5.0 MODEL PROCESS UNIT ENVIRONMENTAL AND ENERGY IMPACTS

This chapter discusses the environmental and energy impacts of controlling HAP emissions from new and existing combustion sources at kraft and soda pulp and paper mills. The environmental and energy impacts of each control option discussed in Chapter 4 are presented for the individual model combustion process units. The total nationwide environmental and energy impacts associated with each control option are presented in a separate memorandum.[1]

Section 5.1 of this chapter discusses the general approach used to determine the environmental and energy impacts associated with each control option. Sections 5.2 through 5.5 present the environmental and energy impacts of each control option for model process units representing recovery furnaces, BLO units, SDT's, and lime kilns. Section 5.6 contains the references cited in this chapter.

5.1 GENERAL APPROACH

This section introduces the types of environmental and energy impacts associated with the control options and discusses how these impacts were determined for each of the model process units. The types of impacts discussed include air pollution, energy consumption, water pollution, solid waste disposal, and other impacts (i.e., noise, visual, odor, and irreversible and irretrievable commitment of resources). Impacts were calculated for each model process unit on an annual basis. In calculating the annual impacts, all process units were assumed to operate 24 hr/d for 351 d/yr, which is equivalent to 8,424 operating hr/yr. This operating time accounts for 14 days of scheduled shutdown annually for maintenance and repair.

The procedure for estimating air pollution impacts is described in the following section. The general approaches used to develop energy impacts, water pollution impacts, solid waste disposal impacts, and other impacts are provided in Sections 5.1.2, 5.1.3, 5.1.4, and 5.1.5, respectively.

5.1.1 Air Pollution Impacts

This section presents the methodology used to determine both primary and secondary air impacts.

5.1.1.1 Primary Emissions. For this impact analysis, primary air impacts include the reduction of emissions directly attributable to the control option (i.e., the reduction of emissions due to the use of APCD's or process modifications). Primary emissions of PM, PM HAP's, gaseous organic HAP's, HCl, and SO_2 were estimated based on model concentrations and emission factors at baseline and at control levels. Gaseous organic HAP's include acetaldehyde, benzene, formaldehyde, methanol, methyl ethyl ketone, methyl isobutyl ketone, phenol, toluene, and xylenes.

As discussed later in this chapter, PM is used as a surrogate measure for PM HAP's, i.e, trace metals, such as antimony (Sb), arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), and selenium (Se). The primary emission estimates for PM were derived for each model recovery furnace and lime kiln by multiplying the model PM concentration by the model gas flow rate corrected to dry conditions at standard temperature and by 351 operating d/yr.

Primary emission estimates of gaseous organic HAP's, HCl, and SO_2 from model recovery furnaces and PM from model SDT's were determined by multiplying their respective model emission factors by the model BLS firing rates and by 351 operating d/yr.

Primary emission estimates of PM HAP's were determined as a percentage of PM for each model recovery furnace, SDT, and lime kiln; the percentages were derived based on a comparison of PM and PM HAP emissions for kraft and soda recovery furnaces, SDT's, and lime kilns. The percentages of PM were estimated to be

0.2 percent for recovery furnaces, 0.06 percent for SDT's, and 1.4 percent for lime kilns.[2]

The control level HCl emission factor was derived from an outlet HCl emission concentration of 5 ppmv guaranteed by packed-bed scrubber manufacturers for inlet HCl concentrations less than 500 ppmv.[3,4] However, the actual outlet HCl emission level achieved at a particular mill will be site-specific. The baseline HCl emission estimates (and percent HCl reduction) in this impact analysis may be underestimated because the baseline HCl emission factor includes emissions data from recovery furnaces with HCl emissions at or below 5 ppmv.

The SO_2 emission reduction obtained with the packed-bed scrubber was estimated for each model recovery furnace by applying a percent SO_2 reduction to average uncontrolled SO_2 emission estimates. Uncontrolled SO_2 emission factors for recovery furnaces have already been developed and are presented in the Air Pollution Engineering Manual.[5] As shown in the manual, the average uncontrolled SO_2 emission factor for NDCE recovery furnaces is 2.1 kilograms per air-dried megagram of pulp (kg/ADMP) (4.2 pounds per air-dried ton of pulp [lb/ADTP]).[5] Using a conversion factor of 1,700 kg BLS/ADMP (3,400 lb BLS/ADTP) (the average for both bleached and unbleached pulp mills), the average uncontrolled SO_2 emission factor for NDCE recovery furnaces is equivalent to 1.24×10^{-3} kg/kg BLS (1.24×10^{-3} lb/lb BLS).[6] The average uncontrolled SO_2 emission factor for DCE recovery furnaces is 1.8 kg/ADMP (3.5 lb/ADTP), which is equivalent to 1.03×10^{-3} kg/kg BLS (1.03×10^{-3} lb/lb BLS).[5] Based on information from individual mills, at least 50 percent SO_2 control was assumed to be achievable with packed-bed scrubbers.[7] The control level SO_2 emission estimates were determined using the uncontrolled emission factors and the 50 percent SO_2 control.

To estimate the incremental reduction in emissions for each primary pollutant (i.e., PM, PM HAP's, gaseous organic HAP's, HCl, and SO_2), the control level emission estimate for each

primary pollutant was compared to its corresponding baseline emission estimate.

5.1.1.2 Secondary Emissions. Secondary air impacts include the indirect or induced impacts resulting from implementing a control option. These indirect or induced impacts include the following:

(1) changes in power boiler emissions of criteria pollutants such as PM, SO_2, nitrogen oxides (NO_x), and carbon monoxide (CO) resulting from the generation of energy required to operate APCD's or other equipment included in the control options; and

(2) changes in power boiler emissions of SO_2 resulting from the incineration of TRS compounds present in the BLO vent gases routed to the power boiler to control gaseous organic HAP emissions.

The power boiler secondary emissions of PM, SO_2, NO_x, and CO resulting from the generation of electricity to operate APCD's or other equipment were estimated based on emission factors related to electricity usage. The emission factors used are 0.23 kilograms of PM per megawatt-hour (kg PM/MWh) (0.15 pounds of PM per million Btu [lb PM/MM Btu]), 1.1 kg SO_2/MWh (0.73 lb SO_2/MM Btu), 0.45 kg NO_x/MWh (0.29 lb NO_x/MM Btu), and 0.85 kg CO/MWh (0.55 lb CO/MM Btu).[8] The secondary emission estimates were calculated as a product of these emission factors and the model process unit electricity impacts discussed in the next section.

Secondary SO_2 emissions can be generated under the BLO vent gas control option when TRS compounds present in the vent gases are incinerated in a power boiler or other incineration device. All of the TRS from the BLO unit is assumed to be routed to a power boiler or other incineration device; none is "lost" as condensate along the way. In deriving the chemical equation for the conversion of TRS to SO_2, the TRS was assumed to be in the form of H_2S. During combustion, the H_2S would be combined with O_2 to produce SO_2 and H_2O. The chemical equation is as follows:

$$H_2S + \frac{3}{2}O_2 \rightarrow SO_2 + H_2O$$

As shown in this equation, one mole of SO_2 is formed for each mole of H_2S combusted. This molar ratio was used in the following equation to estimate the mass ratio of SO_2 to TRS:

$$(1\ kg\text{-}mole\ SO_2\ formed/1\ kg\text{-}mole\ H_2S\ combusted) \times (1\ kg\text{-}mole\ H_2S/34.08\ kg\ H_2S) \times (64.06\ kg\ SO_2/kg\text{-}mole\ SO_2) \approx 1.88\ kg\ SO_2/kg\ H_2S$$

The English unit equivalents for this equation are the same as the metric unit values presented in the equation. To determine the secondary SO_2 emission estimates, the ratio of SO_2 to TRS was multiplied by the estimate of TRS emissions incinerated by the BLO control system. These secondary SO_2 emission estimates represent worst-case estimates because some control of SO_2 emissions is likely to be achieved through the application of wet scrubbers on incineration devices such as power boilers and lime kilns that could be used to incinerate BLO vent gases.

To estimate the change in emissions for each secondary pollutant (i.e., PM, SO_2, NO_x, and CO), the control level emission estimate for each secondary pollutant was compared to its corresponding baseline emission estimate.

5.1.2 Energy Impacts

The energy impacts of the combustion source control options include changes in electricity and steam requirements. The increases in electricity requirements from the operation of APCD's were calculated using electricity cost equations from the EPA's Office of Air Quality Planning and Standards (OAQPS) Control Cost Manual.[9] These electricity requirements are divided into fan, pump, and operating electricity requirements and were calculated assuming 8,424 operating hr/yr. The electricity requirements to operate a BLO vent gas control system were calculated based on information from a kraft pulp mill.[10] The methods used to calculate the BLO control system energy impacts are described in Section 5.3.2.

The fan electricity requirement (applicable to ESP's and scrubbers) is equal to a numerical factor (0.00018) times the product of the gas flow rate, pressure drop, and operating hr/yr.[9] The gas flow rate varies with each model process unit. The pressure drop is based on information from individual mills.[6] Although the pressure drop is not the sole parameter that determines PM collection efficiency for lime kiln scrubbers, for the purposes of estimating impacts, the pressure drop was used as an indicator of PM collection efficiency for lime kiln scrubbers. (Note: A different scrubber design, rather than a higher pressure drop, was used to improve the PM collection efficiency for SDT scrubbers.)

The gas flow rate and pressure drop do not change for ESP's relative to current operation when the ESP's are upgraded or replaced to improve PM collection. Therefore, the fan electricity requirements for ESP's do not change relative to current operation. However, if a scrubber is added after an ESP, the gas flow rate would be reduced, thereby reducing the fan electricity requirements for the ESP.

The pump electricity requirement (applicable to packed-bed scrubbers) is equal to a numerical factor (0.000188) times the product of the liquid flow rate, amount of head pressure, and operating hr/yr divided by the pump-motor efficiency.[9] The liquid flow rate varies with each model process unit. A head pressure of 18 m (60 ft) and a pump-motor efficiency of 70 percent were assumed.

The operating electricity requirement (applicable to ESP's) is equal to a numerical factor (0.00194) times the product of the ESP plate area and operating hr/yr.[9] The ESP plate area is calculated as a product of the exhaust gas flow rate and the ESP SCA. The gas flow rate varies with each model process unit, and the SCA is based on information from individual mills.[6] Although the SCA is not the sole parameter that determines PM collection efficiency for ESP's, for the purposes of estimating impacts, the SCA was used as an indicator of PM collection efficiency.

Steam energy savings result from the increased steam flow that occurs with the gaseous organic HAP control option of converting the DCE recovery furnace system to an NDCE recovery furnace.[11] With NDCE recovery furnaces, more heat is available for steam production than with DCE recovery furnaces because combustion gases are not used to concentrate black liquor. The increased steam production resulting from converting the DCE recovery furnace system to the NDCE design reduces the power boiler steam production requirements. A fuel savings can be realized from this steam energy savings because the amount of fuel required for steam production in the power boiler decreases. The steam energy savings are partially offset by low-pressure steam requirements for the concentrator, which is a part of the NDCE recovery furnace system. The low-pressure steam would be used to concentrate the black liquor. These concentrator steam requirements were determined based on the low-pressure steam flow rate and the change in enthalpy between the entering feedwater and the steam leaving the superheater.[12]

Another energy savings from converting the DCE recovery furnace system to an NDCE recovery furnace is the electricity saved by removing the BLO unit. The BLO operating energy savings were determined by dividing the BLO electricity cost savings presented in Chapter 6 by the unit cost of electricity in the U. S. EPA Handbook: Control Technologies for Hazardous Air Pollutants.[13]

The exact methods used to determine the energy impacts of converting DCE recovery furnace systems to NDCE recovery furnaces are presented in Section 5.2.3.2 and corresponding tables.

5.1.3 Water Pollution Impacts

Some of the control options for recovery furnaces, SDT’s, and lime kilns may have a significant impact on the amount of wastewater generated, treated, and disposed. If lime kilns reduce PM emissions by replacing the existing scrubber with a new ESP, the existing scrubber discharge would be completely eliminated. On the other hand, if recovery furnaces reduce HCl emissions by adding a packed-bed scrubber, a new scrubber

discharge would be generated. If SDT's reduce PM emissions by replacing the existing PM control device with a new scrubber, the wastewater discharge may be increased because of the increased amount of PM in the scrubber liquid. The additional discharge from the recovery furnace and SDT scrubbers may simply be recycled and used elsewhere in the plant. Alternatively, the scrubber discharge may require treatment and disposal. The wastewater disposal impacts and the exact methods used to estimate them are discussed for each of these control options in their respective sections.

5.1.4 Solid Waste Disposal Impacts

The recovery furnace and lime kiln PM control options include ESP's for PM control and, therefore, will generate a PM catch. The PM catch from the ESP may simply be recycled back into the process. Potential solid waste disposal impacts are discussed for each of these control options in their respective sections.

5.1.5 Other Impacts

Other impacts considered for the control options include noise impacts, visual impacts, odor impacts, and irreversible and irretrievable commitment of resources.

Noise impacts may occur as a result of changing the fan size to accommodate the new or upgraded APCD's. Visual impacts may occur as a result of reducing the amount of PM and moisture (i.e., steam) emitted from the stack. Odor impacts may occur as a result of reducing malodorous TRS emissions. Because the odor impacts were based on available TRS emissions data, these impacts were easily estimated quantitatively. However, little information was available to estimate noise, visual, and other impacts quantitatively; therefore, only a qualitative assessment of these impacts was done for each control option, where applicable.

Odor impacts were determined for the gaseous organic HAP control options by comparing TRS emissions at baseline and at control levels for those control options. The TRS emissions for DCE and NDCE recovery furnaces were derived from TRS emissions

data (in parts per million [ppm] as H_2S) provided by individual pulp and paper mills.[6] These TRS concentrations were converted to annual TRS emissions using the ideal gas law and the model BLS firing rates, assuming 351 operating d/yr. Total reduced sulfur emissions from BLO units are generally emitted in the range of 0.04 to 0.06 kg/ADMP (0.08 to 0.13 lb/ADTP).[14] A mid-range value of 0.05 kg/ADMP (0.10 lb/ADTP) was used to calculate the annual TRS emissions from model BLO units based on the model pulp production rates, assuming 351 operating d/yr. The mid-range value for BLO units was used because the only data available for BLO TRS emissions were the bounds of the range.

5.2 RECOVERY FURNACE CONTROL OPTIONS

The following sections discuss the model environmental and energy impacts of implementing control options designed to reduce emissions of PM (as a surrogate for PM HAP's), methanol (as a surrogate for gaseous organic HAP's), and HCl. These control options include PM controls (Section 5.2.1), wet to dry ESP system conversion (Section 5.2.2), conversion of a DCE recovery furnace system to an NDCE recovery furnace (Section 5.2.3), and addition of a packed-bed scrubber (Section 5.2.4). Table 5-1 presents the model recovery furnace sizes and operating parameters.

5.2.1 PM Controls

Two PM control options were evaluated for model NDCE recovery furnaces RF-1 through RF-6 and model DCE recovery furnaces RF-7 through RF-9. The control options apply to both new and existing recovery furnaces and are described below.

One PM control option that was evaluated would reduce PM emissions from existing recovery furnaces to the NSPS level of 0.10 g/dscm (0.044 gr/dscf). The PM control option evaluated would involve replacing or upgrading the recovery furnace ESP.

A second PM control option that was evaluated would reduce PM emissions from existing recovery furnaces to 0.034 g/dscm (0.015 gr/dscf). This more stringent PM control option would involve replacing or upgrading the recovery furnace ESP and adding a packed-bed scrubber. The second PM control option also

applies to new recovery furnaces; the option could be used to evaluate the impact on new sources subject to a more stringent standard (0.034 g/dscm [0.015 gr/dscf]) than the current NSPS.

The PM control impacts for model NDCE recovery furnaces with dry ESP systems (i.e., RF-1 through RF-3) are assumed to be identical to the PM control impacts for model NDCE recovery furnaces with wet ESP systems (i.e., RF-4 through RF-6) because PM emissions are not affected by whether or not black liquor is used in the ESP system. The environmental and energy impacts associated with the PM control options are presented for the model NDCE and DCE recovery furnaces in the following sections.

5.2.1.1 Air Pollution Impacts. This section presents the primary and secondary air impacts resulting from implementing PM controls.

5.2.1.1.1 Primary emissions. Although emission test data from recovery furnace ESP's on PM HAP performance are limited, data collected from other combustion sources on the relative performance of APCD's for PM and PM HAP's indicate that systems that achieve the greatest PM removal also provide the best performance for the HAP portion of the PM.[15] Therefore, PM performance can be used as a surrogate for PM HAP's. Because emission test data from recovery furnace ESP's indicate that PM emissions are reduced with PM controls, PM HAP emissions would also be reduced.[6] As stated in Section 5.1.1.1, PM HAP emissions from recovery furnaces were estimated to be 0.2 percent of PM based on a comparison of PM and PM HAP emission data for recovery furnaces.

Tables 5-1 and 5-2 present the operating parameters for model NDCE and DCE recovery furnaces, respectively. Tables 5-3 and 5-4 present PM concentrations and PM HAP emission factors for model NDCE and DCE recovery furnaces, respectively. Table 5-5 presents the annual PM and PM HAP emission estimates. Figures 5-1 and 5-2 illustrate the annual PM emission estimates for model NDCE and DCE recovery furnaces, respectively.

The baseline PM concentration for model NDCE recovery furnaces RF-1a through RF-6a is 0.27 g/dscm (0.12 gr/dscf).[2] By

controlling PM emissions from baseline to the NSPS level (0.10 g/dscm [0.044 gr/dscf]), PM emissions would be reduced by 63 percent. On an annual basis, PM emissions would be reduced by about 227 to 593 Mg/yr (250 to 654 ton/yr); PM HAP emissions would be reduced by about 0.5 to 1.2 Mg/yr (0.5 to 1.3 ton/yr). By controlling PM emissions from baseline to a more stringent PM control level of 0.034 g/dscm (0.015 gr/dscf), PM emissions would be reduced by 88 percent. On an annual basis, PM emissions would be reduced by about 313 to 818 Mg/yr (345 to 902 ton/yr); PM HAP emissions would be reduced by about 0.6 to 1.6 Mg/yr (0.7 to 1.8 ton/yr).

The baseline PM concentration for model NDCE recovery furnaces RF-1b through RF-6b is the NSPS PM level (0.10 g/dscm [0.044 gr/dscf]). By controlling PM emissions from the NSPS baseline to 0.034 g/dscm (0.015 gr/dscf), PM emissions would be reduced by 66 percent. On an annual basis, PM emissions would be reduced by about 86 to 225 Mg/yr (95 to 248 ton/yr); PM HAP emissions would be reduced by about 0.2 to 0.4 Mg/yr (0.2 to 0.5 ton/yr).

The baseline PM concentration for model DCE recovery furnaces RF-7a through RF-9a is 0.18 g/dscm (0.08 gr/dscf).[2] By controlling PM emissions from baseline to the NSPS level, PM emissions would be reduced by 45 percent. On an annual basis, PM emissions would be reduced by about 65 to 194 Mg/yr (71 to 214 ton/yr); PM HAP emissions would be reduced by about 0.1 to 0.4 Mg/yr (0.1 to 0.4 ton/yr). By controlling PM emissions from baseline to a more stringent control level of 0.034 g/dscm (0.015 gr/dscf), PM emissions would be reduced by 81 percent. On an annual basis, PM emissions would be reduced by about 117 to 350 Mg/yr (129 to 386 ton/yr); PM HAP emissions would be reduced by about 0.2 to 0.7 Mg/yr (0.3 to 0.8 ton/yr). The PM emission reductions at both PM control levels are lower for model DCE recovery furnaces than for model NDCE recovery furnaces because the baseline PM concentration for model DCE recovery furnaces is lower than that for model NDCE recovery furnaces.

The baseline PM concentration for model DCE recovery furnaces RF-7b through RF-9b is the NSPS PM level (0.10 g/dscm [0.044 gr/dscf]). By controlling PM emissions from the NSPS baseline to 0.034 g/dscm (0.015 gr/dscf), PM emissions would be reduced by 66 percent. On an annual basis, PM emissions would be reduced by about 52 to 156 Mg/yr (57 to 172 ton/yr); PM HAP emissions would be reduced by about 0.1 to 0.3 Mg/yr (0.1 to 0.3 ton/yr).

5.2.1.1.2 Secondary emissions. Secondary emissions of PM, SO_2, NO_x, and CO generated under the PM control options were estimated for model NDCE and DCE recovery furnaces. Table 5-6 presents the annual secondary emission estimates. As shown in the table, the secondary emissions generated under the PM control options are small. The increases in secondary PM emissions are especially insignificant compared to the reductions in primary PM emissions. The more stringent PM control option includes both an ESP upgrade and the addition of a packed-bed scrubber. The increases in secondary SO_2 emissions under the more stringent PM control option are insignificant compared with the large reductions in primary SO_2 emissions that result from adding the packed-bed scrubber. The reductions in primary SO_2 emissions using a packed-bed scrubber are presented in Table 5-12 and discussed in Section 5.2.4.1.1.

5.2.1.2 Energy Impacts. The energy requirements of the PM control options were estimated for model NDCE and DCE recovery furnaces. The energy requirements were estimated based on model SCA values for the ESP. Tables 5-1 and 5-2 present the baseline and control level SCA values for model NDCE and DCE recovery furnaces, respectively. Table 5-7 presents the annual energy requirements. As shown in the table, the annual energy requirements of the PM control options are small.

5.2.1.3 Water Pollution Impacts. Because the ESP operates on a dry basis, no water pollution impacts are associated with an ESP replacement or upgrade used to improve PM collection. Section 5.2.4.3 presents a discussion of the water pollution

impacts resulting from adding a packed-bed scrubber (which is included in the more stringent PM control option).

5.2.1.4 Solid Waste Disposal Impacts. As mentioned in Chapter 2, the PM catch from the recovery furnace ESP is primarily Na_2SO_4 (i.e., saltcake) and Na_2CO_3. These chemicals are subsequently added to the concentrated black liquor in a mix tank (i.e., recycled back into the process) in order to conserve chemicals. Approximately 95 percent of the Na_2SO_4 is recovered. The Na_2SO_4 recycled back to the recovery furnace is reduced to Na_2S, a cooking liquor chemical, in the reducing zone of the furnace. Reprocessing of the Na_2S and Na_2CO_3 into cooking liquor continues in the SDT. The recovery process was assumed to have sufficient capacity to absorb the additional PM resulting from the ESP replacement or upgrade. Thus, no solid waste disposal impacts are expected with an ESP upgrade or replacement. Also, no solid waste disposal impacts are expected with the addition of a packed-bed scrubber (which is included in the more stringent PM control option).

5.2.1.5 Other Impacts. Limited information was available to estimate quantitatively impacts such as noise, visual, odor, and irreversible and irretrievable commitment of resources. Beneficial visual impacts are expected to result from the reduced PM emissions coming out of the recovery furnace stack. However, there also may be negative visual impacts under the more stringent PM control option. The more stringent PM control option would involve adding a packed-bed scrubber, which would add to the moisture (i.e., steam) coming out of the stack. Adding a packed-bed scrubber also would require additional equipment (i.e., larger fans to overcome pressure drops and pumps) that would increase noise levels. However, these incremental noise increases are expected to be small compared to the typical background noise levels at pulp and paper mills. The other impacts, if any, are expected to be minimal as a result of implementing the recovery furnace PM control options.

5.2.2 Wet to Dry ESP System Conversion

Two control options were evaluated for reducing emissions of gaseous organic HAP's such as methanol from existing NDCE recovery furnaces. These control options are (1) converting an ESP system that uses unoxidized black liquor or HAP-contaminated process water in the ESP bottom or PM return system (referred to as a wet ESP system) to an ESP system that uses "clean" water (i.e., water uncontaminated with methanol and other gaseous organic HAP's) in the ESP bottom or PM return system; and (2) converting a wet ESP system to a dry-bottom ESP with a dry PM return system (referred to as a dry ESP system). With these two control options, the potential stripping of methanol and other gaseous organic HAP's from the black liquor or HAP-contaminated process water in the ESP system would be eliminated.

Only the impacts for the second control option, converting from a wet to a dry ESP system, were evaluated. This decision was based on (1) the lack of emissions data from ESP systems that use "clean" water in the ESP bottom or PM return system; and (2) the fact that very few mills use water in the ESP system.

The wet to dry ESP system conversion control option applies to model NDCE recovery furnaces RF-4 through RF-6, which represent existing NDCE recovery furnaces with wet ESP systems. These models represent existing NDCE recovery furnaces only, because no wet ESP systems are expected to be installed on new NDCE recovery furnaces. The environmental and energy impacts associated with this control option are presented in the following sections.

5.2.2.1 Air Pollution Impacts: Primary Emissions. This section presents the primary air impacts for model NDCE recovery furnaces RF-4 through RF-6 resulting from a wet to dry ESP system conversion. As discussed below in Section 5.2.2.2, no additional electricity requirements are expected in order to operate a dry ESP system. Therefore, no additional secondary emissions are expected to be generated from operation of a dry ESP system.

The impact of the wet to dry ESP system conversion on emissions of gaseous organic HAP's was evaluated. Table 5-3

presents the gaseous organic HAP emission factor for the model NDCE recovery furnaces. Table 5-8 and Figure 5-3 present the annual gaseous organic HAP emission estimates for model NDCE recovery furnaces.

Gaseous organic HAP emissions are reduced by about 72 percent with a wet to dry ESP system conversion. On an annual basis, gaseous organic HAP's are reduced by about 22 to 58 Mg/yr (25 to 64 ton/yr). Approximately 49 percent of these reductions result from the reduction of methanol emissions.

5.2.2.2 Energy Impacts. The tradeoff in horsepower requirements between the wet and dry ESP systems is expected to be approximately equal. For example, a wet-bottom ESP design requires four agitators and a recirculation pump, whereas a dry-bottom ESP design requires four drives for the drag system.[16] Therefore, additional energy requirements are not expected in order to operate dry ESP systems.

5.2.2.3 Water Pollution Impacts. The conversion to wet ESP systems that use "clean" water in the ESP bottom or PM return system was not considered as a control option for the reasons cited in Section 5.2.2. Therefore, no water impacts are expected for the wet to dry ESP system conversion control option.

5.2.2.4 Solid Waste Disposal Impacts. The wet to dry ESP system conversion control option is not expected to have an effect on PM control by the ESP. Furthermore, the PM catch from the ESP is recycled back into the process, and the recovery process is assumed to have sufficient capacity to absorb the additional PM. Therefore, no solid waste disposal impacts are expected for this control option.

5.2.2.5 Other Impacts. Limited information was available to estimate impacts such as noise, visual, and irreversible and irretrievable commitment of resources. The impacts, if any, are expected to be minimal under this control option.

Odor impacts were determined for the wet to dry ESP system conversion control option by comparing TRS emissions before and after the ESP conversion. Wet ESP systems are different from dry ESP systems in that they have the capability of increasing TRS

emissions in the furnace gas stream by stripping TRS from the black liquor.[17] Table 5-9 and Figure 5-4 present the annual TRS emission estimates.

The TRS emission estimates were derived from TRS emissions data (in ppm as H_2S) provided by individual pulp and paper mills.[6] Baseline TRS emissions were estimated based on the 10 percent trimmed mean TRS concentration (2.2 ppm) for NDCE recovery furnaces assumed to be equipped with wet ESP systems.[6] This trimmed mean is a compromise between the mean and the median. Using a trimmed mean with a moderate trimming proportion, such as 10 percent, yields a measure which is neither as sensitive to outlying values as the mean (since any small number of outlying values will be deleted before averaging) nor as insensitive as the median. The 10 percent trimmed mean was estimated by eliminating the smallest 10 percent and the largest 10 percent of the sample and then averaging what was left over.[18] Control level TRS emissions were estimated based on the available TRS concentration data (1 ppm) for an NDCE recovery furnace known to be equipped with a dry ESP system.[6] Using these baseline and control level numbers, it was estimated that TRS emissions would be reduced by approximately 55 percent under the wet to dry ESP system conversion control option. On an annual basis, the TRS emissions for models RF-4 through RF-6 would be reduced by about 3.0 to 7.8 Mg/yr (3.3 to 8.6 ton/yr).

5.2.3 Conversion of a DCE Recovery Furnace System to an NDCE Recovery Furnace

Converting a DCE recovery furnace system to an NDCE recovery furnace (or "low-odor conversion") was evaluated as a control option for reducing emissions of gaseous organic HAP’s from DCE recovery furnace systems. The conversion of a DCE recovery furnace system to an NDCE design involves removing the DCE and BLO unit, adding a concentrator, and extending or replacing the boiler economizer. Additional upgrades are included in the low-odor conversion control option, i.e., an ESP upgrade to improve PM collection and a wet to dry ESP system conversion to reduce gaseous organic HAP emissions.

At stated in Chapter 3, the DCE provides some PM control. Therefore, with the removal of the DCE, the recovery furnace ESP often must be upgraded or replaced during a low-odor conversion in order to meet applicable PM emission limits. For the purposes of this impact analysis, an ESP upgrade PM control option that would maintain or reduce PM emissions to the NSPS level of 0.10 g/dscm (0.044 gr/dscf) has been evaluated for existing DCE recovery furnaces that have baseline PM emissions at or above the NSPS level. This PM control option applies to model DCE recovery furnaces RF-7a/7b through RF-9a/9b. These models represent existing sources only, because no new DCE recovery furnaces are expected to be built.

A PM control option that would reduce PM emissions to 0.034 g/dscm (0.015 gr/dscf) has also been evaluated for DCE recovery furnaces that have PM emissions at or below the NSPS level but greater than 0.034 g/dscm (0.015 gr/dscf). This PM control option includes an ESP upgrade coupled with the addition of a packed-bed scrubber and applies to model DCE recovery furnaces RF-7b through RF-9b.

The environmental and energy impacts associated with the low-odor conversion control option are presented for model DCE recovery furnaces in the following sections.

5.2.3.1 Air Pollution Impacts. This section presents the primary and secondary air impacts resulting from implementing the low-odor conversion control option.

5.2.3.1.1 Primary emissions. The impact on emissions of gaseous organic HAP's from converting a DCE recovery furnace system to an NDCE design and converting the wet ESP system to a dry ESP system was evaluated. The impact on PM and PM HAP emissions from upgrading the ESP was also studied. Table 5-2 presents the operating parameters, and Table 5-4 presents the model concentrations and emission factors for the model DCE recovery furnaces. Table 5-5 and Figure 5-2 present the annual emission estimates for PM and PM HAP's; Table 5-8 and Figure 5-3 present the annual emission estimates for gaseous organic HAP's.

The PM and PM HAP emission reductions achievable by upgrading the ESP for the model DCE recovery furnaces were discussed in Section 5.2.1.1.1.

With a low-odor conversion, gaseous organic HAP emissions from model DCE recovery furnace systems (including BLO units) would be reduced by about 93 percent; on an annual basis, emissions would be reduced by 69 to 206 Mg/yr (76 to 227 ton/yr). Approximately 70 percent of these reductions result from the reduction of methanol emissions.

5.2.3.1.2 Secondary emissions. Secondary emissions generated under the low-odor conversion control option were estimated for model DCE recovery furnaces. Table 5-10 presents the annual secondary emission estimates. The secondary emission reductions resulting from the removal of the BLO unit and the secondary emission increases resulting from the implementation of the low-odor conversion PM controls are discussed separately below.

As a result of the removal of the BLO unit, secondary emissions are reduced for model DCE recovery furnaces RF-7 through RF-9. The secondary PM emission estimates range from -567 to -1,100 kg/yr (-1,250 to -2,430 lb/yr); the secondary SO_2 emission estimates range from -2,770 to -5,350 kg/yr (-6,110 to -11,800 lb/yr); the secondary NO_x emission estimates range from -1,100 to -2,130 kg/yr (-2,430 to -4,700 lb/yr); and the secondary CO emission estimates range from -2,090 to -4,050 kg/yr (-4,600 to -8,920 lb/yr).

The procedures for estimating secondary emissions associated with the PM control options were presented previously in Section 5.2.1.1.2 and are the same for both converted and unconverted model DCE recovery furnaces; therefore, only the differences between the converted and unconverted models that impact secondary emissions are discussed below. The model SCA values for upgraded ESP's on DCE recovery furnaces converted to the NDCE design are higher than the model SCA values for ESP's on unconverted DCE recovery furnaces. Removal of the DCE, which removes a portion of the PM prior to the ESP, is the primary

reason for increasing the existing ESP's SCA after the low-odor conversion. The increased SCA results in an increase in the electricity requirements, and, subsequently, an increase in secondary emissions. Although the gas flow rates from converted DCE's are lower than the gas flow rates from unconverted DCE's (which reduces the fan electricity requirements), the associated decrease in electricity requirements is more than offset by the larger increase in electricity requirements due to the higher SCA. Therefore, the secondary emission estimates presented in Table 5-10 for converted DCE recovery furnaces are higher than those presented in Table 5-6 for unconverted DCE recovery furnaces. For example, the incremental PM secondary emissions for model RF-7a for the NSPS PM control option are equal to 90 kg/yr (199 lb/yr) for a converted DCE recovery furnace and 45 kg/yr (100 lb/yr) for an unconverted DCE recovery furnace. Although secondary PM emissions are higher when the PM control options are applied to the converted DCE recovery furnaces than to the unconverted DCE recovery furnaces, the secondary emissions are insignificant when compared to the primary PM emission reductions achieved with the PM control options.

5.2.3.2 Energy Impacts. Energy impacts for the low-odor conversion control option were estimated for model DCE recovery furnaces. The energy impacts include electricity impacts from both the elimination of the BLO unit and the PM controls and steam energy impacts from the furnace conversion. Table 5-2 presents the baseline and control level SCA values used to estimate the PM control electricity impacts for each model DCE recovery furnace. Table 5-11 presents the annual estimates of the energy impacts.

5.2.3.2.1 Electricity impacts. The incremental electricity impacts from the elimination of the BLO unit and the low-odor conversion PM controls are discussed separately below.

With the elimination of the BLO unit, the BLO operating electricity savings were estimated to range from -2,450 to -4,750 MWh/yr for models RF-7 through RF-9. The operating electricity savings were estimated by dividing the annual BLO

operating cost savings by the unit cost of electricity. The annual BLO operating cost savings are discussed in Chapter 6 and range from $147,000/yr to $285,000/yr for models RF-7 through RF-9. The unit cost of electricity is $0.06/kilowatt-hour (kWh).[13] Most of the BLO operating costs (about 60 percent) is for power to operate the blowers and pumps. The remaining 40 percent is for operating the reheater.[10]

The procedures for estimating the electricity requirements associated with the PM control options were presented previously in Section 5.2.1.1.3 and are the same for both converted and unconverted model DCE recovery furnaces; therefore, only the differences between the converted and unconverted models that impact electricity requirements are discussed below. As discussed in Section 5.2.3.1.2, the model SCA values for upgraded ESP's on converted DCE recovery furnaces are higher than the model SCA values for ESP's on unconverted DCE recovery furnaces. The increased SCA results in an increase in the electricity requirements. Although the gas flow rates from converted DCE recovery furnaces are lower than the gas flow rates from unconverted DCE recovery furnaces (which reduces the fan electricity requirements), the associated decrease in electricity requirements is more than offset by the larger increase in electricity requirements due to the higher SCA. Therefore, the electricity requirements for the PM control options are higher for the converted DCE recovery furnaces shown in Table 5-11 than for the unconverted DCE recovery furnaces shown in Table 5-7. For example, the electricity requirements for model RF-7a for the NSPS PM control option are equal to 391 MWh/yr for a converted DCE furnace and 191 MWh/yr for an unconverted DCE recovery furnace. Although electricity requirements are higher when the PM control options are applied to the converted DCE recovery furnaces than to the unconverted DCE recovery furnaces, these requirements are insignificant when compared to the energy savings obtained from removing the BLO unit or the energy requirements of pulp and paper mills.

5.2.3.2.2 Steam energy impacts. Implementing the low-odor conversion control option may increase steam energy production.[11] Table 5-11 presents the estimates for steam energy production for unconverted DCE recovery furnaces and the net increase in steam energy production after a low-odor conversion. The increased steam energy production for model DCE recovery furnaces RF-7 through RF-9 ranges from 1.97×10^8 megajoules per year (MJ/yr) (1.87×10^5 million Btu per year [MM Btu/yr]) to 5.91×10^8 MJ/yr (5.61×10^5 MM Btu/yr).

The net increase in steam energy production was estimated to be equal to the steam production from a low-odor conversion minus the steam requirements to operate the concentrator.

To determine the steam production from a low-odor conversion, the increase in the thermal efficiency that results from the low-odor conversion was estimated. The heat input to the system was calculated using a BLS heat content of 13,900 kJ/kg (6,000 Btu/lb) of BLS fired.[19] The increase in the thermal efficiency that results from a low-odor conversion was estimated to be 10 percentage points, based on average thermal efficiencies of 56 percent for DCE recovery furnaces and 66 percent for NDCE recovery furnaces.[20,21] Therefore, the increase in the amount of heat input that can be converted to steam with a low-odor conversion was estimated by multiplying the heat input by the 10 percentage point increase in thermal efficiency. The heat input value was divided by the thermal efficiency for a power boiler (about 85 percent) to determine the required energy input for a power boiler. The required energy input is equivalent to the increased steam production. The increased steam production was converted to annual steam production estimates for each model DCE recovery furnace, assuming 351 operating d/yr. The energy input for the power boiler can be converted to fuel savings by using the heat contents for specific power boiler fuels.

To determine the concentrator steam requirements, the steam flow for each model DCE recovery furnace was multiplied by the change in enthalpy between the entering feedwater (439.8 kJ/kg

[189.2 Btu/lb]) and the steam leaving the superheater (3,095.0 kJ/kg [1,331.5 Btu/lb]).[12] The model steam flows were based on a steam flow of approximately 4,500 kg/hr (10,000 lb/hr) of low-pressure steam for a 1.1 million kg BLS/d (2.4 million lb BLS/d) furnace.[22] The steam flow was extrapolated for each model DCE recovery furnace size, assuming that steam usage is proportional to the amount of black liquor concentrated.

5.2.3.3 Water Pollution Impacts. The conversion to ESP systems that use "clean" water in the ESP bottom or PM return system was not evaluated as a control option for the reasons cited in Section 5.2.2. Therefore, no water impacts are expected from the wet to dry ESP system conversion included under the low-odor conversion control option. The water pollution impacts resulting from adding a packed-bed scrubber (included under the more stringent PM control option) are discussed in Section 5.2.4.3.

5.2.3.4 Solid Waste Disposal Impacts. As noted in Section 5.2.1.4, the PM catch from the ESP is recycled back into the process. The recovery process was assumed to have sufficient capacity to absorb the additional PM resulting from upgrading the ESP. Therefore, no solid waste impacts are expected to be associated with the low-odor conversion PM control options.

5.2.3.5 Other Impacts. Odor impacts were determined for the low-odor conversion control option by comparing TRS emissions before and after the low-odor conversion. Table 5-9 presents the baseline TRS emission estimates for unconverted model DCE recovery furnace systems (which include BLO units) and the TRS emission reductions for converted model DCE recovery furnaces. Figure 5-4 illustrates the annual TRS emission estimates.

In order to determine the baseline TRS emissions from DCE recovery furnace systems, the baseline TRS emissions from DCE recovery furnaces and BLO units were combined. The DCE recovery furnace baseline TRS emission estimate was derived from TRS emissions data (in ppm as H_2S) provided by individual pulp and paper mills.[6] Based on the available TRS emissions data, the

10 percent trimmed mean TRS concentration for DCE recovery furnaces is approximately 12 ppm.[6] The BLO unit TRS emission estimate was derived from the pulp and paper NSPS supporting document.[14] Based on the bounds of TRS values given in the supporting document, a median value of 0.05 kg/ADMP (0.10 lb/ADTP) was used as the baseline TRS emission estimate for BLO units. The control level TRS emission estimate (1 ppm) for converted DCE recovery furnaces was derived from TRS emissions data provided for an NDCE recovery furnace known to be equipped with a dry ESP system.[6] Emissions of TRS compounds are expected to be reduced by approximately 94 percent under the low-odor conversion control option. On an annual basis, the TRS emission reductions would be 22 to 67 Mg/yr (25 to 74 ton/yr).

Limited information was available to estimate quantitatively impacts such as noise, visual, and irreversible and irretrievable commitment of resources. Beneficial visual impacts are expected under the low-odor conversion control option. The beneficial visual impacts include the reduction in PM emissions, the elimination of the BLO vent gas stacks, and the reduction in the amount of moisture (i.e., steam) coming out of the stack with the elimination of the DCE. This reduction in moisture content could be completely eliminated if the more stringent PM control option is implemented. The more stringent PM control option includes a packed-bed scrubber, which would increase the moisture content in the stack. Adding a packed-bed scrubber also requires additional equipment (i.e., larger fans to overcome pressure drops and pumps) that would increase noise levels. However, these incremental noise increases are expected to be small compared to the typical background noise levels at pulp and paper mills. The other impacts, if any, are expected to be minimal as a result of implementing the low-odor conversion control option.

5.2.4 Addition of Packed-Bed Scrubber

The addition of a packed-bed scrubber downstream of the ESP is included in two of the control options examined for recovery furnaces. These control options are (1) the use of an ESP plus a packed-bed scrubber to meet an outlet PM emission level of

0.034 g/dscm (0.015 gr/dscf); and (2) the use of a packed-bed scrubber to reduce HCl emissions from recovery furnaces.

The impacts of combining an ESP upgrade or ESP replacement with a packed-bed scrubber to control PM emissions to 0.034 g/dscm (0.015 gr/dscf) are presented in Section 5.2.1. The impacts presented in the sections below are based on the use of a packed-bed scrubber to control HCl emissions from recovery furnaces. The applicable model recovery furnaces for the packed-bed scrubber HCl control option are model NDCE and DCE recovery furnaces RF-1 through RF-9. The model DCE recovery furnaces include both DCE recovery furnaces converted to the NDCE design and unconverted DCE recovery furnaces. Tables 5-1 and 5-2 present the sizes and operating parameters for model NDCE and DCE recovery furnaces, respectively.

5.2.4.1 Air Pollution Impacts. This section presents the primary and secondary air impacts resulting from adding a packed-bed scrubber to control HCl emissions from model recovery furnaces.

5.2.4.1.1 Primary emissions. The impact of the packed-bed scrubber control option on emissions of HCl and another acid gas, SO_2, was evaluated for model recovery furnaces. Tables 5-3 and 5-4 present the HCl and SO_2 emission factors for model NDCE and DCE recovery furnaces, respectively. Table 5-12 presents the annual emission estimates for HCl and SO_2; Figures 5-5 and 5-6 illustrate the annual emission estimates for HCl and SO_2, respectively.

The incremental HCl emission reductions for model NDCE and converted model DCE recovery furnaces RF-1 through RF-9 range from 8.3 to 36 Mg/yr (9.1 to 40 ton/yr). The incremental HCl emission reductions for the unconverted model DCE recovery furnaces RF-7 through RF-9 are slightly lower because of different furnace characteristics (i.e., higher model gas flow rates). The HCl emission reductions for unconverted models RF-7 through RF-9 range from 7.8 to 24 Mg/yr (8.6 to 26 ton/yr).

The incremental SO_2 emission reductions for model NDCE and converted model DCE recovery furnaces RF-1 through RF-9 range

from 59 to 384 Mg/yr (65 to 423 ton/yr). The incremental SO_2 emission reductions for the unconverted model DCE recovery furnaces RF-7 through RF-9 are slightly higher because the control level SO_2 emission factor associated with DCE recovery furnaces is lower than the control level SO_2 emission factor associated with NDCE recovery furnaces. The SO_2 emission reductions for unconverted models RF-7 through RF-9 range from 74 to 221 Mg/yr (81 to 244 ton/yr). Overall, the SO_2 emission reduction achievable with a packed-bed scrubber is approximately 10 times greater than the HCl emission reduction.

Based on information from a scrubber manufacturer, emissions of gaseous HAP's such as methanol, formaldehyde, and acetaldehyde may be reduced with a packed-bed scrubber, but no emissions data were available to estimate potential reductions for these HAP's.[23] Therefore, HCl and SO_2 were assumed to be the only gaseous pollutants reduced with a packed-bed scrubber.

5.2.4.1.2 Secondary emissions. Secondary emissions generated under the packed-bed scrubber control option were estimated for model recovery furnaces. The baseline secondary emissions for the packed-bed scrubber control option are equal to zero (i.e., no packed-bed scrubber at baseline). Table 5-13 presents the incremental secondary emissions relative to baseline for each model recovery furnace.

The increases in secondary PM emissions from operating a recovery furnace packed-bed scrubber are insignificant compared to the reductions in primary PM emissions from implementing the recovery furnace PM control options. The secondary PM emission estimates for model NDCE and converted DCE recovery furnaces RF-1 through RF-9 range from 138 to 594 kg/yr (304 to 1,310 lb/yr). The secondary PM emission estimates for unconverted model DCE recovery furnaces RF-7 through RF-9 range from 145 to 435 kg/yr (320 to 960 lb/yr).

The increases in secondary SO_2 emissions from operating a recovery furnace packed-bed scrubber are insignificant compared to the reductions in primary SO_2 emissions from operating a packed-bed scrubber. For model NDCE/converted DCE recovery

furnaces RF-1 through RF-9, the secondary SO_2 emission estimates for the packed-bed scrubber control option range from 671 to 2,900 kg/yr (1,480 to 6,390 lb/yr). The secondary SO_2 emission estimates for unconverted model DCE recovery furnaces RF-7 through RF-9 range from 708 to 2,120 kg/yr (1,560 to 4,670 lb/yr).

For model NDCE and converted DCE recovery furnaces RF-1 through RF-9, the secondary NO_x emission estimates range from 266 to 1,150 kg/yr (587 to 2,540 lb/yr). For unconverted model DCE recovery furnaces RF-7 through RF-9, the secondary NO_x emission estimates range from 281 to 844 kg/yr (619 to 1,860 lb/yr).

For model NDCE and converted DCE recovery furnaces RF-1 through RF-9, the secondary CO emission estimates range from 503 to 2,190 kg/yr (1,110 to 4,820 lb/yr). For unconverted model DCE recovery furnaces RF-7 through RF-9, the secondary CO emission estimates range from 531 to 1,600 kg/yr (1,170 to 3,520 lb/yr).

5.2.4.2 Energy Impacts. The increases in energy impacts for the packed-bed scrubber control option were determined for model recovery furnaces. The baseline energy level for the packed-bed scrubber control option is equal to zero (i.e., no packed-bed scrubber at baseline). Table 5-14 presents the incremental energy impacts relative to baseline.

The energy impacts for the packed-bed scrubber control option range from 593 to 2,570 MWh/yr for NDCE/converted DCE models RF-1 through RF-9 and 625 to 1,870 MWh/yr for unconverted DCE models RF-7 through RF-9.

5.2.4.3 Water Pollution Impacts. Adding a packed-bed scrubber creates a new wastewater stream for recovery furnaces, thereby affecting the water balance at the mill. Whether there are any significant wastewater disposal impacts for this option depends on whether or not the scrubber discharge could be recycled and reused elsewhere in the mill. Wastewater impacts were estimated for model recovery furnaces assuming there was no prior recycle or reuse. Tables 5-1 and 5-2 present the model wastewater flow rates used to estimate wastewater impacts for model NDCE and DCE recovery furnaces, respectively. The baseline

wastewater impacts for the packed-bed scrubber control option are equal to zero (i.e., no packed-bed scrubber at baseline). Table 5-15 presents the incremental wastewater impacts relative to baseline.

Information was available from two sources to determine the amount of wastewater generated by the packed-bed scrubber control option. Wastewater flow rate values were estimated using procedures in the OAQPS Control Cost Manual and using wastewater flow rate values provided by a scrubber manufacturer.[9,23] The wastewater flow rate values calculated using the OAQPS Control Cost Manual are presented in Chapter 6 in Table 6-23. A scrubber manufacturer provided wastewater flow rate values of 21.24, 53.07, and 84.79 liters per minute (L/min) (5.61, 14.02, and 22.40 gallons per minute [gpm]) for three model recovery furnaces with scrubber inlet gas flow rates of 47.2, 118, and 189 m^3/sec (100,000, 250,000, and 400,000 acfm), respectively.[23] The wastewater flow rates from the scrubber manufacturer were corrected to correspond to the model sizes used in this impact analysis and then were averaged with the wastewater flow rates obtained using the OAQPS Control Cost Manual to determine the average wastewater impacts for the packed-bed scrubber control option. The increased wastewater impacts presented below for the recovery furnace packed-bed scrubber control option are insignificant compared to the reduced wastewater impacts presented in Section 5.5.1.3 for the lime kiln PM control option, which involves replacing existing wet scrubbers with ESP's.

The wastewater impacts for NDCE/converted DCE models RF-1 through RF-9 range from 6.1 to 26 million liters per year (L/yr) (1.6 to 7.0 million gallons per year [gal/yr]). The wastewater impacts for unconverted DCE models RF-7 through RF-9 range from 6.3 to 19 million L/yr (1.7 to 5.0 million gal/yr).

5.2.4.4 Solid Waste Disposal Impacts. No solid waste disposal impacts are expected from adding a packed-bed scrubber.

5.2.4.5 Other Impacts. Adding a packed-bed scrubber requires additional equipment (i.e., larger fans to overcome higher pressure drops and pumps) that would increase noise

levels. However, these incremental noise increases are expected to be small compared to the typical background noise levels at pulp and paper mills. Limited information is available to estimate quantitatively the visual, odor, and other impacts. However, because adding a packed-bed scrubber increases the moisture (i.e., steam) coming out of the stack, there may be negative visual impacts. Beneficial odor impacts may result from the reduction in acid gas emissions. The other impacts, if any, are expected to be minimal as a result of implementing this control option.

5.3 BLACK LIQUOR OXIDATION UNIT CONTROL OPTION

Two control options, (1) conversion of a DCE recovery furnace system to an NDCE recovery furnace and (2) incineration of BLO vent gases, were evaluated for controlling gaseous organic HAP emissions from air-sparging BLO units. The environmental and energy impacts of the first option--converting DCE recovery furnace systems to NDCE recovery furnaces--were presented in Section 5.2.3. The following sections present the environmental and energy impacts of the second BLO control option--incineration of BLO vent gases. This BLO control option applies to model BLO units BLO-1 through BLO-3, which represent existing BLO units associated with DCE recovery furnaces. These models represent only existing BLO units because no new DCE recovery furnace systems with BLO units are expected to be installed.

5.3.1 Air Pollution Impacts

This section presents the primary and secondary air impacts for model BLO units resulting from implementing the BLO vent gas control option.

5.3.1.1 Primary Emissions. The impact of the BLO vent gas control option on emissions of gaseous organic HAP's is discussed below for the model BLO units. Table 5-16 presents the operating parameters, as well as the model emission factors, for each model BLO unit. Table 5-17 and Figure 5-7 present the gaseous organic HAP annual emission estimates for model BLO units.

Gaseous organic HAP emissions are assumed to be reduced by about 98 percent from the model BLO units with the incineration

of BLO vent gases in a power boiler or other incineration device. For models BLO-1 through BLO-3, gaseous organic HAP emissions are estimated to be reduced by 29 to 86 Mg/yr (31 to 94 ton/yr). Approximately 85 percent of these reductions result from the reduction of methanol emissions.

5.3.1.2 Secondary Emissions. The secondary emissions generated under the BLO vent gas control option were estimated for the model BLO units. The baseline secondary emissions for the BLO vent gas control option are equal to zero (i.e., no BLO control at baseline). Table 5-18 presents the incremental secondary emissions relative to baseline.

For models BLO-1 through BLO-3, the secondary PM emission estimates range from 400 to 1,210 kg/yr (883 to 2,670 lb/yr); the secondary NO_x emission estimates range from 776 to 2,340 kg/yr (1,710 to 5,160 lb/yr); and the secondary CO emission estimates range from 1,470 to 4,440 kg/yr (3,240 to 9,780 lb/yr).

The secondary SO_2 emission estimates associated with controlling BLO vent gas emissions range from 9,710 to 29,200 kg/yr (21,400 to 64,300 lb/yr) for models BLO-1 through BLO-3. As discussed in Section 5.1.1.2, the secondary SO_2 emissions associated with the BLO vent gas control option include (1) SO_2 emissions resulting from the generation of energy required to collect and incinerate the BLO vent gases and (2) SO_2 emissions generated when the TRS in the BLO vent gases is combusted. All of the TRS collected is assumed to be combusted. Also, all of the SO_2 that is formed from the combustion of TRS compounds is assumed to be emitted to the atmosphere; this assumption is a worst-case assumption since many power boilers are equipped with scrubbers for SO_2 control.

5.3.2 Energy Impacts

The energy impacts for the BLO vent gas control option were estimated for the model BLO units. The baseline energy impacts for the BLO vent gas control option are equal to zero (i.e., no BLO control at baseline). Table 5-19 presents the incremental energy impacts relative to baseline.

The model energy impacts were estimated based on the information provided by an individual mill regarding the total horsepower requirements to operate the mill's BLO vent gas control equipment.[10] The energy requirements for the BLO control system at this mill were scaled for the model BLO units, assuming a direct relationship between BLO vent gas flow rate and energy requirements. The mill has a BLO vent gas flow rate of 7.7 m^3/sec (16,327 acfm).[6] Based on information supplied by the mill, 980 kilowatts (kW) (100 horsepower [hp]) are required to operate the mill water booster pump motor, 29 kW (3 hp) to operate the BLO condenser condensate pump motor, and 3,900 kW (400 hp) to operate the BLO off gas blower motor.[10] The annual energy requirements were estimated assuming the BLO system operates 8,424 hr/yr and range from 1,720 to 5,210 MWh/yr for models BLO-1 through BLO-3.

5.3.3 Water Pollution Impacts

Although some condensate is collected from the BLO vent gases, the quantity is negligible.[24] Therefore, the water impacts for the BLO control option are expected to be negligible.

5.3.4 Solid Waste Disposal Impacts

No solid waste impacts are expected to be associated with the BLO control option.

5.3.5 Other Impacts

Beneficial odor impacts are expected to result from implementing the BLO vent gas control option and are discussed below for the model BLO units. Table 5-20 and Figure 5-8 present the annual TRS emission estimates.

As discussed in Section 5.1.5, a mid-range value of 0.05 kg/ADMP (0.10 lb/ADTP) was used to calculate the baseline TRS emissions from BLO units.[14] The baseline TRS emissions are assumed to be reduced by about 98 percent with the incineration of BLO vent gases in a power boiler or other incineration device. On an annual basis, the TRS emissions were estimated to be reduced by about 4.1 to 12 Mg/yr (4.6 to 14 ton/yr) for models BLO-1 through BLO-3.

Beneficial visual impacts are expected to result from the elimination of BLO vent gas stacks. Limited information was available to estimate impacts such as noise and irreversible and irretrievable commitment of resources. The impacts, if any, are expected to be minimal as a result of implementing the BLO vent gas control option.

5.4 SMELT DISSOLVING TANK CONTROL OPTIONS

This section discusses the environmental and energy impacts resulting from implementing the SDT PM control options. Two PM control options that would reduce PM emissions from SDT's have been evaluated. The first option would reduce PM emissions from existing SDT's to the NSPS level of 0.10 kg/Mg (0.20 lb/ton) of BLS. The second option would reduce PM emissions from existing SDT's to a more stringent level of 0.06 kg/Mg (0.12 lb/ton) of BLS; scrubbers installed on new SDT's would also be required to meet a PM level of 0.06 kg/Mg (0.12 lb/ton) BLS.

For mills with existing SDT scrubbers, the environmental impacts of both PM control options were estimated based on replacing the existing scrubber with a new scrubber. These impacts were estimated for SDT models SDT-1 through SDT-4. The environmental impacts of installing scrubbers on new SDT's under the second, more stringent PM control option also apply to SDT-1 through SDT-4.

For mills with existing SDT mist eliminators, the environmental impacts of both PM control options were estimated based on replacing the existing mist eliminator with a new scrubber. These impacts were estimated for SDT models SDT-5 through SDT-7. The impacts of installing new mist eliminators were not examined because mist eliminators are not assumed to be installed on new SDT's.

5.4.1 PM Controls

Table 5-21 presents the model SDT sizes and operating parameters for the PM control options. The environmental and energy impacts associated with the control options are discussed in the following sections.

5.4.1.1 Air Pollution Impacts. This section presents the primary and secondary air impacts for model SDT's resulting from the implementation of the PM control options.

5.4.1.1.1 Primary emissions. Although emission test data from SDT's on PM HAP performance are limited, available information indicates that APCD's that achieve the greatest PM removal also provide the best performance for the HAP portion of the PM.[15] Therefore, PM performance can be used as a surrogate for PM HAP's. Because emission test data from SDT scrubbers indicate that PM emissions are reduced with PM controls, PM HAP emissions would also be reduced.[6] As stated in Section 5.1.1.1, PM HAP emissions from SDT's were estimated to be 0.06 percent of PM based on a comparison of PM and PM HAP emission data for SDT's.

Table 5-21 presents the model PM emission factors for models SDT-1 through SDT-7. The baseline PM emission factor is 0.18 kg/Mg (0.37 lb/ton) BLS for model SDT's with scrubbers (models SDT-1 through SDT-4).[2] The baseline PM emission factor is 0.23 kg/Mg (0.46 lb/ton) BLS for model SDT's with mist eliminators (models SDT-5 through SDT-7).[2] The control level PM emission factors are 0.10 kg/Mg (0.20 lb/ton) BLS and 0.06 kg/Mg (0.12 lb/ton) BLS.

Table 5-22 and Figure 5-9 present the annual PM and PM HAP emission estimates. By controlling PM emissions from a baseline of 0.18 kg/Mg (0.37 lb/ton) BLS to a control level of 0.10 kg/Mg (0.20 lb/ton) BLS, PM emissions would be reduced by 46 percent from models SDT-1 through SDT-4. On an annual basis, PM emissions would be reduced by about 12 to 53 Mg/yr (13 to 58 ton/yr); PM HAP emissions would be reduced by about 0.007 to 0.03 Mg/yr (0.008 to 0.03 ton/yr).

By controlling PM emissions from 0.18 kg/Mg (0.37 lb/ton) BLS to a more stringent control level of 0.06 kg/Mg (0.12 lb/ton) BLS, PM emissions would be reduced by 68 percent from models SDT-1 through SDT-4. On an annual basis, PM emissions would be reduced by about 18 to 78 Mg/yr (20 to 86 ton/yr); PM HAP

emissions would be reduced by about 0.01 to 0.05 Mg/yr (0.01 to 0.05 ton/yr).

By controlling PM emissions from a baseline of 0.23 kg/Mg (0.46 lb/ton) BLS to a control level of 0.10 kg/Mg (0.20 lb/ton) BLS, PM emissions would be reduced by 57 percent from models SDT-5 through SDT-7. On an annual basis, PM emissions would be reduced by about 19 to 56 Mg/yr (21 to 62 ton/yr); PM HAP emissions would be reduced by about 0.01 to 0.03 Mg/yr (0.01 to 0.04 ton/yr).

By controlling PM emissions from 0.23 kg/Mg (0.46 lb/ton) BLS to a more stringent control level of 0.06 kg/Mg (0.12 lb/ton) BLS, PM emissions would be reduced by 74 percent from models SDT-5 through SDT-7. On an annual basis, PM emissions would be reduced by about 24 to 73 Mg/yr (27 to 81 ton/yr); PM HAP emissions would be reduced by about 0.01 to 0.04 Mg/yr (0.02 to 0.05 ton/yr).

5.4.1.1.2 Secondary emissions. As discussed in the following section, there is only a small increase in energy requirements from implementing PM controls for SDT's. The increases in energy requirements from a scrubber replacement were considered negligible; because the secondary emissions were estimated based on the increase in energy requirements, they were also considered negligible and are not presented in this impact analysis for models SDT-1 through SDT-4. A different scrubber design, rather than a higher pressure drop, is used in this impact analysis to estimate the impacts for improved PM control for SDT scrubbers.

Although small, the difference in pressure drop between the existing mist eliminator and the new design scrubber replacing it was considered large enough to justify estimating the increase in APCD energy requirements for those model SDT's replacing existing mist eliminators with new wet scrubbers (models SDT-5 through SDT-7). The increases in secondary emissions were then estimated for those SDT models based on the increase in APCD energy requirements. Table 5-23 presents the annual secondary emission estimates for models SDT-5 through SDT-7. As shown in the table,

the increases in secondary emissions associated with replacing an existing mist eliminator with a new scrubber are small; the increases in secondary PM emissions are especially insignificant compared to the reductions in primary PM emissions associated with the SDT PM control options.

5.4.1.2 Energy Impacts. For those SDT's replacing existing scrubbers with new scrubbers, the resulting increases in energy requirements are not included in this impact analysis; the increases are considered negligible. The pressure drop for the existing scrubber design, i.e., 12 mm Hg (6.5 in. of H_2O), is only slightly lower than the pressure drop for the new scrubber design, i.e., 13 mm Hg (7 in. H_2O).[6,25] A different scrubber design, rather than a higher pressure drop, is used in this impact analysis to estimate the impacts for improved PM control for SDT scrubbers. Therefore, no energy impacts are presented for models SDT-1 through SDT-4.

As discussed in the previous section, the difference in pressure drop between the existing mist eliminator and the new design scrubber replacing it was considered large enough to justify estimating the incremental APCD energy requirements for models SDT-5 through SDT-7. Based on information from mills, the baseline pressure drop for existing mist eliminators is 1.3 mm Hg (0.7 in. H_2O); the pressure drop for the new scrubber design is estimated to be 13 mm Hg (7 in. H_2O).[6,25] The increase in pressure drop from 1.3 to 13 mm Hg (0.7 to 7 in. H_2O) was used to estimate the incremental energy requirements. Table 5-24 presents the annual energy requirements for models SDT-5 through SDT-7. As shown in the table, the incremental energy requirements associated with replacing an existing mist eliminator with a new scrubber are small.

5.4.1.3 Water Pollution Impacts. By increasing the amount of PM removed from the exhaust gases, the SDT PM control options would increase the amount of PM in the blowdown. Blowdown rates would have to increase because of the greater amount of PM, thereby increasing the amount of wastewater generated. Because wastewater from SDT scrubbers and mist eliminators would

typically be allowed to drain into the SDT to react with the smelt, the additional wastewater generated under this control option is expected to be reused. The SDT is assumed to have sufficient capacity to absorb the additional wastewater and PM resulting from implementing the PM control options; therefore, no wastewater impacts are expected.

5.4.1.4 Solid Waste Disposal Impacts. No solid waste disposal impacts are expected from implementation of the PM control options for SDT's.

5.4.1.5 Other Impacts. Beneficial visual impacts are expected from the reduced PM emissions coming out of the stack. Replacing an existing mist eliminator with an SDT scrubber that has a higher pressure drop would require a larger fan to overcome the higher pressure drop. The larger fan would increase noise levels. However, these incremental noise increases would be small compared to typical background noise levels at pulp and paper mills. Limited information is available to determine the other impacts; however, the impacts, if any, are expected to be minimal as a result of implementing the SDT PM control options.

5.5 LIME KILN CONTROL OPTIONS

This section discusses the environmental and energy impacts resulting from implementing control options designed to reduce PM emissions from lime kilns. Two PM control options were evaluated for existing and new lime kilns. These control options are described below.

One PM control option that has been evaluated for existing lime kilns would reduce PM emissions to the NSPS level of 0.15 g/dscm (0.067 gr/dscf). For existing lime kilns with wet scrubbers, the control option would involve replacing the existing scrubber with an ESP. The actual control device (i.e., ESP or high-efficiency scrubber) selected by a particular mill would actually be site-specific. The impacts for this PM control option were estimated for model lime kilns LK-1 through LK-3, which represent existing lime kilns controlled with wet scrubbers.

Based on PM emissions data supplied by mills, lime kilns controlled with ESP's already achieve a PM level of 0.15 g/dscm (0.067 gr/dscf).[6,25] Therefore, the impacts for the control option reducing PM emissions to 0.15 g/dscm (0.067 gr/dscf) were not estimated for lime kilns controlled with ESP's (represented by models LK-4 through LK-6).

A second PM control option that was evaluated for new and existing lime kilns would reduce PM emissions to 0.023 g/dscm (0.010 gr/dscf). For existing lime kilns with wet scrubbers, the control option would involve replacing the existing scrubber with an ESP; impacts would be estimated for model lime kilns LK-1 through LK-3. For existing lime kilns with ESP's, the control option would involve upgrading the existing ESP. For new lime kilns, the control option would involve installing a new ESP capable of achieving the 0.023 g/dscm (0.010 gr/dscf) PM level. The impacts for upgrading or installing an ESP were estimated for model lime kilns LK-4 through LK-6. The actual control device selected by a particular mill would actually be site-specific.

5.5.1 PM Controls

Table 5-25 presents the model lime kiln sizes and operating parameters used in estimating the impacts of the lime kiln PM control options. The environmental and energy impacts associated with the control options are presented in the following sections.

5.5.1.1 Air Pollution Impacts. This section presents the primary and secondary air impacts estimated for each model lime kiln.

5.5.1.1.1 Primary emissions. Emission test data from lime kiln ESP's on PM HAP performance are limited. As mentioned in Section 5.4.1.1.1, PM performance can be used as a surrogate for PM HAP's, and because emission test data from lime kiln ESP's indicate that PM emissions are reduced with PM controls, PM HAP emissions would also be reduced.[6] As stated in Section 5.1.1.1, PM HAP emissions from lime kilns were estimated to be 1.4 percent of PM based on a comparison of PM and PM HAP emission data for lime kilns.

Table 5-25 presents the PM emission concentrations for the PM control options. Table 5-26 and Figure 5-10 present the annual PM and PM HAP emission estimates.

The baseline PM concentration is 0.27 g/dscm (0.12 gr/dscf) for model lime kilns with wet scrubbers (models LK-1 through LK-3).[2] By controlling PM emissions from a baseline of 0.27 g/dscm (0.12 gr/dscf) to an NSPS control level of 0.15 g/dscm (0.067 gr/dscf), PM emissions would be reduced by 44 percent from models LK-1 through LK-3. On an annual basis, PM emissions would be reduced by about 16 to 53 Mg/yr (18 to 58 ton/yr); PM HAP emissions would be reduced by about 0.2 to 0.7 Mg/yr (0.2 to 0.8 ton/yr).

By controlling PM emissions from 0.27 g/dscm (0.12 gr/dscf) to a more stringent control level of 0.023 g/dscm (0.010 gr/dscf), PM emissions would be reduced by 92 percent from models LK-1 through LK-3. On an annual basis, PM emissions would be reduced by about 33 to 110 Mg/yr (37 to 121 ton/yr); PM HAP emissions would be reduced by about 0.5 to 1.5 Mg/yr (0.5 to 1.7 ton/yr).

The baseline PM concentration for model lime kilns with ESP's (models LK-4 through LK-6) is the NSPS PM level (0.15 g/dscm [0.067 gr/dscf]). By controlling PM emissions from 0.15 g/dscm (0.067 gr/dscf) to a control level of 0.023 g/dscm (0.010 gr/dscf), PM emissions would be reduced by 85 percent from models LK-4 through LK-6. On an annual basis, PM emissions would be reduced by about 17 to 57 Mg/yr (19 to 63 ton/yr); PM HAP emissions would be reduced by about 0.2 to 0.8 Mg/yr (0.3 to 0.9 ton/yr).

5.5.1.1.2 Secondary emissions. The incremental secondary emissions were estimated based on the difference between the baseline and control level APCD energy requirements for lime kilns. Table 5-27 presents the annual secondary emission estimates associated with the PM control options.

Less energy is needed to operate ESP's than to operate scrubbers. Therefore, if the existing scrubber is replaced with an ESP to improve PM control, APCD energy requirements would be

reduced. Because the secondary emissions were estimated based on the APCD energy requirements, they would also be reduced. As shown in Table 5-27, the reductions in secondary emissions are small; the reductions in secondary PM emissions are especially small compared to the reductions in primary PM emissions under the lime kiln PM control options. The reductions are smaller under the more stringent PM control option since that option would require a larger ESP with more energy requirements.

If the existing ESP is upgraded to reduce PM emissions to a more stringent level, secondary emissions would be increased because the upgraded ESP would have higher energy requirements. As shown in Table 5-27, the increases in secondary emissions resulting from the ESP upgrade are small; the increases in secondary PM emissions are especially insignificant compared to the reductions in primary PM emissions associated with this more stringent PM control option.

5.5.1.2 Energy Impacts. Table 5-28 presents the annual APCD energy requirements associated with the lime kiln PM control options.

Because ESP's require less energy to operate than scrubbers, energy requirements are reduced for lime kilns that reduce PM emissions by replacing the existing scrubber with an ESP. The baseline energy requirements for the existing scrubber were determined based on a baseline pressure drop of 39 mm Hg (21 in. H_2O) for lime kiln scrubbers.[6] The energy requirements for ESP's controlling PM emissions to 0.15 g/dscm (0.067 gr/dscf) were determined based on an SCA of 90 $m^2/(m^3/sec)$ (460 ft^2/1,000 acfm) from an ESP with long-term PM emission data below 0.15 g/dscm (0.067 gr/dscf).[6,25] The energy requirements for ESP's controlling PM emissions to 0.023 g/dscm (0.010 gr/dscf) were determined based on an SCA of 220 $m^2/(m^3/sec)$ (1,120 ft^2/1,000 acfm) from an ESP with long-term PM emission data at or below 0.023 g/dscm (0.010 gr/dscf).[6,25]

As shown in Table 5-28, the reductions in energy requirements associated with replacing an existing scrubber with an ESP are small. The reductions are even smaller when baseline

PM emissions are controlled even further, to a level of 0.023 g/dscm (0.010 gr/dscf); additional energy is required for the ESP, thereby reducing the energy savings from replacing the existing scrubber with an ESP.

Energy requirements are increased if existing ESP's are upgraded to improve PM control. An increase in SCA from 90 $m^2/(m^3/sec)$ (460 ft^2/1,000 acfm) to 220 $m^2/(m^3/sec)$ (1,120 ft^2/1,000 acfm) was used to estimate the increase in energy requirements associated with an ESP upgrade. As shown in Table 5-28, the increases in energy requirements associated with an ESP upgrade are small.

5.5.1.3 Water Pollution Impacts. If a wet scrubber is replaced with an ESP to improve PM control, the wastewater stream from the scrubber would be eliminated, thereby affecting the water balance at the mill. Whether there would be any significant reduction in wastewater disposal for this option would depend on whether or not the scrubber discharge was previously recycled and reused. Wastewater impacts were estimated for model lime kilns assuming there was no prior recycle or reuse.

The wastewater impacts were estimated based on a factor of 2,250 kilograms of wastewater per oven-dried megagram of pulp (kg wastewater/ODMP) (4,500 pounds of wastewater per oven-dried ton of pulp [lb wastewater/ODTP]) for lime kiln scrubber blowdown.[21] This factor was converted to annual wastewater impacts using conversion factors of 1.0 kg H_2O/L (8.345 lb H_2O/gal) and 0.9 ODMP/ADMP (0.9 ODTP/ADTP) and multiplying by the product of the model ADMP/d (ADTP/d) and 351 operating d/yr. Table 5-29 presents the annual wastewater impacts for model lime kilns LK-1 through LK-3. With the replacement of existing wet scrubbers with ESP's, the wastewater discharge would be reduced; the reductions in wastewater impacts were estimated to range from -226 to -709 million L/yr (-60 to -187 million gal/yr).

Because ESP's operate on a dry basis, no water pollution impacts are associated with lime kiln PM control if the control involves an ESP upgrade.

5.5.1.4 Solid Waste Disposal Impacts. Dry PM catch would be generated if the existing scrubber is replaced with an ESP to improve PM control. Also, a larger PM catch would be generated if the existing ESP is upgraded to improve PM control. As stated in Chapter 2, existing lime kilns with ESP's return the PM catch directly to the lime kiln. The lime kiln is expected to have sufficient capacity to absorb the PM catch resulting from implementing the lime kiln PM control options.

5.5.1.5 Other Impacts. Beneficial visual impacts are expected as a result of the reduced PM emissions and reduced moisture (i.e., steam) coming out of the stack. The moisture content in the stack is lower with an ESP as the control device than with a scrubber. If the existing scrubber is replaced with an ESP to improve PM control, the noise from the larger fans used to overcome the higher pressure drop would be eliminated, thereby reducing noise impacts. However, the reduction in noise is not expected to be noticeable due to the high background noise levels typically associated with pulp and paper mills. Limited information is available to determine the other impacts, but the impacts, if any, are expected to be minimal as a result of implementing the lime kiln PM control options.