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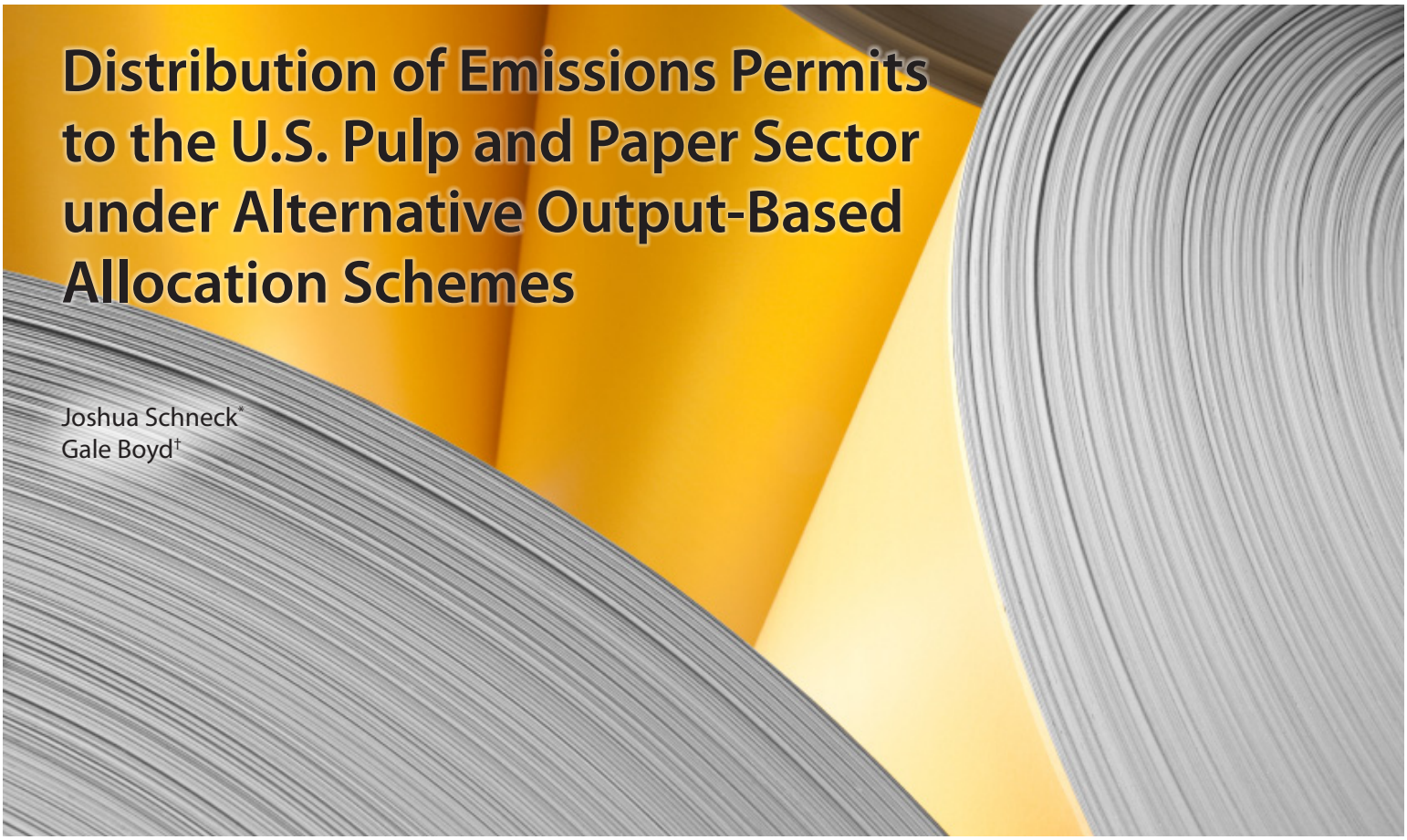

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SUMMARY

This paper looks at key design elements and industry characteristics that can affect the distribution of allowances to firms under output-based allocation, focusing on the important U.S. pulp and paper sector as an example. We examine allowance distributions under three variations of a proposed output-based allocation program—the American Power Act's emissions allowance rebate program. We compare these distributions to the plant's actual emissions, or "compliance burden," which is effectively a comparison of these output-based allocations to a "grandfathered" allocation based on the individual mill's historical emissions. One of the principal outcomes of output-based allocation is that it gives relatively more emissions coverage to plants with lower emission intensities (i.e., ratio of emissions to unit [or dollar] of product produced). The "fairness" of the output-based allocation depends, in part, on the range of emissions intensity within a sector and the associated financial redistribution that this type of allocation entails. We show that a sectoral scheme tailored to the industry compared to the NAICS industry definitions identified in the American Power Act ameliorates some of the extremes of the underlying variability and transfers, but that a large variation still remains in some sectors. A large portion of this variation is due to differences in the type of fuel used, which a tradable permit system is designed to influence. We compute that the differences in net compliance burden (i.e., the actual emissions less allocated permits), monetized at $20 per ton, relative to a simple estimate of industry average plant revenue, ranges from ±1% to 4%. Compared to a "typical" profit margin of 12%, we can see that the implicit transfers between plants can have substantial within-sector financial implications.

1. INTRODUCTION

Under a cap-and-trade climate policy, emissions allowances—tradable rights to emit a fixed amount of greenhouse gases (GHGs)—become scarce and valuable resources that change the economic incentives to implement more energy-efficient processes and energy management practices, and to select fuels with lower carbon content. A key question accompanying the design of any such policy is how to allocate these allowances, even though it is well established that an allowance system changes the incentive structure *regardless of how allowances are obtained*. In general, allowances may either be auctioned or distributed for free to industrial emitters, with most emissions programs opting for some mixture of the two approaches. Since these allowances have value, the method of initial allocation does have consequences with respect to equity, as it involves the transfer of potentially large sums of money.

Free distribution is often sought by businesses with sunk capital as compensation for lost investments or forgone profits. Another reason put forward for free allocation of allowances is to provide protection against any loss of competitiveness for industries that face competition from foreign firms not operating under comparable regulation. Moreover, were this loss of competitiveness to be accompanied by a loss of market share (and jobs) to unregulated foreign competitors, the shifting of economic activity to uncapped countries could generate a corresponding increase in uncapped countries' GHG emissions—what is referred to as "emissions leakage"—thereby undermining the environmental objective of the climate policy.

If allowances are to be distributed for free, two approaches are most often considered in the literature. One approach scales distributed allowances to a measure of a sector's historical emissions in what is known as "grandfathering." The other approach distributes permits according to firms' level of production in what is known as "output-based allocation." Output-based allocation has emerged as the preferred approach among studies that have compared the two allocation methods, in part because it is potentially more effective at mitigating competitiveness impacts.[1] What have been less explored in the literature are

[1] See C. Fischer and A. Fox, "Output-Based Allocation of Emissions Permits for Mitigating Tax Interactions," *Land Economics* 83, no. 4 (2007): 575–599, and R. Stavins, "Worried about International Competition? Another Look at the Waxman-Markey

the equally important program rules that in turn affect the distribution of permits to firms within sectors under an output-based allocation system.

This paper looks at key design elements and industry characteristics that can affect the distribution of allowances to firms under output-based allocation, focusing on the important U.S. pulp and paper sector as an example. Since plant-level data is needed to compute these distributions, we use a dataset containing confidential data on energy use and production collected by the American Forest Products and Paper Association (AF&PA) with support from the National Council for Air and Stream Improvement, Inc. (NCASI).[2] We examine allowance distributions under three variations of a proposed output-based allocation program—the American Power Act's (APA) emissions allowance rebate (EAR) program. We compare these distributions to the plant's actual emissions, or "compliance burden," which is effectively a comparison of these output-based allocations to a "grandfathered" allocation based on the individual mill's historical emissions.

One of the principal outcomes of output-based allocation is that it gives relatively more emissions coverage to plants with lower emission intensities (i.e., ratio of emissions to unit [or dollar] of product produced). One view of this approach is that it rewards those plants that have been "proactive" in lowering emissions through energy efficiency and technology investments. However, it can also punish those plants using high-emissions fuels (e.g., coal or petcoke) regardless of any investments in energy efficiency. The "fairness" of the output-based allocation depends, in part, on the range of emissions intensity within a sector. If the range of intensity within a sector is "large," then the difference in terms of financial impact between low and high emitters will also be "large." This difference grows as the value of allowances rises. Politically, we may find some level of financial reallocation between different GHG emitters to be acceptable in terms of equity, but not if these reallocations are "too large."

However, differences in plant-level emissions intensity can also arise for reasons unconnected to efficiency. Differences can be due to fuel choice, to the way in which mills producing different products are grouped together, or to the degree to which plants are vertically integrated—that is, the extent to which they produce intermediate input products onsite. Fuel choice has an obvious and direct impact on emissions intensity. The imposition of an allowance system is designed to change these incentives. However, location-specific fuel availability may be a significant component of fuel choice.[3] In the second case, it's well known that the production of different products often requires different amounts of energy inputs. In the third case, a plant's choice to produce some intermediate inputs onsite rather than purchase the same material may cause plant-level emissions for the vertically integrated plant to be higher than those of a non-vertically integrated plant producing the same final product. In both cases, evaluating plant-level efficiency on the basis of emissions intensity with respect to final products produced can be misleading.

Factors affecting a mill's total emissions intensity include the emissions intensity of both purchased electricity and onsite fuels consumed, and the use of combined heat and power (CHP) systems. With

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Cap-and-Trade Proposal," Grist, June 19, 2009, http://www.grist.org/article/worried-about-international-competitiveness-another-look-at-the-waxman-mark. Note that the kind of grandfathering approach contrasted by Fisher and Fox, Stavins, and others with output-based allocation is a "lump-sum" transfer of emissions permits based on a mill's historical emissions. It is, however, possible to design an output-based allocation system that uses individual mills' historical emissions instead of sector-wide emissions benchmarks as a basis for allocating permits. Such an approach would by definition have no intersectoral variability among mills in terms of percentage of emissions covered by an allocation, but would fail to distinguish among firms that have been "proactive" in making efficiency investments (see page 2). Alternatively, it would dampen the market distortions among regions that have access to different fuel types, i.e., gas or coal. The cap/ceiling concept considered in the paper's conclusion incorporates some aspects of this approach.

[2] This data was provided to Duke University under a nondisclosure agreement.

[3] Location may impact relative fuel prices, but in extreme cases it may mean that some fuels are simply not available—for example, some rural plants may not be near a gas pipeline.

purchased electricity, emissions intensity is largely outside the control of individual firms, being a function of where plants are located. For onsite fuels, one of the stated goals of any cap-and-trade climate policy is to incentivize a shift towards lower-carbon fuels, which generally means a move away from coal and towards natural gas and carbon-free renewables. At the same time, some industry stakeholders have argued that a mill's historical choice of onsite fuels and related equipment has often been dictated more by the availability of fuel sources (e.g., the availability of biomass or a natural gas supplier) than by any decision on whether or not to invest in GHG efficiency.

Finally, CHP systems capture heat energy that would otherwise be lost and turn it into usable electricity and/or steam. While these systems result in an overall (onsite and offsite) reduction of emissions, a mill incorporating CHP will have higher onsite emissions than an identical mill lacking CHP, and therefore may potentially be worse off under a climate policy capping only direct onsite emissions.

For all the above reasons, the rules governing output-based allocation can have a significant impact on the distribution of allowances to plants within sectors, as well as on stakeholders' ultimate perceptions of how "fair" an allocation program is. Our analysis of simulated allowance distributions to pulp and paper mills under alternative output-based allocation rules bears this and other points out. In particular, our study reveals that distribution of permits under APA rules using the existing standard industry classification system—the North American Industry Classification System (NAICS)[4]—results in differential treatment for vertically and non-vertically integrated mills residing in the same sector, as well as for mills that do and do not incorporate an onsite bleaching process.[5] We find that a tailored approach reflective of industry characteristics can reduce some of the variability in terms of the benefits each mill receives from the program relative to other mills in the same sector, and also eliminate bias attributed to vertical integration or onsite bleaching. Lastly, we find that the emissions intensity of mills' onsite fossil fuel mix is correlated with the number of allowances received for most pulp and paper sectors in all distributions, while the emissions intensity of purchased electricity appears significant for only those sectors in which purchased electricity is a relatively large energy input.

Results of this study can inform efforts to design output-based allocation schemes for use in climate and other environmental programs. Additionally, while much of the focus is on the pulp and paper industry, many of the issues faced by this manufacturing sector are common to other manufacturing sectors.

Section 2 provides an overview of the pulp and paper industry, including processes involved in making pulp and paper and other industry-specific issues. Section 3 details the design of our study, including the EAR program and variants. Section 4 looks at the energy and emissions characteristics of the sectors used to create energy and GHG benchmarks in the study. Section 5 provides results of our study and section 6 concludes with an assessment of the various options examined.

2. OVERVIEW OF THE PULP AND PAPER INDUSTRY

The U.S. pulp and paper industry is comprised of three primary types of producers: (1) pulp mills, which manufacture pulp from wood and other materials (such as wastepaper); (2) paper mills, which manufacture paper from wood pulp and other fiber pulp; and (3) paperboard mills, which manufacture paperboard products from wood pulp and other fiber pulp. Also included in this industry are converting plants, that is, plants that make paper and paperboard products from paper and paperboard stock produced

[4] NAICS is used by business and government to classify business establishments according to type of economic activity. NAICS is a two- through six-digit hierarchical classification system, offering five levels of detail. Each digit in the code is part of a series of progressively narrower categories, and the more digits in the code signify greater classification detail. The first two digits designate the economic sector, the third digit designates the subsector, the fourth digit designates the industry group, the fifth digit designates the NAICS industry, and the sixth digit designates the national industry. A complete and valid NAICS code contains six digits. (From Census Bureau NAICS FAQ, http://www.census.gov/eos/www/naics/faqs/faqs.html.)

[5] Bleached paper tends to be more energy-intensive.

by primary mills. This report focuses on the former, which is the most energy-intensive stage of production. These sectors are encompassed by four 6-digit NAICS sectors:

- 322110, Pulp mills
- 322121, Paper (except Newsprint) mills
- 322122, Newsprint mills
- 322130, Paperboard mills

In the 2007 Census of Manufacturing these four sectors had shipments worth over $80 billion, purchased $7.6 billion in fossil fuels and electricity, and had a total employment of over 124,000 and average annual wages of over $63,000.

The main energy-using processes in pulp and paper mills include raw materials preparation, pulping (chemical, semi-chemical, mechanical, and waste paper), bleaching, chemical recovery, pulp drying, and paper making. For a more detailed description see Kramer et al (2009).[6] Within these broadly defined production stages there are important plant configuration and process distinctions that influence the energy use of a mill. The first is integration. Paper and paperboard mills may be Non-Integrated or Integrated—that is, mills may purchase the pulp or produce it as an intermediate material. Integrated plants are essentially mills that combine a pulp mill with a paper or paperboard mill. The second distinction is the source of fiber. The source of fiber for pulping may come from virgin materials (wood) or recycled paper or paperboard. The third distinction is the pulping process. The dominant[7] pulping processes are chemical (kraft and sulfite) and mechanical (ground wood). The type of pulp will largely dictate the type of paper produced. Mechanical pulp is used primarily for newsprint and related types of paper. The final distinction is pulp bleaching/de-inking. Bleaching of virgin pulp is required for white paper products, although de-inked recycled fiber can also be used for "white products."

Plants that produce chemical pulp from virgin fiber produce substantial amounts of biomass-based byproduct fuels, called "black liquor," that can be used to "replace" purchased fossil fuels.[8] This includes both pulp mills and integrated mills. Recycled fiber and ground wood do not generate the same volume and type of byproduct that can be used for energy. Pulp mills and integrated mills may also produce "hog fuel," that is, recovered bark from the trees that provide the input source of fiber. Bleaching pulp is an energy-using step of the process and is one of many of the final product distinctions that impact plant energy use. There are a wide range of final product types and plant configurations in this industry that may also influence the energy requirements, but these four characteristics are arguably the most important. These distinctions are not encompassed in the typical industry classification schemes, such as NAICS, used by the government.

3. AMERICAN POWER ACT EAR PROGRAM AND STUDY DESIGN

Purpose of program

The draft American Power Act (APA), introduced by senators John Kerry and Joseph Lieberman on May 12, 2010, is a climate and energy bill that would establish an economy-wide cap-and-trade program for reducing U.S. emissions of GHGs. Seen as the Senate companion to the House-passed American Energy and Security Act of 2009 (H.R. 2454), the two bills share similar reduction targets and timetables.

[6] See K. Jan Kramer, E. Masanet, T. Xu, and E. Worrell, *Energy Efficiency Improvement and Cost Saving Opportunities for the Pulp and Paper Industry*, Lawrence Berkeley National Laboratory Report # LBNL-2268E (Berkeley, CA: Lawrence Berkeley National Laboratory, 2009) for more details on the production and energy use in this industry.
[7] There are also less common forms of pulping, such as semi-chemical and other types of chemical processes.
[8] Mills using virgin fiber may also use various wood wastes, bark, etc., as biomass fuels.

A major issue accompanying the debate surrounding both bills as well as earlier efforts to craft federal climate legislation concerns the potential impacts on the competitiveness of U.S. manufacturers. By imposing a cost on the production of carbon-intensive goods at a time when other countries are not, there is concern that a cap-and-trade or similar policy would shift comparative advantage, followed by market share and jobs, to foreign competitors not subject to equivalent regulation. Moreover, the shifting of economic activity to uncapped countries could result in emissions leakage, thereby undermining the environmental objective of the climate policy.

In response to these concerns, both APA and H.R. 2454 would establish a nearly identical program for freely allocating a number of emission allowances to manufacturers that meet certain thresholds for energy intensity and trade exposure. The four six-digit NAICS industries that comprise the pulp and paper sector are part of an estimated 44 six-digit NAICS industries that would qualify for the program.[9]

The stated purpose of the APA's EAR program is

> (1) to provide a rebate to the owners and operators of entities in domestic eligible industrial sectors for the greenhouse gas emission costs incurred under this title, but not for costs associated with other related or unrelated market dynamics; (2) to design the rebates in a manner that will prevent carbon leakage while also rewarding innovation and facility-level investments in energy efficiency performance improvements; and (3) to eliminate or reduce distribution of emission allowances under (the EAR program) when the distribution is no longer necessary to prevent carbon leakage from eligible industrial sectors.[10]

However, except for purchased electricity, the APA did not consider the competitive distortions it could cause within sectors for some of reasons described above.[11]

American Power Act EAR program rules

The EAR program links the distribution of allowances to individual mill production levels and sector-wide averages (also called "benchmarks") for direct (onsite) and indirect (offsite) emission and energy intensities. While mills covered under APA's cap-and-trade program are only required to submit allowances covering their onsite emissions, the distribution of allowances tied to indirect emissions is meant to cover an expected rise in the cost of mills' purchased electricity due to the cap's effect on electricity producers.[12] A further adjustment to the number of allowances each mill receives is made to account for differences in the emissions intensity of purchased electricity across the United States.

For each covered manufacturing facility, allocation is based on the sum of what are called Direct and Indirect Carbon Factors, which are meant to capture a mill's direct and indirect emissions. A more detailed description of the calculations used to determine a mill's allocation of emission permits is found in the Appendix.

As discussed in the introduction, a key component that strongly affects the distributional outcome of an output-based allocation program is the way in which industry sectors are defined—that is, the way that

[9] U.S Environmental Protection Agency, Energy Information Administration, and Treasury, *The Effects of H.R. 2454 on International Competitiveness and Emission Leakage in Energy-Intensive Trade-Exposed Industries*, Interagency Report, December 2, 2009.
[10] The American Power Act §771(b).
[11] Some provisions would consider different sector definitions that we explore below, but not regional fuel choice and availability.
[12] APA calls for an adjustment to be made that lowers the amount of permits a mill receives for its indirect emissions in the case where the mill's electricity provider receives a free allocation of permits which are then used for the benefit of its industrial consumers. This is to ensure that firms receiving free allowances are not credited for costs which are not borne by them (APA § 774 (b)(3)). For the sake of simplicity, this study assumes no permits are distributed to electricity providers, and therefore no adjustment of this kind is made to the calculation of permits received for indirect emissions.

individual mills are grouped together for the purposes of calculating the emissions and energy intensity benchmarks that are then used in allocating allowances. While APA uses the six-digit NAICS codes to define sectors eligible to receive permits, language in the bill provides the Administrator of the U.S. Environmental Protection Agency (EPA) some flexibility in defining sectors used to calculate the emissions and energy intensity benchmarks. The bill states "(n)otwithstanding the criteria used to determine eligible sectors…the Administrator shall, by rule, identify sectors or subsectors for the purposes or calculating (energy and emissions intensity benchmarks)…based on "(i) the intermediate and final products produced; and (ii) the extent or use of combined heat and power technologies."[13] The added flexibility allowing the Administrator to account for intermediate and final products (i.e., vertical integration) is not found in H.R. 2454.

Study design

Using a dataset provided by AF&PA we look at the simulated distribution of allowances to mills in our sample under APA EAR program rules, varying the way in which different mills are grouped together for the purpose of calculating GHG and energy intensity benchmarks. The three sectoral grouping schemes are as follows:

1. **NAICS sectors** – Mills are sorted according to the four six-digit NAICS sectors that comprise the pulp and paper sector:

    - *Pulp mills (322110)*
    - *Paper mills, except newsprint (322121)*
    - *Newsprint mills (322122)*
    - *Paperboard mills (322130)*

2. **Integrated/Non-Integrated sectors** – Mills are sorted based both on final product and whether or not a mill meets certain criteria for being an integrated mill. A mill is classified as an integrated mill if at least one-third of its output is paper product and the mill generates pulping residues used for onsite energy inputs. Of note, we classify paper mills that produce pulp via mechanical means with Non-Integrated paper mills based on an analysis of these mills' energy intensity profile.[14] The six-digit NAICS sector for newspaper mills is unchanged. The result is the following six sectors:

    - *Pulp mills (non-NAICS)*[15]
    - *Integrated paper mills*
    - *Non-Integrated paper mills*
    - *Newsprint mills*
    - *Integrated paperboard mills*
    - *Non-Integrated paperboard mills*

3. **Integration/Bleaching sectors –** This sectoral scheme is identical to the integrated/Non-Integrated scheme, except that two of the Integrated/Non-Integrated sectors—Non-Integrated Paper mills and Integrated Paperboard—are further sorted according to whether any onsite bleaching occurs at mills. The result is the following eight sectors:

[13] APA § 774 (b)(5).
[14] This is done purely based on empirical observation and not because of any process similarities.
[15] The Pulp mill sector in the Integrated/Non-Integrated and the Integration/Bleaching scheme differs from the six-digit NAICS Pulp mill sector in that under the Integrated/Non-Integrated and Integration/Bleaching schemes, at least two-thirds of mill output must be market pulp. In contrast, a mill will be classified as a pulp mill under the six-digit NAICS codes if a majority (>50%) of output is market pulp.

- *Pulp mills (non-NAICS)*
- *Integrated Paper mills*
- *Non-Integrated Bleached Paper mills*
- *Non-Integrated Unbleached Paper mills*
- *Newsprint mills*
- *Integrated Bleached Paperboard mills*
- *Integrated Unbleached Paperboard mills*
- *Non-Integrated Paperboard mills*

Regression analysis guiding the design of sectoral schemes

The justification for the three classification schemes is based on a series of regressions shown in Table 1.[16] These regressions are intended to identify potential sources of bias in the NAICS-based allocations. We first compute the allocations for the NAICS classifications for each plant and compare this to the compliance burden.[17] The ratio of allocated to actual emissions is the percentage covered. We then regress the percentage covered on a nonlinear function of production and on two sets of plant characteristics. The first set includes dummy variables for CHP, if the plant is vertically integrated, and if the plant has onsite bleaching; the second set includes the emission intensity of fossil fuel, the EPA Emissions & Generation Resource Integrated Database (eGRID)[18] emission rate at the subregion level (this serves a proxy for the emissions intensity of a mill's purchased electricity), and the percentage of the plant's total energy consumed that is biomass.

First we find that CHP has no effect or a marginally significant effect in both regressions, that is, regardless of whether we account for biomass and fuel choice. We believe that this is due to the inclusion of both direct and indirect emissions in the computation of the allocation and compliance burden (see "Additional study notes" below). The fact that the CHP variable is not significant suggests that accounting for direct and indirect emissions adequately "handles" CHP. We find that in the first pair of regressions integration has the expected sign and is significant for paper but not for paperboard—that is, paper plants tend to receive 44% more coverage of their compliance burden if they are integrated, compared to their counterparts. This is due to efficiencies that may arise from integration and also the availability of biomass fuels (we return to this point in the second set of regressions). Bleaching has the expected sign and is marginally significant for paperboard—that is, paperboard plants with onsite bleaching tend to receive 25% less coverage of their compliance burden relative to paperboard plants with no onsite bleaching. Plant size is also significant for paperboard but not for paper. The nonlinear effect implies that as production increases the coverage declines—that is, larger plants, on average, have less of their GHG burden covered. When we add the variables that account directly for emissions, that is, the emissions intensity of fossil fuel, percentage of direct fuel use provided by biomass, and the eGRID emission rate, the intensity of fossil fuel and biomass percentage has the expected impact on coverage. Adding these variables also helps to explain a much larger portion of the variability in coverage than in the first regression as seen by the increase in R squared from .15 and .18 to .55 and .56. The eGRID emission rate, however, remains insignificant. When the percentage of biomass variable is included, the sign changes on vertical integration, since these plants have more biomass in the form of black liquor. When you take into account the average percentage of biomass used, integrated plants still tend to have

[16] The sample size for Pulp mills and Newsprint mills is very small and the first set of plant characteristics are not applicable, so we only report the results for paper and paperboard. We also conducted the analysis using a more detailed set of plant categories based on those used by NCASI. None of the NCASI variables were significant leading us to develop the simpler categories used in the first regression.

[17] This process is described is more detail below.

[18] U.S. Environmental Protection Agency eGRID2010 Version 1.0. eGRID is a comprehensive source of data on the environmental characteristics of almost all electric power generated in the United States. Available at http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html.

more allowances, and this grows with the percentage of biomass they use. Taken together, there is a suggestion that the NAICS allocation is biased against bleached plants and in favor of integrated plants, for paperboard and paper, respectively. We proceed to examine the distribution of emission coverage in the two additional schemes that disaggregate by integration and bleaching.

Table 1. Regression analysis of the factors influencing the ration of allocated to actual emission.

Variable	Paper (1st regression)	Paperboard (1st regression)	Paper (2nd regression)	Paperboard (2nd regression)
CHP	0.4389	6.1829	1.4496	12.4785*
Vertical integration	44.4586**	23.2894	-65.8363***	-66.1415***
Onsite bleaching	-15.1098	-25.1129*	-28.5321	-39.1666***
Production (thousands)	0.0728	-0.0975**	0.0857	-0.1296***
Production^2 (thousands)	-3.10E-11	9.10E-11 ***	-5.20E-11	1.00E-10 ***
Emission intensity of onsite fossil			-0.9952***	-0.7746***
eGRID emission rate			4.1772	-2.7646
Percent onsite biomass in total energy consumption			2.2007***	1.6738***
constant	77.1657***	112.9252***	124.9939***	158.5898***
N	68	95	68	95
R squared	0.1525	0.1838	0.5533	0.5584
				legend: * p<.1; ** p<.05; ***p<.01

Additional study notes

The question of whether and how emissions resulting from the burning of biomass will be regulated is both unsettled[19] and important[20] for the pulp and paper industry. This industry relies upon biomass for roughly half of its energy needs.[21] At the same time, many industry observers expect that the EPA will eventually declare emissions from most biomass (e.g., bark, black liquor) used by the paper industry to be carbon-neutral on the grounds that such emissions are not "additional," are recently removed from the atmosphere, and will be reabsorbed as new trees are grown to replace the harvested ones. For example, in July 2011 the EPA ruled that biomass emissions will not be subject to any caps on emissions for a period of three years while the agency studies the issue further.[22] In this study, all emissions from biomass are treated as carbon-neutral.

Although covered entities under the APA cap-and-trade program are only responsible for submitting emission allowances covering their direct emissions, the cost of purchased energy is expected to rise under the policy, as electricity and steam providers seek to pass on the costs of their emissions to downstream consumers.[23] For the sake of simplicity, we assume complete pass-through of these emissions costs to pulp and paper mills, and use the sum of a mill's direct and indirect emissions to represent its total compliance burden under the policy.

Lastly, the purpose of this study is to evaluate the relative distributions of allowances to mills under differing program rules, not whether the total allowances allocated to pulp and paper mills are adequate in terms of achieving any policy goal. Moreover, the APA program is ambiguous as to the total amount of emissions allocated to eligible sectors, as the number of allowances each sector receives is in part

[19] J. Broder, "E.P.A. Puts Off Regulating Biomass for Now," *New York Times*, January 12, 2011, http://green.blogs.nytimes.com/2011/01/12/e-p-a-puts-off-regulating-biomass-for-now/.

[20] Along with affecting the simulated allowance allocations (see below), a report by the consulting firms McKinsey & Company and Ecofys suggests that industries like the pulp and paper industry may bear higher costs if renewables or climate change policy increase demand for wood chips and wood products for power generation. McKinsey & Company and Ecofys, *EU ETS Review: Report on International Competitiveness*, 2006.

[21] U.S. Energy Information Agency, 2006 *Manufacturing Energy Consumption Survey*.

[22] G. Nelson, "EPA Grants Biomass a Final Reprieve from CO_2 Rules." *Greenwire*, July 5, 2011.

[23] See note 5.

dependent upon the number of mills successful in petitioning for program eligibility. We assume that each sector receives 100% of the allowances needed to cover both direct and indirect emissions of all mills contained therein.

Notes on the dataset used

Our dataset consists of energy, production, and location data for a subset of mills in the pulp and paper sector for the years 2008, 2006, 2004, and 2002. All observations from plants that were not present in 2008—the year of simulated allowance distributions—were dropped. In addition, three observations from years 2006, 2004, and 2002 that appeared to be missing information were dropped.[24] The resulting sample includes 189 plants in year 2008, 164 plants in year 2006, 168 plants in year 2004, and 172 plants in 2002. To get a sense for how our sample compares with the total number of domestic mills in the industry, we compare the sample against the establishment counts found in the U.S. Energy Information Administration's 2006 Manufacturing Energy Consumption Survey (MECS).[25] We can thus estimate that our sample of 189 mills in year 2008 represents around

- 60% of all U.S. pulp mills (NAICS: 322110)
- 25% of all U.S. paper mills (NAICS: 322121)
- 35% of all U.S. newsprint mills (NAICS: 322122)
- 50% of all U.S. paperboard mills (NAICS: 322130)

AF&PA estimates that the total U.S. pulp, paperboard, and market pulp production that is covered by the 2008 AF&PA survey is 81%. This implies that larger mills are more likely to be in our data, vis-à-vis those in MECS. Since the mills in our dataset are not obtained through any random sampling process, but are instead a self-selected group based on membership within the AF&PA, our ability to draw inferences on the entire population of mills within this sector are somewhat limited. In addition, when interpreting our results it's important to keep in mind that the number of mills in each sector varies, ranging from a low of seven mills in the Newsprint mills sector to a high of 95 mills in the paperboard mills sector.

4. ENERGY AND EMISSIONS CHARACTERISTICS OF SECTORS

Figures 1–3 show the average composition of GHG emissions by fuel source and sector. In general, pulp mills are most reliant upon biomass for energy, while mills in the newsprint sector rely most heavily upon purchased electricity and steam. In terms of grouping together mills that are strongly dependent upon a single fuel source, the Pulp mill (non-NAICS) sector in the Integrated/Non-Integrated and Integration/Bleaching schemes is notable, with an average of 90% of total emissions tied to the burning of biomass. Also notable is the near-absence (5%) of emissions tied to biomass for mills in the Non-Integrated Paperboard sector.

Grouping emissions together by four broad fuel source categories (fossil fuels, biomass, purchased electricity, and purchased steam) masks some of the variability in emissions intensity within. Table 2 shows the onsite emissions factors used to convert fossil and biomass fuel energy[26] into CO_2-equivalent tons[27] of emissions. Of note, the emissions intensity of fossil fuels used by mills varies by a factor of nearly two. Also, the emissions intensity of biomass used by mills is homogenous and rather high—higher in fact than that of bituminous coal. Not shown is the variability in the emissions intensity of purchased electricity, which also varies by a factor of around two within most sectors of our sample.

[24] Based on personal communication with NCASI staff.
[25] U.S. Energy Information Agency, 2006 *Manufacturing Energy Consumption Survey*, Table 1.4 Number of Establishments Using Energy consumed for All Purpose. Available at: http://www.eia.doe.gov/emeu/mecs/mecs2006/2006tables.html
[26] If biomass were not treated as carbon-neutral.
[27] The term *ton* in this report refers to the metric ton. One metric ton (or *tonne*) = 1 megagram (Mg) = 1,000 kg = 2,204.62 lbs.

For insight into what is driving the allocation of allowances, Figure 4 shows the distribution of total (on- and offsite) emissions intensity within sectors, with values normalized to the sector mean to facilitate cross-sectoral comparisons. Using sector mean-normalized values, a mill with an emissions intensity equivalent to the sector average would have a value of "1." Distribution of emissions intensities is indicated by a histogram (tan bar) overlaid by kernel density estimation (red line). The kernel density estimation can be thought of as a smoothed out histogram that is not as susceptible to the number of bins chosen to draw a histogram. Note that the height of the histogram and kernel density estimation can be misleading, as the number of mills in each sector is not constant. Table 3 reports summary statistics for the distribution of total emissions intensity by sectors.

Looking at the distribution of total emissions intensities across sectors, we see that overall, most distributions are skewed to the right, meaning they are characterized by having a larger number of mills with below-average emissions intensities. In addition, this implies that the GHG compliance burden will tend to fall upon a relatively smaller number of mills in these sectors with a right-skewed distribution. Excluding biomass emissions can yield some surprising findings. For example, the mean emissions intensity for Integrated Paper mills is lower than that of Non-Integrated paper mills. This is due to integrated mills having access to biomass in the form of pulping residues. When biomass emissions are included, this paradox goes away. It's also notable that variation about the mean is markedly reduced in most sectors when biomass emissions are included. This is largely due to fact that the emissions intensity for biomass is constant for mills in our sample, whereas the emissions intensities of fossil fuels and purchased electricity and steam are variable (see Table 2). Finally, the sector mean normalized standard deviation, which correlates well with overall variability in allowance distribution, is highest for the two pulp sectors and lowest in the Newsprint mills sector when biomass emissions are excluded. The distributions bear this out (see Section 5).

Figure 1. Average composition of facilities' GHG emissions within the four NAICS sectors in 2008.

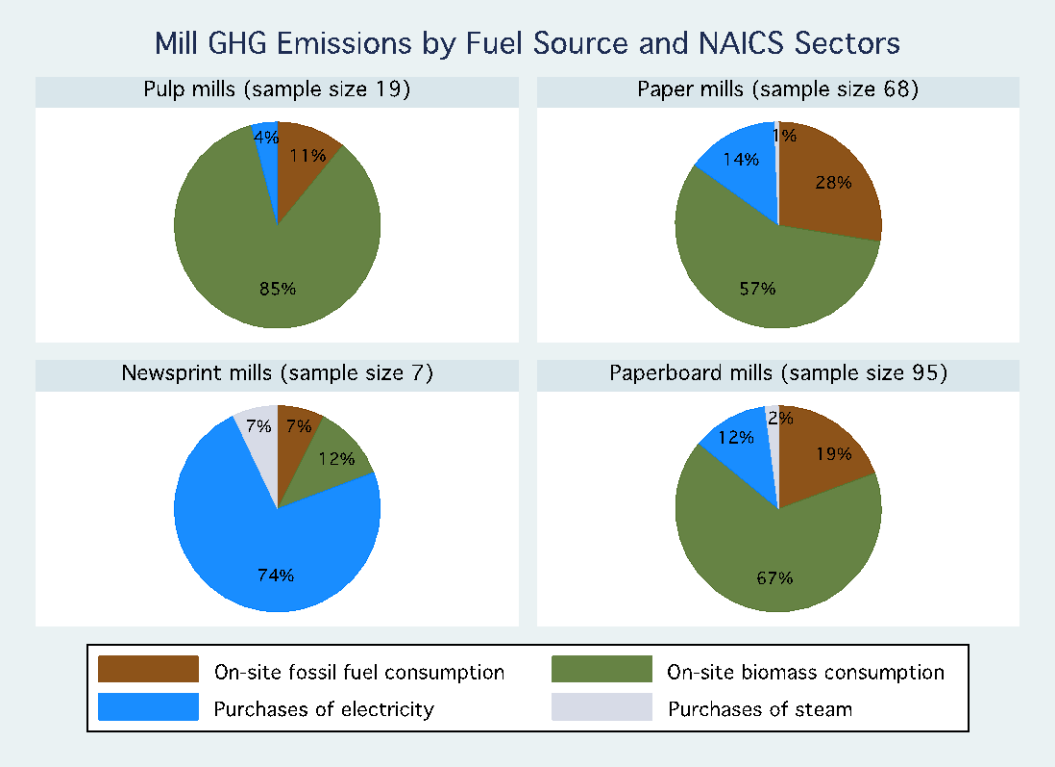

Figure 2. Average composition of facilities' GHG emissions in 2008 using the Integrated/Non-Integrated sectoral grouping scheme.

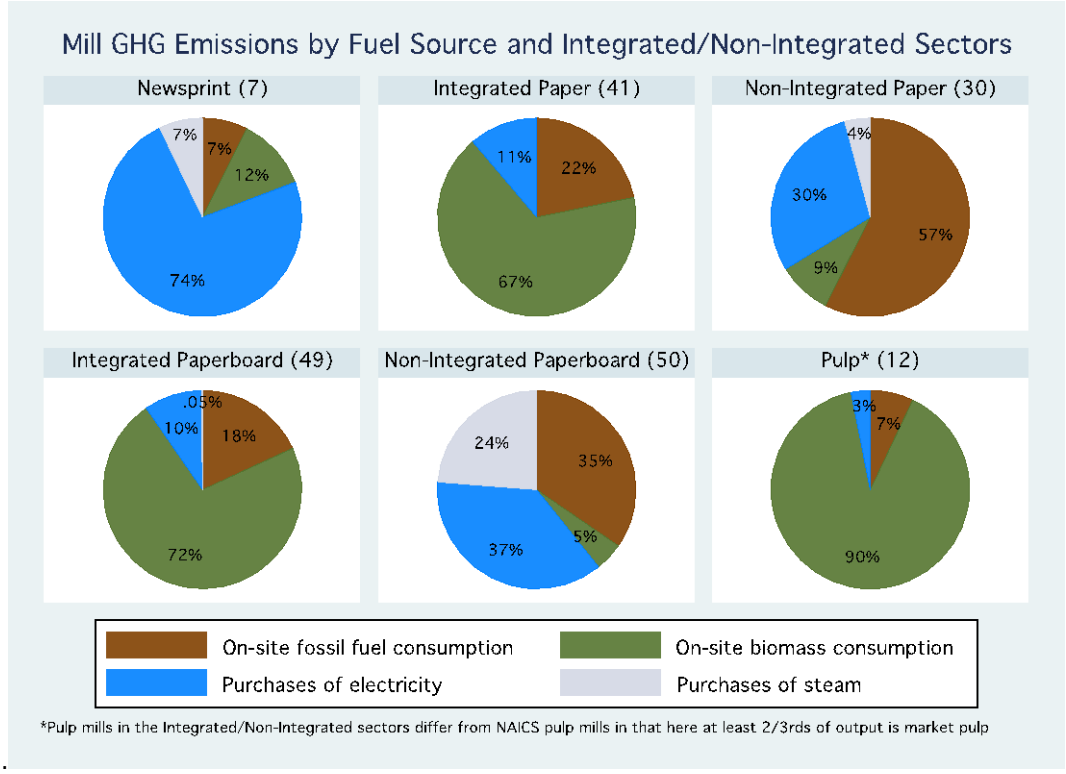

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Figure 3. Average composition of facilities' GHG emissions in 2008 using the Integration/Bleaching sectoral grouping scheme. Note that four of the sectors in this scheme—the Pulp (non-NAICS), Newsprint, Integrated Bleached Paper, and Non-Integrated Paperboard sectors—are not shown, as they are identical to the same-named sectors in the Integrated/Non-Integrated scheme.

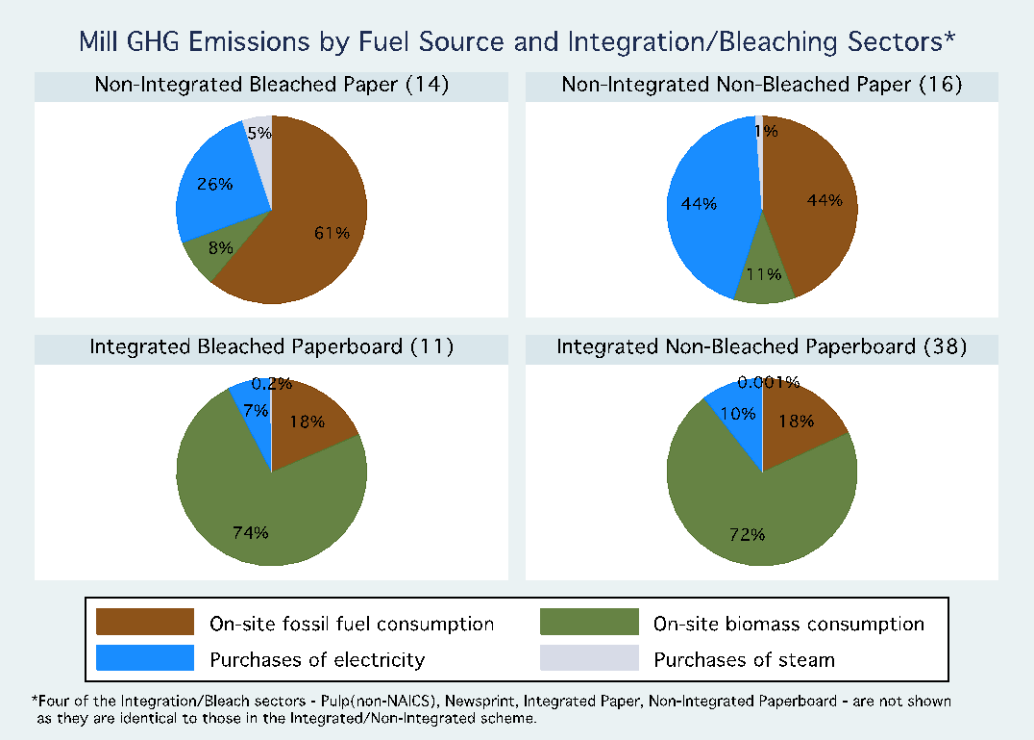


Table 2. Emissions factors for fossil fuels and biomass used onsite by mills in our sample. Emissions intensity varies by a factor of nearly two for fossil fuels.

Onsite fuel	CO_2e* content coefficient (kg CO_2e/billions of BTUs)
Petroleum coke	102,659
Biomass (average for wood, paper, and spent liquor)	96,116
Bituminous coal	94,127
Rubber tire chips	87,944
Purchased steam**	86,845
Kerosene	75,449
Residual fuel oil (No. 5 & 6)	74,259
Distillate fuel oil No. 2	74,209
Diesel	74,089
Gasoline	70,469
Liquid propane gas (LPG)	63,229
Natural gas	53,072

Source: U.S. Environmental Protection Agency, Mandatory Reporting of Greenhouse Gases, Final Rule, October 30, 2009 (40 CFR Part 98). http://www.epa.gov/climatechange/emissions/ghgrulemaking.html.

* Carbon dioxide equivalent.

** From U.S. Energy Information Agency Form EIA-1605, Voluntary Reporting of GHGs, p. 157. Value includes 10% loss during transmission.

Note that we assume "Other fuel" and "Other fuel 1" (not shown but reported by facilities) to be diesel fuel, based on guidance from NCASI staff.

Figure 4. Total (on- and offsite) emissions intensity (total CO_2e emissions divided by total output in tons) for mills in our sample in 2008 excluding emissions from biomass, as grouped into the three different sector classification schemes: NAICS sectors, Integrated/Non-Integrated NAICS sectors, and Integration/Bleaching sectors. Levels are normalized to sector means. A facility with an average total emissions intensity would have a normalized total emissions intensity (plotted on the *x* axis) of 1.

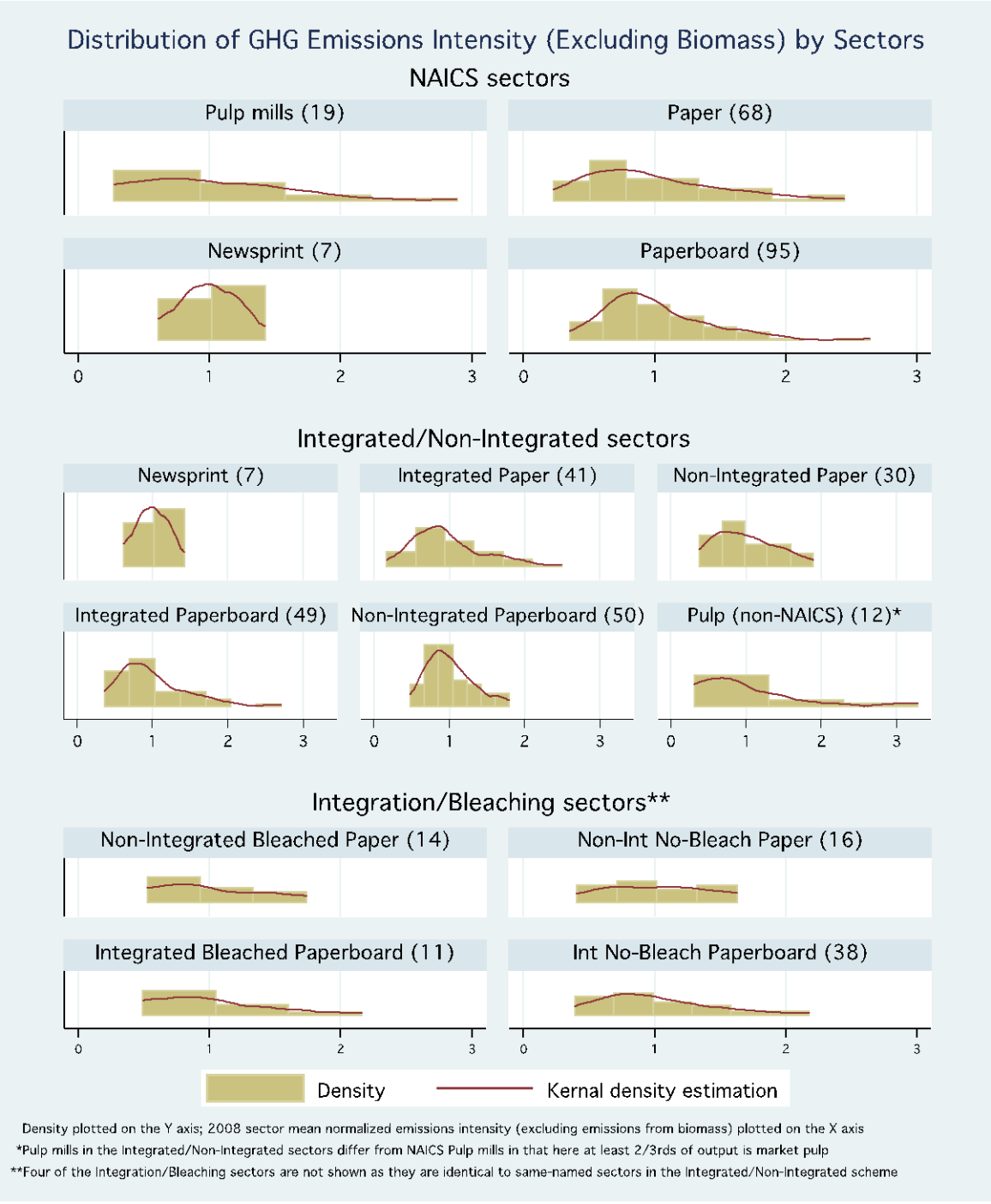


Table 3. Summary statistics for total (on- and offsite) emissions intensity for all sectors considered. Most distributions have positive skewness, meaning that most mills have a total emissions intensity that is lower than the sector average, and the distributions have a long right tail. Biomass emissions are shown for clarity; however, all distributions are run assuming emissions from biomass are carbon-neutral (see Section 3).**

	Excluding biomass emissions				Including biomass emissions			
Sector	Mean emissions intensity (tons CO_2e/ tons of product)	Sector mean normalized median emissions intensity	Sector mean normalized standard deviation	Skew	Mean emissions intensity (tons CO_2e/ tons of product)	Sector mean normalized median emissions intensity	Sector mean normalized standard deviation	Skew
Pulp mills	0.48	0.83	0.68	1.11	2.95	1.02	0.27	-0.30
Paper mills	1.32	0.84	0.52	0.89	2.41	1.01	0.33	0.07
Newsprint mills	1.46	1.05	0.26	0.11	1.63	1.00	0.26	-0.60
Paperboard mills	0.66	0.89	0.40	1.19	1.45	0.79	0.66	0.82
Pulp (non-NAICS)*	0.42	0.77	0.86	1.70	3.19	0.97	0.25	-0.43
INT Paper	0.98	0.93	0.51	0.94	2.84	0.95	0.21	0.80
Non-Int Paper	1.71	0.87	0.42	0.49	1.88	0.91	0.38	0.32
INT Paperboard	0.64	0.87	0.47	1.36	2.29	1.01	0.32	0.36
Non-Int Paperboard	0.67	0.95	0.31	0.69	0.70	0.93	0.32	0.76
Non-Int Bleached Paper	1.86	0.86	0.43	0.57	2.11	0.94	0.37	0.23
Non-Int Non-Bleached Paper	1.58	0.94	0.40	0.04	1.68	0.98	0.36	-0.14
INT Bleached Paperboard	0.80	0.73	0.50	1.20	3.26	1.01	0.12	0.17
INT Non-Bleached Paperboard	0.59	0.94	0.43	0.93	2.01	1.05	0.27	0.36

INT = Integrated mill (produces pulp and paper products onsite); Non-Int = Non-Integrated mill (produces only paper products onsite using purchased pulp).

* Pulp (non-NAICS) sector, found in both the Integrated/Non-Integrated and Integration/Bleached sectoral schemes, differs from the NAICS Pulp Mill sector in that at least two-thirds of mill output is market pulp.

** *Skew* (also called *skewness*) is a measure of the asymmetry of the distribution. A negative skew indicates that the tail on the left side of the distribution is longer than the right side and the bulk of the values lie to the right of the mean. The reverse is true for positively skewed distributions. A zero value indicates that the values are relatively evenly distributed on both sides of the mean.

5. STUDY RESULTS

Distribution using NAICS sectors

Figure 5 shows the simulated distribution of allowances to mills in our sample using the four NAICS sectors to calculate emissions and energy intensity benchmarks, and expressed as the percentage of mills' emissions covered by allocated permits. Table 4 reports summary statistics as percentages, and Tables 5 and 6 show the monetized value of the distribution and net compliance burden (total emissions minus allocated permits) for mills in the lower, inner, and upper quartiles[28] of each sector's distribution. Distributions of allowances within the Pulp mill and Paper mill sectors exhibit the highest degree of variability, with some upper-quartile mills receiving four times the amount of coverage of emissions as lower-quartile mills. In contrast, allowance distribution to the Newsprint mills sector has a narrow range of variability, with an inner-quartile range of only 35% coverage. Distribution to mills in the paperboard mills sector is somewhere between the two extremes, but there are still a fair number of outliers (shown as dots). Lastly we note that the median value for the percentage of mills' emissions covered by the

[28] Quartiles refer the percentage of mill's emissions covered within each sector. For example, lower-quartile mills are mills whose percentage of emissions coverage is equal to or lower than the 25th percentile of emissions coverage among mills in the same sector.

distribution is greater than 100% in all but the Paper mill sector. This is reflective of the fact that most sectors are characterized by having a greater numbers of mills with lower-than-average emissions intensities, and a smaller number of larger mills (in terms of output) with higher-than-average emissions intensities.

Monetizing the results using a $20 per ton carbon price—an estimate in line with EPA modeling of the American Power Act[29]—reveals that the highest-value allocations, in terms of the amount of allocated permits per ton of product produced, occur in the Paper and Newsprint sectors, which are the two most emissions-intensive NAICS sectors (excluding emissions from biomass). For inner-quartile mills in the Paper and Newsprint sectors, the median value of allocated permits is $23.09 per ton and $32.36 per ton respectively. Perhaps most striking is the very large difference between the median net GHG compliance burden of lower- and upper-quartile mills in the Paper sector—a difference of nearly $32 dollars per ton of product. It's also interesting to note that lower-quartile mills actually receive more permits per ton of product in all but the Pulp sector. This seeming paradox is explained by the fact that the number of permits per ton of output given to mills within the same sector varies only with the intensity of individual mill's purchased electricity, and therefore these lower-quartile mills are located in a region with a relatively higher purchased electricity emissions intensity (eGRID rate).[30]

To put these results into economic context for the industry we consider the average size of the net compliance burden relative to the average value of shipments of a mill (see Table 6), and make similar comparisons to the average price of a ton of paper. The average value of shipments of a mill ranges from $130 to almost $200 million per year, while the absolute size of the net compliance burden ranges from +$1.7 to -$4.8 million, that is, anywhere from ±1 to 4%.[31] We can also compare this to the average price of a ton of paper. If we take the statistic cited by the AF&PA of 83.8 million tons of paper produced in 2007 and divide by the total value of shipments for the Paper, Newsprint, and Paperboard sectors,[32] we get $896 per ton. Compared to the range of the net compliance burden per ton for upper- and lower-quartile mills, this is a range of -0.5% to +2.5%. These comparisons are relative to *revenue, not profits*. Our data do not allow us to compute profits, but if we compare the ±1–4% to a typical pulp and paper profit margin (EBITDA/Sales) of 12%[33] we can see that these changes in net compliance burden can have large impacts on the affected firms.

As a means of comparing this distribution to the two that follow, we provide the mill-weighted average of the difference in median net GHG compliance burden, on a per-ton basis, for upper- and lower-quartile mills.

[29] U.S. Environmental Protection Agency, *EPA Analysis of the American Power Act in the 111th Congress.* June 14, 2010. Available at: http://www.epa.gov/climatechange/economics/economicanalyses.html. EPA's analysis predicted an allowance price of $16–$17/ton in 2013 and $23–$24/ton in 2020 in their core scenario.
[30] The other factors used to calculate the number of allowances given per ton are two intensity benchmarks that are shared by all mills within the same sector (see the Appendix for calculation of Direct and Indirect Carbon Factors).
[31] These are upper- and lower-quartile medians, so some individual mills can be even higher.
[32] Assuming that the entire value of the pulp industry is an input to paper making to avoid double-counting.
[33] 2007 data taken from http://www.tappi.org/content/events/07epe/papers/07EPE00.pdf, page 13, for example purposes only.

Figure 5. Distribution of emissions allowances shown as percentage of coverage of facilities' 2008 emissions (their compliance burden for the year of permit distribution) under the American Power Act EAR program using the four NAICS sectors. Distribution is shown under rules treating emissions from biomass as carbon-neutral. Outliers, shown as dots, are values that are 1.5 times the interquartile range above the third quartile (75th percentile) or below the first quartile (25th percentile). The dotted green line shows where emissions are perfectly covered (100%).

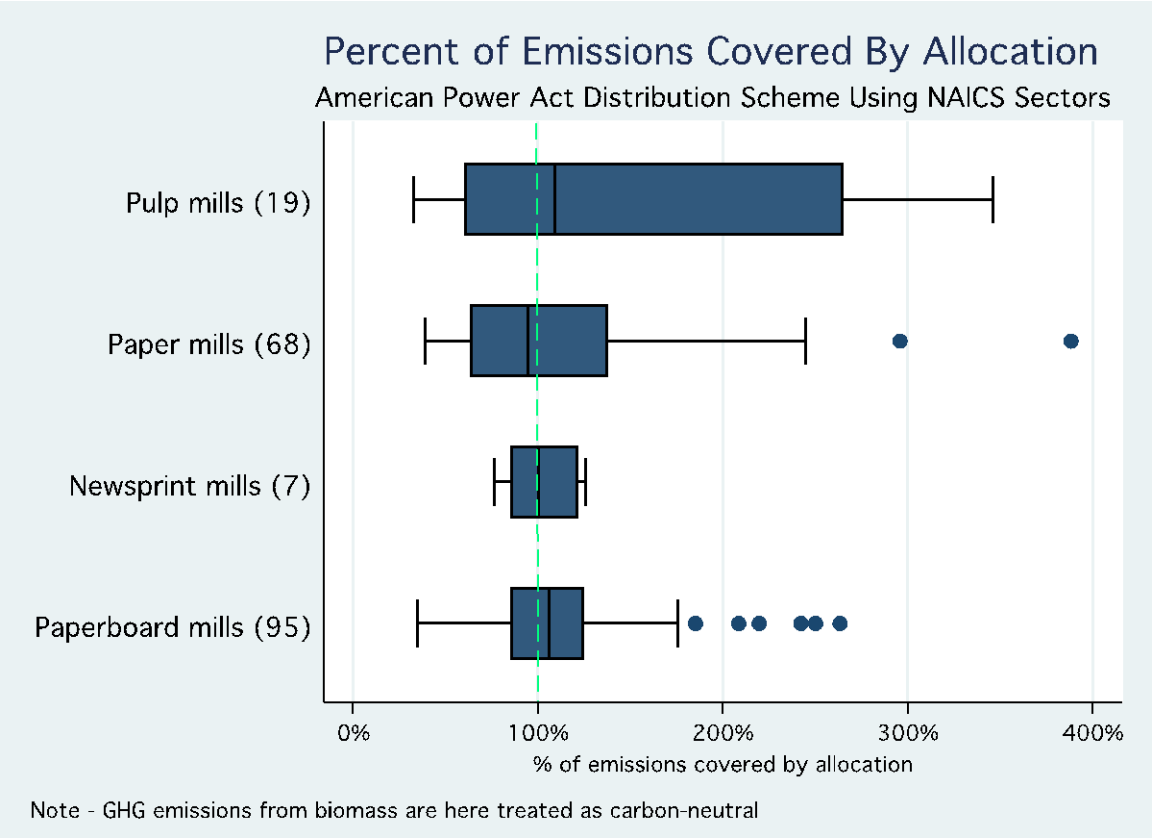


Table 4. Summary statistics by sector and weighted average for percentage of emissions covered under distribution of emissions permits based on the APA NAICS distribution scheme.

Sector	Mean	Median	Standard deviation	Interquartile range	Skew
Pulp mills	147%	110%	102%	203%	0.68
Paper mills	111%	95%	64%	73%	1.80
Newsprint mills	101%	100%	18%	35%	0.12
Paperboard mills	111%	106%	43%	39%	1.34
Mill-weighted average	**114%**	**105%**	**59%**	**54%**	**1.76**

Table 5. Monetized values of allocated allowances and net GHG compliance burden assuming a $20/ton carbon price for mills whose percentage of emissions coverage from received permits places them in the lower, inner, and upper quartiles of mills in the sector, under the APA NAICS distribution scheme.

Sector	Median 2008 emissions (tons CO_2e)	Median value of allocation at $20/ton carbon price			Median net GHG compliance burden** with allocation		
		Lower-quartile mills*	Inner-quartile mills	Upper-quartile mills	Lower-quartile mills	Inner-quartile mills	Upper-quartile mills
Pulp	187,527	$4,266,261	$4,699,375	$4,993,709	$3,351,111	($314,033)	($3,425,776)
Paper	359,672	$5,657,935	$8,241,625	$12,136,315	$3,666,291	$40,917	($4,872,356)
Newsprint	356,920	$7,048,428	$8,907,640	$4,785,196	$1,695,661	($277,625)	($984,506)
Paperboard	229,808	$4,843,186	$2,406,690	$6,706,938	$2,873,550	($78,692)	($2,122,741)

*Quartiles refer to percentage of mill emissions covered by allocation (Figure 5), not the absolute size of the allocation. The median value of allocation for lower-quartile mills is therefore the median value of allocated permits among mills whose percentage of emissions covered places them in the lower quartile of the distribution.

**Net GHG compliance burden is a mill's total emissions (excluding emissions from biomass) minus that mill's allocation of permits (each permit covers one ton of CO_2e emissions) times the value of permits ($20 per permit).

Table 6. Value of allocated allowances and net GHG compliance burden expressed as per ton of product, assuming a $20-per-ton carbon price, for mills whose percentage of emissions coverage from received permits places them in the lower, inner, and upper quartiles of mills in the sector, under the APA NAICS distribution scheme.

Sector	Median value of allocation per ton of product at $20/ton carbon price			Median net GHG compliance burden per ton of product with allocation and $20/ton carbon price			
	Lower-quartile mills	Inner-quartile mills	Upper-quartile mills	Lower-quartile mills	Inner-quartile mills	Upper-quartile mills	Difference between upper- and lower-quartile mills
Pulp	$8.73	$9.02	$9.04	$8.02	($0.89)	($6.15)	$14.17
Paper	$23.86	$23.09	$21.54	$22.40	$1.19	($9.47)	$31.87
Newsprint	$28.01	$32.36	$22.57	$6.77	($0.68)	($4.64)	$11.41
Paperboard	$13.48	$13.40	$13.40	$6.81	($0.66)	($4.29)	$11.10
Mill-weighted average							**$18.89**

Table 7. Average value added and average value of shipments for mills in the four NAICS Pulp and Paper sectors.[34]

Sector	2007 mill average value added (in millions)	2007 mill average value of shipments (in millions)
Pulp	$58.3	$128.9
Paper	$102.3	$192.1
Newsprint	$70.3	$163.8
Paperboard	$66.2	$135.6

Source: U.S. Energy Information Agency, *2006 Manufacturing Energy Consumption Survey*.

To see what characterizes mills in the upper and lower tails of the distributions we examine three key components of mills' emissions intensity for all three modeled distributions: percentage of onsite biomass in total energy consumed, the emissions intensity and composition of onsite fossil fuels, and the emissions intensity of purchased electricity.

Because biomass is essentially a free fuel in terms of emissions under rules treating biomass emissions as carbon-neutral, we can expect to see the relative amounts of biomass consumed among mills play a dominant role in driving the allocation of permits. Figure 6 bears this out, with upper-quartile mills much more reliant upon biomass than lower-quartile mills for all sectors except the Newsprint sector, which as a whole uses relatively little biomass for energy (see Figure 1).

The emissions intensity of onsite fossil fuels (Figure 7) appears well correlated with the relative number of permits required for all sectors except the Newsprint sector, which as a whole uses relatively little onsite fossil fuel in its total energy consumption. Also striking is the difference in degree to which lower- and upper-quartile mills in the paper and paperboard sectors incorporate coal and petcoke in their fossil fuel mix—a level that varies by a factor of nearly four for both sectors.

As noted earlier, the emissions intensity of purchased electricity varies by a factor of around two within all sectors of our sample. This driver of mill emissions intensity appears correlated with the relative number of permits received for all sectors except the Pulp mills sector. This is likely due to the empirical fact that increases in mill emissions linked to changes in the emissions intensity of purchased electricity are not fully covered by the allocation formula. The largest difference in emissions intensity for upper- and lower-quartile mills is found among Newsprint mills, which are reliant upon purchased electricity for the large majority of their energy needs.

[34] Note that these are industry-wide values taken from the U.S. Census, not from our sample, which does not have data on the dollar value of production. The Census data includes all mills, in particular the small ones, while our data is more likely to include mostly the larger mills. The mills in our sample, or a "typical size" mill as represented by a median value that we cannot compute from Census data, would likely have higher value of shipments.

Figure 6. Average percentage of biomass energy in total onsite energy consumed for mills whose percentage of emissions coverage from received allowances places them in the upper (green) and lower (brown) quartiles of mills in the sector, under the APA NAICS distribution. A strong correlation is shown for all sectors except the Newsprint sector, which on average consumes little biomass relative to other fuels.

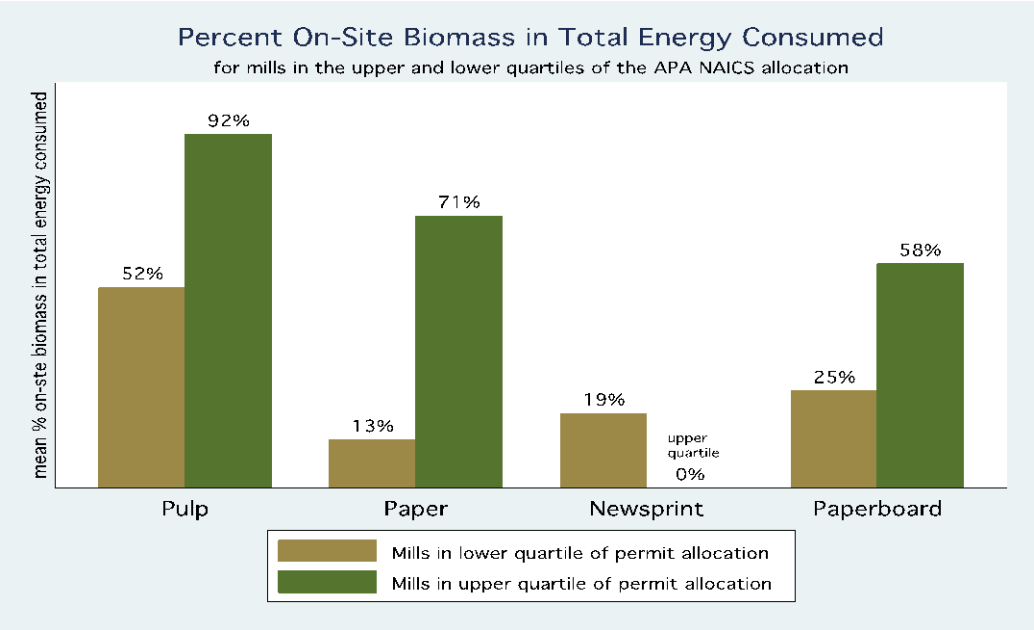


Figure 7. Mean emissions intensity (tons CO_2e/BBTU consumed) and composition of onsite fossil fuel mix for mills whose percentage emissions coverage from received allowances places them in the upper and lower quartiles of mills in the sector, under the APA NAICS distribution. A large difference in the percentage of coal and petcoke in the on-site fossil fuel mix between upper and lower quartile mills is seen in the Paper and Paperboard sectors.

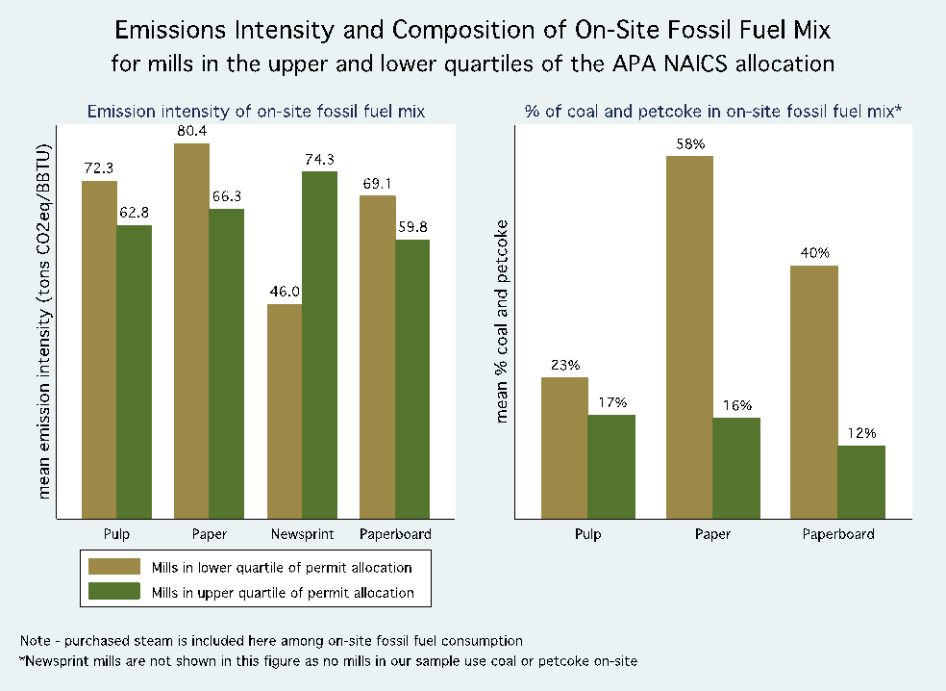
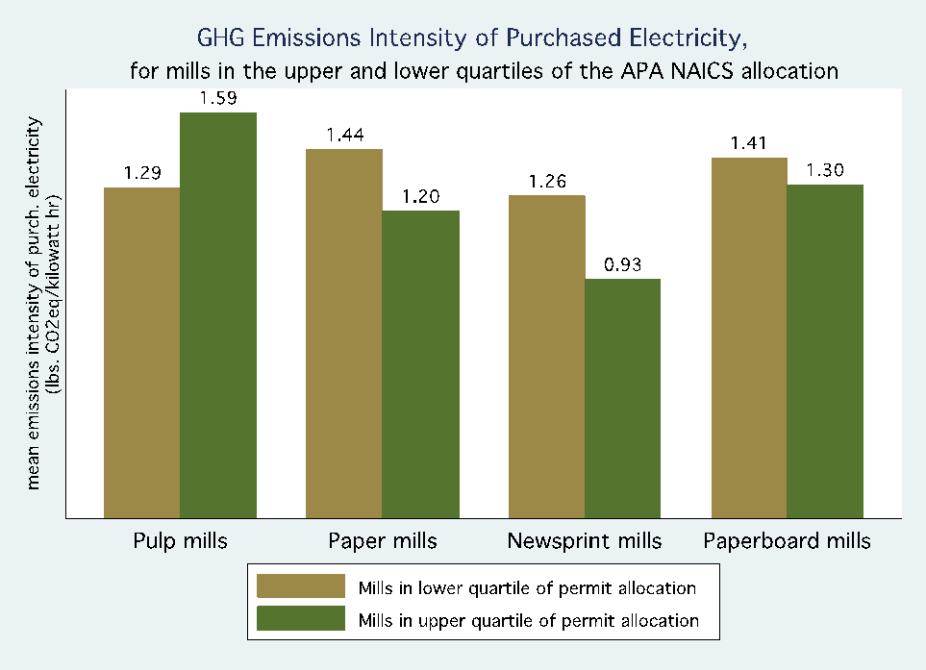


Figure 8. Average emissions intensity of purchased electricity for mills whose percentage emissions coverage from received allowances places them in the upper and lower quartiles of mills in the sector, under the APA distribution scheme using NAICS sectors. Intensity of purchased electricity appears correlated with the relative number of permits received for all sectors except the Pulp mills sector.



The last element we explore under this distribution is the relative benefits received by Integrated and Non-Integrated mills (Figure 9), and mills with and without an onsite bleaching process (Figure 10). Non-integrated paper mills fare substantially worse than integrated ones, with a difference in median net GHG compliance burden of nearly $13 per ton. The reverse is true to a lesser degree for pulp mills.[35] Not much of an effect from integration is seen, however, in the Paperboard mills sector.

Looking at the treatment of mills incorporating an onsite bleaching process, a relatively modest effect can be seen in the Paperboard sector, with a difference in the median net GHG compliance burden between mills with and without onsite bleaching of $1.18 per ton. A much larger difference is seen among paper mills, but the effect is in the opposite direction as expected, assuming all other factors are equal. In this case, closer inspection reveals that paper mills in our sample with onsite bleaching are much more reliant upon biomass for energy than those without onsite bleaching (49% vs. 10% mean onsite biomass in total energy consumed), which is likely masking any effect from onsite bleaching.

[35] We define an integrated pulp mill as one in which less than two-thirds of its output is market pulp.

Figure 9. Do integrated mills (red) fare worse than non-integrated mills (blue) under an allocation using NAICS sectors to calculate emissions and energy intensity benchmarks? Non-Integrated paper mills fare substantially worse than Integrated mills. The reverse is true for Pulp mills.* Not much effect from integration is seen in the Paperboard mills sector.

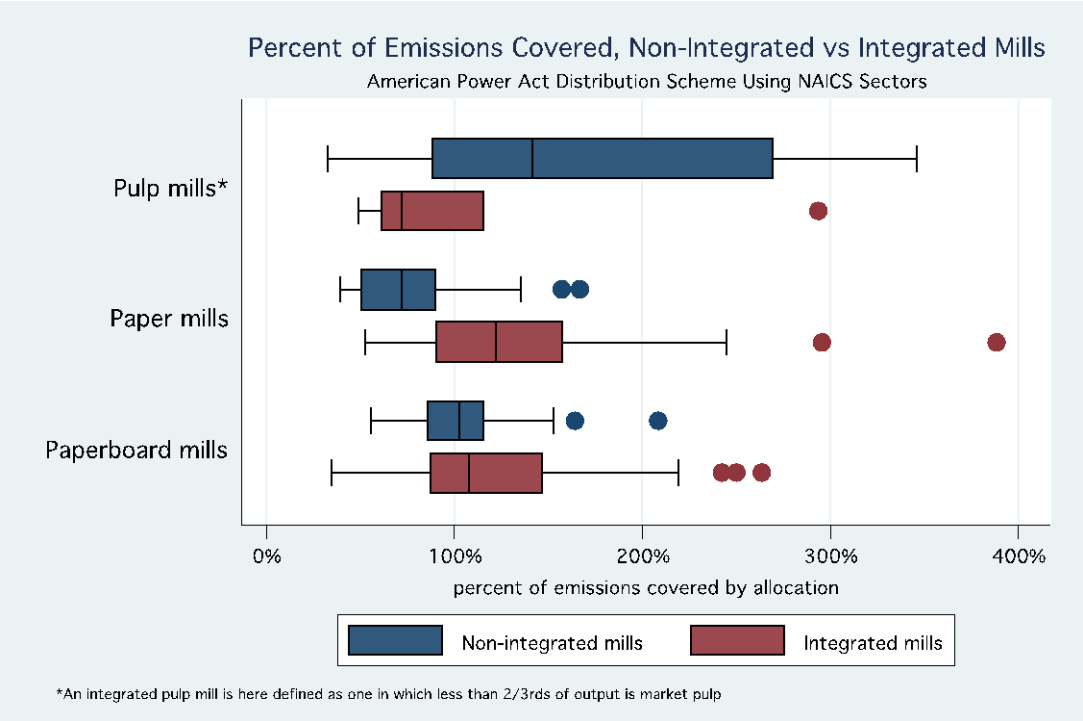


Table 8. Summary statistics comparing allocation to vs. Integrated Pulp, Paper, and Paperboard mills under APA NAICS distribution scheme. The largest variation in mean percentage of coverage is found between Integrated and Non-Integrated Paper mills.

Sector	Non-Integrated mills			Integrated mills		
	Mean percentage of emissions covered	Median percentage of emissions covered	Median net GHG compliance burden* per ton with $20/ton carbon price	Mean percentage of emissions covered	Median percentage of emissions covered	Median net GHG compliance burden per ton with $20/ton carbon price
Pulp	171%	141%	($2.37)	104%	72%	$3.32
Paper	80%	72%	$8.61	136%	122%	($4.36)
Paperboard	103%	103%	($0.35)	120%	108%	($0.98)

*Net GHG compliance burden is a mill's total emissions (excluding emissions from biomass) minus that mill's allocation of permits (each permit covers one ton of CO_2e emissions) times the value of permits ($20 per permit).

Figure 10. Do mills with an onsite bleaching process (red) fare worse than mills without (blue) under an allocation using NAICS sectors to calculate emissions and energy intensity benchmarks? While true for the Paperboard mills sector, the opposite effect is seen in the Paper mills sector—an outcome we attribute to a higher of percentage of biomass energy consumed among paper mills with on-site bleaching than those without in our sample.

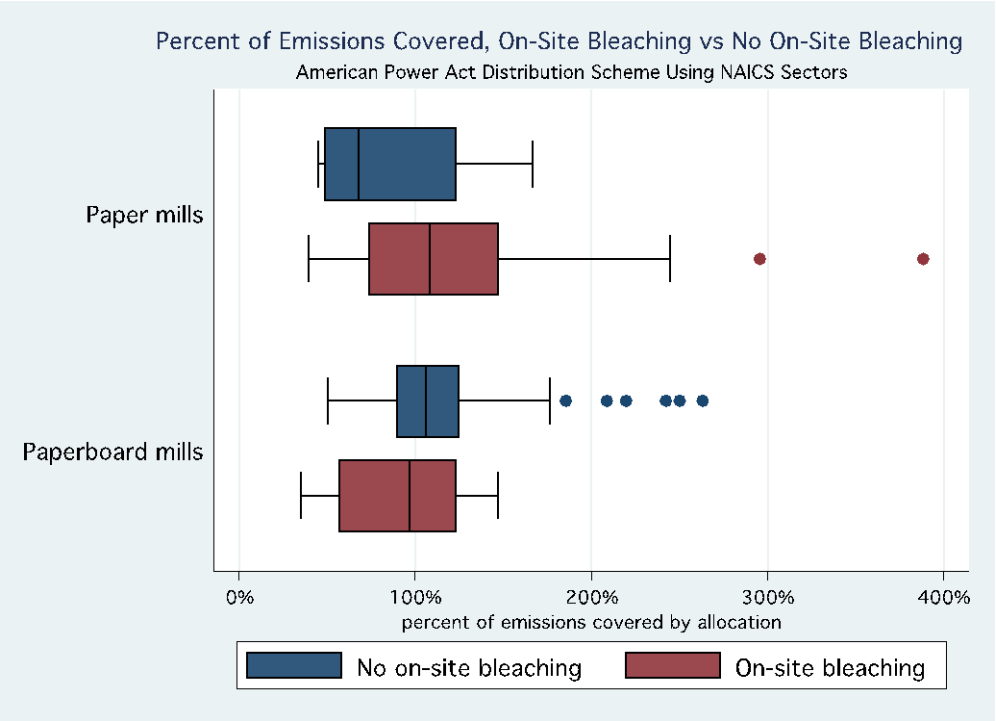


Table 9. Summary statistics comparing allocation to Pulp, Paper, and Paperboard mills with and without onsite bleaching under APA NAICS distribution scheme. Paperboard mills incorporating an on-site bleaching process appear to fare slightly worse than those that do not. An opposite effect is seen in the Paper mills sector but is attributable to differences outside factors (see text).

	No onsite bleaching			Onsite bleaching		
Sector	Mean percentage of emissions covered	Median percentage of emissions covered	Median net GHG compliance burden* per ton with $20/ton carbon price	Mean percentage of emissions covered	Median percentage of emissions covered	Median net GHG compliance burden per ton with $20/ton carbon price
Paper	85%	68%	$9.03	119%	109%	($1.65)
Paperboard	113%	106%	($0.57)	93%	97%	$0.61

*Net GHG compliance burden is a mill's total emissions (excluding emissions from biomass) minus that mill's allocation of permits (each permit covers one ton of CO_2e emissions) times the value of permits ($20 per permit).

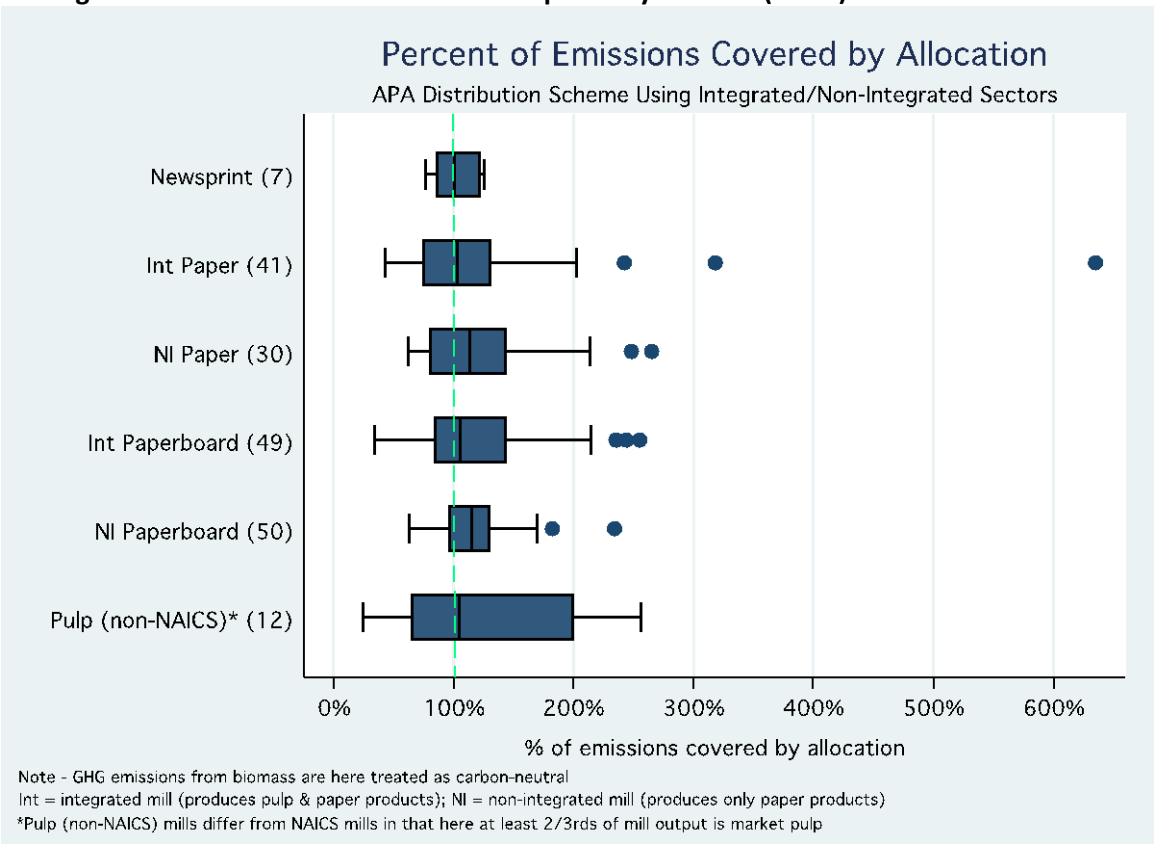
Distribution using Integrated/Non-Integrated sectors

Figure 11 shows the simulated distribution of allowances to mills using the six Integrated/Non-Integrated sectors to calculate emissions and energy intensity benchmarks. Table 10 reports summary statistics and Tables 11 and 12 show monetized values. Along with controlling for any bias attributable to the presence or absence of vertical integration, this scheme is successful at reducing some of the extreme variability that characterizes the NAICS pulp mill sector, where the inner-quartile range of emissions coverage drops

from 203% in the NAICS scheme to 134% using the non-NAICS Pulp sector. The same is true to a lesser degree for the two new paper sectors (Integrated and Non-Integrated) and the Non-Integrated Paperboard sector, all of which exhibit a narrower range of emissions coverage among inner-quartile mills compared with the larger Paper and Paperboard NAICS sectors. Perhaps the clearest indication that this sectoral scheme has reduced the disparity in emission coverage between upper- and lower-quartile mills from that of the NAICS distribution is given in the mill-weighted average for the median net GHG compliance burden per ton of product. The mill-weighted average of the difference in median net GHG compliance between upper- and lower-quartile mills falls from $18.89 to $16.82 per ton of product.

Note that the Newsprint mills sector is unchanged from the NAICS sectoral scheme. The median value for the percentage of mills' emissions covered by this distribution is greater than 100% for nearly all of the sectors. Again, this indicates that most sectors are characterized by having a greater numbers of mills with lower-than-average emissions intensities, and a smaller number of larger mills (in terms of output) with higher-than-average emissions intensities.

Figure 11. Distribution of emissions allowances shown as percentage of coverage of facilities' 2008 emissions (their compliance burden for the year of permit distribution) under the APA EAR program using Integrated/Non-Integrated sectors. Distribution is shown under rules treating biomass emissions as carbon-neutral. Outliers, shown as dots, are values that are 1.5 times the interquartile range above the third quartile (75th percentile) or below the first quartile (25th percentile). The dotted green line shows where emissions are perfectly covered (100%).



Note: Integrated paper mills that produce pulp via mechanical means (six in all) were grouped with Non-Integrated Paper mills based on analysis of their energy intensity profiles.

Table 10. Summary statistics by sector and weighted average for percentage of emissions covered under distribution of allowances based on the APA Integrated/Non-Integrated scheme.

Sector	Mean	Median	Standard deviation	Interquartile range	Skew
Newsprint	101%	100%	18%	35%	0.12
INT Paper	126%	103%	99%	55%	3.64
Non-Int Paper	126%	113%	57%	63%	0.92
INT Paperboard	116%	105%	50%	59%	0.96
Non-Int Paperboard	115%	115%	32%	33%	1.01
Pulp (non-NAICS)*	127%	105%	78%	134%	0.26
Weighted average	**120%**	**110%**	**62%**	**51%**	**3.51**

INT = Integrated mill (produces pulp and paper products onsite); Non-Int = Non-Integrated mill (produces only paper products onsite using purchased pulp).

* Pulp (non-NAICS) sector, found in both the Integrated/Non-Integrated and Integration/Bleached sectoral schemes, differs from the NAICS pulp mills sector in that at least two-thirds of mill output is market pulp.

Table 11. Monetized values of allocated allowances and net GHG compliance burden assuming a $20/ton carbon price, for mills in the lower, inner, and upper quartiles of the APA Integrated/Non-Integrated distribution scheme.

Sector	Median emissions (tons CO_2e)	Median value of allocation at $20/ton carbon price			Median net GHG compliance burden** with allocation		
		Lower-quartile mills*	Inner-quartile mills	Upper-quartile mills	Lower-quartile mills	Inner-quartile mills	Upper-quartile mills
Newsprint	356,920	$7,048,428	$8,907,640	$4,785,196	$1,695,661	($277,625)	($984,506)
Int Paper	434,204	$9,196,599	$9,787,409	$12,825,292	$5,287,444	($393,585)	($4,937,315)
Non-Int Paper	161,733	$1,976,054	$4,700,190	$5,820,391	$709,485	($68,858)	($2,716,369)
INT Paperboard	371,382	$8,913,772	$7,829,035	$10,232,423	$4,120,021	($514,213)	($4,656,395)
Non-Int Paperboard	70,977	$2,677,431	$1,363,129	$1,645,006	$642,747	($130,553)	($494,546)
Pulp (non-NAICS)	146,890	$2,086,359	$3,948,410	3,599,534	$1,671,838	($358,805)	($2,065,552)

* Quartiles refer to percentage of mill emissions covered by allocation (Figure 5), not the absolute size of the allocation. The median value of allocation for lower-quartile mills is therefore the median value of allocated permits among mills whose percentage of emissions covered places them in the lower quartile of the distribution.

** Net GHG compliance burden is a mill's total emissions (excluding emissions from biomass) minus that mill's allocation of permits (each permit covers one ton of CO_2e emissions) times the value of permits ($20 per permit).

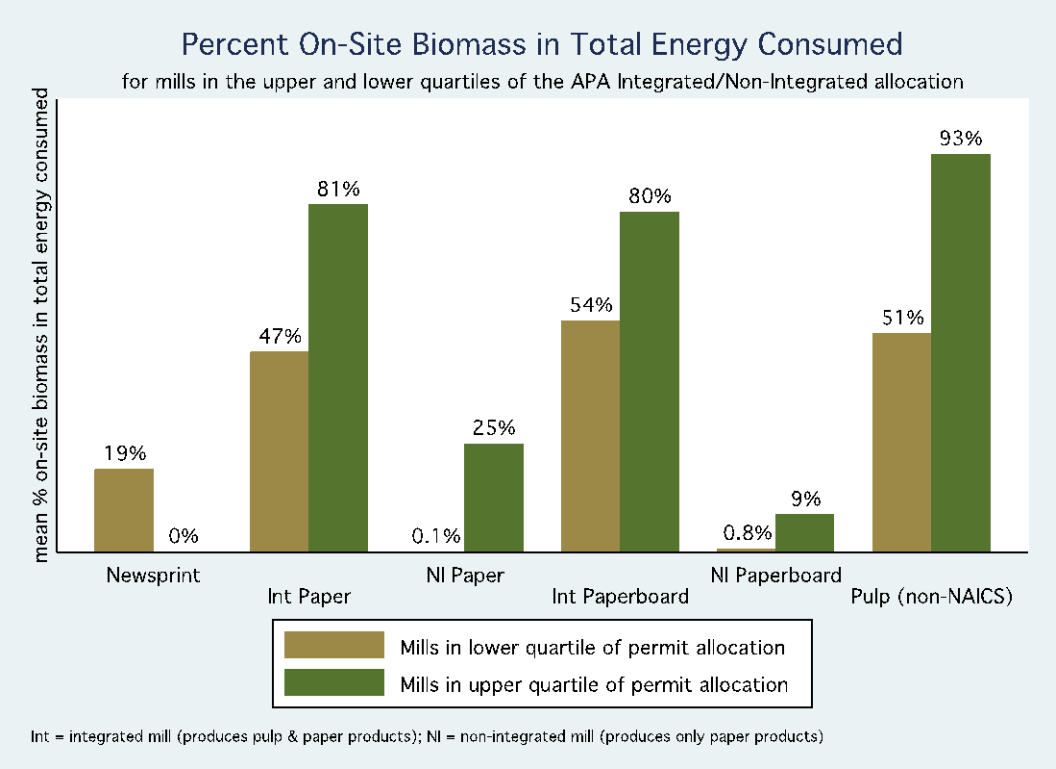
Table 12. Monetized values of allocated allowances per ton of product and net GHG compliance burden per ton of product, assuming a $20 per ton carbon price, for mills in the lower, inner, and upper quartiles of the APA NAICS distribution scheme.

Sector	Median value of allocation per ton of product at $20/ton carbon price			Median net GHG compliance burden per ton of product with allocation & $20/ton carbon price			
	Lower-quartile mills	Inner-quartile mills	Upper-quartile mills	Lower-quartile mills	Inner-quartile mills	Upper-quartile mills	Difference btw upper- and lower-quartile mills
Newsprint	$28.01	$32.36	$22.57	$6.77	($0.68)	($4.64)	$11.41
Int paper	$19.41	$17.76	$17.76	$12.52	($0.94)	($8.21)	$20.73
Non-Int paper	$37.43	$37.89	$37.89	$13.57	($4.18)	($19.12)	$32.69
INT paperboard	$13.00	$12.39	$13.00	$7.21	($0.67)	($5.30)	$12.51
Non-Int paperboard	$15.22	$15.11	$13.89	$5.23	($1.85)	($4.60)	$9.83
Pulp (non-NAICS)	$6.24	$6.68	$6.68	$10.10	($0.06)	($3.64)	$13.74
Mill-weighted average							**$16.82**

As shown in Figure 12, the percentage of onsite biomass in mills' total energy consumption again appears strongly correlated with the percentage of emissions covered by the allocation. One sign that this sectoral scheme may be successful at grouping plants with more similar production characteristics together compared with the NAICS sectors is that the difference in the mean percentage of onsite biomass for

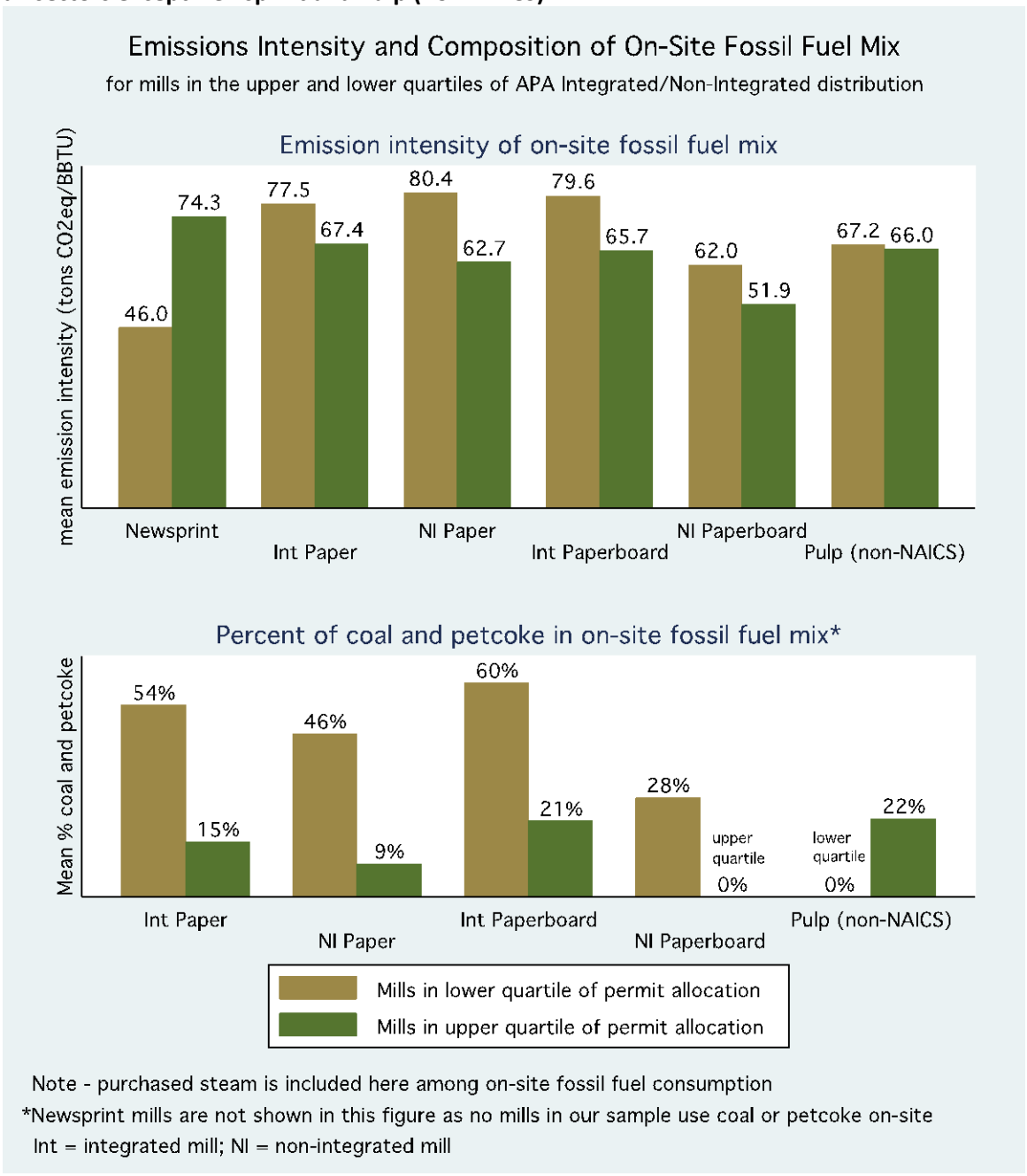
upper- and lower-quartile mills is smaller within the new Paper and Paperboard sectors (the difference is slightly more pronounced in the new Pulp sector, however).

Figure 12. Average percentage of biomass energy in total onsite energy consumed for mills whose percentage of emissions coverage from received allowances places them in the upper (green) and lower (brown) quartiles of mills in the sector, under the APA integrated/Non-Integrated distribution. A strong correlation between biomass consumption and emissions coverage is shown within all sectors except the newsprint sector.



As with the NAICS distribution, the emissions intensity of onsite fuels (Figure 13) appears strongly correlated with the relative number of allowances received by mills for all new sectors tested except the Pulp (non-NAICS) mills sector, where mean emissions from fossil fuels make up only 7% of total emissions (compared to 11% in the NAICS Pulp sector). Among the five new sectors, the Non-Integrated Paperboard sector is the only one in which the emissions intensity of purchased electricity (Figure 14) appears strongly correlated with emissions coverage. Mean emissions from purchased electricity for mills in this sector comprise 37% of total emissions, compared with only 12% in the larger NAICS Paperboard sector (see Figures 1 and 2).

Figure 13. Mean emissions intensity (tons CO_2e/BBTU consumed) and composition of onsite fossil fuel mix for mills whose percentage of emissions coverage from received allowances places them in the upper and lower quartiles of mills in the sector, under the APA Integrated/Non-Integrated distribution. A strong correlation between onsite fossil fuel emissions intensity and emissions coverage is seen in all sectors except Newsprint and Pulp (non-NAICS).

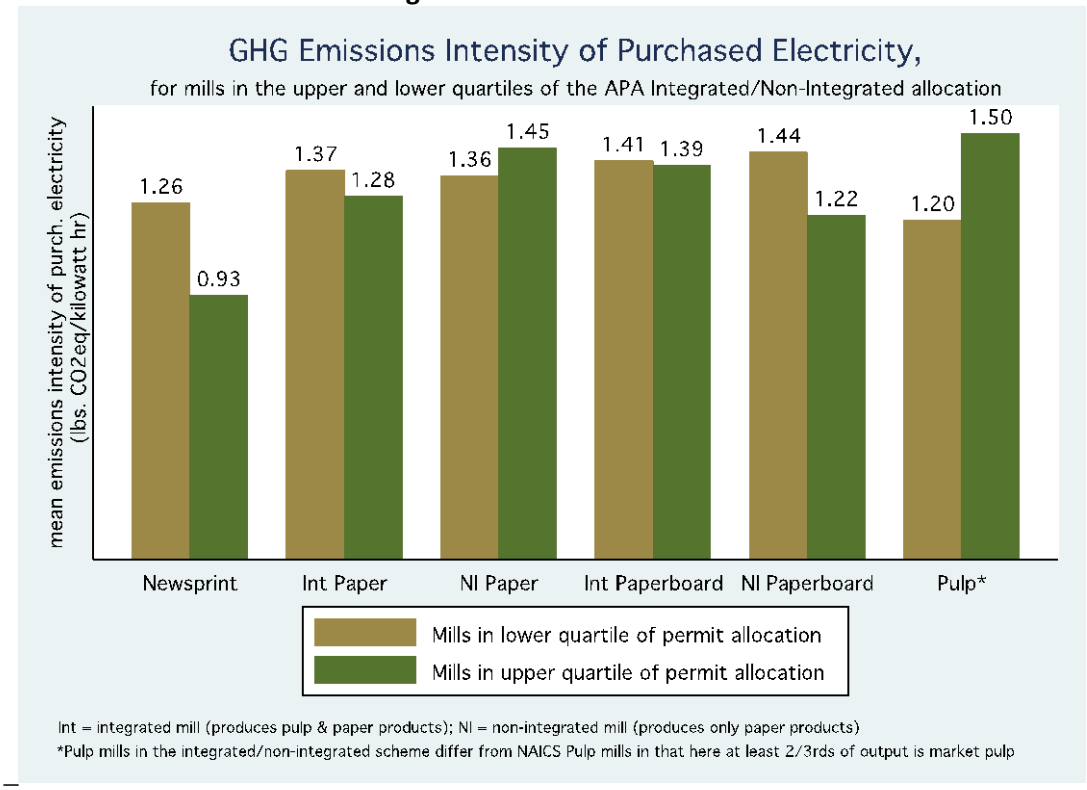


Note - purchased steam is included here among on-site fossil fuel consumption

*Newsprint mills are not shown in this figure as no mills in our sample use coal or petcoke on-site

Int = integrated mill; NI = non-integrated mill

Figure 14. Average emissions intensity of purchased electricity for mills whose percentage of emissions coverage from received allowances places them in the upper and lower quartiles of mills in the sector under the APA Integrated/Non-Integrated distribution scheme. The Newsprint mills sector is unchanged from the NAICS Newsprint sector. Among the five new sectors, the Non-Integrated Paperboard sector is the only one where emissions intensity of purchased electricity appears strongly correlated with emissions coverage.



Distribution using Integration/Bleaching sectors

Overall, moving from a distribution using Integrated/Non-Integrated sectors to one that adds an additional grouping criteria for onsite bleaching in the paper and paperboard sectors (with four new sectors replacing two) does not produce any dramatic changes in the allocation. While we know that this distribution is effective in eliminating any bias associated with onsite bleaching, the mill-weighted average for the difference in median net GHG compliance burden between upper- and lower-quartile mills actually rises from $16.82 per ton in the Integrated/Non-Integrated scheme to $17.35 per ton here. Part of this increase seems tied to the newly created Non-Integrated Bleached Paper sector—a sector with the highest mean emissions intensity (1.86 tons CO_2e/ton product) of all sectors considered (see Table 3), and in which there is a wide degree of variation among mills in the degree of biomass used for fuel (see Figure 16). In this sector, the difference in the median net GHG compliance burden among upper- and lower-quartile mills is $42.04 per ton of product.

Figure 15. Distribution of emissions allowances shown as percentage of coverage of facilities' 2008 emissions (their compliance burden for the year of permit distribution) under the APA EAR program using Integration/Bleaching sectors. Distribution is shown under rules treating biomass emissions as carbon-neutral. Outliers, shown as dots, are values that are 1.5 times the interquartile range above the third quartile (75th percentile) or below the first quartile (25th percentile). The dotted green line shows where emissions are perfectly covered (100%).

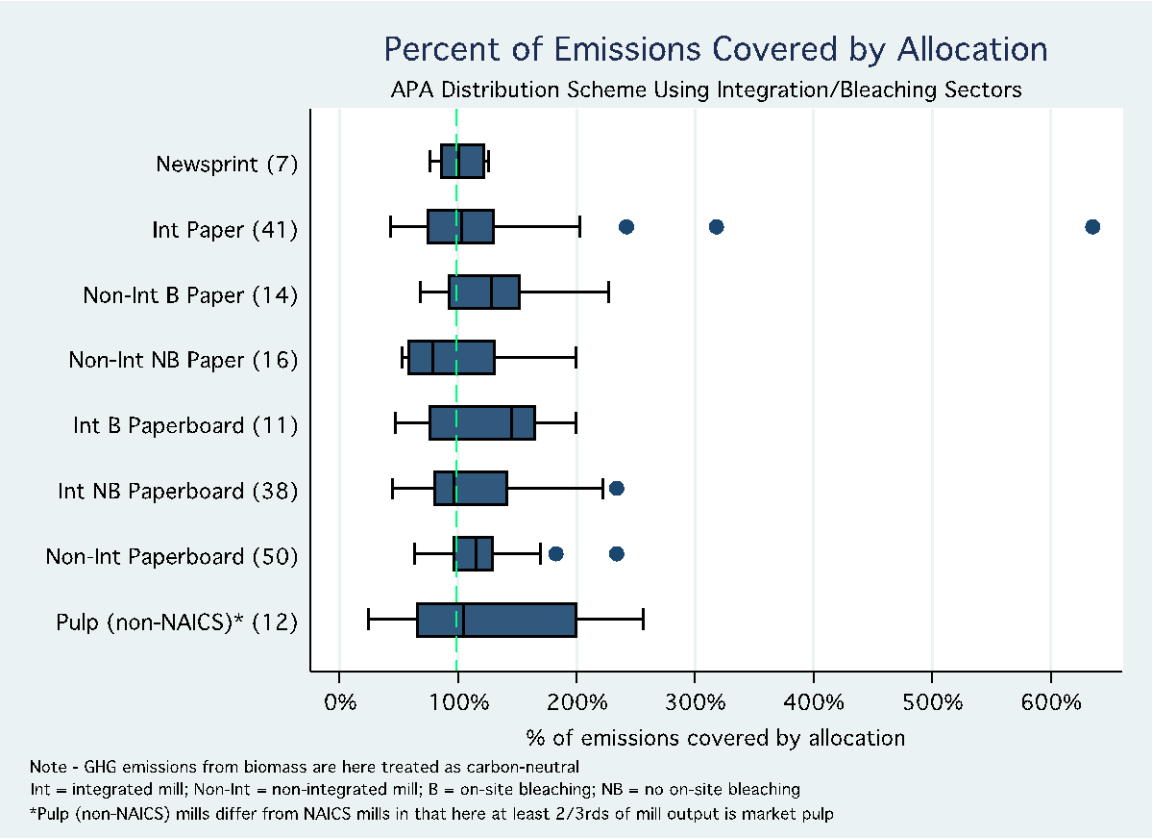


Table 13. Summary statistics by sector and weighted average for percentage of emissions covered under distribution of allowances based on the APA Integration/Bleaching distribution scheme.

Sector	Mean	Median	Standard deviation	Interquartile range	Skew
Newsprint	101%	100%	18%	35%	0.12
INT Paper	126%	103%	99%	55%	3.64
Non-Int Bleached Paper	131%	128%	52%	59%	0.46
Non-Int Non-Bleached Paper	99%	79%	49%	72%	0.91
INT Bleached Paperboard	127%	145%	49%	88%	-0.23
INT Non-Bleached Paperboard	112%	96%	48%	60%	0.95
Non-Int Paperboard	115%	115%	32%	33%	1.01
Pulp (non-NAICS)*	127%	105%	78%	134%	0.26
Weighted average	**118%**	**108%**	**61%**	**59%**	**3.64**

INT = integrated mill (produces pulp and paper products onsite); Non-Int = Non-Integrated mill (produces only paper products onsite using purchased pulp).

*Pulp (non-NAICS) sector, found in both the Integrated/Non-Integrated and Integration/Bleached sectoral schemes, differs from the NAICS Pulp mills sector in that at least two-thirds of mill output is market pulp.

Table 14. Monetized values of allocated allowances and net GHG compliance burden assuming a $20/ton carbon price, for mills in the lower, inner, and upper quartiles of the APA Integration/Bleaching distribution scheme.

Sector	Median emissions (tons CO_2e)	Median value of allocation at $20/ton carbon price			Median net GHG compliance burden** with allocation		
		Lower-quartile mills*	Inner-quartile mills	Upper-quartile mills	Lower-quartile mills	Inner-quartile mills	Upper-quartile mills
Newsprint	356,920	$7,048,428	$8,907,640	$4,785,196	$1,695,661	($277,625)	($984,506)
INT Paper	434,204	$9,196,599	$9,787,409	$12,825,292	$5,287,444	($393,585)	($4,937,315)
Non-Int Bleached Paper	337,587	$15,410,280	$5,695,946	$6,492,886	$6,767,581	($1,212,434)	($3,285,650)
Non-Int Non-Bleached Paper	27,362	$272,240	$592,984	$641,718	$228,385	$64,158	($274,863)
INT Bleached Paperboard	371,382	$9,779,602	$10,486,871	$9,968,547	$3,067,808	($2,525,123)	($4,638,669)
INT Non-Bleached Paperboard	384,496	$7,927,402	$8,356,669	$8,992,185	$3,993,649	$129,960	($3,621,180)
Non-Int Paperboard	70,977	$2,677,431	$1,363,129	$1,645,006	$642,747	($130,553)	($494,546))
Pulp (non-NAICS)	146,890	$2,086,359	$3,948,410	$3,599,534	$1,671,838	($358,805)	($2,065,552)

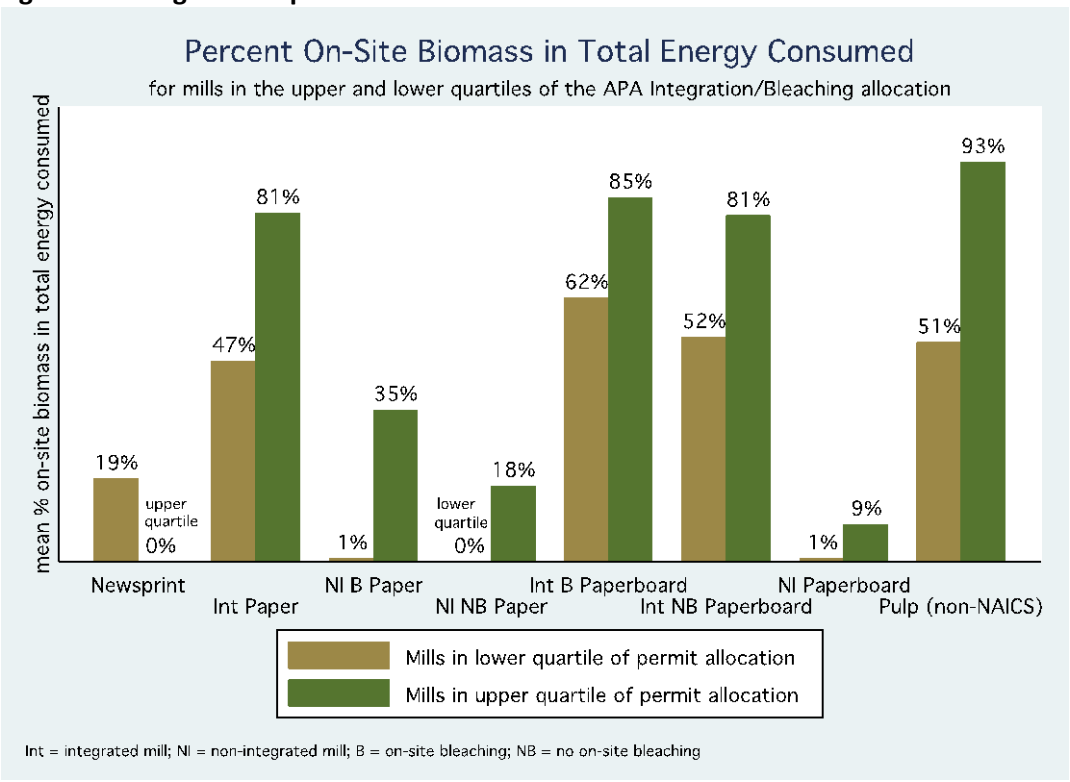
*Quartiles refer to percentage of mill emissions covered by allocation (Figure 5), not the absolute size of the allocation. The median value of allocation for lower-quartile mills is therefore the median value of allocated permits among mills whose percentage of emissions covered places them in the lower quartile of the distribution.

**Net GHG compliance burden is a mill's total emissions (excluding emissions from biomass) minus that mill's allocation of permits (each permit covers one ton of CO_2e emissions) times the value of permits ($20 per permit).

Table 15. Monetized values of allocated permits per ton of product and net GHG compliance burden per ton of product, assuming a $20 per ton carbon price, for mills in the lower, inner, and upper quartiles of the APA Integration/Bleaching distribution scheme.

Sector	Median value of allocation per ton of product at $20/ton carbon price				Median net GHG compliance burden per ton of product with allocation and $20/ton carbon price			
	Lower-quartile mills	Inner-quartile mills	Upper-quartile mills	Difference btw upper and lower-quartile mills	Lower-quartile mills	Inner-quartile mills	Upper-quartile mills	Difference btw upper- and lower-quartile mills
Newsprint	$28.01	$32.36	$22.57	$5.44	$6.77	($0.68)	($4.64)	$11.41
Int Paper	$19.41	$17.76	$17.76	$1.65	$12.52	($0.94)	($8.21)	$20.73
Non-Int Bleached Paper	$43.54	$41.53	$44.28	$0.74	$19.27	($9.45)	($22.77)	$42.04
Non-Int Non-Bleached Paper	$26.04	$23.88	$26.22	$0.18	$21.58	$5.91	($10.39)	$31.97
INT Bleached Paperboard	$16.36	$17.87	$16.87	$0.51	$5.61	($5.46)	($7.75)	$13.36
INT Non-Bleached Paperboard	$11.88	$10.74	$11.88	$0.00	$6.88	$0.30	($4.87)	$11.75
Non-Int Paperboard	$15.22	$15.11	$13.89	$1.33	$5.23	($1.85)	($4.60)	$9.83
Pulp (non-NAICS)	$6.24	$6.68	$6.68	$0.44	$10.10	($0.06)	($3.64)	$13.74
Mill-weighted average				**$1.04**				**$17.35**

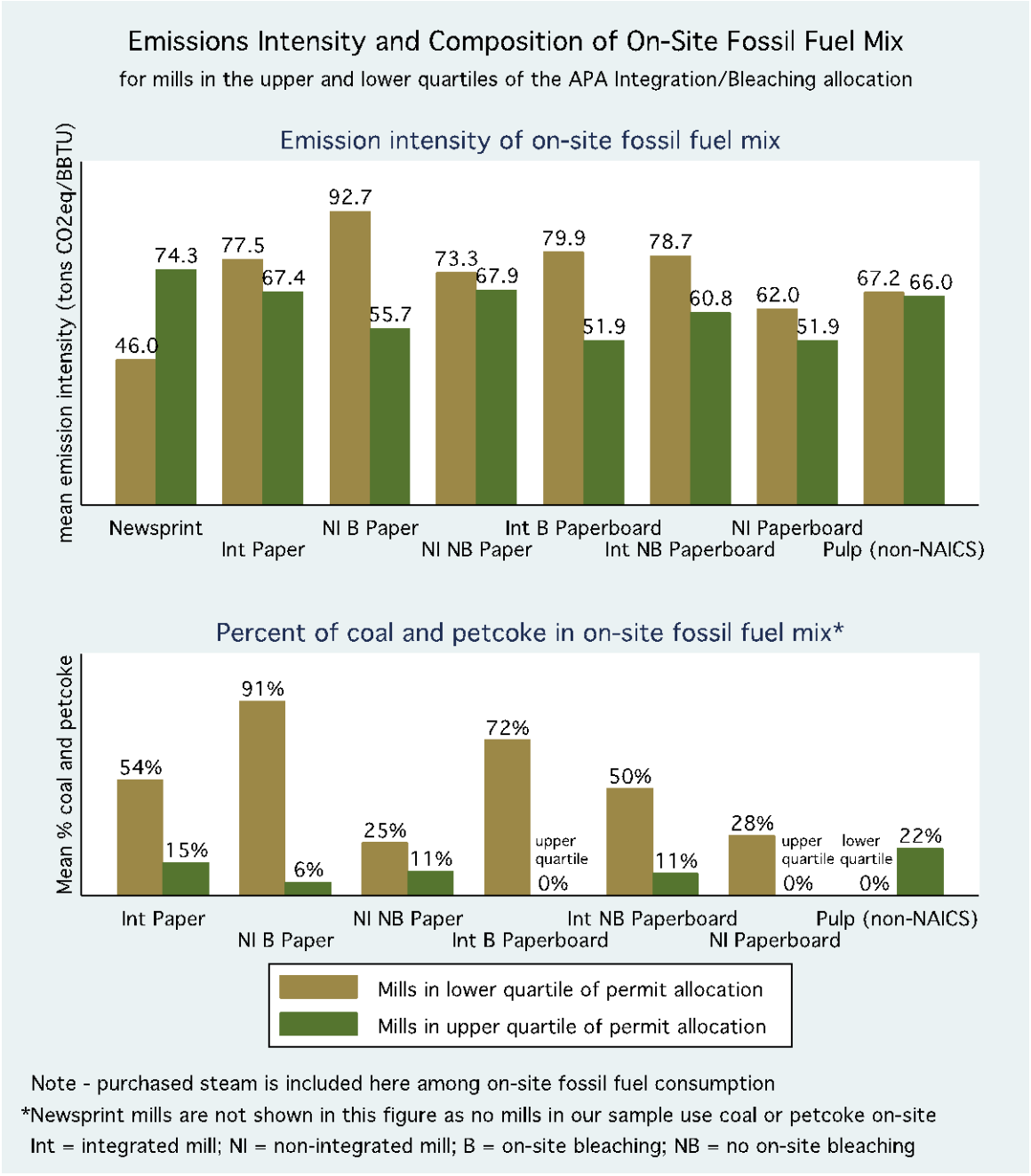
Figure 16. Average percentage of biomass energy in total onsite energy consumed for mills whose percentage emissions coverage from received allowances places them in the upper (green) and lower (brown) quartiles of mills in the sector, under the APA Integration/Non-Integration distribution. Of note, among the four new sectors, the Non-Integrated Bleached Paper sector shows a wide separation in the percentage of biomass consumed between lower- and upper-quartile mills compared with the larger Non-Integrated Paper sector.



Looking at the emissions intensity and composition of onsite fossil fuels (Figure 17), we note the very large separation in these values between upper- and lower-quartile mills in the in the newly created Paperboard and Integrated Bleached Paperboard sectors. The mean percentage of coal and petcoke in onsite fossil fuels is 91% vs. 6% for lower- and upper-quartile Non-Integrated Paperboard mills, respectively, and 72% vs. 0% for lower- and upper-quartile Integrated Bleached Paperboard mills, respectively.

For the four new sectors in this distribution, differences in the emissions intensity of purchased electricity between lower- and upper-quartile mills is small, and largely uncorrelated with emissions coverage (Figure 18).

Figure 17. Mean emissions intensity (tons CO_2e/BBTU consumed) and composition of onsite fossil fuel mix for mills whose percentage emissions coverage from received allowances places them in the upper and lower quartiles of mills in the sector, under the APA Integration/Bleaching distribution. Among the four new sectors, the largest separation in values of upper- and lower-quartile mills is seen in the Non-Integrated Bleached Paper and Integrated Bleached Paperboard sectors.

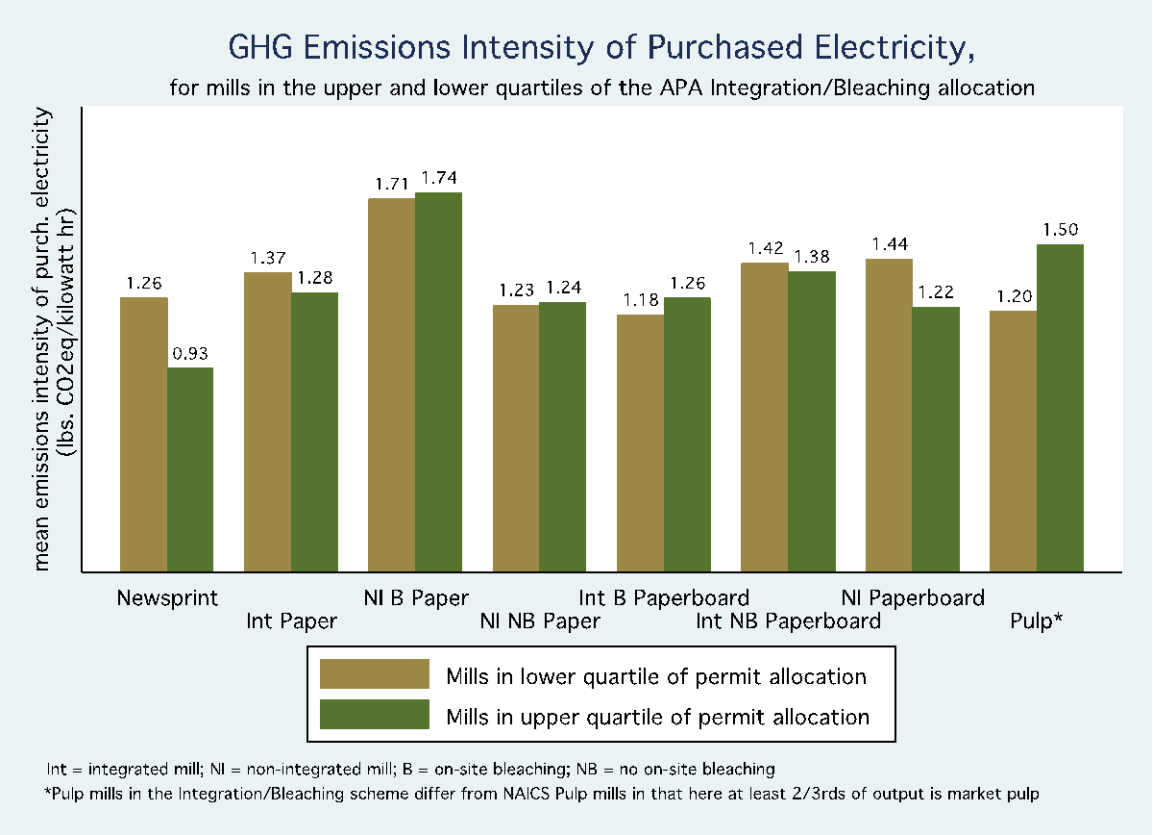


Note - purchased steam is included here among on-site fossil fuel consumption

*Newsprint mills are not shown in this figure as no mills in our sample use coal or petcoke on-site

Int = integrated mill; NI = non-integrated mill; B = on-site bleaching; NB = no on-site bleaching

Figure 18. Average emissions intensity of purchased electricity for mills whose percentage emissions coverage from received allowances places them in the upper and lower quartiles of mills in the sector, under the APA Integration/Bleaching distribution scheme. Differences in emissions intensity for all four new sectors is small, and appears largely uncorrelated with whether or not a mill is above or below the sector average in terms of emissions coverage.



6. CONCLUSIONS

Efforts to forge a political consensus to establish limits on U.S. emissions of GHGs will depend in large part on stakeholders' perceptions of how equitable any proposed climate policy is. Under a cap-and-trade policy, a critical element affecting equity is the distribution of allowances. This study examines key design elements and industry characteristics that can affect the distribution of allowances to firms under output-based allocation, focusing on the U.S. pulp and paper sector.

Results show that if the intent of a distribution program is to award a relatively larger share of allowances to firms that have and continue to make investments in efficiency, then the allocation rules must be capable of distinguishing among differences in emissions that arise for reasons unconnected to efficiency. In particular, for mills in our sample, whether or not a mill is vertically integrated or uses an onsite bleaching process is shown to affect plant-level emissions intensities, and therefore allowance distributions. Using an industry classification system that groups vertically integrated mills together with non-integrated mills and that fails to distinguish among mills that do or do not have an onsite bleaching process—as does the six-digit NAICS code system—results in perverse effects when those industry groupings are used to create sector-wide benchmarks for the purpose of allocating allowances. Simulated allowance distributions using separate benchmarks for integrated and non-integrated firms and firms with and without an onsite bleaching process are shown to be successful at reducing some of the extreme variability in terms of the benefits each mill receives from the program relative to other mills in the same sector.

One idea unexplored in the paper but relatively easy to implement would be to incorporate a floor and ceiling on the percentage of individual mill emissions covered by allocated permits. For example, if stakeholders are concerned about the potential for some firms to receive allowances far and above or below their compliance burden, an allowance floor and ceiling could specify the maximum range of emissions coverage within sectors under the allowance distribution program. Using a floor/ceiling of 50%/200% would in fact require fewer allowances in all three distributions considered here—ranging from 2% fewer allowances under the APA distribution using NAICS sectors, and 1.5% fewer allowances under the APA distribution using Integration/Bleaching sectors.

For the pulp and paper industry, the question of how emissions from biomass will be treated under a cap-and-trade or similar policy is important. Under rules treating biomass emissions as carbon-neutral, as is done in this study, biomass is essentially a free fuel. The extent to which plants rely upon biomass for their total energy consumption is shown to be strongly correlated with emissions coverage in all distributions considered.

Lastly, we find that the emissions intensity of mills' onsite fossil fuel mix is correlated with the number of allowances received for most pulp and paper sectors, while the emissions intensity of purchased electricity, which is determined by where mills are located, appears significant for those sectors where purchased electricity comprises a relatively large energy input. It is hoped that results of this study contribute to the design of more environmentally effective and equitable output-based allocation programs.

APPENDIX: CALCULATING ALLOCATED PERMITS

In the American Power Act, allocation to each covered manufacturing facility is based on the sum of what are called Direct and Indirect Carbon Factors.[36] Both are defined below.

Direct Carbon Factor (DCF) for an individual facility:

DCF = (Output) * (Average Direct GHG per Unit of Output for Sector)

where

- Output is the average annual output of the entity for the two years preceding the year of permit distribution.
- Average Direct GHG per Unit of Output for Sector is an emissions intensity benchmark, calculated as the average direct GHG emissions (expressed in tons of CO_2e) per unit of output for all covered entities in the sector.

Indirect Carbon Factor (ICF) for an individual facility:

ICF = (Output) * (Elec. Intensity Factor) * (Elec. Efficiency Factor)

where

- Output is the annual output of the entity for the two years proceeding the year of permit distribution.
- Elec. Intensity Factor is the emissions intensity (expressed in tons of CO_2e per kilowatt hour) of a facility's purchased electricity.
- Elec. Efficiency Factor is an energy intensity benchmark, calculated as the average quantity of purchased electricity (in kilowatt hours) used per unit of output for all entities in the sector.

Calculation of the emissions intensity benchmark (Average Direct GHG per Unit of Output for Sector) is to be based on an average of five years of the best available data from up to seven years prior, and updated every four years.[37] This updating of the emissions intensity benchmark is designed to provide continuous incentives for efficiency improvements.

This study uses the EPA's Emissions & Generation Resource Integrated Database (eGRID) values at the subregion level as a proxy for the Electricity Intensity Factor, which is a measure of the emissions intensity of a mill's purchased electricity.

Scaling of allocated permits to equal each sector's total emissions

This study assumes that each sector's emissions are fully covered by allocated permits. To facilitate this, after determining the total amount of allowances allocated to each sector based on calculation of mills' Direct and Indirect Carbon Factors, the number of allowances allocated to individual mills is multiplied by a scaling factor. The scaling factor is computed as follows:

$$\text{Scaling Factor} = 1 - \left(\frac{\text{Sector's Total Allocation} - \text{Sector's Total Emissions}}{\text{Sector's Total Emissions}}\right)$$

[36] The American Power Act, §774.
[37] The American Power Act, §774(b)(4).

Accounting for sales of electricity and steam

Several mills in our sample are sellers of electricity and steam. Because the emissions and energy intensity benchmarks used to calculate the Direct and Indirect Carbon Factors (see above) are meant to capture only the energy and emissions associated with pulp and paper production, it is necessary to separate the energy and emissions associated with any sold electricity and steam from that which is associated with pulp and paper production. Data collected by AF&PA and used in this study does not identify the source of fuel used for onsite power or steam generation. We therefore assume equal consumption of all onsite fuels for energy and steam generation. Default efficiency factors[38] for electricity and steam production of 35% and 80%, respectively, are used for converting fuel BTUs to sold electricity and steam (i.e., from 100 BTUs of onsite fuel consumption a mill can produce 35 BTUs of sold electricity or 80 BTUs of sold steam).

[38] U.S. Environmental Protection Agency. *Indirect Emissions from Purchases/Sales of Electricity and Steam.* Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance. June 2008. Available at: http://www.epa.gov/climateleaders/resources/cross-sector.html.