

## Climate policy impacts on the competitiveness of energy-intensive manufacturing sectors

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### ABSTRACT

This study examines the impacts of energy price changes resulting from different carbon-pricing policies on the competitiveness of selected US energy-intensive industries. It further examines possible industry responses, and identifies and provides a preliminary evaluation of potential opportunities to mitigate these impacts. The industry sectors investigated – steel, aluminum, chemicals and paper – are among the largest industrial users of fossil fuels in the US economy. The results of this examination show that climate policies that put a price on carbon could have substantial impacts on the competitiveness of US energy-intensive manufacturing sectors over the next two decades, if climate regulations are applied only in the United States, and no action is taken to invest in advanced low- and no-carbon technologies. The extent of these impacts will vary across industries, depending on their energy intensities, the mix of energy sources they rely on and how energy is used in production activities (heat and power, feedstock). Of relevance is also the speed and rigor with which industries adopt new technologies and retire (or replace) old ones. Other factors affecting these impacts include an industry's vulnerability to foreign imports and its ability to pass through cost increases to its customers in the face of international market competition.

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### 1. Introduction

The Flambeau River Papers case, the success story of a paper mill that evolved to survive and invested in new biomass-energy boilers and cellulosic ethanol production to become the first fossil-fuel free, energy independent and integrated pulp and paper mill in North America, exemplifies the challenges facing many American businesses from escalating and volatile energy prices, amplified in some sectors by intense international competition. There is much concern that policies to curb global warming by placing a cap on greenhouse gas (GHG) emissions and constraining the use of carbon-based energy sources could further exacerbate these impacts. Nevertheless, the mill's success in turning itself into an energy-efficient, carbon-free competitive enterprise illustrates that there may be new opportunities created as well. A climate policy that puts a price on carbon is intended to promote energy-

efficiency gains throughout economy, as well spawn new industries and generate new jobs. However, making the transition to a low-carbon economy will not be without costs. Moreover, it would require the right kinds of supporting public policies and serious industry commitments, consisting in wise and transparent investment strategies, to embark in such transformations.

The climate change policy debate is taking place against a backdrop of a weakening national economy, volatile energy prices and uncertainties about future energy supplies, concerns over national security, which is linked to our dependency on foreign oil, a major housing crisis, an unremitting, massive trade deficit and a manufacturing sector struggling to remain globally competitive. A major obstacle in the way of passing comprehensive climate legislation has been – and remains – the fear that policies constraining and putting a price on carbon in the economy will create further economic damage, adding to the economic distress that many workers, businesses and communities are already experiencing (GES, 2005). Over the past year, legislators have been turning their attention to finding ways to mitigate potentially harmful impacts of climate change legislation on the competitiveness of American manufacturing.

In recognition of these challenges, the present study on *Climate Policy Impacts on the Competitiveness of Energy-Intensive Manufacturing* (“HRS-MI”), which uses the Integrated Industry

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Model-Carbon Policy (IIM-CP), examines the carbon permits system impacts (e.g. energy price changes resulting from different carbon-pricing policies) on the competitiveness of selected energy-intensive industries, especially in the face of international competition. It further examines possible industry responses, and identifies and provides a preliminary evaluation of potential opportunities to mitigate these impacts. The industry sectors investigated in the study – steel, aluminum, chemicals and paper – are among the largest industrial users of fossil fuels in the US economy (US Census Bureau, 2006a, b, c). The results of this examination, however, may also shed light on the implications of climate policies for other important energy-intensive sectors, such as cement and ceramics, and for manufacturing as a whole.

Since the new administration has made public that it intends to approve a climate legislation before the Conference of Parties (COP15) to be held in December 2009, the main body of the study proposes what can be considered the worst-case scenario for US energy-intensive manufacturing sectors. This is due to the boundaries of the analysis and the assumptions underlying various scenarios.

Furthermore, this partial equilibrium study hopes to build on the general equilibrium analyses already available (EIA, 2006, 2008a, b, c) by researching the impacts of climate legislation on selected 4–6 digits North American Industrial Classification System (NAICS), while avoiding the study of the broader economy-wide policy repercussions (both positive and negative).

Employing a computer-based System Dynamics modeling approach, supplemented by econometric and qualitative analyses, the study investigates three questions:

#### Cost impacts

- How will climate policy-driven energy price increases affect the production costs and profitability of manufacturers in energy-intensive manufacturing sectors?  
*International market impacts*
- In the face of energy-driven cost increases, and constraints on manufacturers' ability to pass these costs along to consumers, how will international competition affect the industry's competitiveness (i.e., profitability and market share)?  
*Investment options and opportunities*
- How could manufacturers respond to the energy price increases and possible threats to their competitiveness?

These questions have been examined for a range of energy price increases associated with different climate proposals. In particular, the HRS-MI study it evaluates three climate bills, a "Low-CO<sub>2</sub> Price Policy", such as the Low-Carbon Economy Act of 2007 (S. 1766) (US Congress, 2007b) introduced by Senators Jeff Bingaman (D-NM) and Arlen Specter (R-PA), a "Mid-CO<sub>2</sub> Price Policy", such as the Climate Security Act of 2007 (S. 2191) (US Congress, 2007a) introduced by Senators Joseph Lieberman (I-CT) and John Warner (R-VA), and a variation of the latter, considered as "High-CO<sub>2</sub> Price Policy", Lieberman–Warner with no international offsets.

#### 1.1. Competing climate policies

A number of legislative proposals have been introduced and debated in Congress over the past few years aimed at reducing greenhouse gas emissions in the US economy (WRI, 2008). The larger policy debate has revolved around two major types of mandatory policies for achieving GHG reductions on an economy-wide basis: a carbon tax and cap-and-trade schemes. Both aim at

limiting the total amount of GHG emissions generated at the national level and they differ primarily in the policy mechanisms that would be used to achieve emission reduction goals.

Although strong support remains for a carbon tax system among some policymakers and energy experts (Canes, 2007), the policy debate in the US Congress has mostly been over competing cap-and-trade proposals, embodied in legislation introduced in both the House and Senate (e.g. S.1766 and S.2191). Cap-and-trade schemes require "regulated" entities (e.g. high carbon content energy fuel suppliers) to submit a quantity of tradable "permits" or allowances necessary to cover their GHG emissions; the total number of emissions allowances in the economy available would depend on the emissions cap set for a given year (UNEP, 2002; PEW, 2007). Regulated entities must reduce output (and emissions) or purchase the permits they require to cover their emissions content, above any allowances that may have been "grandfathered" to them. The net result will be additional costs primarily borne by fossil-fuel energy suppliers (including major fossil-fuel-based electricity generators, if also regulated) who then pass most or all these costs down to end users (industrial and commercial enterprises, households and individual consumers) (Ellerman et al., 2003). As with a carbon tax, the additional carbon-based energy costs rippling through the economy would encourage reduced use of carbon-based energy sources, fuel switching and efficiency improvements, thereby lower GHG emissions (Nordhaus and Danish, 2003).

The present study is solely focused on evaluating cap-and-trade proposals.

#### 1.2. Energy-intensive industries

The HRS-MI study evaluated five of the most energy-intensive manufacturing industries in the economy: iron and steel and ferroalloy products, aluminum (primary and secondary aluminum), paper and paperboard mills, petrochemicals and alkalies and chlorine (chlor-alkali) manufacturing. The North American Industrial Classification System (US Census Bureau, 2006a, b, c) was used to guide data collection and model development.

Table 1 shows the energy intensity for manufacturing as a whole, as well as the energy intensity of the major industries and sub-sectors examined in the study. The selected industries have some of the highest levels of energy intensity in the manufacturing sector, measured as total energy expenditures (fuels and electricity) as a share of total operating expenditures. In fact, these numbers are understated for some of the industries (e.g. petrochemicals and iron and steel), which consume large quantities of energy fuels as feedstock, and therefore are substantially more energy intensive than reported in Table 1.

Chemicals, primary metals and paper ranked 1st, 3rd and 5th among all major manufacturing sectors in energy spending, not including energy fuels used as feedstock (US Census Bureau, 2006a, b, c). These three sectors together accounted for 41 percent of all energy expenditures for energy fuels and electricity in manufacturing in 2006 (US Census Bureau, 2006a, b, c). Within these divisions, basic chemicals (3251), iron and steel and ferroalloy products manufacturing (3311), aluminum production and processing (NAICS 3313) and pulp, paper and paperboard mills (3221) are the largest (4-digit) industrial categories in terms of value of shipments and energy use (US Census Bureau, 2006a, b, c).

The selected industries have other important characteristics worth noting:

- The industries differ in the mix of primary energy sources they rely on (EIA, 2002).

**Table 1**  
Energy intensity<sup>a,b</sup> for selected energy sectors, 2006.

NAICS code	Industry sector	Energy intensity <sup>a</sup> (%)
31–33	Manufacturing	2.9
325	Chemicals manufacturing	5.6
3251	Basic chemicals	10.2
<b>32511</b>	<b>Petrochemicals</b>	<b>8.0</b>
<b>325181</b>	<b>Alkalies and chlorine</b>	<b>38.9</b>
331	Primary metals	6.4
<b>3311</b>	<b>Iron and steel and ferroalloy products</b>	<b>8.8</b>
3313	Alumina and aluminum production and processing	7.5
331312,4	Primary and secondary aluminum production	14.8
<b>331212</b>	<b>Primary aluminum production</b>	<b>26.5</b>
<b>331214</b>	<b>Secondary aluminum production</b>	<b>6.2</b>
322	Paper manufacturing	7.3
<b>32212,3</b>	<b>Paper and paperboard mills</b>	<b>14.5</b>
<b>32212</b>	<b>Paper mills</b>	<b>13.0</b>
<b>32213</b>	<b>Paperboard mills</b>	<b>18.0</b>

Industries in bold are examined in the study.

<sup>a</sup> Energy intensity is calculated as the share of total energy expenditures (fuel and electricity) as a share of total operating expenditures (roughly equal to sum of materials costs, labor compensation and new capital expenditures in the Census Bureau's *Annual Survey of Manufactures*, 2006).

<sup>b</sup> Does not include expenditures on energy fuels used as manufacturing feedstock (e.g. natural gas used in petrochemical production; coke used in steel production).

- Over the past decades, all have experienced shrinkage in their overall capacity and employment, largely to reduce costs and remain competitive.
- Rising energy costs are an increasingly critical concern in the future investment decisions of all four industries. Because they compete in global markets, passing along additional costs to consumers is difficult.
- The potential for these industries to improve their energy efficiency at existing technology levels, in order to offset increased energy costs from GHG policies, varies.
- Recycling or recovery of scrap or waste materials is a major part of the iron and steel, aluminum and paper and paperboard industries.
- Several of the industries also internally generate heat and power as by-products of their production processes.

## 2. Literature review

Until recently, the economic debate has been supported by general equilibrium studies, and limited to macroeconomic impacts of climate policies. When the US Department of Energy (DOE-EIA) analyzes different pieces of climate legislation it mostly calculates projected impacts on broad economic indicators, such as GDP, total consumer spending and industrial output (EIA, 2006, 2008a, b, c). Many other studies, by environmentalists and academic economists, use general equilibrium models that also mostly yield economy-wide impacts (EIA, 2008a, b, c; Paltsev et al., 2007), though some contains industrial input–output (I–O) modules, which can calculate distributional effects, mainly at a high level of sector aggregation (Morgenstern et al., 2004). The modest climate policy impacts observed – for example, from a fraction of a percent to only a couple of percent declines in GDP by 2020 or 2030 – indicate that climate policies will have small or minimal impacts on a nation's economy (Hauser et al., 2008; EIA, 2006). At worst, they show that GHG policies are likely to have significant direct impacts on coal and other domestic energy industries (EIA, 2008a, b, c). The potential for losses of output and jobs in these sectors, however, was a key reason that the US

Government has not ratified the Kyoto Protocol and another was lack of large developing nation's participation in the agreement (Scott, 1997; Standard & Poor's DRI, 1998).

A relatively small number of studies have attempted to examine climate policies and their implications for manufacturing industries in much depth. One set of studies are largely qualitative—they do not quantify policy impacts on industry sectors, but include in-depth industry profiles, and evaluate different energy and climate policy options in light of industry analyses (EPA, 2007; MGI, 2007; Hauser et al., 2008), perhaps including supplemental economic modeling. Another set of studies apply modeling tools in attempts to quantify these impacts (Morgenstern et al., 2004, 2007; McKinsey/Ecofys, 2006; Reinaud, 2005; Ruth et al., 2000a, b, 2002, 2004; Davidsdottir and Ruth, 2005). Among others, the latter category include Resources for the Future (RFF) ongoing studies aimed at understanding how carbon-dioxide charges affect industrial competitiveness, measured as impacts on operating costs, profits and production output (Morgenstern et al., 2004, 2007). In addition, two detailed studies of the impacts of the European Union Emissions Trading Scheme (EU ETS) on the competitiveness of European manufacturing industries provide a good degree of detail. Their focus on the other hand was on narrower, more energy-intensive industrial categories than traditional economic studies usually evaluate (McKinsey/Ecofys, 2006; Reinaud/IEA, 2005).

Important insights and lessons emerge from these studies, as a RFF paper notes, “the impact of a CO<sub>2</sub> price on domestic industries is fundamentally tied to the energy (and more specifically carbon) intensity of those industries, the degree to which they can pass costs on to the consumers of their products (often other industries), and the resulting effect on US production” (Morgenstern et al., 2007). The impact on production, in turn, depends on the extent an industry's domestic products face import competition, and consumers ability to substitute less carbon-intensive alternatives for a product. Another concern is the carbon leakage problem: increased US production costs cause energy-intensive manufacturers to shift their operations to nations that have weaker to, or do not adopt, GHG limiting policies, undermining the environmental objectives of the domestic policy.

Unfortunately, as Morgenstern observes, “information concerning industry-level impacts associated with new carbon mitigation policies is quite limited” (Morgenstern et al., 2007). This information not only is important for helping craft measures that minimize economic losses of affected sectors. We also need tools for evaluating measures that encourage and enable manufacturers to invest in technologies, equipment and processes that reduce their carbon-based energy intensities.

Only a few studies over the past decade have attempted to evaluate climate policies and their impact on the manufacturing sector, especially on energy-intensive industries, using dynamic modeling tools (see, for example, Ruth et al., 2000a, b, 2002, 2004; Davidsdottir and Ruth, 2005). The HRS-MI study is a new addition to this small group. Like the others, it attempts to quantify the increased production costs resulting from policies that impose a price on carbon emissions, and the subsequent impacts on manufacturers bottom-lines and production output. It further evaluates these industries under different assumptions concerning the ability of import-sensitive manufacturers to pass along their new cost increases to consumers of their products, both domestically and in global markets. Finally, it differs significantly from the other recent studies in its use of a System Dynamics modeling approach applied to a partial equilibrium analysis of the impacts of climate policies. IIM-CP can support the evaluation of several carbon-pricing policy scenarios and their longer term (through 2030) impacts on the competitiveness of six specific

energy-intensive industries (4–6-digit NAICS codes) from four broad (3-digit NAICS) manufacturing sectors.

### 3. Research approach

The research project involved developing detailed economic and energy profiles of these manufacturing industries, including the collection and processing of historical economic data, and construction of substantial, System Dynamics partial equilibrium industry sector models, supported by group model building sessions. The main steps are briefly described below.

- *Profile development and data gathering*: this involved extensive gathering and analysis of statistical data and information from multiple sources, including the professional literature, US government databases and studies, domestic and international industry sources and academic research, most notably the Census Bureau's *Annual Survey of Manufactures (ASM)* (US Census Bureau, 2006a, b, c) and the United States International Trade Commission (USITC) databases. Drawing on this large body of information, economic and energy profiles of each industry sector being examined were developed.
- *Model development*: the project employed a powerful, flexible, transparent and interactive modeling tool based on the Vensim<sup>®</sup> modeling platform. This modeling approach enables examination of complex, dynamic economic interrelationships at the industrial sector level, which few traditional economic models are capable of carrying out. A detailed model was constructed of each industry sector, which enabled simulations of alternative climate policy impacts on the industry's cost structure and market dynamics.
- *Group modeling sessions and interviews*: numerous group modeling sessions were held involving representatives of industry trade associations and their corporate members from each of the subject industries. These meetings enabled the collection of a substantial amount of primary industrial data, provided perspectives and information about industry behavior and trends, and elicited invaluable feedback about industry model structures, assumptions and data. The meetings involved PowerPoint presentations and computer-based demonstrations of the model, which helped guide discussion and enabled participants to view and respond to changes in model parameters and assumptions in real time.

#### 3.1. Model description

The System Dynamics methodology supports the representation of the context in which policies are formulated and evaluated, using feedback loops, nonlinearity and delays (Sterman, 2000). Such properties of complex systems are explicitly analyzed and accounted for in the partial equilibrium model hereby proposed. This is particularly advised when considering that the enactment of a climate policy has no precedents in history and may trigger feedback loops generating unprecedented and unexpected behavior (Sterman et al., 1988). For this reason optimization tools, econometrics and computable general equilibrium (CGE) models may generate an analysis limited to historical experience, narrow boundaries and detailed complexity (Sterman, 1988). The IIM-CP model is intended to complement existing general equilibrium studies, assessing the impacts of climate policies on selected industry segments at a level of detail (4–6-digits NAICS) that cannot generally be addressed with economy-wide models.

The modeling work proposed in this study followed a three-phased approach. First, we constructed basic production cost models for each of the chosen industries. These were then

extended and broadened to enable modeling of market dynamic features, that accounted for international trade flows and their impacts on the industries' bottom-lines and outputs, under the different emissions pricing scenarios and under different market assumptions (e.g. regarding cost pass along). Finally, results of the simulation helped to inform our analyses of investment and policy options, the third leg of the study, for the different industries. However, although no direct modeling of investment issues was attempted, we did undertake a preliminary modeling of an important policy alternative aimed at offsetting cost and market impacts and we investigated needed energy-efficiency improvements to offset increasing energy costs. Finally, we carried out several sensitivity simulations using our models to examine variations in our results from different assumptions about key model variables, notably materials costs, domestic and world prices, elasticities of demand and energy-efficiency improvement rates.

- *Modeling production costs*: models of production cost structures for all industries analyzed were constructed to calculate the impacts of carbon-pricing policies on profitability. Production cost calculations were based on a cost component model that summed the operating (or variable) costs associated with production outputs for the selected industries – i.e., materials and capital expenditures, labor expenditures (full compensation including wages, salaries and benefits) and energy expenditures (i.e., direct use and feedstock, non-fuel and energy). Historical data on the key cost components (materials, capital, labor, purchased fuels and electricity data) and other important industry financial data (i.e., value of shipments, value added), back to 1992, was obtained from the Census Bureau's *Annual Survey of Manufactures (US Census Bureau, 2006a, b, c)*. Energy costs and intensity for the BAU and policy cases were calculated using industrial energy use data from the Department of Energy's *Manufacturing Energy Consumption Survey (MECS)* (DOE, 2002), and the energy price data generated by EIA's National Energy Modeling System (NEMS) (EIA, 2003) in the Annual Energy Outlook (AEO) 2008 (EIA, 2008a, b, c), were used to characterize the policy scenarios. Industry associations, supplemented by government and other data sources, when available, provided primary data on production output quantities and other important production-related statistics.

The models were dynamically calibrated to track costs starting from 1992, and set up to project them out to 2030 for the policy and BAU cases. The average error for the 1992–2007 time period is within 2% for most variables considered, including demand, revenues and labor, material and energy costs. The models incorporated assumptions about future materials, investment and labor cost trends based on historical trends and feedback from industry experts. Care was taken to include costs associated with carbon-fuel-based feedstock (coke in steelmaking, natural gas in petrochemicals) in the energy cost calculations and subtracted from materials costs.

- *Modeling market dynamics*: models of the market dynamics for all the industries were constructed, incorporating import and export trends and integrated with the production cost models. The expanded models were then used to assess the consequences of carbon policy-driven production cost increases on the sectors' profitability, production output and market share. Simulations were done assuming both zero pass through and 100% pass through of additional costs to consumers.<sup>3</sup> An

<sup>3</sup> As energy prices drive domestic production costs higher relative to foreign prices, there is a subsequent impact on import market shares and domestic

**Table 2**  
Main industry assumptions used in IIM-CP.

Industry	Materials (capital production) costs	Labor costs	Feedstock energy costs	GDP/demand
Steel	Constant	<i>Compensation</i> : constant <i>Labor intensity</i> : long term trend, flattens in 2016	Natural gas, coal and coke feedstock	Slightly declining ratio. 2.48% average growth rate 1992/2030
Primary aluminum	Constant	<i>Compensation</i> : constant <i>Labor intensity</i> : constant	No feedstock (petroleum coke counted as materials costs)	Constant demand/GDP ratio. 1.63% average growth rate 1992/2030
Secondary aluminum	Constant	<i>Compensation</i> : constant <i>Labor intensity</i> : constant	No feedstock	
Paper and paperboard	Constant	<i>Compensation</i> : constant <i>Labor intensity</i> : long term trend, flattens in 2020	No feedstock	Slowly decreasing ratio. 0.53% average growth rate 1992/2030
Petrochemicals	Constant in nominal terms	<i>Compensation</i> : constant <i>Labor intensity</i> : long term trend, flattens in 2020	Natural gas and LPG feedstock	Slowly decreasing ratio. 1.67% average growth rate 1992/2030
Alkalies and chlorine	Constant in nominal terms	<i>Compensation</i> : constant <i>Labor intensity</i> : constant	LPG feedstock	Slowly decreasing ratio. 0% average growth rate 1992/2030, 0.2% growth rate after 2007
Other assumptions and specifications	<ul style="list-style-type: none"> <li>• All trends for material, labor costs and GDP are to be considered in real terms, unless otherwise noted</li> <li>• Compensation: long term trend takes into account forecasted inflation (CBO/EIA) and historical increase in compensation</li> <li>• Energy intensity: based on MECS 2002 and energy efficiency increasing by 0.25% per year in reference case for future projections</li> <li>• Steel production assumes a continuation of historical trends for BOF and EAF production</li> </ul>			

important consideration in manufacturing firms' decisions regarding production capacity, output and investment, is whether additional costs they incur, in this case resulting from government-imposed policies, is the extent these costs can be passed through. This has actually happened historically when increasing material and energy costs were driven by global concerns and market balances, but uncertainty remains on whether the US producers, considering the context they are in, would allow for such transfer of costs on to market price and their customers. A cost pass along scenario, simulating a global energy price increase driven by the broader enactment of climate policies by other countries (such as in the European Union), is presented in the findings. On the other hand, while trade balances for each of the industry studied were calculated for the 10 most relevant countries, a detailed analysis of trade impacts based on the advancement of each of these countries is formulating and adopting climate policies was not carried out at this time.

The creation and incorporation of the market dynamic component, when simulating cost pass-along scenarios, adds an important feedback to the model. Such feedback shows that increasing domestic market prices leads to a reduction in market share, according to the sensitivity of the market to changes in prices. As a consequence, the factors defining operating surplus of domestic producers, revenues and production costs, are both influenced by domestic production, which is impacted by the price differential between domestic and foreign production, which in turn defines the domestic market share. Delays and nonlinearity are taken into account in the definition of such feedback in order to correctly represent the real response of the market to increasing

prices driven by growing production costs in the domestic market.

- *Assessing investment options and policy alternatives*: potential investment options – from capacity changes to energy-saving technologies – available for each sector, were identified, and evaluated in light of the production cost-market dynamics simulations. This phase of the work included: (i) a review of technology investment options; (ii) a modeling-based assessment of energy-efficiency requirements; and (iii) a preliminary alternative policy option for offsetting costs.

### 3.1.1. Modeling assumptions

The main baseline assumptions used to calibrate the model are contained in Table 2. All assumptions were discussed with industry representatives to fully incorporate their view and understanding of the market/industry in the modeling work hereby presented. Many assumptions were directly simulated and tested in real time during group modeling sessions and meetings.

### 3.2. Research analysis

We simulated a variety of scenarios for each industry, and conducted sensitivity analyses to examine variations on the key assumptions used in the II-CPM models, concerning material costs, market prices and market sensitivity to price changes. The scenarios presented in this paper are summarized below:

- *Core scenarios*: simulations estimating the impacts of the Low, Mid and High-CO<sub>2</sub> Price Case relative to BAU on the six energy-intensive industries analyzed, assuming no cost pass along by the industries to their customers (NCPA).
- *Cost pass-along scenarios*: simulations of the three CO<sub>2</sub> price cases relative to BAU assuming that the 100% of the additional energy costs are passed along by industries (CPA).
- *Required energy-efficiency gains*: calculations of the energy-efficiency gains required to offset the increased energy costs associated with the climate policy case relative to BAU.

(footnote continued)

production, depending, however, on assumptions about an industry's capabilities to pass through these costs to consumers. A critical issue in the current policy debate regarding manufacturing, is concern that climate policies that drive up domestic manufacturers' costs would place them at a competitive disadvantage relative to foreign firms not similarly burdened by regulations that constrain GHG-emissions.

- **Allowance allocation:** simulations of the impact of an allowance allocations equal to 90% (diminishing by 2% per year) of the increased prices for energy consumed by each industry resulting from CO<sub>2</sub> price cases.

### 3.2.1. Carbon policy and energy price scenarios

The HRS-MI study compares three cap-and-trade policy scenarios based on recent policy proposals and a business-as-usual scenario, which assumes no climate policies are enacted into law throughout the study period. While the “Low-CO<sub>2</sub> Price Policy” accounts for \$12/ton growing at 5% per year in real dollars (EIA, 2007), EIA’s analysis of the “Mid-CO<sub>2</sub> Price Policy” projects the inflation-adjusted (2006 real USD) allowance price to be \$30 per metric ton of CO<sub>2</sub>-equivalent by 2020 and \$61 by 2030 (EIA, 2008a, b, c). The models simulate policy impacts from 1992 through 2030, though the policy cases are assumed not to go into effect until 2012.

The EIA uses its National Energy Modeling System model (EIA, 2003) to analyze energy sector and energy-related impacts of various GHG emission reduction proposals and to create projections of the *Annual Energy Outlook 2008* (EIA, 2008a, b, c). Our study uses AEO 2008 projected energy prices for the reference case (BAU). Furthermore, specific NEMS energy price projections for each policy case – for electricity and five fuel types, including metallurgical coal, natural gas, liquid petroleum gas, residual fuel and distillate fuel – were used as inputs into the HRS-MI models to characterize the carbon policy scenarios.

The AEO 2008 projects the highest price increases by 2030, under the Mid-CO<sub>2</sub> Price Policy case, for carbon intensive energy sources, such as coal coke and metallurgical coal (+180%), followed by residual fuel oil (+43%), natural gas (+39%) and distillate fuel oil (+24%). Finally, electricity and liquefied petroleum gas will incur small and no increases, +13.1% and –0.1%, respectively, (EIA, 2008a, b, c).

It is likely, in light of the increasing volatility of energy prices in the last few years that actual future energy trends will deviate, perhaps substantially, from the EIA model’s projections. For this reason, our interpretation of the cost projections in the HRS-MI study emphasizes the relative changes for the policy cases with each other and the BAU, rather than the absolute values in the future projections.

## 4. Findings

Our findings show that climate change policies that put a price on CO<sub>2</sub> and other greenhouse gas emissions, when applied only in the United States and with no relevant energy-efficiency investments, could have substantial impacts on the competitiveness of US energy-intensive manufacturing industries over the next two decades. On the other hand, we also found that technology investment and policy options exist that could mitigate the industries’ policy-related cost increases, improve their energy efficiency, and ultimately enhance their economic performance.

The extent of these impacts, challenges and opportunities will vary across industries, depending on their energy intensities, the mix of energy sources they rely on (electricity, natural gas, coal), and how energy is used in production activities (heat and power, feedstock). Other factors include the industries’ vulnerabilities to foreign imports and their ability to pass through cost increases to their customers in the face of international market competition. This indicates that, while energy-intensive industries may suffer from the implementation of a climate legislation, some economic sectors will profit from it, as indicated by general equilibrium studies (EIA, 2007, 2008a, b, c).

### 4.1. Higher production costs

Policy-related energy price increases will drive up energy costs, and consequently total production costs, in the energy-intensive industries, depending on the future rate of energy-efficiency improvement and adoption. Not surprisingly, the low carbon-price scenario would generate substantially smaller cost increases compared to the higher carbon-cost scenarios. The extent of these impacts would vary by industry. The iron and steel industry would suffer the largest cost increases under any scenario, ranging from 2.5% to 10% by 2020 and 6% to 18% over business-as-usual. Chlor-alkali production costs also would grow substantially, (4–17% by 2030), while paper and paperboard production costs would rise more modestly (5–9%). Primary aluminum and petrochemicals would experience somewhat smaller cost increases—2–4% and 0.2–5%, respectively. Production costs in secondary aluminum manufacturing, the least energy-intensive of the industries studied (energy costs are only 5% of production costs), would grow only by 0.4–2%.

The industries’ cost impacts reflect the mix of energy sources they rely upon, how energy is used in their production activities, and the range of variation in the prices of these energy sources associated with higher emissions allowance prices. As Fig. 1 illustrates, iron and steel production costs would grow as a result of higher fuel and feedstock energy cost increases. These increases in turn reflect the impact of higher carbon prices associated with climate policies on the prices of metallurgical coal, coke and to a lesser extent, natural gas and fuel oils.

Those industries that rely more on natural gas, fuel oils and coal as fuels for heat and power (paper and paperboard, chlor-alkali), would show relatively more substantial cost increases. However, secondary aluminum production costs would grow very modestly, despite its large reliance on natural gas and fuel oils – and secondarily electricity – for heat and power in its smelting processes – reflecting that industry segment’s low energy intensiveness.

### 4.2. Profit declines and potential threats to production capacity

The HRS-MI industry simulations – assuming that manufacturers will not be able to pass through energy cost increases (no cost pass along, or NCPA), and assuming no relevant energy-efficiency investments – show that as the carbon charge increases, industries would suffer profit declines. The estimates of the impacts on industries’ operating surplus – a proxy for profits – and profit margins take into account the market dynamics associated with international competition. However, these results also only show what might happen if over the 2012–2030 time period, climate legislation and resulting energy price increases, are impacting the US only.

As Fig. 2 shows, using the iron and steel industry as an example, the operating surplus – the difference between market price and production costs – steadily shrinks over time for all the policy cases, and the shrinkage is highest for the higher carbon-pricing cases relative to the low-carbon cost case. As operating surpluses (and profits) are cut into, some manufacturers may eventually find that their operating revenues no longer cover their average production costs (fixed plus variable), which could compel them to take action to mitigate climate policy-induced cost increases.

Every industry in the study would face operating (and/or profit) declines under the carbon-pricing scenarios relative to BAU if costs are not passed along. Not surprisingly, the industries with the greatest production cost increases associated with higher energy costs, also suffer the largest operating surplus/profit

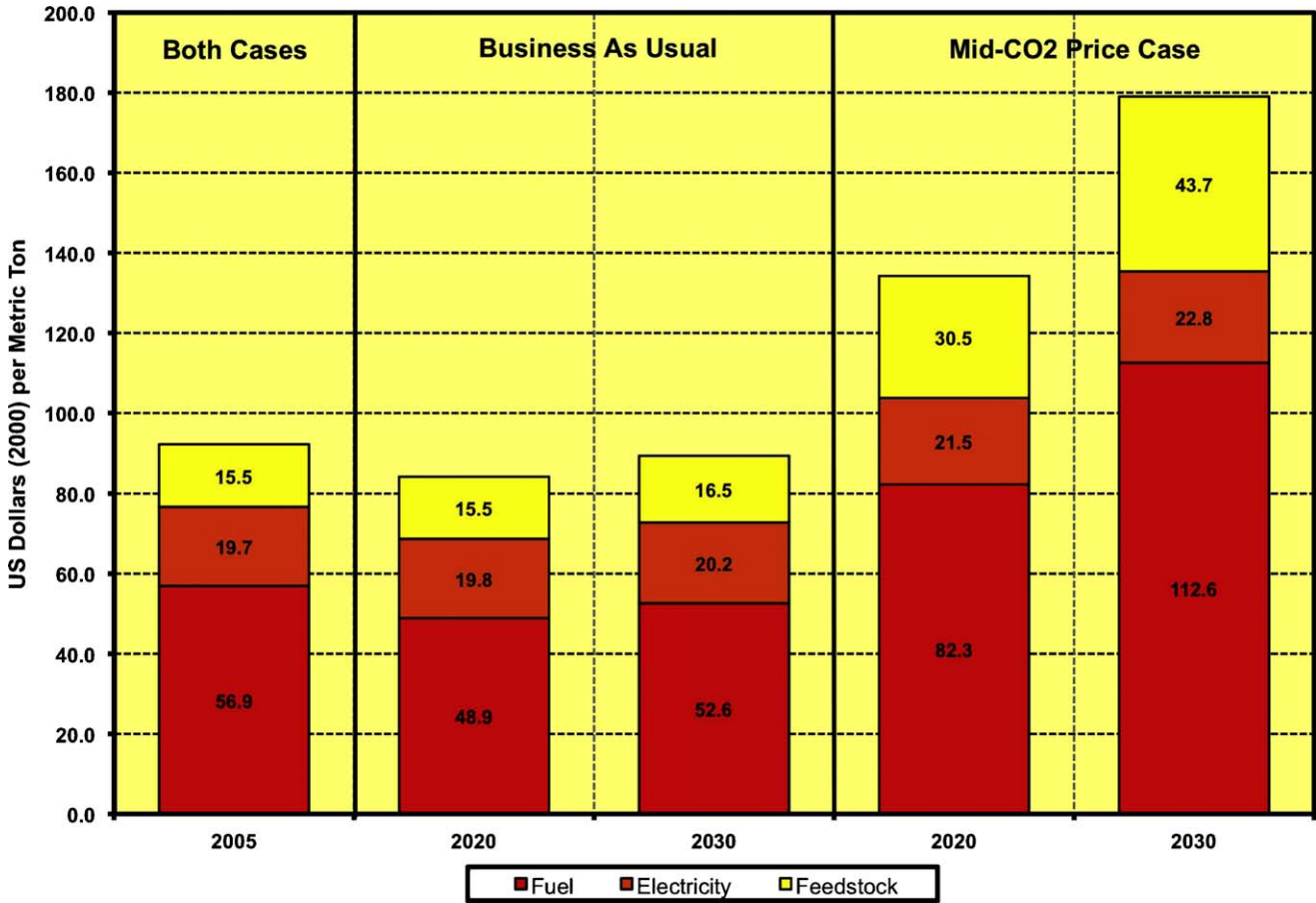


Fig. 1. Energy cost components for iron and steel sector.

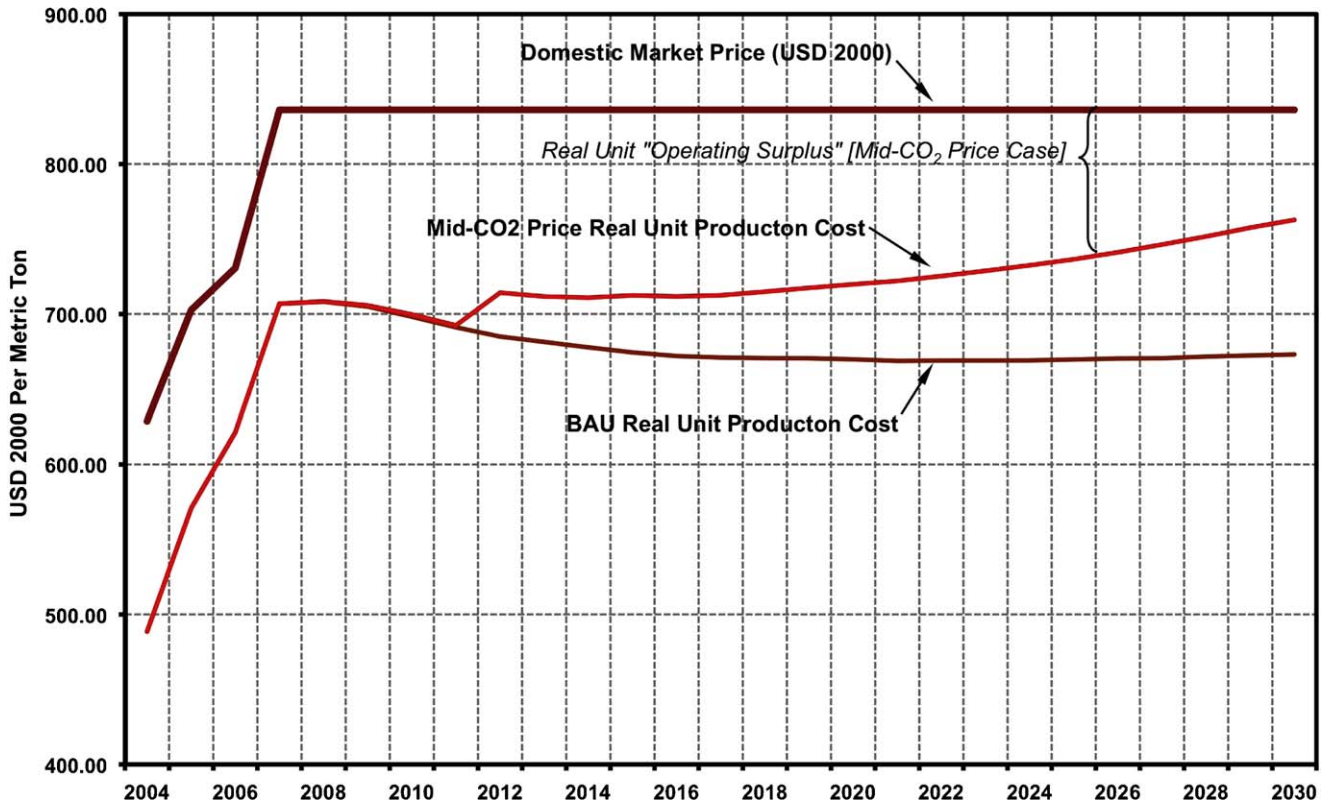


Fig. 2. Iron and steel real unit production cost, compared to domestic market price.

declines. In particular, the iron and steel, chlor-alkali and paper and paperboard industries could experience operating surplus declines, relative to BAU, ranging from 10–40%, 5–28% and 3–11%, by 2020, respectively, and 26–75%, 35–52% and 6–21%, by 2030, respectively, depending on the policy case.

By contrast, declines in operating surplus for petrochemicals, primary aluminum and secondary aluminum do not rise above 10% over the same time period, even under the highest carbon-pricing policy case.

It has to be noted that none of the industries analyzed is projected to incur net losses during the time frame of the study and that the economy-wide impacts of a climate policy would be much milder than those observed on energy-intensive manufacturing sectors.

#### 4.3. Market share losses

In contrast to the NCPA scenarios, if we assume that the industries would pass along all new energy-related costs (CPA) to their customers, they would retain, if not increase, their unit profits (and operating surpluses) relative to BAU. However, they would lose market shares (domestic production as a share of total domestic supply (demand)) to foreign competitors, reflecting the higher domestic prices relative to foreign competitors. If manufacturers simply increase their prices by the exact amount their costs rise (cost basis), unit operating surpluses would hardly change relative to BAU, but total operating surpluses would decline in the medium to longer term because of diminished sales associated with market share losses. If prices were raised to maintain original operating margins (margin basis) – i.e., to maintain the same share of total revenues – unit and total operating surpluses would be substantially higher than the NCPA operating surpluses, even becoming a net positive gain relative to BAU for some industries. These results, for the industries analyzed, would resemble the case in which a global agreement on CO<sub>2</sub> regulation would be reached by the time the US enacts a domestic climate policy. In fact, a partial equilibrium analysis of the CPA scenario, margin basis, equals a case in which prices would increase globally and impacts on the industries' profitability would be in line with BAU results.

On the other hand, if the main trade partners of the United States do not enact a climate legislation similar to the one applied in the US, the IIM-CP simulations show that all industries would suffer some losses in their domestic market shares, ranging from as high as 4.5–11.9% for iron and steel, to as low as 0.2–0.8% for the petrochemical sector.

The extent of these losses in an industry would largely depend on the *elasticity* of demand for its goods – how much the demand for these goods would decline relative to an increase in prices – calculated in this study using historical trade flows, which also reflect the industries' vulnerabilities to import substitution. Iron and steel, aluminum and paper and paperboard have the highest elasticities, while petrochemicals and chlor-alkali have relatively low elasticities.

#### 4.4. Investment options

Manufacturers have several options when confronted with higher production costs. Among others, they could attempt to preserve domestic production capacity by making investments in energy-saving technologies. A review of short, mid and long-term energy-efficiency and energy-reducing technologies available to the industries, suggests that a number of technology options do exist for each industry. However, most of these industries have steadily invested over the years in “low-hanging” fruit – moving

down the energy savings curve – and additional incremental gains in energy efficiency would be relatively small for the high marginal costs required to achieve them. Furthermore, the current economic downturn may not allow industries to access the capital needed to invest in large pieces of equipment, and the capital vintage of industries may further delay the adoption of new technology.

On the other hand, some of these improvements may become more cost effective as energy costs increase in response to CO<sub>2</sub>-pricing policies, making major step jumps in energy-saving production technologies – especially in key process technologies, not just in heat and power generation – more affordable.

##### 4.4.1. Energy-efficiency gains needed

The IIM-CP industry models enabled estimations of the energy-efficiency gains that would be needed in each industry to offset the energy cost impacts from climate policies. The iron and steel industry, for example, would need to increase its energy efficiency in the use of fuels by 41%, in the use of electricity by 8% and in the use of feedstock (coal, coke) by 49%, by 2020 to offset the rise in the costs of these energy supplies under the mid-CO<sub>2</sub> price case. These numbers would rise by 53%, 12% and 62%, respectively, by 2030, if no investments to reduce energy use in iron and steel production were made by then.

Primary aluminum would need to make efficiency improvements of 17% in fuel use and 8% in electricity by 2020, for the same policy case. Similarly, paper and paperboard would need to improve its fuel use by 28%. Chlor-alkali and petrochemicals would need to make efficiency improvements in fuel use of 18% and 16%, respectively, by 2020, to offset higher energy costs due to CO<sub>2</sub> pricing under the same policy.

#### 4.5. Allowance allocation

We also conducted a preliminary examination of policies for mitigating the impacts of carbon-pricing policies on energy-intensive manufacturers. Specifically, the IIM-CP models were used to evaluate a policy that would allocate free emissions allowances that offset the energy cost increases from carbon pricing over 90% by 2012 and reduced annually by 2%. The results showed that, regardless of the policy case or industry, operating surplus reductions as a percent above BAU would be reduced by nearly three-quarters under the allocation scenario compared to the non-allocation case by 2020, and over 50% less by 2030. The implication is that providing free allocations – at least for the short-to-mid-term – would greatly lessen the cost pressures on industries such as iron and steel and chlor-alkali, for example. Ideally, this would buy time for these industries to maintain their domestic production capabilities, until they are able to invest in energy-saving technologies as they become commercially available. Nevertheless, the risk that companies will not invest timely, finding themselves in a more challenging situation as time advances and energy prices increase, should be taken into account.

## 5. Conclusions

This study examines the impacts of energy price changes resulting from different carbon-pricing policies on the competitiveness of six US energy-intensive industries, especially in the face of international competition. Key assumptions of the study include the enactment of climate legislation in the US only and no considerable investment in energy efficiency by the industries analyzed.

The HRS-MI study, a partial equilibrium analysis using System Dynamics industry simulation models, shows that climate change policies that put a price on carbon could have substantial impacts on the competitiveness of US energy-intensive manufacturing sectors over the next two decades if costs cannot be passed along to their customers. The extent of these impacts will vary across industries, depending on their energy intensities, the mix of energy sources they rely on and how energy is used in production activities (heat and power, feedstock). Other factors affecting these impacts include an industry's vulnerability to foreign imports and of course the speed of technology development and technology adoption/turnover.

Furthermore, a preliminary evaluation of an allowance allocation aimed at offsetting industry cost increases shows that this measure might effectively forestall the adverse competitiveness impacts of carbon pricing, at least over the short-to-mid-term, with the risk of delaying (instead of reducing or solving) the negative impacts of increasing energy prices on market competitiveness.

We also began an examination of the extent the energy-intensive industries might be capable of countering the cost impacts from carbon-pricing policies by investing in energy-saving technologies and processes. The study estimated that, depending on the industry and its energy use pattern, significant energy-efficiency gains would be needed over time to avoid and offset rising, policy-driven energy costs. The sooner an industry invests in energy-saving technologies, the greater the cost savings would be, and the greater the opportunity would be to invest in further energy-efficiency improvements.

Limitations of this research concern both methodology and assumptions used. Regarding the former, the partial equilibrium analysis proposed does not account for the positive impacts that a climate policy could have on the economy and on sectors not analyzed in this study, which is an analysis typically provided by general equilibrium models. Regarding the assumptions used, we provide results on a zero or 100% cost pass along, the two extremes on the positive and negative side for the industries analyzed. Furthermore, while insights are provided on the very small impacts, if any, energy-intensive manufacturing sectors will face in case of a global agreement on carbon regulation, most of the analysis focuses on the extreme assumption that a longer term climate policy will be implemented only in the US.

For these reasons, more research is needed to provide a comprehensive analysis of the impacts of climate policy, and the result of this study, complementing existing general equilibrium analyses, should be considered as the worst-case scenario for US manufacturing sectors.

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