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Energy and Manufacturing in the United States

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Energy and Manufacturing in the United States

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Abstract

The Energy sector is critical to the economic vitality of the United States, but has been undergoing significant change in recent decades both with respect to traditional energy resources and a growing clean energy economy. Simultaneously, the decarbonization of the energy sector is occurring in parallel to other macroeconomic transitions, e.g. automation, digitization, and globalization. This white paper will explore the close relationship between the energy and manufacturing sectors of the U.S. economy within this broader context. Historically, energy costs and reliability have played a key role in manufacturing competitiveness and anchored the location of manufacturing in the Midwest and Appalachia. In addition, the energy sector has traditionally provided a large market for manufactured goods in generating equipment, energy infrastructure products, and fuels production equipment. This paper will explore how the decarbonization of energy production and energy policy may impact manufacturers, especially the energy intensive, trade-exposed industries, offering opportunities while also creating challenges that will make them more vulnerable to international competition if unaddressed. Finally, the paper will conclude with recommendations for the optimal policy environment to spur the manufacturing of new technology in the United States. All of this will be informed by two case studies, one on the performance of the 48c Advanced Energy Manufacturing Tax Credit, and the other on the effects of the 2012 CAFE standards on the motor vehicles industry.

Introduction

Historically, the development of industrial manufacturing technologies and processes has been intertwined with the development of energy systems. From the primitive use of combustion to convert minerals into usable metallurgical products to the utilization of waterpower to run textile equipment to the electrification systems that enabled mass production, energy has been closely linked to our capacity to convert human labor into infinitely more productive forms of mechanical labor.

In addition, energy production itself has also created significant demand for the manufactured goods that are needed for the production and distribution of energy across all sectors of the economy. For much of the 19th and all of the 20th Centuries this symbiosis was a critical feature of economic development.

As energy demand rose in other sectors of the economy such as agriculture and transportation, this virtuous cycle was repeated, sparking additional manufacturing. Consequently, most early energy production centers in the U.S. also became centers of manufacturing. Not surprisingly, the textile industry grew up around the rivers of New England that provided the energy systems for that era. Similarly, when the shift to fossil fuels and electrical generation occurred in the early 20th Century, the extraction industries for coal, oil, and gas in Pennsylvania, Ohio, and West Virginia became the incubator for the US manufacturing industry. Even today seven of the top 10 states with coal mining jobs are among the top ten states for producing primary metals and five are among the top 10 for producing fabricated metals products. Similarly, when coal, oil, and gas production, fossil power generation, and fossil TDS jobs are combined, the top 15 states with the most fossil fuel related jobs have 60% of those total jobs and are also home to 68% of the energy intensive manufacturing jobs in the country. (USEER, 2019; US BLS QCEW, 2018)

State	Chemicals	Primary Metals	Pulp and Paper	Petroleum	Total EITE	Total Fossil
Texas	81,712	20,052	17,916	22,444	142,124	402,573
California	80,469	17,174	21,262	12,996	131,901	142,928
Ohio	45,680	35,764	20,101	4,692	106,237	51,044
Pennsylvania	40,807	35,755	22,012	6,159	104,733	56,750
Illinois	46,156	18,449	18,801	5,698	89,104	50,187
Indiana	29,979	41,884	9,933	3,422	85,218	24,707
North Carolina	41,898	7,702	17,162	612	67,374	13,106
Michigan	30,497	22,714	12,096	1,579	66,886	20,296
New York	38,220	10,629	14,520	1,810	65,179	22,057
New Jersey	42,479	4,394	9,783	2,856	59,512	34,409
Georgia	22,005	7,874	19,549	1,096	50,524	13,445
Tennessee	25,587	11,016	11,976	1,132	49,711	8,378
Louisiana	26,269	4,017	7,095	12,030	49,411	90,453
South Carolina	22,651	5,709	12,333	467	41,160	11,454
Florida	21,452	4,994	8,492	3,465	38,403	39,300
Total—15 States	**595,861**	**248,127**	**223,031**	**80,458**	**1,147,477**	**981,087**
U.S. Total	**830,472**	**375,875**	**364,188**	**112,606**	**1,682,651**	**1,642,269**

Table 1: Top 15 states with the most fossil fuel related jobs (USEER, 2019; US BLS QCEW, 2018)

Cheap energy and manufacturing, supporting each other, were a common form of economic development in the U.S. in the 20th Century and often a prerequisite for economic development in underdeveloped countries. For instance, rural electrification in the Pacific Northwest was driven in the 1930's by the partnership between the aluminum smelting industry and the Bonneville Power Administration, where the heavy electricity demand of the former supported the investments necessary to build the hydroelectric system that otherwise would have been unaffordable for rural communities. (Heiner, A., 1991) In the 1960's, a similar strategy was used to finance electrification in Ghana with the building of the Akosombo Dam to provide electricity under a "take or pay" contract to a Kaiser Aluminum smelter built with the encouragement of the Kennedy Administration (Wikipedia, 2020).

However, in the 1970's this relationship between energy and manufacturing started to diverge in advanced economies. Energy's share of nominal U.S. GDP reached its zenith during the Arab Oil Embargo at roughly 14% and then proceeded to decline to 5.6% in 2016, with one notable exception during the spike in oil prices between 2006-08, directly before the Great Recession. (Energy Information Administration, AEO, 2019.) At the same time, manufacturing's share of nominal US GDP declined from 26.9% in 1967 to about 11% in 2016. (Yuskavage, Fahim-Nader, 2005) During roughly that same period from 1970 to 2016, overall industrial energy consumption went from its high point of almost 23,000 trillion BTU's to 21,550 trillion BTU's. (EIA, AEO, 2019) At the same time, manufacturing GDP went from $217 billion in 1967 to $879 billion in 1987 to $2.3 trillion in 2018. (US DOC, BEA, 2019) Energy consumption per unit of manufacturing GDP has dropped substantially, although the share of energy consumption by energy intensive industries has stayed relatively constant at roughly 80%. (DOE, MECS, 2017).

This paper on Energy and Manufacturing will explore how the divergence in the relationship between energy production and manufacturing will affect the opportunities and risks presented by climate change solutions to the US economy. It will also provide policy recommendations on how to maximize U.S. manufacturing jobs and GDP during the transition to low carbon technologies. We recognize that manufacturing and the economy have changed dramatically due to the COVID-19 health and economic crisis and that many recommendations dealing with health and safety will take priority in reopening workplaces. However, COVID-19 has also demonstrated the fragility of American manufacturing supply chains and the need to create flexible, domestic options across all sectors. This vulnerability is of special importance when addressing the need for domestic supply chains for new energy technologies.

1 Historic Background: Energy and Manufacturing in the US Economy

Since 1970, there has been a decline in contribution to the US economy in both energy and manufacturing as seen in Figure 1 below. In 1967, manufacturing made up 26.9% of nominal GDP and energy 10% (Bureau of Economic Analysis, 2020). Fast forwarding to 2016, manufacturing declined by over half to 11% while energy was reduced to only 5.6% (Manufacturing Energy Consumption Survey, MECS, 2014). US energy expenditures peaked at $1.6 trillion in 2005 and have since fallen by over $600 billion or 37%, while US GDP increased by 665% in the last decade.

These relative declines in economic contributions by manufacturing and energy and the absolute decline of energy can be attributed to a number of factors including the rapid growth of the financial, professional services, information, and educational and health service sectors of the economy, an increase in the globalization of labor markets and supply chains in manufacturing, and corporate incentives to decrease labor costs and maximize company profits. While the US had maintained balanced trade in the 1980s, a deficit has increasingly grown with a $621 billion deficit recorded in 2018 (U.S. BEA, 2019).

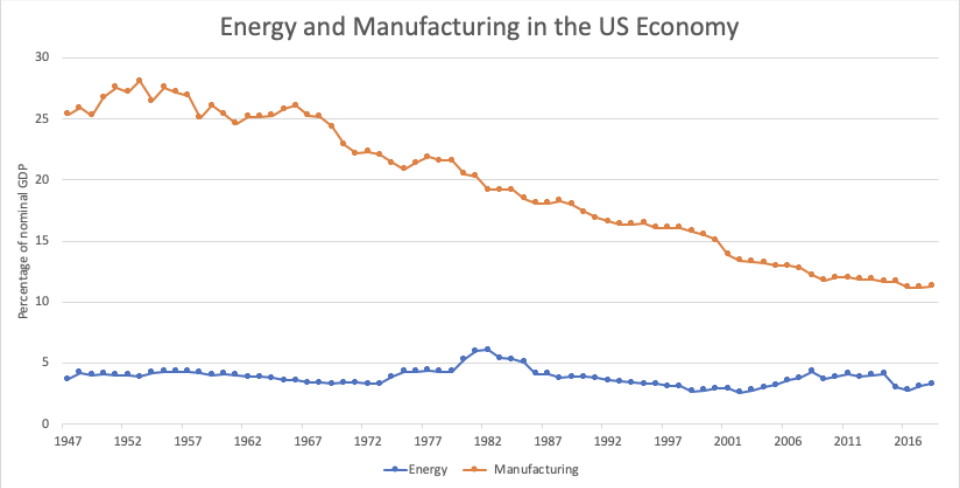


Figure 1: 1970-2018 charts that show manufacturing and energy as % of GDP by decade (US BEA Value Added by Industry, 2019)

As manufacturing's relative role in economic contribution decreased, its absolute contribution to GDP grew from $879 billion in 1987 to $2.3 trillion in 2018 (US BEA Value Added by Industry (Historical), 2019; US BEA Value Added by Industry, 2019). However, employment declined steadily as a result of both automation and globalization. As seen below in Figure 2, manufacturing employed over 17 million Americans in the 1970s, trending downward, while also fluctuating with the business cycles until a sharp drop between 2000 and 2011, when 5 million jobs were lost, including the Great Recession when 2 million jobs were lost in a two-year period. Since then, manufacturing jobs have increased, but have not made it back to the pre-Recession level, much less to those of the 1970's.

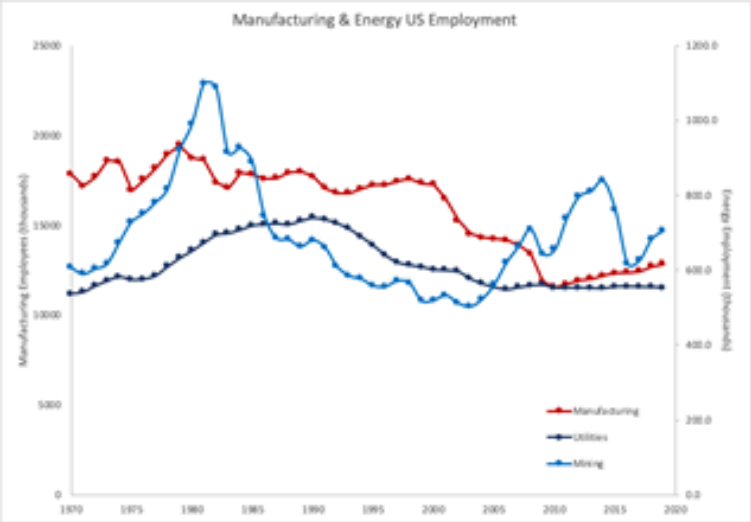


Figure 2: 1970-2018 charts that show employment in manufacturing, utilities, and mining by decade (US BLS CES, 2019)

Recent trends have deviated from the historically held view that energy demand increases in parallel with economic growth as was the case from 1900 to 1950. During this period, GDP more than doubled and energy demand almost doubled due to the change in technologies such as the introduction of electric power generation (Sharma, Smeets, & Tryggestad, 2019). As noted above, during the 1970's and 80's, manufacturing continued to grow in terms of absolute GDP, but shrank rapidly as a portion of the overall economy. The US has increasingly moved from being an industrial to a service economy, requiring less energy intensive processes with 80% of GDP contributed from the service sectors (Sharma, Smeets, & Tryggestad, 2019), thus starting the process of decoupling economic growth from energy demand. In the 1990's, this phenomenon also became apparent in manufacturing.

As energy production diversified in the last two decades, particularly with the addition of low-cost natural gas and renewable energy, and with a growing focus on energy efficiency, there has been an additional decoupling of energy consumption from GDP growth. As a result, the relationship between the energy and manufacturing sectors has grown both more complex and multi-tiered. And while decarbonization of the US economy is necessary to mitigate climate change effects, the industrial sector will be challenging to address because of the energy intensive processes required and the potentially negative societal impacts on the American workforce.

1.1 Major Sectors of the US Industrial Sector

The US industrial sector is responsible for over 20 percent of the country's emissions with 70 percent produced by five energy intensive, trade-exposed industries (EITE's), including aluminum, cement, chemicals, iron and steel, and pulp and paper.

As seen in Figure 3, these five sectors utilize high-grade heat for which there are limited, cost-effective alternatives to burning fossil fuels. This barrier will create technological and political obstacles to address GHG reductions and improve energy efficiency while not putting these industries at a competitive disadvantage. However, developing successful reduction strategies is necessary since industrial energy

use is projected to increase globally by 10% by 2050. In this paper, we will focus on these EITE's and discuss how decarbonization and energy efficiency will affect these sectors.

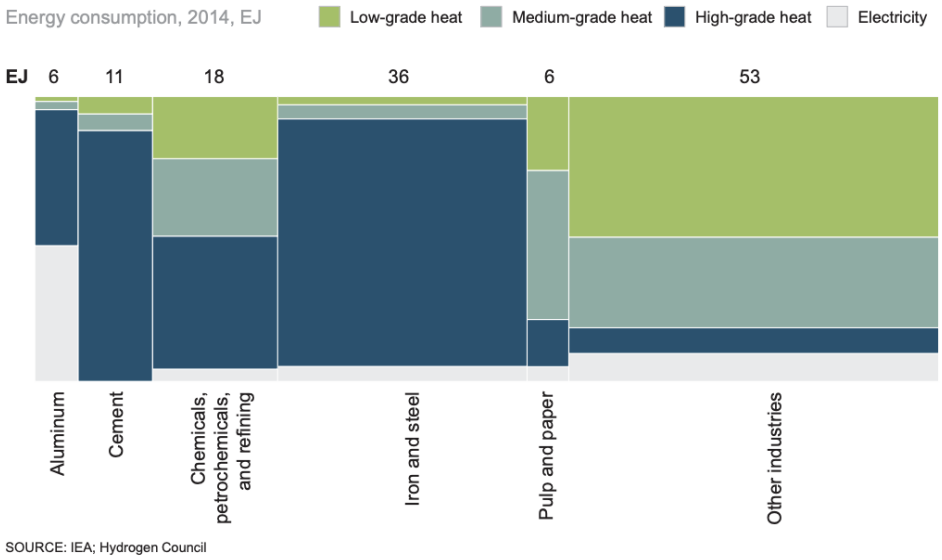


Figure 3: Industrial sector energy consumption (Hydrogen Council, 2017)

As section 3 will discuss in further detail, the EITE's have experienced significant changes since 1970 in economic vibrancy, concentration, global integration, and employment. Petroleum refining has experienced continuous growth, increasing from a gross output of $175 billion production output index in 1997 to $652 billion in 2018. Primary metals, chemicals, and paper manufacturing were impacted by the recession but have responded differently, post-economic hardships of 2007-08.

For instance, across the energy intensive industries, employment recovery has varied. Chemical manufacturing is by far the largest manufacturing sector with a recorded 830,000 American workers in 2019. Oil and gas extraction employment peaked in the early 1980's at 264,500 employees, decreasing until employment bottomed at 120,200 workers in 2003 before springing back to 198,000 in 2013 and then continuing to fluctuate. Employment varied for primary metals where 688,600 Americans worked in 1990, but has since dropped by almost half to 366,900 in 2018. Finally, petroleum and coal products fluctuated every few years but overall trended downward by more than 40,000 employees.

Between February and April 2020, manufacturing employment dropped by over 1.3 million in response to the COVID-19 pandemic. Since that low point, roughly half those jobs have been restored for a workforce of 12,112,000 or a decline of 733,000 jobs since July, 2019.

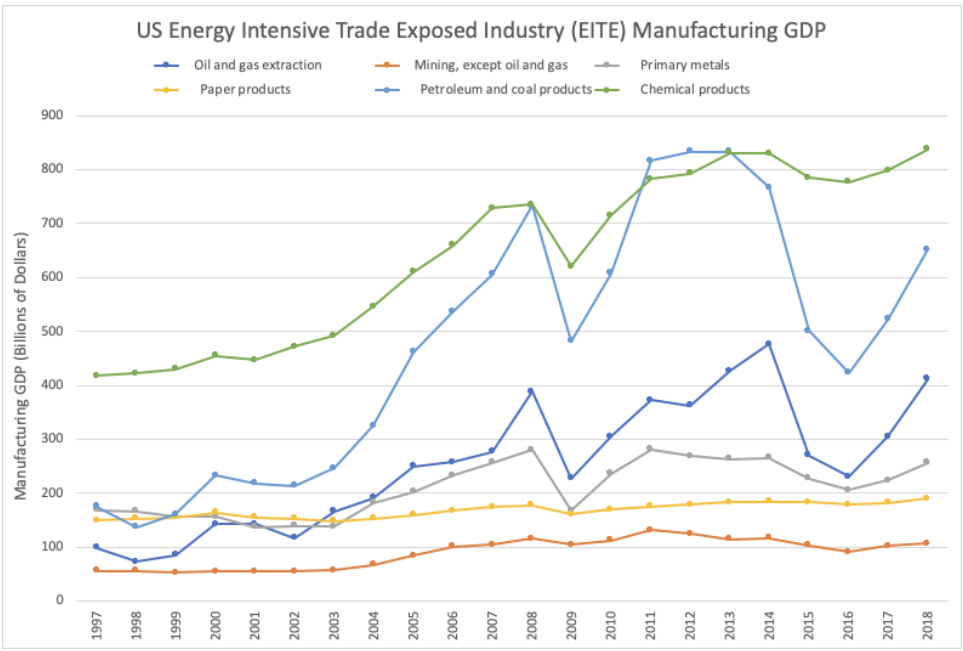


Figure 4: 1990-2018 chart that shows portion of manufacturing nominal GDP created by Energy Intensive Trade Exposed industries (iron ore, steel, aluminum, pulp and paper, chemicals, oil, cement,) (US BEA Value Added by Industry, 2019)

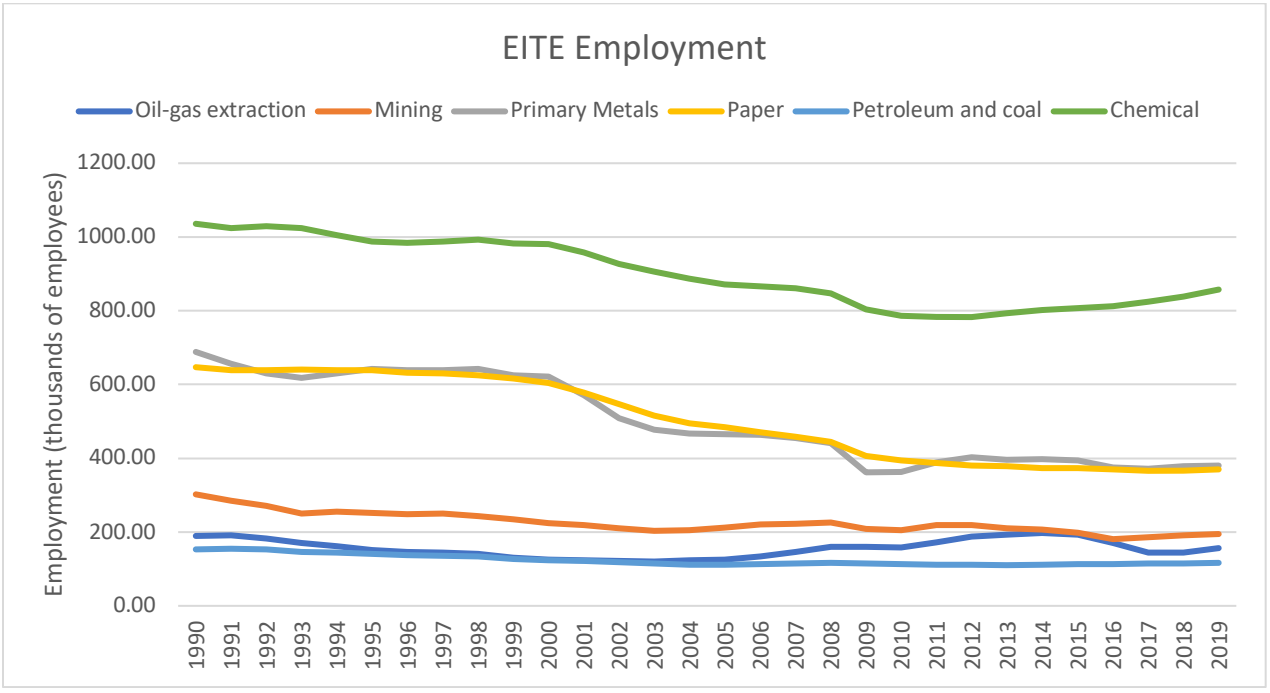


Figure 5: 1990-2018 chart that shows direct employment created by Energy Intensive Trade Exposed industries (iron ore, steel, aluminum, pulp and paper, chemicals, oil, cement, glass, brick, and foundries) (US BLS CES, 2019)

1.2 Industrial Emissions as a Portion of GHG's Globally and in the US

Figure 6 shows the GHG emissions by the US since 1990. Although the US has maintained a relatively constant emission level throughout the years, we have traditionally been the highest contributor of global carbon dioxide emissions globally, only overtaken by China in recent years.

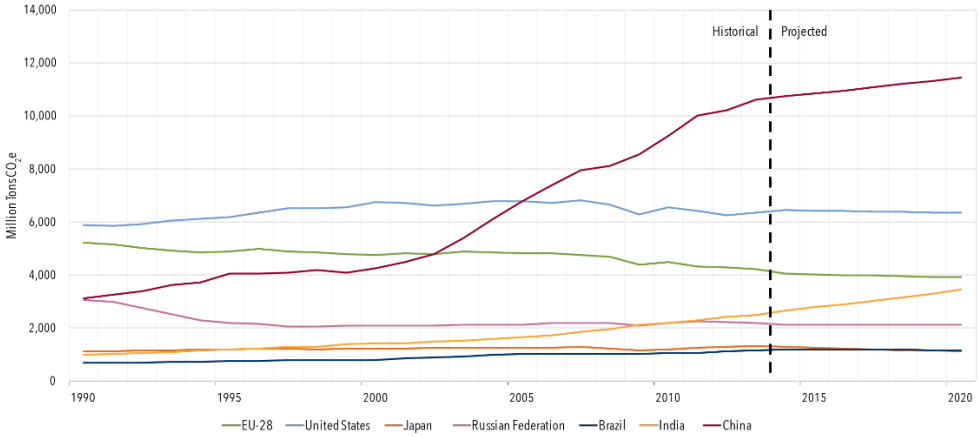


Figure 6: GHG emissions for major economies (International Energy Agency, 2019; U.S. Environmental Protection Agency, 2016c)

At a global level, the industrial sector accounts for about 20 percent of the overall GHG emissions (U.S. Environmental Protection Agency, 2016a), and we see a similar proportion of contribution by the industrial sector within the US as well (U.S. Environmental Protection Agency, 2016b).

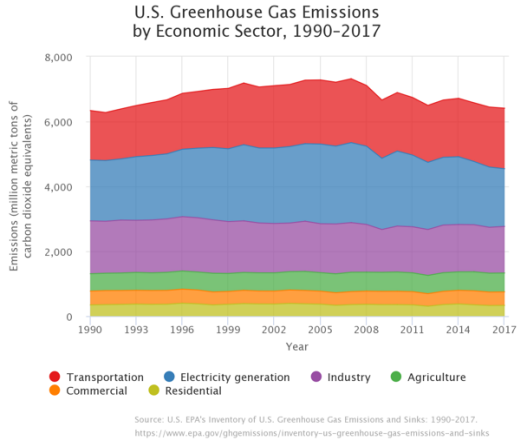


Figure 7: US Greenhouse Gas Emissions by Economic Sector from 1990-2017 (U.S. Environmental Protection Agency, 2016a)

Figure 8 below details a 12.5 percent decrease in U.S. GHG emissions from the industrial sector since 1990 --from about 1600 to 1400 million metric tons of Carbon Dioxide.

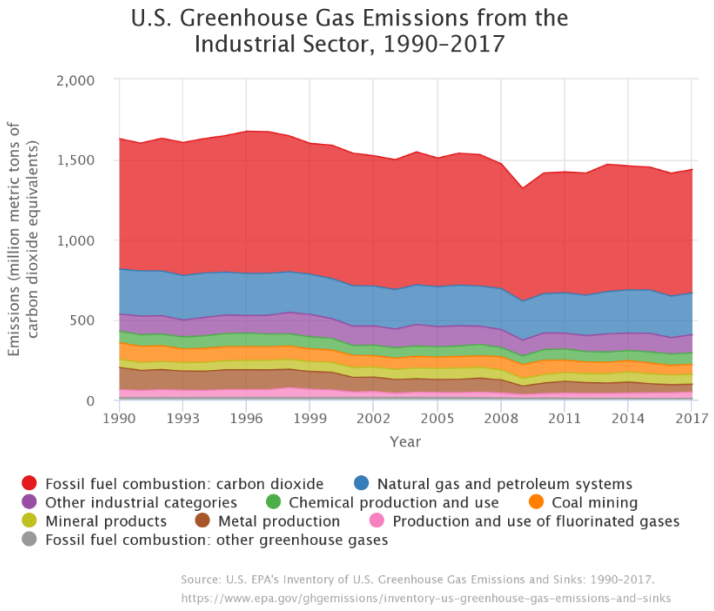


Figure 8: US Industrial Greenhouse Gas Emissions from 1990-2017(U.S. Environmental Protection Agency, 2016a)

In any decarbonization scenario, the industrial sector presents a significant opportunity to develop GHG reduction policies. At the same time, the manufacturing sector plays an essential role within the US economy both socially and economically. Consequently, any successful reduction strategy must do so in a manner that doesn't damage manufacturing competitiveness.

2 Manufacturing and Energy Products

This section examines the energy intensive manufacturing subsectors and identifies how changes in energy policy can affect them and, in many cases, distinct parts of the country. The decrease in manufacturing jobs has had a significant effect, especially in states such as Indiana and Michigan which heavily rely on manufacturing both for state gross product and employment. Manufacturing contributes 29 percent of Indiana's gross state product and employs 17 percent of the state labor force. In Michigan manufacturing contributes 19 percent of GSP and employs almost 14 percent (NAM, 2019). We will also discuss the correlation between the metals and coal industries and show how their relationship differs from the chemical and petrochemical industries with oil and gas.

2.1 Primary Metals: Iron, Steel and Aluminum

Figure 9: Top 15 States with Primary Metals Employment

The global steel industry has experienced significant changes since 2000, with global peak demand reached in 2013 (Chalabyan, Mori, & Vercammen, 2018). Much of this can be attributed to China's rapid growth as a result of infrastructure development during the 21st century. Now that its domestic market growth is beginning to stall, China is increasing exports, affecting steel prices, steel companies, and their employees. Additionally, there is a global oversupply of 600 million tonnes of steel, seven times larger than the entire US steel production in 2017 (Chalabyan, Mori, & Vercammen, 2018). This has forced other countries, including the US, to specialize in high-grade products, lobby for an array of tariffs, and determine how to compete in a global steel market with lower steel prices, deriving from China's overcapacity and large scrap steel supply.

While the US and other countries have been adjusting to the changing global industry landscape, there have been several positive outcomes related to environmental sustainability. Since 1990, the US steel industry has decreased its energy intensity by 35 percent and greenhouse gas emissions by 37 percent (AISI, 2019). Furthermore, more steel is now recycled than paper, plastic, aluminum and glass combined every year. Energy intensity is expected to further decrease by 27% by 2040 with steel production moving from primary to secondary production (US EIA, 2016). Secondary production, also known as recycled production, uses an electric arc furnace that melts scrap steel instead of the traditional blast furnace which produces steel from iron ore, coking coal and limestone. EIA estimated that between 1991 to 2010, the US steel industry increased its use of electric arc furnaces from 38 to 61 percent (US EIA, 2016).

According to an economic impact study by the American Iron and Steel Institute, the iron and steel industry added more than $206 billion directly to the US economy with 386,753 jobs for American workers in its production, processing, and distribution. Including the indirect employment and industry output that is a result of these primary processes (Table 2 below), iron and steel are estimated to make a total economic impact of over $500 billion and almost 2 million jobs. Most of these jobs are located in the Midwest and South.

Economic Impact of the American Iron and Steel Industry

	Jobs	Wages	Industry Output
Direct Impact			
Materials / Mill Services	75,606	$5,791,881,500	$25,982,986,900
Iron and Steelmaking / Steel Mill Products	140,877	$13,765,596,100	$115,074,150,700
Other Steel Products / Processing / Distribution	170,270	$13,987,958,700	$65,591,246,400
Total Direct Impact	386,753	$33,545,436,300	$206,648,384,000
Total Supplier Impact	715,510	$52,694,054,800	$172,914,724,100
Total Induced Impact	877,743	$45,016,028,500	$143,029,447,900
Total Economic Impact	1,980,006	$131,255,519,600	$522,592,556,000

	Federal Taxes	State and Local Taxes	Total Taxes
Business Taxes	$33,125,794,600	$22,738,282,400	$55,864,077,000

Table 2: Economic Contribution of US Iron and Steel Production and Processing (AISI, 2018)

While the current administration vowed to increase domestic production and protect steelworkers from foreign products by implementing higher tariffs and conducting more import investigations, steel imports have increased from 25 to 30 percent when the current administration imposed section 232 of the Trade Expansion Act, illustrating that US policies such as antidumping have not been effective in competing with lower costs from other countries.

In order to address these concerns, the steel and other related industries, including the automotive and energy sectors, are exploring new business models that will allow them to have a competitive edge. According to an analysis by Global Efficiency Intelligence, the U.S. steel industry "final energy and CO_2 emissions intensities rank 4th lowest" (Hasanbeigi, & Springer, 2019) in the world. Nonetheless, in 2017, the United States was also the world's largest steel importer, bringing in 34.5 Mt of steel. (US DOC, International Trade Administration, September, 2018)

In the automotive industry, 60 percent of a vehicle is made up of steel components (AISI, n.d.). Since 100 percent of the steel used is recyclable, this is an area of opportunity in which steel companies can specialize(AISI, n.d.). With the design and integration of new lightweight, high-strength steel grades, the auto industry will be able to meet the Corporate Average Fuel Economy (CAFE) requirements that double a motor vehicle's fuel economy by 2025 to 54.5 mpg (AISI, n.d.). Additionally, fewer emissions will be produced during the manufacturing process since steel has been reported to be the most environmentally friendly body material used in automotive manufacturing by material life cycle assessments.

In the energy sector, steel is widely used in infrastructure for electricity generation such as nuclear and natural gas power plants and wind farms, as well as transmission and distribution towers. To give a sense of how much steel is used in energy infrastructure, a recent industry study estimated that if the US implements 6 percent wind power by 2020, then 13 million tons of steel will be needed (AISI, n.d.). For

a typical high-voltage transmission tower, about 40 to 60 thousand pounds of steel are used (AISI, n.d.). Since decarbonization of the US economy will require a significant increase in energy infrastructure and construction, ensuring the participation of US steelworkers and their employers will be an important policy outcome of any successful strategy.

2.2 Aluminum

According to the Aluminum Association, the United States aluminum industry contributes $174 billion to the economy and directly employs 162,000 workers overall with another 692,000 indirect and induced jobs (The Aluminum Association, 2019). Transportation makes up 40 percent of domestic aluminum consumption with packaging, building and electrical uses following behind (US DoI, & US GS, 2019). North America supplied 26.4 billion pounds of aluminum with 34 percent of its supply coming from primary domestic production, 37 percent from secondary domestic production, and 27 percent imported in 2016 (The Aluminum Association, 2017). Unlike China, who increased primary production by 1,500 percent between 2000 and 2017, the American industry has experienced difficulty with 18 of 23 smelters shutting down between 2010 and 2017. (Scott, R. E., 2018). However, the USGS Mineral Consumption Survey reported that aluminum production increased for the first time in 2018, since 2012, when plants were operating at a little above half of their capacity with secondary production playing a significant role (US DoI, & US GS, 2019).

Salient Statistics—United States:	2014	2015	2016	2017	2018e
Production:					
Primary	1,710	1,587	818	741	890
Secondary (from old scrap)	1,690	1,560	1,570	1,590	1,600
Secondary (from new scrap)	1,870	2,000	2,010	2,050	2,100
Imports for consumption:					
Crude and semimanufactures	4,290	4,560	5,410	6,200	5,500
Scrap	559	521	609	700	730
Exports:					
Crude and semimanufactures	1,520	1,460	1,470	1,330	1,400
Scrap	1,720	1,550	1,350	1,570	1,700
Consumption, apparent[2]	5,070	5,300	5,090	5,670	4,900
Supply, apparent[3]	6,940	7,310	7,100	7,720	7,000
Price, ingot, average U.S. market (spot), cents per pound	104.5	88.2	80.4	98.3	115.0
Stocks, yearend:					
Aluminum industry	1,280	1,350	1,400	1,470	1,500
London Metal Exchange (LME), U.S. warehouses[4]	1,190	507	362	254	200
Employment, number[5]	30,900	31,000	31,900	31,700	32,000
Net import reliance[6] as a percentage of apparent consumption	33	41	53	59	50

Table 3: Aluminum industry in the past 5 years (US DoI, & US GS, 2019).

Much of the recent production growth is from secondary production with an estimated 83 percent of aluminum production in the US in recycled processes (CRS, 2018), making America the world's largest producer of secondary aluminum which has proven to be more steady than primary production. Secondary aluminum production consists of recycling material from previous applications, using only 6 percent of the total consumption of energy needed for primary production. Secondary production can mostly replace primary aluminum except for electronics and aerospace which need high purity products (CRS, 2018). This is significant considering that electricity can make up to 40 percent of the cost of primary production. Consequently, even America's largest producers, Alcoa and Century, have moved operations outside the US to Iceland, Russia and other countries where electricity is cheaper (CRS, 2018). Unfortunately, the offshoring of aluminum production, particularly to China, where most of the

electricity is generated from coal-fired power plants, has resulted in significant carbon emission increases. Much of the shuttered capacity in the US was located in the Pacific Northwest where electricity was generated with carbon-free hydroelectric power. Still, there are additional opportunities to cut energy consumption by reducing emissions through the electrolysis, raw material and secondary melting processes as illustrated in the DOE EERE report below.

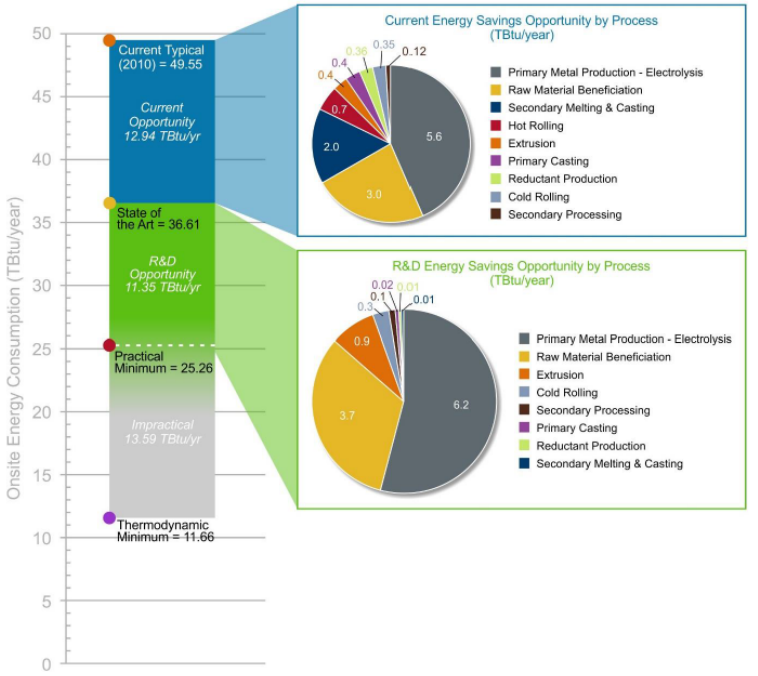


Figure ES-1. Current and R&D energy savings opportunities for the aluminum manufacturing subareas studied (considering lightweighting application area production only)
Source: EERE

Figure 10: Potential energy saving opportunities in the US aluminum industry (DOE EERE, 2017)

Unlike secondary production, primary aluminum has suffered since 2000, with production at 741,000 metric tons in 2017, the lowest it has ever been since the 1950s (CRS, 2018). As a result, the United States has increased imports by 64 percent since 2007, half of which comes from Canada (CRS, 2018). America only produces 1.2% of the world's primary aluminum supply while China makes up more than half of global production. The decline of the U.S. primary aluminum industry resulted from multiple factors, including the deregulation of electricity markets in parts of the United States, trade agreements without environmental border adjustments, and the high capital costs required for new primary aluminum production capacity and updated technology. Nonetheless, the US has continued to strengthen its secondary production and imposed international tariffs on aluminum imports under Section 232 of the Trade Expansion Act. The 10 percent tariff placed on foreign primary producers have resulted in two American smelters reopening, although operating at low capacities.

Looking to the future, decarbonizing the primary metals--iron, steel and aluminum--will impact a number of industries such as electric vehicles, construction and electronics. Their carbon emissions are significant and must be addressed in any efforts to decarbonize the US economy. Both industries are innovating and increasing material recycling which will help decrease America's contribution to climate change. Section 6 will discuss more specific policy recommendations that will help rebuild these industries.

2.3 Pulp and Paper

Figure 11: Top 15 States with Pulp and Paper Employment

The US is the second largest producer of paper and paperboard products in the world with China first and Japan third (DOE EERE, 2015). In 2018, the paper manufacturing industry contributed almost $57 billion to the US economy and employed 360,000 American workers with the concentration of production in the South, Northeast, and North Central regions of the country (Statista, 2019). This industry has experienced significant changes from digitization, consumer preference shifts and energy fuel sources (Berg, & Lingqvist, 2019). Increasing digitization has decreased paper use in the US as well as the world with 2015 marking the first year in decrease in global demand. While paper will not be completely removed, the industry is restructuring to meet the increasing demand for packaging paperboard and tissues needed for online shopping and shipping industrial products. Finally, energy intensive primary paper production is further incentivizing corporations to recycle paper in order to reduce high energy consumption rates. Such changes do provide opportunities for US companies such as International Paper and Kimberly-Clark to innovate and implement more energy efficient practices in order to provide a competitive edge in an evolving market.

As indicated above, the pulp and paper industry consumes the third largest portion of energy in the manufacturing sector following chemicals and petroleum refining. Primary paper manufacturing, or the conversion of virgin wood pulp into paper, is an energy-intensive process and an area in which the US is the largest global producer. The energy used is primarily fuel, typically natural gas or coal which is used in boilers and combined heat and power (CHP) systems. Areas with large energy savings' potential include powerhouse losses, paper drying and the paper machine wet end. As estimated by the DOE EERE Bandwidth study in 2015, 61 percent of energy could be saved by revamping paper production with new technology and practices and an additional 20 percent estimated savings if research and development technology that is being investigated worldwide were implemented in pulp and paper plants. Of the current energy savings opportunity, not including R&D, paper drying has 24 percent of energy savings available and the paper machine wet end has a 14 percent opportunity as seen in figure 12 below.

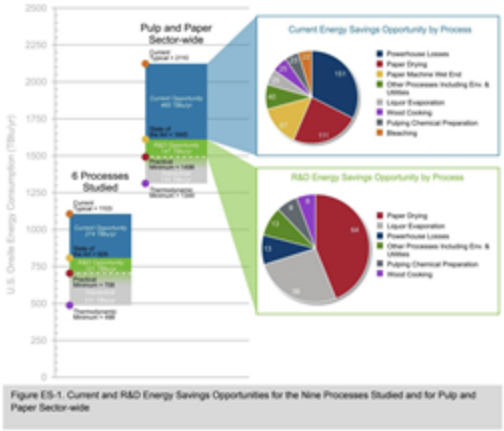


Figure 12: Potential energy saving opportunities in the US pulp and paper industry (DOE EERE, 2015)

Such energy savings do not include those that come from paper and paperboard recovery. It is estimated that there is a 40% reduction in the amount of energy needed to produce recycled paper compared to virgin wood pulp, thereby reducing CO_2 emissions (US EPA, 2016). This is particularly important seeing that the US has almost doubled its paper recovery rate from 33.5 percent in 1990 to 68.1 percent in 2018 (Paper Recycles, n.d.). However, there is still room for improvement and opportunities for companies to cut energy and emission costs.

2.4 Chemicals, Petrochemicals, and Refining

Figure 13: Top 15 States with Chemical Industry Employment

Similar to the pulp and paper industry, the chemical and petrochemical industries are in a period of transition. The recent decline in oil prices has advantaged those countries who were closest to fuel sources. With lower oil prices, these producers were able to maintain higher margins with relative ease. Such players include China, the Middle East and the United States (Cetinkaya, Liu, Simons, & Wallach, 2018). China's overall rapid economic growth contributed to their success in this sector whereas the Middle East and the United States benefited from being near large gas supplies. However, this is expected to change in the next decade as demand slows from China and other emerging economies. As a result, previously held advantages in feedstock will contribute a smaller percentage in overall value creation, forcing major chemical and petrochemical companies to refine core strengths and limit investments on feedstock infrastructure (Cetinkaya, Liu, Simons, & Wallach, 2018).

As one of the chemical producers with low-cost gas supply, a key feedstock, the US chemical industry has dominated the global market and, in turn, contributed significantly to the overall US economy. In figure 14 below, the value added from chemical product manufacturing has more than doubled in the last 20 years. In 1998, chemical product manufacturing added $181 billion to the economy; today it contributes $378 billion. While this has been beneficial to the industry, American workers have been relatively unaffected by such changes. With increased productivity, employment numbers declined continuously from 1998 levels with 993,000 Americans through the Great Recession when 48,000 jobs were lost between 2008 and 2009. However, since 2011, the chemicals' industry has added roughly 40,000 jobs for total current employment of 830,000.

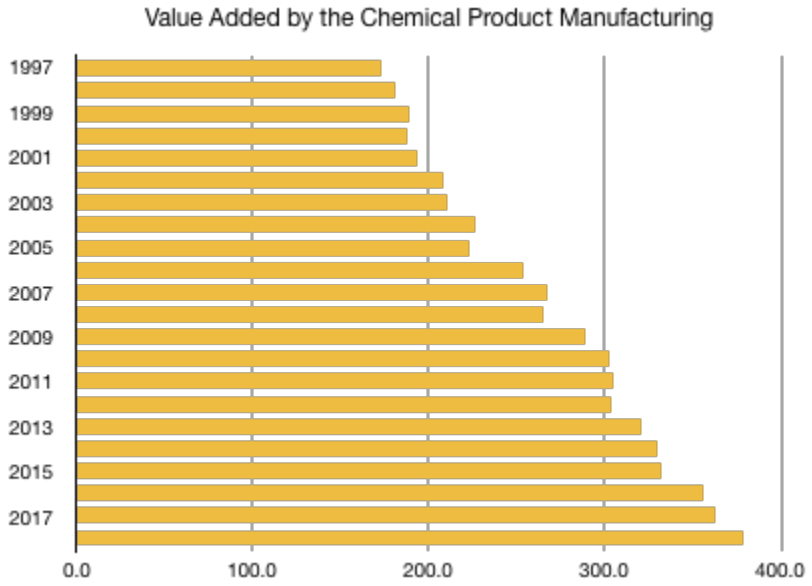


Figure 14: Value added by US chemical manufacturing from 1998 to 2018 (US BEA, Value Added by Industry, 2019)

Chemical and petrochemical manufacturing has been concentrated in specific regions, particularly the Gulf Coast and Midwest. Texas is by far the largest chemical exporter with a reported $44 billion of value added in chemical exports (Garside, 2019) and is also the country's largest producer of both crude oil and natural gas. Texas alone produced 37 percent of US crude oil and 24 percent of natural gas (US EIA, 2019). Louisiana is also one of the top five natural gas producers, accounting for 7% of total gas production as well as the second largest chemical exporter with more than $10.6 billion of value added (Garside, 2019).

Figure 15: Top 15 States with Petroleum Products and Refining Employment

Industrial sectors and energy consumption are also closely related. Total energy consumption in these states is also rated the highest. Texas is the largest energy consumer, making up roughly one-seventh of the country's total consumption. Within the state, the industrial sector accounts for half of its end use energy consumption, (US EIA, 2019) much of it attributed to chemical manufacturing and petrochemical refining. Texas is home to almost 18% of all traditional energy jobs (598,908) in the US, with 338,562 Americans employed in just the fuels sector (Energy Futures Initiative, & National Association of State Energy Officials, 2019).

Figure 16: US shale gas plays (US EIA, 2015).

The Gulf Coast and Midwest regions are projected to see a decline in annual production growth rates between 2019 and 2023 by almost half (Garside, 2019). While this will impact specific regions, industry can improve returns and increase profits by increasing digitization and advanced analytics as well as being prudent with capital investments. There are also expected opportunities for chemical manufacturers to return to petroleum-based feedstocks from natural-gas, especially considering that oil companies are interested in finding new investment opportunities as petroleum transportation fuels decline.

2.5 Mining

Mining encompasses coal, metal ores and non-metal mineral products such as sand, limestone, and gravel. As reported by the EIA Annual Energy Outlook, mining accounted for 12% of industrial sector energy consumption and contributed $95 billion directly to US nominal GDP and $119 billion indirectly in 2017. The 13,000 mining operation sites across the country have created 1.5 million direct, indirect, and induced jobs. The economic contribution by product is shown below as reported by the National Mining Association:

Sector	Coal Mining	Metal Ore Mining	Non-metallic Mineral Mining	Total
Employment				
Direct	118,901	81,487	322,646	523,034
Indirect & Induced	300,629	205,037	502,628	1,008,294
Total	419,531	286,524	825,273	1,531,328
Labor Income ($billions)				
Direct	$10.8	$6.9	$19.1	$36.7
Indirect & Induced	$18.9	$11.6	$27.9	$58.4
Total	$29.6	$18.4	$47.0	$95.1
Contribution to GDP ($billions)				
Direct	$22.3	$29.2	$47.0	$98.5
Indirect & Induced	$35.3	$21.5	$62.2	$119.0
Total	$57.6	$50.7	$109.2	$217.5

Table 4: Economic Contribution of US Mining Operations (NMA, 2017)

As a McKinsey report found, the largest factor in increased productivity is reducing the number of mining workers and increasing efficiency and output as illustrated with employment and product rates, a 3% decrease and 1.8% increase respectively (Flesher, Moyo, Rehbach,& van Niekerk, 2018).

Mining Employment in the United States, 1985-2015

Sector	1985	1990	1995	2000	2005	2015
Metal	43,961	54,005	48,734	37,650	30,395	41,459
Non-metal	37,002	33,818	29,441	25,918	23,039	21,235
Coal	183,373	146,505	103,076	76,025	81,891	68,413
Sand/Gravel/Stone	121,877	121,214	115,924	127,614	126,245	99,767
Contractors	28,948	48,773	64,472	81,340	83,266	112,035
Total	415,161	404,315	361,647	348,547	344,836	342,909

MSHA. Includes workers in mines, processing plants, independent shops and yards, office workers.

Table 5: Mining Employment in US (NMA, 2016)

The mining sector is continuing to see an increase in demand, especially in the battery market as the US and global economies are increasingly decarbonizing and pushing for renewables. However, there are some particular mining and energy products that have suffered as a result of decarbonization. The coal industry illustrates this in Table 5, where over 114,000 American coal workers lost jobs between 1985 and 2015. Non-metallic and metal production has also witnessed a decrease in employment during this same period. Table 5 highlights another interesting development with the significant increase in the share of American contractors used in the mining industry. In 1987, almost 29,000 workers were identified as contractors but this number increased almost four times to 112,000 Americans in 2015. This raises the question of whether there truly was a decrease in these industries or if there was instead a transition in terms of the types of jobs available in the industry.

2.6 Cement

Cement is another non-metallic mineral product that contributes significantly to America's overall emissions. It is estimated by the International Energy Agency that cement alone contributes 7 percent

of global carbon emissions (Harvey, 2018). Of the cement used in the US, 87.8 million tons of Portland cement was produced in 2018 across almost 100 plants in the US, resulting in $10.7 billion of company sales (PCA, 2017). The cement industry employs over 12,000 Americans and contributed over $15 billion to the US economy. Texas, California, Missouri, Florida and Alabama were among the top state producers of cement, comprising almost 50 percent of total US production (USGS Mineral Consumption Survey).

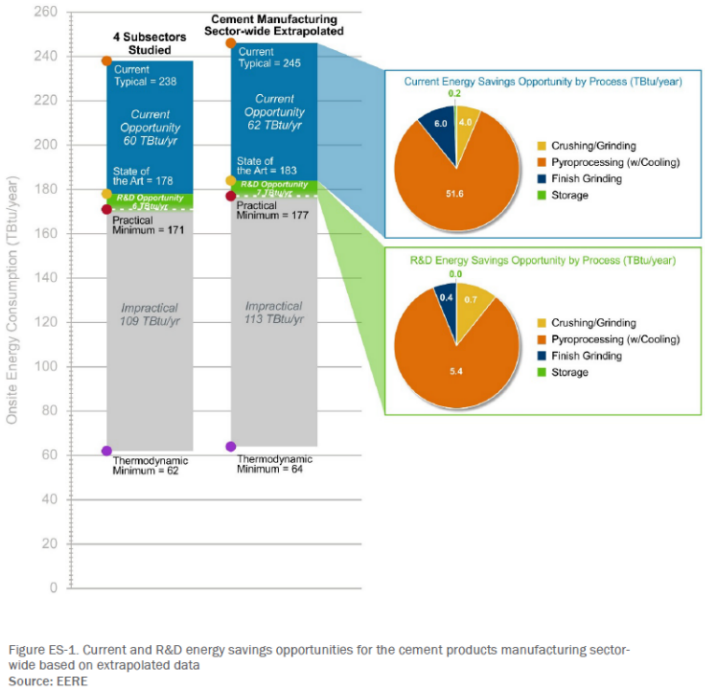


Figure ES-1. Current and R&D energy savings opportunities for the cement products manufacturing sector-wide based on extrapolated data
Source: EERE

Figure 17: Potential energy saving opportunities in the US cement industry (DoE EERE Cement, 2017)

It is estimated that emissions created by cement will increase by 3.5 percent globally between 2019 and 2024 (Business Wire, 2019). This is extremely critical to address as the United States updates its aging infrastructure. As Section 4 will discuss in further detail, significant investments will be required if the country is to move from its current failing infrastructure grade. Cement production's environmental impact is being addressed by research and country-wide initiatives like Breakthrough Energy. While the task is daunting, a DOE EERE report estimates that cement manufacturing can reduce energy consumption by 62 TBtu/yr primarily through pyro processing, finish grinding, and, crushing and grinding manufacturing processes using current state of the art technology. An additional 7 Tbtu/yr reduction can be achieved through R&D work.

3. Electrification of the Motor Vehicle Industry and Its Social Impact on the U.S.

Over the past year, multiple automotive companies have announced their transition plans to vehicle electrification which has the potential to change significantly the industry and its workforce. For example, Toyota plans to electrify its entire lineup by 2025 while General Motors plans to release an additional 20 new EVs by 2023. Volvo has announced that all its models after 2019 will be hybrids or all-electric, placing significant emphasis on electrification of their models as a key part of their business strategy. Tesla has moved toward global manufacturing of its electric vehicles, announcing plant openings in both China and Europe. VW predicts it will sell 500,000 EV's globally by 2022. Ford has committed to investing $11 billion in developing 40 hybrid and EV models while also joining with VW in an EV and autonomous vehicle alliance. While all these announcements offer promise towards decarbonizing the US economy, the social impacts may not be as positive.

According to several studies, vehicle electrification will result in net job losses. The Congressional Research Service predicted earlier this year that a transition to electric vehicles would result in job losses that affect both production and engineering jobs, particularly those associated with traditional internal combustion engines (McMahon, 2019). Even if electric vehicles are assembled domestically, less employment is expected since fewer components are required in the vehicle and less complexity required in a vehicle battery pack than a combustion engine.

A major analysis completed by FTI Consulting of the European Commission's EV projections, concluded that vehicle electrification would have a negative impact on jobs. (FTI Consulting, July, 2018) The analysis was based on comparing the relative job creation between the internal combustion engine (ICE) VW Golf with the all-electric GM Bolt, vehicles of roughly the same size. As indicated in their chart below, the negative impacts affected, not only production, but also repair and maintenance which were estimated to decline by some 60%. In the U.S., vehicle repair and maintenance employ roughly one million Americans, while dealerships employ a similar number. Interestingly, the FTI study found that hybrid vehicles were more labor intensive than either EV's or ICE's and would create more jobs. This is particularly interesting when coupled with estimates that, in the next decade, more emissions' reductions could be achieved from hybrids, than EV's alone.

Aspect	ICEs (VW Golf)	BEVs (Chevrolet Bolt)
Mechanical complexity	More complex due to ~6-times more moving parts in the powertrain	Fewer moving parts, especially in engine and transmission
Complexity of electronics	Less complex	More complex: 6-10-times more semiconductor content
Spare parts	More spare parts required	Around 60% fewer spare parts required
After treatment equipment	Catalysts, filters which wear	None
Maintenance[3]	More maintenance needed First service after 16,000 km	Around 60% less maintenance First service after 240,000 km

Table 6: Differences between ICEs and BEVs (FTI Intelligence, May 2018).

The impact of vehicle electrification has been analyzed more extensively in Europe than in the U.S., including the geographical effects. As in the U.S. vehicle production is concentrated in specific communities. The FTI study noted that motor vehicle production employment ranged from 2-8% of all employment in some communities and was from 20-36% of all manufacturing employment in given communities. In Stuttgart, Germany, for instance, the 160,445 motor vehicle employees represented 8% of all employment and 28% of manufacturing.

Overall in Europe there are increasing concerns over job loss from the 3 million employees working in the auto industry since employment levels are already decreasing within most major countries (Lionel Laurent, 2019).

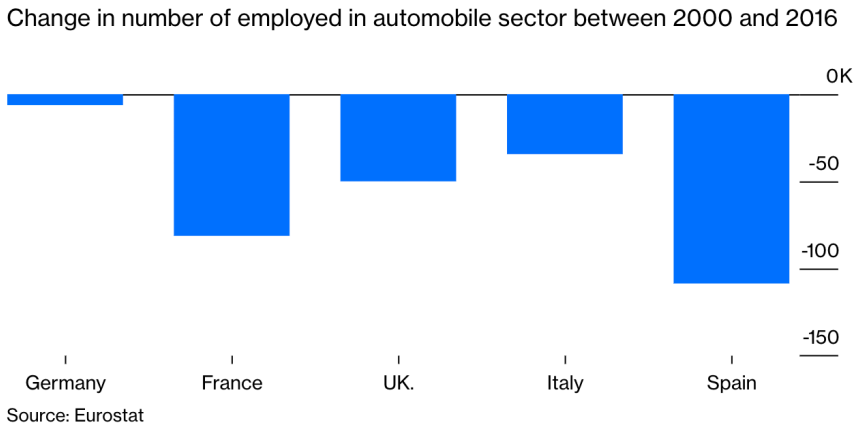


Figure 18: Change in number of employed in automobile sector of selected European countries.

In the US, there are currently about 2.5 million employed in the motor vehicle and component parts' industry with another 2 million Americans working in dealerships and retail, all of which will be disrupted by the move towards electric vehicles (National Association of State Energy Officials & Energy Futures Initiative, 2020). In 2019, slightly more than one million employees worked in manufacturing, 960,000 in repair and maintenance, 515,000 in wholesale trade and transport, and 71,000 in professional and business services. Currently, 78,000 work in electric vehicles and 165,000 in hybrids and plug-in hybrids. A detailed analysis of the component parts industry showed that 494,000 employees worked in jobs that contributed to achieving greater fuel economy as mandated by the 2011 CAFE standards.

It is interesting to note that the large number of employees producing fuel efficient component parts emerged during the period in which the motor vehicles industry added over 200,000 manufacturing jobs in the U.S. from 2012 to 2018. The success of the motor vehicles industry during this period in achieving both job growth and emissions' reductions is important evidence that both goals can be met when well-designed policy is implemented with the proper workforce and economic development supports.

Similar to Europe, the United States concentrates its motor vehicle manufacturing employment in specific states. 754,000 or just under 75% of those jobs are in 10 states with three of those—Michigan, Indiana, and Ohio—with almost 425,000. (USEER, 2019). Consequently, a reduction in employment as

a result of vehicle electrification will have disproportionate impacts on specific states. These impacts could be further exacerbated if the transition is accompanied by additional offshoring, relocation of domestic plant sites, and increased entrants into the U.S. market from European and Asian companies.

In addition to geographic impacts, however, there could also be adverse social impacts to specific demographic groups because of the unique role that the motor vehicles' industry has played within the African American community. Currently, 16.7 percent of employees in the manufacture of motor vehicles and component parts are African American, significantly above the 12 percent average in the US workforce (U.S. Bureau of Labor Statistics, 2019). However, the number of African-Americans in the auto industry has declined significantly over the last 40 years. According to a study by the Economic Policy Institute, in 2008, at a time when African American employment in the motor vehicles industry had declined by 13.8% in the previous 12 months, their wages were still 17% higher than the national average. (Scott, 2018.)

The importance of the automotive industry to the rise of the African American middle class and social mobility cannot be overstated. During the Great Migration, triggered by the labor shortages of WWI and social oppression in the south, six million African Americans left southern states to work in northern and western factories. As detailed in their study, The Economic Impact of the Automotive Industry on Urban Communities, the automotive industry was at the heart of this redistribution of income. (Citizenship Education Fund, 2012.) In addition, as the Center for Automotive Research reports, the job multiplier effect of urban manufacturing is significantly higher than in rural areas, at 3.6 compared to 2.1. This is the result of much higher levels of re-spending in local urban communities creating additional employment. (Citizenship Education Fund, 2012.)

As seen in Figure 19 below, during the major contraction in automotive production caused by the Great Recession, African American employment dropped sharply in the automotive industry to the same levels as in other sectors of the workforce. However, as employment returned, we see that over the last six years the percentage of African Americans has again climbed above the overall average.

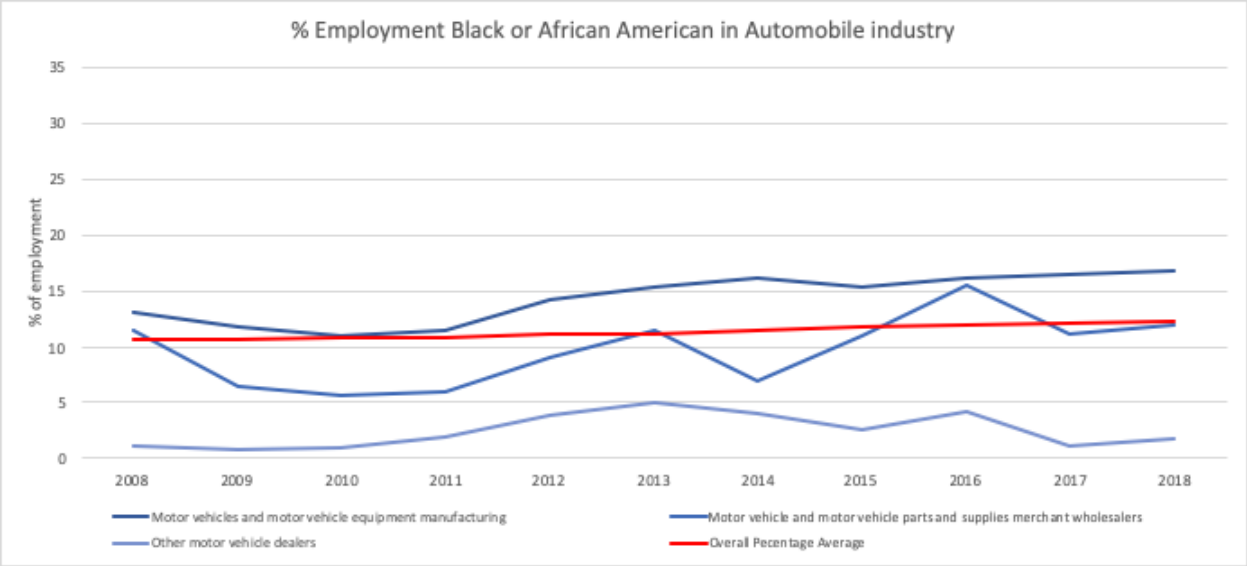


Figure 19: Percentage of Black or African Americans employed within the Automobile industry

As in our White Paper #7 discussion of the energy workforce transition and how to address the disproportionate impacts caused by the move to a lower carbon economy, it is important to understand both the starting point and the end point of public policy. In the case of the motor vehicle industry, as with certain energy and energy efficiency technologies, it will be critical to protect the gains in job quality, diversity, and unionization achieved by previous generations in order to assure that we succeed in creating greater social equity and avoid undoing the very benefits we are trying to achieve.

4 Effect of Current Carbon Reduction Strategies on Manufacturing

Over the last two decades, at both the federal and state levels, we have seen an increasing emphasis on carbon reduction strategies that can have a significant impact on the manufacturing sector. In this section we will look at how two different carbon reduction strategies have impacted U.S. manufacturing to provide future guidance for public policy on how to reduce industrial and transportation GHG emissions while supporting domestic manufacturers. Those two strategies are the Corporate Average Fuel Economy (CAFE) standards, and the 48c Advanced Energy Manufacturing Tax Credit.

4.1 CAFE Standards

With the introduction of the first CAFE standards in 1975, car manufacturers were required to meet minimum fuel economy requirements for fleets of vehicle sold in specific classes. These standards were subsequently strengthened by a subset of states, led by California, and, in 2012, the Obama Administration announced a new agreement with automakers, EPA, NHTSA, and the state of California to raise fuel economy standards to 54.5 miles per gallon by 2025 (Julian Morris, 2018).

The Motor Vehicles and Component Parts manufacturing sector workforce currently makes up about 9% of the entire manufacturing workforce (U.S. Bureau of Labor Statistics, 2020b). This translates to roughly 1.01 million employees who would be affected by performance adjustments to CAFE standards, since this would have significant associated impact on the design, cost, material, parts, and supply chains of manufacturing vehicles.

According to the National Highway Traffic and Safety Administration, figure 20 shows the estimated fuel savings from the introduction of CAFE. While we see the fuel savings benefits from CAFE, we also see a positive trend within the motor vehicle manufacturing sector from the early 1980's to 2000. Figure 21 shows an employment graph in the U.S automobile industry in the early years after the introduction of the 1975 CAFE standards. We can see from this initial study done by the National Research Council, assessing the impact of CAFE standards on automobile manufacturing, that there was a positive impact on the employment levels within automobile manufacturing (Board & Council, 2002). However, the role of motor vehicle manufacturing changed dramatically in the United States from the late 1970's. Other factors that impacted domestic manufacturing included the development of global supply chains, the passage of NAFTA, and domestic content rules.

Finally, Figure 22, using QCEW data, shows the sharp growth in motor vehicles manufacturing from the depth of the Great Recession to 2018. From 2012 onward, after implementation of the 2012 CAFE standards, U.S. motor vehicle manufacturing added over 200,000 jobs.

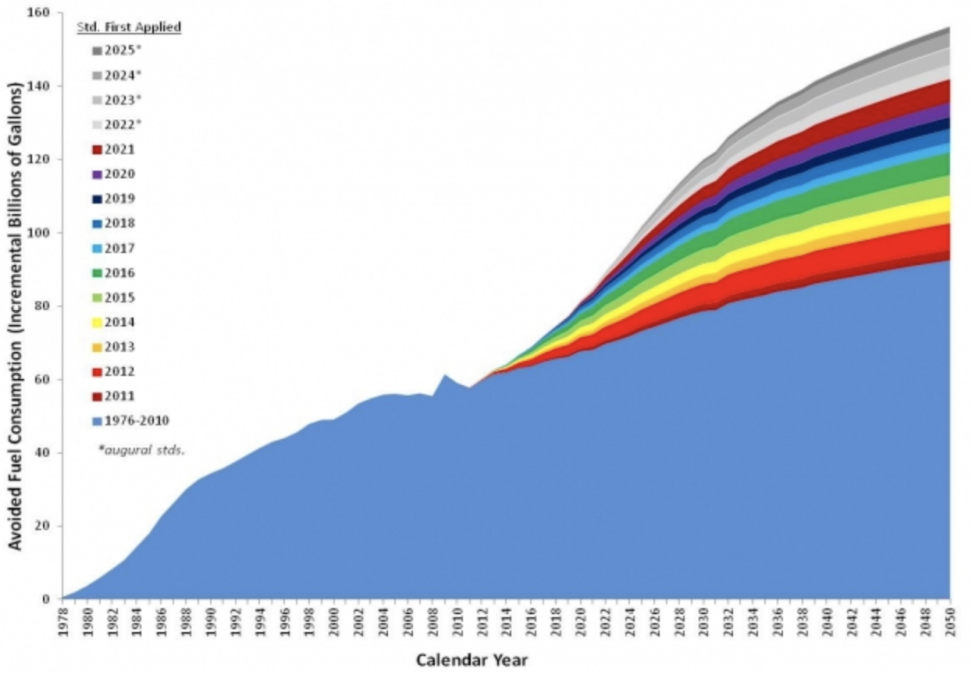


Figure 20: Estimated fuel savings by National Highway Traffic and Safety Administration (NHTSA) from CAFE Standards (U.S. Department of Transportation, 2014)

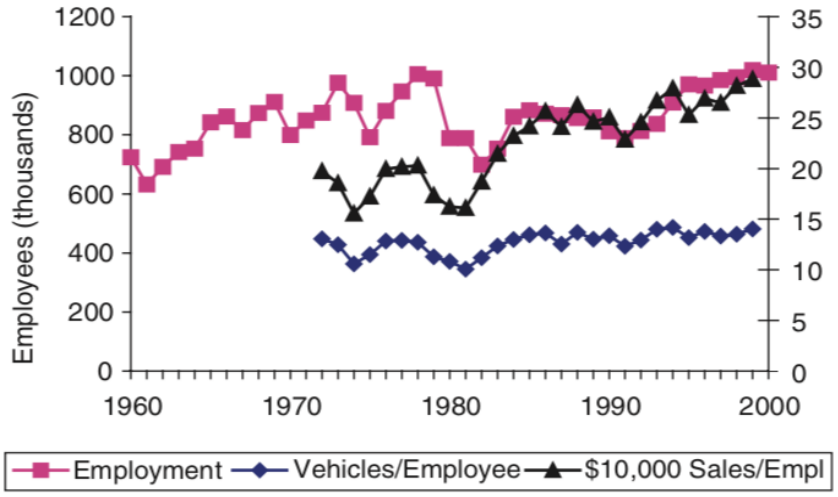


Figure 21: Employment and productivity in the U.S. automotive industry from 1960 to 2000. SOURCE: Wards Automotive Report.

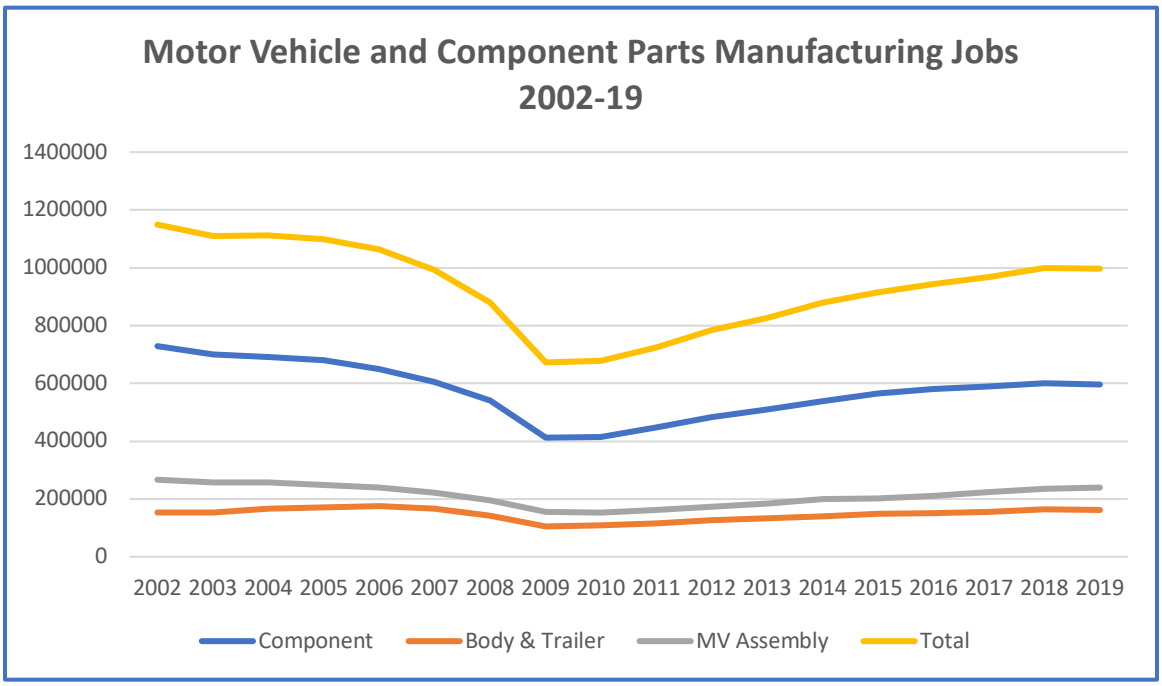


Figure 22: Employment in the U.S. automotive industry from 2002 to 2018.
SOURCE: Bureau of Labor Statistics (U.S. Bureau of Labor Statistics, 2020a).

4.2 48C Advanced Energy Manufacturing Tax Credit

In phase 1 of the 48c Advanced Energy Manufacturing Tax Credit, introduced in 2009, $2.3 billion in competitive, tax credits for clean-energy manufacturers were awarded as part of the American Recovery and Reinvestment Act (U.S. Department of Energy, 2013).

A big part of the program served to foster investment and job creation within the clean energy manufacturing sector. At the time, the 183 manufacturers, who were competitively awarded 30 percent investment tax credits, estimated they would create 17,000 jobs. In the 4 years after the 48C introduction, the U.S doubled renewable energy generation from wind, solar and geothermal sources, while also becoming more active in the global clean energy manufacturing race (Jen Anesi, 2013).

The tax credits played a significant role in increasing domestic production levels for renewable energy equipment and component parts. According to the 2020 U.S Energy and Employment Reports, the domestic manufacturing employment within solar, wind and CHP energy sources are 19 percent, 23 percent and 7 percent respectively of each sector. In 2010, the U.S. wind industry reported 18,500 manufacturing jobs in the U.S. By 2018, that number had risen to 26,400. As demand increases for these renewable technologies, with the reauthorization and expansion of similar tax credit policies, we could expect an increase in the number of manufacturing workers employed in these technologies.

Looking at the overall trend of manufacturing GDP in the U.S. (figure 23), we see that there has been a sharp increase from 2009 to 2018, rising by over $350 billion. While the data does not currently exist to determine how much of this GDP growth resulted from low carbon technologies, we do know that over

903,000 employees work in the manufacture of renewable energy, energy efficiency, and fuel-efficient technologies (National Association of State Energy Officials & Energy Futures Initiative, 2019; U.S. Bureau of Economic Analysis (BEA), 2020).

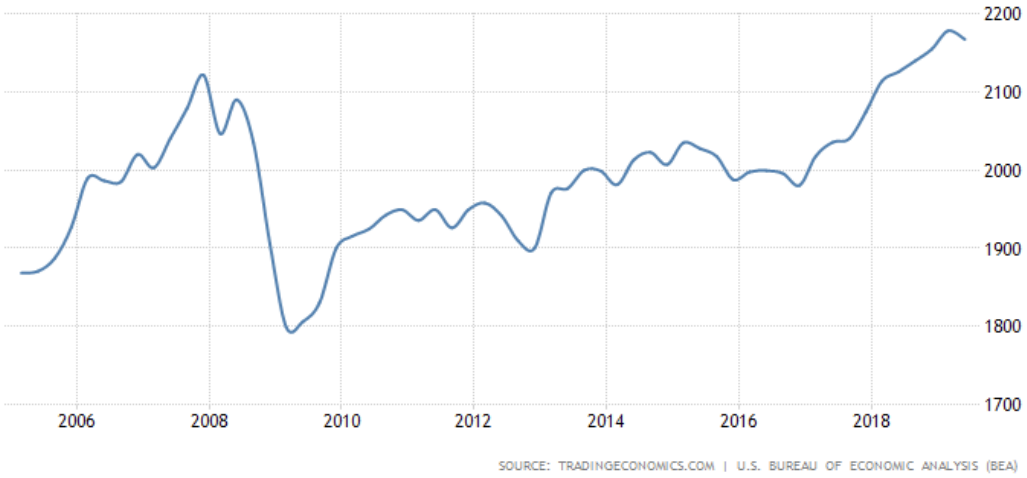


Figure 23: U.S. GDP from Manufacturing (in USD Billion)
SOURCE: (U.S. Bureau of Economic Analysis (BEA), 2020)

5 The Impact of Low Carbon Technologies on the Manufacturing Workforce

Several studies have been completed on how existing renewable energy technologies would impact the manufacturing sector and how the deployment of emerging clean energy technologies, such as Small Modular Reactors (SMRs) and Carbon Capture and Storage (CCS), would create manufacturing jobs.

5.1 Existing Renewable Energy on the Manufacturing

In 2009, the BlueGreen Alliance released a report: How Renewable Energy Can Revitalize U.S. Manufacturing and the American Middle Class (BlueGreen Alliance, 2009).

This study depicted how renewable electricity can provide 3 to 6 times as many jobs as equivalent investments in fossil fuels when manufacturing, installation, operation and maintenance jobs are taken into account. In addition, it found that if the U.S. electric generation share of renewable content from wind, solar, geothermal and biomass can be increased to 25% by 2025, this would create as many as 850,000 jobs in existing U.S. manufacturing firms across the country. At least 42,000 manufacturers could participate in the increased demand for component parts required to produce these renewables. These estimates were based on 100% domestic sourcing of all component parts and assembly.

Currently, renewable energy sources, including wind and hydro, the two largest sources, provide nearly 20% of U.S. electricity. Wind, solar, geothermal, and biomass supplied roughly 10% of U.S. electricity supply in 2018 (U.S. Energy Information Administration, 2018). According to employment reports released by U.S. Energy and Employment Report (National Association of State Energy Officials & Energy Futures Initiative, 2020) and the National Solar Jobs Census (The Solar Foundation, 2019) there are roughly 483,000 jobs producing electricity from renewable sources in 2018, with 415,000 of those from wind, solar, geothermal and biomass. 82,000 of all renewable generation jobs are within the manufacturing sector.

Although a significant number of manufacturing jobs have been created from the growth of renewable electricity, and overall jobs in renewables continue to rise (figure 25 and figure 26), the clean energy manufacturing sector faces the same challenges of globalization and automation as the rest of the manufacturing sector. As noted in Figure 24 below, manufacturing jobs in most renewable electricity technologies have declined in recent years with the exception of 2019 in the solar industry which added 700 jobs. This issue will be addressed in the policy recommendations in the final sector of this paper

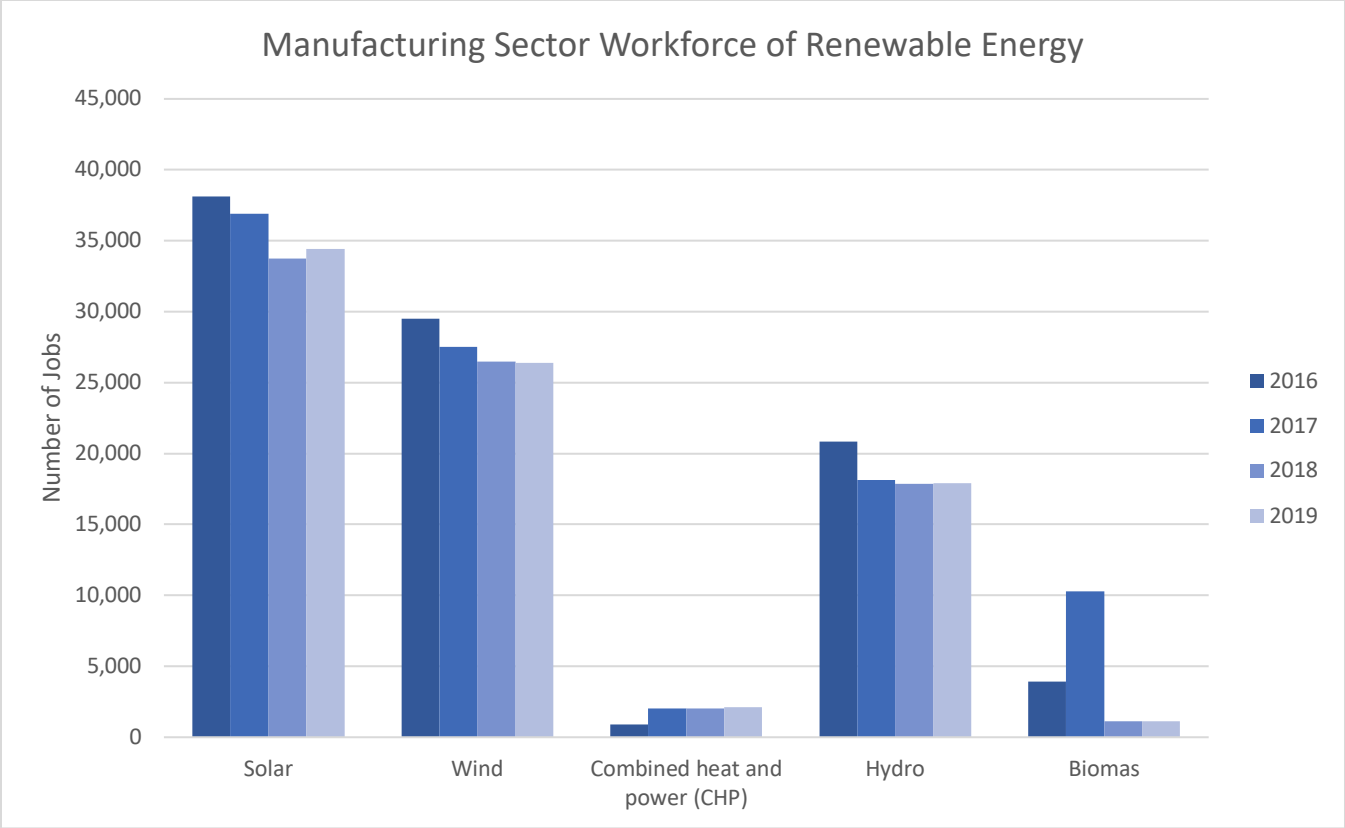


Figure 24: 2016, 2017, 2018, 2019 employment numbers within the manufacturing sector of various renewable technologies.

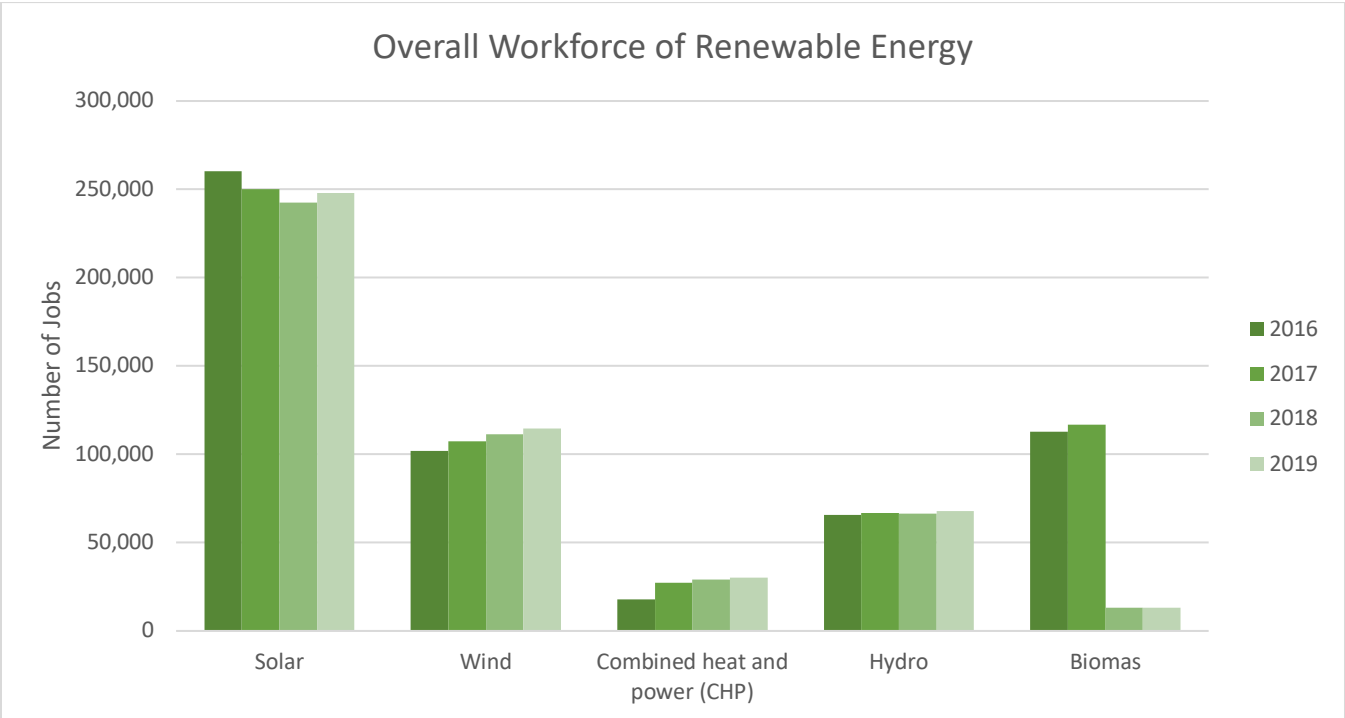
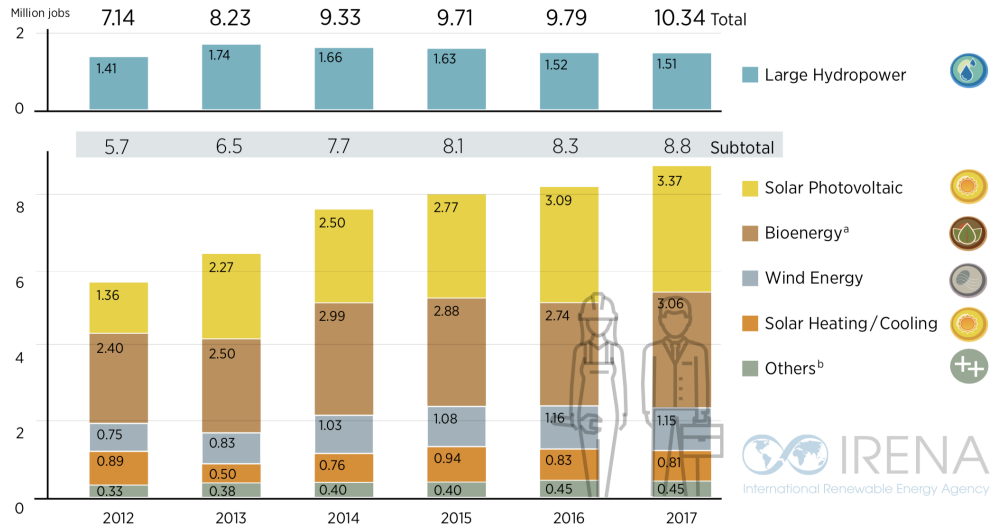


Figure 25: 2016, 2017, 2018, 2019 total employment numbers of various renewable technologies.



Source: IRENA jobs database.

Note: The numbers shown in this Figure reflect those reported in past editions of the Annual Review.

a Includes liquid biofuels, solid biomass and biogas

b Other technologies include geothermal energy, hydropower (small), concentrated solar power (CSP), heat pumps (ground-based), municipal and industrial waste, and ocean energy.

Figure 26: IRENA Report on the Global Renewable Energy Employment by Technology, 2012-2017

5.2 Emerging clean energy technologies

In White Paper #7, when analyzing the impacts of decarbonization on the workforce system, we examined several technologies to assess the scope of their skills' needs. Similarly, we want to examine three of those technologies—Small Modular Reactors, Carbon, Capture and Sequestration, and Battery Storage—to assess their potential impacts on manufacturing.

Small Modular Reactors. When we consider the feasibility of nuclear power for decarbonizing the US energy system, SMRs are commonly seen as the most viable option that might be deployed at significant scale over the next several decades (Morgan et al., 2018). SMRs provide the potential to reduce the capital cost of nuclear power plants by standardizing production, as well as providing the capacity to power smaller grid systems (OECD & Nuclear Energy Agency, 2016).

NuScale Power LLC is currently one of the main firms focused on advancing the deployment of SMR design applications. To date, NuScale has engaged in over 70 research collaborations with a range of academic, government and private sector partners, spending approximately $34 million in preparation for the first commercial test, planned for Idaho on the site of the Idaho National Laboratory in partnership with the State of Utah. As companies like NuScale prepare to deploy SMR plants, they anticipate significant growth in employment to construct and operate these plants, as well as in the associated domestic manufacturing supply chain. Currently, NuScale estimates it will deploy 73 plants by 2030. Each four-unit plant would require about 300 full time operating staff and create 1,200 peak construction jobs. In addition, NuScale estimates that its modular design would create an additional 13,500 manufacturing jobs within the domestic supply chain (Lenka Kollar, 2019).

Carbon, Capture and Sequestration. With the deployment of CCS in both generation and industrial applications, we can expect a similar trend in terms of manufacturing employment. As part of President Barack Obama's economic stimulus plan in 2009, the Department of Energy (DOE) awarded an $8.4 million grant to support training and education in CCS technology (University of Texas at Austin, 2018). This grant provided the stimulus for further development and deployment of CCS and continues to be relevant today. A 2018 report on Carbon Dioxide Capture and Storage by the IPCC expects that the cost of deployment of CCS will be reduced with greater research and technological development and economies of scale (Bert Metz et al., 2005). This would in turn result in larger deployment projects and generate employment in CCS.

A 2016 analysis by the U.S. Department of Energy found that with the regulatory environment created by the Clean Power Plan, coupled with a proposed revision of the 45Q tax credit, as much as 30 GW of coal and natural gas-fired power plants could be retrofitted with CCS. In addition, a 2019 analysis by EFI of the State of California's carbon reduction goals found that CCS would be the only technology available to decarbonize the industrial sector.

A study done by Patrizio et al, in 2018 found that reducing U.S. coal emissions through carbon capture methods can boost employment (Patrizio et al., 2018). This study found that the coal industry could retain 40,000 jobs and create 22,000 new jobs in the forestry and transportation sector, with associated manufacturing activities, such as building new forestry and transportation equipment (Patrizio et al., 2018).

These predicted jobs' numbers are similar to the employment numbers for CCS provided by the CCS Skills Study released by the Industrial and Power Association in the United Kingdom. Figure 27 below shows the projected jobs from CCS deployment within the UK and Scotland, rising to 85,000 jobs by 2030. This study was estimating the effects of CCS deployment in 2010 to reduce emissions in the UK power sector and provides a useful model for the kinds of jobs created by widescale usage. CCS jobs would be spread across a variety of disciplines, including engineering (mechanical, civil, electrical process, etc.) and craft jobs which typically include manufacturing employment. To see the full listing of CCS-related occupations, refer to Section 5 of White Paper #7.

Another study produced by Sintef for a consortium of business and trade union groups in Norway estimated that a Norwegian-based initiative to deploy CCS technology could strengthen the competitiveness of 80,000 to 90,000 existing jobs while creating 30,000-40,000 new jobs by 2050. 30,000 of the new and more competitive jobs would be in Norway's "process industries", manufacturing industries such as cement, aluminum, steel, and chemicals that require significant process heat and emit process emissions during the course of production. Interestingly, Sintef describes Norway's commitment to this technology as an important future competitive advantage to producing carbon-free products.

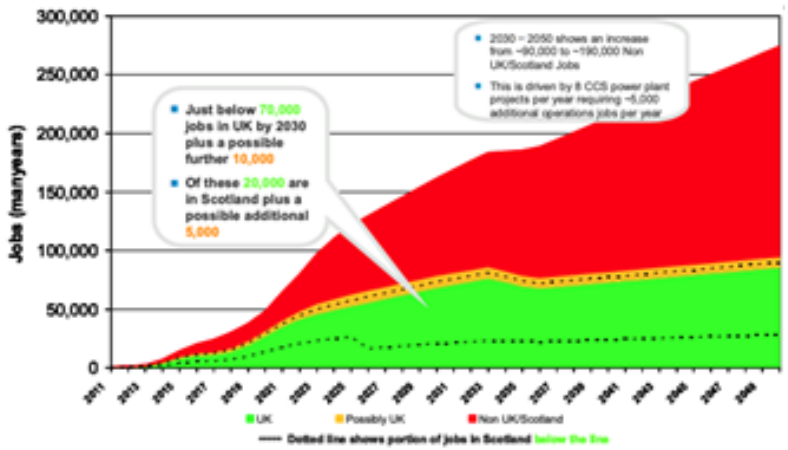


Figure 27: Total CCS jobs in UK (Alan Young et al., 2010)

Overall, new energy technologies such as SMR's and CCS will provide significant opportunity for manufacturing in the U.S. However, as the changes in manufacturing in the U.S. over the last four decades have shown, potential domestic manufacturing job creation in these new technologies will be more dependent on the industrial policy of the country than on its energy or climate policies per se. While the potential for a clean energy manufacturing renaissance in the United States was recognized more than a decade ago, without a suite of policies to support a dynamic manufacturing economy in the U.S. this opportunity will be lost to other countries.

Battery Storage. The impact of battery storage in the US energy system has been increasing rapidly in recent years. According to the 2020 USEER report (National Association of State Energy Officials & Energy Futures Initiative, 2020), the battery storage workforce in the US in 2019 was approximately 66,000. Figure 28 shows a breakdown of the battery storage employment in 2018. The construction and manufacturing industries provide the most jobs in battery storage, with manufacturing growing at a greater pace. In 2018, there battery storage grew by 18%, adding over 9,500 new jobs with manufacturing being the main driver.

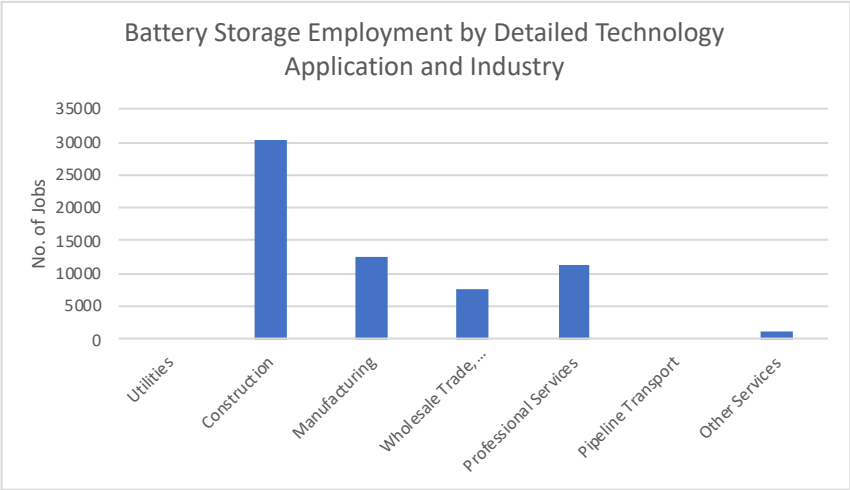
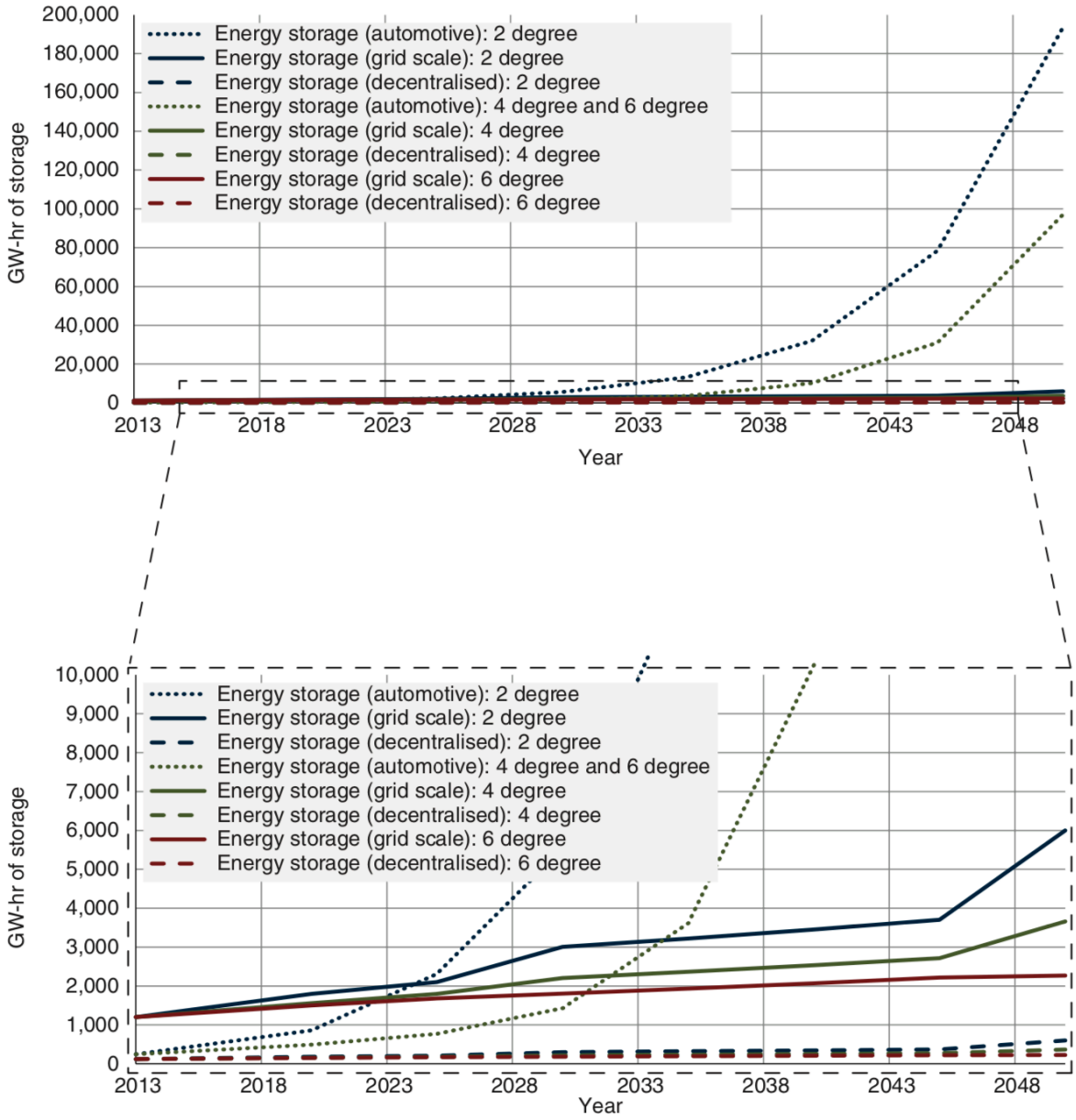


Figure 28: Battery storage employment by technology application and industry in 2018.

A World bank report on “The Growing Role of Minerals and Metals for a Low carbon future” (Arrobas et al., 2017) in 2017 found that lithium-ion batteries, due to their excellent energy-to-weight ratio and decreasing prices, are the preferred technology for battery storage and are widely used for full electric vehicles. Based on demand scenarios documented by the International Energy Agency in 2016, there could be 140 million electric vehicles in operation by 2030 which would result in growing demand for additional battery storage units. Figure 29 below shows this projected trend.

However, lithium ion batteries require different types and increased amounts of minerals and metals as compared to lead acid batteries. Table 7 shows some of the key metals required for the different battery types while Figure 30 provides a preliminary assessment of how overall demand for metals might increase by 2050 with greater demand for batteries for electric vehicles. With manufacturing making up 20% of battery storage employment, an increased demand for battery storage will expand both manufacturing and mining employment.

Based on a CSIS brief on “Critical Minerals and the Role of U.S. Mining in a Low-Carbon Future” (Center for Strategic & International Studies, 2019) the U.S. currently imports more than 50% of its annual consumption of critical mineral commodities, creating potential strategic vulnerabilities both economically and in terms of national security. With many of the global supply chains still not fully developed, there are significant potential rewards if the U.S can rebuild its domestic supply chain, including increased employment in mining, metal processing, and battery manufacturing.



Note: 2DS = 2 degree scenario; 4DS = 4 degree scenario; 6DS = 6 degree scenario. Global energy storage scenarios. Data obtained from the IEA Energy Technology Perspectives scenarios (2015a), as well as scenarios described in International Electrotechnical Commission (2009).

Note: Global energy storage scenarios, zoomed in to see detail for all scenarios other than the 2DS electric vehicle scenario. Data obtained from the IEA Energy Technology Perspectives scenarios (2015a), as well as scenarios described in International Electrotechnical Commission (2009).

Figure 29: Expected global energy storage capacity scenarios (Arrobas et al., 2017)

	Energy storage batteries	
	Lead acid	Lithium ion
Aluminum		X
Cobalt		X
Lead	X	
Lithium		X
Manganese		X
Nickel		X
Steel	X	X

Table 7: Comparison of Significant Metal Content in Lead-Acid and Lithium-Ion Batteries (Arrobas et al., 2017)

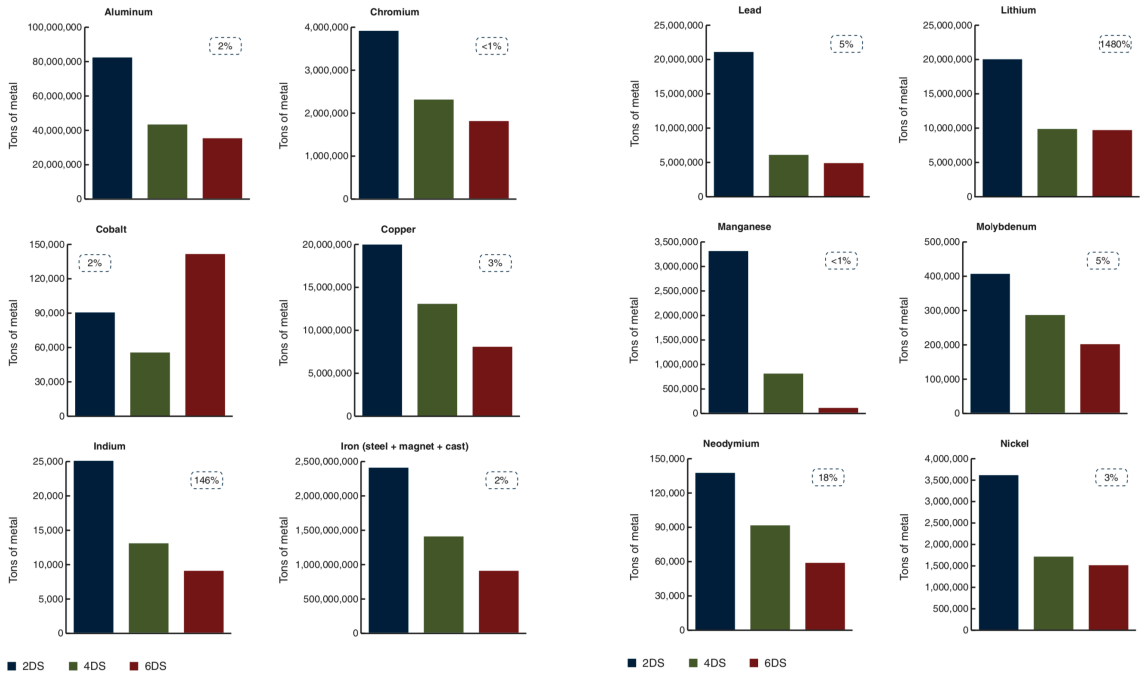


Figure 30: Mean cumulative demand, 2013-50, for raw materials under 2, 4 and 6 degree scenarios (Arrobas et al., 2017)

6 Key Policies to Enable Domestic Manufacturing Supply Chains in Energy

The lack of an overarching industrial policy has been one of the distinguishing features of the U.S. economy, setting it apart from its chief rivals, China, Germany, Japan and South Korea. That absence is, perhaps, best characterized by the push to participate in the first waves of globalization in the 1970's and 1980's. Jack Welch, the long term CEO of General Electric, at one point the largest industrial enterprise in the U.S, (Kiplinger, 2012) notably said, ""Ideally, you'd have every plant you own on a barge to move with currencies and changes in the economy." (The Economist, 2013) Similarly, in 1987 a leading spokesman for the U.S. Chamber of Commerce asked, "Where in the Bible is it written that the American worker should be paid more than the South Korean?" (Foster, 1987)

Guided by the general view at the time that a company's chief purpose was to maximize value for its shareholders, U.S. manufacturing companies participated widely in both the consolidation of key global industries and the relocation of U.S. facilities to take advantage of lower labor costs and laxer regulations. Instead of focusing on public policies that would reward R&D, support deployment of new technologies, and develop long-term workforce policies that supported upskilling, U.S. manufacturing aggressively dismantled existing industrial infrastructure in pursuit of short term profits.

Typical was the story of GE Transportation that once employed over 18,000 workers in its Erie, PA locomotive plant and supplied 40% of the global demand for locomotives. (Goerie.com) Since the 1980's GE had sold 420 freight locomotive engines to China, but then collaborated to build diesel locomotive factories in China, Brazil and Kazakhstan. (GE Reports, 2008) The Chinese plant was built to supply China's need for 6,500 diesel locomotives Today, CRRC, a Chinese firm, is the largest rolling stock supplier in the world, with multiple factories in the U.S., over 180,000 employees, (CRRC, 2020) globally, while GE divested itself of its transportation division to Wabtec. (Wabtec.com). The Erie, PA factory employs 1,600 people today.

Nonetheless, the U.S. is still the second largest manufacturing economy in the world and with the demand for new energy, transportation, and infrastructure products along with new advanced manufacturing technologies such as additive manufacturing and more rigorous supply chain management, the opportunity for growth is significant. Indeed, one recent study by Deloitte predicts that the U.S. may re-emerge as the most competitive manufacturing economy in the world within the next five years. (Deloitte, 2018)

As pointed out in Section 2.1 of White Paper #7: Energy Workforce Development in the 21st Century, there are currently 827,000 (USEER, 2020) manufacturing jobs in the U.S. directly producing energy or energy efficiency products from wind turbines to high efficiency HVAC systems. This does not include the indirect manufacturing jobs, producing upstream inputs such as the steel plate for wind turbine towers or the aluminum used in the construction framing for a solar installation. Described below are a range of policies, some of which have been used in the past, to support domestic manufacturing and the growth of supply chains in new technologies.

Government procurement policies

- **Buy America.** The Buy America Act of 1982 and the Buy American Act of 1933 have been a staple of procurement policies for several U.S. federal agencies, including the Departments of

Transportation and Defense. Under these policies, U.S. manufactured products must be given preference by both contractors working for the federal government or by the Departments themselves. Exclusions are granted when required products cannot be produced in the U.S. In order to realize the full potential of the U.S. Government spending on climate-related infrastructure, energy technology and energy efficiency technology, Buy America provisions should be extended to all such projects.

- **Buy Clean.** In 2018, the State of California passed the nation's first Buy Clean legislation, requiring state funded projects to give preference to the lowest carbon emitting construction products, including steel, glass, and insulation. (State of CA, 2020) This legislation, broadly supported by labor, business and environmentalists in California, was passed in reaction to the purchase of Chinese steel with three times the carbon footprint of U.S. manufactured steel to rebuild the Oakland Bay Bridge. Similar Buy Clean legislation should be passed at the federal level to cover U.S. procurement and be expanded to cover a broader range of construction products, including all steel, cement, glass, foundry products, aluminum, and, certain critical minerals.

Border Adjustments

In order to encourage additional investments in emissions' reductions in the Energy Intensive, Trade Exposed industries (EITE's) and promote global compliance, the U.S. should include a border adjustment within the framework of the U.S. Mexico Canada (USMCA) trade agreement to price the carbon emissions associated with the products of the steel, aluminum, pulp and paper, glass, petroleum, brick, cement, foundry, and other EITE's as defined in the Waxman-Markey legislation of 2009. Establishing such a threshold for the US, Canada, and Mexico would make industrial emissions' reductions a competitive advantage for the US manufacturing industries that are the largest emitters of industrial emissions. (Waxman-Markey, 2009)

Technology Development

- **48c Advanced Energy Manufacturing Tax Credit.** The 48c Advanced Energy Manufacturing Tax Credit, jointly administered by the US Departments of Energy and Treasury during the American Recovery and Reinvestment Act, successfully distributed $2.3 billion and created an estimated 17,000 manufacturing jobs. Detailed in a number of reports, 48c should be expanded as a 10-year program, designed to accelerate the growth of domestic manufacturing in all the key supply chains that will contribute to reducing emissions and meeting 2050 goals. (US DOE, 2020)

- **Advanced Technology Vehicle Manufacturing Loan Program (ATVM).** The ATVM program, authorized in 2006 and administered by DOE should be expanded with specific targeting to encourage vehicle electrification products and supply chains. The current trend toward supporting U.S. assembly of both electric and ICE vehicle models by the Big Three in individual plants should be supported. However, electrification will have serious impacts on the number of jobs in the domestic internal combustion engine supply chain. ATVM programs should be focused on plant conversion of existing motor vehicle parts' facilities to EV production in order

to minimize negative impacts on existing automotive manufacturing communities. (US DOE, ATVM, 2020)

- **Electric Vehicle Tax Credits.** A new federal electric vehicle tax credit should be established that provides a double credit for domestically manufactured EV's and charging equipment with high domestic content.

- **Expansion of Industrial Assessment Centers (IAC's).** The Industrial Assessment Centers, coordinated by the Department of Energy, should be expanded as a key tool for enhancing manufacturing competitiveness among small and medium manufacturers and should be provided with a tax credit mechanism to help finance efficiency measures in these plants. (US DOE, IAC's, 2020)

- **Energy Efficiency Industrial Loan Program and Tax Credit.** The DOE Loan Program should be broadened to finance the expansion of energy efficiency product manufacture beyond simply financing new or innovative products. A refundable energy efficiency tax credit should be established to help with the introduction of large-scale application of CHP and WHP in EITE's.

- **Workforce Development.** Similar to the recommendation in White Paper #7, the Department of Energy, in cooperation with the Departments of Labor, Education, Commerce, Defense, and the National Science Foundation should issue an annual report on workforce trends in advanced manufacturing, curricula needs, and a skills' assessment of the existing workforce.

R&D Supports

The overall ecosystem for R&D support of manufacturing should be strengthened.

- **Expansion of Manufacturing USA (formerly the National Network of Manufacturing Institutes.** Started in 2014 and jointly sponsored by the Departments of Energy, Commerce and Defense, along with NASA and the National Science Foundation, these 14 institutes should be expanded and given a special role in assessing the future of climate-related manufacturing opportunities. (ManufacturingUSA)

- **Emission Reduction Research Tax Credit.** Given the difficulty in accomplishing industrial emission reductions, Congress should consider a research tax credit for manufacturing companies to specifically address their own industrial emissions.

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