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TO: Ms. Becky Nicholson, RTI International

CC: Brad Upton, Ron Yeske, Al Lucier, Jay Unwin – NCASI  
Rhea Hale, Jerry Schwartz – AF&PA

FROM: Reid Miner

SUBJECT: Calculations documenting the greenhouse gas emissions from the pulp and paper industry

In your email of May 13, you asked a number of questions related to greenhouse gas emissions from pulp and paper mills. Herein, I attempt to address some of those questions. The material below is drawn largely from analyses done by others on our staff, especially Jay Unwin and Brad Upton.

#### TOTAL INDUSTRY EMISSIONS

We have been assisting AF&PA in estimating CO<sub>2</sub> emissions related to fossil-fuel consumption at AF&PA member companies as part of the industry's commitment in the Climate VISION program. Rhea Hale will send you a copy of the latest VISION report which is now undergoing review.

In a separate effort, we have been working with the U.S. Forest Service to develop a carbon and greenhouse gas profile of the U.S. forest products industry. Although that analysis is not complete, Brad Upton has finished his calculation of total industry emissions related to fossil fuel consumption (CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O) and biomass fuel consumption (CH<sub>4</sub> and N<sub>2</sub>O). The following text is copied from the draft report containing the full profile.

“Almost all direct GHG emissions from forest products industry manufacturing facilities are the result of fossil fuel combustion. The industry satisfies much of its energy requirements by also burning large quantities of biomass fuels, but the CO<sub>2</sub> released from biomass combustion is not included in GHG totals because it contains biogenic carbon.... Small amounts of nitrous oxide (N<sub>2</sub>O) and methane (CH<sub>4</sub>) are also released during combustion of biomass fuels and fossil fuels. [Note: These biomass-related emissions of CH<sub>4</sub> and N<sub>2</sub>O are added to fossil fuel-derived greenhouse gas emissions below.]

... Pulp and paper sector energy consumption during 1990 and 2004 were determined from data obtained from the American Forest and Paper Association (AF&PA). GHG emission factors from IPCC (1997) were used in conjunction with this data to calculate direct emissions from fuel combustion. The IPCC Tier 1 CH<sub>4</sub> and N<sub>2</sub>O emission factors were used with the exception of CH<sub>4</sub> and N<sub>2</sub>O from biomass fuel combustion, which were estimated using emission factors from the International Council of Forest and Paper Associations and NCASI (ICFPA/NCASI) [reference omitted]. Emission factors are shown in Table 2.1 [table omitted]. GHG emission estimates are expressed as CO<sub>2</sub> equivalents (CO<sub>2</sub> eq.) and include CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O, including

CH<sub>4</sub> and N<sub>2</sub>O from combustion of biomass fuels. Global warming potentials (GWPs) of 21 and 310 were used for CH<sub>4</sub> and N<sub>2</sub>O, respectively.

... Available fuel consumption data for 2004... was obtained from [AF&PA] survey responses representing 84,660,000 metric tons of production. Total US pulp and paper sector production in 2004 (including paper, paperboard, and market pulp production) was estimated to be 102,340,000 metric tons based on data published by AF&PA (reference omitted). Therefore, in order to arrive at a representation of the total US pulp and paper industry the emission estimates based on 2004 AF&PA energy data were multiplied by a factor of 1.21 (= 102,340,000 ÷ 84,660,000).

Pulp and paper industry manufacturing direct emissions from fuel consumption were ... 57.7 [million metric tons] CO<sub>2</sub> eq. in 2004..."

We have not estimated biomass-derived CO<sub>2</sub> emissions because they are not included in greenhouse gas emission totals in any of the protocols with which we are familiar. Furthermore, in our experience, estimates of biomass-derived CO<sub>2</sub> emissions are never used.

### GREENHOUSE GAS EMISSIONS BY EMISSION SOURCE

Our estimates of greenhouse gas emissions from combustion are based on corporate-wide reporting of fuel consumption preventing many of the disaggregated estimates you seek. We have, however, generated estimates for some of the non-combustion operations you listed and these are discussed below.

#### On-site landfills

Summary: NCASI's analysis indicates that these emissions could reasonably be excluded from EPA's registry because they are small (on the order of 1% of the industry's direct emissions) and estimated only with great uncertainty. Additional information is provided below.

When the ICFPA/NCASI calculation tools for pulp and paper mills were first developed, the intent was to be as comprehensive as possible because (a) the tools would serve a range of purposes and (b) the experience at that point was inadequate to know whether certain emissions were so small that they could be ignored. At the time, there were no data on the methane emissions from mill landfills, so in the interest of being as comprehensive as possible, NCASI included calculation methods that were based largely on estimation methods for MSW landfills. Several years ago, NCASI began work to develop estimation methods better tailored to mill landfills.

Wastewater treatment plant (WWTP) residuals (i.e. sludges) and ash comprise most of the material being placed in pulp and paper mill landfills (see *Solid Waste Management Practices in the U.S. Paper Industry - 1995*. NCASI Technical Bulletin No. 793, 1999). Because the ash is almost completely inert, any greenhouse gas emissions from mill landfills are likely attributable to WWTP residuals. Therefore, to better understand the contribution of mill landfills to methane emissions and carbon sequestration, NCASI conducted laboratory and field tests on several WWTP residuals. The work was only recently completed, but we can share some preliminary findings that help characterize the role of landfills.

NCASI conducted laboratory studies using the methods of Dr. Morton Barlaz at North Carolina State University. These methods are the same as those used in USEPA studies to characterize landfill degradation of municipal solid waste, most of which have also been conducted by Dr. Barlaz. The laboratory studies indicate the ultimate methane yield of the WWTP residuals and, conversely, the fraction of the carbon in the WWTP residuals that is essentially non-degradable under anaerobic conditions. This non-degradable fraction of the organic carbon remains stored in landfills for very long

periods, sequestering the carbon. The laboratory studies yield data to calculate values for the parameter  $L_o$ , which is the “ultimate” cubic meters of methane generated per dry metric ton of waste.

To calculate methane generation over time using EPA’s methods, you also need to know the first order rate parameter,  $k$ . NCASI constructed field test cells and operated them for over 5 years to generate data that could be used to estimate  $k$ . Below we summarize the findings of both the laboratory and field studies.

The normal method to estimate methane emissions from landfills assumes that the generation process occurs according to first order kinetics. The rate of generation is defined by two parameters, a rate parameter,  $k$  ( $\text{yr}^{-1}$ ), and an ultimate yield parameter,  $L_o$  ( $\text{m}^3/\text{Mg}$ ). There are two primary ways to estimate these parameters from laboratory and field data.

1. You can let the laboratory studies define  $L_o$  and then use this value with the field data to estimate  $k$ .
2. You can rely entirely on the field data to determine  $L_o$  and  $k$ , using regression techniques to find the values for these parameters that best fit the field data and first order kinetics.

NCASI found that the field data gave very different values for  $L_o$  than obtained from the laboratory tests. The reasons for this remain unclear although they may include (a) a lag period in the degradation process or (b) the inability of first order kinetics to describe the field data. Because of the large uncertainty in the estimates for  $L_o$  obtained using method 2 above, NCASI decided to rely on method 1. The results are shown below. A much larger variation in  $k$  is seen than for  $L_o$ , but this may be because  $k$  is based, in part, on field data that showed much more variability than the laboratory data. To date, NCASI has been unable to explain the variability between the results for samples from different mills.

Table 1. Methane generation parameters from laboratory and field data\*

<b>Residual</b>	<b>Description</b>	<b><math>k, \text{yr}^{-1}</math></b>	<b><math>L_o, \text{m}^3/\text{Mg}</math></b>
A	Bleached Kraft, combined	0.0034	69.9
B	Deinked, combined	0.020	73.0
C	Deinked, primary	0.014	101
D	Nonintegrated, primary	0.016	78.1
	Average	0.013	80.5

\*  $L_o$  was obtained from laboratory tests and then used in combination with the field data in a regression analysis to estimate  $k$ .

To calculate industry methane emissions over time, the average values for  $L_o$  and  $k$  were used, together with data on the historical rates of placement of mill WWTP residuals in landfills back to 1970. The calculation method was the same as used by EPA and IPCC. A global warming potential of 21 was used to convert methane to  $\text{CO}_2$  equivalents. Methane releases in 2005 are estimated to have been approximately 1.2 million metric tons  $\text{CO}_2$  equivalents. These emissions are offset, to a significant degree, by carbon storage in these same landfills, discussed below.

To understand the net impact of mill landfills, one needs to examine the potential significance of landfill sequestration as an offset to methane emissions from mill landfills. The carbon not degraded in the landfill, and remaining in long-term storage, can be estimated directly from  $L_o$  by assuming that (a) the gas generated from decomposing biomass is a 50/50 mix of methane and carbon dioxide and (b) material not degraded to gas remains stored in the landfill. Using this approach, one finds that on a long-term basis

approximately 2/3 of the carbon remains sequestered in the landfill representing a net removal of carbon from the atmosphere. Considering global warming potentials, this is adequate to offset approximately one-half of the long-term methane emissions from these same landfills.

Consequently, while the estimates shown above for methane emissions from mill landfills are small (1.2 million metric tons CO<sub>2</sub> equivalents in 2005), the net emissions associated with mill landfills are smaller still. With the true net impact of mill landfills being closer to 0.6 million tons CO<sub>2</sub> equivalents per year, these emissions are barely 1% of emissions related to burning fossil fuels at all U.S. pulp and paper mills, estimated by NCASI to be 57.7 million metric tons CO<sub>2</sub> equivalents in 2004.

Therefore, it appears reasonable not to include mill landfill emissions in a mandatory greenhouse gas reporting program. Not only are the emissions very small, their estimation is subject to large uncertainty associated with (a) uncertainty in the proper form of the equation describing the decay process, and (b) the unexplained variability among WWTP residuals, especially evident in the field testing.

#### On-site wastewater treatment

Summary: NCASI's recent measurements of methane emissions from mill wastewater treatment plants indicate that these emissions can reasonably be excluded from reporting in EPA's registry because they are small (less than 1% of the industry's direct emission) and are estimated only with great uncertainty. Information explaining these observations follows.

As noted above, when the ICFPA/NCASI calculation tools for pulp and paper mills were first developed, the intent was to be as comprehensive as possible. At the time, the only recommendations from IPCC for estimating emissions from wastewater treatment were for methane emissions from systems that were designed to accomplish removal of organic matter under anaerobic conditions. The IPCC methods for such systems, therefore, were included in the ICFPA/NCASI tools, although it was known that there were, and still are, very few such systems in the industry, especially in the U.S.

In its annual inventory, however, EPA had been estimating methane emissions from a range of types of treatment plants in the pulp and paper industry. These estimates were not based on data generated at mill treatment plants so NCASI undertook a sampling program (in conjunction with a program to measure releases of sulfur compounds) to generate data that would improve the ability to estimate these emissions. The data have been gathered and the report will be published soon. The data reveal several important findings.

NCASI studies have confirmed that mechanical clarifiers and aerobic biological treatment systems with high-intensity mixing, such as activated sludge treatment systems, do not generate significant amounts of methane. Anaerobic treatment systems are known to generate methane, but there are very few biological treatment systems in the U.S. forest products industry that are designed to provide treatment via the anaerobic decomposition of organic matter. There are, however, a number of operations that can have zones within them that become anaerobic; namely, aerated stabilization basins (ASBs), primary settling basins, and post-aeration basins. These emissions are estimated below.

ASB Emissions: NCASI measurements suggest that, although there is great unexplained variability between the few systems for which emissions have been measured, on average about 1 percent of removed BOD is converted to methane by ASBs. Several sources of information were used to identify 125 U.S. mills operating ASBs in the U.S. and the final effluent BOD loads from these ASBs. The sum of annual final effluent BOD for all mills with ASBs was used to derive an estimate on incoming BOD loads by assuming a treatment efficiency of 90% across the ASBs. Using these data, the annual mass of methane emitted from ASBs was calculated to be 6,563 metric tons, or approximately 0.14 million metric tons CO<sub>2</sub> equivalents.

Settling Pond Emissions: In lieu of mechanical clarifiers, some mills use earthen primary settling ponds to remove suspended solids from the wastewater prior to entering an ASB or activated sludge treatment system. Temporary storage of solids in these ponds can result in anaerobic conditions and the subsequent release of methane. NCASI measured the methane generation rate at one primary settling pond. These data were used to generate an industry-wide estimate using statistics presented in EPA's 1993 Technical Development Document wherein it was noted that approximately 10 % of U.S. pulp and paper production is associated with treatment of wastewaters in such ponds. Using the same production data as described above, the annual mass of methane emitted from settling ponds was calculated to be 5,094 metric tons, or approximately 0.11 million metric tons CO<sub>2</sub> equivalents.

Post-Aeration Basins: Many mills that operate ASBs use a post-ASB (quiescent) basin to allow suspended solids to settle out. In situations where mills do not have a separate quiescent basin, they often use a non-aerated tail-end portion of the ASB to settle solids. In either arrangement, the mixing energy is low enough that some of the solids settle to the bottom of these basins. The storage of solids in these ponds can result in anaerobic conditions and the subsequent release of methane. Methane emission measurements from post-aeration basins are limited to one study by NCASI conducted at a southern Kraft mill that utilizes a quiescent basin to settle solids prior to final discharge. Using annual methane emission rates for this quiescent basin and the annual production for the mill, the methane emitted on a per metric ton basis was calculated. This emission rate was multiplied by the sum of the production for all mills operating ASBs. The resulting sum of methane produced by solids in quiescent basins was 9,538 metric tons methane in 2004, equal to approximately 0.2 million metric tons CO<sub>2</sub> equivalents per year.

Total on-site wastewater management-related emissions: Based on the estimates above, it appears that the combined emissions of methane from industry wastewater management systems were approximately 0.45 million metric tons CO<sub>2</sub> equivalents 2004, which is less than 1% of the emissions associated with burning fossil fuels at pulp and paper mills, according to NCASI estimates.

It is important to emphasize that the factors used by NCASI to estimate methane releases from the industry's wastewater treatment plants are not appropriate for use at individual mills. In some cases, for instance, NCASI scaled up from a single treatment plant to the entire industry based only on production. Clearly, there are many mill-specific factors that this does not consider. We know, for instance that methane emissions should be related in some way to organic load from the mill, the degree of aeration, the basin area, the amount of settled solids in a basin, how frequently solids are removed and perhaps other factors. All of these would be expected to affect the methane emissions from a pulp and paper mill wastewater treatment plant but currently there is inadequate knowledge of the mechanisms for methane generation and release to include these factors in predictive equations or emission factors. Consequently, there is a significant risk of unintended consequences if a reporting program is based on emission factors normalized to only one of these factors. For instance, if an emission factor is based on raw waste load, a mill that reduced methane emissions by improving mixing intensity would not be able to show this and would actually be required to report increased methane emissions if raw waste load increased.

Accordingly, because the emissions from wastewater treatment plants are so small and because the uncertainty associated with estimating these emissions at individual mills is so large, it is reasonable omit them from a mandatory GHG reporting program.

#### On-site mobile sources and machinery

Because the estimates we make are usually based on corporate-wide fuel use data, these emissions, to the extent they are direct emissions for the company, are usually included in the emissions totals that we calculate. Of course, in some cases, these emissions are not direct emissions for the reporting company. We have been told by several companies that have examined these emissions that they represent around

one percent (give or take) of a pulp and paper mill's direct emissions, but this will of course vary depending on how large the mill's direct emissions are.

#### Make up chemicals

Summary: Information from a variety of sources provide a basis for excluding from reporting requirements the CO<sub>2</sub> emissions associated with purchased make-up carbonates at Kraft mills because these emissions are very small (certainly less than 0.7% of the industry's direct emissions) and are offset, to at least some degree, by the sequestration of carbonates in Kraft recovery system wastes in landfills. Explanatory material follows.

When companies first began estimating mill emissions of CO<sub>2</sub>, questions arose about how to handle the emissions from Kraft mill lime kilns. These kilns are very different from cement kilns or other types of lime kilns in that essentially all of the CaCO<sub>3</sub> fed to Kraft mill lime kilns contains carbon that originated in the tree and is therefore biogenic. This biogenic carbon is not included in greenhouse gas totals (although the CO<sub>2</sub> released from burning fossil fuels in Kraft mill lime kilns is included). To be comprehensive, the ICFPA/NCASI calculation tools included methods to estimate the CO<sub>2</sub> emissions formed via the disassociation of that small fraction of the CaCO<sub>3</sub> that contains carbon not of biogenic origin. This small amount of CaCO<sub>3</sub> is added to the process at some mills to make up for small amounts of chemical that are lost on a routine basis. The potential significance of these make-up carbonates was examined in a paper by Miner and Upton (*Methods for estimating greenhouse gas emissions from lime kilns at Kraft pulp mills*. Energy, Volume 27 No. 8, Sept. 2002). In that paper the following assessment was described.

“At some Kraft mills, a small portion of the CaCO<sub>3</sub>, fed to the kiln contains carbon of fossil and mineral origin. These small amounts originate in purchased calcium carbonate and sodium carbonate that some mills use to make up normal losses of sodium and calcium from the recovery system. In most cases, the carbon in these purchased carbonates is fossil (or mineral) in origin. For several reasons, however, it is clear that these amounts are so small that they can be ignored in developing estimates of overall industry greenhouse gas emissions. First of all, at many mills, sodium and calcium are added to the recovery system in forms that do not contain carbon, such as sodium sulfate, sodium hydroxide, and calcium oxide [reference omitted]. Furthermore, even in those cases where sodium- and/or calcium carbonate are used, the amounts of make-up chemical are small. Calcium make-up, required to compensate for losses in the recovery cycle, normally amounts to only 2 to 5% of the kiln throughput [references omitted]. As far as sodium carbonate is concerned, the United States Geological Survey (USGS) estimates that, in 1999, the pulp and paper industry used 121,000 metric tons of sodium carbonate for all purposes [reference omitted].”

The paper goes on to indicate that “US Kraft mills released about 9.6 million metric tons of calcium carbonate-derived CO<sub>2</sub> in 1995.” If 3.5% of this was derived from make-up chemicals (the mid-point of the range noted above) it would amount to 340,000 metric tons CO<sub>2</sub> potentially associated with the use of make-up calcium carbonate. If the 121,000 metric tons of sodium carbonate, noted above, are converted to CO<sub>2</sub>, it amounts to 50,000 tons CO<sub>2</sub> per year. Together, therefore, emissions related to make-up calcium carbonate and sodium carbonate are less than 390,000 tons CO<sub>2</sub> per year, or less than 0.7% of the industry's direct emissions. One can be confident that the emissions are less than this, mostly because many mills compensate for calcium and sodium losses by using make-up chemicals that do not contain carbon (e.g. CaO and NaOH). In addition, since the writing of the paper discussed above, it has been realized that some of the calcium carbonate and sodium carbonate that is lost on a routine basis from the Kraft recovery system is contained in solids that are sent to landfills where the carbon is, for all intents and purposes, permanently sequestered, representing an offset to the small amounts of CO<sub>2</sub> released from

make-up chemicals. It is evident, therefore, that the emissions associated with make-up carbonates are very small and it is reasonable to exclude them from EPA's reporting requirements.

Flue gas desulphurization (FGD) systems

Methods for estimating emissions from FGD systems were added to the ICFPA/NCASI calculation tools to address the potential that such systems are used in the pulp and paper industry. This is not, however, a process that is unique to the pulp and paper industry. Indeed, we have never given this aspect of the tools much attention because there are very few such systems used in the U.S. pulp and paper industry.

EMISSIONS DISTRIBUTION CURVES

This is a question we have forwarded to AF&PA and I expect that you (or EPA) will be hearing from them.

We hope you find this information helpful.