



Ohio Third Frontier: Targeting Growth Opportunities for the Next 3-5 Years



Prepared for: Ohio Third Frontier

Prepared by: Battelle Technology Partnership Practice

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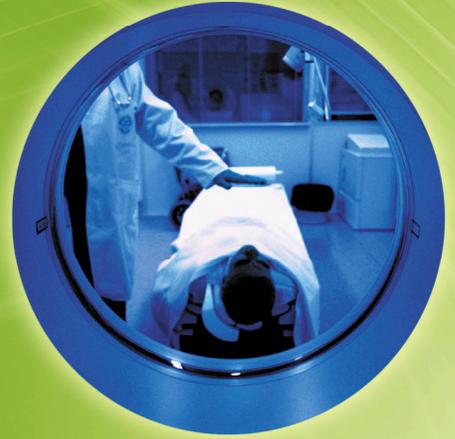




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EXECUTIVE SUMMARY

“My only purpose, my only passion in all of this has been to lift Ohio, to make us competitive again, and to create jobs for our families.”

These words from Governor Kasich’s Inaugural Address sets a clear pathway for economic development in Ohio. In the years ahead, Ohio must spur a more competitive, high-growth economy able to generate high-quality jobs.

This is no longer as simple as waiting for the national recovery to take hold and expecting good-paying manufacturing jobs to return. In today’s global economy, the performance bar has been raised. Foreign competition has intensified and now reaches nearly every industry and business function.

What is also different in today’s global economy is the terms of global competition have shifted to focus on access to skilled workers and technology know-how and innovation as drivers of 21st century economic development. The rapid pace of technology innovation and development has become a defining focus for the global economy. From the rise of the Internet to advances in biotechnology and nanotechnology to new micro-electronic chips and devices to the development of alternative energy sources and biobased products, technology is redefining how existing business is conducted, and creating new products and industries for the future.

Need for Focus to be Successful

In today’s difficult fiscal times, states cannot afford to spread their resources too thin and chase fields of

dreams or declining industries. All too often states simply attempt to copy the perceived leaders in technology industry development or follow fads of the moment. These states miss the

fact that not all states are built alike in industry and technology capabilities, and it is the differences that can best define how a state can be most successful and globally competitive.

It is a lesson that industry has learned well by focusing on their core competencies to advance competitive advantage that leads to growth in the global marketplace. As Gary Hamel and C.K. Prahalad in their landmark study, *Competing for the Future*, explain: “To successfully compete for the future...requires top management to conceive of the company as a portfolio of core

The opportunity set of advancing technologies is enormous in today’s global economy, but for a particular state’s economy to succeed it needs to identify those industry sectors and the growth opportunities within those industry sectors in which it is best positioned to differentiate itself and build specialized areas of expertise in which it can be a world leader.

competencies rather than a portfolio of individual business units...core competencies are the gateways to future opportunities.”¹

Key Tool for Ohio’s Competitiveness – The Ohio Third Frontier Program

A key tool for Ohio to meet this global competitive standard of competition is the Ohio Third Frontier (OTF) program. OTF was created in 2002 to advance Ohio’s economic competitiveness and the generation of high quality jobs. The results have been significant, generating 79,464 jobs, \$6.6 billion in leveraged funding and creating, attracting, or capitalizing 701 companies between 2002 and June 2011. In addition, qualitative changes have also resulted from Ohio Third Frontier investments, including the advancement of Ohio’s entrepreneurial culture and the deepening collaborations between and among Ohio’s industrial and research base.

It is widely understood by Ohio business leaders, economic development professionals and academic leaders that best practice in economic development must recognize that each state and its regions have a set of target industry sectors in which it can differentiate itself by gaining industry specialization, while also establishing high levels of technological capabilities to support continued innovation and market leadership. ***It is this intersection of having industry strengths and technology capabilities that define industry sectors of interest for the Ohio Third Frontier.***

Ohio Third Frontier has succeeded in putting forward a disciplined, market-oriented approach that is tailored to Ohio’s areas of specific technology industry strengths and growth opportunities within them.

¹ Hamel and Prahalad, *Competing for the Future*, Harvard Business Press, 1994, pg 90 and 217.

Purpose of this Report

With the recent voter approval of continued funding for the Ohio Third Frontier, it is critical to update likely industry and technology focus areas in which Ohio has comparative advantage and strong growth prospects over the next 3 to 5 years. As we look towards the future of the Ohio Third Frontier, it is particularly important to take account of how Ohio’s economy has changed since the initiative was put in place back in 2002 as well as consider the significant changes in the overall global and national economic backdrop and markets.

A three step process has been undertaken to provide a fact-based, in-depth and objective analysis of Ohio’s position in likely industry and technology focus areas, with active engagement of a broad set of industry, university and economic development stakeholders involved in Ohio, including the discussions and guidance from the Ohio Third Frontier Advisory Board and industry forum discussions.

These three steps included:

- *Assessing the changing Ohio economy since 2002 and the leading industry sectors for technology-based economic growth.*
- *Identifying from recent trends in detailed industry and technology innovation activities likely focus areas for growth opportunities.*
- *Integrate guidance from industry forum discussions and further validation based on reviews of market research studies to identify specific recommendations on growth opportunities for Ohio.*

To assist in this effort, the Battelle Technology Partnership Practice (TPP), the technology-based economic development arm of Battelle, was

retained. Battelle TPP had been involved in prior assessment and strategic planning work leading up to the formation of the Ohio Third Frontier back in 2002 and in providing more in-depth analysis of Ohio's core technology competencies in 2006, along with many other technology-based economic development projects in Ohio.

Report Findings

There were eight leading growth opportunity areas identified from this comprehensive analysis that involved extensive consultation with industry leaders from across leading technology-based industry sectors and ongoing engagement with the Ohio Third Frontier Commission and Advisory Committee.

These eight leading growth opportunity areas were approved by the Ohio Third Frontier Commission and Advisory Committee because they address where Ohio is best positioned in growth markets over the next three to five years, building on Ohio's existing industry strengths and technology capabilities. They include:

- **Advanced Materials**
 - *Advanced Polymer Materials; Ceramics; Composites; Carbon Fibers and Nanotubes; Specialty Metals and Alloys*
- **Aero-Propulsion Power Management**
- **Fuel Cells and Energy Storage**
- **Medical Technology**
 - *Medical Imaging; Surgical Instruments and Equipment; Implant Devices; Regenerative Medicine*
- **Sensing and Automation Systems**
- **Situational Awareness and Surveillance Systems**
- **Software Applications for Business and Healthcare**
- **Solar Photovoltaics**

Table ES-1: Identified Growth Opportunity Focus Areas for the Next 3–5 Years

| ADVANCED MATERIALS | |
|--|--|
| WHAT IS IT? | Unconventional materials that outperform conventional materials allowing them to play a large role in product development |
| MARKET OUTLOOK | High growth in multiple technologies including: advanced polymer materials, ceramics, composites, carbon fibers and nanotubes, and specialty metals & alloys |
| WHY OHIO? | Presence of research centers and institutes, academic publications, significant corporate R&D operations, patent activity, strong supply chain |
| AERO-PROPULSION POWER MANAGEMENT | |
| WHAT IS IT? | Machines that produce power required to push or pull a vehicle into motion |
| MARKET OUTLOOK | Increasing from \$8.7B in 2009 to \$11.2B in 2015 |
| WHY OHIO? | Specialized employment, industry presence and home to commercial, military and academic research centers focused on propulsion |
| FUEL CELLS AND ENERGY STORAGE | |
| WHAT IS IT? | Technologies that enable the storage of energy and/or the conversion of chemical energy to electrical energy |
| MARKET OUTLOOK | Battery market to increase from \$9.6B in 2011 to \$12B in 2016 Fuel Cells market to grow at 20% CAGR to reach \$1.2B in 2014 |
| WHY OHIO? | Large share of U.S. employment, industry presence, academic, corporate and institutional research, strong supplier base, patent activity, and specialized fuel cell development consortiums |
| MEDICAL TECHNOLOGY | |
| WHAT IS IT? | Healthcare products used to diagnose, monitor or treat diseases or conditions that affect humans |
| MARKET OUTLOOK | Healthy growth across technologies with fast growing niches in: medical imaging, surgical instruments and equipment, implant devices and regenerative medicine |
| WHY OHIO? | Employment strengths, industry presence, strong VC investment, strong patent and research activity |
| SENSING AND AUTOMATION TECHNOLOGIES | |
| WHAT IS IT? | Technologies that reduce the need for human labor in the production processes and/or receive and respond to external signals or stimuli |
| MARKET OUTLOOK | High rates of growth in multiple technologies such as: micro-electromechanical systems, process control instruments, industrial controls, sensors and machine vision |
| WHY OHIO? | Strong corporate R&D and manufacturing presence, robust patent and publication activity |
| SITUATIONAL AWARENESS AND SURVEILLANCE TECHNOLOGIES | |
| WHAT IS IT? | Technologies that allow users to perceive information about environment factors and anticipate their affect in the near future |
| MARKET OUTLOOK | Growing market with fast growing niches in: surveillance equipment, sensors, and related software |
| WHY OHIO? | Growing employment, AFRL's Sensor Directorate, high level of remote sensing publications, significant industry presence |
| SOFTWARE APPLICATIONS FOR BUSINESS AND HEALTHCARE | |
| WHAT IS IT? | Applications that enable organizations to reduce costs, increase productivity, achieve greater profitability, and improve efficiencies; Healthcare IT improves the quality and efficiency of healthcare delivery |
| MARKET OUTLOOK | High growth expected in enterprise software, enterprise cloud-based services, business intelligence, e-commerce, business process management, clinical healthcare, mobile healthcare |
| WHY OHIO? | Growing employment, strong talent base, industry presence, strong VC investment, active patent and publication base, biomedical institutional presence, development of statewide HIE |
| SOLAR PHOTOVOLTAICS | |
| WHAT IS IT? | Converts solar energy into electricity using cells, films or modules |
| MARKET OUTLOOK | North American PV market revenues to increase at 28.3% CAGR from 2010–2017 to reach \$17B; high growth niches include: thin film PV, concentrator PV, building integrated PV |
| WHY OHIO? | Large share of U.S. establishments, growing employment, strong industry presence, skilled workforce, base of VC-backed companies, academic and institutional research assets |



INTRODUCTION

The Ohio Third Frontier (OTF) was created in 2002 to advance Ohio's economic competitiveness and the generation of high quality jobs. The results to date have been significant. Through the OTF program, Ohio has generated 79,464 jobs, \$6.6 billion in leveraged funding and created, attracted, or capitalized 701 companies between 2002 and June 2011. In addition, qualitative changes have also resulted from OTF investments, including the advancement of Ohio's entrepreneurial culture and the deepening collaborations between and among Ohio's industrial and research base.

The OTF is Ohio's response to keeping up with the rapid pace of technology development and innovation that is integral to the economic competitiveness of state and local economies across the United States. From the rise of the Internet, to advances in biotechnology and nanotechnology, to new micro-electronic chips and sensing technologies, to the development of alternative energy sources and biobased products, technology is redefining how existing business is conducted and creating new products and industries for the future.

The opportunity set of advancing technologies is enormous in today's global economy; but, for a particular state's economy to succeed, it needs to identify those industry sectors and growth opportunities within those industry sectors in which it is best positioned to differentiate itself

and build specialized areas of expertise where it can be a world leader. This is a critical best practices lesson in economic development for states in the 21st century global economy.

As Michael Best, a leading scholar chronicling the growth and development of industries across states and broader regions, explains in *The New Competitive Advantage*, state and broader regional economies

"...can be thought of as developing specialized and distinctive technology capabilities, which give them unique global market opportunities. The successful pursuit of these market opportunities in turn reinforces and advances their unique regional technological capabilities. Regional specialization results from cumulative technological capability development and the unique combinations and patterns of intra- and inter-firm dynamics that underlie enterprise and regional specialization."²

The OTF has succeeded in putting forward a disciplined, market-oriented approach that is tailored to Ohio's areas of specific technology industry strengths and growth opportunities within them. Based on past analyses of Ohio's economy, the broad technology industry sectors of focus have included alternative energy, biomedicine, advanced materials, instruments

² Michael Best, *The New Competitive Advantage*, Oxford University Press, 2001.

and controls, and aerospace and defense, with targeted growth opportunities pursued in medical imaging, cardiovascular, regenerative medicine, sensors, aerospace propulsion, fuel cells, and solar photovoltaics.

With the recent voter approval of continued funding for the OTF, it is critical to update likely industry and technology focus areas in which Ohio has comparative advantage and strong growth prospects over the next 3 to 5 years. Looking toward the future of the OTF, it is particularly important to examine how Ohio's economy has changed since 2002 when the initiative was put in place as well as to consider the significant changes in the overall global and national economic backdrop and markets.

Changing Economic Backdrop for the OTF

When the OTF was enacted in 2002, the U.S. economy was hailed as the world's undisputed leader and was well positioned in a growing global economy. Ohio was seeking to improve its position in this rising tide of economic growth. Today, there is great concern that the U.S. economic successes of the past decade were unsustainable, hiding the reality that our economic competitive strength was being eroded by the rise of a new breed of technology-savvy global competitors.

In a September 2010 update by the members of the highly influential 2005 report from the National Academies, *Rising Above the Gathering Storm*, the unanimous view is that the U.S. outlook in global competitiveness has worsened:

In the five years that have passed since Rising Above the Gathering Storm was issued [in 2005], much has changed in our nation and world...America's competitive position in the world now faces even

*greater challenges, exacerbated by the economic turmoil of the last few years and by the rapid and persistent worldwide advance of education, knowledge, innovation, investment and industrial infrastructure.*³

The rise of a more integrated global economy seems to be unabated even in the aftermath of the recent severe global economic recession. McKinsey & Company in its 2010 survey of business executives reports as follows:

*An ongoing shift in global economic activity from developed to developing economies, accompanied by growth in the number of consumers in emerging markets, are the global developments that executives around the world view as the most important for business and the most positive for their own companies' profits over the next five years.*⁴

Also, serious concerns remain about the pace of the overall U.S. recovery in the aftermath of the most severe economic recession since the Great Depression of the 1930s. Heading into 2012, overall national economic growth prospects continue to be downgraded and job creation is weak.

This makes it imperative for the OTF to focus on near-term growth opportunities for advancing Ohio's economy. The investments of OTF must renew their emphasis on those specific growing markets that Ohio industry can serve over the near term, particularly on a global stage. Ohio's immediate and near-term economic success is even more dependent today than in 2002 on the ability of the OTF to assist and enable existing

³ National Academy of Sciences, *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*, September 2010, page x.

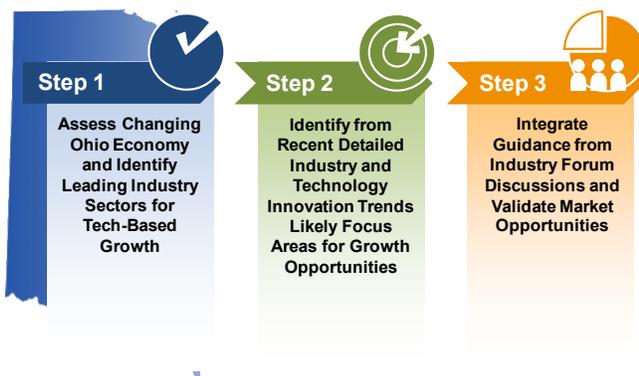
⁴ McKinsey & Company, "Five Forces Reshaping the Global Economy," McKinsey Global Survey, May 2010, page 1.

companies and entrepreneurs to seize likely market innovation opportunities and gain competitive advantages in specific growing global markets.

Approach to Updating Technology Industry Focus Areas for the OTF

A three-step process was undertaken to provide a fact-based, in-depth, and objective analysis of Ohio’s position in likely industry and technology focus areas, with active engagement of a broad set of industry, university, and economic development stakeholders involved in Ohio, including the discussions and guidance from the OTF Advisory Board and industry forum discussions (Figure 1).

Figure 1: Overview of Project Steps



These three steps were as follows:

Step 1: Assessing the changing Ohio economy to identify leading industry sectors for technology-based industry growth. This assessment included a detailed analysis of 25 primary industry sectors in Ohio, representing the “wealth-creating” sectors of the state’s economy involved in exports or substitutes for imported goods and services from outside of the state. Key factors analyzed included industry job and economic output performance, industry innovation and productivity levels, and university

areas of excellence in research and scholarly activity.

Step 2: Identifying likely areas for growth opportunities over the next 3 to 5 years based on a “line-of-sight” analysis considering detailed industry and technology innovation trends. The objective of the line-of-sight analysis was to identify more specific market opportunity areas or market niches for which Ohio is well positioned for growth over the next 3 to 5 years within and across six technology industry sectors. This line-of-sight analysis examined the focus areas of strength in Ohio today based on the most recent detailed industry and technology innovation performance (“where the puck is today”) together with a forward-looking, industry-driven assessment of growth prospects within the technology industry sectors (“where the puck is going”). Twenty-seven potential focus areas were identified by the line-of-sight analysis across the six technology industry focus areas for further consideration.

Steps 3: Integrating guidance from industry forum discussions and further validation based on reviews of market research studies to identify specific recommendations on growth opportunity areas for Ohio. To address “where Ohio is best positioned in growth markets over the next 3 to 5 years,” a series of industry forums targeted to the technology industry sectors were held to gain the insights of leading corporate executives and their partners from research institutions and economic development organizations. At each of these industry forum sessions, potential focus areas based on recent industry and technology innovation performance were presented and discussed with the industry forum participants, who provided specific guidance on growth opportunities for Ohio in the next 3 to 5 years. As a follow-up to these industry forum discussions, market research studies were

reviewed to validate the market potentials of the specific growth opportunities identified by the industry forum participants.

Report Findings

These leading growth opportunity areas were presented to the OTF Commission and Advisory Board for their consideration and approval. As a result, the following eight leading growth opportunity areas were selected in which Ohio is well positioned for industry growth in the next 3 to 5 years:

- **Advanced Materials**
 - *Advanced Polymer materials; Ceramics; Composites; Carbon Fibers and Nanotubes; Specialty Metals and Alloys*
- **Aero-propulsion Power Management**
- **Fuel Cells and Energy Storage**
- **Medical Technology**
 - *Medical Imaging; Surgical Instruments and Equipment; Implant Devices; Regenerative Medicine*
- **Sensing and Automation Systems**
- **Situational Awareness and Surveillance Systems**
- **Software Applications for Business and Health Care**
- **Solar Photovoltaics.**

The Battelle Technology Partnership Practice (TPP) was retained to perform the industry and technology innovation analyses and to facilitate discussions of the OTF Commission and Advisory Board as well as the industry forum participants. Battelle TPP is the technology-based economic development arm of Battelle, the world's largest independent nonprofit research and development (R&D) organization. A leader in developing and advising many of the most successful technology-based economic development programs in the nation, Battelle TPP also has been involved in prior assessment and strategic planning work in Ohio, including an Ohio state economic strategy that informed the formation of the OTF in 2002 and a more in-depth analysis of Ohio's core technology competencies in 2006.

This report sets out the results from this detailed approach to update the technology industry focus areas for the OTF. Each of the following report sections corresponds to the steps of the analysis undertaken.



Assessing Ohio’s Changing Economy and Industry Sectors to Target

It is widely understood by business leaders, economic development professionals, and academic leaders that best practices in economic development must recognize that each state and its regions have a set of target industry sectors in which it can differentiate itself by gaining industry specialization, while also establishing high levels of technological capabilities to support continued innovation and market leadership. ***It is this intersection of industry strengths and technology capabilities that define industry sectors of interest for the OTF.***

From an economic development perspective, it is particularly important to focus on those industry sectors that address the “wealth-creating” sectors of the state’s economy, or what are often referred to as “economic base” or “primary” industries. These primary industries address needs beyond local residents and businesses, and so are involved in either exports or substitute for importing goods and services from outside of the state. Other nonprimary industries are often referred to as local or sheltered economic activity. While they do not generate new economic wealth for the state, these nonprimary industries address local needs and ensure a high quality of life in the state. Typically, these nonprimary industries

include most retail services, physician offices, state and local government, and other services to local residents.

For this reason, two principal questions guided Battelle’s assessment of Ohio’s changing economy:

- *How has Ohio’s primary industry base changed over recent years?*
- *How has the footprint of these primary industries in innovation and productivity evolved in recent years along with the related Ohio university R&D base to these primary industry sectors?*

The focus on changes to Ohio’s industry base relies on more standard regional economic analysis approaches for identifying industry targets involving recent trends on the level of industry specialization, absolute levels of job growth, and gains in job growth relative to the nation. For Ohio, which has a major focus on manufacturing, it is also important to consider not only employment changes but also economic output changes that measure the recent trends in wealth creation of industries for Ohio. In manufacturing, wealth creation can increase, while overall employment may fall. This is a sign

of economic strength not weakness because it means that Ohio’s manufacturing base is becoming more productive and focused on high value goods. This, in turn, supports higher wages and maintains a broader economic multiplier across the supplier base and worker spending, given that much of the competitiveness in manufacturing comes from modernizing production processes to be more automated.

Standard regional economic analysis also often neglects to focus on more “forward-looking” measures of “know-how” or core competencies within different industry sectors and related academic research strengths that align with those industry sectors. From a state economic development perspective, specialized know-how can be identified where there is a “critical mass” of expertise and activities across product development and productivity in industry as well as research activities in universities, hospitals, and nonprofit research centers. As defined by Gary Hamel and C.K. Prahalad in *Competing for the Future*,⁵ a “competence is a bundle of skills and technologies representing the sum of learning across individual skill sets and organizational units.” It is from these specialized areas of know-how in industry and core competencies that gaining a position in a focused area of technology-based economic development can best be realized.

How Ohio’s Primary Industry Base Has Changed in Recent Years

The starting point for considering how Ohio’s primary industry base has changed in recent years is to define the industry sectors that comprise Ohio’s primary industry base.

⁵ G. Hamel and C.K. Prahalad, *Competing for the Future*, Harvard Business School Press: Boston, MA, 1994, pp. 90 and 217.

Battelle took a bottom-up approach to identifying the primary industry sectors in Ohio.

First, Ohio’s primary industries were considered at the most detailed level of industry classification to identify and understand key underlying drivers of the state economy—those industry sectors with a sizable economic footprint of at least 500 jobs in 2009. With this foundation of industry drivers, Battelle then grouped these and other smaller sectors into 25 industry clusters based upon their related markets and integration into supply chains. Altogether, 455 detailed industries were incorporated into the 25 clusters.

In the standard regional economic analysis approach, three basic regional economic measures are used to assess the position of an industry sector for a state:

- **Level of specialization of the industry sector in a state.** *This is a measure of how concentrated an industry sector is in a specific geographic area relative to the nation, and so gauges “competitive advantage” for the industry sector relative to the nation. The specific measurement of specialization is known as a location quotient. A location quotient is the share of a state’s employment or economic output in a particular industry sector divided by the share of total industry employment or economic output in that industry sector for the nation. A location quotient greater than 1.0 indicates a higher level of specialization, whereas a location quotient of less than 1.0 signifies a relative underrepresentation. A location quotient greater than 1.20 denotes employment concentration significantly above the national average, and is considered highly specialized.*

- **Employment/Output changes for industry sector in a state.** This is a more straightforward measure of whether an industry sector is gaining or losing jobs and economic output in a state.
- **Relative growth of industry sector.** This third measure of state trends examines whether a local industry sector is gaining or losing competitive share in employment and economic output compared with the nation. It is measured as the difference between the percentage change in employment and economic output in an industry sector at the state level minus the percentage in employment and economic output in that same industry sector for the nation.

The 2001 to 2009 time period was used to make these comparisons for Ohio. It is important to realize that this broad period encompasses two distinct economic periods. The first period of 2001 to 2007 represents an entire business cycle from peak to peak. The second period from 2007 to 2009 covers the recent recession years and shows how deeply employment and economic output have fallen over the recession. So, putting these two periods together provides a broad understanding of how Ohio has fared over time across an entire business cycle and its following recession period.

Table 1 organizes these standard regional economic analyses over the 2001 to 2009 period for the 25 primary industry sectors across industry employment and industry economic output.

One way to consider the results in industry sector performance is to consider those industries that are highly specialized in Ohio, representing the industry's long-standing presence in the state, and those that are recently emerging.

Ohio has nine highly specialized industry sectors with more than a 50 percent higher level of specialization than the nation in both employment and economic output. All of these nine highly specialized industry sectors are involved in more traditional manufacturing industries, including consumer appliances, consumer products, industry chemicals, polymers and advanced materials, instruments and controls, machinery and equipment, metals, packaging, rubber and plastic products, and transportation manufacturing.

The employment performance across all of these nine highly specialized industry sectors in Ohio is weak, with none of them gaining jobs. However, five of these nine specialized industry sectors are gaining in economic output on an inflation-adjusted basis. These gains in output suggest that the industry remains competitive, though it must find ways to raise productivity and so must reduce jobs in order to do so. By generating higher economic output, these industries are able to contribute to Ohio's economy and particularly to support the established supply chains that serve them. The five highly specialized industry sectors gaining in economic output are as follows:

- **Consumer Appliances**
- **Consumer Products**
- **Machinery and Equipment Manufacturing**
- **Metals**
- **Packaging.**

Table 1: Summary of Primary Industry Position and Trends From 2001–2009 in Industry Employment and Economic Output

| Ohio Primary Industry Cluster | Industry Employment | | | Industry Economic Output | | |
|---|------------------------------|-----------------------------|--|------------------------------|---------------------------------------|--|
| | Level of Specialization 2009 | Percentage Change 2001–2009 | Competitive Share Gain or Loss 2001–2009 | Level of Specialization 2009 | Percent Change (Current \$) 2001–2009 | Competitive Share Gain or Loss 2001–2009 |
| Aerospace | | ✓ | ✓ | | ✓ | |
| Agricultural Chemicals | ✓✓ | | ✓✓ | ✓✓✓ | ✓✓✓ | ✓✓✓ |
| Biosciences Research, Testing and Medical Labs | | ✓✓✓ | ✓✓✓ | | ✓✓✓ | ✓✓ |
| Business Services | ✓✓ | ✓✓✓ | ✓✓ | ✓✓ | ✓✓✓ | ✓✓ |
| Computers and Electronics | | | | | | |
| Consumer Appliances | ✓✓✓ | | | ✓✓✓ | ✓ | |
| Consumer Products | ✓✓✓ | | | ✓✓✓ | ✓ | |
| Commercial R&D and Testing Services (non-Bio) | | | | | ✓ | |
| Energy | ✓ | | ✓ | ✓ | ✓✓✓ | ✓✓✓ |
| Financial Services | | | | | ✓✓✓ | ✓ |
| Food Products | | | | ✓✓ | ✓ | |
| Industrial Chemicals, Polymers and Advanced Materials | ✓✓✓ | | ✓ | ✓✓✓ | | |
| Information Technology | | ✓✓ | ✓ | | ✓ | ✓ |
| Instruments and Controls | ✓✓✓ | | | ✓✓✓ | | |
| Logistics and Transportation Services | ✓ | | ✓ | ✓✓ | ✓✓ | ✓✓ |
| Machinery and Equipment Manufacturing | ✓✓✓ | | | ✓✓✓ | ✓ | |
| Medical Devices | | | | | ✓ | |
| Metals | ✓✓✓ | | | ✓✓✓ | ✓ | |
| Packaging | ✓✓✓ | | ✓ | ✓✓✓ | ✓ | ✓ |
| Pharmaceuticals | | ✓✓ | ✓✓ | | ✓✓✓ | |
| Publishing and Printing | ✓ | | ✓ | ✓✓ | | ✓ |
| Pulp and Paper Mills | | | | | | |
| Rubber and Plastic Products | ✓✓✓ | | | ✓✓✓ | | |
| Transportation Manufacturing | ✓✓✓ | | | ✓✓✓ | | |
| Wood Products | | | | ✓ | ✓ | |

Scoring: ✓✓✓ >1.5 ✓✓✓ >25% ✓✓✓ >40% ✓✓✓ >1.5 ✓✓✓ >50% ✓✓✓ >40%

✓✓ >1.2 but <1.5 ✓✓ >10% but <25% ✓✓ >10% but <40% ✓✓ >1.2 but <1.5 ✓✓ >25% but <50% ✓✓ >10% but <40%

✓ >1.0 but <1.2 ✓ >0% but <10% ✓ >0% but <10% ✓ >1.0 but <1.2 ✓ >0% but <25% ✓ >0% but <10%

At the same time, the following five emerging industry sectors are not yet highly specialized, but are growing in employment and economic output, and often outpacing national growth:

- ***Aerospace***
- ***Biosciences Research, Testing and Medical Labs***
- ***Business Services***
- ***Information Technology***
- ***Pharmaceuticals.***

How Innovation and Productivity for Primary Industries Stand

There is no single source of information sufficient to identify how well positioned an industry sector stands in the breadth and depth of its core technology competencies. Instead, the following specific measures should be considered:

Patent activity of firms in the industry sector:

Patents represent the intellectual property owned by companies. Through patents, many companies are able to protect their innovations in products from being replicated. To learn the extent of patent activity generated by Ohio companies, Battelle identified Ohio-invented patents held by firms based in Ohio and crosswalked those firms into industry sectors based on their industry classifications reported in Hoover’s database of firms.

Presence of innovative emerging venture capital or SBIR-backed companies: Innovation is often brought forward through emerging high growth potential companies. A good way to understand whether an industry sector possesses such companies is to examine the extent of emerging companies that have received venture financing or federal Small Business Innovation Research (SBIR) funding in recent years. Both venture financing and SBIR funding target innovation that

has potential to be commercialized and reach the marketplace. Battelle used venture financing reported by VentureOne and SBIR funding reported by the Small Business Administration.

Level of productivity: Industry technology competencies are more than just advancing new products and processes. Just as critical, if not as widely heralded, is the ability of industry to “put technology to work.” To assess Ohio’s position in technology deployment, industry productivity data—output per employee—was analyzed to see how well the 25 primary industry sectors in Ohio compare with the United States overall. Higher productivity suggests more effective deployment of technologies as well as an ability to produce more complex, higher-value products. Battelle calculated productivity from data on employment and value-added economic output reported for industries in Ohio and the United States by IMPLAN.

Publications activity: Publications in peer-reviewed journals is a key indicator of scholarly activity, typically led by universities and nonprofit research organizations in a state. Two measures of publications activity capture how specific fields of research stand out within the universities of a state. One is the share of U.S. publications, which measures level of activity, and the other is the state’s level of citations per publication compared with the U.S. average for that field, which offers a perspective on the quality of publications generated. Both of these measures are provided by Thomson Reuters’ University Science Indicators database that tracks major university and medical center publications activity across well over 200 discrete research fields associated with specific peer-reviewed journals.

Table 2 organizes these innovation and productivity measures for the 25 primary industry sectors.

Table 2: Summary of Primary Industry Position and Trends From 2001–2009 in Innovation and Productivity

| Ohio Primary Industry Cluster | Industry-Held Patents Invented in Ohio 01/07 to 09/10 | Presence of Venture-Backed and SBIR-Funded Companies 2006–2010 | Level of Productivity for Industry Relative to U.S. Average 2009 | Publications Activity |
|---|---|--|--|-----------------------|
| Aerospace | ✓✓✓ | ✓ | ✓✓ | ✓✓✓ |
| Agricultural Chemicals | | | | |
| Biosciences Research, Testing and Medical Labs | ✓ | ✓✓ | | ✓✓✓ |
| Business Services | ✓ | ✓ | | |
| Computers and Electronics | ✓✓✓ | ✓✓ | | ✓ |
| Consumer Appliances | ✓✓ | ✓ | ✓ | ✓ |
| Consumer Products | ✓✓✓ | ✓ | | |
| Commercial R&D and Testing Services (non-bio) | ✓✓ | ✓✓✓ | | ✓ |
| Energy | ✓ | ✓✓ | | ✓✓✓ |
| Financial Services | ✓ | ✓ | | |
| Food Products | ✓ | ✓ | ✓✓✓ | |
| Industrial Chemicals, Polymers and Advanced Materials | ✓✓✓ | ✓✓✓ | | ✓✓✓ |
| Information Technology | ✓✓ | ✓✓✓ | | |
| Instruments and Controls | ✓✓✓ | ✓✓✓ | | ✓ |
| Logistics and Transportation Services | ✓ | ✓ | | ✓✓ |
| Machinery and Equipment Manufacturing | ✓✓✓ | ✓ | | ✓ |
| Medical Devices | ✓✓✓ | ✓✓✓ | | ✓✓✓ |
| Metals | ✓✓ | ✓ | ✓ | ✓ |
| Packaging | ✓✓ | | ✓ | ✓ |
| Pharmaceuticals | ✓ | ✓✓ | | ✓✓✓ |
| Publishing and Printing | ✓ | ✓ | | |
| Pulp and Paper Mills | ✓ | | | ✓ |
| Rubber and Plastic Products | ✓✓✓ | | | ✓ |
| Transportation Manufacturing | ✓✓ | ✓ | | ✓✓ |
| Wood Products | | ✓ | | |

Scoring: ✓✓✓>400 ✓✓✓>50 ✓✓✓>15% ✓✓✓ At least 1 field being high share and high citation
 ✓✓ >100, but <400 ✓✓ >10, but <50 ✓✓ >10, but <15%
 ✓ >0, but <100 ✓ >0, but <10 ✓ >0, but <10% ✓✓ At least 1 field being high citation and at least 1 field being high share
 ✓ Only having fields being either high share or high citation

From the analysis, a grouping emerges of primary industries into several performance categories:

High Innovation Industries in Ohio: Several industries emerged as driving forces in Ohio’s innovation landscape. These industries are characterized by a large volume of activity across innovation metrics. Ohio’s highly innovative industries include the following:

- *Aerospace*
- *Industrial Chemicals, Polymers and Advanced Materials*
- *Instruments and Controls*
- *Medical Devices.*

Moderate Innovation Industries in Ohio: Ohio’s moderately innovative industries are marked by strengths in specific categories of innovation or moderate strength in two or more areas, but are not as robust across multiple innovation metrics. Within this category, the innovation ecosystem is not as deep and interconnected as for highly innovative industries. Moderately innovative industries include the following:

- *Biosciences Research, Testing and Medical Labs*
- *Computers and Electronics*
- *Commercial R&D and Testing Services*
- *Consumer Products*
- *Energy*
- *Food Products*
- *Information Technology*
- *Machinery and Equipment*
- *Metals*
- *Pharmaceuticals*
- *Rubber and Plastics Products*
- *Transportation Equipment.*

Low Innovation Industries in Ohio: Out of the 25 primary industry sectors, eight were characterized by low levels of innovation within Ohio. Many of them are not traditionally considered highly innovative because they have not made the transition to more commoditized goods. Ohio’s low innovation industry sectors are as follows:

- *Agricultural Chemicals*
- *Business Services*
- *Financial Services*
- *Logistics and Transportation Services*
- *Packaging*
- *Publishing and Printing*
- *Pulp and Paper Mills*
- *Wood Products.*

Identifying Ohio’s Leading Industry Sectors for Technology-Based Industry Growth

Bringing together the performance analyses of industry and technology innovation, the OTF Commission and Advisory Board considered the 25 primary industries. The deliberations by the OTF Commission and Advisory Board focused on how best to link those industry sectors that excel in industry specialization and growth and have ties to where Ohio possesses strengths in technology innovation. The result of this deliberation was the identification of six broader industry sectors that typically represent a combination of the 25 primary industry sectors. These six broad industry sectors are as follows:

- *Aerospace*
- *Biomedical*
- *Diversified Materials Industries*
- *Energy*

- *Information Technology*
- *Instruments, Controls and Electronics.*

Aerospace Industry Sector

The aerospace and defense sector is emerging in Ohio, growing in jobs and economic output, while outpacing the nation in job growth. Historically, Ohio has been home to many innovations in aerospace and aviation, including powered aviation, high-bypass turbine engines, ion thrusters, and hydrogen rockets. Traditionally, aircraft engines have dominated the aerospace industry; but, other detailed aerospace industries are gaining strength in Ohio, including search and navigation. Also, aerospace innovation growth areas are increasingly aligning with other areas of Ohio's industry strengths, such as advanced materials, sensors, and instruments and controls.

Biomedical Industry Sector

The broad biomedical industry sector brings together several closely related primary industries focused on products and services to address human health, including biosciences research, testing and medical labs; medical devices; pharmaceuticals; and medical, dental, and hospital equipment and supply wholesaling. Together, this broad biomedical industry sector reached 29,292 jobs in 2009 and grew nearly 15 percent from 2001 to 2009. But, it is far from specialized in its concentration of employment and economic output in Ohio, suggesting that there is room to grow in the future.

Another link in this broader biomedical industry sector is the importance of biotechnology breakthroughs in reshaping all aspects of biomedical development, ranging from the way we study medicine, discover and develop therapeutics, design medical devices, and diagnose and treat diseases and medical conditions, to the need to integrate advances in

information technology, sensing and automation, and advanced materials to offer innovative new medical products and services.

Diversified Materials Industry Sector

Ohio has a broad and rich tradition encompassing a wide variety of materials processing and related product segments-ranging from steel production to tire production to plastic products and beyond. The OTF Commission and Advisory Board decided to consider the primary industry sectors focused on materials together, given the increasing need for integrated material solutions and the highly overlapping nature of technology innovation advances across various materials.

Bringing together the three primary industries of industrial chemicals, polymers and advanced materials; metals; and rubber and plastic products represents a very sizable broad industry sector with nearly 150,000 jobs in Ohio. Although employment decreased by 14.5 percent during the expansion years across the broad materials industry sector, economic output increased by 31 percent, suggesting its overall competitiveness.

Energy Industry Sector

In consultation with the OTF Commission and Advisory Board, it was recognized that traditional energy industries are just one component of the overall energy industry sector in Ohio. The emergence of the renewable energy sector is harder to measure because it is not separately identified in established industry classifications. The analysis does illustrate that the energy industry sector excels in technology innovation with strengths in university activities and emerging growth companies.

Combined with Ohio's more traditional energy sector involving power generation, transmission, and distribution, which are distinguished in

growing economic output but are not adding substantial new jobs, the emerging renewable industries in Ohio offer an important new source for job generation. With early insights from Battelle’s work with The Brookings Institution on developing a unique detailed national database of renewable energy firms for the *Sizing the Clean Economy* study, which was formally released in September 2011, Ohio’s strengths in the renewable energy industries on a comparable national scale were able to be considered.

Information Technology Industry Sector

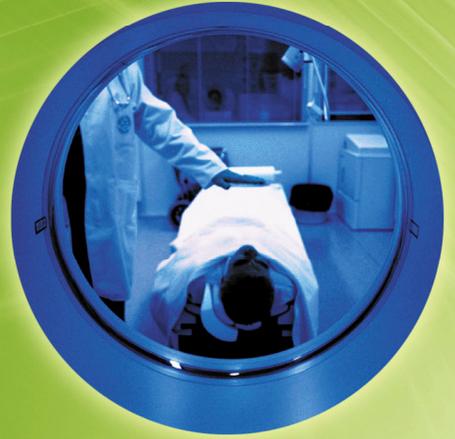
Ohio’s information technology sector has undergone impressive growth since 2001, adding jobs and generating higher economic output, at levels above the overall nation. In addition, information technology stands out in patent generation and presence of emerging growth companies in Ohio.

There is also a strong embedded nature to information technology in Ohio. It is critical to supporting the growth of Ohio’s diverse industry base from business services to financial services to corporate headquarters and administrative services to manufacturing operations.

Instruments, Controls and Electronics Industry Sector

Ohio’s instruments and controls sector is highly specialized in both employment and economic output, though it did not grow over the 2001 to 2009 period. This industry sector was considered by the OTF because of its importance in high-technology solutions for a wide range of markets served by Ohio industries and the high level of capacity in technology innovation for instruments and controls found across Ohio’s industry and university base. Technological advances in instruments and controls are driving new opportunities for growth based on improvements

in sensing and automation that are critical for more advanced solutions in aerospace, biomedical, energy, and information technology products and services. The instruments and controls sector is a leader in patents and emerging growth companies in Ohio and has an active base of university research and scholarly activity.





Line-of-Sight Analysis of Growth Opportunities for Ohio

To consider the likely future growth opportunities in technology-based industries for Ohio over the next 3 to 5 years, this study sets out a “line-of-sight” analysis. The objective of this analysis is to identify more specific market opportunity areas or market niches for which Ohio is well positioned for future growth over the next 3 to 5 years within and across six technology industry sectors.

This line-of-sight analysis examines the focus areas of strength in Ohio today based on the most recent detailed industry and technology innovation performance (“where the puck is today”) together with a forward-looking, industry-driven assessment of growth prospects within the technology industry sectors (“where the puck is going”) (Figure 2).

Figure 2: Line of Sight to Growth Opportunities Within and Across Ohio’s Leading Technology Industry Sectors



This line-of-sight analysis was applied to the following six technology industry sectors that are distinguished as economic drivers for Ohio and prime focus areas for the OTF’s efforts:

- **Aerospace**
- **Biomedical**
- **Energy**
- **Information Technology**
- **Instruments and Controls**
- **Materials.**

Where the Puck is Today

To address the focus areas of growth based on recent industry and technology innovation performance within these six major technology-based industry sectors in Ohio, several key analyses were completed:

- **Detailed industry-level analysis of specific product and service focus areas in Ohio to identify the drivers of major technology industry sector growth in Ohio.** Examining the most detailed level of industry classification available for each major technology industry sector offers insights into the specific industry drivers of growth and the evolution of Ohio’s major technology industries across specific product and service

focus areas over time.⁶ (See Appendix A for a listing of these detailed industries for the six major technology industry sectors).

The line-of-sight analysis focused on those detailed industries that stand out as growth drivers in one of three categories:

- Current industry strength, where a detailed industry is specialized in Ohio, growing jobs and outpacing national growth over the 2001 to 2009 period.
 - Emerging industry strength, where a detailed industry is not yet specialized in Ohio, but did grow jobs over the 2001 to 2009 period.
 - Specialized industry strength, where a detailed industry stands out in its level of existing employment in Ohio compared with the nation (at least 20 percent higher concentration of private sector jobs than the nation), but did not grow in jobs over the 2001 to 2009 period.
- **Technology innovation focuses and trends related to each of the six major technology industry sectors.** Measures of technology innovation offer insights into where the know-how exists for growth. There is no single measure of technology innovation, so several perspectives were considered for each major technology industry sector:
 - Focus areas of recent patent activities of Ohio inventors associated with each major technology industry sector.
 - Presence of companies in specific technology product markets, based on

the technology business database maintained by CorpTech.

- Presence of innovative, emerging technology firms, based on firms receiving venture capital funding between 2006 and 2010 or SBIR grants.
- Focus of scholarly excellence in Ohio based on performance of Ohio in peer-reviewed publications analysis.
- Trends in university research funding in research fields closely related to each major technology industry sector.

Where the Puck is Going

To address “where Ohio is best positioned in growth markets over the next 3 to 5 years,” a series of industry forums targeted to the technology industry sectors were held to gain the insights of leading corporate executives and their partners from research institutions and economic development organizations.⁷ Among the key questions addressed by the industry forum participants were the following:

- What are Ohio’s key selling points?
- What are the key market niches and technology developments that will drive growth in a specific technology industry sector?
- What are the specific markets in which Ohio is well positioned for industry growth in the next 3 to 5 years?

⁷ These industry forums were held for advanced energy, advanced materials, biomedical, information technology, and instruments and controls. In lieu of an industry forum, Battelle referred to the *Ohio Targeted Industry Development Aerospace Recommendations* report completed in December 2010 by the Ohio Aerospace & Business Aviation Advisory Council to gain insight into Ohio’s position in the aerospace market. In several cases, key industry participants unable to make the industry forum meeting were consulted in separate interviews with the Battelle project team.

⁶ These detailed industries are the six-digit-level industries found in the North American Industry Classification System (NAICS).

- *What are key strategic development directions that Ohio must address in this niche from a technology development and broader economic development perspective?*

The Battelle project team, in consultation with the Technology Development Division of the Ohio Department of Development and the OTF Advisory Board, then integrated the intelligence on potential focus areas based on recent industry and technology innovation performance with the guidance from the industry forums to identify specific growth opportunities for Ohio. As part of this effort, Battelle also surveyed market research studies to validate the market potentials of these growth opportunities.

For each of the six leading technology industry sectors, a profile was developed to present the key findings of this line-of-sight analysis.

AEROSPACE AND DEFENSE LINE OF SIGHT

Where the Puck is Today: Focus Areas From Recent Trends and Performance

Highlights of Detailed Industry-Level Focus Areas

Two emerging strengths appear at the detailed industry level in aerospace and defense:

- *Other Aircraft Parts and Auxiliary Equipment Manufacturing*
- *Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing.*

Employment in the other aircraft parts and auxiliary equipment manufacturing sector grew 2.6 percent from 2001 to 2009, with the majority of jobs added during the recession years from 2007 to 2009. The search, detection, navigation, guidance, aeronautical, and nautical system and instrument manufacturing detailed industry

added jobs during both the expansion and recession years, increasing employment 640 percent from 2001 to 2009, albeit starting from a small employment base. Although employment growth in both of these detailed industry sectors outpaced the United States, neither has become specialized based on employment concentration.

Highlights of Technology Innovation-Driven Focus Areas

Innovation in Ohio's aerospace industry is marked by patent activity, industry presence, and the level and excellence in scholarly publications.

- *Ohio's aerospace-related patents are concentrated in five classes: power sources/plants (147), rotary kinetic fluid motors (83), stock material (71), fluid reaction surfaces (68), and metalworking (30).*
- *Leading aerospace companies have developed a concentration in several technology product markets: major aircraft systems, ground support equipment, and air/spacecraft propulsion.*
- *Analysis of Ohio's scholarly publications activity shows multiple fields in which Ohio has achieved excellence: aerospace engineering, mechanical engineering, composites, and remote sensing.*

Where the Puck is Going

Why Ohio?

Based on the report, *Ohio Targeted Industry Development Aerospace Recommendations*, by the Ohio Aerospace & Business Aviation Advisory Council, Ohio was viewed as having a competitive location for the aerospace industry based on the following:

- Existing aircraft engine manufacturing and development industry
- A strong presence in military aeronautics acquisition and R&D with the presence of Wright-Patterson Air Force Base, Air Force Research Laboratory (AFRL), and Air Force Material Command
- The broad, deep presence of firms in the aerospace supply chain
- An extensive base of federal R&D facilities in Ohio related to aerospace, including the National Aeronautics and Space Administration (NASA), AFRL Materials and Manufacturing Directorate and Sensor Directorate, aerospace and human performance research facilities, and propulsion testing facilities
- Significant business aviation industry presence with NetJets, Flight Options, and General Electric (GE) Aviation.

Growth Opportunities for Ohio Over Next 3 to 5 Years

- **The guidance from the Ohio Aerospace & Business Aviation Advisory Council targeted a lead pure-play growth opportunity in aero-propulsion power management over the next 3 to 5 years.** This growth opportunity is confirmed by the data on industry specialization, patent activity, and publication strengths. Aero-propulsion power management is a historical strength in Ohio serving a spectrum of end-user markets such as military and defense, commercial aviation, business aviation, and even unmanned aerial vehicles. Aero-propulsion power management takes advantage of Ohio's strengths in advanced materials and sensors and is grounded by the presence of industry leader GE Aviation as well as many research strengths.

Several other important growth opportunity areas for the aerospace and defense industry sector are noted by the Ohio Aerospace & Business Aviation Advisory Council, which more appropriately fall into other technology industry focus areas. This reveals the important market that aerospace and defense plays in Ohio and the convergence of technologies needed to serve markets. These crosscutting growth opportunity areas include the following:

- Unmanned aerial systems, particularly focused on Ohio's strengths in situational awareness and surveillance systems which utilize unmanned vehicles as a platform and then offer highly integrated solutions spanning sensors, sensor and data processing, communications, and decision support.
- Advanced Materials, particularly in composites and carbon fiber for air frames. Of particular note is the ability to promote transitions of scalable advanced materials to the aerospace industry as well as the ability to engage Ohio's broad supply chain in advanced materials.
- Sensors, which also are critical inputs into situational awareness and surveillance systems, and involve key federal research drivers at the AFRL Sensors Directorate at Wright-Patterson Air Force Base and at NASA Glenn.

Identified Strategic Development Approaches for Ohio

The Ohio Aerospace & Business Aviation Advisory Council identified key strategic development approaches that would enable Ohio to realize its potential in the aerospace industry sector.

Strategic Technology Development Approaches for Ohio

- *Commercialization efforts would benefit from improved technology transfer involving federal laboratories and universities, particularly in sensors, propulsion, platforms, and human factors.*
- *The availability of talent is a concern as much of the engineering and technical workforce in the aerospace industry is approaching or has reached retirement age.*

Broader Strategic Economic Development Approaches for Ohio

- *Overcome the negative perception of labor-management relations that limits Ohio's ability to attract new players in the aerospace industry.*
- *Play a role in helping local companies maintain global competitiveness in aerospace manufacturing costs.*

BIOMEDICAL SECTOR LINE OF SIGHT

Driven by the strong employment growth over the 2001 to 2009 period, along with the importance of biotechnology breakthroughs in reshaping all aspects of biomedical development from the way we study medicine, discover and develop therapeutics, design medical devices, and diagnose and treat diseases and medical conditions, it is not surprising that an analysis of Ohio's biomedical sector suggests many areas of possible development from the most recently available trends and performance.

Where the Puck is Today: Focus Areas From Recent Trends and Performance

Highlights of Detailed Industry-Level Focus Areas

Six detailed industries well outpaced national growth over the 2001 to 2009 period, and even added jobs through the recent economic recession years of 2007 to 2009. But, each of these detailed industries is still emerging in Ohio, and its share of private industry employment in Ohio lags well behind the national average share for that industry. These include the following:

- **Medical, Dental and Hospital Equipment Wholesalers**
- **Medical Labs**
- **Biosciences R&D**
- **Pharmaceutical Preparations**
- **Dental Equipment and Supplies Manufacturing**
- **In Vitro Diagnostic Substance Manufacturing.**

Other notable detailed biomedical industries in Ohio include the following:

- **Medical, Dental and Hospital Equipment Wholesalers**—With 7,622 jobs, it is Ohio's largest detailed biomedical industry. It grew by 26 percent over the 2001 to 2009 period and is 4 percent more specialized than the nation.
- **Surgical Appliance and Supplies Manufacturing**—With 4,937 jobs in Ohio in 2009, it is distinguished as the only detailed biomedical industry in Ohio that is specialized in its share of employment, with a 27 percent higher employment concentration than the nation. This industry, however, lost 9 percent of its jobs over the 2001 to 2009 period, while the nation gained employment by 9 percent.

- **Life Sciences Testing Labs**—A small industry in Ohio with 558 jobs in 2009, but it has doubled in size since 2001 and stands 14 percent more specialized than the nation.

Highlights of Technology Innovation-Driven Focus Areas

The biomedical industry is noted for the depth and pace of its research and innovation activities. In Ohio, the biomedical sector has a rich base of technology innovation activities across patents, venture capital financing, and scholarly activity.

- **Patents:** *The biomedical industry sector held the largest number of patents of the six leading technology industry sectors analyzed in depth.*
- **Venture Financing:** *Over 24 percent of Ohio’s total venture financing is found in the biomedical sector. Numerous focus areas have 10 or more companies*
- **Scholarly Activity:** *Medical science is the largest area of university research, standing at 40 percent of Ohio’s \$1.9 billion university research base in 2009, and growing robustly with Ohio outpacing the nation. Not surprisingly, more than 40 biomedical fields of peer-reviewed publications stand out in excellence for Ohio statewide on either share of U.S. publications or quality based on citations per publication. In addition, many specific institutional strengths are found across academic medical centers in Ohio.*

Where the Puck is Going

Why Ohio?

The industry forum participants for the biomedical sector were very optimistic about Ohio’s ability to continue to grow jobs in the biomedical sector based on a compelling set of strengths in Ohio:

- *Existing base of Ohio businesses, including many multinational firms. Of note are Philips Medical Systems, GE Healthcare, Hitachi Medical Systems, Siemens Medical Solutions, and Toshiba Medical Systems.*
- *Outstanding clinical research infrastructure, with name “brand” academic health centers and three centers for translational sciences supported by the National Institutes of Health (NIH).*
- *Sizable and growing research base that extends across the regions of Ohio. In overall medical sciences, Ohio universities increased their research base by a hefty 87 percent from 2003 to 2009, compared with only 43 percent nationally.*
- *Integration with advanced materials and manufacturing base. Ohio offers a high-density and high-value supply chain for biomedical products.*
- *Experienced technical workforce, able to design, engineer, and produce complex biomedical products.*

Growth Opportunities for Ohio Over Next 3 to 5 Years

The guidance from the industry forum discussion on the biomedical sector identified *Medical Technology* as the leading area of focus in biomedical development for growth over the next 3 to 5 years. It is highly integrative with new “systems” approaches for advancing more functional medical products that combine the capabilities in Ohio. Increasingly, the industry forum participants noted that the key to success for Ohio is to link its broad capacities in medical technology with a specific disease area, whether cardiovascular, diabetes and obesity, cancer, or orthopedics.

A growth opportunity area involving technology convergence with information technology to serve the biomedical marketplace is *Health Informatics*. This growth opportunity area leverages Ohio’s strengths in developing business process software applications, while also building upon the expertise found across Ohio’s leading medical centers and is a key focus of the state’s three NIH-funded Clinical and Translational Science Institutes. Already, Ohio is among the most active states on health information exchanges, providing a key enabling infrastructure for innovative health informatics to move forward in Ohio.

The industry forum participants also provided insights into other potential growth opportunity areas in biomedical development in which Ohio is less well positioned or which are just emerging in Ohio, including the following:

- ***Molecular and Other In-Vitro Diagnostics***—Possible opportunity to access university technologies on biomarkers/reagents. But, Ohio is not distinguished—is not seen as having a competitive advantage.
- ***Contract Research and Manufacturing Support***—Contract research for clinical trials viewed as a commodity market in which Ohio does not stand out. A possible approach for Ohio to advance in this growth opportunity is to create stronger connections between contract research organizations and universities. It was also noted that, even if Ohio is not distinguished in contract research for clinical trials, this is an area that can create jobs in short time frames. In contract manufacturing, Ohio is not viewed as having a sufficient base of biologics strengths for use in high growth opportunities in this area.
- ***Drug Delivery and Development***—Ohio’s lack of sizable venture capital firms to lead the

formation and growth of new firms involved in drug delivery and development is a major weakness that is hard to overcome and limits the growth potential of this opportunity for Ohio. There is a potential for specialty pharmaceutical companies to leverage Ohio’s strength in advanced materials in both polymer-based and nanomaterial advances in drug delivery.

- ***Cell Therapeutics***—Ohio’s primary focus is on addressing diseases through the application of adult stem cell technologies, which are closer to market than embryonic stem cells. While a few companies are growing in Ohio, this area is still emerging and very competitive nationally.

Identified Strategic Development Approaches for Ohio

The industry forum participants identified key strategic development approaches that would enable Ohio to realize its potential in the biomedical industry sector.

Strategic Technology Development Approaches for Ohio

- ***Need for stronger connections between industry and the state’s strong clinical infrastructure*** to further market-driven product innovations as well as to test new medical products.
- ***Significant gap between NIH funding and having a commercially viable product.*** Calls for more focused funding on translational research infrastructure (prototyping centers, drug development centers, etc.) and support mechanisms to connect with emerging and established industry. A major opportunity exists with the formation of the new NIH institute for translational sciences to build off of the presence of the state’s three

NIH-supported Clinical and Translational Research Institutes.

- **Talent gaps in Ohio for biomedical fields.** *Lack of depth in biologics, level of graduate students lagging other states, and connection to engineering talent for biomedical firms lagging other states.*

Broader Strategic Economic Development Approaches for Ohio

- **Accelerate reaching critical mass of biomedical companies in regions across the state.** *Ohio is seen as a highly competitive location for biomedical development as confirmed by its strong growth trends, but it needs to be more aggressive in reaching a more critical size across the regions of the state. This approach calls for more proactive marketing and increased focus on ensuring that recent start-up firms have access to follow-on venture financing.*
- **Address concern that venture capital in Ohio is not well positioned to support high-growth biomedical start-ups,** *particularly in the biopharmaceutical area.*

DIVERSIFIED MATERIALS INDUSTRIES SECTOR LINE OF SIGHT

Where the Puck is Today: Focus Areas From Recent Trends and Performance

Highlights of Detailed Industry-Level Focus Areas

Several detailed industry sectors are driving growth in materials with a higher employment concentration in that industry than the national average, growing employment and gains in the national share of employment from 2001 to 2009. These detailed industries representing

Ohio's current materials strengths include the following:

- **Plastics Material and Resin Manufacturing**
- **Urethane and Other Foam Product (except Polystyrene) Manufacturing**
- **Gum and Wood Chemical Manufacturing**
- **Metal Tank (Heavy Gauge) Manufacturing**
- **Nonferrous Forging**
- **Power Boiler and Heat Exchanger Manufacturing**
- **Nonferrous Metal (Except Copper and Aluminum) Rolling, Drawing, and Extruding**
- **Saw Blade and Handsaw Manufacturing**
- **Enameled Iron and Metal Sanitary Ware Manufacturing.**

A set of emerging strengths have also come into focus as opportunity areas; these industries have experienced employment growth and gained in share of national employment, but have not yet achieved employment concentration levels well above the national average share for that industry. These following emerging strengths increased employment from 2001 to 2009:

- **Polystyrene Foam Product Manufacturing,** *increased employment 30.5 percent*
- **Alkalies and Chlorine Manufacturing,** *increased employment 0.3 percent*
- **Explosives Manufacturing,** *increased employment 14.1 percent*
- **Hardware Manufacturing,** *increased employment 5.3 percent*
- **Other Aluminum Rolling and Drawing,** *increased employment 249.5 percent.*

Highlights of Technology Innovation-Driven Focus Areas

The materials industry in Ohio is assisted by a rich innovation environment as evidenced by the

presence of high-technology firms, venture capital, and SBIR awards.

- *Industry-held patents invented in Ohio in the broad materials sector stood out in four key areas: synthetic resins (170), material composites (67), solid antifriction materials (36), and coatings (25).*
- *Eleven companies received \$98.5 million in venture capital financing from 2006 to 2010; \$85.3 million was invested in three advanced chemical companies, \$6.2 million in two coatings firms, \$3.3 million in two polymer companies, \$2.4 million in two ceramics and composites companies, and \$1.3 million in one company in other specialty materials.*
- *Forty-five Ohio materials companies received 301 Phase I and Phase II SBIR awards from 2006 through 2010. Leading focus areas were ceramics and composites with 14 companies and \$31.7 million, coatings with 11 companies and \$16.2 million, and polymers with six companies and \$4.3 million.*

Where the Puck is Going

Why Ohio?

The industry forum participants for the materials sector saw Ohio as having a competitive location for materials based on the following:

- *Outstanding supplier “value chain” in Ohio and across all materials industries*
- *Exceptional innovation base with significant strengths in development and materials analysis across multiple universities within the state*
- *Considerable presence of end-use industries within Ohio*

- *Strong and engaged base of industry organizations creating a “connective” fabric in Ohio.*

Growth Opportunities for Ohio Over Next 3 to 5 Years

Consider advanced materials from a broad technology and market application focus: Ohio’s advanced materials sector should not be viewed by class of material, such as polymers or composites, but instead should be considered from the viewpoint of market applications. Based on this perspective, the growth opportunity builds upon the broad range of advanced materials already in Ohio, addresses market requirements for the industry, and then focuses on specific market applications for materials both within and outside of Ohio.

Identified Strategic Development Approaches for Ohio

The industry forum participants identified key strategic development approaches that would enable Ohio to realize its potential in the materials industry sector.

Strategic Technology Development Approaches for Ohio

- *OTF needs to operate on a real-world business schedule in order to capitalize on opportunities in large company development projects. An open request for proposal (RFP) process that is available as opportunities arise is needed.*
- *Ohio needs a targeted focus on entrepreneurial development in advanced materials. New ventures in advanced materials have specific requirements that must be recognized in the state’s approach to entrepreneurial development. The state’s approach should*

focus on common services, SBIR support, business partnering, scale-up, etc.

- *There is a need to better connect Ohio innovations in advanced materials to Ohio industry customers. Industry players are calling for more scale-up and demonstration facilities. The focus here should be on “de-risking” the adoption of advanced materials solutions.*
- *Difficulties with contracting and technology transfer processes are resulting in diminished industry support to universities. There is a need for more “template” agreements between industry and universities.*

Broader Strategic Economic Development Approaches for Ohio

- *Encourage competitive manufacturing costs relative to the rest of the world. Consider ways to reward those who seek to pursue the manufacturing of innovations made in Ohio.*
- *Emphasize recruitment of emerging innovative advanced materials companies to Ohio. Ohio stands out in its support of advanced materials making it an attractive location for businesses looking to move or expand operations.*

ENERGY INDUSTRY SECTOR LINE OF SIGHT

Where the Puck is Today: Focus Areas From Recent Trends and Performance

Highlights of Detailed Industry-Level Focus Areas

At the detailed industry level, Ohio has many emerging strengths pointing to opportunities for further development. **Five detailed industries added jobs between 2001 and 2009 in addition to outpacing national growth during the same time frame.** However, all five detailed industries

are still emerging opportunities, and as such have a share of private industry employment far below that of the national average. Ohio’s emerging energy industry sectors are as follows:

- **Electric Power Distribution**
- **Nuclear Electric Power Generation**
- **Power, Distribution, and Specialty Transformer Manufacturing**
- **Other Electric Power Generation**
- **Semiconductor and Related Device Manufacturing.**

Ohio has specialized employment in the following four detailed industry sectors, although none of them added employment from 2001 to 2009:

- **Ball and Roller Bearing Manufacturing**
- **Electric Bulk Power Transmission and Control**
- **Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing**
- **Mechanical Power Transmission Equipment Manufacturing.**

Understanding the dynamics of Ohio’s advanced energy industry is critical to furthering development within the energy industry. Brookings and Battelle recently developed a comprehensive database of renewable companies in “Sizing the Clean Economy,” which allows the ability to measure employment and establishment levels in the individual renewable segments. Based on these data, Ohio is distinguished in the following segments:

- **Smart Grid Systems/Smart Metering—** 5.2 percent of U.S. employment, 8.6 percent of U.S. establishments
- **Fuel Cells/Hydrogen—** 9.8 percent of U.S. employment, 8.4 percent of U.S. establishments
- **Solar PV (including installers)—** 1.6 percent of U.S. employment, 5.6 percent of U.S. establishments

- **Energy Storage/Batteries**—5.7 percent of U.S. employment, 5.3 percent of U.S. establishments
- **Wind**—1.9 percent of U.S. employment, 2.6 percent of U.S. establishments
- **Biofuels/Biomass**—3.5 percent of U.S. employment, 2.3 percent of U.S. establishments.

Highlights of Technology Innovation-Driven Focus Areas

Among innovation factors, Ohio's energy industry stands out in venture capital investment activity:

- *Between 2006 and 2010, seven energy companies received \$26.6 million in venture capital investments. Investments were not concentrated in any single area, but were spread across fuel cells, batteries, biofuels, energy management, and solar photovoltaics.*

Where the Puck is Going

Why Ohio?

The industry forum participants for the energy sector saw Ohio as having a competitive location for energy based on the following:

- *Ohio's supply chain is a major selling point as it allows for innovative solutions to be assembled more quickly and at reduced costs.*
- *Ohio's strength in materials R&D is critical to advancing innovative energy applications.*
- *Forward-thinking utility companies have a presence in Ohio.*
- *Leading companies are present in specific niche areas such as Energizer Battery for batteries, Rolls-Royce for fuel cells, Parker Hannifin for wind turbine controls, Timken for wind turbine bearings, and Battelle for smart grid technologies.*

Growth Opportunities for Ohio Over Next 3 to 5 Years

The discussions with the industry forum participants identified two growth opportunity areas for Ohio in advanced energy markets for the next 3 to 5 years:

- **Solar Photovoltaics.** *Ohio's most significant opportunities in solar photovoltaics in the next 3 to 5 years are in base load solar using thin-film technology in which Ohio's leading firm, First Solar, currently holds a 90 percent market share. Ohio also is distinguished in building-integrated photovoltaics (BIPV) solutions that incorporate PV modules into building materials such as curtain walls, windows, and roofing and can be a principal or ancillary source of electrical power, given its industry strengths in more complex product integration solutions.*
- **Fuel Cells and Energy Storage.** *Ohio has leading battery firms along with key university research strengths in electrochemistry, which is critical to advancing energy storage and batteries. Similar to battery technology, fuel cells convert chemical energy into electrical energy through electrochemical reaction. Ohio also stands out with a significant level of national employment and establishments involved in fuel cell development, including the headquarters of Rolls-Royce fuel cells.*

Identified Strategic Development Approaches for Ohio

The industry forum participants identified key strategic development approaches that would enable Ohio to realize its potential in the energy industry sector.

Strategic Technology Development Approaches for Ohio

- **The OTF should leverage Ohio's strengths in advanced materials and sensors and controls for advanced energy applications.**
- **A crosscutting competency in power electronics is critical to the success of technology development in many energy application areas. Ohio was considered to be strong in power electronics in the past, but is not a leader today. Activities such as the new GE research center can have broader implications for advancing power electronics in Ohio.**

Broader Strategic Economic Development Approaches for Ohio

- *Address high capital requirements to advance innovative energy technologies with more high-value infrastructure resources. Development of shared-use facilities to reduce costs and demonstration facilities to shorten the development cycle would help address this issue.*
- *Assess local markets, which are key to the development of the advanced energy industry. With no national standards, every state is its own market.*
- *Use state incentives and regulatory approaches to influence Ohio's early adoption of advanced energy applications.*
- *Leverage the intersection of environmental and energy in state approaches. Through advanced energy solutions, innovative approaches to environmental issues can be moved forward.*

INFORMATION TECHNOLOGY SECTOR LINE OF SIGHT

Where the Puck is Today: Focus Areas From Recent Trends and Performance

Highlights of Detailed Industry-Level Focus Areas

Compared with the loss of 10 percent in total private sector employment in Ohio, the following detailed industries within the information technology (IT) industry grew more than 20 percent in employment from 2001 to 2009:

- **Software publishing**, with a gain of 29 percent in employment
- **Custom computer programming services**, with a gain of 26 percent in employment
- **Computer systems design services**, with a gain of 22 percent in employment.

Given the highly embedded nature of many IT functions within non-IT businesses, it is important to consider how Ohio has fared in the growth of IT occupations. The key findings are as follows:

- *Ohio nearly doubled the national growth in IT workforce, rising 22.1 percent in Ohio from 2004 to 2010, compared with 11.9 percent nationally.*
- *Software developers well outpaced the national trends, growing 34.3 percent in Ohio, compared with 17.2 percent nationally.*
- *Ohio had a 10 percent higher level of concentration of IT workers in computer systems analysts and network/computer systems administrators than the nation in 2010 (new occupational categories are not able to be tracked for growth).*

Highlights of Technology Innovation-Driven Focus Areas

What stands out among the technology innovation drivers is the significant level of venture capital support for IT.

A closer look at specific focus areas reveals two leading sectors:

- **Business software**, with 36 companies that received \$362 million of venture-capital funding from 2006 to 2010.
- **Health IT**, with 13 companies that received \$66 million of venture-capital funding from 2006 to 2010.

Where the Puck is Going

Why Ohio?

The industry forum participants for the IT sector saw Ohio as having a competitive location for IT based on the following:

- *Presence of large and mid-sized corporate administrative offices and leading academic health centers based in the state.*
- *Lower cost of living compared with established leaders in IT, largely found on the East and West coasts.*
- *Less staff turnover than in IT hotspots around the nation.*
- *Ability of new IT start-ups to access seed and start-up capital with the presence of Ohio's Entrepreneurial Signature Program.*
- *One of the most active health information exchanges found among large states, which offers a platform and distribution network for health-care software applications.*

Growth Opportunities for Ohio Over Next 3 to 5 Years

The industry forum participants identified that Ohio's leading growth opportunity area in IT is in *Business Process-Related Software*. The focus of Ohio's IT companies, among both established and emerging firms, is on serving enterprise computing needs of industry to automate; generate intelligence; and add value to sales, financial management, supply chain management, human resource management, production systems, and customer services. It is rooted in having a base of large headquartered companies in Ohio and is as diversified in its industry focus as the overall Ohio economy. The growth of this industry is being fueled by cloud computing-enabled software as a service model for delivering on-demand software for business applications. It also involves increasing use of open source platforms that enable businesses to advance more modular applications customized to their needs.

An emerging area of Ohio's business process-related software is found in *Health Informatics*. This growing market is being heralded as the most promising technology for improving the quality and efficiency of health-care delivery, including streamlining administrative procedures, preventing medical errors, and reducing the need for duplicative tests and procedures.

Identified Strategic Development Approaches for Ohio

The industry forum participants identified key strategic development approaches that would enable Ohio to realize its potential in the IT industry sector.

Strategic Technology Development Approaches for Ohio

- *The needed linkages and networking between emerging IT companies and well-established corporate and health-care customer community in Ohio is too ad hoc and needs better facilitation and engagement mechanisms.*
- *The integration of health-care IT with medical devices is a major hurdle to moving toward systems that can improve patient outcomes. If Ohio can begin to address this by bringing these two communities together, it will have an opportunity to be a market leader.*
- *The talent base being generated in Ohio is not viewed as sufficient across the broad spectrum of IT skills. Specific concerns about top IT talent are that too few students are being trained on large-scale enterprise systems, information security, and applications development. There is also a perception that an insufficient emphasis is being placed on generating “creative” talent able to leverage the disruptive nature of IT. Recruiting such talent from outside of Ohio is difficult because Ohio’s IT sector lacks a national standing; once recruited, however, IT talent does realize the value of being in the state.*

Broader Strategic Economic Development Approaches for Ohio

- *Address power costs that hurt opportunities to pursue the data centers that drive cloud computing.*
- *Increase practical know-how of commercial banking in Ohio about IT businesses. These companies often must seek outside banks for financing of equipment, working capital, and mobilization on contracts.*

- *Address lack of adequate later-stage venture financing for emerging IT companies in Ohio.*

INSTRUMENTS AND CONTROLS SECTOR LINE OF SIGHT

Where the Puck is Today: Focus Areas From Recent Trends and Performance

Highlights of Detailed Industry-Level Focus Areas

The instruments and controls sector was hard-hit by the recent recession, with all but one detailed industry losing jobs from 2001 to 2009.

- **Relay and Industrial Control Manufacturing**—*This industry added a very small number of jobs between 2001 and 2009. With 3,829 jobs in 2009, it is Ohio’s only growing and specialized detailed industry within the larger instruments and controls sector.*
- **Scale and Balance Manufacturing and Fluid Power Cylinder and Actuator Manufacturing**—*During the expansion years from 2001 to 2007, these industries added jobs and increased national share as well as outpacing national growth, but shed jobs from 2007 to 2009.*

Specialized industry strengths that did not grow in jobs during either the expansion or recession periods include the following:

- *Fluid Power Valve and Hose Fitting Manufacturing*
- *Automatic Environmental Control Manufacturing for Residential, Commercial, and Appliance Use*
- *Fluid Power Pump and Motor Manufacturing.*

Highlights of Technology Innovation-Driven Focus Areas

The level of technology innovation in Ohio’s instruments and controls industry is robust with impressive levels of activity in patents, venture capital, and SBIR awards and the presence of leading companies.

- *Patent activity in Ohio’s instruments and controls industry largely fell into five categories: generic controls systems (54), measuring and testing (45), electricity measuring and testing (32), electrical communications (28), and optics measuring and testing (25).*
- *Between 2006 and 2010, 10 companies received venture capital totaling \$103 million for automation and process control and sensor and sensor systems technologies. Forty-six companies received a combined \$81.2 million in SBIR awards during the same time frame for technologies focused in security and surveillance, sensors, communications technologies, automation devices, environmental controls, and semiconductors.*
- *There is a significant instruments and controls industry presence in Ohio, particularly in assembly manufacturing systems, automatic test equipment, manufacturing control systems, manufacturing measuring equipment, materials handling equipment, robots/robotics equipment, and automation services.*
- *In addition to these important technology innovation focus areas, Ohio exhibits statewide excellence in remote sensing and industrial engineering publications. The Ohio State University also has institutional publications excellence in automation and control systems.*

Where the Puck is Going

Why Ohio?

The industry forum participants for the instruments and controls sector saw Ohio as having a competitive location for instruments and controls based on the following:

- *Strengths across all components of advanced instrument and control systems, including sensors, automation, signal processing, information processing, distribution, and decision support*
- *Presence of AFRL Sensors Directorate at Wright-Patterson Air Force Base*
- *University strengths, particularly in sensors and sensing systems.*

Growth Opportunities for Ohio Over Next 3 to 5 Years

The industry forum participants identified that Ohio can distinguish itself in both a “top-down” systems use of instruments and controls and a “bottom-up” technology component:

- **Situational Awareness and Surveillance**—*Ohio is seen by the industry forum participants as having strengths in integrating all of the component technology areas into a total solution for situational awareness and surveillance systems. This is reinforced by the breadth of patent activity and the presence of venture-backed and SBIR-funded firms.*
- **Sensing and Automation Technologies**—*Ohio is viewed as having many technology capabilities in sensing and automation technology development. This is confirmed by the state’s publications activity in remote sensing as well as venture-backed and SBIR-funded companies.*

Identified Strategic Development Approaches for Ohio

The industry forum participants identified key strategic development approaches that would enable Ohio to realize its potential in the instruments and controls industry sector.

Strategic Technology Development Approaches for Ohio

- *Test bed facilities are needed to allow emerging companies and consortia to test and demonstrate solutions.*
- *Talent is an area of concern for Ohio’s instruments and controls industry, particularly given the high numbers of retirement-eligible engineers working in sensing and automation at Wright-Patterson Air Force Base. In addition, it is difficult to attract both young graduates and experienced workers to Ohio.*

Broader Strategic Economic Development Approaches for Ohio

- *Attract more prime integrators to Ohio, especially with the expansion of Wright-Patterson Air Force Base.*
- *Consider providing matching funds to companies that are awarded Phase II SBIR funds tied to commercialization within Ohio. Further capital is needed in support of commercialization, and SBIR funding is particularly important in sensors and sensing technology systems.*
- *Improve contracting approaches with the AFRL for the benefit of small and mid-sized Ohio companies.*



Growth Opportunity Areas for Next 3 to 5 Years

Across the six leading **technology industry sectors, eight growth opportunity areas** in which Ohio is well positioned for future growth were identified based on the line-of-sight analysis, guidance by industry forum participants, and further input and refinement by the OTF Commission and Advisory Board. These eight growth opportunity areas are as follows:

- **Advanced Materials**
 - *Advanced Polymer Materials; Ceramics; Composites; Carbon Fibers and Nanotubes; Specialty Metals and Alloys*
- **Aero-propulsion Power Management**
- **Fuel Cells and Energy Storage**
- **Medical Technology**
 - *Medical Imaging; Surgical Instruments and Equipment; Implant Devices; Regenerative Medicine*
- **Sensing and Automation Systems**
- **Situational Awareness and Surveillance Systems**
- **Software Applications for Business and Health Care**
- **Solar Photovoltaics.**

In the following section, each of these eight growth opportunities is discussed in detail, including its market outlook, how it builds on

Ohio’s strengths, and insights into markets that Ohio can serve from industry forum discussions.

Two crosscutting observations, however, are in order about the changing nature of these eight identified technology-related areas where Ohio is well positioned for growth over the next 3 to 5 years.

Rising Importance of Technology Convergence and Systems Approaches That Integrate Technology

These eight growth opportunity areas for Ohio are distinguished by the fact that they no longer emphasize distinct, stand-alone technology industry focus areas as was the case in the past for OTF. Instead, the importance of technology convergence and more “systems” approaches that integrate technologies for market solutions is now more emphasized. This suggests that multidisciplinary approaches in academia over the past decade are becoming critical to serving markets. As the *Chronicle of Higher Education* noted in 2002, “[interdisciplinary] partnerships are proliferating in academe—and slowly changing the face of science—because they offer the best hope for answering some of the thorniest research subjects including climate change, biodiversity and cancer.”⁸

⁸ Jeffrey Brainard, “U.S. Agencies Look to Interdisciplinary Science,” *Chronicle of Higher Education*, June 14, 2002.

Among the growth opportunity areas that emphasize technology convergence and particularly call for more systems integration are the following:

- **Medical technology**, bringing together innovative technologies across imaging, surgical instruments and equipment, implant devices, and regenerative medicine—and increasingly enabled with wireless communications—into new more functional medical devices and approaches.
- **Situational Awareness and Surveillance Systems**, involving sensor technologies, processing (sensor data and information processing), data storage, data distribution, and data exploitation in an integrated solution.
- **Software for Health Care**, a specialized application of broader business process–related software, i.e., incorporating cutting-edge informatics approaches together with health outcomes and effectiveness research.

- **Solar Photovoltaics**, involving applications in BIPV that incorporate PV modules into advanced building materials used in curtain walls, windows, and roofing.

Many Growth Opportunities Serve Multiple Markets

Along with the rising importance of technology convergence and use of a systems approach among Ohio’s leading technology-related growth opportunities, it is also important to recognize that many of these growth opportunities for Ohio serve multiple markets. In doing so, these growth opportunities can serve as “platform” technologies that can position Ohio in multiple ways to grow industries.

Table 3 shows how the eight identified growth opportunity areas for Ohio reach across several markets.

Table 3: Eight Growth Opportunity Areas for Ohio and the Markets That They Serve

| | Medical Products | Aerospace and Defense | Transportation | Energy Solutions | Green Products and Environment | Industrial Equipment | Distribution and Logistics | Corporate Offices | Insurance and Finance |
|--|------------------|-----------------------|----------------|------------------|--------------------------------|----------------------|----------------------------|-------------------|-----------------------|
| Advanced Materials | ● | ● | ● | ● | ● | | | | |
| Aero-propulsion Power Management | | ● | | | | | | | |
| Fuel Cells and Energy Storage | | ● | ● | ● | | | | | |
| Medical Technology | ● | | | | | | | | |
| Sensing and Automation Systems | ● | ● | ● | ● | ● | ● | ● | | |
| Situational Awareness and Surveillance Systems | ● | ● | | ● | | ● | ● | | |
| Software Applications for Business and Health Care | ● | | | | | | ● | ● | ● |
| Solar Photovoltaics | | | | ● | ● | | | | |

Detailed Profiles of Growth Opportunity Areas for Ohio

Growth Opportunity Focus Area: **ADVANCED MATERIALS**

What is it?

Advanced materials are unconventional materials that outperform conventional materials, allowing them to play a large role in product development. Typically, this class of materials refers to sophisticated technologies in metals and alloys, ceramics, polymers, and composites. Advanced materials are focused on enabling the creation of lighter, cheaper, smaller, and higher-quality products across many end-user markets. Desirable attributes of advanced materials commonly include greater durability, enhanced conductive properties, elasticity, and strength. Advanced materials are widely used in biomedical, aerospace, transportation, and advanced energy market applications.

Market Outlook

- *Advanced materials are used in multiple industries and offer numerous physical attributes. To understand their market potential, it is best to organize them by the class of materials. Despite different technologies, market drivers for advanced materials in all classes remain the same.*

Key Drivers:

- *Multifunctional Materials*
- *Light Weighting*
- *Sustainability, Biobased and Recyclable Products*
- *Harsh Environment Applications*

- **Advanced Polymer Materials:** *The U.S. market for conductive and electronic polymers will continue to grow 3 percent annually between 2009 and 2014.⁹ BCC Research expects global consumption of nanocomposites to increase at a compound annual growth rate (CAGR) of 27 percent, increasing from 64,567 metric tons and a market value of \$460 million in 2009 to reach 214,081 metric tons and \$1.4 billion by 2014.¹⁰ Globally, the high-performance polymer market was valued at \$6.1 billion in 2008, with growth anticipated to occur at a CAGR of 6 percent through 2012.¹¹ Biopolymer capacity will grow from under 2 billion pounds in 2009 to 5 billion pounds in 2013 and nearly 8 billion pounds in 2020.¹²*
- **Ceramics:** *The U.S. market for advanced ceramics, which comprises monolithic ceramics, ceramic matrix composites, and ceramic coatings, is forecasted to increase 6.2 percent annually from 2009 through 2014, growing from \$9.1 billion to \$12.2 billion.¹³*
- **Composites:** *According to Lucintel LLC, the global composite materials market was valued at \$17.7 billion in 2010, with the composite end products market worth \$50.2 billion, and is forecast to grow at a*

⁹ Freedonia Reports, *Freedonia Focus on Conductive Polymers*, 2010.

¹⁰ BCC Research, *Nanocomposites, Nanoparticles, Nanoclays, and Nanotubes*, 2010.

¹¹ Principia Partners, *High Performance Polymers*, 2008.

¹² Plastic News, *Biopolymers Building Muscle in Market*, 2010.

¹³ Freedonia Reports, *Freedonia Focus on Advanced Ceramics*, 2010.

CAGR of 7.8 percent through 2016 to reach a market value of \$27.4 billion and an end products market valued at \$78 billion.¹⁴

- **Carbon Fibers and Nanotubes:** Carbon fibers are used in a wide range of applications, including commercial aircraft, recreational, industrial, and transportation markets. Although the market experienced reduced demand during the global economic recession, Lucintel expects the market to recover and grow by approximately 13 percent annually through 2015 to reach \$2.3 billion (2010).¹⁵ Carbon nanotubes are making a large impact in advanced materials because they enable combinations of properties not possible in the past and afford multifunctionality and efficiency. In 2010, Nanoposts estimated the global market for carbon nanotubes to be worth approximately \$247 million and conservatively estimated market value reaching \$2.7 billion by 2015.¹⁶ A more optimistic report by Global Industry Analysts (2010) project the market value may reach as high as \$7.7 billion by 2015 if certain applications reach production status.¹⁷
- **Specialty Metals and Alloys:** According to First Research Inc., the metal coatings, engraving, and heat treating industry includes approximately 6,000 companies in the United States with annual revenue estimated at \$22 billion.¹⁸ Metal coatings account for nearly 55 percent of industry

revenue. Industry gross profit for metal coatings and allied services to manufacturers was estimated to be nearly 35 percent in 2009, according to Suppliers Relations US (2010). The metal coatings and allied services industry used a projected 79 percent of its full production capacity in 2009.¹⁹

The potential for engineered specialty metal components (i.e., parts are engineered in a specific manner to exploit the benefits of the various materials where intricate shapes, greater core complexities, tighter dimensional tolerances are required) is currently tied to a significant degree by the prospects and demands of the automotive and aerospace industry (consumer markets) and defense, homeland security, and space mission requirements (federal markets), especially for many harsh environment applications.

How It Builds on Ohio Strengths

Ohio has a significant legacy and future in advanced materials upon which to build unique solutions and applications. Ohio can build upon the capabilities and assets in both academia and industry, including the following:

- Ohio's universities (and their industry partners) have developed numerous research centers and institutes that are performing cutting-edge and market-focused advanced materials research, ranging from the Liquid Crystal Institute, the National Composite Center, the Ohio Center for Multifunctional Polymer Nanomaterials and Devices (CMPND), Ohio BioProducts Innovation Center, and the National Polymer Innovation Center. Additionally, unique capabilities are also

¹⁴ Lucintel LLC, *Keynote Address ACMA COMPOSITES 2011 Show*, 2011.

¹⁵ Lucintel LLC, *Growth Opportunities in Carbon Fiber Market 2010–2015*, 2010.

¹⁶ Nanoposts.com, *The Global Market for Carbon Nanotubes: A Realistic Market Assessment—2nd Edition*, 2010.

¹⁷ Global Industry Analysts, *Carbon Nanotubes: A Global Strategic Business Report*, 2010.

¹⁸ First Research, *Metal Coating, Engraving, & Heat Treating 2010*.

¹⁹ Suppliers Relations US, LLC, *Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers Industry in the U.S., 2010*.

present within the Structures and Materials Division of the NASA Glenn Research Center.

- From a research perspective, Ohio universities provide both breadth and depth in advanced materials research. For the period covering 2005–2009, Ohio universities share of all U.S. academic publications reached 11 percent in polymers, 9 percent in material characterization and testing, 8 percent in composites, 8 percent in metallurgy, and 7 percent in biomaterials.
- The state is also home to significant corporate R&D operations in the advanced materials—ranging from PolyOne to GrafTech, Sherwin Williams to Owens Corning, and Lubrizol to Goodyear. Numerous smaller advanced materials firms also have significant R&D capabilities in the state, including AlphaMicron Applied Sciences, Renegade Materials, Maverick Corporation, Kent Displays, Akron Polymer Systems, Faraday Technology, PowderMet, UES, Wright Materials Research, Webcore, and Zyvex Performance Materials.
- The state’s strength in advanced materials innovation is also demonstrated in significant patent activity. From January 2007 to September 2010, Ohio inventors received more than 300 patents related to specific polymers, more than 130 patents related to composites, and nearly 60 patents in both ceramics and advanced metal alloys. Included among these patents are more than 100 that involve nanotechnology applications.
- The industry forum participants noted the significant strengths of Ohio’s supply chain in materials.

Insights Into Markets That Ohio Can Serve From Industry Forum Discussions

Advanced materials are directed at many markets: Advanced Energy, Aerospace and Defense, Biomedical, Building and Construction Products, and Transportation.

Industry forum participants stressed the importance of relating advanced materials to their end-user markets.

Growth Opportunity Focus Area: **AERO-PROPULSION POWER** **MANAGEMENT**

What is it?

Propulsion systems are machines that produce power required to push or pull a vehicle into motion and enable the vehicle to accelerate, decelerate, and maneuver while already in motion. In aircraft, turbine engines provide the propulsion required to operate reliably for extended periods. Propulsion requirements differ depending on the use requirements of the aircraft. For instance, commercial aircraft need propulsion systems that allow them to transport people and cargo from one point to another, while military aircraft must meet those requirements in addition to acting as a weapons platform, which can mean supersonic speeds and quick maneuverability among many other defense needs. Globally, the aircraft engine market is dominated by three companies: GE Aviation, Pratt & Whitney, and Rolls-Royce.

Market Outlook

The global market for aircraft engines had an estimated value of \$8.7 billion in 2009. The market is expected to achieve healthy gains, growing 5.5 percent annually through 2015 when market revenues will reach \$11.2 billion.²⁰

Aerospace engineers have sought to improve aircraft engines in response to increased industry pressure to reduce environmental impacts, increase efficiency, and cut operating costs. GE Aviation, Pratt & Whitney and Rolls-Royce have each developed “green aero engines” that result in 20 percent fuel savings.²¹ These new engines

use composite materials, specialized coatings, and innovative designs to create engines that are lighter, quieter, and more durable to increase fuel efficiency, lessen environmental impact, and reduce maintenance.

Key Drivers:

- *Reduction of operating costs*
 - *Increasing performance*
 - *Improvement in efficiency and reliability*
 - *Environmental sustainability*
 - *Replacing of aging commercial air fleet*
 - *Increasing global commercial aircraft and air cargo*
 - *Microturbines for UAVs*
-

How It Builds on Ohio Strengths

Built upon a core industrial context, with significant and related efforts from Ohio’s two national laboratories, propulsion power management is not only a significant part of Ohio’s technological history, but also a key component of its technological future. Included among the state’s assets and capacities are the following:

- Ohio is highly specialized in aircraft engines and engine parts manufacturing, the state’s largest aerospace industry with 11,786 workers in 2009.
- GE’s aircraft engine R&D center is located in southwest Ohio as part of the overall GE Aviation operations. This R&D operation is responsible for generating more than 600 aircraft engine and related patents in the 2005–2009 period. In addition to GE Aviation, Rolls-Royce also maintains an aircraft engine manufacturing facility in Mount Vernon, Ohio.
- Building upon its Ohio aviation operations, GE recently announced the formation of

²⁰ Freedonia, *Focus on Turbines*, 2010.

²¹ Frost & Sullivan, *The Green Aircraft Marketplace*, 2009.

the GE Electrical Power Integrated Systems Research and Development Center in Dayton. The advanced electrical power systems will serve as an integrated power source to an aircraft's engine ignition, communications, lighting, air conditioning, braking, landing gear, and flight control systems. The University of Dayton Research Institute will assist with modeling, simulation, analysis, and validation of new electrical power systems in partnership with GE Aviation Systems that will engineer, design, and manufacture the systems.

- The presence of the AFRL's Propulsion Directorate at Wright-Patterson Air Force Base is a significant asset for Ohio.
- Ohio's universities stand out in aerospace engineering, comprising 5.7 percent of all peer-reviewed publications from 2005 to 2009 and having a 10 percent higher level of citations per publication than the nation, a measure of publication quality.

Among university research centers, the Ohio Research Scholars Program Center for Intelligent Propulsion and Advanced Life Management Systems at the University of Cincinnati responds to the needs of the state and the nation for efficient, environmentally friendly, and low-cost propulsion and power systems. The Ohio State University maintains the Center for Advanced Propulsion and Power (OCAPP). Industry collaborators on the project include GE Aircraft Engines, NASA Glenn Research Center, and the AFRL. Academic partners include the University of Dayton, Case Western Reserve University, the University of Cincinnati, and the University of Akron.

Insights Into Markets That Ohio Can Serve From Industry Forum Discussions

Ohio's propulsion industry is closely tied to military and business and commercial aviation markets. A specific application that holds exciting promise for Ohio's strengths, not only in propulsion but also in materials and situational awareness and surveillance, is unmanned aerial vehicles.

Growth Opportunity Focus Area: **FUEL CELLS AND ENERGY STORAGE**

What is it?

Energy storage is a term used to describe various types of technologies that store energy in order to allow us to use it at a later time. Energy storage technologies include utility battery storage, flywheel storage, superconducting magnetic energy storage, compressed air energy storage, pumped hydropower, and supercapacitors. Efficient energy storage systems can make electronics last longer with less frequent charging, start or power vehicles, and ensure that energy derived from solar or wind power is available for use long after sunset or when the wind stops blowing. Batteries are an important solution to energy storage needs; and new technological innovations are enabling them to run longer, produce higher voltages, reduce emissions, reduce recharge times, and increase the number of recharges while increasing safety. Batteries store energy in the form of chemical energy; when connected in a circuit, the battery can produce electricity.

Similar to battery technology, fuel cells convert chemical energy into electrical energy through electrochemical reaction. Fuel cells differ from batteries in that the fuel feeding the electrochemical reaction is supplied outside of the cell. Many different fuels can be used to generate energy, including hydrogen, methanol, biogas, natural gas, and hydrocarbons. Hydrogen has received the most attention as a fuel because it generates water as an outcome yielding electricity with zero emissions. Fuel cell applications include transportation, stationary power (usually connected to the electric grid to provide supplemental power or on-site generation), and portable devices.

Market Outlook

ENERGY STORAGE

The U.S. battery market is poised for an annual growth of more than 4 percent from 2011 through 2016, growing from a \$9.6 billion market in 2011 to nearly \$12 billion in 2016.²²

Key Drivers:

- *Demand for consumer electronics*
- *Increased adoption of plug-in hybrid electric vehicles and all-electric vehicles*
- *Integration of renewable energy sources and smart-grid technologies*
- *Raw material costs and availability*
- *Environmental sustainability*

The following discussion highlights the market potential of specific technologies:

- **Rechargeable Batteries:** *Rechargeable batteries have gained in market share in recent years and currently account for 56 percent of the battery market as a result of growth in high-drain portable electronic products.²³ Global Industry Analysts predicts the world market for rechargeable batteries, which are used in a range of applications, including automotive, communications, medical, laptops, and emergency power, to reach \$16.4 billion by 2015.²⁴ Rechargeable lead-acid batteries are anticipated to own market share for the next 5 years, but non-lead-acid battery technologies (particularly lithium ion, lithium polymer, and, to a lesser extent, nickel-metal hydride) will experience the fastest growth rates.²⁵*

²² IBISWorld, *Battery Manufacturing in the U.S.*, 2011.

²³ IBISWorld, *Battery Manufacturing in the U.S.*, 2011.

²⁴ Global Industry Analysts, Inc., *Rechargeable Batteries*, 2011.

²⁵ Freedonia, *World Batteries Market*, 2010.

- **Energy Harvesting:** Energy harvesting captures ambient energy, convert it to a usable form, and preserve it for future use by small, autonomous devices such as solar-powered calculators, satellites, and nodes in sensor networks. Still an emerging technology, the energy harvest market is expected to grow from \$13.75 million in 2011 to \$4.4 billion in 2021.²⁶ Advantages of energy harvesters include environmental friendliness, the ability to power devices without electric wires, less maintenance, and the extension of battery life or elimination of batteries altogether.
- **Thin-Film Batteries:** Thin-film batteries are an emerging technology with promising market growth potential. A report by iRAP, Inc., indicates that thin-film batteries could grow from a \$90 million market in 2010 to \$600 million in 2015, with average annual growth rates ranging from 38 to 68 percent.²⁷ Immediate applications for thin-film batteries exist for smart card and sensor technologies, with important future applications in medical devices. Implantable advanced medical devices, smart bandages, cosmetic and pharmaceutical patches, and therapeutic products will boost demand for thin-film batteries.

FUEL CELLS

Although still an emerging market, growth in fuel cell technology has been substantial in recent years. According to SBI Energy, the fuel cell market revenues grew from \$353 million in 2005 to \$498 million in 2009.²⁸ Growth in the fuel cell

market is anticipated to continue at a CAGR of 20 percent to reach \$1.2 billion in 2014.

Key Drivers:

- Energy security
- Environmental sustainability
- Infrastructure deployment
- Durability and reliability

The following discussion highlights the market potential of specific technologies:

- **Polymer Electrolyte Membrane Fuel Cells (PEMFCs):** PEMFCs represent the most dominant technology with approximately 64 percent of the market because their technology is the most flexible and market adaptable.²⁹ PEMFCs are frequently used in backup power, portable power, distributed generation, transportation, and specialty vehicle applications. The U.S. Department of Energy is focusing on PEMFCs as the most likely technology to be used in transportation applications.
- **Molten Carbonate Fuel Cells (MCFCs):** MCFCs represent another prominent fuel cell technology used in large stationary power generators. Operation of MCFCs generates steam that can be used to produce more electricity. MCFCs do not need exotic fuels to function, making operating costs lower than other fuel cell technology.
- **Solid Oxide Fuel Cells (SOFC):** Similar to MCFCs, SOFCs are best utilized for large stationary power plants and are suitable for cogeneration. SOFCs operate at very high heat, making their durability and reliability an issue if the fuel cells are cycled on and off repeatedly, but are very stable if run

²⁶ IDTechEx, *Energy Harvesting and Storage for Electronic Devices 2011–2021*, 2011.

²⁷ iRap, Inc., *Rechargeable and Non-Rechargeable, Flexible, Thin-Film Batteries*, 2010.

²⁸ SBI Energy, *Fuel Cell Technologies Worldwide*, 2010.

²⁹ Global Industry Analysts, *Fuel Cells: A Global Strategic Business Report*, 2010.

*continually. The market for SOFCs could reach \$241 million by 2015.*³⁰

How It Builds on Ohio Strengths

- According to a recently released comprehensive national database produced by The Brookings Institution and Battelle in “Sizing the Clean Economy,” Ohio distinguishes itself in batteries and energy storage and fuel cells. Batteries and energy storage accounted for 5.3 percent of U.S. establishments and 5.7 percent of U.S. employment in 2010, while fuel cells accounted for 8.4 percent of U.S. establishments and 9.8 percent of U.S. employment.
- Among the key Ohio battery and energy storage firms are Energizer Corporate Research and Technology Facility, Blue Spark Technologies (flexible, thin-film batteries), Cobasys LLC (hybrid electric vehicle energy storage), Inorganic Specialists, and Nanotek Instruments. In addition, several firms active in fuel cell development are located in Ohio, including Rolls-Royce Fuel Cell Systems, Honda, GrafTech, Catacel Corporation, NexTech Materials, Crown Equipment Corporation, and Battelle.
- Ohio’s academic and institutional research accounts for 4.7 percent of all U.S. electro-chemical (includes both fuel cell and battery-related research) publications in the 2005–2009 period.
- Industry forum participants noted that Ohio has a strong base of suppliers that provide fuel cell manufacturers a competitive advantage.

- Ohio companies held 58 fuel cell-related patents by Ohio inventors issued between January of 2007 and September of 2010.
- Several specialized consortia in fuel cell development are in Ohio, including the following:
 - *Stark State College of Technology’s Fuel Cell Prototyping Center is designed for use by emerging and fuel cell-related technology companies to assist them in precommercialization prototyping and demonstration stages of the development of fuel cell-based power generation systems.*
 - *Ohio Fuel Cell Coalition is a united group of industry, academic, and government leaders working collectively to strengthen Ohio’s fuel cell industry and to accelerate the transformation of Ohio to global leadership in fuel cell technology.*

Insights Into Markets That Ohio Can Serve From Industry Forum Discussions

Continued advances of energy storage devices for the automotive sector are a leading opportunity for Ohio in the next 3 to 5 years in light of rising automobile and trucking efficiency standards. Key opportunities for near-term fuel cell development are military needs in aerospace and base operations, stationary power more broadly for facilities, and niche areas of transportation equipment such as forklifts.

³⁰ Global Industry Analysts, *Solid Oxide Fuel Cells: A Global Business Strategic Report*, 2010.

Growth Opportunity Focus Area: **MEDICAL TECHNOLOGY**

What is it?

According to the Advanced Medical Technology Association, medical technology encompasses a wide range of health-care products, and, in one form or another, is used to diagnose, monitor, or treat diseases or conditions that affect humans. These innovative technologies include imaging, surgical instruments and equipment, implant devices, and regenerative medicine. Together, these innovative technologies are improving, largely through innovative medical instruments and devices, the quality of health care delivered and patient outcomes through earlier diagnosis, less invasive treatment options, and reductions in hospital stays and rehabilitation times. Advances in medical technology are often based on a “systems” approach in which a range of innovative technologies are integrated to provide more functional medical products.

Market Outlook

A positive level of annual growth is expected across the technologies, with some particularly fast-growing niches:

- **Medical Imaging:** Considerable gains are expected with a CAGR of 5.1 percent from 2009–2014 by BCC Research.³¹ Global revenues in the medical imaging market were \$22.6 billion in 2009 and are projected to increase to \$29 billion in 2014. This involves mature, slower-growth segments of X-ray, computer tomography, and ultrasound, as well as emerging, fast-growth segments

³¹ BCC Research, *Medical Imaging Reagents and Analysis Equipment*, 2010.

involved with positron emission tomography (PET) and radiopharmaceuticals.

Key Drivers:

- Improved image acquisition technologies
- Miniaturization of imaging instruments
- Improved modeling and quantification

- **Surgical Instruments and Equipment:** Positive growth trends are expected for the overall market of 5.2 percent CAGR through 2015, with the U.S. market standing at \$95 billion in 2010.³² Minimally invasive surgical devices and instruments are a key growth segment, with a CAGR of 7.8 percent through 2014 and substantial revenues of \$14.8 billion in 2008; the largest segment is cardiothoracic surgery.³³

Key Drivers:

- Disposable instruments and equipment
- New materials enabling new applications and product development
- Hybrid technologies that incorporate pharmaceutical products and surgical equipment
- Instrument miniaturization

- **Implant Devices:** This niche is best viewed through key application markets. In cardiovascular implants, the market is sizable at \$85 billion, but maturing and so has only a 2.8 percent CAGR through 2015.³⁴ The orthopedic market is also substantial and maturing, standing at \$28 billion with a CAGR of 2.7 percent through 2015.³⁵ A fast-emerging

³² IBISWorld, *Medical Instrument & Supply Manufacturing in the U.S.*, 2010

³³ BCC Research, *The Market for Minimally Invasive Medical Devices*, 2009.

³⁴ BCC Research, *Cardiovascular Devices: Technologies and Global Markets*, 2009.

³⁵ BCC Research, *Advanced Orthopedic Technologies, Implants and Regenerative Products*, January 2011

*segment is neuromodulation, which stood at \$3 billion in 2008, but is expected to grow at a CAGR of 26 percent through 2014.*³⁶

Key Drivers:

- *Niche cardiac products for atrial fibrillation and ventricular assist*
- *Orthobiologics redefining orthopedic implants*
- *New applications of neuromodulation for a broad array of medical conditions*

-
- **Regenerative Medicine:** *According to Arshad Ahmed, partner of Scientia Advisors, the market for technologies that repair the body stood at \$1.6 billion in 2010, but could swell to \$15 billion to \$20 billion over the next 15 years. Regenerative medicine will be focused on practical, specific clinical applications, in the short-term, such as spine fusion applications that currently account for half of regenerative medicine revenues.*³⁷

How It Builds on Ohio Strengths

For Ohio, the key drivers of its strengths in medical technology span a wide range of capabilities from medical imaging, sensing and remote monitoring, minimally invasive surgery, and advanced implant medical devices.

These strengths are well represented across identified focus areas from recent trends and performance across detailed industry drivers and technology innovation activities in Ohio:

- Ohio is distinguished in the level of specialization of its surgical appliance and supplies manufacturing industry, along with recent growth across dental equipment,

surgical and medical instruments, and ophthalmic goods industries.

- Ohio is particularly noted for its leading medical companies based in the state, including Cardinal Health, Ethicon Endo-Surgery, STERIS, and Philips Medical Systems.
- At the same time, there is a strong presence of venture-backed emerging companies in medical technology areas, including the following:
 - *Medical imaging, with 10 venture-backed companies attracting \$170 million in venture financing from 2006 to 2010*
 - *Advanced surgical instruments and equipment, with 9 venture-backed companies attracting \$112.5 million in venture financing from 2006 to 2010*
 - *Implant medical devices, with 10 venture-backed companies attracting \$63 million in venture financing from 2006 to 2010.*
- Medical technology is also prominent as an area of significant innovation for Ohio companies, with 162 patents for surgical instruments generated by Ohio inventors from January 2007 to September 2010, 179 patents in medical imaging, 84 patents for mechanical components used in medical devices, and 47 patents for surgical blood/fluid devices.
- In scholarly activity, among the research fields in which Ohio excels in both the high level and quality of peer-reviewed publications are biomedical engineering, surgery, and cardiac and cardiovascular systems. Ohio also is noted for its high level of peer-reviewed publications in orthopedics and biomaterials. There were also a sizable number of peer-reviewed

³⁶ Neurotech, *Reports in Medical Device Technology Alert*, 2010.

³⁷ DOTmed News, *Regenerative Medicine to Be a \$20 Billion Industry by 2025*, 2010.

publications in radiology, nuclear medicine, and medical imaging in Ohio from 2005 to 2009, reaching 856 publications or 3.3 percent of the U.S. total.

***Insights Into Markets That Ohio Can Serve
From Industry Forum Discussions***

Medical technology is broadly focused on the health-care marketplace and advancing more effective and lower-cost treatments. Increasingly, the industry forum participants noted the key to success for Ohio is to link its broad capacities in medical technology with a specific disease area, whether cardiovascular, diabetes and obesity, cancer, or orthopedics.

Growth Opportunity Focus Area: **SENSING AND AUTOMATION SYSTEMS**

What is it?

Automation technologies reduce the need for human labor in the production of goods and services through the use of control systems. Sensors, which receive and respond to external signals or stimuli, are critical to the process of automation. Combined, sensing and automation technologies comprise a “nervous system” for manufacturing plants and improve process efficiency. Environmental sensing technologies can help monitor changes in water and air quality, fluctuations in temperature and humidity, and atmospheric changes such as the presence of smoke or carbon monoxide. Advances in sensing and automation technologies carry large impacts for those who employ them, such as improved plant energy efficiency; increased throughput, yield, and product quality; enhanced safety; greater production flexibility; increased environmental quality; and reduced material waste and pollutants.

Market Outlook

Growth in the sensing and automation technologies industry is largely dependent on manufacturing and processing activity. Barring a double-dip recession, production volumes and capital investment will recover, spurring further investment in the sector.

Key Drivers:

- *Macroeconomic trends*
 - *Government regulations*
 - *Technological advances improving efficiency and reliability*
 - *Miniaturization*
 - *Reduction of energy consumption*
-

The following discussion highlights the market potential of specific technologies:

- **Micro-Electromechanical Systems (MEMS):** *The U.S. market for MEMS is projected to experience robust growth through 2014, doubling from its 2009 value of \$2.2 billion to \$4.5 billion in 2014.³⁸ New applications in areas such as memory and fuel cells are stimulating demand for MEMS devices; however, the market is moving toward integrating multiple MEMS into a single module that will inhibit growth for separate MEMS outside the forecast period. MEMS-based sensors account for 50 percent of market revenues and are expected to grow 13.1 percent annually to reach \$2.1 billion by 2014.*
- **Process Control Instruments:** *After a challenging year in 2009 due to drop-offs in manufacturing and capital investment resulting from the global recession, the U.S. market for process control instruments will experience moderate growth, increasing from \$6.5 billion in 2009 to \$8 billion in 2014.³⁹ Flow and level instruments will experience the largest market gains through 2014, increasing by 5 percent annually based on accelerating chemical, plastics, and petroleum product production activity.*

³⁸ Freedonia, *Focus on Micro-Electromechanical Systems (MEMS)*, 2010.

³⁹ Freedonia, *Focus on Process Control Instruments*, 2010.

Temperature instruments, commonly used in production of pharmaceuticals, food, and beverages will see annual increases of 4.4 percent.

- **Industrial Controls:** *U.S. demand for industrial controls will drive industry revenue increases of 5.1 percent annually through 2014, growing from a \$12.1 billion industry in 2009 to \$15.5 billion.⁴⁰ The most promising technologies for U.S. producers will be in advanced industrial controls such as solid-state electronics, programmable logic controllers, proximity and positioning sensors, and adjustable speed drive controls. The U.S. market for advanced industrial controls will grow 5.4 percent per year from its \$6.8 billion base in 2009 to \$8.8 billion in 2014.*
- **Sensors:** *In 2010, the global market for sensors was valued at \$56.3 billion, with an expectation to increase at a CAGR of 7.8 percent to reach \$91.5 billion by 2016.⁴¹ Sensor technology improvements in areas such as MEMS, photoelectronics, and optoelectronics will support gains in the U.S. market. In 2009, industrial applications were the largest single end-user, accounting for 23 percent of market revenues, followed by motor vehicles and military/aerospace that each accounted for 21 percent of the industry revenues.⁴² As the global economy recovers, motor vehicle production is expected to resume its status as the largest end-user for sensor technology. The environmental sensing and monitoring technologies market will witness substantial growth, increasing*

from \$10.1 billion in 2009 to \$13 billion by 2014.⁴³

- **Machine Vision:** *Machine vision (MV) technology enables automated capture and analysis of visual information. The global market for MV systems will experience substantial growth through 2015, with revenues increasing from \$11.2 billion in 2010 to \$18 billion at a CAGR of 9.9 percent.*

How It Builds on Ohio Strengths

Due to Ohio's manufacturing heritage, a significant presence in sensing and automation technologies has developed. These technologies range from applications within specific pieces of equipment to applications in broad automated processing lines and systems. A key context of many of Ohio's leading firms is the connection between the sensing technologies, the automated systems, and the integrating operational software.

- Ohio is home to numerous corporate R&D and manufacturing operations in the sensing and automation technologies arena, including Rockwell Automation, Nordson Corporation, Parker Hannifin, Diebold, and Advanced Assembly Automation.
- The CorpTech database of technology firms identifies the broad strengths of Ohio across specific sensing and automation technology industry product areas, including 148 Ohio firms in automation services, comprising 7 percent of all U.S. firms; 76 Ohio firms in automatic testing equipment, comprising 4 percent of all U.S. firms; and 30 firms in manufacturing

⁴⁰ Freedonia, *Focus on Industrial Controls*, 2010.

⁴¹ BCC Research, *Sensors: Technologies and Markets*, 2011.

⁴² Freedonia, *Sensors*, 2010.

⁴³ BCC Research, *Environmental Sensing and Monitoring Technologies: Global Markets*, 2009.

control systems, comprising 4 percent of all U.S. firms.

- From January 2007 to September 2010, Ohio inventors received more than 140 patents related to specific sensors. Of these patents, 20 were related to pressure sensors, 20 to temperature sensors, 18 to fluid and flow sensing, and 11 to force sensing (including torque and strain sensors). Ohio firms also had nearly 30 patents in this period related specifically to automation technologies.
- Ohio universities have an active presence in automation and control systems, with 203 peer-reviewed publications from 2005 to 2009, comprising 4.1 percent of all U.S. publications, as well as 287 publications in artificial intelligence from 2005 to 2009, comprising 3.3 percent of U.S. publications. In addition, sensing and automation leverages Ohio's broader strength in industrial engineering where Ohio comprises 4.8 percent of U.S. peer-reviewed publications, with 217 from 2005 to 2009.

Insights Into Markets That Ohio Can Serve

Sensing and automation technologies serve multiple industries, including automotive, military and aerospace, unmanned aerial vehicles, industrial manufacturing, energy production and distribution, and processing. Ohio's presence in sensing and automation technologies is ideally positioned to serve the aerospace, manufacturing, and food processing industries.

 **Growth Opportunity Focus Area:**
SITUATIONAL AWARENESS and SURVEILLANCE SYSTEMS

What is it?

Situational awareness and surveillance systems encompass a comprehensive set of technologies that allow users to perceive information about their environment with respect to time and space and anticipate how those environmental factors may affect circumstances in the near future.

Enhanced situational awareness improves decision making in dynamic environments and helps reduce accidents based on human error, making it invaluable in situations with high levels of information flow and where poor decision making can have disastrous effects. Situational awareness technologies are commonly used in aviation, defense, and law enforcement.

Surveillance equipment allows security personnel to monitor behavior or activities occurring in a defined area to reduce threats and prevent or investigate criminal activity. Surveillance is often conducted through electronic devices; and modern surveillance systems integrate sophisticated networks of cameras, sensors, alarm systems, personnel, and IT to improve security.

Market Outlook

The market for situational awareness and surveillance products is growing and involves the coordinated application of discrete technologies. As a result of the powerful impact that situational awareness and surveillance can have on achieving desirable outcomes, demand for these technologies is on the rise.

Key Drivers:

- Ability to respond quickly to events
 - Increasing efficiency and effectiveness of operations
 - Providing uniform operating environment for decision makers, analysts, and operators
 - Collaboration and communication across multiple organizations
 - Border security
-

The following discussion highlights the market potential of specific technologies:

- **Surveillance Equipment:** *The global market for surveillance equipment was \$78 billion in 2009 and is expected to grow at a CAGR of 11.7 percent to reach \$139.2 billion in 2015.⁴⁴ Law enforcement is the largest end-user market, worth nearly \$50 billion in 2009 and anticipated to reach \$94 billion in 2015. The military and government segment of the market was valued at \$10 billion and should reach \$16 billion by 2015.*
- **Sensors:** *In 2010, the global market for sensors was valued at \$56.3 billion, with an expectation to increase at a CAGR of 7.8 percent to reach \$91.5 billion by 2016.⁴⁵ Unattended ground sensor systems are an emerging technology that is gaining attention for its unique capabilities in promoting enhanced situational awareness through real-time image capture, video relays, and other intelligence inputs. The global remote sensing products market was worth an estimated \$8.2 billion in 2009 and is projected to increase at a CAGR of 6.1 percent through 2014 to reach \$11 billion.⁴⁶*

⁴⁴ BCC Research, *Surveillance and Security Equipment: New Technologies and Markets*, 2010.

⁴⁵ BCC Research, *Sensors: Technologies and Markets*, 2011.

⁴⁶ BCC Research, *Remote Sensing Technologies and Global Markets*, 2009.

- **Software:** *Situational awareness and surveillance personnel must be able to receive and use the data they are receiving from multiple inputs in order to be effective. Platform software is critical to making the network achieve optimal results. Situational awareness platform software must be able to integrate information from multiple sources such as access credential management; video surveillance; intrusion and fire alarms, building management systems; intercoms; radio communication; vehicle scheduling and management systems; and chemical, biological, radiological, and nuclear (CBRN) detection systems. In many installations, platform software must be able to integrate older, proprietary software from discrete systems into an overall, modern network.*

How It Builds on Ohio Strengths

- Over the past decade, Ohio has been establishing an industry base in search, detection, and navigation guidance systems and instruments. It grew from a mere 194 jobs in 2001 to 1,436 jobs in 2009.
- The presence of AFRL’s Sensors Directorate at Wright-Patterson Air Force Base includes specialized centers for sensor exploitation technologies and systems, involving remote sensing, sensor data management systems, modeling, and simulation and testing.
- The focus of the Ohio Wright Center’s Institute for the Development and Commercialization of Advanced Sensor Technology (IDCAST) is primarily tied to this growth opportunity area.
- Ohio universities excel in the high level of remote sensing peer-reviewed publications, with 160 publications from 2005 to 2009 comprising 5.0 percent of all U.S. publications.

- Ohio has several industry participants working on cutting-edge technologies with situational awareness and surveillance applications. These include Woolpert, L-3 Communications Cincinnati Electronics, and Persistent Surveillance Systems.

Insights Into Markets That Ohio Can Serve From Industry Forum Discussions

Situational awareness and surveillance technologies are a key growth area in aerospace/defense using the platform of unmanned vehicle systems. A growth area in the next 3 to 5 years is expected in homeland security and law enforcement markets with the development of Federal Aviation Administration’s (FAA’s) NextGen Air Traffic Management System and continued testing for unmanned systems.

 **Growth Opportunity Focus Area:**
SOFTWARE APPLICATIONS for
BUSINESS and HEALTH CARE

Software applications enable organizations to reduce costs and increase productivity, achieve greater profitability, and improve efficiency. These technologies have become ubiquitous among industries and are constantly advancing to maintain relevance in a rapidly evolving global economy. The types and sophistication levels of business software being used largely depend on the size of the company, with small firms commonly using office suites and accounting software and medium-size businesses using more complex applications such as shopping cart software and human resources software. Enterprise software applications are the most sophisticated and can range from enterprise content management to product life-cycle management.

Health IT is being heralded as the most promising technology for improving the quality and efficiency of health-care delivery. Health IT utilizes hardware and software to store, retrieve, share, and use health-care information data and knowledge for improved communication and decision making. Immediate benefits of widespread and consistent use of health IT include improved health-care quality, prevention of medical errors, reduced health-care costs, streamlined administrative procedures, and expanded access to affordable care. In the longer term, information gathered from the implementation of health IT infrastructure will yield greater public benefits through health informatics that uses IT to analyze clinical data and improve patient outcomes.

Market Outlook

BUSINESS

After a year of modest growth (just 2.8 percent in 2010), the North American business software market is anticipated to grow at a CAGR of 7.7 percent through 2015 to reach \$165 billion.⁴⁷

Key Drivers:

- *Growth of software as a service and on-demand applications enabled by expansion of cloud computing*
 - *Connection with wireless applications development*
 - *Emphasis on open platforms*
-

Growth in specific market segments is detailed as follows:

- **Enterprise Software:** *After a year of decline in worldwide revenues in 2009, the enterprise software market is recovering. According to Gartner Inc., the worldwide enterprise software market increased 8.5 percent in 2010, reaching \$245 billion.⁴⁸ Although the market is dominated by IT giants Microsoft, IBM, and Oracle, smaller vendors accounted for nearly 50 percent of market revenues in 2010.*
- **Enterprise Cloud-Based Services:** *Adoption of cloud-based services will experience significant growth through 2015. Globally, the market for enterprise cloud-based services will grow at a CAGR of 24 percent, increasing from \$12 billion in 2010 to nearly \$36 billion in 2015.⁴⁹ Software-as-a-service*

⁴⁷ Datamonitor, *North America Market Trends 2010: Business Software Forecasts*, 2011.

⁴⁸ Gartner, *Market Share Analysis: Enterprise Software, Worldwide, 2010, 2011*.

⁴⁹ Analysys Mason, *Enterprise cloud services: worldwide forecast 2010–2015*, 2010.

(SaaS) accounted for 70 percent of industry revenue in 2010, while 30 percent was related to infrastructure-as-a-service (IaaS); however, by 2015, IaaS market share will improve to 40 percent.

- **Business Intelligence:** The global market for business intelligence (BI) software is projected to grow nearly 10 percent in 2011 to reach \$10.8 billion and continue through 2014.⁵⁰ BI ranked five on the list of top 10 technology priorities for chief information officers (CIOs) in Gartner’s annual global CIO survey as BI assists organizations in cutting costs and improving productivity and agility.
- **E-Commerce:** Cisco Systems Inc. expects global e-commerce (including travel and auto purchases) to grow 13.5 percent annually to reach \$1.4 trillion in 2015. The expansion of the e-commerce market is partially due to increasing Internet access through smart phones, tablet devices, video game consoles, and Internet-connected television sets; but new shopping models offering discounted prices, broader inventory variety, and book and music downloads are also contributing to growth in the market.
- **Business Process Management:** The business process management (BPM) market is anticipated to grow at a CAGR of 13.3 percent through 2017, with market revenues increasing from \$2.3 billion in 2010 to \$5.5 billion in 2017.⁵¹ The adoption of cloud computing is driving growth in the BPM market.

⁵⁰ Gartner, *Magic Quadrant for Business Intelligence Platforms*, 2011.

⁵¹ WinterGreen Research, *Business Process Management (BPM) Market Shares, Strategies, and Forecasts, Worldwide, 2011 to 2017*, 2011.

HEALTH CARE

Health IT will experience significant growth across all niches in the next several years, with the overall market increasing from \$99.6 billion in 2010 to \$162.2 billion in 2015 at a CAGR of 10.2 percent.⁵²

Key Drivers:

- Reducing health-care costs—especially with impetus of federal funding for health information exchanges
- Regulatory and liability issues concerning technological applications and patient information
- Technological advancements such as electronic medical records, picture-archiving and communications systems, data management systems, smart phones, and personal health records
- Aging population and insurance coverage for treatment and procedures
- Development of “meaningful use”
- Increasing consumerism in health care and patient engagement through IT
- Growth of “accountable care organizations”

Growth in specific market segments is detailed as follows:

- **Software Applications:** Software applications accounted for 71 percent of the health IT market in 2010. Although market share is expected to drop to 66 percent by 2016, this segment of the health IT market will still experience impressive growth, increasing from \$4.5 billion in 2010 to \$11 billion in 2016—a CAGR of 17 percent.⁵³

⁵² MarketsandMarkets, *World Healthcare IT Market: Trends and Forecast (2010-2015)*, 2011.

⁵³ BCC Research, *Healthcare Information Technology*, 2011.

- **Clinical Health-Care Applications:** *Clinical health-care IT is projected to grow at a CAGR of nearly 19 percent, increasing from \$7.4 billion in 2011 to \$17.5 billion in 2016.*⁵⁴
- **Mobile Health Care:** *The market for mobile health-care IT, which includes remote data collection and monitoring, disease and epidemic outbreak tracking, and diagnostic and treatment support, will grow at a CAGR of approximately 22 percent through 2014 from its projected value of \$2.1 billion by the end of 2011.*⁵⁵

How It Builds on Ohio Strengths

- Ohio made strong job gains in custom computer programming services and computer systems design services industries, which grew 26 percent and 22 percent, respectively, from 2001 to 2009.
- In its IT talent base, Ohio is distinguished in computer systems analysts and network/computer systems administrators, with a 10 percent higher level of its share of the workforce than the nation. Plus, the share of software developers in Ohio grew by 34.3 percent compared with 17.2 percent nationally.
- Within IT industry product markets, Ohio is prominent in manufacturing software, with 53 firms based in Ohio, representing 6 percent of all U.S. firms, and employing 17,618 workers in Ohio, based on data from CorpTech's database of technology firms. Other leading areas of IT industry product markets in Ohio include insurance software, with 5 percent of U.S. firms based in Ohio, and education and training software, with

4 percent of U.S. firms based in Ohio. Thirty-four companies based in Ohio were identified from the CorpTech database of technology firms as providing health services software, comprising 4 percent of all U.S. firms in health services software, and employed a total of 2,404 workers in Ohio and other states.

- Business software is a very active area of venture-backed emerging companies in Ohio, with 36 venture-backed companies attracting \$362 million of venture capital funding from 2006 to 2010. Health informatics is also an active area of new venture-backed software companies in Ohio, with six venture-backed medical/health software companies receiving \$30 million in venture-capital funding from 2006 to 2010.
- While much of IT is protected by copyrights, there is still an active base of patenting among Ohio's IT companies in methods for data processing used in financial and business practices, with 39 patents generated from Ohio inventors and held by Ohio companies from January of 2007 to September 2010.

Connection to Ohio's Biomedical Institutional Strengths

- Ohio's substantial and world-renowned academic medical centers offer an important platform for developing and demonstrating health informatics applications. It was noted that health informatics is a key focus of the state's three NIH-funded Clinical and Translational Science Institutes, which are charged with focusing on how to bring new advances in medical sciences to improved treatments for patients.

⁵⁴ BCC Research, *Healthcare Information Technology*, 2011.

⁵⁵ RCNOS, *U.S. Healthcare IT Market Analysis*, 2011.

- As a field of scholarly activity, medical informatics excels in its level of peer-reviewed publications from Ohio researchers, with 140 publications from 2005 to 2009 or 4.3 percent of the national total.
- Ohio has a strong start on the development of a statewide health information exchange through the nonprofit Ohio Health Information Partnership. Ohio’s statewide Health Information Exchange (HIE)—CliniSync—has been designed and has begun establishing the connections among hospital systems. Out of 6,000 slots available through federal government support, Ohio had 3,690 physicians signed up for electronic health record systems as of May 2011. One of the more active of the nation’s largest states in establishing this new technology infrastructure of a health information exchange, Ohio has in place a strong platform for health informatics application development and demonstration and particularly for creating meaningful linkages to its extensive base of academic medical centers.

***Insights Into Markets That Ohio Can Serve
From Industry Forum Discussions***

Ohio’s focus in software applications is as diversified in its industry focus as the overall Ohio economy. The growth of business applications in Ohio is being fueled by cloud computing-enabled software as a service model for delivering on-demand software for business applications. It also involves increasing use of open source platforms that enable businesses to advance more modular applications customized to their needs.

As health informatics shifts toward a focus on improving the quality and outcome of health-care treatments, Ohio is well placed to build the needed clinical research relationships that can inform future health informatics applications.

In addition, Ohio is also well placed to advance the integration of health-care information technology with medical devices to improve patient outcomes, given its sizable medical device industry. This can both further growth for advanced medical devices and drive new health informatics applications.

Growth Opportunity Focus Area: **SOLAR PHOTOVOLTAICS**

What is it?

Solar power harnesses the energy of the sun and converts it to electricity or heat. Although photovoltaic (PV) technology, which converts solar energy into electricity using cells or modules, has existed for more than 50 years, it has taken decades to turn the technology into commercialized products, and, as a result, become an industry. Innovations in solar technology are enabling a wide spectrum of uses from concentrated solar power plants and building-integrated PV to powering electronic devices. Increasing social and political concern for environmental sustainability combined with the need for secure energy supplies has stimulated demand for alternative energy resources, including solar.

Market Outlook

While the global solar PV market is projected to remain flat from 2011–2017, growing at a CAGR of only 0.8 percent, the North American market is expected to experience substantial growth. According to Frost & Sullivan, PV market revenues in North America will grow at a CAGR of 28.3 percent from 2010–2017 to reach nearly \$17 billion.⁵⁶ The U.S. market accounted for more than 90 percent of North American installations in 2010 and is expected to increase capacity by as much as 5.5 gigawatts from 2009–2014.⁵⁷

⁵⁶ Frost & Sullivan, *Global Solar Power Market*, 2011.

⁵⁷ Solarbuzz, *United States PV Market*, 2009.

Key Drivers:

- *Government incentives and mandates*
- *Cost competitiveness with conventional electricity generation methods*
- *Energy security*
- *Environmental sustainability*

The following discussion highlights the market potential of specific technologies:

- **Solar PV Materials:** *Solar PV modules are constructed using one of three technologies: crystalline silicon, thin film, and concentrating PV. Crystalline silicon technology is estimated to comprise more than 80 percent of market share, with thin film owning most of the remaining market. Thin-film technology is anticipated to make a significant impact on the market in the near-term. Bank Sarasin reports that, as a proportion of total solar cell output, thin-film PV rose five percentage points in 2009.⁵⁸ Particularly important to Ohio, the cadmium telluride (CdTe) solar cell market, of which Ohio's leading thin-film firm First Solar currently holds 90 percent market share, is expected to increase from a \$2.8 billion business in 2009 to \$4.6 billion by 2015.⁵⁹ Concentrator PV (CPV) use concentrating optics to bundle the arrays, enabling greater power output while reducing the size or number of cells needed. CPV is an emerging technology that is gaining traction in the marketplace, and industry experts forecast that the CPV market could grow from \$64 million in 2009 to \$266 million in 2014 at a CAGR of 33 percent.⁶⁰*

⁵⁸ *PV Magazine*, "2011 World PV Market Overview," 2010.

⁵⁹ Solar&Energy, *CdTe Solar Cell Technology Trend and Market Forecast (2006–2015)*, 2011.

⁶⁰ Markets and Markets, "Global Concentrated Photovoltaic Market Worth US\$266.0 Million by 2014," 2009.

- **Building Integrated PV:** BIPV incorporate PV modules into building materials such as curtain walls, windows, and roofing and can be a principal or ancillary source of electrical power. In the past, the BIPV market has been hampered by high costs, difficult installation, and unpopular aesthetics. However, thin-film technologies are creating greater design options while lowering costs. As a result of these advances, Pike Research anticipates the market to grow from 215 megawatts (MW) in 2009 to 2,385 MW in 2016—an impressive CAGR of 41 percent.⁶¹ At that growth, market revenues will increase from \$740 million to \$4 billion during the same time frame. Under ideal development conditions, market revenues could reach as much as \$6 billion in 2016.

How It Builds on Ohio Strengths

- Ohio is distinguished in solar power, with 5.3 percent of U.S. establishments in 2010, according to a recently released comprehensive national database produced by The Brookings Institution and Battelle in “Sizing the Clean Economy.”
- For Ohio, the state’s growing industry strengths in semiconductor and related devices industry is connected with solar power and the production of PV cells. Ohio’s semiconductor and related devices industry grew by 6.2 percent during the last full business cycle from 2001 to 2007 and 11.4 percent during the recession years of 2007 to 2009, reaching 1,957 jobs in 2009. It still has a low level of specialization in Ohio, in part because of its emphasis on solar power rather than broader aspects of semiconductor use in electronics.

- Industry forum participants also noted that Ohio’s legacy of glass and plastics manufacturing has created a unique skill set capability in Ohio that lends itself to solar PV materials.
- Ohio is best known for the presence of First Solar, one of the largest U.S. solar power manufacturers. Recently, Isofoton, a large Spanish solar power firm, selected Ohio as the location for a new manufacturing facility.
- Ohio also has a base of venture-backed companies in solar power, with two companies (Xunlight, Nextronex) receiving investments between 2006 and 2010. Other leading solar PV firms in Ohio include Willard & Kelsey, GreenField Solar, Energy Focus, Inc., and Replex Plastics.
- The Center for Photovoltaics Innovation and Commercialization at the University of Toledo has been building up a significant research focus in thin-film photovoltaics.
- The Photovoltaic and Power Technology Branch at NASA Glenn brings strong expertise for thermophotovoltaic energy conversion systems that convert electricity from heat differentials.

Insights Into Markets That Ohio Can Serve From Industry Forum Discussions

Ohio is viewed as having growth opportunities in both the development of solar power plants, as well as in building-integrated solar applications. In the case of solar power plants, the long-standing presence of First Solar, now joined by Isofoton Solar, are the two industry drivers. For building-integrated solar applications, this market was viewed as playing to Ohio’s high-value manufacturing strengths of integrating innovative technologies into existing products.

⁶¹ Pike Research, *Building-Integrated Photovoltaics*, 2010.