-specific intensity values, NCASI determined CO_2 emission intensity factors for the composite panels, lumber, plywood, and other product categories. This was done by determining the median value from the distribution of all reporting facilities whose production was at least 90% in that category. Use of the median limits the influence of particularly large and small values, making it a reasonable approach given the wide range of values encountered (a range of at least five orders of magnitude within each product category).

Tables C6 and C7 show the median intensity values and the estimated total direct and purchased electricity-related indirect CO_2 emissions for 2000, 2002 and 2004, respectively.

Table C6. Estimated Direct CO_2 Emissions for Wood Products Manufacturing [a]

Product Category	Median Direct CO_2 Emission Intensity (metric ton CO_2/MCF)				Direct Fossil Fuel CO_2 Emissions (metric ton/year)			
	2006	**2004**	**2002**	**2000**	**2006**	**2004**	**2002**	**2000**
Lumber	0.10	0.12	0.15	0.18	96,000	120,000	170,000	180,000
Structural panels [b]	0.52	0.58	0.49	0.32	400,000	470,000	420,000	240,000
Non-structural panels [c]	1.60	1.40	1.20	1.20	230,000	420,000	370,000	440,000
Other	0.48	0.66	0.57[d]	0.57[d]	10,000	30,000	35,000	17,000
Totals (rounded)					**740,000**	**1,000,000**	**1,000,000**	**880,000**

a) Mills whose primary product is veneer were not included in emission calculations. It has been estimated that the veneer production contribution to CO_2 direct emissions is less than 0.3% of the total direct emissions for the wood products sector.
b) Category includes: OSB, softwood plywood and engineered wood products.
c) Category includes: hardwood plywood, MDF, particleboard, hardboard and fiberboard.
d) Originally, the intensity factor for the "Lumber" category was used in 2002 and 2000 because less than 35% and 10% of "Other" production was represented in 2002 and 2000 respectively. The 2002 and 2000 intensity values have since been revised to be the production weighted average of the 2006 and 2004 intensity values for the "Other" category to be more reflective of the CO_2 emission intensity for this category.

Table C7. Estimated Indirect CO_2 Emissions Attributable to Purchased Electricity in Wood Products Manufacturing

Product Category	Median Indirect CO_2 Emission Intensity (metric ton CO_2/MCF)				Indirect CO_2 Emissions (metric ton/year)			
	2006	**2004**	**2002**	**2000**	**2006**	**2004**	**2002**	**2000**
Lumber	1.6	1.5	1.5	1.4	1,500,000	1,500,000	1,800,000	1,400,000
Structural panels[1]	2.6	2.6	2.7	2.6	2,000,000	2,200,000	2,300,000	2,000,000
Non-structural panels[2]	3.7	3.9	3.8	3.6	540,000	1,200,000	1,200,000	1,300,000
Other[3]	3.5	3.3	3.6	-	80,000	150,000	220,000	-
Totals (rounded)					**4,100,000**	**5,000,000**	**5,460,000**	**4,690,000**

1) Category includes: OSB, softwood plywood and engineered wood products.
2) Category includes: hardwood plywood, MDF, particleboard, hardboard and fiberboard.
3) Intensity factor for "Lumber" category was used in 2002 and 2000 because less than 35% and 10% of "Other" production was represented in 2002 and 2000 respectively. Also, a production weighted average of the 2004 and 2002 median CO_2 emission intensity factors was used to calculate the emission factor for 2006 because of the small number of mills reporting energy data for the other wood products category in 2006.

APPENDIX D

CALCULATING INDUSTRY OUTPUT

For purposes of calculating emissions intensity, it is necessary to divide emissions by output. For purposes of the VISION program, the industry is measuring output by mass.

1. Paper and paperboard

The pulp, paper, and paperboard emissions data are derived from AF&PA energy surveys. These are submitted to AF&PA at the same time the AF&PA members submit Environment, Health, and Safety (EHS) surveys and the EHS surveys include mill-level production data. The AF&PA member output of final pulp, paper, and paperboard products will be derived from these data by summing all of the final output reported by the mills and then extrapolating it to the total production estimated by AF&PA for its complete membership.

The following outputs, reported in the EHS survey, are summed to estimate the production represented in the EHS responses.

- paper and paperboard net production (machine dry)
- Market pulp (dried and wet lap on a dried basis)

The total production reported by AF&PA for its membership for 2000 through 2006 are shown in Table D1.

Table D1. Paper, paperboard and market pulp production from AF&PA members

Paper, paperboard and market pulp production*	10^6 Short tons	10^6 Metric tons
2000	92.3	83.7
2002	85.6	77.6
2004	85.6	77.7
2006	79.1	71.8

* From AF&PA EHS survey responses

2. Wood products

The AF&PA EHS survey asks for facility production in the following categories:

- Softwood Lumber
- Hardwood Lumber
- Engineered Products (I-joists, LVL, etc.)
- Particleboard
- MDF
- Fiberboard
- Softwood Plywood
- Hardwood Plywood
- OSB
- Hardboard
- Veneer (Hardwood & Softwood)
- Other Wood Products
- Chip mill production
- Treated wood products

The production numbers in these categories are converted from the reported units (shown below) to Thousand Cubic Feet (MCF) solid wood equivalent using the following conversion factors unless companies provide mill-specific conversion factors. Chips as products are not included in the production totals shown below.

Table D2. Default conversion factors to estimate Thousand Cubic Feet (MCF) solid wood equivalent

Plywood, OSB and Veneer: multiply $MSF_{3/8}$ by 0.03125
Softwood Lumber: multiply MBF by 0.0565
Hardwood Lumber: multiply MBF by 0.0833
Particleboard and MDF: multiply $MSF_{3/4}$ by 0.0625
Hardboard: multiply $MSF_{1/8}$ by 0.01042
Engineered Products: factor varies significantly by product type

The results of these calculations for 2000 through 2006 are shown in Table D3.

Table D3. Wood products production from AF&PA members [1]

	Thousand cubic feet			
	2000	2002	2004	2006
Lumber	1,000,000	1,200,000	960,000	950,000
Structural Wood Panels (3/8 inch basis) [2]	760,000	850,000	820,000	770,000
Nonstructural Wood Panels (3/8 inch basis) [3]	360,000	300,000	310,000	140,000
Other	29,000	61,000	46,000	22,000

1) Production amounts do not include veneer production, an intermediate product
2) Category includes OSB, softwood plywood and engineered wood products.
3) Category includes hardwood plywood, MDF, particleboard, hardboard and fiberboard.

The same production, shown in terms of mass, and the conversion factors used to convert from volume to tonnes of product, are shown in Table D4.

Table D4: AF&PA member production statistics (metric tons) – 2000 to 2006

Product	Conversion factors * from units in Table D3 to Metric Tonnes	Million Metric Tonnes (totals not equal to sum due to rounding errors)			
		2000	2002	2004	2006
Lumber	16.4 **	16.4	19.6	15.7	15.6
Structural Wood Panels	19.4 ***	14.8	16.5	15.9	14.9
Nonstructural Wood Panels and Other	11.4 ****	4.42	4.10	4.05	1.84
Total		35.5	40.2	35.7	32.3

* Conversion from AF&PA survey units to volume units based on AF&PA Environmental, Health and Safety survey conversion factors. Conversion of volume to mass based on Howard, J.. 2001. *U.S. timber production, trade, consumption, and price statistics: 1965 – 1999*. Research Paper FPL-RP-595, United States Department of Agriculture, Forest Products Laboratory, Madison WI, 2001
** Weighted average of softwood and hardwood lumber, based on 1998 production data in McKeever 2002 (73% softwood and 27% hardwood
*** Weighted average of plywood (61%) and OSB (39%), based on production data in McKeever 2002
**** Weighted average of hardwood plywood (10%), particle board including MDF (65%), hardboard (8%) and insulation board (17%), based on production data in McKeever 2002

The total output of AF&PA members in 2000, 2002 and 2004 are shown in Table D5.

Table D5. Total production from AF&PA members

Total production*	10^6 Metric tons
2000	119
2002	118
2004	113
2006	104

* Total of paper, paperboard, market pulp and wood products from AF&PA EHS survey responses