

Cynthia Morgan, Carl Pasurka\* and Ron Shadbegian  
***Ex ante* and *ex post* cost estimates  
of the Cluster Rule and MACT II Rule**

**Abstract:** This paper compares EPA's *ex ante* cost analysis of the Cluster Rule, EPA's first integrated, multi-media regulation, and MACT II Rule to an *ex post* cost assessment. The goal of this assessment is to determine if actual costs diverged from *ex ante* costs and, if so, what factors caused this divergence. We find the EPA *ex ante* costs overestimated the *ex post* capital costs for the Cluster Rule by 30 to 100%. Contributing factors appear to be use of cleaner technology, flexible compliance options, site-specific rules, shutdowns and consolidations. *Ex ante* estimates for the MACT II Rule are found to be overestimated by 25% for capital costs and 200 or more percent for annual costs. The primary reason for the overestimate is the use of the bubble compliance strategy that required fewer paper mills to install pollution abatement equipment than anticipated by EPA.

**Keywords:** chlorine substitution; Cluster Rule; oxygen delignification; pulp and paper; retrospective analysis.

DOI 10.1515/jbca-2014-0026

## 1 Introduction<sup>1</sup>

The U.S. Environmental Protection Agency (EPA)<sup>2</sup> often takes a single-media approach to protecting the environment. However, pollution releases to one medium (air, water or land) often spill over or affect other environmental media. The Pulp and Paper industry, a highly regulated industry, is a case in point. The

---

<sup>1</sup> Morgan, Pasurka, and Shadbegian (2014) contains more detailed information, additional tables, and specific page citations.

<sup>2</sup> Please see Glossary for a list of acronyms.

---

**\*Corresponding author: Carl Pasurka**, US EPA, National Center for Environmental Economics, Washington, DC 20460, USA, e-mail: Pasurka.carl@epa.gov

**Cynthia Morgan and Ron Shadbegian:** US EPA, National Center for Environmental Economics, Washington, DC 20460, USA

pulping process, which separates wood fiber to create pulp using a chemical or mechanical process, releases hazardous chemicals to air. The chlorine bleach used to whiten this pulp for paper generates substantial quantities of water pollutants. In the 1990s EPA began an extended rulemaking to reduce pollution in both air and water. On April 15, 1998, EPA published new “National Emission Standards for Hazardous Air Pollutants from the Pulp and Paper Industry (subpart S)” as well as “Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards: Pulp, Paper, and Paperboard Point Source Category.” Because the promulgated rule integrated air and water rulemakings, the combined standards and guidelines became known as the “Cluster Rule.”

The Cluster Rule, EPA’s first integrated, multi-media regulation, set limits to reduce releases of toxic (e.g., dioxin, furans, chloroform) and nonconventional (e.g., adsorbable organic halides, chemical oxygen demand) pollutants to both air and water from the pulp and paper industry. According to the EPA, 155 of the 565 pulp, paper and paperboard mills in the US needed to comply with the new maximum achievable control technology (MACT I and III) standards for hazardous air pollutants. Of those 155 mills, 96 mills were also required to comply with either a new set of best available technology (BAT) economically achievable effluent guidelines or pretreatment standards for existing sources (PSES) (EPA, 1997b).<sup>3</sup> Most requirements of the Cluster Rule became effective April, 2001.

Later, on January 12, 2001, EPA published the MACT II (combustion sources) Rule to regulate chemical recovery combustion sources in the pulp and paper industry. This rule, which had to be met by January 12, 2004, established standards for sources annually emitting at least 10 tons of a hazardous air pollutant (HAP) or 25 tons of total HAPs. When MACT II was proposed, it was anticipated that 149 of the mills subject to MACT I would also be subject to MACT II (EPA, 1998a). By the time of the promulgation of the final rule, EPA (2001b, Appendix B) identified 133 mills that would be subject to MACT II.

In this paper we compare EPA’s *ex ante* cost analyses of the Cluster and MACT II Rules to an *ex post* assessment of costs. This is not an evaluation of how well EPA conducted its *ex ante* analyses at the time of the rulemaking. Instead, we attempt to gather enough information on the key drivers of compliance costs to make an informed *judgment* as to whether *ex post* costs are higher or lower than the estimates of *ex ante* costs for these rules. This allows us to observe whether

---

<sup>3</sup> U.S. EPA (1997b) summarizes the mill subcategories (i.e., pulping processes) subject to the air and water provisions of the Cluster Rule. According to the U.S. EPA (1997b, p. 1–3), the technological basis for PSES is “... the same as the basis for the BAT limitations ..., with the exception of biological treatment.” Hence, in this paper we often refer to the effluent limitation guidelines (ELGs) of the Cluster Rule as BAT.

actual costs diverged from *ex ante* costs and, if so, what factors caused this divergence (e.g., changing market conditions, technological innovation, etc.).

The remainder of this paper is organized as follows. Section 2 details the impetus and timeline for regulatory action. Section 3 presents EPA's *ex ante* cost estimates of the Cluster Rule and MACT II, while Section 4 discusses the information available to conduct the *ex post* evaluation of costs. Section 5 presents the results of our *ex post* assessment of compliance costs. Finally, Section 6 summarizes our findings and discusses limitations of our analysis.

## 2 Impetus and timeline for regulatory action

A citizen's petition filed in October 1984 by the Environmental Defense Fund (EDF) and the National Wildlife Federation (NWF) represents the origin of the Cluster Rule and MACT II regulations.<sup>4</sup> After the EPA denied the petition, the EDF and NWF filed a lawsuit against the EPA that ended when EPA signed a consent decree in 1988. The consent decree required the EPA to address the issue of discharges of dioxins and furans into surface waters by October 31, 1993, while the Clean Air Act (CAA) amendments of 1990 required EPA to set MACT standards for the industry by 1997. As a result, the EPA decided to combine the rulemakings and design the most cost-effective rule *and* reduce cross-media pollution transfers.<sup>5</sup> EPA proposed its regulations on December 17, 1993 and solicited comments and data on the rule.

The 1993 proposed Cluster Rule required complete substitution of elemental chlorine-free bleaching, which uses chlorine dioxide (ClO<sub>2</sub>) as the bleaching agent, for elemental chlorine bleaching as well as the use of oxygen delignification (i.e., O<sub>2</sub> delig) and/or extended delignification (i.e., extended delig) for 77 bleached papergrade kraft mills in mid-1995 (see U.S. EPA, 1997b, p. 4–5). O<sub>2</sub> delig reduces the amount of lignin in the pulp before bleaching, minimizing the bleaching chemicals required to brighten the pulp. In addition, 10 papergrade sulfite mills were required to use totally chlorine-free bleaching. The EPA anticipated 300 pulp and paper mills would incur costs due to the proposed 1993 Cluster Rule, with 11 to 13 mills confronting the possibility of closure. EPA projected that capital

---

<sup>4</sup> The discussion of the origins of the Cluster Rule and MACT II Rule is drawn from Powell (1997, pp. 1–12), and the U.S. EPA (1993c, chapter 2).

<sup>5</sup> By promulgating the air and water standards simultaneously, the EPA was able to develop control options that included process change technology that would control both emissions to air and pollutant discharges to water.

expenditures would approach \$4 billion (in 1992 dollars) with annual operating and maintenance (O&M) costs of \$401 million (EPA, 1993a). Non-EPA sources estimated the Cluster Rule would cost \$11.5 billion (Pauksta, 1995), while the cost of the combined Cluster Rule and MACT II Rule would be \$13.2 billion (Barton et al., 1995). An important component of the cost of the proposed regulation was the requirement of O<sub>2</sub> delig and/or extended delig. Barton et al. estimated the combined cost of the O<sub>2</sub> delig systems and improved brown stock washing would be \$2.3 billion, while ClO<sub>2</sub> upgrades and conversions would cost another \$530 million.<sup>6</sup> In the ensuing years, the Cluster Rule underwent substantial modification before the final rule was promulgated in 1998.<sup>7</sup> In addition to fewer mills being affected by the final rule compared to the 1993 proposal, the final rule dropped the O<sub>2</sub> delig/extended delig requirement, which led some companies to petition the EPA and request incentives/rewards for mills that had already installed O<sub>2</sub> delig (EPA asked to reward O<sub>2</sub> delig users, 1996).

In the final Cluster Rule for air pollutants, the EPA set MACT standards (referred to as MACT I&III) that required pulp and paper mills to capture and treat toxic air pollutant emissions produced during the pulping and bleaching stages of the manufacturing process. The MACT I (non-combustion sources) rule covers mills that chemically pulp wood using kraft, semi-chemical, sulfite, or soda processes, while the MACT III Rule covers mills that mechanically pulp wood, or pulp secondary fiber or non-wood fibers, or produce paper or paperboard. The EPA estimated that HAPs emissions would decline by 139,000 mg (one ton equals 0.908 mg) per year.<sup>8</sup> These standards could be met in a variety of ways including performance standards (percent reductions in emissions, mass reductions in emissions, and concentration or mass limits), design standards (use of specific technologies operated in a certain way), and routing emissions to combustion or control devices.

The effluent limitation guidelines (ELGs) covered two subcategories of mills: bleached papergrade kraft and soda and papergrade sulfite. The ELGs and pretreatment standards set technology-based limits on dioxins, furans, chloroform, 12 chlorinated phenolics, and adsorbable organic halides (AOX), requiring a 96% reduction in dioxin and furan, and a 99% reduction in chloroform. These requirements were

---

**6** The goal of brown stock washing is to remove the maximum amount of spent cooking liquor from the pulp using the minimum amount of wash water. The solids left in the pulp can interfere with the bleaching process and increase the costs of bleaching.

**7** Rule and implementation information for the air portion of the Cluster Rule can be found at: <http://www.epa.gov/ttnatw01/pulp/pulppg.html>. Information on the Effluent Guidelines for the Cluster Rule can be found at: <http://water.epa.gov/scitech/wastetech/guide/pulppaper/index.cfm>.

**8** The HAPs covered by the Cluster Rule included compounds such as methanol, chlorinated compounds, formaldehyde, benzene, and xylene.

based on substituting chlorine dioxide for chlorine in the bleaching process (i.e., using elemental chlorine-free or totally chlorine-free bleaching). The options for the bleached papergrade kraft and soda subcategory (listed in terms of increasing stringency) were 100% substitution of chlorine dioxide for elemental chlorine-free, 100% substitution of chlorine dioxide for elemental chlorine-free plus oxygen delignification and/or extended delig, and total chlorine free bleaching. EPA only estimated costs for total chlorine free bleaching and 100% substitution of chlorine dioxide (elemental chlorine-free) for elemental chlorine.

The Cluster Rule encouraged additional pollutant reductions through the Voluntary Advanced Technology Incentives Program. Mills who were interested in this program were given extended compliance time in order to explore all technology options or make process changes that would reduce pollution beyond the discharge limits required by the rule. The program was voluntary and only available to mills that discharged directly to surface waters. Mills that chose to participate received 6 years to comply with the air standards (by April 15, 2004) and an extension of up to 8 years for high volume low concentration system vents at kraft mills (by April 17, 2006). This extension was designed to encourage mills to install technology to reduce toxic air pollutant emissions as well as discharges of pollutants to air and water from the bleaching process.

In addition to the MACT I and MACT III standards, on January 12, 2001 EPA published the MACT II Rule that regulates chemical recovery combustion sources in the pulp and paper industry. The MACT II Rule covers kraft, soda, sulfite, and stand-alone semi-chemical pulp mills. The MACT II standards covered HAP metals and gaseous organic HAPs using particulate matter (PM) as a proxy for HAP metals and methanol, and total hydrocarbons as proxies for gaseous organic HAPs. A provision of the MACT II that improved the efficiency of the regulation for existing kraft and soda mills was a “bubble compliance alternative” that allowed mills to reduce PM emissions at any unit as long as the mill-specific bubble limit was achieved.

### **3 Ex ante cost estimates**

The ELGs and MACT standards are technology-based regulations. The Cluster Rule set new baseline emission limits for pollutants – these are reductions in water discharges and air emissions resulting from the new regulations. To determine the reductions and costs from the new standards, the EPA needed to establish baseline emissions and loadings. At the proposal the baseline was 1992; however, the EPA later updated the baseline to reflect emissions and discharges resulting from technology in place in mid-1995 (EPA, 1997a). The 1995 baseline values and reductions expected from rule are reported in Table 1.

**Table 1** Pre-regulation and post-regulation releases of selected pollutants (mid-1995 baseline).

Air pollutants	Baseline (mg/year)	Air emission reductions (mg/year)	
		Final Cluster Rules	Final Cluster Rules and proposed MACT II
Hazardous air pollutants	240,000	139,000	142,000
Volatile organic compounds	900,000	409,000	440,000
Total reduced sulfur	150,000	79,000	79,000
Particulate	NA	(83)	24,000
Carbon monoxide	NA	(8700)	49,000

Water pollutants	Units	Baseline discharge (BPK mills)	Estimated reductions; final BAT/PSES (BPK mills)	Baseline discharge (PS mills)	Estimated reductions; final BAT/PSES (PS mills)
2,3,7,8 – dioxin	g/year	15	11	0.78	0.65
2,3,7,8 – furan	g/year	115	107	6.7	6.4
Chloroform	kkg/year	48	40	5.4	5.2

g, grams; kkg, metric ton (1000 kilograms); BPK, bleached papergrade kraft and soda; PS, papergrade sulfite. Values in ( ) are estimated emission increases over baseline air emissions. NA, not available.

Source: U.S. EPA (1998a, p. 18575).

The *ex ante* cost estimates of the technologies for the Cluster Rule and MACT II Rule are reported in Table 2. The combined or total cost for BAT/PSES and MACT I is \$1.5 billion in capital costs, \$233 million in O&M costs, and \$253 million in post-tax annualized costs. The combined costs of the Cluster Rule plus MACT II is \$1.8 billion in capital costs, \$238 million in O&M costs, and \$277 million in post-tax annualized costs. With the publication of the final MACT II Rule (EPA, 2001a), the EPA revised its estimates – relative to those in Table 2 – of the MACT II capital expenditures to \$227.4 million (in 1995 dollars), and its estimate of the annual cost of MACT II to \$30.4 million (in 1995 dollars). According to the EPA (1997a, pp. 2–2 and 2–3), “The MACT III Rule contains National Emission Standards for Hazardous Air Pollutants (NESHAP) for mechanical pulping, secondary fiber pulping, and non-wood pulping mills. No emission reductions or control costs, however, are associated with the MACT III Rule ....”

Table 2 is supplemented by Tables 3 and 4, which show estimated *ex ante* costs from several non-EPA sources. Table 3 is divided into three parts based on which rule(s) is associated with the corresponding cost estimate. First, we list two non-EPA estimates that combine the cost of the Cluster Rule and MACT II Rule. Next, we list three non-EPA estimates of the Cluster Rule, and finally we

**Table 2** U.S. EPA *ex ante* cost estimates of the Cluster Rule & MACT II Rule (thousands of 1995 dollars).

	MACT IA	MACT II (alternate A)	BAT/PSES	Cluster Rule (MACT I plus BAT/PSES)	Cluster Rule plus MACT II
Capital	500,758	258,389	1,039,388	1,540,146	1,798,535
O&M	74,718	5202	158,413	233,131	238,334
Post tax annualized	81,767	23,139	171,619	253,386	276,525

Source: EPA (1997a, p. 5–27).

list two non-EPA estimates of portions of MACT I. Table 4 lists three non-EPA estimates of MACT II. Comparing Tables 2–4 reveal: (1) both EPA and the pulp and paper industry believed the Cluster Rule would be more costly than the MACT II Rule and (2) industry believed EPA *ex ante* cost estimates substantially underestimated the cost of the Cluster Rule and MACT II Rule.

One factor affecting cost estimates of the Cluster and MACT II Rules is the number of mills that closed after the introduction of the new regulations. Of the 96 mills expected to bear incremental costs due to ELGs, the available data allowed closure analyses to be performed on 94 mills. EPA determined about 9 of these mills would be baseline closures (EPA, 1997a). In addition, the EPA

**Table 3** Non-EPA *ex ante* cost estimates of the Cluster Rule.

Source	Capital expenditures	Operating costs
<i>Cluster Rule plus MACT II</i>		
American Forest & Paper Association (see Miller Freeman Publications, Inc., 1998, p. 77)	\$2.6 billion	\$273 million
<i>Pulp &amp; Paper Project Report</i> , April 1998 (see Miller Freeman Publications, Inc., 1998, p. 77)	\$3.2+ billion	–
<i>Cluster Rule</i>		
Parthasarathy and Dowd (2000, p. 41)	\$2.625 billion*	–
National Council for Air and Stream Improvement (2003, p. 5)	\$3 billion (1999–2005)	–
Jensen (1999, p. 72)	\$2.675–2.916 billion	–
<i>MACT I</i>		
Garner (2001, p. 44)	\$2–3 billion**	–
Garner (2001, p. 44)	\$0.775 billion***	–

\*\$1.375 billion for MACT I & III and \$1.250 billion for BAT and best management practices (BMP).

\*\*MACT I (April 2001 compliance).

\*\*\*MACT I (high volume low concentration pollutants, April 2006 compliance).

**Table 4** Non-EPA *ex ante* cost estimates of MACT II.

Source	Capital expenditures	Operating costs
Parthasarathy and Dowd (2000, p. 41)	\$0.35 billion	–
Garner (2001, p. 45)	\$0.90 billion	–
National Council for Air and Stream Improvement (2003, p. 5)	\$1 billion or less	–

projected two mill closures due to the final BAT/PSES and final MACT I. Under all MACT II options, a third mill closure was expected (EPA, 1997a).

## 4 Information available to conduct *ex post* evaluation

Data for our *ex post* assessment come from several sources. We use data acquired from Beca AMEC – a consulting firm – on when O<sub>2</sub> delign and extended delign systems were installed and the extent of ClO<sub>2</sub> substitution as a bleach alternative starting in 1997 for mills subject to the BAT provisions of the Cluster Rule. Data on when air pollution control devices (APCDs) were installed are acquired from the 2011 survey for the Risk and Technology Review (RTR) of the technology-based standards for HAPs.

For *ex post* cost estimates, we rely on publicly available data from the National Council for Air and Stream Improvement, Inc. (NCASI, 1999, 2002a,b,c), which produced an annual survey of capital expenditures borne by pulp and paper industry from 1970 through 2002.<sup>9</sup> The survey requested information on each firm's capital expenditures, including capital expenditures for pollution abatement. The questionnaire also asked firms to separate their pollution abatement capital expenditures by media (air, water, and solid waste) and by the type of mill (i.e., integrated or non-integrated).<sup>10</sup> Finally, firms divided their pollution abatement capital expenditures into those (1) for “sole-purpose” equipment and

<sup>9</sup> Another potential source of data is the annual *Pollution Abatement Costs and Expenditures* (PACE) survey (U.S. Department of Commerce, various years). The PACE survey collects facility-level data on pollution abatement capital expenditures and operating costs associated with compliance to local, state, and federal regulations and voluntary or market-driven pollution abatement activities. However, because the PACE Survey was discontinued in 1994 and was only conducted in two subsequent years (1999 and 2005), it cannot be used for the *ex post* portion of our analysis.

<sup>10</sup> An integrated mill produces at least 20% of its total pulp consumption from on-site wood pulping operations (NCASI, 2003).

(2) incremental pollution abatement costs for equipment that would have been purchased in the absence of environmental regulations.

The 1998 to 2002 NCASI surveys collected information from firms that accounted for 84 to 94% of wood pulping capacity and 68 to 79% of paper and paperboard capacity. From 1973 to 1986, the NCASI survey found pollution abatement capital expenditures values for air, water, and solid waste pollution abatement were approximately 4% higher than the PACE values for Paper and Allied Products (SIC 26). However, its values for 1988 to 1994 were approximately 15% higher than PACE. Unlike the PACE survey, which assigned values for missing observations to be able to produce national estimates of pollution abatement costs, NCASI treated missing observations as zero costs. Table 5 shows the NCASI pollution abatement capital expenditure data for 1990–2002.<sup>11</sup>

Cost information on MACT II and the implementation of a PM bubble strategy was provided by Abt Associates/RTI International. These sources are supplemented with firm-level data found in the U.S. Securities and Exchange Commission (SEC) 10-K form, which provides some firm-level data for *ex ante* and *ex post* costs of Cluster Rule compliance, and data on mill closures during the implementation of the Cluster Rule and MACT II Rule. The SEC 10-K information on mill closures is augmented by the U.S. EPA (2001b, Appendix B and 2006, Appendix), USDA (2005), the *Pulp & Paper North American Fact Book* (Miller Freeman Publications, Inc., 1998; Paperloop.com, 2000, 2002, 2003) and internet searches.

## 5 *Ex post* assessment of compliance costs

### 5.1 Regulated universe

According to the EPA (1997a), of the 158 mills that used kraft, soda, sulfite, or semi-chemical processes at the time of the *ex post* analysis, 155 were expected to incur pollution abatement costs as a result of MACT I and MACT III. In addition, 96 of these mills would incur additional abatement costs as a result of the new ELGs and pretreatment standards. This constituted the basis of the industry size

---

<sup>11</sup> The only other source of data was *Selected Air Pollution Control Equipment* (see U.S. Department of Commerce, 2000). This survey provided data on expenditures for particulate emissions collectors by selected industries including pulp and paper and pulp mill operations. Unfortunately, expenditures on (1) gaseous emissions collectors and (2) other types of industrial air pollution control devices were withheld to avoid disclosing data for individual companies. These data show a 41% increase in 1998 expenditures on particulate emissions collectors relative to 1997. This survey was discontinued after the 1998 survey.

**Table 5** Pollution abatement capital expenditures (NCASI) (millions of 1995 dollars).

Year	Water	Air	Solid waste	Total	Percent of total capital expenditures
1990	669	553	272	1494	12
1991	765	542	214	1521	19
1992	533	416	201	1150	18
1993	354	289	131	774	14
1994	289	252	188	729	14
1995	309	219	97	625	12
1996	343	244	133	720	13
1997	305	142	105	552	12
1998	288	119	172	579	13
1999	340	294	65	699	17
2000	364	633	74	1071	23
2001	170	287	72	529	12
2002	105	170	29	304	9

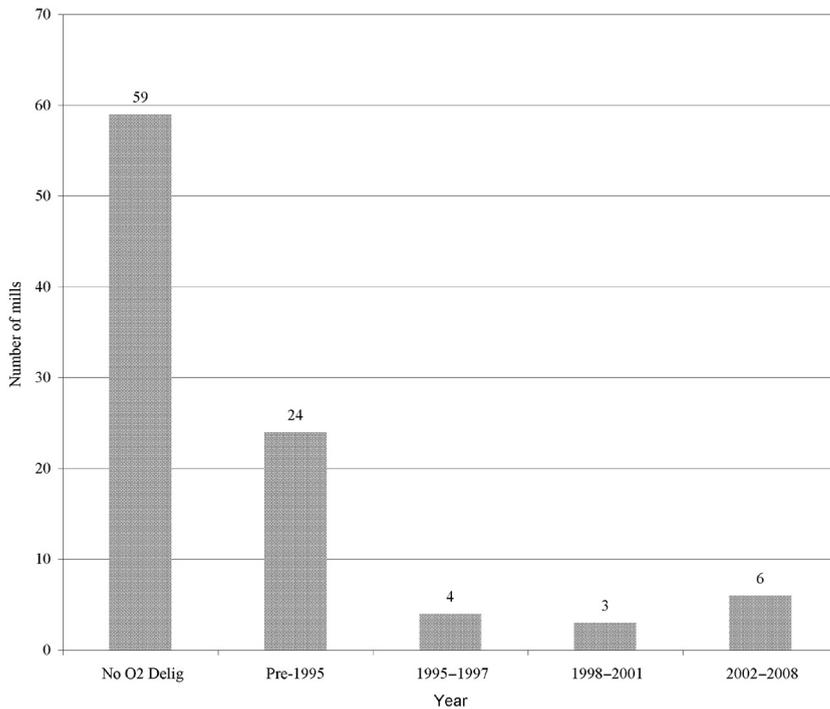
Current dollar values are deflated to 1995 dollar values using the *Engineering News – Record* Construction Cost Index (NCASI, 2003, pp. A2–A3).

when *ex ante* cost estimates of the Cluster Rule and MACT II Rule were generated. By 2001, the EPA (2001b, Appendix B) estimated 133 mills would be subject to the MACT II emission standards.

## 5.2 Baseline

It has been argued that some mills undertook pollution abatement actions in anticipation of the Cluster Rule. The 1993 proposal used a 1992 baseline (EPA, 1997a), which was updated to mid-1995 for the final rule. After the rule was proposed in 1993, “... a number of pulp mill owners and operators announced plans to install new technologies at their facilities ....” (EPA, 1997b, p. 10–16). Some mills addressed concerns about dioxin releases by installing extended delignification and/or O2 delig systems (EPA, 1993b). Figure 1 shows the number of mills that installed their first O2 delig systems during selected time periods. It can be seen that over half of the mills that installed O2 delig did so by 1995. Only four mills installed O2 delig during 1995–1997, the years prior to 1998, the year the rule was promulgated.<sup>12</sup>

<sup>12</sup> This trend was anticipated by Johnson (1995). Johnson believed that lack of growth in O2 delig installations was because industry believed O2 delig was not needed since ECF bleaching would meet the Cluster Rule limits.

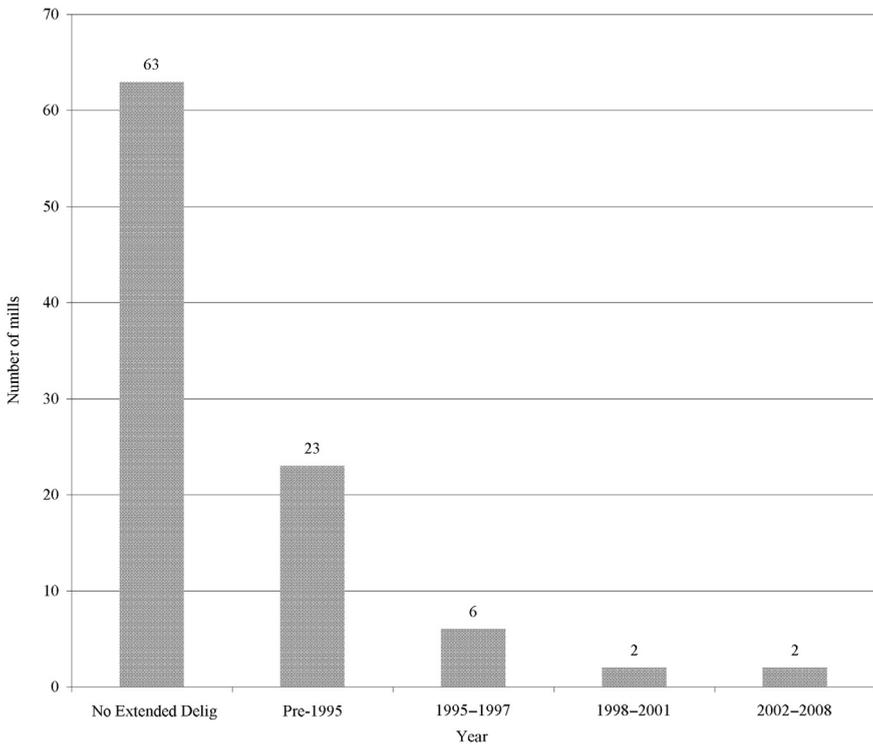


**Figure 1** Number of mills installing O<sub>2</sub> delig for first time, by year.

Source: Beca AMEC (2013b).

Unlike O<sub>2</sub> delig systems, lack of data on extended delig systems precludes developing a complete inventory of installed extended delig systems. Nevertheless, EPA (1993b) provided a list of installed extended delig systems through 1994. In addition, Beca AMEC (2013b) provides a partial list of extended delig systems installed through 2013. By combining the two sources, we compiled a complete list of mills that were subject to the ELG provisions of the Cluster Rule and installed extended delig systems prior to 1995. In addition, Beca AMEC provides the minimum number of mills that installed extended delig systems starting in 1995, with the last installation occurring in 2003. Remembering the post-1994 information on extended delig systems is incomplete, Figure 2 shows a dramatic decline in the installation of extended delig systems after 1997.

The first survey of ClO<sub>2</sub> substitution by U.S. pulp and paper mills was the “104 Mill Study” conducted by NCASI and the U.S. EPA (1990). Data was collected for 165 lines at 86 kraft mills in 1988. Of the 165 lines, 59 used no ClO<sub>2</sub> substitution. Of the lines employing ClO<sub>2</sub>, 99 lines used between 0 and 30%, 4 used between 30 and



**Figure 2** Minimum number of mills installing extended delig for first time, by year.  
Source: Beca AMEC (2013a).

50%, 2 used between 50 and 70%, and 1 used more than 70%. In addition, of the 18 lines at 16 sulfite mills only one used  $\text{ClO}_2$  – at a rate of <5%.  $\text{ClO}_2$  substitution increased rapidly in the following years. According to the U.S. EPA (1997b), in 1992 6.6% of bleached papergrade kraft and soda mill production used total elemental chlorine-free bleaching. By 1994, approximately 22% of all bleached chemical production was elemental chlorine-free (AET, 2002).<sup>13</sup> This increased to 33.2% of bleached papergrade kraft and soda mill production in mid-1995 (U.S. EPA, 1997b).

While Table 5 shows higher pollution abatement expenditures during 1990–1994, we cannot determine whether this reflected pollution abatement undertaken in anticipation of the Cluster Rule and MACT II Rule or was a reaction to local concerns about the undesirable by-products generated by pulp and paper

<sup>13</sup> The Paper Task Force (1995, p. 5) found 22% of bleached chemical production in 1994 was traditional, enhanced, or ozone ECF. Johnson (1994) reported that in 1994 between 20 and 25% of US mills had no  $\text{ClO}_2$  substitution, while 10 to 15% of US mills had 100%  $\text{ClO}_2$  substitution.

mills. Table 1 shows anticipated reductions in releases of key air and water pollutants as a result of the Cluster Rule and MACT II Rule. This is in addition to a substantial decline in releases of dioxins and furans between the proposal (1992 baseline) and the final rule (mid-1995 baseline). The baseline releases of dioxins declined from 70 g per year in 1992 to 16 g per year in mid-1995, while furans declined from 341 g per year in 1992 to 122 g per year in mid-1995 (EPA, 1997a).

However, it has been suggested the pulp and paper industry abstained from aggressive abatement efforts until the Cluster Rule was finalized (Ferguson, 1995). Ferguson's hypothesis was supported by Maynard and Shortle (2001), who used a double hurdle model and found the uncertainty associated with an irreversible investment (i.e., installing O2 delig, extended delig, or ECF) resulted in a value of waiting that led some bleached kraft mills to delay their investment in cleaner technologies. In addition, Maynard and Shortle found "public pressure" variables were statistically significant in explaining the adoption of cleaner technologies.

### 5.3 Methods of compliance

Under the Cluster Rule, BAT involves switching to elemental chlorine free or total chlorine free bleaching. The data in Table 6 show that from 1990 to 2001 there was a substantial switch to ECF bleaching. Both Figure 3 and Table 6 reveal that approximately half the switch to ECF occurred prior to 1998, which is the first year the Cluster Rule was implemented for some mills. Among the mills covered by the water provisions of the Cluster Rule, only one mill opted for totally chlorine-free bleaching.

Starting with 1997, Beca AMEC (2013a) provided us with information on the percent of ClO<sub>2</sub> substitution used on lines at mills subject to the ELGs of the Cluster Rule. Weighting the percent of ClO<sub>2</sub> substitution by the production of each line allows us to construct a weighted average of ClO<sub>2</sub> substitution for each year. It should be noted that during 1997 to 2005, the number of active mills subject to the ELGs of the Cluster Rule declined from 95 to 76. Figure 4 shows the weighted average of ClO<sub>2</sub> substitution for active mills increased from 55% in 1997 to 99% in 2005.

In order to observe the variation in ClO<sub>2</sub> substitution among mills, Figure 5 reports the percentage of active mills that fall in various ranges of ClO<sub>2</sub> substitution. While half of active mills subject to ELGs undertook at least 50% ClO<sub>2</sub> substitution in 1997, only 28% undertook 100% ClO<sub>2</sub> substitution. By 2000, 91% of active mills had at least 50% ClO<sub>2</sub> substitution, while 67% reported 100% ClO<sub>2</sub> substitution. In 2002, 90% of active mills had 100% ClO<sub>2</sub> substitution, and 95% of mills had 100% ClO<sub>2</sub> substitution in 2005. Three mills that participated in the Voluntary Advanced Technology Incentives Program did not permanently convert to

**Table 6** US bleached chemical pulp production by bleaching process (millions of tonnes).

Year	Elemental chlorine-free	Totally chlorine free	Other
1990	0.5	0.0	26.8
1991	1.6	0.0	25.6
1992	2.8	0.0	24.4
1993	4.0	0.2	23.0
1994	6.0	0.2	21.0
1995	9.1	0.3	17.9
1996	10.4	0.2	16.6
1997	13.3	0.2	13.8
1998	15.5	0.2	11.4
1999	18.1	0.2	8.9
2000	20.7	0.2	6.3
2001	25.9	0.1	0.9

Source: Alliance for Environmental Technology (2002).

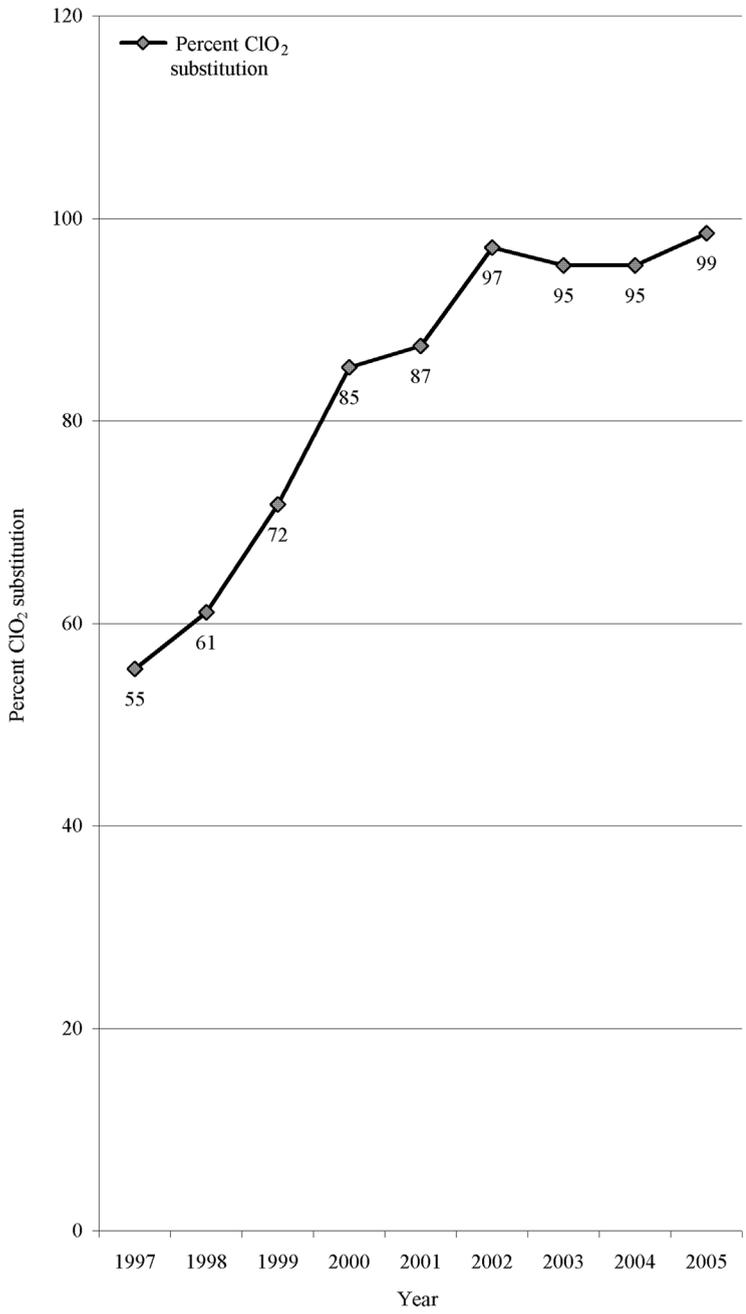
1 tonne = metric ton = 1000 kg = 2204.62 lb.

100% ClO<sub>2</sub> substitution until 2005. On the other extreme, 20% of the mills undertook no ClO<sub>2</sub> substitution in 1997, which declined to 5% in 2005.<sup>14</sup>

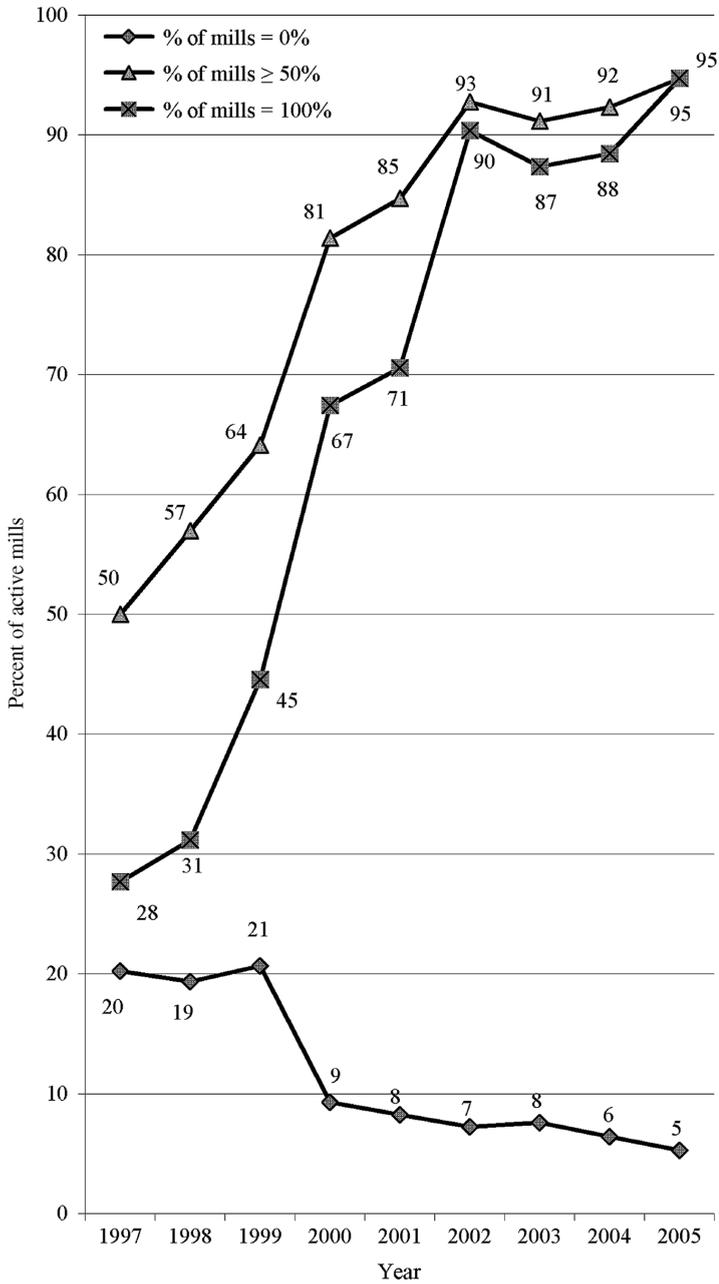
The Beca AMEC data showing the increased use of ClO<sub>2</sub> substitution, O<sub>2</sub> delig, and extended delig validates the findings of three previous studies that environmental regulations targeting the pulp and paper industry in the US drove technological innovation. First, Norberg-Bohm and Rossi (1998) conducted a case study of the pulp and paper industry's response to the Cluster Rule. They found firms preferred incremental approaches (i.e., introducing ClO<sub>2</sub> substitution, oxygen delig, and extended delig) to reduce dioxin releases to more radical approaches (i.e., ozone bleaching and totally chlorine-free). Second, Snyder, Miller, and Stavins (2003) conducted an econometric analysis of the effects of the Cluster Rule on the diffusion of technological change in the chlorine manufacturing industry.<sup>15</sup> Finally, Popp and Hafner (2008) used information on regulations affecting dioxins and patents from Canada, Finland, Japan, Sweden, and the

<sup>14</sup> In 2005, the four mills that did not report 100% ClO<sub>2</sub> substitution undertook no ClO<sub>2</sub> substitution. One mill employed totally chlorine-free bleaching so ClO<sub>2</sub> was not required. Three mills were Segment B papergrade sulfite mills and not required to monitor dioxin under the Cluster Rule (EPA, 2006).

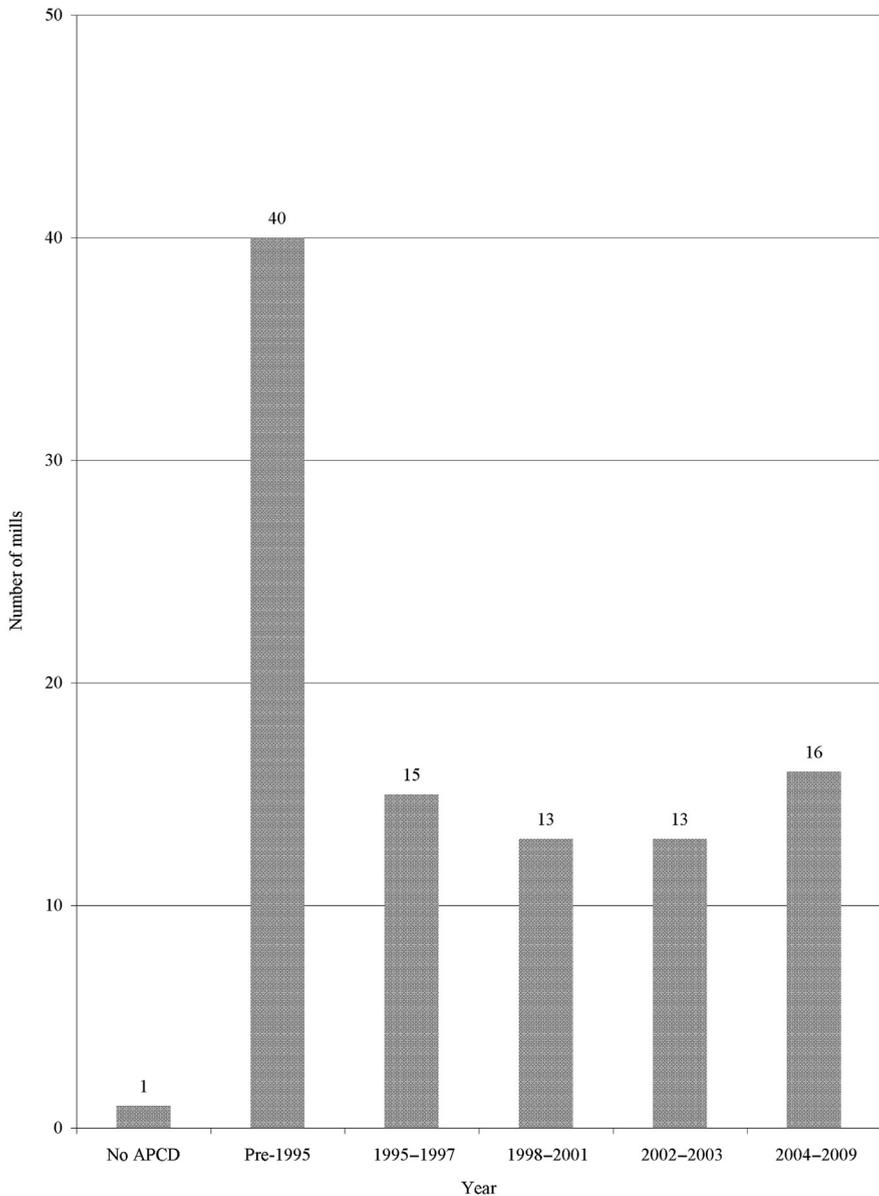
<sup>15</sup> Using plant-level data, they focused on the diffusion of a new, cleaner production process within the chlorine industry. Snyder et al. found that chlorine facilities affected by the reduced demand for chlorine resulting from the Cluster Rule (and the Montreal Protocol) were more likely to close than were other facilities. This factor, along with the adoption of new technology at existing plants, increased the share of chlorine plants employing a cleaner production technology.



**Figure 3** Percent of ClO<sub>2</sub> substitution (1997–2005).  
Source: Beca AMEC (2013a).



**Figure 4** Extent of ClO<sub>2</sub> substitution, by percent of mills (1997–2005).  
Source: Beca AMEC (2013a).



**Figure 5** Number of mills, by year, of last installed or updated APCD.

Source: Hanks et al. (2013).

US, to investigate the association between regulations and patent activity. They found “substantial innovation” to reduce chlorine use in the bleaching technology occurred in response to the environmental regulations.

Summarizing the technology employed to meet the air provisions of the Cluster Rule is more difficult than summarizing the technology used to meet the water provisions. The 2011 technology review survey (Hanks, Holloway, & Gooden, 2013) collected information on APCDs installed at 98 kraft mills in 2009. Of these mills, 67 were subject to both the air and water provisions of the Cluster Rule. Most mills reported multiple emission units (i.e., sources of emissions) and multiple APCDs, sometimes more than one APCD for an emission unit. Hence, summarizing when these devices were installed is challenging. In this paper, we focus on the last year a mill installed or updated an APCD. These results are summarized in Figure 5. According to the survey, only one mill reported no installed APCD. For the years prior to the Cluster Rule, 40 mills report their last installation/update prior to 1995, while 14 mills reported their last installation/update during 1995–1997. Thirteen mills reported their last installation/update during 1998–2001, which covers the period for implementing the Cluster Rule. Finally, 29 mills reported their last installation/update during 2002–2011, of which 13 reported their last installation/update in 2002–2003. Of the 29 mills that reported their last APCD installation/update during 2002–2011, six mills installed/updated at least one APCD during 1995–2001.

## 5.4 Compliance costs for MACT I and BAT/PSES

For our *ex post* assessment of cost, we construct a pre-Cluster Rule baseline level of pollution abatement capital expenditures that allows us to identify the incremental capital costs of the Cluster Rule. Since the share of the abatement capital expenditures assigned to the Cluster Rule depends upon the baseline, we construct three baseline scenarios. The EPA established a mid-1995 baseline for its economic analysis of the Cluster Rule and MACT II Rule (EPA, 1997a). Because we want to avoid the possibility of selecting an arbitrary base year in which capital costs may be unusually high (low) which will result in underestimating (overestimating) *ex post* costs, we use the average capital expenditures for air and water pollution abatement between 1995 and 1997 as our preferred baseline. Since no additional regulations were promulgated on the pulp and paper industry between 1995 and 2001, we assume all increases in air and/or water pollution abatement capital expenditures during 1998 to 2001 relative to the 1995–1997 baseline costs reflect the incremental capital costs of the Cluster Rule.<sup>16</sup>

---

<sup>16</sup> For cases when capital expenditures during 1998–2002 were less than the baseline capital expenditures, we assume no capital costs are associated with the Cluster Rule (i.e., *ex post* costs are nil).

During 1998 to 2001, the time between the promulgation of the Cluster Rule and its compliance date, capital expenditures for air and water pollution abatement were \$2.5 billion (in 1995 dollars). Our preferred baseline yields an estimate of \$65 million in Cluster Rule water pollution abatement capital costs and \$610 million in Cluster Rule air pollution abatement capital costs during 1998 to 2001 (all values in constant 1995 dollars). This *ex post* Cluster Rule capital cost estimate of \$675 million is 55% lower than the EPA *ex ante* capital cost estimate of \$1.54 billion. We investigate the sensitivity of our results to the baseline year by repeating the analysis using 1996 and 1997 pollution abatement capital expenditures as alternate baselines.<sup>17,18</sup> Using 1996 and 1997 as the baseline yields *ex post* Cluster Rule capital expenditure estimates of \$503 million and \$882 million respectively, which are 67% and 43% lower than the EPA *ex ante* capital expenditure estimate.<sup>19</sup>

One important caveat is that while most of the compliance dates for the Cluster Rule occurred on or before April 15, 2001, compliance for two MACT provisions: bleaching systems in the Voluntary Advanced Technology Incentives Program [of which only four mills (see EPA, 2006) participated] and the high volume low concentration system compliance, were not required until April 15, 2004 and April 17, 2006, respectively (EPA, 1998b). While we would prefer to include these MACT provisions in our analysis, the NCASI survey stopped in 2002. Unfortunately, we do not have any *ex post* cost estimates of these two MACT provisions to adjust our *ex post* cost estimates. Because our *ex post* cost estimate is biased downwards, EPA's *ex ante* cost estimate appears to be more of an over-estimate than it actually is.

## 5.5 Compliance costs for MACT II

In order to meet the HAP metals standards of MACT II, approximately 32 pulp and paper mills employed a “PM bubble compliance alternative” strategy, which uses PM as a proxy for HAP metals (Nicholson, Holloway, & Gooden, 2012). The “PM bubble compliance alternative” gives mills the flexibility to set site-specific PM emissions limits for each existing source in the chemical recovery area (i.e.,

---

<sup>17</sup> 1996 and 1997 are selected as baseline years because they are both prior to the promulgation of the Cluster Rule. NCASI (see Paperloop.com, 2003, p. 85) anticipated the pulp and paper industry would experience its highest levels of capital expenditures associated with the Cluster Rule in 1999 and 2000.

<sup>18</sup> Our results could also be sensitive to which mills are included in the NCASI survey, but since we have no access to the underlying micro-data we cannot test this sensitivity.

<sup>19</sup> NCASI estimates of air and water pollution abatement capital expenditures in 1993 and 1994 (in 1995 dollars) are slightly higher than the 1996 value. Hence, if we include expenditures from 1993 and 1994 in the baseline this will lead to a lower *ex post* cost estimate of the Cluster Rule.

recovery furnaces, smelt dissolving tanks, and lime kilns), as long as the total emissions from all the existing sources are less than or equal to the total of the promulgated emissions rates for each existing source.<sup>20</sup> This improvement in the efficiency of pollution abatement resulted in lower *ex post* pollution abatement costs. Although the EPA anticipated the PM bubble compliance alternative would improve the efficiency of pollution abatement, it was unable to develop *ex ante* estimates of cost and emission reductions for this alternative because it could not determine which mills would take advantage of the alternative or what limits the mills would set. The limits mills set determined which, if any, of the emission units in the bubble would require upgrading and which would be unchanged. Table 7 provides the EPA *ex ante* engineering estimates of MACT II, plus BE&K's *ex post* engineering estimates of the cost of complying with MACT II.

The EPA *ex ante* cost estimates are based on projected compliance costs presented in the compliance cost memorandum for the MACT II Rule (Holloway, 2000).<sup>21</sup> The *ex ante* capital expenditure estimate of \$231 million (in 2001 dollars) reported in Table 7 is less than the *ex ante* EPA estimate of \$258 million (in 1995 dollars) reported in Table 2. Because *ex post* cost information was not available for individual mills, *ex post* costs are estimated by combining information on the actual (*ex post*) compliance methods selected by individual mills with estimated costs of these compliance strategies from the engineering firm BE&K. Thus, the

**Table 7** *Ex ante* and *ex post* cost estimates for MACT II (millions of 2001 dollars).

	Total capital investment	Total annual costs
<i>Ex ante</i> (EPA, 1997)	\$231	\$80.6
<i>Ex post</i> (BE&K)	\$188	\$24.2

Source: Nicholson et al. (2012, pp. 15–16).

**20** The mill-specific bubble limit is calculated based on the promulgated emissions standards (referred to in the rule as reference concentrations or reference emissions rates) for each process unit and mill-specific gas flow rates and process rates.

**21** “The *ex-ante* costs for the MACT II rulemaking were first developed on a model process unit basis (e.g., model recovery furnaces, model SDTs, model lime kilns), with applicable control option costs developed for each model process unit. ... These *ex-ante* model costs were then assigned to the individual process units at each mill in the NCASI MACT survey database, based on whether the process unit was expected to be impacted under the control option (i.e., whether or not available emissions data showed the mill to be above the emission limit in the control option). ... The mill-specific *ex-ante* costs for each process unit type were then averaged, and those average costs were extrapolated nationwide to determine nationwide *ex ante* cost estimates for each process unit type...” (Nicholson et al., 2012, p. 4).

*ex post* cost estimates are derived from *ex ante* costs provided by BE&K, applied to actual *ex post* mill-specific compliance information provided by MACT II mills in their responses to EPA's 2011 RTR survey. These estimates constitute the best *ex post* compliance cost data for the MACT II Rule.

Acknowledging the limitations of this approach, Table 7 shows EPA's *ex ante* total capital investment cost estimate was nearly 25% higher than the *ex post* cost estimate. Furthermore, EPA's *ex ante* total annual cost estimate was roughly three times higher than the *ex post* cost estimate. The main reason for the lower *ex post* cost is the use of the "PM bubble compliance alternative" strategy, which allowed for a more cost-effective strategy for abating PM emissions than command-and-control.<sup>22</sup> In particular, a significant percentage of sources subject to MACT II did not require upgrades or replacements of existing air pollution controls, primarily due to the use of the PM bubble compliance alternative. For example, 19 non-direct contact evaporator (NDCE) recovery furnaces were expected to upgrade or replace their existing electrostatic precipitators (ESP) units, but only five were actually upgraded or replaced. In addition, of the 29 direct contact evaporator (DCE) recovery furnaces that expected to upgrade or replace ESP units, only eight were upgraded or replaced (Nicholson et al., 2012). This is further evidence that more flexible pollution abatement strategies lead to substantially lower abatement costs.

## 5.6 SEC 10-K Cluster Rule capital expenditure data

The U.S. Securities and Exchange Commission (SEC) collects financial information on firms via its Form 10-K [Annual Report Pursuant to Section 13 or 15(d) of the Securities Exchange Act of 1934]. Because of the importance of the Cluster Rule, many firms reported anticipated and actual expenditures associated with the Cluster Rule on the Form 10-K. Unfortunately, the Cluster Rule was implemented in several phases (e.g., April 2001 compliance, Voluntary Advanced Technology Incentives Program, and high volume low concentration system compliance) and some firms were not specific about which costs were incurred for the different phases of the Cluster Rule and which were incurred for MACT II. As a result, the cost estimates reported by some firms on the Form 10-K cannot be assigned with certainty to either the Cluster or MACT II Rules. Using the SEC 10-K forms is further complicated when publicly-owned US firms are purchased by foreign firms or by private US companies, neither of which need to submit 10-K forms.

---

<sup>22</sup> It is possible that regulatory-induced technical change played a role in lowering the cost of the MACT II Rule. Mill and equipment shutdowns and consolidations also played a role.

Table 8 provide evidence for seven firms where the SEC data provide a relatively complete picture of the *ex ante* and *ex post* costs of the Cluster Rule. While the *ex ante* cost estimates of Boise Cascade, Pope & Talbot, and Wausau were close to their reported actual *ex post* costs, the *ex ante* cost estimates of Gaylord Containers, Potlatch, Smurfit-Stone, and Temple Inland were substantially higher than their *ex post* costs. Thus, the anecdotal evidence on the accuracy of *ex ante* cost estimates of the Cluster Rule based on the SEC 10-K forms is a bit mixed – some firms accurately predicted the compliance costs, while others substantially overestimated them. However, since no firm clearly underestimated their actual costs, based on the firms that did provide *ex ante* and *ex post* costs estimates, the aggregate *ex ante* cost estimates are higher than the aggregate *ex post* cost estimates, which is consistent with our findings above.<sup>23</sup>

There are several instances in which firms commented on the costs associated with the Cluster Rule. In its 1999 10-K report, Wausau stated “The Company believes that capital expenditures associated with compliance with the Cluster Rules and other environmental regulations will not have a material adverse effect on its competitive position, consolidated financial condition, liquidity, or results of operation.” In its 1999 10-K report, Potlatch stated “In early 1998 the Environmental Protection Agency published the ‘Cluster Rule’ regulations applicable specifically to the pulp and paper industry ... the company estimates that compliance will require additional capital expenditures in the range of \$20 million to \$30 million, the majority of which will be expended over the next 2 to 3 years. The company does not expect that such compliance costs will have a material adverse effect on its competitive position.” These statements and our inability to locate any contrary statements in the SEC 10-K forms indicate that paper firms did not believe the costs of the Cluster Rule would have a substantial impact on their bottom line.

## 5.7 Mill closures

One factor contributing to *ex ante* cost estimates exceeding *ex post* costs are mill closings or a reduction in mill capacity through the shutdown of a machine. Obviously, if a mill shuts down instead of complying with the Cluster Rule this reduces observable *ex post* costs. Jensen (1999) discussed claims of mill shutdowns in response to meeting provisions of the Cluster Rule by April 2001. For example,

---

<sup>23</sup> Because firms were not obligated to disclose specific data regarding their capital expenditures associated with the Cluster Rule, firms such as Rayonier and Kimberley-Clark and Westvaco opted to provide only projected expenditures. As a result it is not possible to draw any conclusions about *ex ante* and *ex post* costs for those firms.

**Table 8** Cluster Rule capital expenditure estimates (in millions of dollars) from SEC 10-Ks for firms with complete data (millions of dollars).

Company	1999		2000		2001			
	Cost	Time frame	Cost	Time frame	Cost	Time frame		
Boise Cascade	120	Next 4 years (projected)	40	Through 1999 (actual)	96	Through 2000 (actual)	117	Through 2001 (actual)
Gaylord Containers	22.5	First 3 years – MACT I and III, no BAT costs (projected)	85	Next 2 years (projected)	32	2001 (projected)	10	Through fiscal 2001 – MACT I and III, no BAT costs (actual)
			10	For April 2001 standards – MACT I and III, no BAT costs (projected)	10	For April 2001 standards – MACT I and III (projected), no BAT costs		
Pope & Talbot	35	Through first quarter of 2001 (projected)	35	Through first quarter of 2001 (projected)	4.3	Through fiscal 2000 (actual)		
Potlatch	20–30	Next 2–3 years (projected)	8.2	Through 1999 (actual)	12	Total cost of project (most spent in 2000) (actual)		Phase I of Cluster Rule completed in 2000
			15	2000 (projected)	204	Through 2000 (actual)	232	Through 2001 (actual)
Smurfit-Stone	310	2–4 years (projected)	310	Next several years (projected)	179	2000 (actual)	28	2001 (actual)
Temple-Inland	≤110	1999–2001 (projected)	1	Through 1999 (actual)	11	Through 2000 (actual)	15	Through December 31, 2001 (actual)
Wausau	16–20	1999–2001 (projected)	20–22	1999–2001 (projected)	20–22	1999–2001 (projected)	19.1	1999–2001 (actual)

Kimberley-Clark decided against undertaking expenditures to bring its Mobile, AL mill into compliance. In addition, the decision by Sappi to close its Westbrook, ME mill was partially due to pending Cluster Rule expenditures. Finally, Donohue decided against bringing its Champion mill in Sheldon, TX into compliance with the Cluster Rule. Some of this story was confirmed by Miller and Freeman's (1998) statement that Proctor & Gamble, Kimberly-Clark, and Donohue, Inc. had closed kraft mills due to the costs of environmental regulations.

We attempt to identify mills affected by the Cluster Rule that permanently closed between 1997 and 2004 and provide documentation on the reason for the mill closing. Complicating this task is the fact that a mill can close, then be sold, and reopened under new management. Starting with the list of the 155 mills subject to the Cluster Rule, we compiled a list of mills that appear to have permanently closed by 2004.<sup>24</sup> This list was compiled from several sources. First, we identified the mills not included on the list of 133 mills subject to MACT II (EPA, 2001b, Appendix B), a 2004 list of the status of the 96 mills subject to the ELG component of the Cluster Rule (EPA, 2006, Appendix), and annual information on the 96 mills provided by Beca AMEC (2013b). Next, the USDA (2005) provided an inventory of the status of pulp mills in the 2005. This list was supplemented with information from the 1999 to 2002 editions of the *Pulp & Paper North American Fact Book*, and information on mill closures provided on SEC 10-K forms. Finally, we sought confirmation of mill closures via searches on the internet. Based on this information, of the 155 mills subject to the Cluster Rule, we identified approximately 18 permanent mill closures between 1997 and 2004 (see Morgan et al., 2014, pp. 57–65). We were unable to locate any statements in the SEC 10-K forms filed by pulp and paper firms that linked mill closures to environmental regulation, let alone the Cluster Rule. In fact, the most common reasons provided for mill closures were reduced demand for paper products and excess capacity.

How did mill closings affect the aggregate *ex post* costs of complying with the Cluster Rule? Since we do not have mill specific *ex post* cost data we cannot provide a precise answer to this question. Instead, we use the number of mill closures to estimate their effect on *ex post* costs. Deriving the number of mill closures due to the Cluster Rule requires subtracting the estimate of nine baseline mill closures used in the EPA's *ex ante* cost analysis from the 18 observed mill closures between 1997 and 2004. Thus, the nine mills estimated to have permanently closed between 1997 and 2004 due to the Cluster Rule plus six operating mills that ceased using bleached chemical processes represent approximately 10% of the mills affected by the Cluster and MACT II Rules. If we assume they are typical mills and we increase our *ex post* cost estimate by 10% we find the EPA over-estimated the costs of the Cluster and MACT II Rules by 1.5 to 2.5 times depending on

---

<sup>24</sup> Hanks et al. (2013) reported trends in the number of chemical pulp mills from 1976 to 2011.

the baseline.<sup>25</sup> Based on this, we conclude mill closures did not account for EPA's over-estimating the costs of the Cluster and MACT II Rules.<sup>26</sup>

## 6 Conclusions

Our findings suggest the EPA's *ex ante* cost estimates overstated the costs of both the Cluster Rule and the MACT II Rule. Using publicly available data from NCASI, we found the EPA overestimated the capital cost of the Cluster Rule by 30 to 100%, depending on the choice of baseline year from which we derived the incremental cost. Among the reasons for EPA's overestimates of these capital costs are the mills' use of the clean condensate alternative (CCA), flexible compliance options, extended compliance schedules, site-specific rules, use of equivalent-by-permit, and equipment/mill shutdowns and consolidations.<sup>27</sup> However, the lack of detail in the available data means we can only speculate on which reason(s) is primarily responsible for the EPA's overestimate.

Furthermore, our findings show the EPA also overstated the compliance costs of the MACT II Rule. Specifically, the EPA overestimated the capital cost by approximately 25% and overestimated the annual cost by 200+ percent. It appears the primary reason for the lower *ex post* cost is the use of the "PM bubble compliance alternative" strategy, which is a more efficient policy to abate the same level of PM emissions and required fewer mills to upgrade or install new pollution abatement equipment than anticipated by the EPA.

Anecdotal evidence of the realized costs of the Cluster Rule provided by the SEC Form 10-K is a bit mixed with some firms accurately predicting their compliance costs, while others substantially overestimated their actual costs. Because no firm dramatically understated its realized costs, the aggregate *ex ante* costs are likely higher than the aggregate *ex post* costs. While equipment/mill shutdowns and consolidations also played a role, they are not enough to account for the EPA's over-estimate of the actual costs of compliance.

---

<sup>25</sup> If we assume the mills that closed are high compliance cost mills, then the result that EPA over-estimated the costs would still hold, but the EPA overestimate would be less than under our typical mill assumption.

<sup>26</sup> U.S. EPA (<http://www.epa.gov/ttn/atw/pulp/milltab.pdf>) lists the 155 chemical (kraft, soda, sulfite, standalone semi-chemical) pulp and paper mills in the US initially subject to the Cluster Rule, while the U.S. EPA (2001b, Appendix B) lists the 133 chemical mills subject to MACT II.

<sup>27</sup> Bradfield and Spence (2011) provide information on the adoption of the clean condensate alternative, which is a pollution prevention option available to kraft high volume low concentration systems that allows the control of HAP emissions without resorting to controlling vent streams via combustion devices.

Defining the baseline remains a challenge for assessing not only the *ex post* costs of the Cluster Rule and MACT II Rule, but the *ex post* analysis of the costs of any regulation. The baseline determines which pollution abatement expenditures are considered a direct consequence of a regulation and which expenditures would have been incurred in a counter-factual world without the regulation. When determining the cost associated with the final Cluster Rule, the U.S. EPA (1997b, p. 10–16)

“excluded the incurred costs of process changes that were already implemented as of mid-1995 in the cost estimates used to analyze the economic achievability of the rules. However, EPA included the costs of the announced process changes not underway as of July 1, 1995 in the cost estimates used to analyze the economic achievability of the rule. Although EPA included the costs of the process changes announced but not yet underway as of mid-1995 in its final cost estimates, EPA nevertheless evaluated the impact of these costs in an alternative analysis reflecting announced corporate commitments that were not underway as of mid-1995.”

The 1995–1997 period, which serves as the baseline for our *ex post* analysis, represents a lull between 1990 and 1994 period when discussions about the Cluster Rule and MACT II Rule were initiated and 1998–2003 period when the rules were implemented. If some (or all) of the increase in pollution abatement expenditures during 1990–1994 can be attributed to actions taken in anticipation of the Cluster Rule, it does not invalidate the findings of this paper. While including expenditures from 1990 to 1994 would increase the total cost of the Cluster Rule and MACT II Rule, the objective of the paper was to compare our *ex post* estimate of the Cluster Rule and MACT II Rule with the *ex ante* cost estimates that were derived using a mid-1995 baseline. As a result, because pre-1995 pollution abatement expenditures related to the Cluster Rule and MACT II Rule were excluded from the *ex ante* cost estimate, consistency requires they be excluded from our *ex post* cost estimates.

While our findings suggest that EPA overestimated the cost of both the Cluster and MACT II Rules, we encounter several issues that limit the accuracy of our conclusions: 1) for the Cluster Rule, we only have access to industry level data, so our results are somewhat sensitive to how we construct the baseline and the exact mills included in this data; 2) for the Cluster Rule, we have no annual *ex post* pollution abatement operating cost data, which means conclusions on *ex post* compliance costs are limited to capital costs<sup>28</sup>; 3) for MACT II, the only industry compliance expert who could provide us with *ex post* cost information

---

<sup>28</sup> Although we did not use the PACE data to determine the capital costs associated with the Cluster and MACT II Rules, we can use the PACE data on O&M costs in 1994 and 2005 to provide an estimate of how pollution abatement O&M costs were affected by the Cluster and MACT II Rules. Assuming 1994 is representative of the baseline (pre-Cluster and MACT II Rules) and 2005 represents the period of compliance (post-Cluster and MACT II Rules), we calculate the ratio of

also supported the *ex ante* cost analysis for the rule and we could not independently verify the accuracy of the data; and 4) for MACT II, the *ex post* cost data was estimated by RTI, the contractor that supported the *ex ante* analysis, using a combination of *ex ante* engineering cost data developed by BE&K based on its experience with similar projects in the pulp and paper industry and the actual (*ex post*) compliance methods chosen by the mills.

## Glossary – List of Acronyms

APCD	Air Pollution Control Devices
BAT	Best Available Technology
ClO <sub>2</sub>	Chlorine Dioxide
ELG	Effluent Limitation Guidelines
HAP	Hazardous Air Pollutants
MACT	Maximum Achievable Control Technology
NCASI	National Council for Air and Stream Improvement
NESHAP	National Emission Standards for Hazardous Air Pollutants
O <sub>2</sub> delig	Oxygen Delignification
PACE Survey	Pollution Abatement Costs and Expenditures Survey
PM	Particulate Matter
PSES	Pretreatment Standards for Existing Sources

**Acknowledgments:** We thank two anonymous referees for helpful comments on an earlier version of this article. We also wish to thank BECA, especially Tony Johnson, for assisting with the acquisition of data on water pollution abatement technologies.

## References

- Alliance for Environmental Technology. (2002). Trends in world bleached pulp production: 1990–2001. Available at: [www.aet.org/reports/market/trends90-01.html](http://www.aet.org/reports/market/trends90-01.html).
- Barton, D., Pinkerton, J., Kaufman, R., Jones, M., Forbes, D., & Johnson, G. (1995). Cluster rule would place unrealistic demand on engineering resources. *Pulp & Paper*, 69(13), 103–108.
- Beca AMEC. (2013a). “Annual US pulp line MTPY” spreadsheet, Tony Johnson, ed.
- Beca AMEC. (2013b). “Pulp mill data – delig study” spreadsheet, Tony Johnson, ed.

---

2005 to 1994 pollution abatement O&M costs for both air and water (in constant dollars). The ratio for air is approximately 0.8 and the ratio for water is around 0.7. The decline in O&M costs suggests O&M costs are not a significant component of the Cluster and MACT II Rule compliance costs.

- Bradfield, J., & Spence, K. (2011). Summary of clean condensate alternative technology review. Memorandum to Docket EPA-HQ-OAR-2007-0544-0129, October 20.
- EPA asked to reward O2 delig users. (1996). *Pulp & Paper*, 70(6), 21.
- Ferguson, K. (1995). Stuck in environmental limbo. *Pulp & Paper*, 69(8), 9.
- Garner, J. (2001). Air emission control regulations pose new challenges for mills. *Pulp & Paper*, 75(10), 44–46.
- Hanks, K., Holloway, T., & Gooden, C. (2013). Projections of the number of new, modified and reconstructed emissions units for the kraft pulp mill NSPS. Memorandum to Kelly Spence, U.S. EPA, from Katie Hanks, Tom Holloway, and Corey Gooden, RTI International, February 4.
- Holloway, T. (2000). Revised nationwide costs, environmental impacts, and cost effectiveness of regulatory alternatives for kraft, soda, sulfite, and semichemical combustion sources. Memorandum to Project file from Thomas Holloway, Midwest Research Institute, EPA Docket A-94-67, Item IV-B-12, October 26.
- Jensen, K. P. (1999). U.S. bleached pulp mills move towards compliance of phase 1 of cluster rule. *Pulp & Paper*, 73(9), 71–75.
- Johnson, T. (1994). Chlorine dioxide usage – a status report on the look of the North American bleaching scene. *TAPPI 1994 Pulping Conference Proceedings, Book 1*, pp. 769–771.
- Johnson, T. (1995). O2 delig system update. *Pulp & Paper*, 69(2), 41.
- Maynard, L. J., & Shortle, J. S. (2001). Determinants of cleaner technology investments in the U.S. bleached kraft pulp industry. *Land Economics*, 71(4), 561–576.
- Miller Freeman Publications, Inc. (1998). *Pulp & paper North American fact book 1999*. San Francisco, CA: Miller Freeman Publications, Inc.
- Morgan, C., Pasurka, C., & Shadbegian, R. (2014). Cluster rule and MACT II rule. In *Retrospective Study of the Costs of EPA Regulations: A Report of Four Case Studies* (pp. 24–65). Washington, DC: National Center for Environmental Economics, Office of Policy. EPA 240-F-14-001.
- National Council for Air and Stream Improvement, Inc. (1999). *A survey of pulp and paper industry environmental protection expenditures – 1998*, Special Report No. 99-05. Research Triangle Park: National Council for Air and Stream Improvement, Inc.
- National Council for Air and Stream Improvement, Inc. (2002a). *A survey of pulp and paper industry environmental protection expenditures – 1999*, Special Report No. 02-01. Research Triangle Park: National Council for Air and Stream Improvement, Inc.
- National Council for Air and Stream Improvement, Inc. (2002b). *A survey of pulp and paper industry environmental protection expenditures – 2000*, Special Report No. 02-02. Research Triangle Park: National Council for Air and Stream Improvement, Inc.
- National Council for Air and Stream Improvement, Inc. (2002c). *A survey of pulp and paper industry environmental protection expenditures – 2001*, Special Report No. 02-07. Research Triangle Park: National Council for Air and Stream Improvement, Inc.
- National Council for Air and Stream Improvement, Inc. (2003). *A survey of pulp and paper industry environmental protection expenditures – 2002*, Special Report No. 03-07. Research Triangle Park: National Council for Air and Stream Improvement, Inc.
- Nicholson, R., Holloway, T., & Gooden, C. (2012). Final white paper. Memorandum to Anna Belova, Abt Associates, from Rebecca Nicholson, Tom Holloway, and Corey Gooden, RTI International, February 28.
- Norberg-Bohm, V., & Rossi, M. (1998). The power of incrementalism: environmental regulation and technological change in pulp and paper bleaching in the US. *Technology Analysis & Strategic Management*, 10(2), 225–245.

- Paperloop.com, Inc. (2000). *Pulp & paper North American fact book 2000*. San Francisco, CA: Paperloop.com, Inc.
- Paperloop.com, Inc. (2002). *Pulp & paper North American fact book 2001*. San Francisco, CA: Paperloop.com, Inc.
- Paperloop.com, Inc. (2003). *Pulp & paper North American fact book 2002*. San Francisco, CA: Paperloop.com, Inc.
- Paper Task Force. (1995). *Economics of kraft pulping and bleaching*. Working Paper No. 7 (19 December), p. 5. Available at: [http://c.environmentalpaper.org/documents/1628\\_WP7.pdf](http://c.environmentalpaper.org/documents/1628_WP7.pdf).
- Parthasarathy, P., & Dowd, S. (2000). Impact of the cluster rule on the cost competitiveness of U.S. papermaking industry in the global market. *TAPPI Journal*, 83(9), 39–45. Available at <http://www.tappi.org/Downloads/unsorted/UNTITLED---00Sep39pdf.aspx>.
- Pauksta, P. M. (1995). The cluster rule: what's at stake for the industry? *Tappi Journal*, 78(9), 50–51.
- Popp, D., & Hafner, T. (2008). Policy versus consumer pressure: innovation and diffusion of alternative bleaching technologies in the pulp industry. In *Environmental Policy, Technological Innovation and Patents*, OECD Studies on Environmental Innovation (pp. 107–138). Paris, France: OECD Publications.
- Powell, M. R. (1997). *Control of dioxins (and other organochlorines) from the pulp and paper industry under the clean water act and lead in soil at superfund mining sites: two case studies in EPA's use of science*. RFF Discussion Paper 97-08.
- Snyder, L. D., Miller, N. H., & Stavins, R. N. (2003). The effects of environmental regulation on technology diffusion: the case of chlorine manufacturing. *American Economic Review*, 93(2), 431–435.
- U.S. Bureau of the Census. (various issues). *Pollution abatement costs and expenditures*. Current Industrial Reports (MA200). Washington, DC: U.S. Government Printing Office.
- U.S. Department of Commerce, Bureau of the Census. (2000). *Selected air pollution control equipment, 1998*. Current Industrial Reports (MA333). Washington, DC: U.S. Government Printing Office.
- U.S. Department of Agriculture, Forest Service, Southern Research Station. (2005). "U.S. wood-using mill locations – 2005," Available at <http://www.srs.fs.usda.gov/econ/data/mills/>.
- U.S. Environmental Protection Agency. (1990). *U.S. EPA/paper industry cooperative dioxin study 'the 104 mill study,' summary report*. Washington, DC: Office of Water Regulations and Standards.
- U.S. Environmental Protection Agency. (1993a). Effluent limitations guidelines, pretreatment standards, and new source performance standards: pulp, paper, and paperboard category; national emission standards for hazardous air pollutants for source category: pulp and paper production. *Federal Register*, 58(241), 66078–66216.
- U.S. Environmental Protection Agency. (1993b). *Handbook on pollution prevention opportunities for the bleached kraft pulp and paper mills*. Washington, DC: Office of Research and Development and the Office of Enforcement. EPA-600-R-93-098.
- U.S. Environmental Protection Agency. (1993c). *Regulatory impact assessment of proposed effluent guidelines and NESHAP for the pulp, paper, and paperboard industry*. Washington, DC: Office of Water. EPA-821-R-93-020.
- U.S. Environmental Protection Agency. (1997a). *Economic analysis for the national emission standards for hazardous air pollutants for source category: pulp and paper production; effluent limitations guidelines, pretreatment standards, and new source performance*

- standards: pulp, paper, and paperboard category-phase 1*. Research Triangle Park, NC: Office of Air and Radiation, Office of Air Quality Planning and Standards, Innovative Strategies and Economics Group and Washington, DC: Office of Water, Office of Science and Technology, Engineering and Analysis Division.
- U.S. Environmental Protection Agency. (1997b). *Supplemental technical development document for effluent limitations guidelines and standards for the pulp, paper, and paperboard category: subpart B (bleached papergrade kraft and soda) and subpart E (papergrade sulfite)*. Washington, DC: Office of Water. EPA-821-R-97-011.
- U.S. Environmental Protection Agency. (1998a). National emission standards for hazardous air pollutants for source category: pulp and paper production; effluent limitations guidelines, pretreatment standards, and new source performance standards: pulp, paper, and paperboard category. *Federal Register*, 63(72), 18504–18751.
- U.S. Environmental Protection Agency. (1998b). *Pulp and paper NESHAP: a plain English description*. Research Triangle Park, NC: Office of Air Quality Planning and Standards, Group. EPA-456/R-98-008.
- U.S. Environmental Protection Agency. (2001a). National emission standards for hazardous air pollutants for chemical recovery combustion sources at kraft, soda, sulfite, and stand-alone semichemical pulp mills. *Federal Register*, 66(9), 3180–3203.
- U.S. Environmental Protection Agency. (2001b). *Pulp and paper combustion sources for national emission standards for hazardous air pollutants (NESHAP): a plain English description*. Research Triangle Park, NC: Office of Air Quality Planning and Standards. EPA-456/R-01-003.
- U.S. Environmental Protection Agency. (2006). *Final report: pulp, paper, and paperboard detailed study*. Washington, DC: Office of Water, Engineering and Analysis Division. EPA-821-R-06-016.
- U.S. Securities and Exchange Commission. (various years and firms). Form 10-K, annual report pursuant to section 13 or 15(d) of the securities exchange act of 1934. Available at: <http://www.sec.gov/answers/form10k.htm>.

---

**Article note:** The views expressed in this article are those of the authors and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.