ASSURING OHIO'S COMPETITIVENESS IN A CARBON-CONSTRAINED WORLD:

A Collaboration between Ohio University and The Ohio State University

Chapter 2: Task 2, Part 2: Risks and Opportunities for Ohio's Manufacturing Sector in a Carbon-Constrained World

Prepared by: Joel S. Yudken, Ph.D., Principal, High Road Strategies, LLC

TABLE OF CONTENTS

I. CLIMATE RISKS AND OPPORTUNITIES

In our view, the climate change challenge, like other challenges our country has confronted in the past, will create more economic opportunities than risks for the U.S. economy.

—U.S. Climate Action Partnership[1]

I would suggest to my Free Enterprise colleagues whether you think [climate change] is all a bunch of hooey, the Chinese don't. They plan on innovating around these problems, and selling to us, and the rest of the world, the technology that'll lead the 21st century.

—Former U.S. Representative Bob Inglis (R-S.C.)[2]

Probably no state exemplifies as much as Ohio the economic and political challenges confronting the nation in trying to address the threat posed by global warming. This section of the Ohio University and The Ohio State University project, "Assuring Ohio's Competitiveness in a Carbon-Constrained World" ("OU-OSU Project"),[3] produced by High Road Strategies, LLC accepts the conclusion of a recent report by the National Academy of Science, that: "climate change is occurring, is caused largely by human activities, and poses significant risks for—and in many cases is already affecting—a broad range of human and natural systems." As former U.S. Representative Sherwood Boehlert (R-NY), who also chaired the U.S. House Committee on Science notes, this position is also supported by "national academies from around the world and 97% of the world's climate scientists."[4]

---

[1] USCAP U.S. Climate Action Partnership. (2009). *A Call For Action*. Retrieved from www.us-cap.org

[2] Wing, N. (2010, Nov. 18). GOP Rep. Bob Inglis Slams His Party On Climate Change. Message posted to www.huffingtonpost.com

[3] This project is funded through the American Recovery and Reinvestment State Energy Program, administered by the Ohio Office of Development, in partnership with the Ohio Environmental Protection Agency.

[4] Boehlert, S. (2010, Nov. 19). Can the part of Reagan accept the science of climate change. *The Washington Post*. Retrieved from http://www.washingtonpost.com/

At the same time, Boehlert also points out that proposed policy approaches to climate change remain legitimate areas of debate. The climate bill passed by the U.S. House of Representatives in June 2009, H.R. 2454—the *American Climate and Energy Security Act of 2009* (*ACESA* or "Waxman-Markey"[5])—stirred strong reactions, including opposition to the legislation, particularly in the industrial heartland of the country. Especially in the wake of the recent financial crisis and recession, which has hit Ohio and other heartland states' economies especially hard, Ohio businesspeople, workers, and their political representatives, are worried about seeing much higher energy bills and the loss of more factories and jobs, many of which could be forced overseas.[6]

Reasonable risks. These fears are not difficult to understand. Nearly 90% of Ohio's electricity comes from burning fossil fuels—mostly coal. Manufacturing, which is the largest sector in terms of output—and largest private sector employer—in Ohio's economy, is heavily reliant on fossil fuels and electricity. Between 2001-2009, Ohioans saw over one-third of their manufacturing jobs disappear—well over 300,000, including 110,000 lost in 2009 alone—and a net loss of nearly 3,000 manufacturing establishments (of all sizes).

To put this in perspective, the effects of the recent recession aside, manufacturing in Ohio—and in the nation as a whole—has been experiencing a long-term erosion for several decades, though this trend has accelerated significantly since 2000. The underlying causes of this decline have been hotly debated. Many economists and analysts place the blame on faulty U.S. trade and tax policies, and the "neo-mercantilist" industrial strategies of China and other nations—including unfair trade practices, lax labor and environmental regulations, subsidies, non-tariff trade barriers, and currency manipulation, among other practices—that put U.S. manufacturers at a competitive disadvantage in global markets. With this backdrop, it is easy to appreciate the concerns over how climate policies, that could drive up the cost of energy, a key factor of production in many industries, could further hurt the competitiveness of U.S. manufacturers—especially if manufacturers from countries such as China are not subject to the same policy-driven cost constraints.

Clean energy opportunities. On the other hand, the U.S. Climate Action Partnership (USCAP), a coalition of major corporations—Alcan, Alcoa, Chrysler, ConocoPhillips, Dow, Dupont, Duke Energy, Excelon, Ford, GE, PG&E, Rio

[5] Refers to the two Congressmen, U.S. Representatives Henry Waxman (D-CA) and Edward Markey (D-MA) who led the effort to craft and then introduce the bill.

[6] Hebert, H. J. (2009, Oct. 11). Climate plan sends air of unease across Rust Belt. AP Online. Retrieved from http://www.highbeam.com/doc/1A1-D9B8UN3O0.html

Tinto, and Shell, among others—and leading environmental organizations,[7] has stressed that the opportunities could outweigh the risks from "enactment of legislation that slows, stops and reverses the growth of greenhouse gas (GHG) emissions." In particular, USCAP argues, "addressing climate change will require innovation and products that drive increased energy efficiency, creating new markets. This innovation will lead directly to increased U.S. competitiveness, as well as reduced reliance on energy from foreign sources."[8]

The opportunities are not just in the development and deployment of clean energy technologies such as wind, solar, biomass, advanced coal and carbon capture and sequestration, and advanced fuel vehicles. There would be at least as many economic growth opportunities in the cost-effective deployment of numerous existing and new technologies to improve energy efficiency and reduce GHG emissions in buildings, transportation and industrial production. Policies designed to reduce GHG emissions would be the most effective means for driving the development and diffusion of clean energy and energy-efficient technologies throughout the economy, which in turn would generate large numbers of "green" jobs. The best approach, however, would harness the power of the markets, as USCAP notes, "through reliance on institutional and regulatory structures that establish clear targets and timeframes."[9]

Need for analysis. Prospects for enactment of climate legislation in Congress, however, appear dim. Nevertheless, there remain several compelling reasons to examine and assess policies and initiatives aimed at promoting the development and deployment of low-carbon and highly-efficient process and end-use technologies throughout the economy, whether or not they are part of comprehensive climate change measures.

- *The U.S. EPA and several states remain engaged in initiatives to mitigate GHG emissions*—e.g., the EPA under the Clean Air Act [10] and regional cap-and-trade programs. Moreover, there currently are numerous federal and state policies[11] and proposals—and others may be introduced, even in the current political climate—aimed at promoting clean energy and energy-efficient technologies.

[7] These include Environmental Defense Fund, The Nature Conservancy, Natural Resources Defense Council, National Wildlife Federation, Pew Center on Global Climate Change, and World Resources Institute. Other corporate members include AIG, Boston Scientific, BP, Caterpillar, John Deere, FPL Group, Johnson & Johnson, Marsh, NRG, Pepsico, PNM Resources, Siemens, and Xerox.

[8] USCAP. *A Call for Action*.

[9] Ibid.

[10] Bradbury, J. (2010). *EPA, The Clean Air Act, and U.S. Manufacturing*. World Resources Institute. Retrieved from http://www.wri.org/stories/2010/11/epa-clean-air-act-and-us-manufacturing

[11] World Resources Institute. (2009). *Regional Cap-and-Trade Programs*. WRI Fact Sheet.

- *Although many new members of the incoming 112th Congress have expressed doubts about the threat of climate change, and especially, that human activity is responsible, the problem of climate change is not going away.* Sooner or later, the nation will have to address the threat of climate change and make serious efforts to move down the low-carbon emissions path. As USCAP has argued, it will better for businesses to have clear, stable regulations in place, to take advantage of the opportunities created when the U.S. finally is ready to make this transition.
- *Industrial strategies to promote U.S. capacity to make clean products and adopt energy-efficient, low-carbon technologies in manufacturing would enhance U.S. industrial competitiveness, stimulate innovation, generate economic growth and create new jobs.* These initiatives could involve partnerships between government and the private sector, and between the federal and state governments. Bipartisan clean energy and energy-efficiency tax, R&D investment, and related policies, are not totally out the realm of possibility—if they are clearly tied to promoting U.S. manufacturing competitiveness—an especially appealing prospect for industrial heartland states, such as Ohio.
- *America's major trading partners, especially China, Japan and Europe, are not waiting to pursue clean-energy and low-carbon technology and product opportunities.* Japan and Europe have already adopted GHG emissions mitigation programs and are pursuing industrial strategies to develop clean-energy technologies, and promote low-carbon, energy-efficient manufacturing industries. China meanwhile has become a dominant player in the global economy in manufacturing and exporting renewable energy technologies. The question remains whether the United States will ever be able to reassume leadership in the production and use of these products. And in any case, even if U.S. manufacturers continue to make clean-energy products, will the steel, aluminum, chemicals, plastics and other basic materials they need be imported from China or other countries?

Chapter overview. The climate and energy policy debate in Ohio is a microcosm of the larger national debate over the impacts of climate change legislation on economic activity. Federal and state climate and clean energy policies could pose genuine economic risks for Ohio's economy, depending on what they are and how they are implemented. On the other hand, such policies could create substantial economic opportunities and benefits for Ohio businesses and workers. The goal of this chapter is to examine both sides of this debate, identifying and evaluating the risks and opportunities associated with climate and clean energy policies, as well as the implications for Ohio's economy, and in particular, its manufacturing sector.

First, this chapter provides an overview and profile of Ohio's manufacturing sector, summarizing both its economic and energy/emissions characteristics. It also identifies which manufacturing industries are likely to be the most economically vulnerable to carbon constraining policies. These typically include energy-intensive trade-exposed (EITE) industries—i.e., they are both heavily reliant on fossil-fuel energy sources and/or fossil fuel generated electric power (and consequently, energy costs account for a relatively large share of their production costs), and, they are highly sensitive to global competition. EITE industries constitute an important segment of the overall Ohio manufacturing base, though there are other important manufacturing industries (autos, industrial machinery) which are not as energy/emissions intensive, but which nevertheless are large GHG emitters, and therefore, potentially subject to emission regulations.

Second, drawing upon and extrapolating from the existing body of literature on climate policy impacts on manufacturing industries and related studies, mostly performed at the national level, this chapter includes a preliminary assessment of the potential economic impacts on Ohio's manufacturing sector, especially its EITE industries, associated with different GHG emissions mitigation policies. This analysis includes comparisons of provisions associated with climate legislation designed to contain and mitigate costs, with policies lacking such measures, as this provides insight into alternative approaches for limiting the risks to Ohio's economy from carbon constraining policies.

Third, this chapter explores a range of options and opportunities for promoting manufacturing growth and competitiveness in Ohio associated with enactment of climate and clean-energy policies, at both the federal and state levels. Many new opportunities for manufacturing clean-energy technology products (renewables, clean coal, advanced fuel vehicles and parts) could be stimulated and enabled by appropriate policies. However, this section examines the energy-efficiency and carbon-abatement opportunities that could result in significant energy savings for Ohio's EITE manufacturing industries, and the policy options—technology innovation, investment, tax, financing, and technical assistance policy options, among others—that could enable them to realize these gains.

Of additional interest are cost-effective strategies, catalyzed and enabled by government policies, but ultimately led and implemented by the private sector, that would promote the conversion to a low-carbon, highly energy-efficient manufacturing base in Ohio. Such a conversion would be key to enhancing Ohio's manufacturing competitiveness, which in turn is vital to revitalizing the state's economy and the preservation and creation of numerous skilled, middle-class jobs.

II. MANUFACTURING IN OHIO

Ohio is one of the premier manufacturing states in the United States. It ranks third in the nation, behind only California and Texas, in the size of its manufacturing output—$84.058 billion, or 5.13% of the U.S. total, in 2008—and in the number of manufacturing jobs—614,500, or 5.3% of the U.S. total, in 2009.[12] In 2009, Ohio was also the seventh largest exporting state—its exports totaled $34.1 billion, and its largest export markets included Canada (42%), Mexico (8%) and China (6%).[13]

Ohio leadership in manufacturing is also reflected in its consistently high ranking in numerous industry sectors—the Ohio Manufacturers' Association (OMA) reports that Ohio is first, second or third among U.S. manufacturers in 84 six-digit industry categories under the North American Industry Classification System (NAICS).[14] Indeed, many manufacturing sectors exist in larger concentrations

[12] Total U.S. manufacturing output in 2008 was $1,636.7 billion, of which CA accounted for 11.1% ($181.1 billion) and TX, for 9.1% ($158.8 billion). The remaining seven in the top ten, in terms of output, included IL, NC, PA, NY, IN, MI, and WI. Total U.S. manufacturing employment in 2009 was 11.63 million, of which CA accounted for 11.0% (1.28 million), and TX, for 7.1% (820,000). The next 7 states in the top ten in terms of manufacturing jobs were IL, PA, NY, MI, IN, NC, and WI. Cited in Ohio Manufacturers' Association (OMA). (2010). *Ohio Powered by Manufacturing.* Output data source is the Ohio Department of Development (ODOD). Manufacturing employment data is from *State Rankings 2010 A Statistical View of America*.

[13] TX, CA, NY, WA, FL, and IL all had greater exports. The United Kingdom, Greece, Brazil, Japan, and Germany each accounted for 3% of Ohio's exports, France and Australia for 2% each, and all others for a total of 25%. Cited in OMA. *Ohio Powered by Manufacturing*. p. 16; data is from ODOD, Policy Research and Strategic Planning Office. *Ohio Exports 2009*.

[14] NAICS is a hierarchical system of categorizing industrial groups and industries, which is divided up into 2-digit "supersectors," such as manufacturing (31-33) and utilities (22). Each 2-digit sector includes several related industry subsectors (3-digit NAICS)—e.g., chemicals (325) and primary metals (331) in the manufacturing supersector—which in turn include 4-digit industrial groups—e.g., basic chemicals (NAICS 3251) in chemicals, and iron and steel and ferroalloys (NAICS 3311) and aluminum (NAICS 3313) in primary metals. Each of the 4-digit NAICS groups includes more specific, disaggregated sets of industries (5-digit and 6-digit NAICS)—e.g., alumina (331311), primary aluminum (331312), and secondary aluminum (331314) in the 4-digit aluminum manufacturing sector (3313).

in Ohio compared to the nation as a whole.[15] The OMA also notes that Ohio accounts for 25% of all U.S. production in three categories, in particular: rolling mill machinery and equipment manufacturing; motor vehicle metal stamping; and custom metal roll-forming.[16]

Manufacturing is also the largest sector in Ohio's economy. It ranks first among all industrial sectors in total output, accounting for 18% of Ohio's gross state product (GSP) and is the state's largest private sector employer, with a workforce of well over 700,000—only the government sector employs more workers (see Table 1). Manufacturing leads all industrial sectors in total state payroll as well—paying out $38.4 billion in wages to employees 2008—followed by government, health care, and professional and technical services.[17]

Table 1. Ohio Industrial Sector Output and Employment[1]

	Output (2009)*			Employment (2008)**		
Industrial Sector	Rank	Contribution to Ohio GSP (billions of $)	% of Ohio GSP	Rank	Monthly Employment Average	% of Ohio Jobs
Manufacturing	1	84.1	17.8	2	738,817	14.1
Government	2	54.1	11.5	1	751,347	14.4
Real estate, rental & leasing	3	46.7	9.9	17	63,365	1.2
Health care & social assistance	4	40.2	8.5	3	704,168	13.5
Finance and insurance	5	34.7	7.4	9	217,743	4.2
Retail trade	6	30.3	6.4	4	589,841	11.3
Wholesale trade	7	30.1	6.4	8	236,490	4.5
Professional & technical services	8	29.0	6.2	7	250,485	4.8
Transportation & warehousing	9	16.5	3.5	11	180,262	3.4
Ohio Total		**472.2**			**5,158,594†**	

1 *All data cited in OMA. (2008). Ohio Powered by Manufacturing. pp. 7, 9.*
* *ODOD Policy Research and Strategic Planning Office Gross Domestic Product of Ohio.*
** *Ohio Dept. of Job and Family Services, Office of Workforce Development. (2008) Bureau of Labor Market Information.*
† *Total covered under Ohio Unemployment Compensation Law.*

[15] An important indicator of this concentration is the Location Quotients (LQ) employed by the U.S. Bureau of Labor Statistics (BLS), which reflects the relative economic importance—i.e., as a job provider—of an industry sector within a geographical area (state, county). If an area's LQ is greater than 1.0 for given industry sector, the industry has a greater share of employment in that area than across the nation. High LQs also reflect the likely existence of significant industry clusters within a geographical area. Based on BLS data, Ohio's LQs can be shown to exceed 1.0 for manufacturing as a whole, and for 11 major (3-digit NAICS) sectors. For several sectors, the employment ratio is nearly or greater than twice the U.S. ratio, with primary metals (LQ of 2.6) approaching a ratio of 3 times the national level. See http://data.bls.gov/8080/LOCATION_QUOTIENT/

[16] OMA. *Ohio Powered by Manufacturing*. p. 23.

[17] OMA. (2008). *Ohio Powered by Manufacturing*. p.14; data is from Ohio Department of Job and Family Services, Office of Workforce Development, Bureau of Labor Information.

Geographic concentration. The sector's economic importance to the state is further reflected in the unusually high concentration of manufacturing jobs throughout the state. In about half of Ohio's 88 counties, 15% or more of all workers are employed in manufacturing.[18] As Table 2 shows, the top 15 counties ranked by total manufacturing employment—which include the largest metropolitan centers and account for well over half of all manufacturing jobs in the state—average a little under 15% of total employment tied to manufacturing. In Cuyahoga County, manufacturing still accounts for nearly one in ten workers.

Table 2. Top 15 Manufacturing Counties in Ohio, 2008[1]

Ranked by Total Manufacturing Employment:					Ranked by Manufacturing Share of County Jobs:				
County	No. Establishments	Employment	% of State Manuf Jobs	Manuf % of County Jobs	County	No. Establishments	Employment	% of State Employment	Manuf. % of County Jobs
Cuyahoga	2,117	79,603	10.7	9.1	Shelby	142	12,966	1.8	38.0
Hamilton	1,110	51,710	7.0	9.3	Williams	133	7,383	1.0	32.6
Franklin	913	34,708	4.7	5.0	Fulton	115	8,491	1.1	30.4
Summit	909	33,152	4.5	10.7	Union	54	7,208	1.0	30.3
Montgomery	811	32,794	4.4	11.1	Holmes	266	6,415	0.9	28.6
Stark	530	25,428	3.4	14.2	Sandusky	116	9,515	1.3	26.9
Lucas	543	24,181	3.3	9.0	Auglaize	87	7,890	1.1	26.7
Lake	672	21,289	2.9	17.7	Wyandot	43	2,686	0.4	25.4
Butler	428	19,857	2.7	10.6	Jackson	36	4,000	0.5	25.1
Trumbull	245	19,655	2.7	17.0	Van Wert	45	3,663	0.5	24.9
Lorain	396	18,228	2.5	15.5	Huron	103	6,873	0.9	24.2
Warren	226	13,741	1.9	13.6	Pike	29	3,129	0.4	23.8
Shelby	142	12,966	1.8	38.0	Logan	54	~7,500	1.0	23.6
Geauga	201	12,765	1.7	18.8	Henry	48	3,248	0.4	23.1
Wood	198	12,206	1.6	17.6	Paulding	40	1,743	0.2	23.0
Sub-Total:	9,441	412,283	55.5	14.5*	Sub-Total:	1,311	92,710	12.5	27.1*
Total Ohio Manufacturing Employment: 742,787					Total Ohio Manufacturing Employment: 742,787				

* Average of manufacturing share of total county jobs.

[1] Manufacturing share of county employment is for 2007.

Sources: U.S. Census Bureau, ODOD, OMA.

[18] OMA. (2009). *Ohio Powered by Manufacturing*. p. 12; data is from ODOD, Policy Research and Strategic Planning Office. *Ohio County Indicators*.

The top 15 counties with the largest concentration of manufacturing jobs—averaging 27.1% of total jobs in each county—account for 12.5% of Ohio's manufacturing jobs. In short, whether in highly populated counties or more rural counties characterized by small towns, manufacturing remains a major source of employment and driver of economic growth throughout Ohio.

Primary sectors. Ohio's manufacturing base is geographically widespread and consists of a wide range of industries, from high tech producers of computers and electronic and aerospace products, to traditional manufacturing sectors. The latter, which the OMA notes "provide a foundation for the state's economy," accounts for the majority of manufacturing jobs in the state. In Table 3, the largest sectors are ranked according to their value added,[19] rather than value of shipments. Value added more accurately reflects the actual economic contribution of a sector to the state's overall GSP. For example, petroleum and coal products (NAICS 324), not shown in the table, ranks as one of the largest in terms of value of shipments ($23.26 billion in 2008), but 14th in value added ($2.05 billion) because of the relatively high expenditures for raw materials (i.e., oil, coal, etc. costing over $20.9 billion). It also is a relatively small employer, providing fewer than 5,000 jobs in 2008.

The 10 sectors in Table 3 represent well over 80% of the state's manufacturing base, including manufacturing jobs. All but paper manufacturing are the largest sectors in terms of employment.[20] However, the two biggest manufacturing sectors in Ohio, transportation equipment (motor vehicles, aerospace) and fabricated metal product manufacturing, alone account for one-third of value added, value of shipments and employment in the state.

[19] According to the Census Bureau's *American FactFinder* (http://factfinder.census.gov), "value added" is calculated by subtracting the cost of supplies, raw materials, purchased machinery installed, purchased fuel, purchased electricity, and contract work from the sum of the value of shipments and receipts for services and capital expenditures. This calculation is adjusted by the addition of value added by merchandising operations (i.e., the difference between the sales value and the cost of products sold without further processing). "Value added" avoids the duplication in the figure for value of shipments and receipts for services that results from the use of products of some establishments as supplies, energy sources, or materials by others.

[20] Non-metallic mineral product manufacturing (327), miscellaneous manufacturing (339), and printing and related support activities (323) employ more workers than the paper sector, but have smaller value added and value of shipments—they rank 11th, 12th and 13th respectively in terms of both indicators.

Table 3. Ohio's Largest Manufacturing Sectors (2008)

NAICS Code	Industry Sector	Value added ($ Billions)	Value of shipments ($ Billions)	Employ-ment*
336	Transportation equipment	22.60	67.06	114,989
332	Fabricated metal product	16.53	31.73	120,093
325	Chemical	14.20	29.36	38,349
311	Food	11.13	25.35	52,431
331	Primary metal	10.24	32.30	45,195
333	Machinery	9.90	19.98	76,318
326	Plastics & rubber products	7.24	17.08	70,549
334	Computer & electronic product	5.05	7.87	30,878
335	Electrical equipment, appliance, & component	4.92	10.18	32,151
322	Paper	3.31	7.69	21,704
Total Manufacturing		**121.53**	**298.16**	**732,335**
Percent of Total Ohio Manufacturing		86.5	83.4	82.3

* Number of paid employees for pay period including March 12.
Data Source: U.S. Census Bureau. *Annual Survey of Manufactures, Statistics for All Manufacturing by State 2008 and 2007*.

Manufacturing trends. Ohio's manufacturing sector has shown the same signs of decline and erosion as the nation as a whole, especially over the past decade, a trend exacerbated by the recent recession and financial crisis. The United States lost a net of over 51,000 manufacturing establishments of all sizes, a 12.5% decline, between 1999 and 2008. An additional 5,730 establishments were lost in 2009, bringing the total to over 57,000.[21] Similarly, over 6 million American manufacturing jobs, one-third of the U.S. manufacturing workforce, have been lost since 1998. The aggregate national trends of declining numbers of manufacturing establishments and employment are replicated in most manufacturing sectors and subsectors.[22] These trends reflect the steady decline in U.S. competitiveness in global markets, indicated by America's massive trade deficits in goods—over $800 billion in 2008, including advanced technology products, once a major area of comparative advantage for U.S. manufacturing

[21] Data source: U.S. Bureau of Labor Statistics' (BLS). *Quarterly Census of Employment and Wages (QCEW)*. Retrieved from http://www.bls.gov/cew/cewsize.html. The number of establishments lost in a specified period of time is the net of the number of establishments that were closed and the number that were created over that period. These include establishments with anywhere from only one employee to 1,000 or more employees.

[22] BLS. *Current Employment Survey*. Retrieved from www.bls.gov.

—and a steadily rising import penetration into U.S. markets, in numerous manufacturing industries.[23]

As shown in Figure 1, in Ohio there has been a similar steady decline in both manufacturing employment and the number of manufacturing establishments from 2001-2009. Ohio has lost nearly one-quarter of its manufacturing workforce since the beginning of the decade, falling from over one million to almost three-quarters of a million by 2008. In 2009, it lost another 110,000 jobs or 11% relative to 2001 levels as result of the recession; it continued to fall in the first quarter of 2010, until showing signs of a slight recovery during the remainder of the year.[24] The number of manufacturing establishments in the state also dropped by about 2,300 between 2001 and 2008, a 12% net loss, and by an additional 500 in 2009.

As Figure 2 shows, the Ohio manufacturing sector's value added suffered a similar decade-long net decline, in real dollar terms (indexed to 2005). Between 1998 and 2008, Ohio's manufacturing sector lost $27.5 billion or one-fifth of its value added. In 2009, alone, however, it lost an additional $22.4 billion in value added—a total decline of one-third of Ohio's value added since 1998.[25]

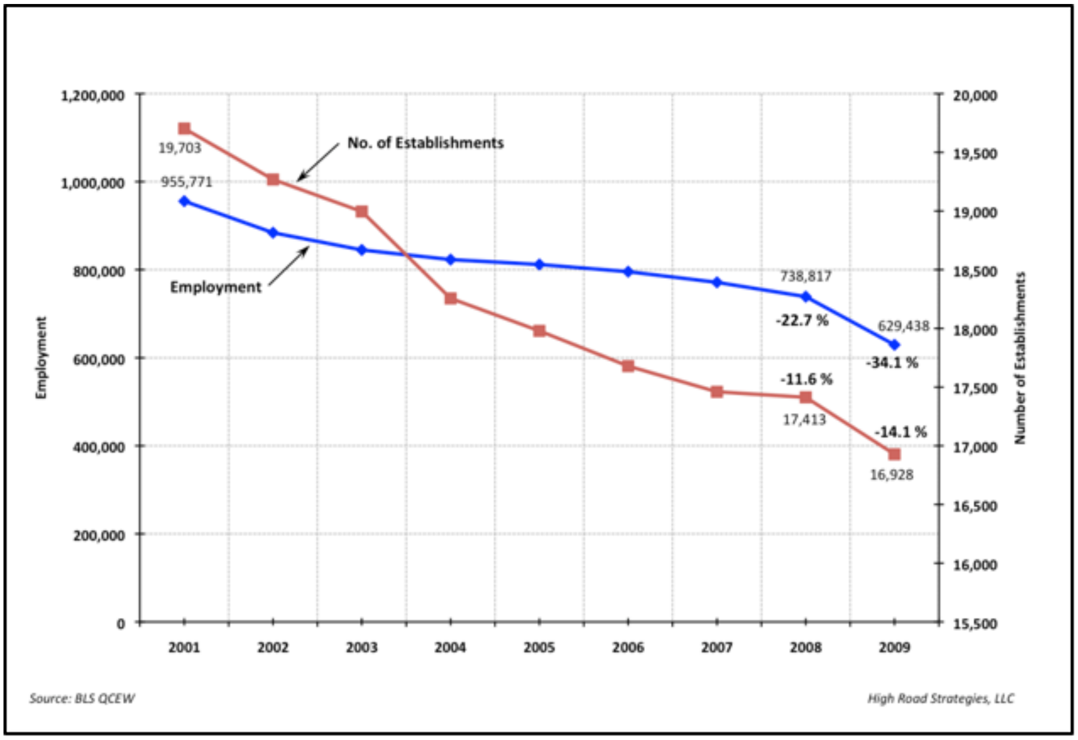
These trends potentially pose significant challenges to any federal or state policies that attempt to mitigate greenhouse gas emissions associated with fossil-fuel energy consumption by Ohio's manufacturing sector. The long-term closure or movement of plants offshore, the steady, large-scale job loss over the past decade and an unemployment rate indicating that at least one in ten Ohioans are jobless, are not conducive to enacting environmental policies that many perceive could put Ohio manufacturing firms at a competitive disadvantage.

[23] For an in-depth examination of the long-term, secular erosion in the U.S. manufacturing base, which accelerated since 2000—and exacerbated even further by the recession and financial crisis—see Yudken, J. S. (2010, Apr.) *Manufacturing Security: America's Manufacturing Crisis and the Erosion of the Defense Industrial Base*, Prepared for the Industrial Union Council, AFL-CIO. (Arlington, VA: High Road).

[24] The figure shows the available data from the BLS's Quarterly Census of Employment & Wages (QCEW), but the references to employment levels before 2001 (i.e., 2000) and in 2010 are from the BLS's Current Employment Statistics (CES). The CES and QCEW are separate surveys, so there usually is a small difference in their employment numbers for the same year.

[25] U.S. Census Bureau. *Annual Survey of Manufactures: Geographic Area Statistics*. Retrieved from http://www.census.gov/manufacturing/asm

Figure 1. Ohio Manufacturing Employment and Establishments, 2001-2009

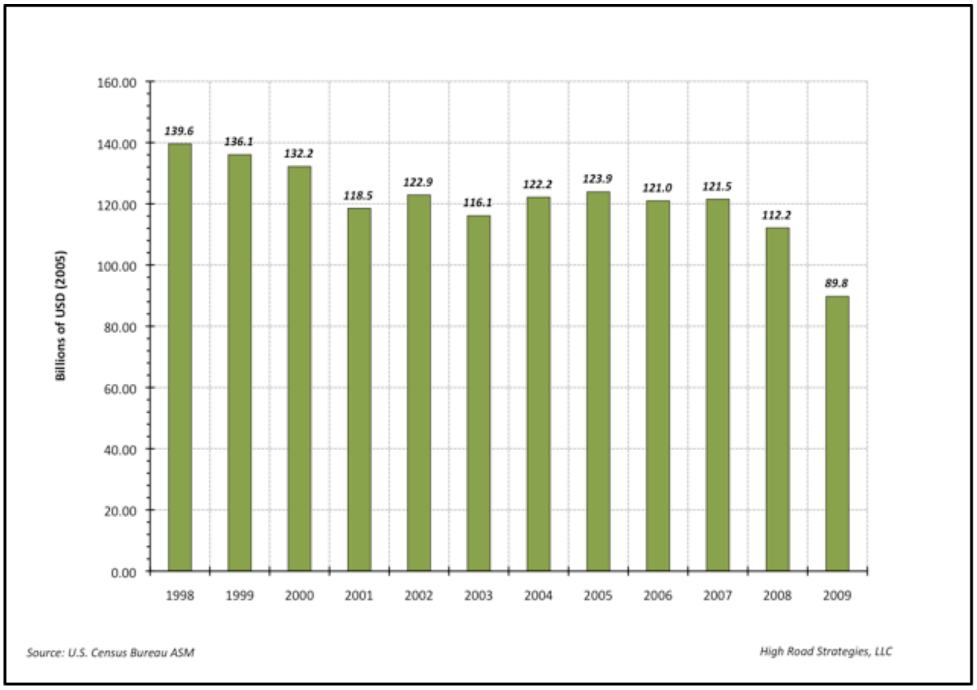


Many key Ohio manufacturing industries also are sensitive to international competition, and could be economically vulnerable if the U.S. imposed carbon pricing that many foreign producers would not be subject to. Ohio was the nation's 7th largest exporting state in 2009—its top exporting industries include machinery, vehicles (except railway), aircraft and spacecraft, electrical machinery, plastics, and optical and medical instruments.[26] Unfortunately, data limitations make it difficult to reliably calculate the trade balance (exports minus imports) for industrial sectors at the state level. However, at the national level, several manufacturing industries prominent in Ohio have had consistent, and in some cases large and growing, trade deficits with international competitors (iron and steel, ferroalloys, primary and secondary aluminum, cement, nitrogenous fertilizer, autos), though a few others (plastics and resins, several other chemical manufacturing sectors, some but not all paper and paperboard segments) have enjoyed trade surpluses.[27]

[26] These six industries accounted for 61% of Ohio's total exports in 2009. See OMA. *Powered by Manufacturing.* p. 18.

[27] The Census Bureau's foreign trade data section can provide some detailed export data at the state level back to 2000, but only provides state import data back to 2008. In addition, the Census Bureau cautions against calculating trade balances by subtracting state imports from state exports for a given year, because of various uncertainties, including determining where imports in a given state might actually be consumed (i.e., they may be reported as coming into Ohio, but then sold and consumed out of state). See http://www.census.gov/foreign-trade/index.html

Figure 2. Ohio Manufacturing Real Value Added, 1998-2009



On the other hand, these challenges highlight the potential benefits of considering a range of options to mitigate emissions and fossil fuel energy costs, as well as opportunities for promoting low-carbon, energy-saving practices and technologies in Ohio's manufacturing sector. As explored later in this section, such strategies could help enhance the competitiveness of Ohio's manufacturing industries and promote the retention, recovery and creation of many new jobs.

III. OHIO INDUSTRIAL ENERGY USE AND CARBON EMISSIONS

Although Ohio is only a moderate producer of energy resources, it is one of the largest consumers of energy in the nation. Most of the state's energy consumption consists of fossil-fuel energy sources (coal, natural gas, petroleum products) used to supply heat and power, including electricity generation, for buildings, industry, and transportation. The industrial sector is the largest consumer of fossil-fuel energy, mostly for energy-intensive and other large manufacturing industries. As a result, Ohio ranks as one of the largest emitters of GHG emissions in the United States.

Energy overview. Table 4 summarizes the main characteristics of Ohio's energy production and use, mostly based on data from the U.S. Department of Energy's (DOE) Energy Information Administration (EIA). Consistent with having the nation's 7th largest population (11.5 million people) and civilian labor force (5.9 million workers), Ohio is the 6th largest energy consuming state,[28] though on a per capita basis it only ranks 24th (2008). Reflecting its large reliance on fossil-fuel energy, it is the 3rd largest consumer of coal, 7th largest user of natural gas, and ranks 8th in petroleum consumption.

[28] It was surpassed by Texas, California, Florida, Illinois and New York, all states with large populations and significant industrial capacities. Pennsylvania and New Jersey, and to a lesser extent, North Carolina, are also large energy users, again, mostly reflecting population and industrial activity.

Table 4. Profile of Ohio's Energy Production and Use

Source or Sector	Quantity	U.S. Rank	Data Year
Energy Production			
Total (trillion Btu)	1,050	17	2008
Crude Oil (thousand barrels)	486	17	Jul-10
Natural Gas (million cu. ft.)	84,858	20	2008
Coal (thousand short tons)	26,251	11	2008
Electricity (thousand MWh)	14,654	6	Aug-10
Energy Consumption			
Total (trillion Btu)	3,987	6	2008
Petroleum (trillion Btu)	1,300	8	2008
Natural Gas (trillion Btu)	824	7	2008
Coal (trillion Btu)	1,438	3	2008
Retail Electricity (trillion Btu)	544	4	2008
Per Capita (million Btu)	346	24	2008
End-Use Sector Consumption			
Residential (trillion Btu)	952	6	2008
Commercial (trillion Btu)	710	6	2008
Industrial (trillion Btu)	1,341	4	2008
Transportation (trillion Btu)	984	8	2008

Source: U.S. Energy Information Administration.

However, Ohio ranked only 17th in energy production in 2008, producing relatively small quantities of crude oil and natural gas relative to other energy producing states. On the other hand, it has the second-highest petroleum refining capacity in the Midwest, supplied with crude oil mostly delivered by pipeline from the Gulf Coast and through an oil transportation hub in central Illinois. It ranked higher as a coal producer, 11th, in 2008. Coal mines in the Appalachian basin in the eastern part of the state typically supply about one-third of its coal consumption; the remainder is shipped in from West Virginia, Wyoming, Kentucky and Pennsylvania.

Electric power generation and use. Table 4 also includes a profile of Ohio's electric power sector.[29] Nationally, Ohio is the 4th largest electricity consuming state and the 6th largest electricity generator—14,654 thousand

[29] U.S. EIA. (2009). *Map of Ohio*. Retrieved from http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=OH#Datum

MWh (August 2010). It also is a major importer of electricity. Electric power generation uses over 90% of coal consumed in the state, and, correspondingly, coal typically fuels close to nine-tenths of net electricity generation—85.2% in 2008. Nuclear power is the second largest generator of electricity, providing a little over one-tenth in 2008. Natural gas and petroleum each account for 1-2% of electric power generation, while renewable energy sources, including hydroelectric, account for less than 1%.

However, the EIA notes that the Ohio has significant offshore wind energy potential. In 2008, Ohio established an alternative energy portfolio standard through Ohio Senate Bill 221, which mandates that 25% of all electricity in the state come from advanced energy resources—wind, solar, hydroelectric, geothermal, biomass, clean coal, etc.—by 2025, at least half of which must be generated in Ohio itself. Whether this mandate persists, and will help to foster accelerated adoption of renewable energy sources, remains uncertain.

Ohio's electricity generation dependency on coal has made it one of the nation's largest emitters of polluting gases, including sulfur dioxide and nitrogen oxide, and carbon dioxide. Over 95% or more of these emissions are tied to coal use. In 2009, Ohio ranked third in the nation in CO_2 emissions produced by electricity generation—nearly 129 million metric tons, 5% of total U.S. CO_2 emissions[30]—only a little behind Pennsylvania, though both are far behind Texas, which produces over twice the emissions of either state.

Industrial sector energy consumption. The EIA provides energy data associated with four primary sectors (two-digit NAICS) categories, which are defined below:

- *The industrial sector,* which consists of all facilities and equipment used for producing, processing, or assembling goods. It includes manufacturing (NAICS 31-33); agriculture, forestry, fishing and hunting (NAICS 11); mining, including oil and gas extraction (NAICS 21); and construction (NAICS 23).
- *The transportation sector,* which consists of all vehicles whose primary purpose is transporting people and/or goods from one physical location to another. It includes automobiles; trucks; buses; motorcycles; trains, subways, and other rail vehicles; aircraft; and ships, barges, and other waterborne vehicles.
- *The residential/commercial sectors,* which consist of housing units, wholesale or retail businesses (except coal wholesale dealers); health

[30] Ohio's share of sulfur dioxide (SO_2) emissions is twice that of the share of total U.S. emissions of SO_2—10.5% in 2009. It also produced a little less than 5% of U.S. nitrogen oxide emissions in 2009.

institutions (hospitals, social and educational institutions including (schools and universities); and federal, state, and local governments (military installations, prisons, office buildings, etc.).[31]

- *The electric power sector,* consisting of electricity only and combined heat and power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public, i.e., plants in the NAICS 22 industry classification.[32]

[31] Vehicles whose primary purpose is not transportation (e.g., construction cranes and bulldozers, farming vehicles, and warehouse tractors and forklifts) are classified in the sector of their primary use.

[32] Excludes shipments to federal power projects, such as TVA, and rural electrification cooperatives, power districts, and state power projects.

As shown in Table 4, in 2008, Ohio's industrial sector ranked fourth in the nation in end-use energy consumption, the residential and commercial sector ranked sixth, and transportation ranked eighth. The residential/commercial sectors accounted for a combined 42% of all end-use energy consumption in the state, transportation for 25%, and the industrial sector for 34%.

Table 5 shows the breakdown of energy consumption by source by the principal sectors, and is summarized below:

- Coal is mostly consumed in electric power generation, though 8% is consumed by industry.
- Natural gas consumption is evenly split between the residential and industrial sectors, which used close to 40% and one-third, respectively, and the commercial sector, which used about one-fifth.
- Transportation vehicles account for about three quarters of petroleum consumption, and industry uses about one-quarter of petroleum-based products for heat, power, and feedstock (especially petroleum refining).
- Renewable sources are spread between residential (almost one-quarter), industrial uses (one-third), and transportation (31%). Only 6% of renewable sources in the state (including hydroelectric) are used to generate electricity.
- The residential/commercial sectors account for two-thirds of retail electricity sales, for heating, cooling and electric power used by buildings and facilities, personal consumer uses, and for numerous commercial activities (e.g., dry cleaning; data centers; copiers, etc.).

Table 5. Sector Shares of Energy Fuels Consumed in Ohio (2008)

Sector	Energy Fuel and Source					
	Coal	Natural Gas	Petroleum	Renewables	Nuclear Electric Power	Retail Electricity Sales
All Sectors (trillion Btus)	1,438	824	1,264	115	183	544
Residential	0%	39%	3%	23%	—	34%
Commercial	0%	21%	1%	4%	—	30%
Industrial	8%	36%	21%	36%	—	37%
Transportation	*	1%	74%	31%	—	*
Electric Power	92%	3%	1%	6%	100%	—
All Sectors (percent)	100%	100%	100%	100%	100%	100%

Source: EIA ** Negligible*

The industrial sector is the leading end-use consumer of energy in Ohio, largely due to several energy-intensive industries, such as chemicals, iron and steel, aluminum, metal casting, and glass, among others. Manufacturing dominates the sector's energy use—the other industrial subsectors, such as agriculture, construction, and mining use only a small fraction of the energy consumed by the overall industrial sector. Other characteristics of the industrial sector's energy use include the following:

- The industrial sector accounts for a little over one-third, 37% in 2008, of retail electricity sales.
- Energy used by the industrial sector is largely for process heat and cooling and powering machinery, with smaller amounts used for facility, heating, air conditioning, and lighting.
- Fossil fuels (coal, petroleum, natural gas liquids, liquefied petroleum gas) are also used as raw materials inputs (feedstock) in the production of manufactured products.
- The sector also includes onsite generators that produce electricity and/or useful thermal output primarily to support production and other industrial activities.
- As Table 6 shows, natural gas accounts for one-third of the net energy the industrial sector consumes. Petroleum is second, with 29%—largely due to the large petroleum refining capacity in the state. Coal only provides a little over one-tenth the energy used by the sector, and electricity for a little over one-fifth. Biomass provides less than 5% of the energy consumed by industry.

Energy use and carbon emissions. The predominant use of fossil fuels in industrial production, for heat, power and feedstock, results in a substantial amount of direct emissions of GHG gases being released by industrial facilities. In addition, since nearly 90% of Ohio's electricity is generated using fossil fuels, and more than a third of that electricity is consumed by the industrial sector, a substantial amount of the emissions resulting from electric power production can be attributed to industrial activities. That is, the industrial sector is responsible for emissions it directly produces from its activities, and indirectly, for the emissions produced in the process of the electricity it purchases and consumes from electric power generators.

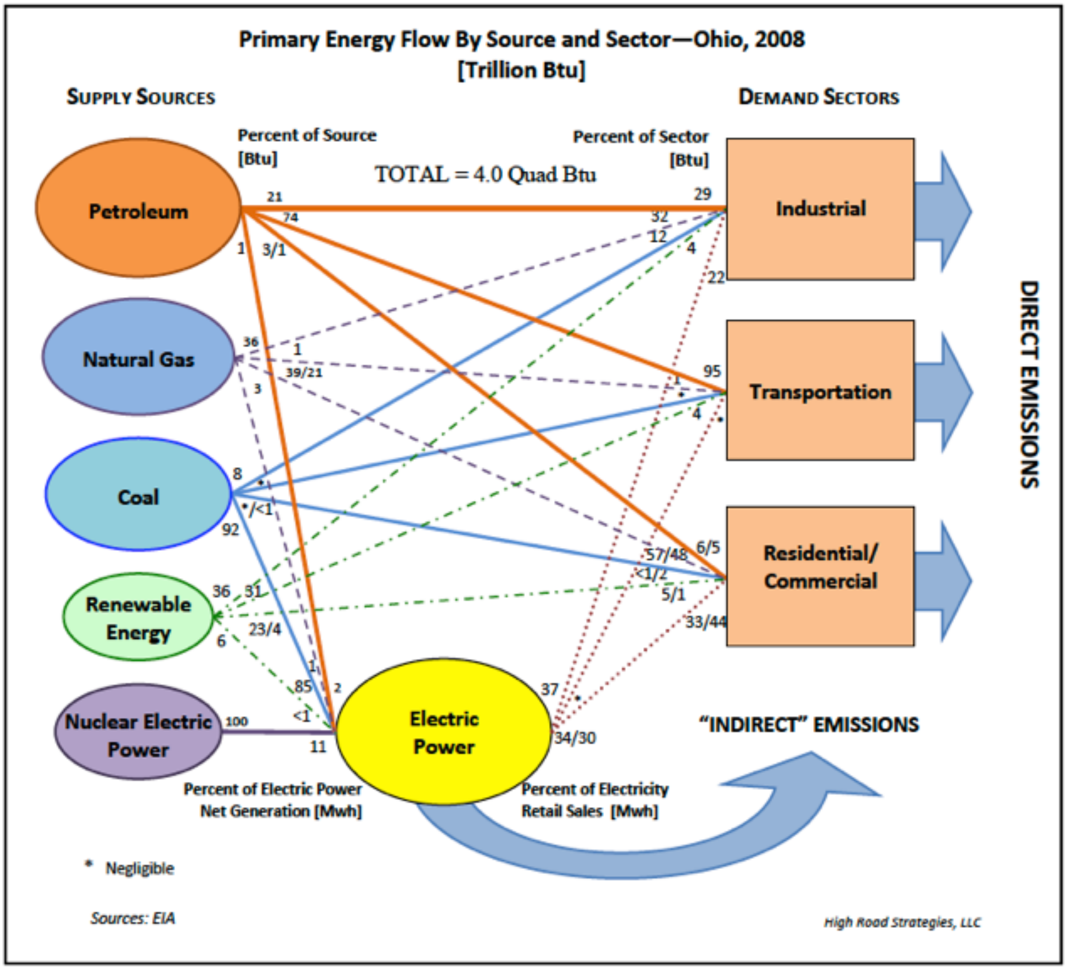
The relationship between energy use and flows from energy sources to end-use sectors with GHG emissions (their CO_2 equivalent, or CO_2e) is schematically illustrated in Figure 3. Based on EIA data, the figure shows the proportion of any given energy source going to the different sectors, and the shares of energy consumed by a sector from the different sources. The electric power sector is actually an intermediate stage in the process, transforming fossil, renewable and nuclear fuels to electricity that is then consumed by the three primary end-use sectors. As noted, each of the sectors directly produces emissions from their various activities. In the industrial sector, for example, this includes stationary point-source emissions from industrial facilities burning fossil fuels for heat and power, or using them as raw materials in production processes. In the transportation sector, this includes mobile sources of emissions, such as motor vehicles.

In estimating the economic impacts of a carbon pricing policy, such as that proposed by cap-and-trade climate legislation, both the direct and indirect emissions produced by a sector need to be identified and estimated. To assess these impacts for the industrial sector, which represents the largest and most important industry subsectors in the state—manufacturing, construction, agriculture—energy consumption and emissions data are needed to enable calculations of emissions associated with fossil fuel energy consumption within these sectors.

Energy-intensive manufacturing in Ohio. This analysis is especially important for evaluating the energy and emissions cost impacts of carbon pricing—as well as for evaluating the effects of energy-efficiency policies—on Ohio's energy-intensive (EI) manufacturing industries. By definition, EI industries are heavily energy-reliant, and energy is a major business expenditure—energy costs range anywhere from a minimum of 10% and often as much as 20-30% or more of their production costs. Hence, they could be vulnerable to emission mitigation policies that drive up their costs, and subsequently weaken their competitiveness in global markets.

For many EI industries, energy costs are comparable to or exceed, sometimes substantially, labor costs, though materials costs usually outweigh both—EI industries comprise most of the basic materials processing industries in the economy (iron and steel, chemicals, cement, glass, ceramics, paper, etc.), and therefore consume large quantities of raw materials. They are at the beginning of the manufacturing supply chain, producing processed materials used downstream in the production of fabricated goods, ranging from auto vehicles, girders, windmills, fertilizers, to cans and plastic consumer products.

Figure 3. Energy Supply and Demand Sectors and Carbon Emissions



Evaluating the impacts of climate and energy policies on the EI sector, therefore, requires examining industries at a sufficiently disaggregated level (six-digit NAICS categories) rather than at a highly aggregated sectoral level (three-digit NAICS), which combine EI industries with industries that are not particularly energy and/or carbon intensive. This entails knowing both the energy use and emissions output of these industries, information that is often hard to come by at the state and disaggregated industry levels.

Unfortunately, emissions data associated with the different end-use industry sectors, much less the industries that make up these sector, are only partially available from federal and state agencies, such as from the U.S. DOE and EPA, at a suitably disaggregated level to enable reliable estimates for the EI manufacturing sector.

Nevertheless, drawing on an extensive inventory of stationary, point-source GHG emissions developed in Task 1 of this project, which estimates the CO_2-equivalent (CO_2e) emissions directly produced by all industrial sites in Ohio, it was possible to conduct preliminary estimates of emissions generated by manufacturing industries in the six-digit NAICS industry categories.[33] This analysis helps identify which industries could be most vulnerable to carbon pricing and energy cost hikes, a prerequisite for conducting a risk-opportunity analysis for Ohio's manufacturing sector under carbon-limiting regulations and related energy policies. It also helps in identifying and targeting options for mitigating energy and emissions costs, as well as investment opportunities in energy-efficient, low-carbon technologies and practices for EI and other vulnerable manufacturing industries, where the greatest energy savings are needed.

Direct and indirect emissions rankings. Attaching a six-digit NAICS code to each point-source data point in the database generated a list of industries and companies in those industries and their estimated direct CO_2e emissions. Table 6 provides a list of the top-level NAICS two-digit "super-sectors" and their emissions. Not surprisingly, the utilities sector (NAICS 22), which includes electric power generation, produced 77.5% of all direct point-source emissions in the state—251.7 billion lbs. or 114.2 million metric tons (MT). Manufacturing (NAICS 31-33) was the largest non-generation emissions producing sector, accounting for 18.6% of the state's point-source emissions—60.2 billion lbs. or 27.3 million MT. The next largest emitting sectors, public administration (NAICS 92), administrative and support and waste management and remediation services (56), and transportation and warehousing (NAICS 48-49) sectors are each responsible for only 1% or less of the point-source emissions.

But, point-source emissions are only part of the industrial emissions picture. The indirect emissions associated with electricity purchased and consumed by manufacturing industries also need to be counted—indeed, for some industries these emissions exceed their direct emissions, and therefore need to be counted in any assessment of carbon mitigation policies. However, comprehensive, highly-disaggregated electricity data for the industrial sector are not available

[33] The emissions inventory developed in Task 1 of the OU-OSU Project estimated the CO_2, CH_4 and N_2O emissions generated by "stationary sources" at industrial sites throughout Ohio in 2009. The sources include internal combustion engines, external combustion boilers, industrial processes, petroleum and solvent evaporation, and waste disposal. Each industrial site stationary source was also assigned to industrial categories at the six-digit NAICS code level. The total CO_2-equivalent ("CO_2e") for each point-source was calculated by summing the CO_2 emissions generated by that source to the other types of GHG emissions with appropriate multipliers (i.e., one pound (lb) of CH_4 is equivalent to 21 lbs of CO_2 and one lb of N_2O is equivalent to 310 lbs of CO_2).

at the state level, as the American Council for an Energy-Efficient Economy (ACEEE) observed in its study of energy-efficiency opportunities in Ohio.[34]

Table 6. Point-Source Emissions of Ohio's Major Industry Sectors, 2009

NAICS (2-digit)	Major Industry Sectors	Total CO_2e (thou. MT)	% of Total
22	Utilities	114,182.4	77.5
31-33	Manufacturing	27,327.5	18.6
92	Wholesale Trade	1,811.4	1.2
56	Public Administration	1,432.9	1.0
48-49	Transportation & Warehousing	852.0	0.6
61	Administrative & Support & Waste Management	691.1	0.5
62	Educational Services	573.0	0.4
54	Health Care & Social Assistance	203.6	0.1
21	Professional, Scientific, & Technical Services	106.0	0.1
43	Mining	61.8	*
81	Retail Trade	15.1	*
42	Other Services (except Public Administration)	3.6	*
51	Information	2.2	*
11	Agriculture, Forestry, Fishing & Hunting	1.9	*
23	Construction	0.4	*
	Grand Total	**147,264.9**	**100.0**

Source: OU-OSU Point-Source Database ** Negligible*

Thus, in order to at least provide a rough estimate of these indirect emissions at the desired level of industry disaggregation—three- and six-digit NAICS categories—a methodology was devised drawing upon 1) the ACEEE's estimates of Ohio electricity consumption apportioned by industry sectors at the three-digit and four-digit NAICS levels; 2) the U.S. Census Bureau's Annual Survey of Manufactures (ASM) data for three-, four- and six-digit NAICS categories; 3) EIA energy data for the state; and 4) the OU-OSU Project's emissions point-source database. (This methodology is described in Appendix 2-1.)

[34] American Council for an Energy-Efficient Economy. (2009, Mar.). *Shaping Ohio's Energy Future: Energy Efficiency Works*. Summit Blue Consulting, ICF International, and Synapse Energy Economics. ACEEE Report Number E092. Washington, D.C. p. 113.

Table 7. Ohio Manufacturing Sector (3-digit NAICS) Emissions

Manufacturing Sector	NAICS Code	Direct Emissions (thou. MT)	Est. Indirect Emissions (thou. MT)	**Total Est. Emissions (thou. MT)**	Total % of Manuf.	Rank (Tot.)	Rank (Dir.)
Primary Metals	331	11,086.4	9,776.8	**20,863.2**	29.2	1	1
Chemicals	325	3,066.5	9,350.5	**12,417.0**	17.4	2	3
Petroleum and Coal Products	324	5,489.5	1,184.4	**6,674.0**	9.4	3	2
Nonmetallic Material Products	327	2,956.3	2,791.5	**5,747.8**	8.1	4	4
Transportation Equipment	336	488.7	4,768.2	**5,256.8**	7.4	5	7
Paper	322	1,863.6	1,777.3	**3,640.9**	5.1	6	5
Plastics and Rubber Products	326	403.7	2,119.2	**2,522.8**	3.5	7	8
Food Products	311	889.4	1,409.2	**2,298.6**	3.2	8	6
Fabricated Metal Products	332	368.3	1,527.7	**1,896.0**	2.7	9	9
Machinery	333	306.5	1,231.2	**1,537.7**	2.2	10	10
Electrical Equipment, Appliances, & Components	335	86.8	811.4	**898.1**	1.3	11	12
Miscellaneous Products	339	2.2	685.8	**688.0**	1.0	12	18
Computers and Electronic Products	334	5.3	646.1	**651.4**	0.9	13	17
Printing	323	19.4	625.5	**644.9**	0.9	14	15
Beverage and Tobacco Products	312	207.8	430.5	**638.3**	0.9	15	11
Furniture and Related Products	337	47.0	485.8	**532.9**	0.7	16	13
Wood Products	321	28.2	345.4	**373.6**	0.5	17	14
Textile Mills	313	11.5	49.6	**61.1**	0.1	18	16
Apparel	315	0.5	39.0	**39.5**	0.1	19	19
Total Manufacturing Emissions*	31-33	29,616.7	41,741.7	**71,358.4**	100.0	—	—

* Total does not include NAICS sectors 314 (textile product mills), 316 (leather products) which together account for 0.2% electricity emissions. Direct emissions were not available in the OU-OSU database, but are assumed to be negligible.

Source: OU-OSU Point-Source Database.

Table 7 shows three-digit NAICS manufacturing sectors, ranked according the total estimated CO_2e emissions associated with each sector in Ohio, which are the sum of the direct, point-source emissions and indirect, electricity-related emissions for each sector. By far the largest sector is primary metals (NAICS 331), accounting for 29.2% of the manufacturing sector's total emissions.

This is not surprising, since it includes both the iron and steel and aluminum industries, which include both large point-source emitters and large consumers of electricity.

The second largest sector is chemical manufacturing (NAICS 325), accounting for 17% of the state's manufacturing total.[35] Petroleum and coal products (NAICS 324), nonmetallic material products (NAICS 324) and transportation products (NAICS 336) round out the top five. Taken together, the top five account for over 70% of all emissions in manufacturing (and the top ten, for 88%). However, to more accurately pinpoint the "risks" and "opportunities" associated with carbon-mitigation policies, analysis at a somewhat more detailed level of industry sector aggregation is necessary.

Table 8 presents a list of the top 15 emitting six-digit NAICS manufacturing industries (out of 142 six-digit manufacturing industries in the state), comparing the direct emissions and indirect, estimated electricity-related emissions associated with manufacturing industries in Ohio. The top 15 industries are ranked in the table according to their total combined (direct + indirect) emissions. Table 9 lists the top 20 emitting manufacturing companies in the state, based on the OU-OSU Project point-source emissions database (indirect, electricity-related emissions data were not available for individual companies).

The leading companies mostly come from the same group of highest (direct and indirect) emitting six-digit industries, topped by AK Steel Corp and ArcelorMittal from iron and steel and BP-Husky Petroleum from petroleum refining. Those three companies alone—out of a total of 361 firms in the OU-OSU point-source database, account for over 40% of the direct emissions in Ohio's manufacturing sector. This ranking undoubtedly would change if electricity-related emissions were counted. For example, Ormet Primary Aluminum, a very large electricity consumer, is the 11th largest point-source emitter in Table 9, but probably would climb close to the top if the indirect emissions associated with its purchased electricity consumption were included.

Both tables point to a relatively small number of industries that account for the bulk of greenhouse gas emissions directly and indirectly produced by their facilities. This list includes, notably, iron and steel, petroleum refineries, lime manufacturing, primary aluminum, paper and paperboard mills, plastic materials and resins, several chemicals industries, cement and nitrogenous fertilizer, though there are several other industries (including plastic products, food processing, industrial machinery, auto manufacturing) located around

[35] Chemical manufacturing actually ranks a little lower, 3rd, if direct emissions only were considered, but like primary metals, it includes a number of large electricity consuming industries.

the state that also generate large quantities of emissions, and therefore are potentially subject to federal and state climate policies.

Again, any interpretation of these rankings needs to be tempered by the recognition that the electricity-related emissions figures are only rough estimates, based on simplifying assumptions concerning the available industry data. Nevertheless, with notable exceptions, most of the top emitting sectors based on combined direct and indirect emissions also ranked highly in the direct emissions list, which has strong empirical foundation. Aside from primary aluminum, which is represented in the state with the large presence of the Ormet Corp. aluminum smelter in Hannibal, Ohio, industries within the larger chemical manufacturing, ferrous foundries, and glass manufacturing sector also rise to higher prominence as overall GHG emitters when electricity use is accounted for.

EITE industries. It is noteworthy that 12 of the top 15 emitting six-digit industries (indicated by bold type in Table 8) meet the criteria of energy-intensive trade-exposed (EITE) industries as defined by the U.S. EPA and other federal agencies as first specified in the Waxman-Markey climate bill (H.R. 2454). This designation was made to determine which industry would be "presumptively eligible" for emission allowance allocations (or "rebates," see discussion below) to "trade-vulnerable" industries if the industry's energy intensity or its GHG intensity is at least 5%, and its trade intensity is at least 15%, or alternatively, if its GHG intensity is at least 20%, regardless of its trade intensity. The eligibility assessment was to be based on specified data sources, including the Census Bureau's ASM and Economic Census, the EIA's Manufacturing Energy Consumption Survey (MECS), and data from the U.S. International Trade Commission. Finally, the bill stipulated that, to the extent feasible, the eligibility assessments should be conducted at the most disaggregated level for which public data are available—the six-digit NAICS industry categories.[36]

[36] U.S. Environmental Protection Agency. (2009, Dec. 2). T*he Effects of H.R. 2454 on International Competitiveness and Emission Leakage in Energy-Intensive Trade-Exposed Industries.* An Interagency Report Responding to a Request from Senators Bayh, Specter, Stabenow, McCaskill, and Brown. pp. 8-11. Retrieved from http://www.epa.gov/climatechange/economics/pdfs/InteragencyReport_Competitiveness-EmissionLeakage.pdf

Table 8. Ohio's Top 15 Emitting Manufacturing Industries (6-digit NAICS)*

Manufacturing Industry	NAICS	Direct Emissions (thou. MT)	Indirect* Emissions (thou. MT)	Total Emissions (thou. MT)	Total % Manuf.	Rank (Tot.)	Rank (Dir.)
Iron and steel mills & ferroalloys[1]	**33111**	10,465.3	2,964.6	**13,429.9**	19.9	1	1
Petroleum Refineries	**324110**	5,238.9	2,544.1	**7,783.0**	11.5	2	2
Lime	**327410**	2,324.8	109.7	**2,434.5**	3.6	3	3
Primary Aluminum	**331312**	351.3	2,019.4	**2,370.6**	3.5	4	7
Paper (except Newsprint) Mills	**322121**	1,254.6	832.1	**2,086.7**	3.1	5	5
Plastics Material and Resins	**325211**	282.4	1,466.8	**1,749.2**	2.6	6	9
Nitrogenous Fertilizer	**325311**	1,434.7	199.6	**1,634.4**	2.4	7	4
All Other Basic Inorganic Chemicals	**325188**	95.1	1,504.9	**1,599.9**	2.4	8	28
Cement	**327310**	258.7	1,287.0	**1,545.6**	2.3	9	11
All Other Basic Organic Chemicals (32519M)[2]	**325199**	246.6	1,009.6	**1,256.2**	1.9	10	13
All Other Plastic Products (32619M)[2]	326199	210.5	850.7	1,061.1	1.6	11	16
Iron Foundries (33151M)[2]	**331511**	74.6	868.5	**943.2**	1.4	12	30
Paperboard Mills	**322130**	402.6	513.5	**916.1**	1.4	13	6
Ethyl Alcohol (32519M)[2]	325193	163.9	673.0	837.0	1.2	14	22
Automobile Manufacturing	336111	210.3	290.5	500.8	0.7	15	17
SUBTOTAL TOP 15 INDUSTRIES		**23,014.4**	**17,133.9**	**40,148.3**	59.5	—	—
TOTAL MANUFACTURING	**31-33**	**27,327.5**	**40,124.1**	**67,451.5**	100.0	—	—

* Manufacturing industries in bold are considered energy-intensive and trade-exposed (EITE) according to EPA criteria

** Indirect (electricity-related) emissions are estimated.

[1] Combines iron and steel mills (331111) and ferroalloy products (331112).

[2] Est. electricity-related emissions includes other 6-digit industries in 5-digit category, hence over-estimated.

Source: OU-OSU Point-Source Database.

Table 9. Ohio's Top 20 Emitting Manufacturing Companies

Company	NAICS Code	Manufacturing Industry	Total Direct Emissions (thou. MT)	Direct % Total Manuf.
AK Steel Corporation	**331111**	**Iron and Steel Mills**	5,830.2	21.3
ArcelorMittal	**331111**	**Iron and Steel Mills**	3,757.3	13.7
BP-Husky Refining LLC	**324110**	**Petroleum Refineries**	2,164.2	7.9
Graymont Dolime (OH), Inc.	**327410**	**Lime Manufacturing**	1,385.1	5.1
PCS Nitrogen Ohio, L.P.	**325311**	**Nitrogenous Fertilizer**	1,249.9	4.6
Lima Refining Company	**324110**	**Petroleum Refineries**	1,216.0	4.4
Marathon Petroleum Company LLC	**324110**	**Petroleum Refineries**	954.5	3.5
Carmeuse Lime, Inc	**327410**	**Lime Manufacturing**	937.7	3.4
P. H. Glatfelter Company	**322121**	**Paper (except Newsprint) Mills**	916.0	3.4
Sun Company, Inc.	**324110**	**Petroleum Refineries**	904.0	3.3
Ormet Primary Aluminum Corp.	**331312**	**Primary Aluminum Production**	351.3	1.3
Evonik Degussa Corporation	**325182**	**Carbon Black Manufacturing**	324.0	1.2
Rolls Royce Energy Systems Inc	333611	Turbine &Turbine Generators	266.4	1.0
CEMEX, Inc.	**327310**	**Cement Manufacturing**	257.5	0.9
Smurfit-Stone Container Enterprises	**322130**	**Paperboard Mills**	249.7	0.9
Cargill, Inc.	**311221**	**Wet Corn Milling**	249.1	0.9
Eramet Marietta, inc.	**331112**	**Electro. Ferroalloy Products**	232.1	0.8
KRATON Polymers U.S. LLC	**325212**	**Synthetic Rubber**	220.1	0.8
Agrium North Bend Nitrogen Operations	**325311**	**Nitrogenous Fertilizer**	184.8	0.7
Cargill, Incorporated - Salt Division	**325998**	**All Other Misc. Chemical Prod.**	172.9	0.6
Total Top 20 Manufacturing Companies			**21,822.9**	**79.9**

* Manufacturing companies in bold are in energy-intensive and trade-exposed (EITE) industries according to EPA criteria.

Source: OU-OSU Point-Source Database.

The top five industries, all of which meet the EITE criteria, together account for 42% of manufacturing emissions in Ohio. Iron and steel and ferroalloys is by far the largest emitting manufacturing industry in the state, producing a fifth of total manufacturing emissions—it ranks first in both direct and indirect emissions. Petroleum refining is a distant second, with a little more than one-tenth of total manufacturing emissions. [37] Lime, primary aluminum, and paper mills round out the top five emitting industries. The relative shares of industry emissions of the total state manufacturing emissions drops off rapidly after that—the top 15 account for about 60%, and the top 25, for two-thirds. The concentration is somewhat higher if only direct emissions are included. The top 15 industries, excluding those mostly electricity-reliant on this list, are responsible for 86% of total manufacturing-based direct emissions.

However, industries that are lower down the top emitters list may still be economically important to the state, and an assessment of their vulnerability to energy costs and emissions pricing under a climate or energy policy is warranted. For example, two glass producing industries, other pressed and blown glass and glassware manufacturing (NAICS 327212) and glass container manufacturing (327213), ranked 20th and 28th in the total emissions list, respectively, are both EITE eligible. According to the OMA, with respect to the former industry, Ohio ranked first in the nation in 2008 in total shipments—the state had 38 facilities, with shipments of over $1 billion, more than a fifth of all U.S. shipments in that industry.[38]

Finally, several important industries that are not EITE may still rank relatively highly in the total emissions tables—some (such as automobile manufacturing) have operations (paint shops, onsite generation facilities) that count as large point-source emitters and others may be large electricity consumers—manufacturers in the other basic inorganic and other basic organic chemical manufacturing NAICS classification fall into this category. Hence, they too may be subject to climate change or U.S. EPA GHG regulations, and warrant a closer look regarding the potential economic risks they may be subject to, as well as the opportunities for mitigating those risks.

[37] Its integrated mills are major sources of point-source emissions and its EAF mills are major consumers of electricity.

[38] OMA. *Ohio Powered by Manufacturing*. pp. 28-29.

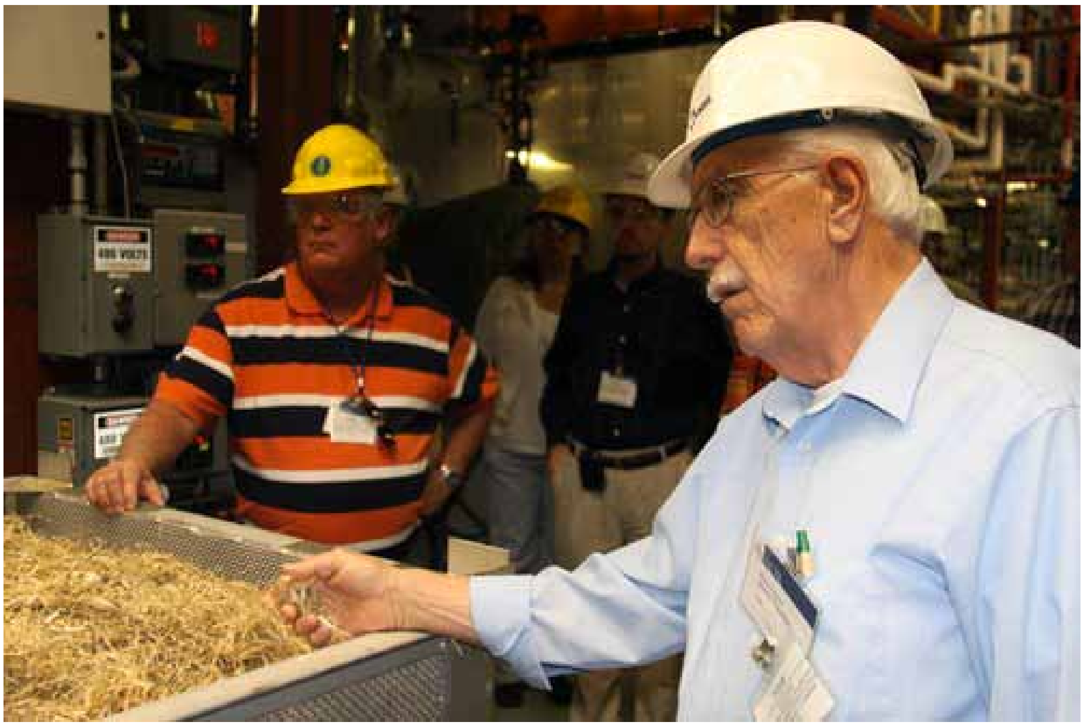
IV. POTENTIAL IMPACTS OF CLIMATE AND CLEAN ENERGY POLICIES

Because of Ohio's heavy reliance on fossil fuels in both its electric power and manufacturing sectors, it would seem, at least on the surface, that climate policies that regulate and set a price on CO_2e emissions could pose risks to the state's economic competitiveness, threatening businesses and jobs. The nature and extent of these economic risks, and the measures that might be able to effectively mitigate them are briefly examined below. At the same time, as the USCAP argues, this challenge could create even greater economic opportunities that enhance competitiveness while also promoting environmental goals, if appropriate policies can be developed and implemented. These opportunities and policies are also explored below.

Since the Clinton Administration's attempts to obtain Senate ratification of the Kyoto Protocol climate agreement in the late 1990s, and throughout the late 2000s when Congress considered consecutive U.S. climate change bills, critics warned that there would be adverse impacts on the nation's economy. In particular, they pointed to the large number of jobs that could be lost in certain sectors, such as coal mining and rail transport (which hauled the coal), and have argued that the resulting higher energy prices would hurt consumers and businesses. There also has been significant concern that a U.S. climate bill would put American firms at a competitive disadvantage, domestically and in global markets, to foreign manufacturers whose governments (i.e., China and India) have not made comparable commitments to reduce GHG emissions.

Proponents, on the other hand, have countered that a number of economic studies of climate legislation, especially by federal agencies, such as the EIA and

EPA, indicate that the macroeconomic impacts actually would be quite small, both for the economy as a whole, and industrial activity in particular—GDP would fall below the baseline by somewhere between 0.5-1.5% by 2030. [39] But even granting the modest overall costs to the economy from climate legislation, others have noted that these studies, largely because of modeling limitations, do not adequately account for impacts on manufacturing industries at a much more disaggregated level.



As business, labor and even environmental organizations became more aware of this gap, they expressed their concerns to Congress that the cap-and-trade systems proposed by climate legislation could negatively affect the competitiveness of the subset of manufacturing industries that are vulnerable

[39] Houser, T. et al. (2008). *Leveling the Carbon Playing Field: International Competition and US Climate Policy Design.* Washington, D.C.: World Resources Institute and Peterson Institute for International Economics. An EIA analysis of the Lieberman-Warner bill projected cumulative drops in industrial shipments below the reference case ranged between 1.3-3.6% between 2009-2030. See U.S. Department of Energy, Energy Information Administration. (2008). *Energy Market and Economic Impacts of S. 2191, the Lieberman-Warner Climate Security Act of 2007.* [SR/OIAF/2008-01]. Washington, D.C. Other macro-analyses include: U.S. EIA. (2009). *Energy Market and Economic Impacts of H.R. 2454, the American Clean Energy and Security Act of 2009.* (SR-OIAF/2009-05). Washington, D.C.; U.S. Environmental Protection Agency. (2010). *Supplemental EPA Analysis of the American Clean Energy and Security Act of 2009*; Paltsev, S. et al. (2007). *Assessment of U.S. Cap-and-Trade Proposals: MIT Joint Program on the Science and Policy of Global Change.* Report 146. Some studies involved distributional effects on the industries, but mainly at a high level of sector aggregation. See Morgenstern, R. D., Ho, M., Shih, J. & Zhang, X. (2004). The near-term impacts of carbon mitigation policies on manufacturing industries. *Energy Policy 32: pp. 1825-1841.*

because they are both energy-intensive and sensitive to international trade (the so-called EITE industries). Environmentalists also expressed concerns about "carbon leakage"—U.S. EITE industries moving production offshore to avoid the added costs imposed by U.S. climate policies would simply shift their emissions to countries with little or no environmental constraints on carbon.

These concerns eventually led to incorporation of measures in the recent climate legislation (i.e., Waxman-Markey in the House (H.R. 2454) and Kerry-Lieberman in the Senate (American Power Act)) designed to mitigate the cost impacts on the EITE industries, to preserve their competitiveness and retain domestic industrial capacity and jobs, while preventing carbon leakage. These include "output-based rebates," which are free emission allowances given to manufacturers based on their production-based emissions output to offset their cost increases, and "border adjustments," which entail fees placed on foreign imports based on their emissions content, from countries that have not made comparable GHG emissions mitigation commitments as specified in U.S. climate bills.[40]

Climate policy and manufacturing studies. A different, smaller set of studies has confirmed the validity of the above concerns, as well as the need for measures to limit the costs on the EITE industries. While some are largely qualitative,[41] many involved in-depth examinations of how climate policies influence manufacturing industries. Of the latter, the most significant study involved attempts to quantify the policy impacts by applying modeling tools.[42] For example, Resources for the Future (RFF) studies measured the impacts of carbon-dioxide pricing on industrial competitiveness—in terms of operating costs, profits and production output.[43] A few detailed studies of the European Union Emissions Trading Scheme (EU ETS) focused on the competitiveness of narrower and more energy-intensive industrial categories in the EU than

[40] For example, USCAP "recognizes that without appropriate design features, a domestic cap-and-trade program could pose significant challenges to energy-intensive industries." It therefore "recommends measures to address competitive pressures on domestic manufacturing of energy-intensive products that compete with similar products made in countries without established climate protection programs." This includes providing "an adequate amount of allowance" to manufacturers of energy-intensive, trade-exposed products. USCAP. (2009). *Issue Overview: Energy Intensive Industries.*

[41] U.S. EPA. (2007). *Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes, Final Report.* Prepared by ICF International. [EPA 100-R-07-003]; McKinsey Global Institute (MGI). (2007). *Curbing Global Energy Demand Growth: The Energy Productivity Opportunity*. San Francisco, CA: McKinsey & Company; Houser et al., *Leveling the Carbon Playing Field.*

[42] Morgenstern, R. (2009). *Competitiveness and Climate Policy: Avoiding Leakage of Jobs and Emissions.* Washington, D.C.: Resources for the Future. Morgenstern, R., Aldy, J. E., Herrnstadt, E. M., Ho, M. & Pizer, W. A. (2008). Competitiveness Impacts of Carbon Dioxide Pricing Policies on Manufacturing. *Issue Brief 7.* In Kopp, R. J. & Pizer, W. A. *Assessing U.S. Climate Policy Options*. pp. 95-106. Washington, D.C.: Resources for the Future; Ho, M., Morgenstern, R. & Shih, J. (2008). *Impact of Carbon Price Policies on U.S. Industry. The Effects of H.R. 2454 on International Competitiveness*. Washington, D.C.: Resources for the Future. See also EPA et al. *The Effects of H.R. 2454 on International Competitiveness.*

[43] Morgenstern, R. (2009). *Competitiveness and Climate Policy;* Morgenstern, R., Ho et al. (2008). *Impacts of Carbon Price Policies;* Morgenstern, R. et al. *The near-term impacts of carbon mitigation policies.*

traditional economic studies usually evaluate.[44] Research on rebates, border adjustments and other cost and leakage mitigation measures also have been conducted in the European Union, Japan and Canada, as well as the United States.[45]

Most of the research on these issues, however, has employed top-down computable general equilibrium models, or some modified version of these models, which are highly aggregated and tend to be quite static. A number of other studies conducted over the past decade, applying system dynamics modeling tools to evaluate climate policies and their implications on the manufacturing sector, especially on energy-intensive industries, avoid these limitations. They examined industries at a highly disaggregated level (e.g., six-digit NAICS), and are flexible and non-static. Researchers at the University of Maryland supported by U.S. EPA grants conducted early studies of this type.[46]

HRS-MI studies. Three studies conducted jointly by High Road Strategies, LLC and the Millennium Institute (HRS-MI), also developed system dynamics models designed to quantify the cost impacts of climate policies and evaluate mechanisms for mitigating these costs on EITE industries. The first study of this series ("L-W EITE") analyzed the impacts of the Lieberman-Warner Climate Security Act of 2007 (S. 2191) on energy-intensive manufacturing industries—in particular, the iron and steel and ferroalloy products, primary aluminum and secondary smelting of aluminum, paper and paperboard mills, petrochemicals, alkalies and chlorine.[47]

The second study ("ACESA I") examined the costs of the Waxman-Markey bill on the six EITE industries in the first study, and the potential effectiveness of the output-based allowance rebate measure in the ACESA to mitigate these costs.[48]

[44] McKinsey & Company and Ecofys. (2006). *EU ETS Review, Report on International Competitiveness*. European Commission: Directorate for Environment; Reinaud, J. (2005). *Industrial Competitiveness Under the European Union Emissions Trade Scheme.* IEA Information Paper; International Energy Agency (IEA). (2008). *Carbon Policy and Carbon Leakage, Impacts of the European Emissions Trading Scheme on Aluminum.* IEA Information Paper.

[45] Fischer, C., Moore, E., Morgenstern, R., & Arimura, T. (2010). *Carbon Policies, Competitiveness, and Emissions Leakage, An International Perspective.* Conference Summary. Washington, DC: Resources for the Future.

[46] A representative sample includes: Davidsdottir, B. & Ruth, M. (2005). *Pulp Non-Fiction.* Dynamic Modeling of Industrial Systems. *Journal of Industrial Ecology 9, 3, pp. 191- 211*; Ruth, M., Davidsdottir, B. & Amato, A. (2004). Climate change policies and capital vintage effects: the cases of US pulp and paper, iron and steel, and ethylene. *Journal of Environmental Management, 70, pp. 235-252*; and Ruth, M., Davidsdottir, B. & Laitner, S. (2000). Impacts of Energy and Carbon Taxes on the US Pulp and Paper Industry. *Energy Policy 28, pp. 259-270*.

[47] Yudken, J. S. & Bassi, A. M. (2009). *Climate Policy and Energy-Intensive Manufacturing: Impacts and Options.* High Road Strategies and Millennium Institute.

[48] Yudken, J. S. & Bassi, A. M. (2010). *Climate Policy and Energy-Intensive Manufacturing: The Competitiveness Impacts of the American Energy and Security Act of 2009.* High Road Strategies and Millennium Institute. Report to the Environmental Defense Fund. While the prior study's impact estimates were based on energy price differences between a core climate case and a business-as-usual or *BAU* case, the new study directly calculated the costs that industries would incur from the purchase of carbon-emissions allowances, and then the cost mitigation impacts of the output-based allowance rebates, closely following the rules to calculate allowances and rebates stipulated in the ACESA.

The third study ("ACESA II") examined alternative ACESA policy scenarios and a border adjustment mechanism and international offsets provisions as specified in Waxman-Markey and their effectiveness in mitigating cost increases for the industries selected.[49]

The HRS-MI studies found, first, that climate policies could impose additional production costs and reduce the profits of EITE manufacturers, trends that would increase over time as the prices of greenhouse emission allowances grow under a cap-and-trade system. This assumes that the climate policy includes no cost mitigation measures and the industries do not invest in significant improvements in energy efficiency. This finding is generally consistent with the conclusions of several of the other studies (i.e., the RFF studies). Pressures on the industries would subsequently grow to reduce costs and prevent profits from decreasing to undesired levels, potentially forcing some manufacturers to cut capacity or even close plants, and lay-off workers.

The subsequent ACESA I and ACESA II studies, which evaluated the Waxman-Markey bill and its cost-mitigation measures, found that the output-based rebate provision, in particular, would be effective in offsetting the cost impacts of emissions allowances on EITE industries, at least over the short to medium term. For example, Figure 4 presents some of the results of this analysis, the impact on production costs, both with and without rebates to the EITE industries. It shows a five-industry—iron and steel, primary aluminum, paper and paperboard, petrochemicals, chlor-alkalies—weighted-average decrease in operating surplus (a proxy for profits) below a business-as-usual reference case for three alternative policy cases.[50] Without the rebates, the industries would experience a rapid and significant increase in production costs and declines in operating surplus. However, with the rebates, the EITE industries would not suffer any losses until around 2020-2022, depending on the particular industry. The impacts would start to grow after 2020, rising rapidly from 2025 as the rebates begin to phase out.

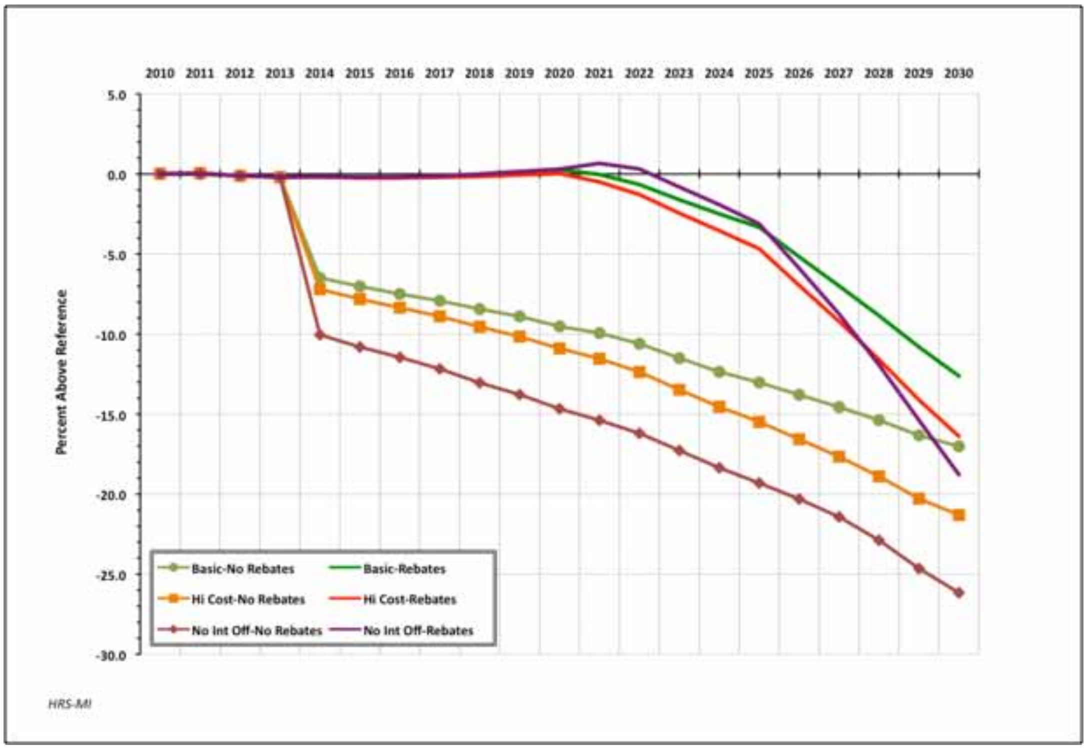
Implications for Ohio manufacturers. Assessing the implications of these studies for Ohio's manufacturing sector is fairly straightforward. Most of

[49] Yudken, J. S. & Bassi, A. M. (2010). *Climate Policy and Energy-Intensive Manufacturing: Alternative Policies and Effectiveness of Cost Mitigation Provisions in the American Energy and Security Act of 2009*. Report to the National Commission on Energy Policy and Working for America Institute, AFL-CIO. The methodology employed is based on modified models for the selected industries, developed and employed in the prior studies. Two alternative policy scenarios, which are compared to the *ACESA Basic* case, were analyzed. The first one assumes that non-carbon sources (nuclear, thermal with CCS, biomass) substituting for carbon-intensive fuels in electricity generation would have higher costs than in the Basic case (the *High Cost (HC)* case), and a second scenario that assumed that the use of international offsets *ACESA*—important for cost containment—would be severely limited (*No International Offsets (NIO) case*).

[50] Ibid.

Ohio's many energy-intensive industries and manufacturers listed in Tables 8 and 9, respectively, would be subject to the requirements in the cap-and-trade bills that require them to obtain allowance allocations covering their production of greenhouse gas emissions. They would incur additional costs, first, from having to purchase allowances to cover the direct emissions from "stationary sources" in their facilities—from combustion of fossil fuels to generate heat and power and production processes. Second, they would incur further additional costs ("indirect" emissions costs) from purchasing electricity from electric power generators that would pass through the added costs of emission allowances they would need to cover their own greenhouse emissions.

Figure 4. Five-EITE Industries Weighted Average Operating Surplus, Percent Above BAU, All Policy Cases



Source: Yudken & Bassi. Climate Policy and Energy-Intensive Manufacturing: Alternative Policies. p.18. figure 5.

The findings on economic impacts from a climate policy projected in the HRS-MI studies would apply to Ohio's EITE industries. The most vulnerable sectors would be the largest directly-emitting industries in Ohio, as shown in Table 8, including iron and steel, petroleum refineries, paper and paperboard, lime manufacturing, plastics and resins, basic inorganic chemical manufacturing, and cement. As noted above, most of these sectors are also large consumers of electricity, and therefore account for a large quantity of indirect emissions produced by Ohio's mostly coal-based electric utilities.

But other heavily electricity-reliant industries in Ohio, especially primary aluminum, that do not have large stationary sources of emissions, also would be vulnerable. In fact, in the HRS-MI studies, the primary aluminum industry was projected to experience some of the largest cost impacts of the EITE industries examined. On the other hand, the studies also show that the potentially adverse impacts from the climate bill would be deferred for nearly a decade after the cap-and-trade system went into effect, if the climate bill contained cost mitigation measures, such as output-based rebates.

That is, if a climate bill, such as Waxman-Markey, were enacted, Ohio's EITE manufacturers would not face any significant economic threats until well into the 2020 decade.

Implications for Ohio's non-EITE industries. The implication for Ohio industries that do not meet the EITE eligibility criteria, but are high on the list of Ohio's top emitting manufacturing industries, is less clear. Unlike the EITE sector, these industries would not benefit from output-based rebates or border adjustments, under the proposed climate bills, yet each could be considered a "covered entity"[51] as defined in the climate bills. For example, this group includes the automobile manufacturing (NAICS 336111), other miscellaneous chemical products (NAICS 325998), asphalt paving mixture and block (NAICS 324121), and turbine generator set units (NAICS 333611) industries, among several others, [52] which ranked in the top twenty-five largest emitting six-digit manufacturing industries (ranking 15th, 16th, 19th and 25th, respectively) in the OU-OSU Project point-source database. Manufacturers in these industries therefore could be subject to requirements to obtain emissions allowances, if they have stationary sources that produce more than 25,000 tons or 50 million pounds of CO_2e emissions annually.

Several major manufacturing facilities in the automobile manufacturing industry (Chrysler's Toledo North Assembly Plant, GM's Lordstown complex, Ford's Ohio Assembly Plant, Honda's Marysville Plant and East Liberty Plant), the basic miscellaneous chemical products (Cargill's Salt Division in Akron) and turbine generator set units (Rolls Royce Energy Systems in Mount Vernon) industries, in fact do meet the EITE eligibility criteria. Indeed, Cargill and Rolls Royce both rank in the top 25 companies with the highest direct emissions, as does Appleton Papers in West Carrollton (coated and laminated paper; NAICS 322222)—each of their associated industries rank in the top 25 direct emissions list, as well.

[51] For a full definition, see H.R. 2454, Sec. 700(13), pp. 847-851.

[52] Other non-EITE industries on this list, in order of their ranking in total emissions include: ethyl alcohol (325193) 11th on the list; coating, engraving, heat treating, and allied activities (332812) 17th; breweries (312120) 18th; industrial trucks, tractors, trailers, and stacker machinery (333924), 22nd; and coated and laminated paper (322222), 23rd.

That is, each of these manufacturing sites contains one or more industrial fossil fuel-fired combustion devices that produce more than 25,000 tons of CO_2e emissions in a year. In all, 87 individual manufacturing facilities, out of 461 in OU-OSU point-source database,[53] could satisfy the criteria of generating more than 25,000 tons of GHG emissions, and therefore would be required to obtain emission allowances. On the other hand, several non-EITE industries, such as the asphalt paving and mixture industry, are comprised of companies with widely distributed production sites, each producing emissions that fall below the threshold that would require them to obtain emissions permits.

Many of these industries are important employers and sources of revenue for the state, not to mention many communities throughout Ohio—as are the EITE industries. But unlike the EITE sector, any added costs from a climate bill would not be offset by a rebate or other cost mitigation measure in the bill. On the other hand, for most of these industries, energy represents a much smaller cost factor than in the EITE sector, hence the economic consequences might be somewhat less adverse.

[53] This is based on an analysis of the OU-OSU point-source emissions database.

For example, Table 10 compares two different ways of measuring energy-intensity for selected industries.[54] It shows that these measures for EITE industries (five- and six-digit NAICS, in bold), are consistently, and usually substantially, higher than the ratios for industry subsectors sectors (three-digit NAICS) that they belong to, and higher than the ratios for most of the non-EITE six-digit manufacturing industries.[55] Most notable are the automobile and turbine and turbine generator set industries, which, despite having some of the largest emitting manufacturers in the state, have energy intensities of 0.5% and 1% respectively—compared to double-digit ratios for most of the EITE industries.

Important exceptions are petroleum refineries and iron and steel—the largest emitters and most important manufacturing sectors in Ohio's economy [56]—which have more modest energy cost ratios. Crude oil accounts for most of petroleum refining's material costs, while iron and steelmaking uses coal and coke as raw materials as well as for producing heat and power. As a result, the ratios of purchased electricity and fuels as a share of these industries' value added (not shown in the table)—another measure of energy-intensity—are much higher than those of the non-EITE industries.[57]

[54] That is, one measure is the ratio of the value of purchased electricity plus energy fuels with the value of shipments (VE/VOS) for a given industry; the other measure is the ratio of the value of purchased electricity plus energy fuels with an industry's total variable production costs—that is, the total of materials, labor, capital, and energy (purchased electricity and energy fuels) expenditures (VE/VPC) in Table 10.

[55] These ratios are based on Census Bureau ASM data, for selected industries that are important in Ohio, though the data is all at the national level. It makes the not unreasonable assumption that these ratios, which are different ways of calculating energy intensity, would largely be consistent with the ratios for the same NAICS industry categories at the state level; the composition of materials, labor, energy, and capital in manufacturing production processes for a given industry would not be substantially different, if one aggregates nationally or disaggregates to the state level—at the very least, the differences may be one of magnitude but not *order* of magnitude.

[56] As noted earlier in the report, however, while iron and steel manufacturing is one of the largest employers and source of value added in the state, and the petroleum refining sector's value of shipments is one of the highest, the latter's value added and employment numbers are relatively small. (See Table 3).

[57] The value added-based energy-intensity measures for petroleum refineries and iron and steel were 14-16%, respectively, in 2008, which are comparable to all other EITE industries' ratios.

Table 10. Energy Intensity of Selected Industry Sectors, 2008

NAICS	Manufacturing Sector	VE/VOS*	VE/VPC**
311	Food	1.8%	2.5%
311221	**Wet corn milling**	**7.7%**	**11.4%**
311422	Specialty Canning (31142M)	2.5%	3.5%
312	Beverage & tobacco product	1.1%	2.2%
31212	Breweries	2.1%	4.0%
322	Paper	5.7%	7.5%
322120	**Paper mills**	**8.9%**	**12.4%**
322130	**Paperboard mills**	**12.9%**	**15.8%**
322222	Coated and laminated paper and packaging	2.5%	3.4%
324	Petroleum & coal products	2.0%	2.1%
324110	**Petroleum refineries**	**1.9%**	**2.1%**
324121	Asphalt paving mixture and blocks	5.7%	6.8%
325	Chemical mfg	3.6%	5.5%
3251	Basic chemical mfg	7.2%	8.9%
325182	**Carbon Black**	**6.9%**	**7.7%**
325188	**All other basic inorganic chemicals**	**8.5%**	**12.6%**
325211	**Plastics material and resins**	**4.8%**	**5.6%**
325311	**Nitrogenous fertilizer**	**8.6%**	**12.3%**
325999	All other misc. chemical products	2.0%	3.1%
327	Nonmetallic mineral product mfg	6.6%	8.8%
327212	**Other pressed and blown glass and glassware**	**28.7%**	**28.0%**
327310	**Cement**	**18.0%**	**21.0%**
327410	**Lime**	**23.9%**	**25.1%**
331	Primary metal	4.7%	5.7%
33111	**Iron and steel mills and ferroalloy**	**5.4%**	**6.7%**
3313	Alumina & aluminum production & processing	8.0%	8.6%
331312	**Primary aluminum production**	**22.0%**	**23.0%**
332	Fabricated metal product	1.5%	2.1%
332812	Coating, engraving, heat treating, and allied activities	3.7%	5.5%
333	Machinery	0.8%	1.1%
333611	Turbine and turbine generator set units	1.0%	1.2%
333924	Industrial trucks, tractors. etc. machinery (33392M)	0.7%	1.0%
336	Transportation equipment	0.8%	1.0%
336111	Automobiles	0.5%	0.5%

* VE=value of purchased electricity + purchased energy fuels; VOS=value of shipments; VPC=total production costs=materials expenditures+annual payroll expenditures+capital expenditures+VE

Data Source: Census Bureau ASM, Statistics for Industry Groups and Industries.

State and regional climate programs. Because of the shift in political circumstances nationally and in Ohio since the November 2010 elections, concerns about how federal climate change cap-and-trade legislation might affect Ohio's economy have lessened. However, the analysis above still might inform efforts to regulate greenhouse gas emissions at the state level.

At this time, there are no Ohio initiatives that directly apply to restricting carbon emissions associated with electricity generation and industrial energy use—Ohio is only a formal "observer" not an active member of the Midwestern Greenhouse Gas Reduction Accord ("the Accord"). Covering six U.S. states and one Canadian province,[58] the Accord—one of three possible regional cap-and-trade programs to reduce greenhouse emissions—aims to establish an economy-wide program that would reduce emissions 20% below 2005 levels by 2020 and 80% below 2005 levels by 2050.[59] In May 2010, the Accord's Advisory Group, comprised of representatives from environmental groups, industry, and the participating jurisdictions, released its final recommendations to set up the program, which is being reviewed by the governors and Canadian premier as of winter 2011 to offer their input on the next steps to be taken.[60]

The Accord's cap-and-trade program would cover the six Kyoto Protocol greenhouse gases and apply to electric, industrial, residential, commercial, transportation combustion, and industrial process emissions. Recognizing that the Midwestern region has intensive manufacturing and agriculture sectors, and is the most coal-dependent region in North America, the Advisory Group recommended using allowances to mitigate cap-and-trade program cost impacts (including energy price impacts) on industrial entities in the region, especially energy-intensive industries that have limited ability to pass costs on to consumers of their products. Overall the goal would be to improve the competitiveness of industry in the Midwest and prevent the leakage of emissions, jobs, and industry outside the program area.

If and when the Midwestern Accord is finally launched—it is scheduled to start in January 2012—it would have some similar features as the federal climate proposals (such as Waxman-Markey). It would cover entities with

[58] These are Illinois, Iowa, Kansas, Michigan, Minnesota, Wisconsin, and Manitoba. Ohio, Indiana and South Dakota are the formal observers.

[59] World Resources Institute. (2009). *Regional Cap-and-Trade Programs*. Fact sheet. Washington, D.C. Retrieved from http://www.wri.org

[60] Midwestern Greenhouse Gas Reduction Accord. (2010). *Advisory Group Final Recommendations*. Retrieved from http://midwesternaccord.org/

annual emissions of 25,000 metric tons or more,[61] and allocate allowances to vulnerable energy-intensive industrial entities, similar to the federal rebate programs. But there also are important differences:

- The allowances would be based on historical emissions, using the average of the most representative consecutive three years of emissions data within the past ten years—the federal bill would use only the prior two-year average of emissions, tied to an entity's production output and emissions intensity.
- The allowances would be allocated to mitigate the program's costs for energy-intensive industries based only on their direct emissions—the federal bill's rebates would be based on the industries' direct *and* indirect emissions.
- To receive an allocation, a company would need to certify that the allowances will be used to improve the competitiveness of its facilities within participating jurisdictions, directly or through investments that lower the costs of compliance, subject to an audit to ensure the allowances serve this purpose, and to detect and prevent windfall profits—the federal bills have no such requirements.

If Ohio were to participate in the Accord, the implications for its manufacturing industries would be similar to those if a federal cap-and-trade bill system was in place. There would be costs incurred from the pricing of CO_2e emissions by industries with large stationary sources, which could be especially high for fossil-fuel energy-intensive industries. Like the federal programs, the Accord would provide for some mitigation of these costs, in recognition of the need to avoid undercutting the region's industrial competitiveness with the climate measure. However, the Accord appears to lack direct mitigation coverage for heavily electricity-reliant industries, such as primary aluminum, to cover their additional costs of electricity-use, even if their direct emissions allowance costs would be offset by allowance allocations.[62] *In a state heavily dependent on coal-generated electric power, such as Ohio, these electricity costs could be appreciable*.

[61] Electric generating units with a capacity of less than 25 megawatts should be exempt and combustion units that burn 100% biomass should be exempt for carbon dioxide emissions only. Annual emissions shall be calculated using a three-year rolling average. Midwestern Accord, *Advisory Group Recommendations*.

[62] The Advisory Group recommends allocating a quantity of allowances directly to electric power generators—both regulated utilities and the unregulated power merchants—though how these allowances could be used would be at the discretion of participating jurisdictions, i.e., for cost mitigation for consumers, GHG reduction initiatives for the sector, and/or climate change adaptation. However, there is no explicit specification for mitigating the costs of indirect emissions from the allowance costs incurred by power plants, whether regulated or merchant, passed along to their customers, including EITE manufacturers. Midwestern Accord, *Advisory Group Recommendations*.

The requirement that the Accord's allowance allocations be tied to certification that they would be used to increase manufacturers' energy-savings is a positive addition, reflecting the awareness by the region's leadership that this ultimately would benefit the participating jurisdictions' competitiveness. As discussed below, Ohio's industries would benefit as well if its energy-intensive industries in particular were able to make substantial energy-efficiency improvements, regardless of whether a carbon-mitigation program was in place—though the free allowances would provide additional incentive and resources to make such investments.

On the other hand, there are genuine time-lags and technological limitations on EITE manufacturers being able to make significant energy-saving gains over the short- to medium-term, that might make it difficult for firms to meet certification requirements. Hence, while the regional program could prompt more rapid adoption of incremental, but not insubstantial, energy improvements—such as introducing combined heat and power (CHP) systems and other heat recovery and energy-efficiency technologies—the federal program essentially just "buys" more time for EITE manufacturers to invest in and adopt more advanced, energy-saving combustion and process technologies over the long-term. However, there are no direct incentives in the federal legislation that would necessarily encourage or assist EITE manufacturers to invest in such a conversion.

EPA GHG regulations. Despite the unlikelihood of federal legislation and uncertainty of Ohio participating in the Midwestern Accord any time soon, Ohio's industries could still be subject to the U.S. Environmental Protection Agency efforts to regulate GHGs. On April 2, 2007, the Supreme Court ruled in *Massachusetts v. EPA*, 549 U.S. 497 that GHGs, including carbon dioxide, fit the definition of pollutants under the Clean Air Act (CAA). It further found that EPA was required to determine whether or not emissions of GHGs from new motor vehicles cause or contribute to air pollution that may reasonably be anticipated to endanger public health or welfare. This ruling and subsequent findings of the EPA led to a rule setting GHG standards for light-duty vehicles, finalized on April 1, 2010, which in turn triggered CAA permitting requirements for stationary sources on January 2, 2011.

On December 23, 2010, the EPA issued a series of rules that put the necessary regulatory framework in place to ensure that industrial facilities can get CAA permits covering their GHG emissions when needed. Beginning in January 2011, industries that are large emitters of GHGs, and are planning to build new facilities or make major modifications to existing ones, must obtain air permits and implement energy-efficiency measures or, where available, the best available control technology (BACT)—determined on a case-by-case basis, taking into account, among other factors, the cost and effectiveness of the control—to reduce their GHGs emissions. This includes the nation's largest industrial GHG emitters, such as power plants, refineries and cement production facilities—the first two, according to the EPA, represent nearly 40% of the GHG pollution in the United States. Emissions from small sources would not be covered by these GHG permitting requirements.[63]

Specifically, the permitting will proceed in two steps, perhaps followed by additional steps. First, between January 2, 2011 and June 30, 2011, no sources would be subject to CAA permitting requirements due solely to GHG emissions. That is, only sources currently subject to the EPA's prevention of significant deterioration (PSD) permitting program—newly constructed or modified in a way that significantly increases emissions of a pollutant other than GHGs—would be subject to permitting requirements for their GHG emissions. For these projects, only GHG emissions increases of 75,000 tons per year (tpy) or more would require determining BACT for these emissions. Similarly, only sources currently covered by the program—newly constructed or existing major sources for a pollutant other than GHGs—would be subject to operating permits under Title V of the CAA, for GHGs.[64]

In step two, from July 1, 2011 through June 30, 2013, PSD and Title V operating permits will apply to projects with GHG emissions, even if they don't exceed permitting thresholds for other pollutants. The PSD program for GHGs will cover new construction projects that emit at least 100,000 tpy of GHG emissions and modifications of existing facilities that increase by at least by 75,000 tpy of GHG emissions. Operating permit requirements would apply to facilities that emit at least 100,000 tpy of GHG emissions.

Implications for Ohio. Although the EPA GHG regulations are controversial, they may not have a very great impact on Ohio's industries—or at least, not for a while—especially compared to the likely cost impacts of a cap-and-trade climate bill. The EPA estimates that fewer than 15% of all major U.S. sources of GHG emissions from the manufacturing and electric power sectors will be required to address GHG emissions through the permitting process annually.[65] The first round of GHG permitting requiring BACT only will apply to a small

[63] EPA is expected to propose standards for power plants in the later half of 2011 and for refineries in December 2011 and issue final standards in May 2012 and November 2012, respectively. See http://www.epa.gov/nsr/ghgpermitting.html

[64] Title V operating permits are legally enforceable documents issued to air pollution sources after the source has begun to operate. Most Title V permits are issued by state, local and tribal permitting authorities.

[65] World Resources Institute. (2010). *EPA, Clean Air Act, and U.S. Manufacturing*. WRI Fact Sheet. Washington, D.C. Retrieved from http://www.wri.org.

set of new facilities and major modifications of existing plants. Also, GHG permitting initially will focus only on the largest industrial sources, which covers nearly 70% of the GHG pollution from stationary sources.[66]

Ohio's electric power sector includes a number of sites that currently exceed even the EPA's highest GHG emissions threshold of 100,000 tpy, and it has several manufacturing facilities (i.e., iron and steel, petroleum refineries, cement) that also may exceed this amount. However, further investigation is needed to determine how many of these facilities, starting in step 2, will be among the 550 sources that EPA estimates will need to obtain Title V permits for the first time due to their GHG emissions—the majority of which are which likely to be solid waste landfills and industrial manufacturers—or among the 900 additional PSD permitting actions EPA predicts will be triggered each year by increases in GHG emissions from new and modified emission sources.

Moreover, a World Research Institute (WRI) analysis of the EPA GHG program argues that under the current rulings, existing manufacturing facilities will not be affected in the regulations' first rounds. It notes that since commercial-scale, end-of-smokestack retrofit technologies are currently not available for capturing and permanently storing carbon emissions, "it is very unlikely that BACT standards will no more than require new and modified facilities to use off-the-shelf energy-efficient equipment, such as boilers, when seeking pre-construction permits."[67] However, although the first rulings are limited to electric generation, refineries, and cement plants, it appears likely that EPA eventually will expand its efforts to control GHG emissions to other energy-intensive industries. For example, it has issued a series of technical "white papers" summarizing readily available information on control techniques and measures to control emissions from the above sectors, as well as the iron and steel and pulp and paper industries, and nitric acid plants.[68]

In short, in the foreseeable future, only a relatively small number of Ohio's electric generators and manufacturing facilities may be subject to the EPA's GHG permitting requirements at all. The costs incurred by Ohio facilities from purchasing operating permits or complying with the BACT requirements cannot be assessed without more information about the facilities and potential future

[66] The PSD thresholds requiring determination of BACT for their GHG emissions of 100,000 tpy (or 200 million pounds per year) for new construction and 75,000 tpy (or 150 million pounds per year) for modifications that significantly increase emissions, and Title V operating permit thresholds of 100,000 tpy, are substantially higher than the 25,000 tpy (50 million pounds per year) threshold set by the Waxman-Markey climate bill, to be subject to allowance allocation costs in the bill.

[67] WRI. *EPA, Clean Air Act, and U.S. Manufacturing.*

[68] These white papers are available at http://www.epa.gov/nsr/ghgpermitting.html

projects. However, many of the investments in BACT required as a result of the permitting process are likely to be limited to times when facilities plan to expand their production capacity—say, steel mills building new, lower-carbon iron-making facilities—or make large energy-efficient upgrades of existing equipment. The latter are not likely to be undertaken until industrial facilities are ready to retire existing equipment—such as, say, integrated steel mills, replacing old with new energy-efficient boilers and related technologies. That is, the PSD permitting process largely would impose BACT requirements on substantial new investments or equipment upgrades that companies may already be planning to make for ordinary business reasons.

Risks of inaction. The potential economic "risks" in Ohio that might be associated with federal or state climate legislation or EPA's GHG regulations, need to be weighed against the environmental, economic and social risks of *not* acting to address climate change—the potential costs of adaptation to the impacts of global warming—for the nation and for Ohio, in particular. This analysis is beyond the scope of the current study. However, it is important to recognize that the efforts to curb GHG emissions in the atmosphere are driven by genuine concerns that over the coming decades, global warming trends could be associated with more volatile weather patterns, more frequent and extreme storm events, and other weather-related effects that could have potentially serious adverse impacts on, say, agricultural output and public health and safety in the state. There is a growing body of research on evaluating the potential economic costs of climate events and adaptation. It appears likely that these costs eventually would far exceed the costs associated with climate change mitigation in the proposed legislation and regulations.

V. ANALYZING OPTIONS AND OPPORTUNITIES

There is a different kind of "risk" associated with Ohio's industrial sector not taking action to increase its energy-efficiency and reduce its dependency on fossil-fuel energy sources: the competitiveness of Ohio's manufacturers could suffer if they fail to take advantage of the opportunities that would be created by climate and GHG regulatory policies to invest in energy-saving technologies and practices. The cost mitigating measures in federal and state climate programs would buy time for manufacturers to adapt to the higher economic costs incurred from putting a price on or regulating GHG emissions. However, they eventually would need to find ways to reduce their use of fossil-fuel energy sources which determine their direct and indirect emissions, if they want avoid the rising costs of carbon-constraining regulatory policies.

On the other hand, there would be a net gain to manufacturers if they were able to make substantial energy-efficiency improvements in their production processes. As the WRI analysis of the EPA GHG regulations points out, the energy-efficiency upgrades that most likely will be required by the BACT regulation "are likely to significantly reduce energy costs for affected U.S. manufacturing facilities." Moreover, it adds, the capital investments manufacturers make to increase energy productivity could "improve competitiveness and create a range of other positive, cascading economic and employment effects benefitting suppliers as well as the workers who install, operate and maintain new equipment."[69]

[69] WRI. *EPA, Clean Air Act, and U.S. Manufacturing.*

Even without the spur of climate policy and emissions regulation, Ohio's energy-intensive and trade-sensitive manufacturing industries could find themselves at a competitive disadvantage with foreign trade competitors, from both developed and emerging economies, if they don't make significant gains in energy efficiency and reduce energy costs in the coming decades. And evidence shows that there is much room for improvement, for the nation as a whole, and for Ohio. Overall, U.S. energy productivity—the amount of goods produced per unit of energy input—is lowest among all developed nations.[70]

U.S. industry lags in energy-efficiency. Of particular significance is that U.S. manufacturers lag in their energy-efficiency attainments compared to many of their international trading partners, despite substantial energy-efficiency gains U.S. industries have made in the past—e.g., the U.S. steel industry reportedly has decreased the energy it consumes to produce one ton of steel by 29% since 1990.[71] For example:

- In 2005, the International Energy Agency (IEA) estimated that the U.S. steel industry was 10% more energy intensive than Korea, 7% more than Germany, and 6% more than Japan.[72]
- The National Academy of Sciences claims that the U.S. cement industry is among the least efficient in the world—it uses 80% more energy to produce "clinker" (the main component of cement) than world leader Japan.[73]
- The IEA estimates that the U.S. pulp and paper sector could improve its electrical energy efficiency by 16% using "best available technology''—it currently lags behind Germany, France, Italy, Sweden, Korea, Japan, Spain, Finland, and Norway.[74]

[70] Japan's energy productivity is more than double, and Northwestern Europe is 23% greater, than that of the United States. Meanwhile, Ohio ranks 30th among the states in energy productivity. Source: U.S. Department of Energy. Oak Ridge National Laboratory. (2008, Dec.). *Combined Heat & Power, Effective Energy Solutions for a Sustainable Future*. State data sources are Bureau of Economic Analysis and Energy Information Administration. Cited in Woodrum, A. (2009, Nov.). *Greening Ohio Industry*. Policy Matters Ohio. p. 6. Table 1.

[71] See the American Iron and Steel Institute's commitment to reduce energy use at http://www.climatevision.gov/sectors/steel/pdfs/AISI-Energy-Efficiency-Fact-Sheet.pdf. Cited in Environmental Defense Fund (EDF). (2009). *Think U.S. Industry Can't Be More Competitive*. Washington, D.C. Retrieved from www.LessCarbonMoreInnovation.org

[72] International Energy Association. *Tracking Industrial Energy Efficiency and CO_2 Emissions*. Cited in EDF. *Think U.S. Industry Can't Be More Competitive*. Retrieved from http://browse.oecdbookshop.org/oecd/pdfs/browseit/6107151E.PDF

[73] EDF. *Think U.S. Industry Can't Be More Competitive*. The report notes in the 1990s, the U.S. cement industry's "energy efficiency decreased as increased demand and lower energy prices resulted in less efficient plants being put back into use. Meanwhile, other countries like Germany and Mexico have reduced the amount of energy to produce a ton of cement by more than 1% a year over the last decade." Sources: IEA. *Tracking Industrial Energy Efficiency*; National Academy of Sciences. *Real Prospects for Energy Efficiency in the United States*. p. 146. Retrieved from http://www.nap.edu/catalog.php?record_id=12621

[74] Cited in EDF. *Think U.S. Industry Can't Be More Competitive*. Source: IEA, *Tracking Industrial Energy Efficiency*.

- The IEA also estimates that for U.S. chemicals manufacturing, the gap between current energy use and energy use using "best practice technology" is almost 30%, well behind Germany (9.8%), Japan (10%), France (11%), India (15.8%), Brazil (17.2%), and China (20.5%).[75]

Emerging nations' efficiency gains. It may not be all that surprising that U.S. manufacturing lags the developed nations in energy-efficiency, which generally have higher energy prices and more stringent environmental controls. However, the major developing countries, especially China and India, also are expanding their commitment to energy efficiency and conservation, largely as a way to deal with growing shortages in energy supplies needed to fuel their rapidly growing economies. These nations' industries, which already benefit from many competitive advantages in global markets relative to the United States and developed nations—low labor costs, lax environmental and labor regulations, government subsidies, non-tariff trade barriers, artificially low currency rates (China)—could over time make additional competitive gains as they improve their energy efficiency.

Typically, the emerging nations' energy-intensive industries have been substantially less efficient and more polluting than their Western counterparts.

[75] Ibid.

For example, China's steel industry, the largest in the world—it produces four times as much as steel as the United States—is also the world's largest polluter.[76] The industry includes 800 small mills—accounting for one-fourth of total steel production in China—which are characterized by limited resources, low efficiency, and minimal or zero pollution control measures. China's steel industry also is dominated by integrated steelmaking using basic oxygen furnaces (BOFs) that mostly burn coal, mostly with high sulfur content not stringently controlled by China's environmental standards.[77]

Nevertheless, China has taken significant steps to reduce its energy use, prioritizing energy efficiency and conservation as a means to keep its economy going and also to fight climate change. Aside from trying to shut down many of the inefficient, polluting small mills located throughout its countryside, it has embraced an energy conservation strategy to improve energy efficiency through new technology, equipment and processes.[78] China's five-year program for national economic and social development (2006-2010), for example, set a binding efficiency target to reduce energy consumption per unit of GDP to 20% below 2005 levels. It recently announced a reported investment of 5 billion Yuan (about $750 million) from 2010 to 2012 to promote energy efficiency technology in the steel industry, such as generating electricity with waste heat from sintering.[79]

China's 1000 Key Enterprises Energy Efficiency campaign involves firms from the steel, power, textiles, chemicals, construction materials, coal, petroleum and petrochemicals, non-ferrous metals, and paper industries, with the goal of reducing coal consumption and its Efficiency Power Plant (EPP) program includes a range of energy-efficient programs to promote electricity savings.[80] India similarly has made progress, as reflected in the delinking of its GDP growth and

[76] On a per ton of steel basis, the emissions of key pollutants—SO_2, particulate matter (PM), and NOx—in China are between three and 20 times greater than the United States. Source: Alliance for American Manufacturing. (2009, Mar.). *An Assessment of Environmental Regulation of the Steel Industry in China*. Washington, D.C. pp. 4-5.

[77] China has about 900 blast furnaces, and another 280 are in construction and 30 more are well along in their planning stages. AAM. *An Assessment of Environmental Regulation of the Steel Industry*. p. 8.

[78] United News of Bangladesh. (2007, Aug. 17). Global impact of China's energy policies. *HighBeam Research*. Retrieved from www.highbeam.com

[79] This investment will be carried out in 37 key steel plants in China; 18 sintering machines in seven steel mills will be equipped with generator units, predicted to save about 400,000 metric tons of standard coal. Over the next three years, 82 sintering machines in the 37 steelworks will receive technology, saving about 1,575 million tons of standard coal every year. Source: HighBeam Research. (2010, Jan. 20). China to Promote Energy-Efficiency Technology in Steel Industry. *AsiaPulse* News. Retrieved from http://www.highbeam.com

[80] HighBeam Research. (2010, July 13). Energy: China Outshines Europe in Efficiency. European Report. Retrieved from http://www.highbeam.com; AAM. *An Assessment of Environmental Regulation of the Steel Industry*. p. 6.

primary energy growth.[81] The Indian government recently started an auditing program for its steel industry, including identifying conservation opportunities which is a preliminary step towards developing energy savings programs at enterprises.[82]

U.S. industry support for energy-efficiency. U.S. industry leaders, especially from the energy-intensive sector, are very aware of the competitiveness implications of limited energy supply and rising costs in the global economy, not to mention the concern of many (e.g., the corporate members of USCAP) over the looming threat of global warming. As already noted, many industries already have made substantial strides in reducing their energy intensity over the past decades. But there also is recognition that there still is a great deal more room and need for further energy-efficiency gains, to reduce their costs associated with energy use and maintain their competitiveness, even in the absence of climate policies.

For example, American Iron and Steel Institute (AISI) CEO Thomas Gibson notes that the gains the steel industry has made in reducing its energy intensity since 1990, "is evidence of the steel industry's longstanding commitment to sustainability." He reports that over the long-term, it is working on developing a breakthrough steelmaking process that emits little or no CO_2.[83] Similarly, the American Chemistry Council (ACC), whose members represent 85% of the chemical industry's production in the United States, has committed to an overall GHG intensity reduction target of 18% by 2012 from 1990 levels.[84] A 2010 survey released by CSC and Chemical Week magazine has found that top manufacturers are seeing large gains as they align core business functions to maximize the environmental and financial benefits of sustainable practices. They note "a significant shift in the industry to reinvent the corporate sustainability agenda as a major driver of innovation." As Sylvain Lhôte, an industry representative, observes, "it's not just carbon management, or energy management—it's about how we can minimize the environment and social impact while maximizing the financial contributions we can make."[85]

[81] In a report to the United Nations, India reported a GDP growth of 8% with only a 3.7% growth in total primary energy consumption. It claims that India's major energy-intensive sectors—steel, aluminum, fertilizer, paper, cement—have achieved levels of energy efficiency at the global level. For example, energy efficiency in India's cement plants are reported to be among the world's highest according to the report. HighBeam Research. (2007, Apr. 18). Energy consumption, GDP growth effectively delinked: *India. The Press Trust of India.* Retrieved from http://www.highbeam.com

[82] Specifically, the state-run Steel Authority of India plans to appoint an Energy Auditing Agency to provide the over-all energy auditing services—in areas including coke oven and power plants and utilities, compressed air, water among others. HighBeam Research. Steel Authority of India to Audit Five Steel Plants' Energy Use. (2010, Oct. 25). *Asia Pulse News*. Retrieved from http://www.highbeam.com

[83] HighBeam Research. (2009, Jan. 1). U.S. steelmakers claiming new achievement in energy efficiency. *Metal Producing & Processing.* Retrieved from http://www.highbeam.com

[84] Cited in EDF. *Think U.S. Industry Can't Be More Competitive.*

[85] Sustainability Identified by Chemical Industry as Key Competitive Differentiator. (2010, Oct. 14). Cited in National Council for Advanced Manufacturing. (2010, Nov. 29). *Sustainable Manufacturing News, Vol. 1, No.7.* Retrieved from http://www.nacfam.org/

Opportunities assessment. It is not clear, however, whether these kinds of gains would be enough to compensate for the added costs of carbon regulations that energy-intensive manufacturers might incur, whether from a federal or state cap-and-trade program or from EPA GHG emissions regulations, or if they can achieve the level of reduction in energy consumption required to reduce their CO_2e emissions to meet climate sustainability goals.

The HRS-MI studies of climate policy and energy-intensive manufacturing estimated that, depending on the industry, energy efficiency gains of 20-30% or more may be required to offset the added costs of GHG emissions allowances for the climate bills studied, if there were no cost-mitigation measures (such as output-based rebates) if cap-and-trade legislation were enacted. Even with cost-mitigation measures in place, the impacts on industry production costs and bottom lines from the policies would only be deferred until after 2025, after which time the energy-efficiency gains required would rapidly grow. Steady energy-efficiency gains by these industries through that period could offset a large share of these costs—but additional energy-efficiency gains are still likely to be needed to maintain the competitiveness of energy-intensive industries in this later period.

Whether these gains can be made by U.S. manufacturers and under what circumstances, depends on a number of factors. These are discussed below, drawing upon a number of studies, by federal, international, and independent research organizations, which examined manufacturers' options and opportunities for achieving the energy-efficiency improvements needed to minimize the financial "risks" associated with GHG emissions regulation, while also enhancing their competitiveness. Although these studies were focused on industries and their production activities at the national and international levels, they nevertheless are largely applicable to Ohio's industries.

The discussion below, in particular, examines three questions:

- How much potential is available for U.S. (and Ohio) energy-intensive manufacturers to achieve cost-effective, energy-efficiency improvements and emissions abatement?
- What are the market conditions and technical and market barriers that prevent firms from investing in the equipment and practices that improve efficiency?
- What federal and state policies, and private sector strategies, are needed to encourage and enable industries' investments in energy-efficiency measures?

Energy efficiency and carbon abatement potential. Most studies of energy-efficiency options for energy-intensive industries indicate that there are substantial opportunities for making significant energy savings and emissions abatement in the coming decades.

- A WRI review of some of these analyses noted that the use of best practices and technologies available today could achieve up to 40% savings in energy use across a broad range of manufacturing processes. It further notes that energy-intensive sectors, in particular, which are more exposed to the risks of international competition and volatile fossil fuel prices would benefit the most from energy-efficiency investments.[86]
- A DOE study identifies a number of advanced, highly energy-efficient technology options and other energy saving means that could significantly contribute to cost-effective emissions reduction.[87]
- A McKinsey & Company study similarly found that there could be energy use and emissions abatement gains ranging from 20-55% by 2030 from abatement opportunities consisting of energy efficiency, shifting fuels, or shifting to low-carbon technology alternatives.[88]
- Another McKinsey study of energy savings potential estimated that capturing this potential could save $47 billion per year in energy costs, with present value investments of $113 billion between 2009 and 2020, yielding a total present-value savings of $442 billion.[89]
- The ACEEE report evaluating energy-saving opportunities for Ohio identifies a diverse set of efficiency measures that could yield a potential total economic electric savings for industry of 16%, plus an additional economic savings of 5-10% for process-specific efficiency measures, primarily in large energy-intensive facilities, resulting in an overall industrial efficiency resource opportunity for electricity between 21-26%.[90]

These potential gains vary across a wide range of manufacturing sectors, involve improvements and innovation opportunities that are both cross-cutting and highly fragmented across subsector-specific process steps (e.g., pulping and bleaching in pulp and paper, clinker production in cement, etc.),[91] and are

[86] WRI. *EPA, Clean Air Act, and U.S. Manufacturing*

[87] U.S. Environmental Protection Agency. (2005). U.S. Climate Change Technology Program, Strategic Plan, Draft for Public Comment. Washington, D.C. Section 4.3, 4-11–4-16. Retrieved from http://www.epa.gov/climatechange/policy/cctp.html

[88] McKinsey & Company. (2009). *Pathways to a Low-Carbon Economy*. p. 32.

[89] Granade, H. C., Creyts, J., Derkach, A., Farese, P., Nyquist, S. & Ostrowsi, K. (2009). *Unlocking Energy Efficiency in the U.S. Economy.* McKinsey Global Energy and Materials. p. 75.

[90] ACEEE et al. *Shaping Ohio's Energy Future*. p. 114.

[91] Granade et al. *Unlocking Energy Efficiency in the U.S. Economy.* p. 76.

achievable over multiple timeframes (i.e., over the short-, medium-, and long-term). For example, McKinsey estimates that 61% of energy saving opportunities resides in energy-intensive industries, the remainder in non-energy-intensive manufacturing industries. Similarly, opportunities for reducing energy use and emissions in sector-specific processes represent two-thirds of the potential energy-efficiency gains in these industries; opportunities for saving energy in cross-cutting energy support systems account for a third.[92]

DOE studies have also made a distinction between the "technical" potential for efficiency improvements—technically achievable gains with existing technologies, though they are not necessarily cost-effective—and the "theoretical" potential for efficiency reductions—based on a theoretical minimum of energy use possible as limited by thermodynamics—for different industrial processes and sectors. McKinsey reports that these studies estimate technical potential gains ranging from 35-71% in many energy-intensive industries, and "theoretically" possible efficiency gains ranging from 43-85%. However, to capture the latter gains, McKinsey notes, would likely require a "clean-sheet" (i.e., greenfield) redesign of operations at industrial production facilities, rather than retrofitting measures into existing facilities, which would be very costly.[93]

[92] Ibid.
[93] Ibid. p. 82.

Drawing from a number of these sources,[94] Table 11 summarizes the range of potential energy-efficiency opportunities for energy-intensive manufacturing industries. It distinguishes between cross-cutting technologies and practices which could have applications in multiple industry sectors and process-specific improvements largely applicable to individual industries—both using existing technologies—and potential savings for several major industry sectors. It also identifies emerging technologies with substantial long-term energy-efficiency potential, requiring more R&D before they become technically and commercially available.

- ***Cross-Cutting Energy-Efficiency Measures***—These include technologies and practices that can be applied in multiple industry sectors and processes within these sectors—tailored to the specific purposes they are applied to—with the potential of generating energy savings. These measures involve existing technologies and capabilities that can be applied over the short- to medium-term, limited only by cost considerations and other technical and market barriers (see below). They can be widely applied to energy-intensive and non-energy-intensive industries. Some measures deserve special attention, due to their particularly large promise for achieving significant energy-savings and emissions abatement:
    - Motor systems—Motor systems are ubiquitous in industrial processes and facilities, used in diverse applications from pumps, fans, and air and refrigeration compressors, to materials handling and processing (conveyors, machine tools and other processing equipment). The ACEEE estimates that motor systems consume nearly 60% of Ohio's industrial electricity, the largest uses in material processing, material handling, pumps, and compressed air systems. Motor systems electricity consumption varies across industry sectors—70% of electricity used in chemicals and petroleum refining, 25% in primary metals, and 75% in food processing. [95] Motors are one of the areas with the largest potential for efficiency gains in Ohio, resulting in reduced electricity demand and GHG emissions tied to electricity use by the state's industrial sector.

[94] McKinsey & Company. *Pathways*. Recently, EPA has released a series of whitepapers intended to provide basic information on GHG control technologies and reduction measures in order to assist regulators and regulated entities in implementing technologies or measures to reduce GHGs under the Clean Air Act, particularly in permitting under the prevention of significant deterioration (PSD) program and the assessment of best available control technology (BACT). Manufacturing industries covered include iron and steel, pulp and paper, cement, and petroleum refineries. See http://www.epa.gov/nsr/ghgpermitting.html

[95] ACEEE estimates that the share of industrial electricity consumed in Ohio in 2008 by motors was 57%; process heating, 13%; electro-chemical processes, 10%; lighting, 7%; HVAC, 8%, and other electric uses, 5%. Motor end use breakdown includes material processing (13% of motor systems electricity consumption); material handling (12%); pumps (10%); compressed air (8%); fans and blowers (7%); refrigeration (4%); and other motors (1%). Source: ACEEE et al. Shaping *Ohio's Energy Future*. pp. 114, 117.

- Combined Heat and Power (CHP)—A form of energy recycling also known as cogeneration, CHP systems employ the heat byproduct of electric generation units to provide heat used in other processes in a facility. Industrial facilities use CHP systems because their facilities require large amounts of thermal energy not only for processes but also heavy electricity loads to operate their mechanical machinery. The double uses of a single fuel input can achieve efficiencies of 85-90%—about three times the efficiency of electric generation-only units.[96] McKinsey notes that chemical and iron and steel sectors, which together consume 20% of total industrial end use energy, represent 47% of total CHP potential, owing to their large steam energy needs.[97] A Recycled Energy Development (RED) paper estimates that in four of Ohio's industrial sectors—petroleum, chemicals, pulp and paper mills, and ethanol—the thermal load requirements at just a few of the largest facilities could be optimized to generate between 850-2000 MW of electricity.[98]

- Waste heat recovery—Another form of energy recycling, waste heat recovery, entails extracting useful energy from the waste gas streams released by industrial processes. These streams typically will be cooled (by water) enough to pass through pollution control devices and then exhausted into the atmosphere. Heat recovery steam generators allow the gases to contact water circulating in tubes, converting water to steam, which then can be used to generate additional electric power or used in another thermal process. RED estimates a potential generation of 50-200 MW at several integrated steel mills in Ohio capturing waste heat from coke oven batteries and blast furnace operations to generate electric power and process steam, without any increases in fuel usage. It also identifies waste recovery opportunities at several steel mini-mill and glass facilities in the state.[99]

- Carbon capture and storage (CCS)—CCS is the capture of CO_2 from a point source and its subsequent sequestration through methods such as injection into subterranean formations for permanent storage. It can be added to new emissions-intensive manufacturing processes or retrofitted to existing plants. A McKinsey study notes that CCS technology is still in

[96] Recycled Energy Development (RED). (2008, Feb. 14). *Energy Recycling Opportunities for Ohio: An Industrial Analysis*.

[97] Granade et al. *Unlocking Energy Efficiency in the U.S. Economy.* p. 86.

[98] RED. *Energy Recycling Opportunities*.

[99] RED identifies four integrated mills in Ohio—ArcelorMittal in Cleveland, Wheeling-Pittsburg Corp. in Steubenville, AK Steel in Middletown and WCI Steel in Warren—each with 100-200 MW recovery potential per facility. It also identified steel mini-mill operations in several locations with 10-20 MW recovery potential per facility, and glass facilities with 5-15 MW recovery potential (e.g., Libbey Glass Inc in Toledo). RED. *Energy Recycling Opportunities*.

an early stage of development and the CCS transport infrastructure has yet to be built, but it could be available for newly built plants in 2021 and retrofits from 2026 on.[100] It could play an increasingly important role in emissions abatement for several industries—capturing emissions from petroleum refineries, cement kilns, ammonia production and fuel-combustion in chemical plants and iron and steel blast furnaces, and injecting them into deep geological formations for permanent storage.[101] McKinsey estimates that CCS could account for a possible 21% of total abatement potential in chemical manufacturing.[102] (More on CCS can be found in Chapter 4.)

- Materials recycling—Recycled waste materials or recovered scrap is playing an increasingly important role in reducing the energy and emissions profiles of several energy-intensive industries, such as in steel, aluminum, paper, and glass manufacturing. Over 70% of steel is recycled and 60% of all domestic steel production comes from the processing of scrap steel. Similarly, nearly 40% of U.S. paper and paperboard products are made from recovered wastepaper. Secondary smelting of recovered aluminum accounts for over 60% of U.S. aluminum production. The recycled segments of these industries are somewhat less energy intensive than processing virgin materials. For example, recycling saves almost 95% of the energy needed to produce aluminum from its original source, bauxite ore.[103]

• ***Process-Specific Measures***—These measures include energy-efficiency and carbon abatement improvements of existing equipment, processes and practices, and the introduction of, or replacement of old equipment by, new, more energy-efficient, lower-carbon equipment specific to an industry. Most of these measures would draw upon available technologies and capabilities, and could be applied over the short- to medium-term, under the right economic conditions. While most of the cross-cutting measures are well-known applications that many manufacturers will usually find cost-effective for achieving energy savings and emissions abatement, process-specific technologies tend to require retrofitting or replacement of existing equipment, which can be more costly. Table 11 shows several of these technologies. For example:[104]

[100] McKinsey & Company. *Pathways.* p. 77.

[101] McKinsey estimates that for new-build steel plants, CCS would yield a 90% capture rate of CO_2, but only 40% of older plants are suitable for CCS retrofits. McKinsey & Company. *Pathways*. p. 84.

[102] McKinsey & Company. *Pathways.* p. 89.

[103] Yudken & Bassi. *Climate Policy and Energy-Intensive Manufacturing.* pp. 79, 113, 153-4, 178, 249-250.

[104] McKinsey & Company. *Pathways;* EDF. *Think U.S. Industry Can't Be More Competitive.*

- Energy-saving alternatives in integrated iron and steel mills include using pulverized coal and natural gas injection, which can more efficiently smelt iron ore, and non-coking coal, which eliminates the need for coke ovens.
- Energy-saving measures specific to the pulp and paper industry include improvements in digester efficiency, the use of chemical recovery boilers that also generate steam, and advanced dryer control systems to optimize the drying process.
- Petroleum refineries can benefit from improved separation efficiency for the distillation process and advanced separation system technology.
- In cement making, gains can be made by using high efficiency roller mills and replacing energy-intensive "clinker" with less energy-intensive alternatives like fuel ash, slag, and other mineral industrial chemicals.
- Chemical manufacturing measures include ethylene cracking improvements and optimization of the catalysts.

• ***Emerging Technologies***—These are advanced production technologies that may not be technically and commercially available or used at a commercial scale for many years, yet they hold the promise of substantial energy-efficiency and/or carbon abatement gains. These long-term opportunities include breakthrough and transformational technologies involving substantial changes in, or the introduction of new processes that replace, older methods of production. In many industries, research and development is underway on these alternatives, and some are already in the demonstration phase. For example, according to the American Iron and Steel Institute, the greatest potential for reducing energy intensity of steelmaking lies in the research and development of new transformational technologies and processes.[105] Examples of transformational R&D initiatives include:

  - The paired straight hearth surface (PSH), under development at McMaster University in Ontario, Canada, which is a cokeless alternative to the energy and carbon intensive blast furnace used in steelmaking. It has a lower coal rate in comparison with other alternative ironmaking processes.[106]

---

[105] U.S. EPA. Office of Air Radiation. (2010). *Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from the Iron and Steel Industry.* p. 62. Retrieved from http://www.epa.gov/nsr/ghgpermitting.html

[106] Alternative processes, also applicable both to integrated and EAF steelmaking, including molten oxide electrolysis (under development at MIT) and ironmaking by flash smelting using hydrogen (being developed at the University of Utah). Ibid. See also Yudken & Bassi. *Climate Policy and Energy-Intensive Manufacturing.* p. 61, Table 3-C; pp. 105-107.

- Black liquor gasification, in kraft pulp and paper mills—involves creating a clean synthesis gas from black liquor (recovered pulping chemicals) that can be used in boilers or in combined-cycle processes to generate on-site electricity and process steam.[107]

- Inert anodes, which replace carbon anodes consumed by the electrolysis process in primary aluminum smelting and are major sources of CO_2 emissions; the wetted drained cathode technology which could result in as much as an 18% reduction in the electrolysis process; and carbothermic and kaolinite reduction processes which could replace the Hall-Héroult technology used in aluminum smelting since the 1866.[108]

[107] Advanced paper drying machines (such as the impulse, gas-fired, and multi-port paper dryers) and advanced papermaking technologies are also under development. U.S. EPA. (2010). *Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from the Pulp and Paper Manufacturing Industry.* p. 46. Washington, D.C. Retrieved from http://www.epa.gov/nsr/ghgpermitting.html. See also Yudken & Bassi. *Climate Policy and Energy-Intensive Manufacturing.* p. 61, Table 3-C; pp. 105-107.

[108] Yudken & Bassi. *Climate Policy and Energy-Intensive Manufacturing*. pp. 147-149.

Table 11. Energy-Efficient Low-Carbon Technology Options

INDUSTRY	PROCESS-SPECIFIC TECHNOLOGIES		EMERGING TECHNOLOGIES
Iron & Steel and Ferroalloy Products	• Pulverized coal and natural gas injection • Direct smelting—eliminating coke oven • Thin slab casting	• EAF—oxy-fuel burners • DC-arc furnace • Scrap preheating • Improved blast furnace controls	• Paired straight hearth furnace • Molten oxide electrolysis • Hydrogen flash melting
Petroleum Refineries	• Improved separation efficiency for distillation • Advanced separation technology	• Improved pre-heater efficiency • Improved catalyst efficiency • Convert condensing turbine to electric motor drive	• Alternative hydrotreater and desalter designs • Progressive distillation design
Chemicals	• Improved efficiency of cold fractionation and refrigeration systems • Improved "cracking" processes and transfer line exchangers		• High temperature furnaces • Gas-turbine integration • Advanced distillation columns • Biomass-based systems
Pulp and Paper	• Cradle and dry debarking • Automated chip handling and thickness screening technology • Improving digester efficiency • Chemical recovery boilers that generate steam	• Heat chlorine dioxide with waste heat • Advanced dryer control systems • Optimize water removal in forming and pressing	• Black liquor gasification • Advanced dryer technologies (impulse, gas-fired, multi-port)
Cement	• High efficiency roller mills and classifiers • Replace energy-intensive "clinker" with fly ash, slag, or other mineral components	• Switch from older, less efficient "wet process" • State-of-the-art dry processing • Improve efficiency of "finishing grinding"	• Oxy-combustion for CCS • Alternative fuels-biomass • Pre-combustion membranes • Superheated Calcium Oxide (CaO)
CROSS-CUTTING TECHNOLOGIES & PRACTICES • Energy monitoring and management systems • Variable speed drives for pumps and fans • Preventative maintenance • Improved process control • Improved efficiency of boilers, heaters, turbines, conveyors, furnaces, and motors • Facility-wide opportunities (lighting, HVAC) • Insulation for steam distribution systems and boilers		MAJOR CROSS-CUTTING TECHNOLOGIES • High efficiency motor systems • Combined Heat and Power (CHP)/Cogeneration • Waste heat recovery • Materials recycling • Carbon capture and storage (CCS) (long-term)	

Sources: McKinsey & Co. "*Pathways.*" Yudken & Bassi. *Climate Policy and Energy-Intensive Manufacturing;* EDF. *Think U.S. Industry Can't Be More Competitive;* McKinsey. *Unlocking*; EPA "whitepapers," http://www.epa.gov/nsr/ghgpermitting.html; and ACEEE. *Shaping Ohio's Energy Future.*

Technical and market barriers. If a cap-and-trade program was enacted at the state or federal levels, the escalating emission allowance costs incurred by manufacturers could help drive investments in adopting energy efficiency and carbon abatement measures in energy-intensive industries, as well as other sectors. But as the HRS-MI studies have shown, while energy-efficiency investments might be more cost effective over the short- and medium-term, cost-effective options may not be available over the long run to offset the increasing costs of emissions allowances after cost-mitigation measures, such as output-based rebates, phase out. More worrisome, rather than make these investments, many manufacturers may opt to cut back their production—or worse, shut down plants and/or move operations to lower cost, less regulated offshore locations.

On the other hand, the controversial EPA GHG regulations may not impose, at least for the short-term, any substantial pressures on most energy-intensive manufacturers to invest in the "best available control technologies," which reduce energy use and carbon emissions. The regulations may help drive new investments in BACT by manufacturers in new-build situations, involving the construction of large-scale production plants or in large modifications of existing facilities. However, they only would apply to the largest facilities, and affect a small number of manufacturing facilities in the United States (and in Ohio).

Without the climate drivers, there would still remain the question raised by WRI, of why, if energy-efficiency investments are so valuable, they aren't more broadly adopted. As the WRI and many other studies of energy-efficiency/carbon abatement opportunities for manufacturing note, manufacturers confront a number of market conditions and technical barriers that prevent them from investing in efficiency improvements, even in existing, proven technologies, such as CHP, much less in longer-term, more costly advanced technologies that can yield even more substantial energy savings.[109] The primary conditions and barriers that limit investments in energy efficiency and carbon abatement technologies are technical, behavioral, and commercial.

- ***Technical limitations and availability***—Although many if not most cross-cutting technologies, such as motors, are currently available and apparently cost-effective, depending on the industries and processes where they are applied, there still may be technical compatibility and configuration issues when they are actually introduced, which increase their costs. Introducing process-specific technologies may have even more design and technical challenges, especially in retrofits. Timing is also an issue, as facility managers may be reluctant to retire equipment of an older

[109] WRI. *EPA, Clean Air Act, and U.S. Manufacturing.*

vintage before they recoup their original investments, and replace them with new equipment (such a boilers used in iron and still mills). In addition, there may be difficulties in procuring the desired equipment from suppliers. Other obstacles associated with implementing efficiency-related process improvements include space constraints, invested resource time, process disruptions, the potential effects on product quality, and safety concerns associated with system integration and energy support system maintenance. [110]

- ***Lack of information and awareness***—Plant managers may be reluctant to introduce energy-efficiency technologies because they lack sufficient information about energy-efficiency alternatives or the awareness of the potential savings that can be achieved. In most non-EITE manufacturing situations, energy represents a relatively small fraction of operating costs (less than 5%), leading to low levels of awareness and attention from senior management at industrial firms. McKinsey observes, that the top managers' lack of focus can lead to under-prioritizing of energy as an important strategic lever or metric to manage.[111] Energy costs play a much larger role in energy-intensive sectors, and therefore should attract more attention. But, other internal, organizational factors may still prevent managers from paying sufficient attention to measures that reduce energy consumption and emissions, despite the financial gains.
- ***Financial hurdles and rapid payback requirements***—Energy-efficiency investments often face "elevated" hurdle rates compared to core projects. Because industrial firms typically have very tight operational budgets, plant managers are encouraged to maximize production while keeping their near-term quarterly costs low, which works against projects with long payback periods. Many managers typically use payback periods of less than three years for energy-efficiency projects, and sometimes 18 months.[112] As the Ohio Manufacturers' Association (OMA) concludes, "Many manufacturers are struggling with implementing efficiency measures even as they acknowledge that efficiency offers many benefits, including reduced consumption that results in lower generation costs and a smaller carbon footprint." Although they understand "that dollars saved on energy go straight to the bottom line," in a world where capital is closely guarded, they require a 12 month payback on their investments. Whereas energy efficiency projects, which usually require a three-to-five year payback period, "tend to lose in the battle for capital dollars."[113]

[110] Granade et al. *Unlocking Energy Efficiency.*

[111] Granade et al. *Unlocking Energy Efficiency.* pp. 80-81; McKinsey & Company. *Pathways.* p. 41.

[112] Granade et al. *Unlocking Energy Efficiency.* pp. 80-81.

[113] Ohio Manufacturers' Association. (2010). *The Policy Point: Electricity and Energy Efficiency. Retooling Ohio.* Retrieved from http://www.ohiomfg.com/communities/energy/archive/2010/oma-lays-out-energy-policy-gains/

Policy options and industrial strategies. As noted above, the HRS-MI studies of the impact of climate policies on U.S. EITE manufacturers concluded that the measures would not be sufficient for encouraging manufacturers to invest in energy-efficiency improvements required to offset the costs incurred under a cap-and-trade system. At best, the cost mitigation measures (output-based rebates, border adjustments) would buy time for manufacturers to make energy saving improvements before they would begin to incur emissions allowance costs.[114] Observing that there so far had been few measures considered in the climate debate that provided genuine support and incentives for innovation and adoption of advanced low-carbon technologies by EITE industries, the HRS-MI reports called for additional policies more directly aimed at encouraging investments in the development and deployment of energy-efficiency technologies by manufacturers on a substantial scale.

Recognizing the opportunity to increase the competitiveness of his state's manufacturing sector, Ohio's Senator Sherrod Brown (D) introduced legislation to encourage such investments. Senator Brown's Investment For Manufacturing Progress and Clean Technology Act of 2009 (IMPACT), whose main elements were rolled into the Waxman-Markey bill, would establish a revolving loan fund that provides capital for manufacturing firms with 500 employees or less for investing in energy efficiency or retooling to produce goods for clean energy markets. IMPACT also would boost funding for the National Institute of Standards and Technology's Manufacturing Extension Partnership (MEP), allowing MEP centers to expand services by almost 20% to help client firms invest in energy efficiency and expand into production for advanced energy markets. A study by Policy Matters Ohio estimated that IMPACT could result in the creation of 52,214 new manufacturing jobs in Ohio over the first ten years of the program.[115]

Senator Brown also promoted legislation to create a National Industrial Transformation Institute (NITI) that would carry out research and development to accelerate demonstration and deployment of technologies that improve the efficiency and competitiveness of domestic manufacturers, while reducing their

[114] The EPA drafters of the legislation tried to design the rebate provision with the expectation that it would result in incentives for the less efficient manufacturers to invest in energy efficiency. The rebates are determined doing an average of emissions per unit across the industry, though some facilities may have higher and some lower emissions per unit, depending on how efficient their production is. Those who are more efficient will receive more rebate value per unit (a "windfall") than their actual emission allowance cost, while others will receive less. The latter, in theory will then have incentive to invest in energy-efficiency improvements to avoid later costs. At best, this could lead to marginal, incremental improvements over time, but not the scale of improvements needed later on when allowance costs rapidly escalate.

[115] Patton, W. (2010, Feb. 24). *The Impact of IMPACT: Creating Jobs in Ohio.* Policy Matters Ohio.

energy consumption and GHG emissions. Although these measures failed to be enacted, Senator Brown's efforts highlighted the importance of policies aimed at strengthening the nation's manufacturing sector while also promoting energy and environmental sustainability.

The Midwestern Accord, meanwhile, though it recognizes the need to mitigate the potential impacts of the regional climate cap-and-trade system on manufacturers, does not contain any specific proposals for how to do it. At the same time, the EPA GHG regulations would not impose substantial costs on manufacturers, at least over the near-term. However, they would still eventually require some large producers to invest in advanced energy/carbon abatement measures, though nothing in the regulations could guarantee that they would be cost-effective and not be harmful to American manufacturers. As already noted, the only step the U.S. EPA has taken so far is to produce a series of industry whitepapers identifying a number of energy-efficiency technology options and evaluating their cost-effectiveness, as a guide for manufacturers in adopting the "best available control technology."

At the state level, Ohio's Senate Bill 221 (SB 221), Ohio's alternative energy portfolio standard, passed in 2008, includes an energy efficiency provision that promotes energy conservation by requiring utilities to implement energy efficiency programs that meet mandated reductions in their average annual kilowatt-hour sales, with a target of 22% savings by the end of 2025. It includes, as well, requirements that the state's utilities achieve peak-demand reductions of 1% in 2009, rising to 7.75% by the end of 2018. A key goal of SB 221 is to contain increases in the cost of electricity by finding ways to use it more efficiently and therefore reduce the need for utilities to build costly new generating capacity.

An OMA position paper has evaluated and endorsed the energy-efficiency measure in SB 221, but notes that the Public Utilities Commission of Ohio (PUCO) has yet to provide clear regulatory guidelines for stakeholders about which actions and energy savings will count towards compliance with the law. As seen above, OMA recognizes the barriers manufacturers confront in adopting cost-effective energy-efficiency measures, and therefore calls for financial incentives for electricity consumers that result in the use of less energy for the same level of production, such as lighting, motor and heating/cooling projects. Specifically, the OMA paper identifies three areas where government action is warranted: the state, particularly PUCO, needs to get the regulatory system in place; it should focus on identifying the cheapest forms of energy efficiency; and, it should create incentives that result in greater investments by manufacturers in energy-saving equipment and processes.[116]

In any event, there appears to be a growing consensus that a policy framework is needed, implemented at both the federal and state levels, to capture the potential of industrial energy and electricity efficiency opportunities for the U.S. (and Ohio) manufacturing sector. As McKinsey maintains, realizing this potential in a cost-effective manner is a significant challenge as it requires finding ways to overcome the array of technical and market barriers identified above.[117] Similarly, WRI calls for a range of policy options such as increasing access to financing and providing technical assistance. It also calls for establishment of a regulatory environment that increases the likelihood that capital-intensive investments in energy productivity deliver higher returns over shorter time periods.[118] Some of the principal options that might be included in such a policy framework include the following:

- ***Financial incentives***—A variety of financial incentives, provided at the state and federal levels, are needed to address the capital allocation and availability constraints U.S. manufacturers face today. They should help

[116] OMA. *The Policy Point: Electricity and Energy Efficiency.*

[117] McKinsey & Company. *Pathways.* p. 41.

[118] WRI also cautions U.S. Congress Members who are trying to help industry realize energy savings as a means of promoting U.S. manufacturing competitiveness not to limit GHG mitigation regulations that would spur efficiency investments. Instead, it calls on Congress to remove technical and financial barriers to these much needed investments in facility upgrades. Source: W*RI. EPA, Clean Air Act, and U.S. Manufacturing.*

manufacturers overcome the challenges of elevated hurdle rate and short payback periods described above. Tax credits that encourage industrial efficiency investments, and/or reward early retirement of existing low-efficiency equipment (e.g., accelerated capital depreciation credits) also should be considered. In Ohio, SB 221 opens the door to enabling the state's investor-owned utility companies to offer financial incentives for manufacturers that implement energy saving projects, though, as OMA notes, there is uncertainty about how PUCO will credit the utilities' energy-efficiency portfolio. OMA also encourages aligning the initiatives of multiple state agencies, such as PUCO and the Ohio Department of Development, to attain greater energy efficiency at manufacturing facilities.[119]

- ***Promotion of energy-management practices***—Government policies can provide technical assistance, information, training, and various incentives that encourage strong company-wide energy management practices, supported by part-time or full-time on-site energy managers dedicated to improving energy efficiency in their facilities. These would help overcome the awareness and information problem described above, which have typically lowered the focus of senior management on energy issues, resulting in under-prioritization of energy efficiency by top managers. Policy measures are needed to help firms improve their monitoring and controls and operating practices, and assure timely repair and regular maintenance, geared to identifying and achieving energy-efficiency improvements within their facilities.[120]

Several federal programs, often involving partnerships with states and industry, already provide this kind of assistance, many of which involve Ohio manufacturers:

- EPA's ENERGY STAR Partnership program helps industrial companies develop and refine corporate energy-management programs. Its services include energy management guidance, benchmarking and tracking tools, and recognition opportunities. It also provides sector-specific and technology-focused guidebooks that highlight operational best practices and provide tools for doing energy-saving assessments. Over 3,000 companies and organizations have joined this program. Four Ohio companies have received ENERGY STAR awards, including two Honda

[119] OMA. *The Policy Point: Electricity and Energy Efficiency.*
[120] Granade et al. *Unlocking Energy Efficiency.* p. 83.

auto assembly plants (in East Liberty and Marysville) and the Ohio Refining Division of Marathon Petroleum Company in Canton.[121]

- Industrial Assessment Centers (IACs), sponsored by the DOE's Industrial Technology Program (ITP), provide no-cost energy assessments to eligible small- and medium-sized manufacturers—facilities with gross annual sales below $100 million and fewer than 500 employees. Currently 26 schools across the country participate in the program, including the University of Dayton in Ohio. The IAC sites conduct energy audits or industrial assessments and provide recommendations to manufacturers to help them identify opportunities to improve productivity, reduce waste, and save energy. The IAC website lists about 35 manufacturing facilities in Ohio that have been helped by the IAC assessments.[122]
- The ITP's Save Energy Now LEADER program is a national initiative involving industrial company partners who have pledged to reduce their energy intensity by 25% or more in 10 years. It reportedly has already helped 2,100 U.S. manufacturing facilities save an average of 8% total energy costs. Industry partners in the program receive priority access to technical resources such as energy assessments and tailored assistance for establishing an energy intensity baseline and developing an energy management plan to meet LEADER requirements.[123]
- Senator Brown's IMPACT bill would strengthen the role of MEP to help small- and medium-sized manufacturers achieve energy-efficiency gains. Although this bill is now dead, the MEP partnered with EPA to start the Green Suppliers Network, working with large manufacturers to engage their small- and medium-sized suppliers in low-cost technical reviews that focus on process improvement and waste minimization. It includes technical reviews coordinated through MEP, teaching suppliers about "lean and clean" manufacturing methods to increase energy efficiency, and identifying cost-saving opportunities and optimizing resources to eliminate waste. EPA provides program support and funding for the network.[124]
- The E3: Economy, Energy and Environment program is a coordinated federal and local technical assistance initiative to help manufacturers adopt

[121] Marathon's Canton refinery reports that during the first five years of the program, it has surpassed its 10-year energy reduction target of 10%. Overall the refinery has reduced energy consumption by more than 1,200,000 MMBTU per year. This was achieved in part through increased and updated insulation used for facilities, piping, and equipment, and capital intensive projects such as additional heat exchange on the distillate hydrotreater, which reduced the fuel required for the process heater. For more information, see http://www.energystar.gov/index.cfm?c=industry.bus_industry

[122] For more information, see http://www1.eere.energy.gov/industry/bestpractices/iacs.html

[123] For more information, see http://www1.eere.energy.gov/industry/saveenergynow/partnerships.html

[124] U.S. EPA. (2010). *The Green Supplies Network*. Retrieved from http://www.epa.gov/greensuppliers/index.html

sustainability practices. E3 began on September 25, 2010, with the signing of a memorandum of understanding between the EPA, the Departments of Energy, Commerce, and Labor, and the Small Business Administration. The program targets opportunities to maximize energy efficiency, reduce environmental wastes, and identify ways to cut carbon emissions, while promoting growth and reducing business costs. One of the two pilot projects underway in the E3 program is in Columbus, Ohio. Federal partners are working with six manufacturers, the city government, the Solid Waste Authority of Central Ohio, and American Electric Power to conduct technical assessments and provide training.[125]

- Research, Development and Demonstration (RD&D). From the 1980s until the middle of the last decade, the DOE's Industries of the Future (IOF) program oversaw the development of technology roadmaps for a number of major energy-intensive industries (steel, forest products, aluminum, chemicals, glass, metal casting, and mining). It also sponsored a large number of detailed technical studies, including DOE's well-known energy bandwidth studies, with the help of the national energy laboratories, which estimated the technical and theoretical minimum energy-efficiency potential for these industries. The IOF road-mapping process involved memoranda of understanding with leaders of the participating industries, and as such the roadmaps were genuine industry-led assessments of the potential technology opportunities for reducing energy use in these sectors.

  Unfortunately, the IOF program was greatly cutback during the Bush Administration. Nevertheless, the DOE's ITP continues to sponsor a modest amount of research in cost-sharing partnership to develop transformational technologies for industry. ITP tries to collaborate with industry to identify R&D opportunities that offer the largest potential energy savings, targeting both energy-intensive industries and crosscutting technologies that benefit multiple industries. However, ITP has faced serious funding cuts since 2001. This includes a drop of 83% in funding for industry-specific research, and a 50% decline in funding for some cross-cutting programs, such as the Industrial Assessment Centers.[126]

[125] E3 provides technical assessments of production processes (reviews, audits, evaluations, and post-assessment recommendations) and training in the four key areas of lean production, clean production, energy, and greenhouse gas emissions. The Columbus, Ohio E3 project has identified energy savings of $1.7 million, environmental savings of $2.6 million, over 250,000 pounds of water pollutants avoided, and solid waste reductions of 24,000 pounds. See http://www.epa.gov/greensuppliers/e3.html

[126] Alliance for Materials Manufacturing Excellence (AMMEX). (2010). Fact sheet. The fact sheet notes that the Energy Independence and Security Act of 2007 reauthorized two portions of ITP core activities (IOF and IAC) at $196 million for FY 2010. It also notes that a peer review of the full ITP program found its research activities to be productive but underfunded. It further reports that the DOE received $50 million from the Recovery Act to begin refilling the R&D pipeline, and urged that this funding continue.

Much more investment by the federal government and industry therefore is needed, not only in research and development, but also in support of demonstration and other projects that speed up the commercialization of critical, breakthrough, energy-saving industrial technologies. Senator Brown's NITI initiative would give a boost to this kind of RD&D. Consideration needs to be given to developing a large-scale, national manufacturing technology program, as envisioned in NITI, perhaps with White House coordination, not only across the Departments of Commerce and Energy (including DOE's ARPA-E), but with other major R&D agencies, such as the Department of Defense, Department of Transportation, National Science Foundation, and perhaps NASA.

- ***Regional energy innovation clusters.*** Government policies can also support private sector-led initiatives to pursue industrial competitiveness and energy-efficiency goals. One approach that economic development leaders have promoted for a number of years is regional innovation industry clusters. An industry cluster is a geographic concentration of interdependent, competing, and complementary organizations that together constitute a competitive economic advantage for the region. They include firms that primarily trade with buyers outside the region (exporters) and the firms that supply these exporters with specialized goods and services. Clusters also include relevant community organizations, including workforce training institutions, research and development organizations (universities, institutes), and infrastructure and utility providers.

Regional innovation clusters have been touted as an effective means to promote economic development and technology innovation, in support of regional economic revitalization. A study by the Information and Technology and Innovation Foundation (ITIF), Breakthrough Institute and the Brookings Institution Metropolitan Policy Program called industry clusters "an innovative way to link and align existing assets at the regional level to help overcome" the challenges that hinder innovation and accelerate technology commercialization. Characterizing them as "functional innovation 'ecosystems' within which inventors, investors, manufacturers, suppliers, and universities, as well as local and state government officials interact and may establish dense, productive networks of relationships," ITIF et al. enumerates cost and innovation advantages these networks create. These include facilitating information exchange, access to high-caliber human resources, and R&D collaborations. Moreover, clusters amplify the human exchanges that accelerate the pace of innovation, from R&D to commercialization, while conferring competitive advantage.[127]

ITIF et al. goes even further and identifies industry clusters designed specifically around clean technology as necessary for accelerating clean energy innovation, production, and commercialization, to regain U.S. clean energy leadership. Regional networks of clean industry clusters would spur public-private collaboration, accelerate technology commercialization, and maximize the economic impact of new clean energy investments.[128]

Efforts by the Northwest Food Processors Association (NWFPA) to develop the Northwest Food Processing Cluster Initiative may demonstrate the potential of innovation clusters to enhance the competitiveness of energy-intensive manufacturing in industrial regions of the country, through the promotion of energy-efficiency and clean energy innovation. The food processing sector, employing more than 65,000 workers in the Pacific Northwest, is the third largest industrial manufacturing sector in the region. The NWFPA, first established in 1916, is comprised of 150 member food processing plants employing 55,000 workers in the region—including Idaho, Oregon, and Washington—with $10 billion in sales.

[127] Atkinson, R., Hackler, D., Jenkins, J., Swezey, D. & Muro, M. (2010). *Strengthening Clean Energy Competitiveness.* Breakthrough Institute, ITIF, and The Brookings Metropolitan Policy Program. p. 15.

[128] Ibid.

In 2003, NWFPA began efforts to revitalize the region's food processing industry, developing the NW Food Processing Cluster Initiative with the support and assistance of federal, state, and industrial resources. In February 2009, at the Northwest Industrial Energy Efficiency Summit, the NWFPA became the first U.S. industry sector to sign a 10-year MOU with the U.S. Department of Energy to reduce member-wide energy intensity by 25% in 10 years, and an additional 25% in 20 years.[129] This collaborative step towards energy efficiency will not only help food processors become more competitive, but will contribute to solving various energy problems in the region, strengthening the cluster as a whole.[130]

In recognition of the value of industry clusters as an important driver of innovation and economic development, the Obama Administration requested $75 million for the Regional Innovation Clusters (RIC) Program, operated by the Department of Commerce's Economic Development Administration (EDA), in its FY2011 budget.[131] EDA is partnering with the DOE, National Institute of Science and Technology (NIST/MEP), and several other agencies in an Energy Regional Innovation Cluster (E-RIC) engaged with the energy-efficient building systems and design industry. Its principal goal is to develop sustainable and efficient models for attaining national strategic objectives, with a focus on developing, expanding, and commercializing innovative energy-efficient building technologies, design and best practices.[132]

As ITIF et al. suggests, programs like this "represent a new paradigm for federal economic development and innovation." Ohio already has multiple and overlapping industrial clusters—primary metals, petroleum refineries, auto manufacturing, chemical manufacturing—that, like the NWFPA cluster initiative, could provide the basis for collaborative technology innovation, manufacturing, and commercialization efforts that enable Ohio manufacturers

[129] Other signatories to the MOU include the Bonneville Power Administration, Pacific Northwest National Laboratory and Idaho National Laboratory.

[130] McGiverin, D. (2010, June 20). *Energy Efficiency: Adopting an Energy Champion*. Northwest Food Processors Association. Retrieved from http://www.nwfpa.org/nwfpa.info/component/content/article/42-energy-champion/92-energy-efficiency-adopting-an-energy-champion

[131] U.S. Economic Development Administration. *Regional Innovation Clusters*. Retrieved from http://www.eda.gov/AboutEDA/RIC/

[132] The other agency partners include the Department of Labor, Department of Education, Small Business Administration and the National Science Foundation. The E-RIC will center around DOE's Energy Efficient Building System Design Hub, and encompass local universities, government research centers, and other R&D resources which will serve as catalysts of innovation and drivers of regional economic growth. The Hub will work within the government agency consortium to link combinations of university, industry, national laboratory, non-profit organizations and local, state and regional governments, as appropriate, with business incubators and other business accelerators to create and/or expand a network of advanced energy technology companies, laboratories, and capabilities that promote economic development and objectives of the E-RIC. For more information about Energy Regional Innovation Clusters, see http://www.energy.gov/hubs/eric.html. On August 24, 2010, the Department of Energy announced the selection of the Greater Philadelphia Innovation Cluster (GPIC), a team led by Pennsylvania State University, to run the Energy-Efficient Buildings System Design Hub. See http://www.energy.gov/news/9380.htm

in different sectors to cost-effectively reduce energy use and carbon emissions while spurring economic growth and industrial competitiveness. One vehicle already in place that could help catalyze this kind of development is the Ohio Third Frontier initiative. Created in 2002, this $2.3 billion effort—with a stated "strategic intent" to develop an "innovative ecosystem"—supports applied research and commercialization, entrepreneurial assistance, early-stage capital formation, and expansion of a skilled workforce that can support technology-based economic group. The Ohio Third Frontier Advanced Energy Program (AEP), in particular, aims to accelerate the development and growth of the advanced energy industry in Ohio.[133]

Realizing the potential. It is helpful to recognize that the energy-efficiency opportunities outlined above are not hypothetical. It is possible for manufacturers, working in partnership with other private and public sector actors, at both the state and national levels, to overcome the barriers to invest in cost-effective energy efficient and/or carbon abatement technologies, which also yield substantial economic gains.

A poster child for this kind of transformation is the Flambeau River Papers plant located in the Park Falls, a small town of 2,262 in northern Wisconsin. Originally opened in 1896, the plant fell on hard times in the early 2000s, closing its doors in 2004 due to escalating energy costs, antiquated machinery and stiff international competition. The mill's closure cost over 300 workers their jobs, leaving 13% of the city's residents unemployed. However, led by "Butch Johnson," owner of Johnson Timber, the primary timber supplier to the mill, who took over ownership of the plant, the mill subsequently retooled with new, energy-efficient boilers and equipment, established energy-efficiency and fossil-fuel-independence goals, made an energy management plan to guide the plant's efforts to meet these goals, and invested $15 million on energy efficiency and alternative energy improvements.[134]

---

[133] Specifically, the AEP is providing "direct financial support to organizations seeking to investigate near-term specific commercial objectives with respect to products, processes, or services, commercialize new products, commercialize manufacturing processes or technologies, or adapt or modify existing components or systems that can reduce the cost of advanced energy systems or address technical and commercialization barriers, or demonstrate market readiness." Although the program is open to any advanced energy projects (excluding fuel cells and photovoltaics), it is giving preference to projects in wind, biomass and energy storage. However, such an initiative conceivably could be directed toward supporting the development, commercialization and diffusion of advanced energy-efficient industrial process technologies. For information on the Ohio Third Frontier, see http://thirdfrontier.com/ThirdFrontierCalendar/Default.aspx. For more information on Ohio Third Frontier AEP, see http://thirdfrontier.com/AdvancedEnergyProgram.html

[134] U.S. DOE. Office of Energy Efficiency and Renewable Energy. Industrial Technologies Program. (2011). *Flambeau River Papers Makes a Comeback With a Revised Energy Strategy.* Retrieved from http://www1.eere.energy.gov/industry/saveenergynow/leader.html. Yudken & Bassi. *Climate Policy and Energy-Intensive Manufacturing*. Box 4, pp. 176-177.

It reopened two years later, hired back nearly all its original workers, and is on its way to becoming one of the only energy-independent paper mills in the nation. The turn-around was made possible both by management's efforts to involve plant-level staff in improving the operations, and with the help of the state of Wisconsin and the U.S. DOE, which provided consultation, technical assistance and financial resources. Flambeau River Papers' efforts have yielded $2.6 million in annual energy savings and increased its paper production by 11.9% since 2006. It also is planning for a biorefinery to come online by 2013, which is expected to produce 8.0 million gallons of "green diesel" and 8.0 million gallons of paraffinic wax each year. In addition, when the biorefinery comes online, the plant expects to grow from its current 315 employees to 355.

Although there may be only a few conversions of industrial facilities quite successful as Flambeau River Papers, there are numerous examples of how investments in energy efficiency have resulted in substantial savings in energy costs in a wide-range of industrial facilities across the country.

For example, ArcelorMittal, which has a large presence in Ohio,[135] saved more than $100 million by installing CHP systems to capture waste heat at its East Chicago, Indiana steel mill.[136] With a $31.6 million Recovery Act grant from the Department of Energy to fund an Energy Recovery & Reuse project at its Indiana Harbor plant in East Chicago, Indiana—the largest steelmaking facility in North America—the company plans to capture blast furnace gas and use it to fuel a new boiler to cogenerate both steam and electricity. It expects the project to reduce its reliance on purchased electricity by generating over 36 MW of its own electricity, the equivalent of powering nearly 30,000 American homes for a year.[137]

The DOE's Office of Energy Efficiency & Renewable Energy (EERE) has many case studies of success stories, as well as plant assessments conducted by its technical assistance programs (IAC, Save Energy Now, etc.).[138] Several of these are listed below, including some notable ones in Ohio.

[135] ArcelorMittal's integrated steel mill in Cleveland is the second largest GHG emitter in Ohio (see Table 9). The company also operates a smaller steel facility in Warren, a tubular products plant in Shelby, and a metal coating and engraving plant in Columbus.

[136] Margonelli, L. (2008). Waste Not. *The Atlantic Monthly.* Retrieved from http://www.theatlantic.com/doc/200805/recycled-steam. Cited in EDF. *Think U.S. Industry Can't Be More Competitive.*

[137] The project is also expected to reduce GHG emissions by approximately 333,000 tons annually, equivalent to removing approximately 60,800 cars off the road. About 350 jobs will be created related to the design, construction, and manufacture of equipment alone, 200 local trades people will be employed for approximately 18 months, and through energy cost savings, the project will support 5,900 jobs associated with mill operations. U.S. Department of Energy. (2010, Nov. 2). *Steel Manufacturer Proves Its "Mittal" by Doing More with Less Energy*. Retrieved from http://blog.energy.gov/2010/11/02/steel-manufacturer-proves-its-%E2%80%9Cmittal%E2%80%9D-doing-more-less-energy

[138] U.S. DOE. Office of Energy Efficiency and Renewable Energy. Industrial Technologies Program. (2011). *Case Studies and Success Stories.* Retrieved from http://www1.eere.energy.gov/industry/saveenergynow/case_studies.html

- An assessment at the Ford Cleveland Casting Plant (CCP) in Cleveland, Ohio, identified 16 short-term energy- and cost-saving projects that addressed combustion, compressed air, water, steam, motor drive, and lighting system efficiency. These projects represent a total of $3.3 million per year in savings with corresponding annual energy savings of almost 18 million kilowatt hours (kWh) in electricity and nearly 139,000 MMBtu in fuel.[139]
- Progressive Powder, a metal finishing plant in Mentor, Ohio, installed an infrared oven on its production line, allowing the plant to increase its conveyor line speed and increase production by 50%. The plant also reduced its natural gas consumption, yielding annual energy savings of approximately $54,000. With a total project cost of $136,000, the simple payback is 2.5 years.[140]
- Dow Chemical has been saving $1.9 million annually by improving the efficiency of the steam system at its Hahnville, LA petrochemical plant. The $225,000 in improvements paid for itself in just 6 weeks.[141]
- Proctor & Gamble, whose global headquarters is located in Cincinnati, started saving $309,000 annually by improving the compressed air system at its paper products mill in Mehoopany, Pennsylvania—an investment that paid for itself in 21 months.[142]
- A 2006 energy audit helped the Harrison Steel Casting Company to realize potential savings available by upgrading equipment and improving production processes to increase efficiency. The company undertook a project costing approximately $17,500 to implement, yielding energy savings of $73,857—with a repayment period of less than three months.[143]
- The Lehigh Southwest Cement Company saved $199,000 annually by improving the efficiency of the compressed air system at its Tehachapi, California cement plant. The total project cost was $417,000, but reduced

[139] Two long-term projects also were identified that would together represent another $9.5 million in cost savings, with energy savings of more than 600,000 MMBtu in fuel and more than 8 million kWh in electricity.

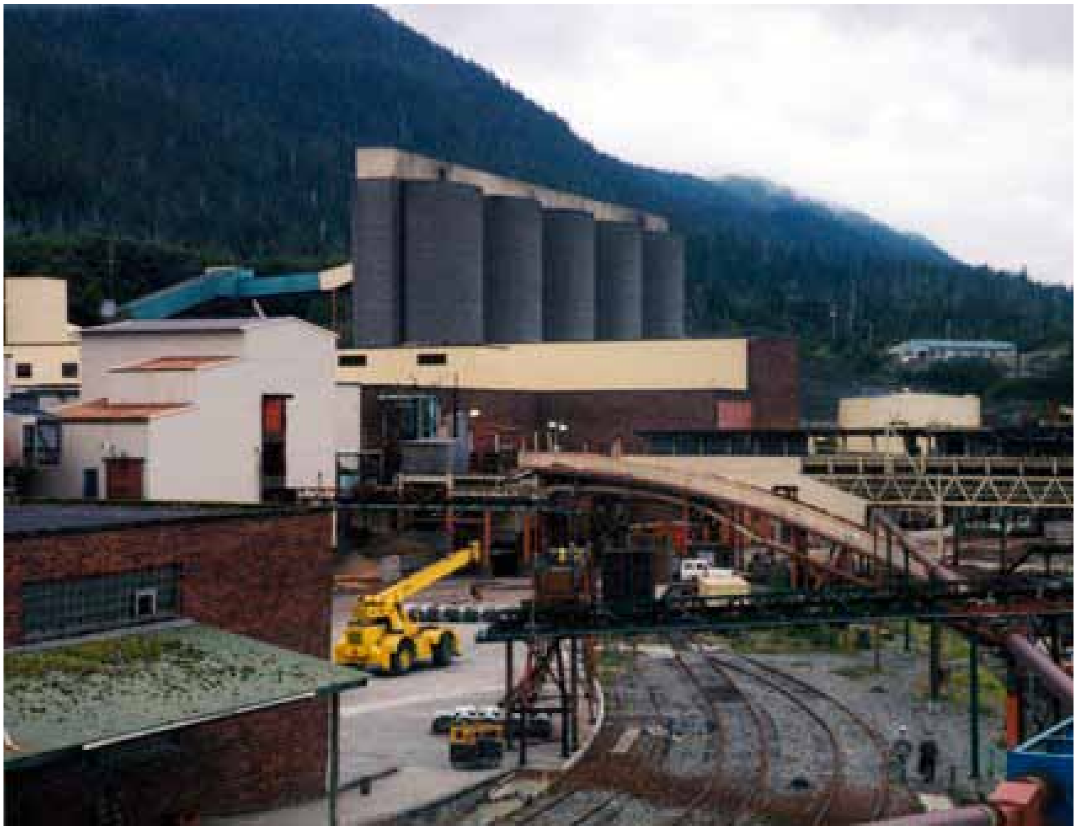
[140] U.S. DOE. Office of Energy Efficiency and Renewable Energy. Industrial Technologies Program. *State and Regional Partnerships.* Retrieved from http://www1.eere.energy.gov/industry/states/state_activities/map_new.asp?stid=OH#stateCaseStudies/bs_cs_progressive_powder.pdf

[141] U.S. DOE. Office of Energy Efficiency and Renewable Energy. Industrial Technologies Program. (2007). *Dow Chemical Company: Assessment Leads to Steam System Energy Savings in a Petrochemical Plant.* Retrieved from http://www1.eere.energy.gov/industry/bestpractices/pdfs/42009.pdf; EDF. (2010). *Think U.S. Industry Can't Be More Competitive*. Retrieved from www.LessCarbonMoreInnovation.org

[142] U.S. DOE. Office of Energy Efficiency and Renewable Energy. Industrial Technologies Program. (2004). *Procter & Gamble: Compressed Air System Upgrade Saves Energy and Improves Production at a Paper Mill.* Retrieved from http://www1.eere.energy.gov/industry/bestpractices/pdfs/bp_cs_procter_gamble.pdf; Cited in EDF. *Think U.S. Industry Can't Be More Competitive.*

[143] Another project that Harrison Steel is currently implementing is an upgrade of variable speed drives for its well pumps which will cost $25,000 to implement but will save the company approximately $16,800 per year in electricity costs —a payback period of less than 18 months. Retrieved from http://www1.eere.energy.gov/industry/saveenergynow/leader.html

to $327,000 with a Southern California Edison incentive payment—a payback of less than 20 months.[144]



The DOE's website also lists numerous examples of on-site energy savings assessments (ESAs) it has conducted that illustrate the large amount of potential savings available to manufacturers from energy-efficiency investments and practices. Their purpose is to identify immediate opportunities to save energy and money that will lead to significant long-term savings. It lists about 40 ESAs that it has conducted with manufacturers in Ohio.[145] A few examples:

- The Corning glass plant in Greenville, Ohio, concerned about the high costs of electricity and natural gas it consumes in its glassmaking process—it spent approximately $6.4 million in 2000—conducted a plant-wide

[144] U.S. DOE. Office of Energy Efficiency and Renewable Energy. Industrial Technologies Program. (2003). *Lehigh Southwest Cement Company: Compressed Air System Improvement Saves Energy at a Lehigh Southwest Cement Plant.* Retrieved from http://www1.eere.energy.gov/industry/bestpractices/pdfs/bp_cs_lehigh.pdf; Cited in EDF. *Think U.S. Industry Can't Be More Competitive.*

[145] U.S. DOE. Office of Energy Efficiency and Renewable Energy. State and Regional Partnerships. *Industrial Technologies Program Activities in Ohio*. Retrieved from http://www1.eere.energy.gov/industry/states/state_activities/map_new.asp?stid=OH

assessment that identified savings of nearly $26 million from improvements that could dramatically reduce its natural gas and electricity use per year.[146]

- A plant-wide energy survey of the Appleton Papers, Inc. paper mill in West Carrollton, Ohio resulted in 21 recommendations for projects to reduce energy consumption and waste production and improve process efficiency. Initial estimates indicate that implementation of these recommendations will save nearly $3.5 million annually with a project cost of only $2.4 million. An average payback period of about 1.2 years per project was expected. Another recommendation to install a fluidized-bed boiler could result in additional annual savings of over $2.6 million.[147]
- A plant-wide assessment at AMCAST 's Wapakoneta, Ohio facility, which produces low-pressure aluminum castings for automotive suspensions, identified $3.6 million in potential savings from increased energy and productivity efficiencies with paybacks ranging from 0 to 29 months. Eventually these and other opportunities will yield savings of nearly $6 million.[148]

[146] U.S. DOE. Office of Energy Efficiency and Renewable Energy. Industrial Technologies Program (2004, Feb. 23). *PWA Finds $26 Million in Potential Savings at Glass Plant*. Retreived from http://www1.eere.energy.gov/industry/bestpractices/news_detail.asp?news_id=7971

[147] U.S. DOE. Office of Energy Efficiency and Renewable Energy. Industrial Technologies Progam. (2002, Mar.). *Appleton Papers Plant-Wide Energy Assessment Saves Energy and Reduces Waste: Best Practices Assessment Case Study*. Retrieved from http://www1.eere.energy.gov/industry/bestpractices/case_studies.html

[148] AMCAST has replicated the assessment methodology at five plants throughout the corporation, and company-wide saving are predicted to reach $36 million. U.S. DOE Industrial Technologies Program (2003, Aug.). *$3.6 Million in Savings Identified in AMCAST Assessment: Plant-Wide Assessment Summary—Metal Casting.* Retrieved from http://www1.eere.energy.gov/industry/bestpractices/case_studies.html

VI. CONCLUSION

Ohio lies at the nexus of two very important policy debates in the United States today: one concerning climate change and energy security, the other concerning the crisis in manufacturing, and what policies are needed to address them. Ohio is one of the most fossil-fuel dependent and largest GHG emitting states in America. It also has one of the greatest concentrations of manufacturing industries, and correspondingly, the manufacturing sector is Ohio's largest employer in the state's economy. As such, Ohio has seen some of the largest declines in its manufacturing capacity and employment in the United States over at least a decade, a trend exacerbated by the recent financial crisis and recession. It is not surprising then, that concerns were raised within the state about the federal legislative efforts to establish an economy-wide cap-and-trade system that would put a price on carbon (or more accurately CO_2-equivalent) emissions associated with electricity generation and energy use in Ohio's industrial sector.

Climate policy impacts and "risks." An objective of this chapter was to evaluate the potential economic impacts and risks to manufacturers of such a system, and of similar efforts at the regional level, as well as the U.S. EPA GHG regulatory initiative that has just gotten underway. And indeed, it found that climate change and GHG regulatory policies could create potentially serious competitive pressures on Ohio's manufacturing industries, especially on energy-intensive trade-exposed (EITE) industries that are especially reliant on fossil-fuel energy sources. Ohio has a large concentration of EITE industries, which an analysis of direct and indirect GHG emissions generated by manufacturing industries shows would be especially vulnerable to carbon-constraining policies. Although these impacts would be limited by cost-mitigation measures in these policies, they eventually (i.e., by 2030 or later) could become serious if industries do not introduce energy-saving technologies or practices over that period.

In particular, drawing on the point-source emissions database created under Task 1of this project, the analysis found that the iron and steel and ferroalloy products industry is by far the largest emitting manufacturing industry in Ohio, and therefore would be the most vulnerable to cost increases tied to a climate policy or GHG regulations. The petroleum refining, primary aluminum, paper, lime, plastics and resins, several chemicals industries and cement also are large-scale emitters in Ohio. Some important non-EITE industries such as automobile manufacturing and industrial machinery manufacturing are large emitters as well, and could incur substantial added costs from a climate policy, though they are much less energy- and emissions-intensive than the EITE industries.

Passage of federal cap-and-trade climate legislation is highly unlikely any time soon, but Ohio is watching the evolving Midwestern Greenhouse Gas Reduction Accord, a regional cap-and-trade system. This system emphasizes the need for cost-mitigation and promotion of energy-efficiency measures to protect the region's significant concentration of EITE industries, and generally promote their competitiveness, though the means for accomplishing this have not yet been specified.

Meanwhile, the EPA GHG regulations will likely affect only a limited number of Ohio's major manufacturing industries, at least in the short run—with the potential exception of its petroleum refineries and its smaller cement industry—and it could affect Ohio's fossil-fuel electric generators. But more investigation is needed to identify those facilities and industries in Ohio who might eventually be subject to the EPA permitting process based on their GHG emissions, and the economic costs that subsequently might be incurred.

Technology and policy opportunities. This chapter also examined a range of technological and policy opportunities that could yield substantial energy savings and cost reductions, which could mitigate the risks associated with climate policies and GHG regulations, while also promoting the competitiveness of U.S. (and Ohio) manufacturing industries, if these measures were adopted. Many studies have shown that although many EITE industries have made substantial reductions in their energy-intensities over the past decades, there remains a great deal of room for improvement. Moreover, the energy-efficiency of U.S. manufacturers lags in a number of sectors compared to their major developed country competitors (i.e., Germany, Japan, the Scandinavian countries). Meanwhile the large emerging economies (China, India, and Brazil) have adopted targeted investment strategies to improve the energy-efficiency and reduce the carbon footprints of their own rapidly-developing EITE sectors.

There should therefore be a strong competitive motive for U.S. and Ohio manufacturers to invest in energy-saving technologies and practices, regardless of whether a climate or GHG regulatory policy is in place. This chapter summarizes a wide range of such measures, that could produce short-, medium-, and long-term improvement in manufacturers' energy efficiency. These include cross-cutting technologies that could reduce energy use and GHG emissions, which could be applied to a large number of industries.

Of special importance are combined heat and power, other heat recovery systems, advanced, highly efficient motor systems, recycling technologies, and carbon capture and storage (CCS). With the exception of CCS, which is unlikely to be commercially available in the near-term, most of these technologies have significant promise—indeed, are already are being successfully deployed, including in Ohio—to foster cost-effective energy-saving improvements over a reasonable time span for a number industries. There also are a large number of cost-effective, industry and process-specific technologies and practices that could be cost-effectively applied.

Over the long-run, research already is occuring to develop and demonstrate breakthrough and transformational production process technologies in a number of industries, which could result in many more substantial gains—helping to convert the U.S. and Ohio manufacturing base to a next-generation, highly-efficient, low-carbon production system.

Barriers and policy options. Although the opportunities appear to be great, the barriers to realizing their potential are considerable. The literature appears to be in agreement that, in general, the major challenges confronting manufacturers in adopting cost-effective energy-efficiency technologies and practices in industrial production include technical limitations and availability, a lack of information and awareness, especially among managers, and financial hurdles and rapid payback requirements, that can prevent companies from making a good business case for investing in energy-savings on any meaningful scale.

A carbon-pricing policy, such as the cap-and-trade system in the proposed federal and state climate measures, could provide added impetus to firms adopting energy-efficient technologies at a faster rate—at least, to make incremental improvements over the short- to long-run. But these alone would be insufficient to motivate larger scale investments in more substantial improvements—especially in transformational and breakthrough process technologies.

There currently exist a number of different programs at the federal and state level that address at least some of these barriers, though it is clear from the analysis that policy options at both levels need to be greatly expanded. For example, financial incentives, including tax credits, provided at the state and federal levels, are needed to address the capital allocation and availability constraints U.S. manufacturers face today. These incentives could help manufacturers overcome the challenges of elevated hurdle rate and short payback periods described above. It was found that Ohio's SB 221 opens the door to enabling the state's investor-owned utility companies to offer financial incentives for manufacturers that implement energy saving projects, but these so far remain undefined.

Government initiatives working directly in partnership with manufacturers, their management and workforces, could consist of technical assistance, information, training and various incentives that encourage strong company-wide energy management practices. The EPA's ENERGY STAR, and the DOE ITP's IACs, Save Energy Now and other programs have helped many manufacturers make energy-efficiency improvements, some substantial, including a number in Ohio. However, as successful and important as these programs have been, they still reach far too few companies, and are likely insufficiently funded to achieve the kinds of large-scale gains required to help U.S. and Ohio manufacturers move down the low-carbon path on any appreciable scale.

Similarly, research, development and demonstration (RD&D) programs that support cross-cutting, process-specific and breakthrough technologies at the DOE, in particular, continue under the ITP program, but are substantially smaller than they were in the past, and far smaller than they could be. The DOE has worked successfully with industry in these initiatives in the past (e.g., the Industries of the Future program, to develop technology road-maps). However, there needs to be a substantial ramping up of federal, state, and private sector investments in RD&D aimed at making U.S. manufacturers both highly energy-efficient and globally competitive in the coming decades.

At the regional or state level, perhaps aided by federal and state incentives and technical assistance (e.g., the MEP centers in Cleveland and Cincinnati, the DOE Industrial Assessments Center at the University of Dayton, the Edison Technology Centers, the Ohio Third Frontier initiative), a clean energy innovation industry cluster (or clusters) could be developed. These clusters could foster collaborative technology innovation, manufacturing, and commercialization efforts that enable Ohio manufacturers in different sectors to cost-effectively reduce energy use and carbon emissions while producing and exporting clean energy products, spurring economic growth and industrial competitiveness in the state. Ohio already has most of the industrial and supporting capabilities (the Edison centers, major research universities, such as OU and OSU, etc.) needed to develop such centers—EITE materials industries, industrial machinery and equipment manufacturers, advanced-fuel vehicle parts and assembly companies, green energy products manufacturers, electric power generators, R&D centers, federal and state technical assistance centers, educational and workforce training institutions, and a highly skilled workforce.

In short, despite the great challenges that appear to face Ohio's economy, and the perceived "risks" associated with climate and clean energy policies, there also exist great opportunities for revitalizing Ohio's manufacturing base, restoring its competitiveness in global markets, while also promoting energy-efficiency and environmental sustainability—indeed, by promoting the latter, the former goals can be achieved. The gains for both the economy and environment would very great, and Ohio could be a leader in the nation in moving down this transformational path.

However, these gains cannot be accomplished by counting on market forces alone. There is a need for stronger, more focused government policies geared towards this end—though these too alone would be insufficient. At the same time, in order for these initiatives to be successful, it is vital that they involve extensive partnerships between the federal and state agencies, and between government, industry, labor, academic, and non-profit communities.

As a final note, Ohio's energy and manufacturing challenges cannot be addressed at the state level alone. The United States also faces substantial challenges created by globalization, and it has been playing on unlevel playing field for many years in international trade. These include currency manipulation, unfair trade practices, non-tariff trade barriers, lax labor and environmental regulations, cheap labor and subsidized industries, and targeted industrial strategies by America's largest emerging country competitors (e.g., China, India, Brazil). This discussion is beyond the scope of this report. However, it sets the larger stage and backdrop which help shape both the risks and opportunities that Ohio confronts today in addressing the energy/climate change-manufacturing challenge.

APPENDIX 2-1:

METHODOLOGY FOR ESTIMATING "INDIRECT" EMISSIONS FOR 6-DIGIT NAICS INDUSTRIES IN OHIO

Because of data limitations, direct estimations of the GHG emissions associated with purchased electricity consumed by industry sectors were not possible at the disaggregated 6-digit NAICS industry levels at the state level. Nevertheless, based on several assumptions, and using available industry and energy data from federal databases (Census Bureau, EIA) and other research sources, it was possible to make reasonable, ball-park estimates of the "indirect" emissions associated the consumption of purchased electricity by 6-digit manufacturing industries in Ohio.

The methodology was built around estimates of electricity consumption by 2-, 3- and selected 4-digit industry sectors and subsectors comprising the industrial sector in Ohio provided by an ACEEE study of energy efficiency potential in Ohio. ACEEE provided a table of base-case electricity consumption by industry in Ohio, showing estimated electricity use (GWh) and percent of total industry sector consumption for the three 2-digit non-manufacturing sectors in the Industrial Sector category (agriculture, mining, and construction) and all the 3-digit, and selected 4-digit NAICS industries in the Manufacturing Sector (NAICS 31-33). This table, with small modifications, is replicated in table A-1.

The following data is available and important in the estimation methodology:

- $\mathbf{QO_I}$ = Total electricity consumed by the Industrial Sector in Ohio (EIA, 2008) =58,621 Gwh
- $\mathbf{CI_o}$ = Total emissions generated by the Industrial Sector in Ohio = 0.358 x total emissions produced by the Utilities Sector (NAICS 22) in Ohio (OU-OSU Point-Source Database, 2009)=43,715 thousand MT of CO2e.
- The quantities of purchased electricity consumed by three-, four- and six digit industries in the manufacturing sector at the national level (Census Bureau, Annual Survey of Manufactures (ASM), 2008). That is:
- **QNj** = Total electricity consumed by 3- or 4-digit industry sector "j" at national level.
- **QNi** = Total electricity consumed by 6-digit manufacturing industry "i" in 3- or 4-digit industry sector "j" at the national level.
- The percent ($\boldsymbol{p_i}$) of total Industrial Sector electricity consumed by each

3-digit NAICS manufacturing sector and each selected 4-digit NAICS sector ("j") in Ohio, from ACEEE (see table A-1).

First, the electricity consumed by each 3- or 4-digit Manufacturing Sector in Ohio (QOj) can be calculated by multiplying the total electricity consumed by the Industrial Sector by this percent. That is:

$$QOj = \boldsymbol{p_j} \times \mathbf{QO_I}$$

Assuming that the 3-digit sector "j" emissions (Cj_O) share of total Industrial Sector emissions ($\mathbf{CI_o}$) is equal the share of industry sector "j" electricity consumed as total Industrial Sector electricity consumed in Ohio then:

$$\mathbf{p_j} = QOj \,/\, \mathbf{QO_I} = Cj_O / \mathbf{CI_o} \rightarrow$$

$$(1) \quad Cj_O = \boldsymbol{p}_j \times \mathbf{CI_o}$$

Assuming also that the ratio of electricity consumed by each 6-digit manufacturing industry "i" (**QNi**) with electricity consumed by 3- or 4-digit industry sector "j" at the national level (**QNj**) is equal to the ratio of electricity consumed by each 6-digit manufacturing industry "i" (QOi) with the electricity consumed by each 3- or 4-digit industry sector "j" in Ohio (QOj) then:

$$(2) \quad \mathbf{QNi} \,/\, \mathbf{QNj} = QOi \,/\, QOj$$

This is not a completely unreasonable assumption, but is likely not fully accurate either. At best, therefore, the results of these calculations should be treated as rough, ball-park estimates. They are based on an assumption that the concentration of industrial activity at the 6-digit level at the national level relative to the 3-digit sector to which it belongs is the same as this concentration at the state level.

In fact, in a state with as great a manufacturing concentration as Ohio, the state's 6-digit industry concentration is probably greater than that at the national level. Hence these estimates may underestimate the total electricity (and associated electricity emissions) for some 6-digit industries in Ohio. On the other hand, for other 6-digit manufacturing industries the concentration at the state level may be less than at the national level, in which case the estimates may overestimate the electricity consumed and associated emissions for those industries in Ohio.

In any case, the emissions associated with a 6-digit manufacturing industry "i" in Ohio (Ci_O) can be calculated assuming the ratio of electricity consumed by industry "i" with the electricity consumed by sector "j" in Ohio (Cj_O) is equal to the emissions generated by industry "i" with the emissions generated by sector "j" in Ohio. That is if (combining with formulas (1) and (2)):

$Ci_O / Cj_O = QOi / QOj \rightarrow Ci_O = (QOi / QOj) \times Cj_O \rightarrow \mathbf{QNi} / \mathbf{QNj} \times Cj_O$

Therefore:

$$Ci_O = \mathbf{QNi} / \mathbf{QNj} \times \boldsymbol{pj} \times \mathbf{CI_o}$$

Using this methodology, estimates were made for about 30 of the top "direct" emitting 6-digit manufacturing industries in Ohio, based on the OU-OSU Point-Source Database.

Table A-1—2008 Base-Case Electricity Consumption by Industry in Ohio

Industry	NAICS Code	Electricity (GwH)	Electricity % of Industrial Sector (pij)
Agriculture	11	844	1.4
Mining	21	592	1.0
Construction	23	1,236	2.1
Food mfg	311	1,987	3.4
Beverage & tobacco product mfg	312	607	1.0
Textile mills	313	70	0.1
Textile product mills	314	91	0.2
Apparel mfg	315	55	0.1
Leather & allied product mfg	316	27	0.0
Wood product mfg	321	487	0.8
Paper mfg	322	2,506	4.2
Printing & related support activities	323	882	1.5
Petroleum & coal products mfg	324	1,670	2.8
Chemical mfg	325	13,184	22.3
Pharmaceutical & medicine mfg	*3254*	*797*	1.3
All other chemical products	*3253, 3255*	*12,387*	20.9
Plastics & rubber products mfg	326	2,988	5.0
Nonmetallic mineral product mfg	327	3,936	6.6
Glass & glass product mfg	*3272*	*877*	1.5
Cement & concrete product mfg	*3273*	*2,545*	4.3
Other minerals	*3271, 3274*	*514*	0.9
Primary metal mfg	331	13,785	23.3
Iron & steel mills & ferroalloy mfg	*3311*	*4,180*	7.1
Steel product mfg from purchased steel	*3312*	*1,775*	3.0
Alumina and Aluminum	*3313*	*3,975*	6.7
Nonferrous Metals, except Aluminum	*3314*	*2,133*	3.6
Foundries	*3315*	*1,702*	2.9
Fabricated metal product mfg	332	2,154	3.6
Machinery mfg	333	1,736	2.9
Computer & electronic product mfg	334	911	1.5
Electrical equipment, appliance, & component mfg	335	1,144	1.9
Transportation equipment mfg	336	6,723	11.3
Furniture & related product mfg	337	685	1.2
Miscellaneous mfg	339	967	1.6
Total Industrial Sector		**59,246**	**100.0**

Source: ACEEE. Shaping Ohio's Energy Future: Energy Efficiency Works. p. 114. Table 30.