

#### Report by

The Climate Group

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# **FOREWORD**

Over the past few years, there has been a shift in the debate on climate change in the United States. The discussion has evolved from one focused on science to one focused on economics - specifically on the relative costs and benefits that will arise from a new comprehensive climate change and energy policy.

In this new debate, a major concern has been uncertainty about the impact climate and energy policies will have on the Midwest manufacturing sector. On the cost side, manufacturers will face increased energy and resource prices, which result in higher production costs. The higher cost could result in a decrease in output from both a decrease in consumption and a shift of production overseas. On the benefit side, manufacturers will have the opportunity to produce new, low-carbon technologies, as global demand for these goods increases.

Credible data on the costs and benefits that climate policies will have on US manufacturing has been lacking in the past, making it difficult for manufacturers and policymakers to assess the total impact on their industries and regions.

On the cost side, a clearer picture has recently emerged. In 2009, The Pew Center on Global Climate Change and Resources for the Future released a report quantifying the impact that a \$15 price on carbon would have on the competitiveness of specific US manufacturing sectors. The findings suggest that these impacts will be both "modest" and "manageable," with an average production decline of 1.3 percent across US manufacturing and "no statistically discernable" effect on employment for the manufacturing sector as a whole<sup>1</sup>.

These findings are consistent with the impact that the American Clean Energy and Security Act of 2009 (ACES) would have on US manufacturing. The U.S. Environmental Protection Agency (EPA) estimated that a \$16 price on carbon would lead to a production decline of .7 percent across US manufacturing by 2020 – with an increase in production of .04 percent in 2015 if a "rebate" program, which provides compensation to energy-intensive, trade-sensitive industries, is implemented.<sup>2</sup>

With this study, The Climate Group and The University of Michigan aim to shed light on the benefits side of climate policy, by quantifying expected growth in new, low-carbon manufacturing sectors, with climate and energy policies in place. Our findings show that the potential for growth in low-carbon manufacturing sectors in the Midwest is significant, with climate and energy policy creating additional market revenues of up to \$12.3 billion, additional tax revenues of up to \$812 million and up to 104,640 new jobs from only three low-carbon technology markets by 2015.

We take an in depth look into the wind turbine component, hybrid powertrain, and advanced battery markets in the Midwest, to provide an idea of the scope of the economic benefits that could result from comprehensive climate and energy policy. More research is needed to complete the picture. We hope this report can mark the start of that important task.



Amy Davidsen, US Executive Director, The Climate Group

# **Support for the Report**

"Good government policy like renewable portfolio standards, which we passed in 2005, are creating family-supporting jobs in our state. This report shows in detail the enormous opportunity that Wisconsin – and the rest of the Midwest – stands to gain by taking the next step. We can stick our heads in the sand and let others seize that opportunity, or we can push forward and create jobs, grow our manufacturing base and leave a better world for our children and grandchildren."

Jim Doyle, Governor of Wisconsin

"The climate and our economy need help urgently. This timely report documents the huge boost we can give our economy if we adopt strategies to accelerate investment in the low-carbon technologies that will rejuvenate the industrial Midwest, put our people back to work and ensure the Midwest remains globally competitive."

Pat Quinn, Governor of Illinois

"The Climate Group's latest publication, American Innovation:Manufacturing Low Carbon Technologies in the Midwest provides clear, solid job and revenue numbers for low carbon manufacturing in the Midwest. The report is a validation that in reducing greenhouse gas emissions, the opportunities are commensurate with the challenges."

Stanley "Skip" Pruss,

Chief Energy Officer and Director of the Department of Energy, Labor & Economic Growth, State of Michigan

"20th century innovations gave America a standard of living unimaginable a century before. In this new century, the industries that will thrive are those that are able to make that standard of living sustainable - by using renewable resources, and ones that do not contaminate our air, water and threaten our climate. As demand shifts from oil-burning cars to ones powered by renewably-generated electricity, the American Midwest can develop the components for that supply chain, the turbines to capture the wind electricity for those cars, and the batteries to store that electricity. The findings in this report show that this kind of Midwest leadership is indeed possible. Just as the region thrived in the 20th century, with a proper adjustment to orient in line with global trends, it will thrive again in this century."

Mike Granoff, Head of Oil Independence Policies, Better Place

"With debate over the implications of prospective climate change regulation hotter than ever in the U.S., American Innovation: Manufacturing Low Carbon Technologies in the Midwest offers timely insight into some of the ways well-crafted policy responses can spur greentech innovation and generate economic opportunity."

William L. Thomas, Counsel, Skadden, Arps, Slate, Meagher & Flom LLP

# **EXECUTIVE SUMMARY**

For too long, the overwhelming body of research related to climate policy has focused exclusively on the costs associated with taking action. And when research has been conducted about the benefits, the findings have often been too vast to easily understand and deconstruct. This report therefore aims to answer the following question:

# WHAT IS THE ECONOMIC OPPORTUNITY FOR MANUFACTURING SELECTED LOW-CARBON TECHNOLOGIES IN THE MIDWEST?

To answer this question, we estimate the economic benefits associated with growth in three low-carbon technology markets: wind turbine components, hybrid powertrains and advanced batteries.

#### We estimate these benefits in two different scenarios.

 The "policy scenario" assumes that three climate and energy policies are in place: a "green" stimulus program; a \$17 price on carbon, resulting from a cap on US emissions; and a national renewable electricity standard (RES) of 20% by 2020.

For wind turbine components, we consider a "high" and "low" policy scenario to account for differences in how policy might affect US wind capacity. For hybrid powertrains, we only consider one policy scenario, due to consistency in projections of the share of hybrids in total US vehicle sales. For advanced batteries, we consider a "high" and "low" policy scenario to account for differences in the share of the advanced battery market that will be supplied by US manufacturers.

 The "no policy" scenario assumes that these three climate and energy policies are not in place.

# The findings in this report should be considered in light of its narrow scope.

This report does not measure the net economic impact of climate and energy policies, in that we do not look at the costs associated with these policies. The revenues and jobs we found in low-carbon sectors do not take into consideration revenues and jobs lost in other sectors. More research is therefore needed to ascertain a truly complete picture.

We also do not consider all of the economic benefits of climate and energy policies, which include substantial energy efficiency savings, new jobs created outside of the manufacturing sector, benefits from the manufacture of hundreds of additional low-carbon technologies not examined in this report, and opportunities to export these low carbon technologies to other countries.

Instead, we take a deep look into one part of the potential benefits: the increased manufacture of three low-carbon technologies in the Midwest.

#### **Low Carbon Technologies in the Midwest**

Primary Metals	Chemicals		
Energy-efficient appliances	Amines for carbon capture and storage (CCS)		
Energy-efficient HVAC and building systems	Electrolytes for advanced batteries		
Public transportation systems	Energy-efficient building insulation		
Wind turbine components	Enzymes for increasing the energy efficiency of industrial processes Photovoltaic (PV) solar cells		
Machinery Production	Automotive		
Biomass boilers	Advanced batteries	Diesel particulate filters	
Combined heat and power systems	Hybrid powertrains	Lightweight vehicles	

Of the 250 low-carbon technologies identified by McKinsey & Company, we look at 3 of the 15 in which the Midwest has a competitive advantage.

We estimate the benefits of manufacturing low-carbon technologies for only the Midwest region, defined as Illinois, Indiana, Michigan, Ohio, and Wisconsin, and we do so only until 2015.

Our limited scope enables us to take sector specific factors into consideration, and not to make too many assumptions about the future, which we feel leads to a more accurate estimate than would otherwise be possible.

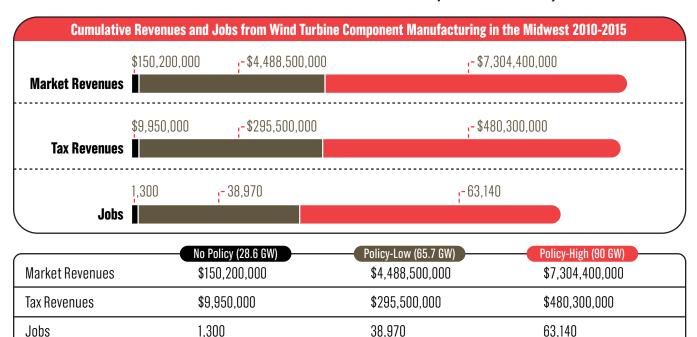
The end result provides a realistic answer to the question we set out to address.

#### **Wind Turbine Components**

Our case study on wind turbine components found that the three climate and energy policies would lead to significant new market revenues, state and local tax revenues and jobs.

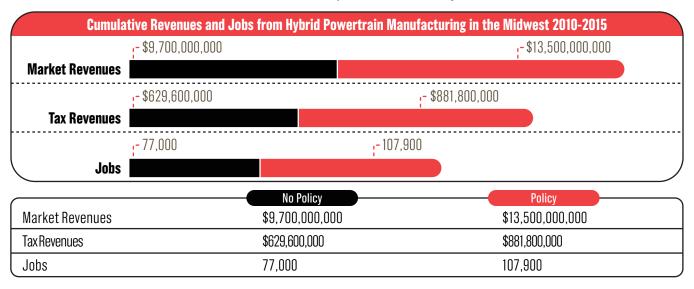
In the "policy-low capacity" scenario, where policies would increase US wind capacity to 65.7 GW, we estimate \$4.3 billion in additional market revenues, \$286 million in additional tax revenues and more than 37,600 new jobs in the Midwest by 2015. ("Additional" revenues and jobs are in comparison to the "no policy" scenario.)

In the "policy-high capacity" scenario, where policies would increase US wind capacity to 90 GW, we estimate \$7.1 billion in additional market revenues, \$470 million in additional tax revenues and more than 61,800 new jobs in the Midwest by 2015.



#### **Hybrid Powertrains**

Our case study on hybrid powertrains found that the three climate and energy policies would lead to \$3.8 billion in additional market revenues, \$252 million in additional tax revenues and 30,900 new jobs in the Midwest by 2015.

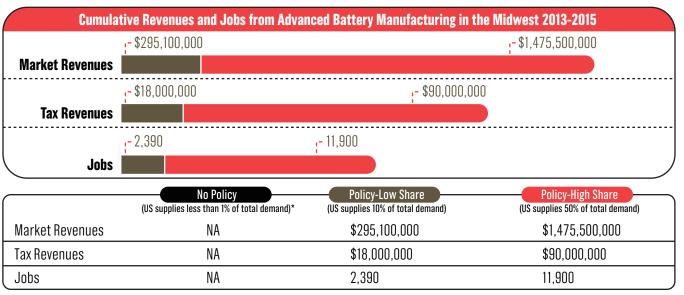


#### **Advanced Batteries**

Our case study on advanced batteries found that the three climate and energy policies would lead to modest new market revenues, state and local tax revenues and jobs.

In the "policy-low share" scenario, where the US supplies 10% of the domestic advanced battery market, we estimate \$295 million in additional market revenues, \$18 million in additional tax revenues and more than 2,300 new jobs in the Midwest by 2015.

In the "policy-high share" scenario, where the US supplies 50% of the domestic advanced battery market, we estimate \$1.4 billion in additional market revenues, \$90 million in additional tax revenues and 11,900 new jobs in the Midwest by 2015.



<sup>\*</sup> Because the US currently supplies less than one percent of the global advanced battery market, the size of the domestic advanced battery market in the "no policy" scenario is assumed to be zero.

In total, the three climate and energy policies would lead to additional market revenues of up to \$12.3 billion, additional tax revenues of up to \$812 million and up to 104,640 new jobs from the wind turbine component, hybrid powertrain and advanced battery manufacturing sectors in the Midwest by 2015.

# OVERVIEW

## **State of the Midwest Manufacturing Sector**

Manufacturing is the backbone of the Midwest economy. Four sectors are of primary importance to the Midwest, according to the most recent data from the Chicago Federal Reserve Midwest Manufacturing Index (CFMMI), which estimates manufacturing output in the Seventh Federal Reserve District. These four sectors are (1) primary metals, (2) chemicals, (3) machinery production, and (4) the automotive sector<sup>1</sup>.

Manufacturing in the Midwest continues to employ a far higher percentage of the population than other regions of the United States, particularly in these core sectors.

The manufacturing industry was still reeling from the 2001 economic downturn when the current recession hit, so even though the region has the nation's highest concentration of manufacturing jobs, total employment in the region has yet to return to pre-2001 levels<sup>2</sup>. Much of the Midwest's

manufacturing base has been lost to competition, both foreign and domestic. Michigan alone lost 800,000 jobs from 2000-2010, totaling 18 percent of its workforce<sup>3</sup>.

In light of this decline, many have taken note of how other countries have increased manufacturing production in emerging sectors.

For example, Germany has had success growing its renewable energy manufacturing sector. With a manufacturing base very similar to that of the US, a price on carbon emissions and a robust feed-in tariff in place, the German renewable energy sector has grown by 330% over the last ten years, employing 280,000 people. By 2020, Germany is expected to employ 500,000 people in the renewable energy sector, more than the auto industry<sup>5</sup>. In a country that is home to BMW, Porsche, Mercedes and Volkswagen, this is a significant shift.

"IN GERMANY THEY CREATED 280,000 JOBS

BY CHANGING THE INCENTIVES FOR THE USE OF WIND AND SOLAR.

WE OUGHT TO BE DOING THE SAME THING IN MICHIGAN."

- GOVERNOR JENNIFER M. GRANHOLM, STATE OF MICHIGAN<sup>4</sup>

This growth was enabled by increased global demand for clean energy and energy efficient technologies. HSBC estimates that the global market for climate change products and services was greater than \$300 billion in 2007, more than the revenue for the entire electrical equipment industry or the communications equipment industry<sup>6</sup>.

As Midwest policymakers look for ways to replace lost manufacturing jobs, information on the potential for job creation in the low-carbon manufacturing sector is needed.

This report aims to answer the question:

# WHAT IS THE ECONOMIC OPPORTUNITY FOR MANUFACTURING SELECTED LOW-CARBON TECHNOLOGIES IN THE MIDWEST?

To answer this question, we estimate the **benefits** associated with three **low-carbon technology** markets in the **Midwest**, in two different **scenarios**: one with climate and energy policies in place and one without.

#### "Policy" Scenario

The first scenario is the "policy" scenario, with three climate and energy policies in place. These policies include:

- 1. A "green" economic stimulus program
- 2. A price on carbon of \$17 per ton of carbon dioxide equivalent (CO<sub>2</sub>e) in 2015 resulting from a cap on US emissions, and
- 3. A national renewable electricity standard (RES) of 20% by 2020.

The "green" economic stimulus we modeled is consistent with the American Reinvestment and Recovery Act of 2009 (ARRA). The \$17 price on carbon in 2015 and the renewable electricity standard of 20% by 2020 are consistent with the American Clean Energy and Security Act of 2009 (ACES) <sup>7</sup>. For the RES, this means that we adjusted for the fact that 5% of the standard can be met though energy-efficiency improvements while the remaining 15% must be met with renewable energy<sup>8</sup>.



<sup>&</sup>lt;sup>7</sup> The US Environmental Protection Agency projected that the price of an emission allowance under the American Clean Energy and Security Act of 2009 would be \$13 in 2015. The US Congressional Budget Office projected that the price of an emission allowance would be \$19 in 2015.

The three policies affect different low-carbon technologies in different ways. For example, the wind turbine component market is driven by all three policies, while the hybrid powertrain market and the nascent advanced battery market are driven primarily by the "green" economic stimulus program and the price on carbon, but not by the RES.

	"Green" stimulus	\$17 price on carbon	20% national RES
Wind turbine components	X	X	X
Hybrid powertrains	X	X	
Advanced batteries	X	X	

# "No Policy" Scenario

The second scenario is the "no policy" scenario, with none of these three climate and energy policies in place. The "no policy" scenario excludes the American Reinvestment and Recovery Act of 2009 (ARRA), which passed in February of 2009 - so it is not the same as the present day or "business as usual" scenario.

#### **Benefits**

The economic and fiscal benefits associated with these policies are measured using the following metrics:

- 1. Market Revenues: These are the additional revenues expected to result from growth in low-carbon manufacturing. Our definition of market revenues includes the amount of money that low-carbon industries spend to produce their technologies. It does not include indirect effects, which result from low-carbon industries and their employees purchasing more from other Midwest industries, or induced effects, which capture the multiplier effect of direct and indirect effects.
- 2. Tax Revenues: These are the additional revenues to state and local governments that result from taxes on all new market revenues. We also identify interstate effects, which result from low-carbon industries purchasing from industries in other Midwest states.

3. Job Creation: These are the new jobs created by growth in low-carbon manufacturing. We distinguish between direct jobs, which are created within the low-carbon sector, and indirect jobs, which are created outside the low-carbon sector - resulting from low-carbon industries buying more from other Midwest industries. Total jobs equal the sum of direct and indirect jobs.

Both market revenues and tax revenues are reported in 2009 dollars.

When we use the word "additional," we are referring to the difference between revenues or jobs in the "policy" scenario and revenues or jobs in the "no policy" scenario.

#### **Midwest**

For the purposes of this report, the "Midwest" refers to the states of Illinois, Indiana, Michigan, Ohio, and Wisconsin, defined by the US Census Bureau as the East North Central Census Region<sup>9</sup>.

## **Low Carbon Technologies**

Low-carbon technologies are technologies that help reduce greenhouse gas emissions, either by reducing fossil fuel based energy consumption, enabling the use of clean energy sources or capturing carbon emissions. Low-carbon technologies exist in a range of economic sectors. In this report, we focus on low carbon technologies within the four core Midwest manufacturing sectors: primary metals, chemicals, automobiles, and machinery.

Based on existing literature including "Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?" (McKinsey & Company), and "Manufacturing Climate Solutions" (Center on Globalization, Governance & Competitiveness), we identified low-carbon technologies within each of these sectors based on 2002 and 2006 US Census production data from industries classified at the six-digit level in the North American Industry Classification System (NAICS). Each technology was assigned to a specific NAICS code and data including the number of establishments, total revenues, annual payroll and number of employees were collected



to estimate production and productivity indicators in the Midwest and the nation.  $^{\rm 10\&11}$ 

Many of these technologies are associated with more than one manufacturing sector. For example, wind turbine components are associated with both primary metals and machinery. Advanced batteries are associated with both the automotive and chemicals sector. However, for the purpose of this report, we have classified each technology under a single economic sector.

Primary Metals	Chemicals		
Energy-efficient appliances	Amines for carbon capture and storage (CCS)		
Energy-efficient HVAC and building systems	Electrolytes for advanced batteries		
Public transportation systems	Energy-efficient building insulation		
Wind turbine components	Enzymes for increasing the energy efficiency of industrial processes Photovoltaic (PV) solar cells		
Machinery Production	Automotive		
Biomass boilers	Advanced batteries	Diesel particulate filters	
Combined heat and power systems	Hybrid powertrains	Lightweight vehicles	

An analysis of the impact that climate and energy policies would have on all of these technologies would provide a near complete picture of the benefits to the Midwest manufacturing sector. To begin creating this picture, this study provides analysis of three of these technologies:

- 1. Wind turbine components (Primary Metals)
- 2. Hybrid powertrains (Automotive)
- 3. Advanced batteries (Automotive)

The case study technologies were chosen based on a number of criteria (see appendix) including availability of industry data and ability to define the market for the technology, which supported an analysis at this period of time.

As such, the case studies selected here do not represent a total picture of the benefits to the Midwest manufacturing sector from climate and energy policies. Instead, they are a proxy to help better understand the scope of the total benefits.

#### **Format**

Each case study begins with an overview of the primary economic sector to which the specific low-carbon technology is tied. It then provides relevant information on the market for the technology and describes the method used for calculating the impact that climate and energy policies would have on

that market. It concludes with the economic findings for the technology in the "policy" and "no policy" scenarios measured by market revenue, state and local tax revenues, and job creation.

#### Scope

The findings represented in this report should be considered in light of their narrow scope.

First, this report does not measure the net impact of climate and energy policies. We do not look at the costs associated with these policies, which result from increased energy prices and higher production costs. These costs are estimated by the US Environmental Protection Agency (EPA) and the US Congressional Budget Office (CBO), among others. Furthermore, the increases in market revenues, tax revenues and jobs that we found in the low-carbon sectors do not take into consideration revenues and jobs lost in other sectors.

We also do not consider all of the economic benefits of climate and energy policies, which include substantial energy efficiency savings, new jobs created outside the manufacturing sector, and opportunities to export low-carbon technologies to other countries.

Second, we do not consider the opportunity for all low-carbon technologies. In their report, "Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?" McKinsey & Company identifies 250 technologies that contribute to reducing emissions. In this report, we identify 15 of these technologies, which the Midwest has a clear competitive advantage in manufacturing. In order to consider as much sector specific detail as possible, the following case studies take an in-depth look at the opportunity for 3 of these 15 technologies.

Last, our regional, economic and temporal scope is also limited. We do not estimate the opportunity for the entire United States, but for only for the Midwest, defined here as the states of Illinois, Indiana, Michigan, Ohio, and Wisconsin - defined by the US Census Bureau as the East North Central Census Region. And we only estimate benefits over the next five years.

Our limited scope enabled us to take sector specific factors into consideration and not to make too many assumptions about the future, which we feel led to a more accurate estimate than would otherwise have been possible.

The end result provides a realistic answer to the question:

What is the economic opportunity for manufacturing selected low-carbon technologies in the Midwest?



# **CASE STUDY 1 WIND TURBINE COMPONENTS**

Our case study on wind turbine components found that the three climate and energy policies would lead to significant new market revenues, state and local tax revenues and jobs.

In the "policy-low capacity" scenario, where policies would increase US wind capacity to 65.7 GW, we estimate \$4.3 billion in additional market revenues, \$286 million in additional tax revenues and more than 37,600 new jobs in the Midwest by 2015.

In the "policy-high capacity" scenario, where policies would increase US wind capacity to 90 GW, we estimate \$7.1 billion in additional market revenues, \$470 million in additional tax revenues and more than 61,800 new jobs in the Midwest by 2015.

# **Primary Metals Sector**

Wind turbine components are primarily classified under the primary metals sector. The primary metals sector includes the manufacture of fabricated metal products; electrical and electronic machinery, equipment, and supplies; and transportation equipment. The metals include steel, iron, aluminum, copper, and specialty metals like titanium and molybdenum. Steel is the dominant primary metal manufactured in the United States, especially in the Midwest<sup>1</sup>.

The US primary metals industry is made up of about 4,000 companies with combined annual sales of about \$150 billion. Together, they employ about 444,000 Americans nationwide, including more than 80,000 in Indiana and Ohio<sup>2</sup>. Large companies include US Steel and Arcelor Mittal, Nucor (steel); Alcoa (aluminum); and Phelps Dodge (copper). Demand comes largely from manufacturers of automobiles, machinery, containers, and construction bars and beams. Profitability depends largely on volume, because of heavy fixed investment, and efficient operations.

Steel production in the Midwest has declined over the past year. Similar to many other manufacturing sectors around the world, steel output in the Midwest dropped 35.6% from its August 2008 level, as the global economic downturn took its toll<sup>3</sup>.

The outlook for primary metals, especially steel, is directly tied to demand from downstream purchasers like automobiles and construction, as well as to production costs (labor, healthcare coverage, energy needs) and productivity.

Emerging low carbon technologies that are downstream of the primary metals sector, like new public transportation systems, HVAC and building systems, energy efficient appliances, and wind turbine components, have the potential to create additional market demand.

## **Primary Metals**

Energy-efficient appliances
Energy-efficient HVAC and building systems

Public transportation systems Wind turbine components

## **The Wind Turbine Component Market**

# THE MARKET FOR WIND TURBINE COMPONENTS IS ESPECIALLY WELL POSITIONED FOR GROWTH IN THE MIDWEST.

Wind energy is the fastest-growing renewable energy source in the US. In 2008, 42% of new power producing capacity brought online in the US was from wind. US wind capacity increased to 25.3 GW - equal to 1.25% of the nation's total energy generation<sup>4</sup>. The expansion added 8,400 domestic manufacturing jobs and 35,000 wind related jobs in total, bringing total US employment in this sector to 85,000<sup>5</sup>.

Demand for wind turbine components comes mainly from large utilities and corporations with significant power needs. The market is concentrated. Twenty companies account for 83.6% of wind facility ownership, and four of these companies account for nearly 50% of total US capacity.

Wind turbines can be broken down into five major components: (1) rotor, (2) nacelle and machinery, (3) gearbox and drive train, (4) generator, and (5) tower. Half of the wind turbine components installed in the US are produced domestically. Market researchers anticipate that the United States - and specifically the Midwest - will capture an even larger share of this market going forward, if current production trends continue.<sup>6</sup>

Based on the distribution of existing wind turbine component factories, the Midwest currently has a competitive advantage

in two of the five component categories. Roughly half of the nation's nacelle and machinery factories (17 out of 38), and more than a third of gearbox and drive train factories (13 out of 30) are located in the Midwest. Other components like turbine towers, for example, which are costly to transport, do not currently play a prominent role in the Midwest<sup>7</sup>.

In 2008, eleven new factories related to wind turbine production opened in the United States, including one in Wisconsin and one in Michigan. Additionally, seven companies from related businesses entered the wind turbines market in Michigan and Ohio<sup>8</sup>.

The Midwest's future in this sector will rely partly on factories shifting from traditional markets, such as automotive parts, to wind turbine components. The potential for this kind of conversion is illustrated by the fact that there are 7,299 factories in the Midwest that manufacture in the same industry classification code as wind turbine components (i.e. fabricated metal products; primary metals; computer and electronic products; plastic and rubber products; and electrical equipment, appliances and components)<sup>9</sup>.

## **Explanation of the Economic Model and Method**

This case study estimates the economic benefits associated with growth in the wind turbine component market in the Midwest, in two different scenarios: the "policy" scenario and the "no-policy" scenario.

The main difference between the two scenarios is the effect that climate and energy policies have on the amount of wind generated electric capacity in the US. Existing projections vary significantly on how large that effect will be. So, in addition to the "no policy" scenario, we consider two different policy scenarios - one with "low" and one with "high" projections of the amount of wind generated electric capacity in the US.

# "No Policy" Scenario

In the "no policy" scenario (which does not include any of the three policies considered, including the stimulus) US wind capacity would increase to 28.6 GW by 2015. Projections of wind capacity in the "no policy" scenario are based on the US Energy Information Agency's (EIA) Annual Energy Outlook 2009, which projects 17.2% growth in wind capacity in the next decade, based on organic growth in the industry, state

# How do the three policies affect the wind turbine component market?

- 1) A "green" economic stimulus program: ARRA extends the Production Tax Credit (PTC) through 2012 and also allows renewable energy projects placed in service by the end of 2012, to choose an upfront Investment Tax Credit (ITC) or cash grant in lieu of the PTC.
- 2) A price on carbon of \$17 per ton of CO2e resulting from a cap on US emissions: A price on carbon makes alternatives to wind energy more expensive, increasing demand for wind energy.
- 3) A national renewable energy standard of 20% by 2020: A renewable energy standard creates guaranteed demand for wind energy by requiring utilities to meet a certain percentage of their electricity generation from renewable sources.

Renewable Electricity Standards,<sup>10</sup> and the extension of the Production Tax Credit (PTC) in the Energy Improvement and Extension Act of 2008 (EIEA)<sup>11</sup>.

<sup>10</sup> Four of the five states targeted in this study have RPSs: Illinois (25% by 2025), Michigan (10% by 2015), Ohio (12.5% by 2024), and Wisconsin (10% by 2015)

## "Policy-Low Capacity" Scenario

In the "policy" scenario using "low" projections, US wind capacity would increase to 65.7 GW by 2015. These projections are based on analysis by the US Environmental Protection Agency that estimates how wind generated electricity capacity would be impacted by ARRA stimulus spending and the price on carbon and national RES included in ACES<sup>12</sup>. From here forward, we refer to this scenario as the "policy-low capacity" scenario.

Increased demand for wind energy would lead directly to increased demand for wind turbine components. Primary metals-and machinery parts related manufacturers in the Midwest are well positioned to meet the demand for turbine components, particularly those making nacelle and machinery components, and gearboxes and drive trains<sup>14</sup>.

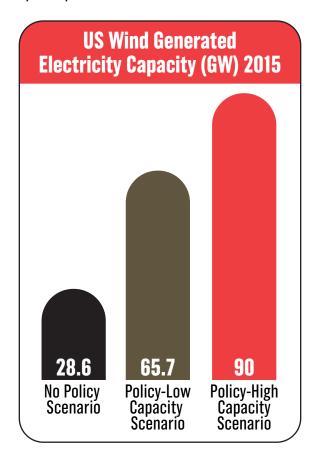
National market revenues were estimated by multiplying expected US wind capacity by a capacity-weighted average turbine price of \$1,360 per kilowatt - based on the US Department of Energy's (DOE) 2008 Wind Technologies Market Report<sup>15</sup>.

Turbine revenues were then allocated across the supply chain based on the relative cost of producing each part. We used an initial allocation of 28% for blade production, 26% for tower production, and 46% for the remaining components <sup>16</sup>. Production in these three segments is then further divided to capture the effect of domestic versus overseas production and state versus state production, using US Department of Energy (DOE) data on factory locations <sup>17</sup>.

# "Policy-High Capacity" Scenario

In the "policy" scenario using "high" projections, US wind capacity would increase to 90 GW by 2015. These projections are based on analysis by Emerging Energy Research (EER), which estimates how a national cap and trade system and a national RES (in addition to current state Renewable Portfolio Standards (RPS)) would impact wind generated electric capacity. From here forward, we refer to this scenario as the "policy-high capacity" scenario 13.

Direct and indirect effects on market revenues, tax revenue and job creation were then estimated using a commercial input-output model (IMPLAN). This model is commonly used to estimate changes in economic output given a shift in demand for a specific product.



# **Additional Assumptions**

#### Operating expenditures are omitted from impact calculations.

The Midwest region, as defined in this report, only accounts for 1.5% of remaining national wind capacity in the country. Therefore, the operational costs of new wind power plants are omitted<sup>18</sup>.

**Plant locations and size remain constant.** We assume that the distribution of plants within each state will remain constant. If the distribution were to change, this would alter the regional effects.

**Access to the electrical grid.** Realizing the full growth potential of this sector will depend on new wind energy plants and their ability to connect to a transmission network.

**No local opposition to wind farms.** A large amount of local opposition to wind farms would limit the pace of installation and therefore could limit demand in the manufacturing sector.

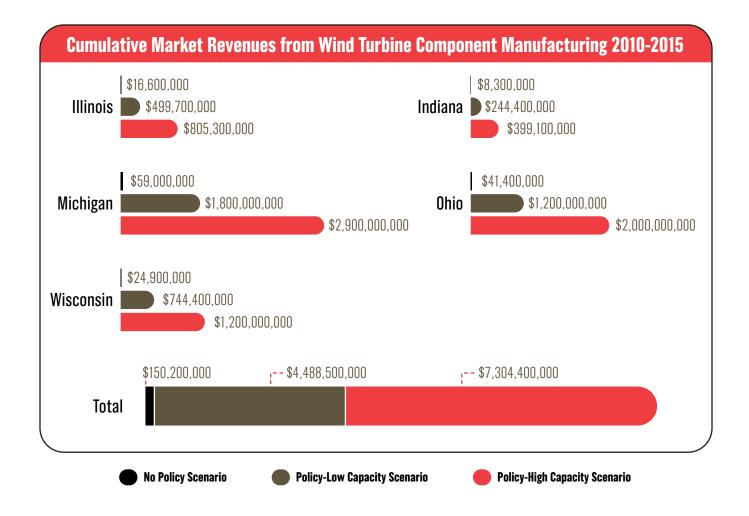
**Availability of skilled labor.** Production of wind turbines requires highly specialized labor, and the industry has already experienced shortages of skilled labor.

# **Findings**

#### **Market Revenues**

Compared to the "no-policy" scenario, the "policy-low capacity" scenario would lead to \$4.3 billion more in market revenues in the Midwest, while the "policy-high capacity" scenario would lead to more than \$7 billion more in market revenues from 2010-2015.

Michigan would experience more than \$740 million in additional market revenues in the "policy-low capacity" scenario and more than \$2.8 billion in the "policy-high capacity" scenario over the same period.

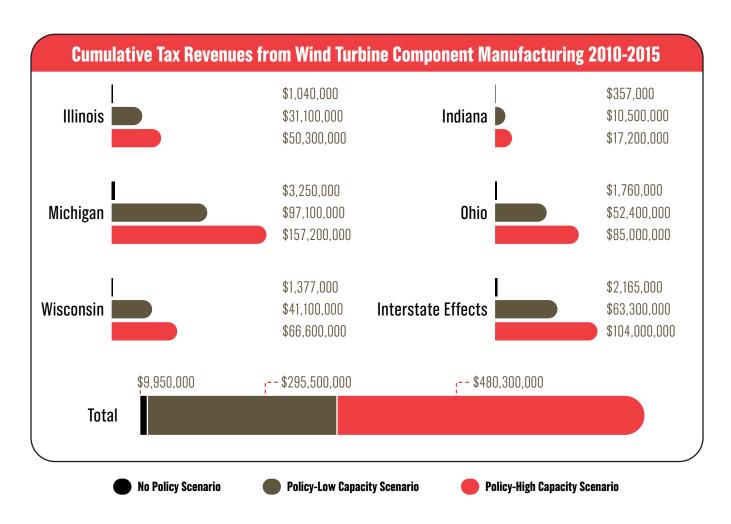


#### **Tax Revenues**

Compared to the "no-policy" scenario, the "policy-low capacity" scenario would lead to more than \$286 million in additional tax revenues in the Midwest, while the "policy-high capacity" scenario would lead to more than \$470 million in increased tax revenues from 2010-2015.

In Ohio, this translates to about \$50 million more in tax revenues under the "policy-low capacity" scenario and more than \$83 million under the "policy-high capacity" scenario.

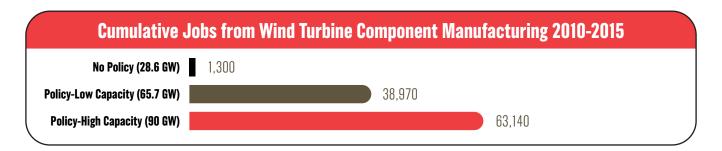
In Michigan, the "policy-low capacity" scenario yields almost \$94 million in additional tax revenues.

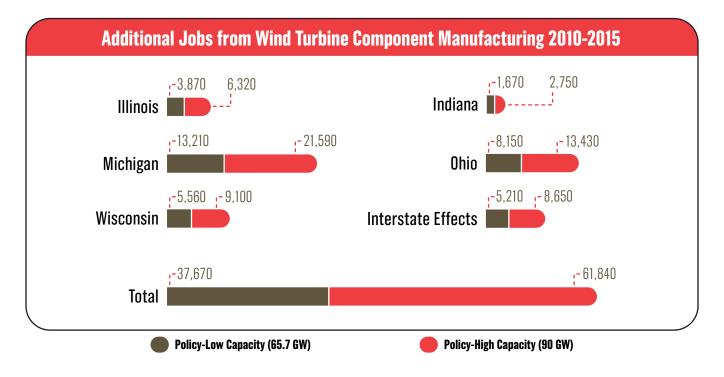


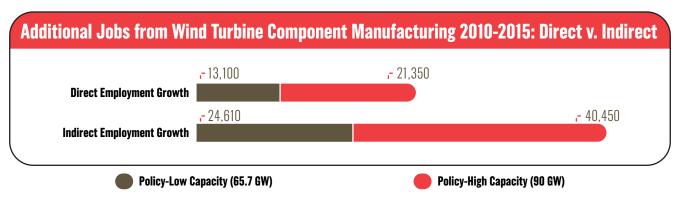
#### **Job Creation**

Throughout the Midwest, the "policy-low capacity" scenario would generate about 13,000 more direct jobs and about 25,000 more indirect jobs than the "no policy" scenario. In

Michigan, which employs the most people in this sector, the "policy-low capacity" scenario would create about 5,400 more direct jobs and 13,200 more indirect jobs.









# **CASE STUDY 2 HYBRID POWERTRAINS**

Our case study on hybrid powertrains found that the three climate and energy policies would lead to \$3.8 billion in additional market revenues, \$252 million in additional tax revenues and 30,900 new jobs in the Midwest by 2015.

#### **Automotive Sector**

Hybrid powertrains are classified under the automotive sector.

The US vehicle manufacturing industry includes three major companies with Ford, General Motors and Chrysler holding 47% of domestic market share in mid 2008<sup>1</sup>. In 2008, the "Detroit Three" had combined annual sales of about \$360 billion and employed about 520,000 Americans. All three companies are based in the Midwest, with 11 of their 24 assembly plants located there<sup>2</sup>.

Motor vehicle manufacturing employment in the US has declined more than 50 percent from 1999 to August 2009<sup>3</sup>.

A number of concerns, including volatile gas prices, climate change and dependence on foreign oil, have caused a shift in consumer demand towards more energy efficient vehicles. A study by Harvard University found that 27% of consumer hybrid purchases from 2002-2006 were motivated by high gasoline prices<sup>4</sup>.

The hybrid powertrain market has historically been dominated by Toyota, with Honda and Ford capturing smaller market shares. In 2008, Toyota held 77% of the US hybrid vehicle market<sup>5</sup>.

Several low carbon technologies are expected to capture an increasingly large market share in the vehicle manufacturing industry. This "basket" of technologies includes advanced batteries, diesel particulate filters, hybrid powertrains, and lightweight vehicles.

While all of these technologies represent potential opportunities for Midwest manufacturing, the markets for hybrid electric vehicles (HEVs) and advanced batteries are especially well positioned for growth in the near future<sup>6</sup>.

#### **Automotive**

Advanced batteries
Diesel particulate filters

Hybrid powertrains Lightweight vehicles

<sup>&</sup>lt;sup>6</sup> While plug-in hybrid electric vehicles (PHEVs) and pure electric vehicles (EVs) also have a promising forecast, they are not considered here, because of the lack of reliable forecasts.

# **The Hybrid Powertrain Market**

# THE MIDWEST HAS A COMPETITIVE ADVANTAGE IN ALL FOUR POWERTRAIN COMPONENTS.

The hybrid powertrain market is experiencing a significant increase in demand. Annual growth of hybrid powertrain sales is expected to average 38% through 2012<sup>7</sup>. To respond to this increase in demand, vehicle manufacturers such as General Motors and Toyota, have announced the introduction of next-generation plug-in hybrids as early as 2010<sup>8</sup>.

Hybrid powertrains consist of four major components: (1) gasoline engine, (2) electrical equipment, (3) battery, and (4) drivetrain. Together, they account for 55% of an HEV vehicle's cost. The Midwest has a competitive advantage in all four powertrain components <sup>9&10</sup>.

# How do Hybrid Powertrains Differ from Conventional Powertrains?

In a hybrid powertrain, the electric motor provides power to assist the engine in accelerating, passing, or hill climbing, allowing for a smaller gasoline engine. In some hybrids, the motor provides sole power for low-speed driving conditions, where internal combustion engines are least efficient. As a result, hybrids have greater fuel efficiency and reduced emissions<sup>14</sup>.

#### **Gasoline engine & parts**

About 30 percent of US engine, fuel delivery, exhaust & emissions, and inverter manufacturers are located in the Midwest, generally near vehicle manufacturers, which allows for joint research and development and reduced delivery lead times<sup>11</sup>.

#### **Electrical equipment**

About 24 percent of US transformers, electric motors, generators, switchgears, relays and controls are manufactured in the Midwest. Wisconsin and Illinois each have more employees in this industry than anywhere else in the US, accounting for 10 and 8 percent of the national total, respectively<sup>12</sup>.

#### **Transmission and powertrain parts**

About 37 percent of US transmission and powertrain part manufacturers are located in the Midwest, in close proximity to vehicle manufacturers<sup>13</sup>.

#### **Explanation of Economic Model and Method**

This case study compares the economic benefits associated with growth in the hybrid powertrain market in the Midwest, in two different scenarios: the "policy" scenario and the "nopolicy" scenario.

The main difference between the two scenarios is the effect that climate and energy policies have on the size of the domestic HEV market.

# How do the three policies affect the hybrid powertrain market?

- A "green" economic stimulus program: ARRA included \$2.4 billion in grants to vehicle and electric components manufacturers<sup>15</sup>.
- A price on carbon of \$17 per ton resulting from a cap on US emissions: A price on carbon increases gasoline prices, leading to increased demand for more fuel efficient automobiles, like HEVs<sup>16</sup>.
- 3) A national renewable electricity standard of 20% by 2020: A renewable electricity standard does not have a major impact on the hybrid powertrain market.

Findings of the size of the domestic HEV market in the "no policy" scenario are based on publicly available forecasts from the industry market research firm IBISWorld<sup>17</sup>. IBISWorld estimates that US hybrid sales will equal 5% of total US vehicle sales in 2010 and 17.7% of total US vehicle sales in 2015.

These figures are consistent with projections by JPMorgan Chase, which estimate that US hybrid sales will be 19.4% in 2020<sup>18</sup>.

These forecasts are considered optimistic by some industry sources, and therefore may overstate the economic impacts if the hybrid market is smaller than these predictions state. However, in our judgment, they are the most credible estimates available.

Findings of the size of the domestic HEV market in the "policy" scenario start with the IBISWorld forecast for US hybrid sales, and account for increases in hybrid sales that result from an increase in gasoline prices, due to a \$17 price on carbon. Increases in gasoline prices are based on a combination of US DOE and US EPA forecasts. The impact that increased gasoline prices have on hybrid purchases is based on a study by Harvard University<sup>19</sup>.

While ARRA included over \$1 billion in grants for electric vehicles, we do not include this funding in our findings, due to the difficultly in assessing the impact they will have on the HEV market at this time. In this regard, our findings may understate the economic impacts.

Increases in market revenue resulting from increases in HEV production, are distributed across Midwest states based on the location of existing factories<sup>20</sup>.

Direct and indirect effects on market revenues, tax revenue and job creation impacts were then estimated using a commercial input-output model (IMPLAN).

# **Additional Assumptions**

**Regional growth based on existing factory locations.** We make the assumption that growth in the HEV market will occur in the same locations as it has in the past. This may not be the case, and would have an impact on the state-level estimates

if it were incorrect. However, without any way to predict the location of new HEV manufacturers, we felt that the past was the best available indicator.

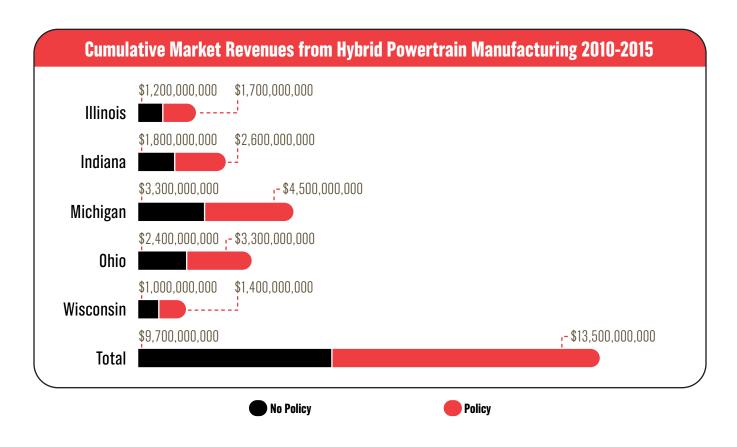
# **Findings**

#### **Market Revenues**

By 2015, the "policy scenario" leads to \$3.8 billion more in hybrid powertrain revenues in the Midwest than the "no policy" scenario.

The most striking feature of market revenue from the production of hybrid powertrains in the 'policy' scenario is the growth in the near term - including \$663 million in 2010 alone.

The combination of policies creates steady growth for the manufacturing industry over the five-year period, generating more than \$13 billion in market revenue for the automotive manufacturing industry.

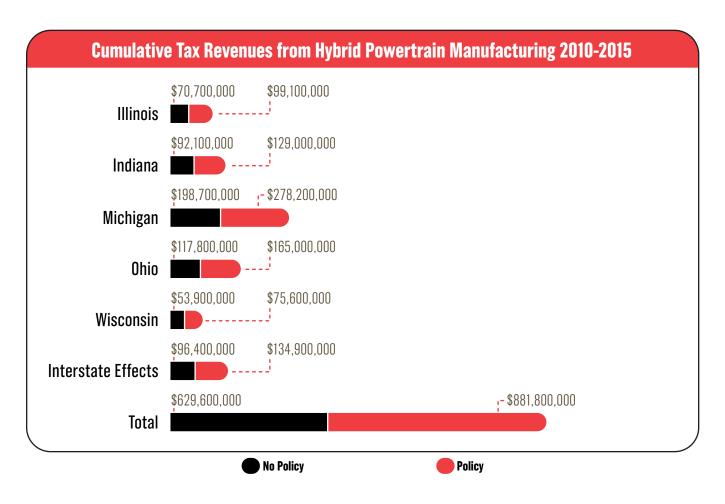


#### **Tax Revenues**

Over the next five years, the "policy" scenario generates \$252 million more in state and local tax revenues than the "no policy" scenario.

In Michigan, this translates to about \$79 million in additional tax revenues over five years, and more than \$14 million in 2010 alone.

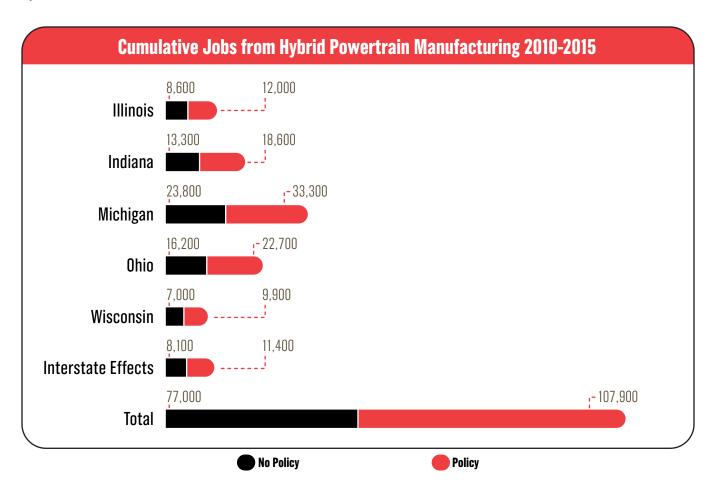
Michigan, Indiana and Ohio have the largest tax benefits.

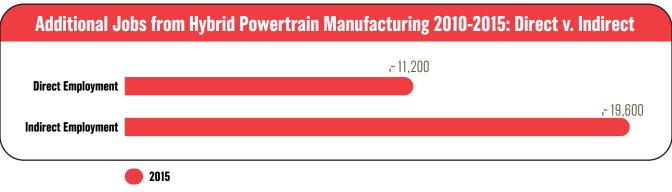


#### **Job Creation**

The policy scenario generates nearly 11,200 more direct jobs and 19,600 more indirect jobs than the 'no policy' scenario by 2015. In Michigan, which employs the most people in this sector, new low-carbon policies would create 9,500 additional jobs by 2015.

The total number of jobs generated is largest for hybrid powertrains relative to the other case study technologies.







# **CASE STUDY 3 ADVANCED BATTERIES**

Our case study on advanced batteries found that the three climate and energy policies would lead to modest new market revenues, state and local tax revenues and jobs.

In the "policy-low share" scenario, where the US supplies 10% of the domestic advanced battery market, we estimate \$295 million in additional market revenues, \$18 million in additional tax revenues and more than 2,300 new jobs in the Midwest by 2015.

In the "policy-high share" scenario, where the US supplies 50% of the domestic advanced battery market, we estimate \$1.4 billion in additional market revenues, \$90 million in additional tax revenues and 11,900 new jobs in the Midwest by 2015.

## **The Advanced Battery Market**

Batteries are most closely tied to the automotive sector.

A small number of companies dominate the US battery industry, with four companies accounting for two-thirds of domestic revenue in 2009 - including Johnson Controls, headquartered in Milwaukee, WI, Exide Technologies, Energizer and Procter & Gamble (Duracel). Companies tend to be located near automotive and consumer electronics manufacturers, primarily in the Midwest and Southeast<sup>1</sup>.

Companies within the battery market manufacture a number of different types of batteries for different applications. The market includes nickel metal hydride (NiMH) and lead acid storage for vehicles, as well as alkaline, nickel cadmium, lithium-ion (Li-ion), and mercuric oxide for consumer electronics, flashlights and marine applications<sup>2</sup>.

Currently, nickel metal hydride is the dominant battery technology used for hybrid electric powertrains in the United States. However, Li-ion<sup>3</sup> batteries are expected to become the dominant technology for electric powertrains in the future, because they store more energy per mass and volume and have twice the cell voltage of other batteries.

Li-ion batteries are expensive - costing about \$10,000 per battery - and they support a limited driving range of about 100 miles. Yet the current infusion of investments into Li-ion research and development is expected to reduce cost and yield a longer lasting, higher capacity, and safer battery.

As the production of HEV vehicles increases, demand for Li-ion batteries is expected to grow. The demand from US automakers alone could create an \$11 billion to \$13 billion market, according to Ford Motor Company<sup>4</sup>.

Whether the United States captures a significant share of this emerging market will depend on its ability to adapt its current supply chain, equipment, and infrastructure. Currently, less than 1 percent of advanced batteries are produced domestically<sup>5</sup>.

In a testimony before the House Subcommittee on Energy and Environment, Steven Chalk of the US Department of Energy stated: "The vehicle fleet of tomorrow will include more and more hybrids. There is a pressing need to establish the facilities to manufacture those batteries in the United States" 6.

<sup>&</sup>lt;sup>3</sup> The term "lithium-ion" refers to a family of battery chemistries that includes many varieties with different strengths and weaknesses.

The effort to develop domestic Li-ion battery manufacturing facilities is underway. ARRA included \$2.4 billion to fund research and development for advanced batteries<sup>7</sup>.

More than 20 Midwest businesses and educational institutions have received almost \$1.5 billion of these grants<sup>8</sup>. For example, the United States Advanced Battery Consortium recently awarded the Wisconsin-based Johnson Controls-Saft Advanced

Power Solutions \$8.2 million to develop a complete plug-in hybrid electric vehicle (PHEV) system over the next two years, and Ford Motor company received \$205 million for HEV and PHEV development<sup>9</sup>.

In August 2009, General Motors announced its plans to build the first US high-volume lithium-ion factory in Brownstone Township, Michigan<sup>10</sup>.

#### **Explanation of Economic Model and Method**

This case study compares the economic benefits associated with growth in the advanced battery market in the Midwest, in two different scenarios: the "policy" scenario and the "nopolicy" scenario.

# How do the three policies affect the advanced battery market?

- A "green" economic stimulus program: ARRA included \$2 billion for the development of advanced batteries in the US.
- 5) A price on carbon of \$17 per ton resulting from a cap on US emissions: A price on carbon increases gasoline prices, leading to increased demand for more fuel efficient vehicles, like HEVs, which use advanced batteries.
- 6) A national renewable electricity standard of 20% by 2020: A renewable electricity standard does not have a major impact on the advanced battery market

The main difference between the two scenarios is the effect that climate and energy policies have on the size of the domestic advanced battery market.

Findings of the size of the domestic advanced battery market in the "policy" scenario are based on the publicly available forecast from Ford Motor Company, which estimates that the US advanced battery market could be worth \$11 billion to \$13 billion by 2015.

However, it is uncertain how much of this new market will be supplied by domestic manufacturers. To address this uncertainty, we project the economic benefits associated with two scenarios: a "high share" scenario and a "low share" scenario. The "high share" scenario assumes that the US supplies 50% of an \$11 billion domestic advanced battery market in 2015. The "low share" scenario assumes that the US supplies 10% of an \$11 billion domestic battery market in 2015.

These market share estimates represent our effort to benchmark potential impact on the Midwest and are not intended as a forecast of how much production will or can be supported by 2015.

<sup>&</sup>lt;sup>8</sup> Note that when companies with multiple locations received grants, it was assumed the grant was allocated equally across locations.

Because the US advanced battery market is so new - current production is less than one percent of the global market - the size of the domestic advanced battery market in the "no policy" scenario is assumed to be zero.

In each scenario, national revenues from the production of advanced batteries were allocated to the Midwest states based on each state's current percentage of national advanced battery shipments, according to US Census data defined by NAICS code 3559.

While the overall impact of ARRA is considered, the state specific distribution of stimulus funding for advanced batteries is not. As a result, our findings may underestimate the impact on states that received a relatively large percentage of this funding.

Direct and indirect effects on market revenues, tax revenue and job creation impacts were then estimated using a commercial input-output model (IMPLAN).

### **Findings**

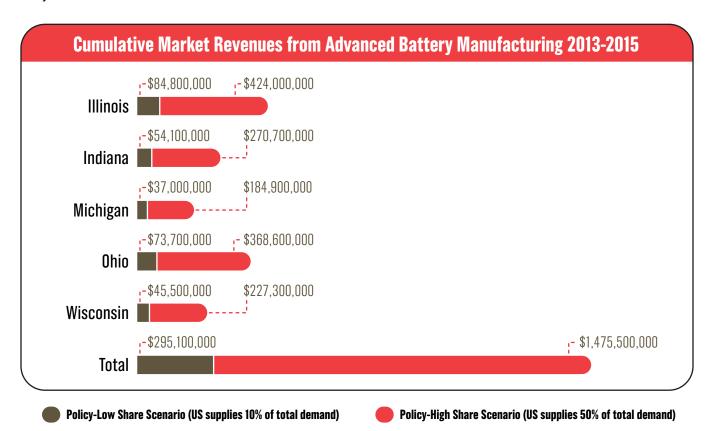
#### **Market Revenues**

In the "policy-high share" scenario, manufacturing revenue from the advanced battery market in the Midwest would grow to about \$1.5 billion by 2015. Market revenues in Illinois would reach around \$424 million, with Ohio closely following at about \$370 million.

In the "policy-low share" scenario, the advanced battery market in the Midwest would grow to \$295 million, with individual state revenues ranging from \$37 million to \$85 million by 2015.

All market revenue growth is new, as the existing advanced battery market is de minimis today. This represents an entirely new manufacturing sector, especially for Michigan, Indiana and Ohio.

Revenues attributed to Michigan are lower than expected as the state has already received over half of the \$2 billion distributed through ARRA in fall of 2009.

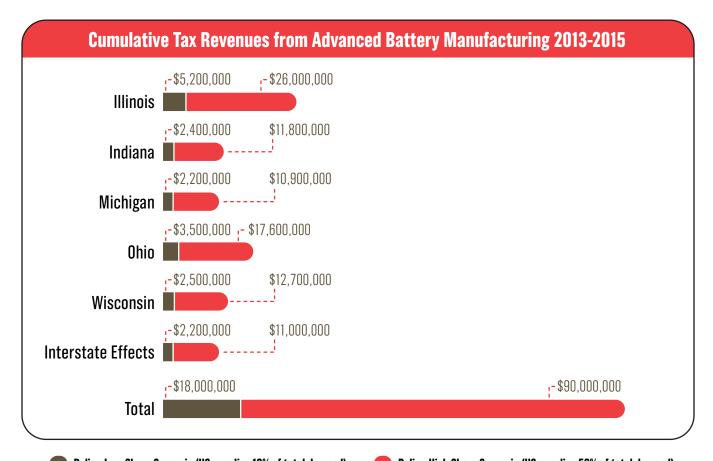


Because the US currently supplies less than one percent of the global advanced battery market, the size of the domestic advanced battery market in the "no policy" scenario is assumed to be zero.

#### **Tax Revenues**

In the "policy-high share" scenario, the Midwest would see additional tax revenues of about \$90 million from 2013 through 2015. Illinois would see revenues of about \$26 million, with Ohio gaining about \$17.5 million.

In the "policy-low-share" scenario, the Midwest would see additional tax revenues of almost \$18 million, with individual state revenues ranging from \$2.2 million to about \$5.2 million. Tax revenues are distributed through the region and show that the initial benefits from breaking into the advanced battery market will benefit the entire Midwest.



Policy-Low Share Scenario (US supplies 10% of total demand) Policy-High Share Scenario (US supplies 50% of total demand)

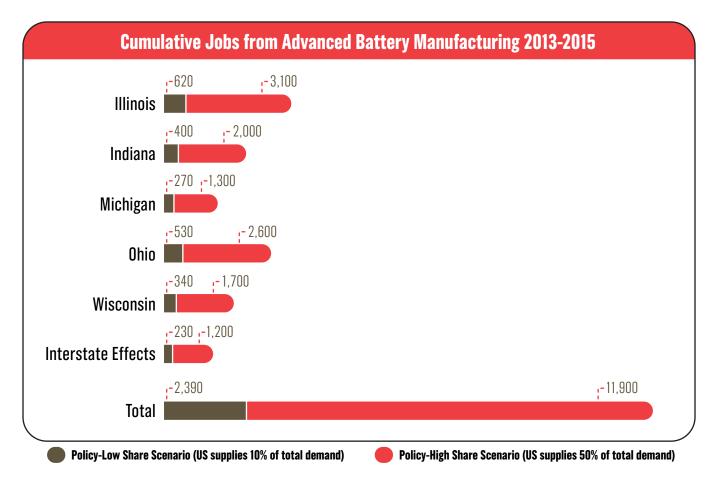
Because the US currently supplies less than one percent of the global advanced battery market, the size of the domestic advanced battery market in the "no policy" scenario is assumed to be zero.

#### **Job Creation**

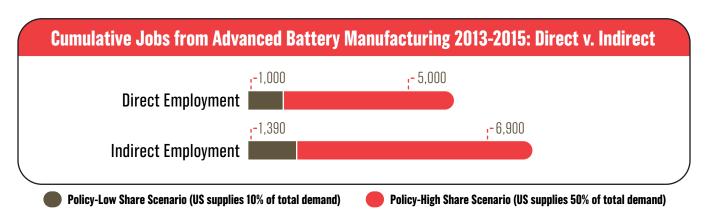
The five Midwest states would see modest job growth in this sector by 2015 in both scenarios.

In the "policy-high share" scenario, more than 11,900 total jobs and approximately 5,000 direct jobs are created by 2015.

In the "policy-low share" scenario, about 2,400 total jobs and 1,000 direct jobs are created by 2015.



Because the US currently supplies less than one percent of the global advanced battery market, the size of the domestic advanced battery market in the "no policy" scenario is assumed to be zero.



Because the US currently supplies less than one percent of the global advanced battery market, the size of the domestic advanced battery market in the "no policy" scenario is assumed to be zero.

# **CONCLUSION**

As global demand for clean energy increases, new, clean energy jobs will multiply exponentially. The question is: "Who will get them?" One possible answer is the Midwest.

The Midwest has a storied history based on determination, innovation and hard work.

In the twentieth century, the United States was the global manufacturing leader – and the Midwest stood at the center of that production. For over fifty years, this manufacturing economy made it possible for men and women to earn middle class wages and create multiple generations of skilled workers. The Midwest was home to the largest steel maker, US Steel, and the biggest car company, General Motors, and retains a competitive advantage in these industries.

Because of this competitive advantage, the Midwest is uniquely positioned to capture new low-carbon manufacturing jobs.

This report shows that, with climate and energy policies in place, the Midwest would see additional market revenues of up to \$12.3 billion, additional tax revenues of up to \$812 million and up to 104,640 new jobs from the wind turbine component, hybrid powertrain and advanced battery manufacturing sectors by 2015.

With the distribution of stimulus funding throughout 2009, we are already starting to see these numbers come to life.

A123 is expanding their advanced battery plant in Livonia, Michigan which will create 500 jobs and will open a new plant in Romulus, Michigan. General Motors produced its first mass produced electric car battery in Brownstown, Michigan in early January. And Brevini Wind's gearbox plant in Delaware County, Indiana received \$12.8 million in tax credits, putting Hoosiers to work.

Our report is only part of the total picture. We do not examine the costs associated with these policies. And we do not consider all of the economic benefits associated with climate and energy policies, including substantial energy efficiency savings, new jobs created outside of the manufacturing sector, benefits from the manufacture of hundreds of additional low-carbon technologies not examined in this report, and opportunities to export these low carbon technologies to other countries.

But this report does offer a sense of the enormous potential for job creation in the Midwest with smart climate and energy policies in place.

It will take vision and hard work to create the kinds of policies needed to incentivize the low-carbon economy.

But climate and energy policy offers us a chance to ensure that the Midwest - indeed America- has a bright, clean and prosperous future.

# **APPENDIX**

## **Overview: State of the Midwest Manufacturing Sector**

## More About Our Choice of Technologies and Selection Criteria

The initial set of technologies analyzed for the report included those considered by McKinsey & Company in their report "Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?", independent research, and selection by The Climate Group<sup>1</sup> and "Manufacturing Climate Solutions," by the Center on Globalization Governance & Competitiveness, 2009<sup>2</sup>. Those technologies that were clearly not relevant to the sectors considered in the report (automotive, chemicals, machinery and primary metals industries), were not well defined, or were extremely speculative were screened out on a first-pass review. The set of initial technologies was narrowed to about fifteen based on initial screening criteria, including a technology's relevance to economic activity in the Midwest in the near term.

For all technologies, the process was to: 1) research external data sources; 2) discuss the data findings; and 3) gather qualitative responses from team members, to determine overall rankings for the technologies. The technologies were grouped into "baskets" based on which of the four noted sectors they were most closely aligned.

The fifteen technologies were then refined to a smaller set, based on a rigorous application of criteria. Criteria were ranked qualitatively as being of high, medium, or low importance. Weights were assigned to each importance level, and the criteria were ranked based on the group's informal survey responses. The weights defined by the team members' rankings were totaled for each criterion and placed in order, as shown in the following table.

Criteria	Importance
1. Is the manufacture and/or a substantial portion of the product's value chain concentrated in the Midwest?	High
2. Does the Midwest have a comparative advantage in production?	High
3. How many years to show value/impact from the use of the technology?	High
4. Is the technology proven or in development?	High
5. What is the availability of relevant and appropriate data?	High
<b>6.</b> Is the technology a target for stimulus dollars?	High
7. What's the level of public understanding of the technology?	High
8. Can a market be defined for the technology or product?	High
<b>9.</b> What's the cost of abatement per ton of $CO_2$ equivalent ( $CO_2$ e) emissions?	Medium
10. How good of a substitute is this technology for an existing technology?	Medium
<b>11.</b> What's the potential reduction of $CO_2e$ ?	Medium
12. Are there significant capital costs related to the development or production of the technology?	Low
13. Will suppliers at any point in the value chain change because of the use of the technology?	Low
14. Does the technology generate large positive externalities or "free ridership"?	Low
15. Are there complements?	Low
<b>16.</b> Does the technology require widespread adoption to generate measureable benefits?	Low

Additional information about each criterion and its assessment, indicated by criterion number:

(1), (2) The technologies were categorized using US Census production data for 2002 and 2006 at the six-digit NAICS level to determine relative values in the Midwest and the nation<sup>3</sup>. The productivity indicators collected for each technology by state included the number of establishments, total revenues, annual payroll, and number of employees. The information by state was totaled to define amounts in Michigan, Illinois, Indiana, Ohio, and Wisconsin. Other data were derived to obtain a better understanding of a technology's overall importance to the Midwestern economy and to be used as more formal selection criteria to compare the study region to the nation, including the percentage of establishments, revenue, and employees. Technologies (identified by NAICS code) with a significant portion of national revenue produced in the Midwest were defined as having a significant proportion of the Midwest value chain; those with a significant proportion of payroll to revenues by state were defined as having a comparative production advantage in the Midwest.

- (3) Two factors were considered relevant to the question of timing: increased value of the technology to the economy and reduction in carbon emissions. Technologies impacting the economy and reducing carbon emissions in the near term were considered preferable to those with a longer horizon.
- (4) Less speculative technologies are more likely to have reliable data to measure economic impacts.
- (5) Information should be current, consistent, and reliable, as well as publicly available, when possible.
- (6) Whether the technology was the target for stimulus dollars had a strong relationship with its relevance to policymakers and public visibility.
- (7) A technology well-understood by the public is more likely to be adopted and to have measurable impacts on the economy and on CO<sub>2</sub>e emissions.
- (8) Measurement of economic impacts is better quantified for a technology with a well-defined market, versus a market that is imprecise or unclear.
- (9) As defined by the McKinsey report, in 2005 real dollars: "The cost of an abatement option reflects its resource (or technoengineering) costs, i.e. capital, operating and maintenance costs, offset by any energy savings associated with abating 1 ton of CO<sub>2</sub>e per year using this option, with the costs/savings levelized over the lifetime of the option using a 7 percent real discount rate. We have excluded transaction costs, communication/information costs, taxes, tariffs, and/or subsidies. We also have not assumed a 'price for carbon' that might emerge as a result of legislation, nor any impact on the economy of such a carbon price. Hence, the per ton abatement cost does not necessarily reflect the full cost of implementing that option."
- (10) Self-explanatory.
- (11) As defined by the McKinsey report, in per year  $CO_2$ e amounts over a 25-year period<sup>4</sup>.
- (12) High up-front capital could slow investment or implementation.
- (13) Employment or production displacement due to the adoption of a technology.
- (14) A large divergence between private and public benefits could affect a technology's adoption.
- (15) Complements are goods that are produced or consumed jointly, such as peanut butter and jelly. If the technology has many complements, there will likely be faster adoption.
- (16) Technologies requiring a large number of independent individual choices to adopt were considered less likely to be widely adopted.

### **More About Our Case Study Selection**

The technologies in the refined selection pool were ranked qualitatively for each of the criteria. As with the criteria ranking, each criteria for each technology had a value. These values were summed across each technology, and the technologies were ranked according to the summed value.

- At the end of this process, hybrid powertrains, advanced batteries, and wind power components were judged to be the most appropriate for this study.
- Other technologies can and should be analyzed.
   Only a select group was chosen due to budgetary constraints.
- The technologies were partially chosen based on their crossover into the four sectors analyzed.

## **About the Findings**

Once the technologies were chose, the first step in the analysis was to research each technology to understand its market, its state of development in the US and the Midwest, and the internal and external forces driving the technologies' adoption and acceptance. To calculate the impact on the Midwest economy, after the technology was well defined and modeled, relevant data was collected so that a traditional economic impact analysis could be conducted. Through all modeling phases, analysis was conducted through the use of

publicly available data and published research.

- The time horizon for modeling was determined to be 5 years.
- Data was culled from public sources, such as the US Census Bureau, the US Department of Energy, and publicly available academic journals, newspapers, magazines, and online sources.
- The product market for each technology was defined, including sub-products if relevant.
- Supply conditions were analyzed for producers in each market and sub-market, considering factors such as capacity, utilization, and barriers to entry.
- Demand conditions were analyzed for each market and sub-market, including whether the product market is local or national, the number of consumers, and price sensitivities.
- The baseline growth rate for the technology was considered.
- Changes in exogenous factors were evaluated, including a carbon price, and how these changes would impact the technology's producers.
- Net impacts were analyzed through a traditional economic impact analysis.

The IMPLAN model was used. IMPLAN is widely used by US state governments and private corporations.

## **Policy Options Considered**

## **Cap-and-Trade Policy**

This study considers the implementation of a cap-and-trade program on greenhouse gas emissions. Under such a program, covered entities would be required to hold one allowance for each ton of CO2 equivalent emissions. The analysis is based on the American Clean Energy and Security Act of 2009 (ACES), which passed in the US House of Representatives on June 26, 2009<sup>5</sup>.

ACES has a set number of allowances available each year, ranging from 4.627 billion in 2012 to 5.056 billion in 2020. Allowances could be banked for future use and borrowed up to five years in advance. Covered entities can use offsets to meet a portion of their allowance requirements; five offsets are required for every four tons of CO<sub>2</sub>e emissions. Offsets are awarded for qualified projects that lower net CO<sub>2</sub> emissions unrelated to the covered entity's operations, such as preventing deforestation. Offsets are capped at 2 billion tons a year program-wide: 1 billion domestic offsets, and 1 billion international offsets. Programs established in ACES also have an impact on the growth of wind-generated electricity.

#### American Recovery and Reinvestment Act of 2009 (ARRA)

This study considers ARRA in the wind turbine component case study. ARRA provides an extension through 2012 of the Production Tax Credit (PTC), originally established by the Energy Policy Act of 1992 and adjusted annually for inflation.

The PTC equaled \$0.021/kWh in 2008. With wind energy production averaging \$0.04/kWh, the PTC represents a 50 percent credit on production. ARRA also allows renewable energy projects placed in service by the end of 2012 to choose an upfront Investment Tax Credit (ITC) or cash grant in lieu of the PTC. Manufacturers of qualified renewable energy technologies also qualify for the ITC, with a cap of \$2.3 billion. Projects electing the ITC or cash grant are no longer susceptible to the "double dipping" penalty. Other advantages under ARRA for qualified renewable and transmission projects include expedited depreciation timelines, loan and borrowing guarantees, funding opportunities for projects and research and development, and financial support for state renewable electricity programs<sup>6</sup>.

### **National Renewable Electricity Standard (RES)**

State renewable portfolio standards (RPS) have a significant effect on the demand for wind energy. To promote renewable energy generation, several states have set target goals for electricity distributors. In most state RPS programs, electricity distributors are expected to meet a target percentage of generation by renewable sources before a set date; while some states simply have a kWh goal for the total state's generation. The current state RPS programs vary widely: The transition to a national RES of 20 percent by 2020 and modernization of the electric grid in ACES would aid in wind energy growth<sup>7</sup>.

# **Case Study 1: Wind Turbine Components**

## **More About the Wind Turbine Market**

Demand for wind power, absent special incentives or subsidies, ultimately depends on its cost to electricity users. Currently, wind power costs about twice as much as new coal power per kilowatt-hours (kWh). Wind currently costs \$.04/ kWh on average, with a fairly broad range of prices nationally; 50 percent of wind power supplied falls between \$.033 and \$.0515/kWh<sup>8 & 9</sup> compared to an average o \$.02/kWh for new coal plants.

omponents	NAICS Code	NAICS Description
ROTOR		
Blade	326199	All other plastic products
Blade extender	331511	Iron foundries
Hub	331511	Iron foundries
Pitch driver	335312	Motors and generators
NACELLE AND MACHINERY	•	
Anemometer	334519	Measuring and controlling devices
Brakes	333613	Power transmission equipment
Controller	334418	Printed circuits and electronics assemblies
Cooling fan	333412	Industrial and commercial fans and blowers
Nacelle case	326199	All other plastic products
Nacelle frame	331511	Iron foundries
Sensors	334519	Measuring and controlling devices
Yaw Drive	335312	Motors and generators
GEARBOX AND DRIVETRAIN		
Bearings	332991	Ball and roller bearings
Coupling	333613	Power transmission equipment
Gearbox	333612	Speed change industrial
High- and low-speed shafts	333613	Power transmission equipment
GENERATOR		
Generator	333611	Turbines, and turbine generators,
		and turbine generator sets
Power electronics	335999	Electronic equipment and components
TOWER		
Tower	332312	Fabricated structural metal
Tower flange	331511	Iron foundries

## **Potential Cross-over Factories**

Factories in the US and in the five Midwestern states that are producing in the same NAICS codes as the turbine components

and sub-components parts and could conceivably enter into turbine component production are listed in the table below <sup>10</sup>.

Wind Turbine Component and Sub-Component Factory Distribution								
Sub-Component	US Total	Illinois	Indiana	Michigan	Ohio	Wisconsin		
Rotor	10,327	629	443	733	776	413		
Nacelle and machinery	12,425	703	458	829	851	440		
Gearbox and drivetrain	1,030	88	41	69	79	68		
Generator	1,089	65	35	36	45	22		
Tower	3,780	167	155	184	253	113		

## **Additional Assumptions**

- **Distribution of new turbine expenditures along the supply chain**. In 2004, 50 percent of blades, 26 percent of towers, and 20 percent of remaining parts were produced domestically, potentially rising to 80 percent, 50 percent, and 42 percent respectively by 2030<sup>11</sup>. For the purpose of this study it was assumed that annual growth was linear<sup>12</sup>. Once total domestic expenditures were calculated, the "remaining parts" category expenditures were further broken down into nacelle/machinery (47 percent), gearbox/drivetrain (38 percent), and generators (15 percent).
- **Growth rate**. We assumed a constant growth rate in domestic production in order to obtain domestic production estimates annually up to 2015.
- **Wind capacity**. Annual wind capacity growth was calculated and multiplied by an estimated capacity-weighted average turbine production cost of \$1,360 per kilowatt, to get the total US expenditures by year<sup>14</sup>.

Domestic Cost Allocation of Wind Turbine Components and Sub-Components							
Components	Cost Allocation by Component	Domestic Production 2004	Forecast Domestic Production – 2030 <sup>13</sup>				
Rotor	28%	50%	80%				
Nacelle and machinery	21.7%	20%	42%				
Gearbox and drivetrain	17.3%	20%	42%				
Generator	7%	20%	42%				
Tower	26%	26%	50%				

<sup>12</sup> It is possible that the growth assumptions used in this paper are conservative and will underestimate the shift from foreign to domestic production and hence economic and fiscal impacts. To the extent that "Buy American" provisions are effectively implemented in ARRA and other policies, the shift could be larger and much more rapid.

## **Case Study 2: Hybrid Powertrains**

#### **More About the Automotive Sector**

The "Cash for Clunkers" program, which concluded on August 24, 2009, generated almost 700,000 new car sales <sup>15</sup>. According to Ford Motor Co. representatives, many of these were deferred purchases from earlier in the year; in other words, consumers planning on trading their vehicles waited to do so to take advantage of the rebate. Approximately 30 to 40 percent of vehicle sales were incremental sales, according to Ford representatives, to customers who would not have otherwise purchased a new vehicle <sup>16&17</sup>.

Vehicle manufacturers selling in the US market are affected by government standards for minimum fuel consumption (known as Corporate Average Fuel Economy, or CAFE). In May 2009, President Obama announced that an automakers' fleet of vehicles will have to average 35.5 miles per gallon (mpg) by 2016. Cars will average 39 mpg, while light trucks will average 30 mpg. This allows automakers to have individual vehicles that get above or below the set mpg, as long as the entire

fleet averages 35.5 mpg<sup>18</sup>. These more stringent standards will reinforce a trend to move toward HEVs and other more fuel-efficient technologies.

The Obama administration's award of \$2.4 billion in grants to US-based manufacturers in early August to support the manufacture of advanced batteries and other components for electric cars breaks down as follows<sup>19</sup>:

- \$1.5 billion to produce batteries and their components and to expand battery recycling capacity.
- \$500 million to produce electric drive components for vehicles, including electric motors, power electronics, and other drive train components.
- \$400 million to purchase thousands of plug-in hybrid and all-electric vehicles for test demonstrations in several dozen locations; to deploy them and evaluate their performance; to install electric charging infrastructure; and to provide education and workforce training to support the transition to advanced electric transportation systems.

<sup>&</sup>lt;sup>17</sup> No adjustments are made to forecast revenue, due to the statistically small sales figures.

## **More About the HEV Powertrain Market**

HEV costs can be broken down by component, with the powertrain and its sub-components accounting for 55 percent of total costs.

HEVs: Component Share of Vehicle Cost <sup>20</sup>	Major Component Category %	Component Category Detail %
POWERTRAIN	55%	
Engine, fuel delivery, exhaust		
& emissions, inverter		12%
Electric motor		10%
Drivetrain <sup>21</sup>		12%
Battery <sup>22</sup>		21%
Other		
Body frame	17%	17%
Other systems	28%	28%
Total	100%	100%

<sup>&</sup>lt;sup>21</sup> The base source (see Pill Soo-Kim) grouped the drivetrain with the engine, fuel delivery, exhaust, emissions and inverter. Together these represented 24 percent of the component cost of a vehicle. In a conventional powertrain, the drivetrain has been estimated to represent 13 percent of vehicle cost. For a hybrid drivetrain, the cost was estimated at 12 percent; half of 24 percent total.

<sup>&</sup>lt;sup>22</sup> For a nickel metal hydride battery

## NAICS 33631: Motor vehicle gasoline engine & engine parts manufacturing

Companies in this industry manufacture or rebuild gasoline engines, manufacture engine parts such as valves and pistons, and produce carburetors, fuel, oil and water pumps, and intake and exhaust systems. Gasoline engines are by far the largest product of this industry, and are forecast to comprise about 86 percent of industry revenue in 2009. Crankshafts and parts follow with 6 percent of industry share; with pistons and related equipment, carburetors and valves accounting for the remaining 7 percent<sup>23</sup>. Over the past five years, vehicle engines within the 3.0-3.9L size have been losing popularity to smaller, 2.9L and under, engines. A similar shift has occurred for light trucks since 2002.

Motor vehicle gasoline engine & engine parts manufacturing						
NAICS 33631 – USA <sup>24</sup>	2005	2006	2007	2008	2009	Units
Industry revenue	36, 210.2	37,486.8	45,800.0	33,795.2	30,111.5	\$Mil
Imports as a share of domestic demand	31.34	27.86	29.34	27.47	26.58	%

## **NAICS 33531: Electrical equipment manufacturing**

Motor and generator manufacturing are forecast to comprise about 34 percent of the value of industry shipments in 2009, up from 29.1 percent in 2002<sup>25</sup>. Industry revenue is expected to increase, on average and in real terms, by 3.6 percent annually in the five years through 2014. Growth will be driven by an increase in domestic demand for industry products<sup>26</sup>.

Electrical equipment manufacturing						
NAICS 33531 USA <sup>17</sup>	2005	2006	2007	2008	2009	Units
Industry revenue	37,582.2	39,439.4	40,946.2	40,112.5	34,420.5	\$Mil
Imports as a share of domestic demand	41.18	43.65	45.27	46.9	50.63	%

#### NAICS 33635: Motor Vehicle Transmission and Powertrain Parts Manufacturing

The major products manufactured in this industry include transmissions and parts (42 percent), axles and parts (32 percent), and drivetrain components (26 percent)<sup>28</sup>. Demand for transmission and powertrain parts fell over the five years to 2009, and industry revenue contracted by 6.7 percent annually to \$28.8 billion. Manufacturers have dealt with cost increases in fundamental raw materials such as steel as expansion in emerging economies put upward pressure on the prices of these inputs. Several parts manufacturers filed for bankruptcy. In 2009, manufacturers in this industry continued to struggle<sup>29</sup>.

Motor Vehicle Transmission and Powertrain Parts Manufacturing						
ICS 33635 – US <sup>30</sup>	2005	2006	2007	2008	2009	Units
Industry revenue	38,535.4	37,364.8	37,566.4	33,131.1	28,797.6	\$Mil
Imports as a share of domestic demand	27.58	28.81	26.93	28.1	29.43	% /

## **About the Policy Assumptions**

- The Cash for Clunkers program has not materially impacted demand for vehicles over the forecast period. No adjustments have been made to sales forecasts presented in the IBISWorld auto and truck industry studies.
- CAFE standards are implicit in sales forecasts
  presented in IBISWorld's industry studies and in
  findings beyond 2015. No explicit adjustments have
  been made for the impact of these standards.
- Tax credits for PEVs and EVs have not been explicitly considered, as it is not possible to predict consumer adoption rates for these vehicles
- These models have not been adjusted to account for the Obama administration's grants to promote EVs.
   It is not possible to predict the impact that these policies will have.

## **About the Methodology: HEV Powertrains**

The first step in developing an estimate for demand for hybrid powertrains was to forecast the demand for hybrid vehicles over the forecast period, then calculate the demand for, and value of, each component of the hybrid powertrain in each forecast year. This data was then broken down by state, based on US Census data, and then by component by NAICS code.

Forecasts for total US sales of light trucks, SUVs<sup>31</sup> and automobiles<sup>32</sup> are based on IBISWorld expectations for 2010 through 2015. The compound annual growth rate (CAGR) from 2010-2015 for autos was 2.3 percent. The CAGR for light trucks and SUVs was 1.9 percent from 2010-2015.

- Across all years, forecasts for vehicles were adjusted to exclude imports. According to IBISWorld, in 2009, 49.8 percent of domestic demand for vehicles was for imported vehicles<sup>33</sup>. For light trucks and SUVs, 37.9 percent was for imports in 2009<sup>34</sup>. There was no indication of how demand would shift during the forecast period; therefore, these import percentages were held constant through the forecast period.
- US hybrid sales, as a percentage of total US vehicle sales, were forecast by IBISWorld for 2010, 2013, and 2015 at 5, 11, and 17.7 percent respectively<sup>35</sup>.
   Forecasts of US hybrid sales as a percentage of total US vehicle sales for inter-years (i.e. 2011, 2012, 2014, and 2016-2019) were calculated through linear extrapolation. Revenue from sales of domestically produced hybrids was calculated for 2010 through 2015.
- The proportion of value for each component was adjusted to allow for the portion of engine value that is imported<sup>36</sup>. There was no indication of how demand might shift during the forecast period; percentages were held constant at 2009 values and formed the basis of the dollar value attributed to national production of the component parts.
- The dollar value of revenue attributed to domestic production was allocated to Illinois, Indiana, Michigan, Ohio, and Wisconsin based on total value of shipments by state as a percentage of total value of national shipments, according to US Census data defined by four digit NAICS codes<sup>37</sup>. This formed the basis of the 2010 scenario.
- A price of \$17 per ton of CO<sub>2</sub>e would add approximately \$0.172 to the price of a gallon of

<sup>&</sup>lt;sup>36</sup> For gasoline engines, the value of imported components is about 26.6 percent of gasoline industry value. Of the 12 percent of hybrid value attributed to gasoline engines, about 74.4 derives from domestic production and thus this value was adjusted accordingly.

gasoline, according to industry research<sup>38</sup>. To model the change in consumer behavior based on this price change, we relied on a study by two Harvard University researchers that found that for a 10 percent increase in gas prices, US hybrid purchases increased by 7.5 percent based on data from 2002 to 2006<sup>39</sup>.

- Base gasoline prices over the forecast period (in real dollars) are based on IBISWorld forecasts for 2010-2015<sup>40841</sup>.
- To calculate how demand would change, \$0.172 was added to the forecast price of gasoline (in constant dollars) in each year. The percentage increase in the total price per gallon was then calculated for each year. The resulting incremental increase in demand for hybrid vehicles was calculated, based on the

- Harvard University study 42,43&44.
- Because the forecast for all model components was
  in real dollars, and the price of gasoline is forecast to
  increase over the forecast period in real dollar terms,
  the percent increase in price per gallon and the
  resulting expected increase in the purchase of hybrid
  vehicles were more significant in earlier years in the
  model. The percent increase in price per gallon over
  the base price ranged from 6.5 percent in the first
  model year to less than 5 percent in the final model
  year. The corresponding incremental increase in value
  of HEVs purchased ranged from about 5 percent in the
  first model year to just over 3.5 percent in the final
  model year.

<sup>&</sup>lt;sup>43</sup> The impact of the shift away from the purchase of other, non-hybrid vehicles was not measured. However, because hybrid powertrains are considered to add a premium of approximately \$2000-\$3000 to the value of a vehicle over a non-hybrid counterpart much of the value of a hybrid powertrain is truly a value-add, and not a value shift.

## **Case Study 3: Advanced Batteries**

## **About the Methodology & Assumptions: Advanced Batteries**

- The elements of demand are not differentiated by factors driven by a carbon price, by tax credits, or direct subsidies to industry.
- Domestic production of advanced batteries by the Midwest states defined for this study is maintained at the proportional value demonstrated by 2006 NAICS code 3359.
- The base case scenario, in keeping with the status
  quo, assumes the US would produce an immaterial
  amount of advanced batteries to satisfy demand, and
  thus assumes no carbon price, and no impacts from
  subsidies, tax credits or other programs. In essence
  the US would produce zero value of this market
  demand over the finding period.
- These models have not been adjusted to account for the Obama administration's grants to promote electric vehicles. It is not currently possible to predict the impact that these policies will have on the distribution of benefits to individual states and regions.

## **Barriers to Realizing Benefits: Advanced Batteries**

- Li-ion batteries must become more cost effective before they can be widely adopted.
- Consumer acceptance of Li-ion batteries may develop differently than expected. Consumers may be hesitant to adopt such new and relatively unproven technology, which may slow development and adoption of advanced batteries.

# **GLOSSARY**

#### 2009 Dollars

IMPLAN output figures reported in 2007 dollars. Output reported in 2009 dollars using GDP deflators given by Price Indexes for Gross Domestic Product reported by Bureau of Economic Analysis.

#### **AEO 2009**

The Annual Energy Outlook 2009 (AEO2009) presents findings and analysis of US energy supply, demand, and prices. Findings are based on results from the Energy Information Administration's National Energy Modeling System.

#### **ACES**

American Clean Energy and Security Act of 2009. Also known as Waxman-Markey, this comprehensive energy bill includes a cap-and-trade plan designed to reduce greenhouse gas emissions 17 percent by 2020. Other provisions include new renewable requirements for utilities, studies and incentives regarding new carbon capture and sequestration technologies, energy efficiency incentives for homes and buildings, and grants for green jobs.

## **Amines**

Amines are basic organic compounds used during carbon capture and storage (CCS) to separate carbon dioxide from other gases when coal is burned.

#### **Anemometer**

An instrument that measures wind speed and transmits wind speed data to the controller.

## ARRA

The American Recovery and Reinvestment Act of 2009 which included \$787 billion in economic recovery funds distributed through grants, tax breaks and loans.

## **CAFE** standards

Corporate Average Fuel Economy standards, first established in 1975 under the Energy Policy Conversation Act and updated several times since. In May 2009, President Obama announced that an automakers' fleet of vehicles will have to average 35.5 miles per gallon (mpg) by 2016.

#### **CAGR**

Compound annual growth rate

## **Carbon footprint**

Impact of human activities on the environment measured in terms of GHG produced, communicated in CO2e.

Cap and trade/cap-and-trade policy

An emissions trading scheme that sets an overall limit on the emission of a certain pollutant and allows participating entities to trade emission allowances.

#### **CBO**

**Congressional Budget Office** 

#### CCS

Carbon capture and storage. A method to reduce GHG emissions by capturing carbon dioxide from large factories and fossil fuel power plants and storing it deep underground or deep in the ocean.

#### **CFMMI**

Chicago Federal Reserve Bank's Midwest Manufacturing Index

#### CO<sub>2</sub>e

Carbon dioxide equivalent. A standard unit, measured in metric tons. of GHG emissions.

#### CHP

Combined heat and power systems, also known as cogeneration.

#### **Drive train**

In a hybrid vehicle, the components of the powertrain that transmit power from the engine to the wheels.

#### **EESA**

The Emergency Economic Stabilization Act of 2008

## **Enzymes**

Biological catalysts capable of speeding up biochemical reactions in manufacturing, reducing the amounts of raw materials needed.

## **EPA**

**US Environmental Protection Agency** 

#### EV

Electric vehicle

#### **FDIC**

Federal Deposit Insurance Corporation

#### **GHGs**

Greenhouse gases. A group of gases that absorb and reemit infrared radiation. These gases occur through both natural and human-influenced processes and include: carbon dioxide, nitrous oxide, methane, sulfur hexafluoride, hydrofluorocarbon, and perfluorocompounds.

#### HEV

Hybrid electric vehicle. Hybrid vehicles combine a conventional internal combustion engine propulsion system with a rechargeable electric storage and propulsion system.

#### HVAC

Heating, ventilation and air conditioning

#### **Hybrid powertrain**

Hybrid powertrains include four major components: the engine, fuel delivery, exhaust & emissions and inverter; electric motor; drivetrain; and advanced battery. In a hybrid powertrain, an electric motor provides power to assist the engine. Conventional powertrains do not have electric motors or inverters.

## **Hybrid vehicle**

Automotive vehicle with an electric motor and a traditional internal combustion engine.

#### Inverter

A device that converts direct current (DC) to alternating current (AC).

#### ITC

Investment tax credit.

## kWh

Kilowatt-hour

#### **Lightweight vehicles**

Vehicles made with lighter materials to improve fuel-efficiency by reducing vehicular weight.

#### Li-ion

Short for lithium ion, these batteries come in various forms and can store more energy per mass and volume than traditional batteries.

#### **Nacelle**

In a wind turbine, the nacelle sits atop the tower and contains the gear box, low- and high-speed shafts, generator, controller, and brake.

#### NAICS

The North American Industry Classification System is the standard used by federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the US business economy.

#### **NAICS** codes

The numerical codes assigned to each NAICS sector.

#### PV

Photovoltaic solar cells convert light from the sun directly into electricity.

#### **PHEV**

Plug-in hybrid electric vehicle

#### PTC

Production tax credit

#### **RES** (renewable electricity standard)

RESs mandate a percent of electricity be generated from renewable sources. Legislation has been introduced into the US Congress to create a national RES.

#### **Smart Grid**

Integration of ICT (information and communication technology) applications throughout the grid, from generator to user, to enable efficiency and optimization solutions.

## **Wind turbine components**

Wind turbines can be broken down into five major components: rotor, nacelle and machinery, gearbox and drive train, generator, and tower. Each of these components corresponds to a six-digit NAICS code.

#### Yaw drive

Upwind turbines face into the wind; the yaw drive is used to keep the rotor facing into the wind as the wind direction changes. Downwind turbines don't require a yaw drive.

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