Prepared by: Dennis Barber/Salman Farooq & Battelle Technology Partnership

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- Biomedical
- Building Materials
- Electronics
- Packaging

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Acknowledgements

This document is an update of the Polymer Strategic Opportunity Roadmap prepared by the Battelle Technology Partnership Practice in September, 2004. It serves as a complementary tool and is focused on new developments in polymer, bio-material and advanced materials from a market opportunity and technology possibility perspective.

This report reflects the thoughts and actions of the Ohio polymer industry leadership, and work and ownership of the actionable items and long term impact is, and should be, in their hands. Clearly, the efforts to institutionalize innovation and growth within the polymer and advanced materials industry will contribute to the growth and health Ohio’s aerospace, automotive, medical, and consumer products industries. In fact, those industries are directly dependent on the development of new, higher performance materials for their new products and applications.

The Ohio Polymer Strategy Council (OPSC) and PolymerOhio surfaced the need for an updated strategic opportunity roadmap at one of their quarterly meetings and have consistently supported the efforts with their time and other resources. The development and assembly of this roadmap would not have been possible without their engagement, contributions and encouragement.

<table>
<thead>
<tr>
<th>OPSC Members across Ohio represent Academia and Industry</th>
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<td>Sherwin Williams</td>
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Marty Grueber, from the Cleveland office of the Battelle Technology Partnership Practice, was co-author of the 2004 report and was a key contributor to this update. His work forms the basis for much of the market and technology data and projections within this report.

Salman Farooq (PolymerOhio) has been an invaluable resource, providing context and perspective from his background of government and industry experience. His contributions to this report represent a significant body of work and were critical to the report's continuity, completeness, and relevance to real-world situations. Thanks, Salman.

A Steering Committee comprised of Tom Waltermire (TeamNEO), Wayne Earley, Joe Jacomet (PolymerOhio), Sharell Mikesell (Center for Multi-Functional Polymer Nanomaterials and Devices), and Stephen Myers (Ohio BioProducts Innovation Center) provided ongoing counsel and direction that markedly improved this update.

From its inception, this update has involved industry stakeholders (academia, industry, government) to assure a broad and informed consensus was solicited and achieved. Leaders from industry met on two occasions in groups of 90+ and 50+ reinforcing the importance of the strategic planning effort. In addition, the OPSC met in several meetings in groups of 16-24 range, to discuss and debate industry parameters and market/technology inferences.
<table>
<thead>
<tr>
<th>Contributors / Members</th>
<th>Organization</th>
<th>Contributors / Members</th>
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<td>Paul Boulier</td>
<td>A. Schulman</td>
<td>Lisa Novelli, Dwight Rust</td>
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<td>Stephen Myers, Denny Hall</td>
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<td>Simon Tripp</td>
<td>Battelle</td>
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<td>Jack Irvin, Dwayne Siekman</td>
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<td>Lou Luedtke</td>
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<td>John Lewis</td>
<td>BioOhio</td>
<td>Dale Arnold</td>
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<td>Sharell Mikesell</td>
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<td>Cathleen Hare</td>
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<td>Emery</td>
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<td>Rich Myers</td>
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<td>Saleh Jabarin</td>
<td>University of Toledo, Polymer Institute</td>
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<td>Qihuo Wei</td>
<td>Kent State University</td>
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<td>Jim Sattler</td>
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<td>Sharmila Mukhopadhyay</td>
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<td>Scott Rickert</td>
<td>Nanofilm &amp; Nano-Network</td>
<td>Lance Criscuolo, John Frechette</td>
<td>Zyvex Performance Materials</td>
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<tr>
<td>Arthur Fritts</td>
<td>NanoSperse LLC</td>
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Executive Overview

This document describes and positions the dynamic and rapidly changing markets and technologies within the field of polymers and advanced materials. It is an update to a previous report that has been used to guide the efforts of industry leaders and individual companies over the past 6 years.

Its primary use is to serve as a platform for discussion and decision making leading to economic growth and job creation that is clearly possible through materials and manufacturing development.

The information should be of value to the industry, aligned academic and research institute stakeholders and respective local, state and national government leaders.

The Ohio polymer industry holds a global leadership position and is poised to strengthen that standing through the development and commercialization of high value-added technology based products that meet increasingly demanding market needs.

Ohio’s strengths in manufacturing include a skilled workforce, recognized applied research capabilities and an understanding of how to meet or exceed customer needs through materials innovation. The educational facilities and research institutes in Ohio addressing new and emerging materials needs are recognized and renowned as the best in the world. Ohio’s state and local governments have consistently demonstrated an understanding and commitment to providing the support necessary to retain the leadership role.

Over the last 2 years, it has become clear that the aforementioned strengths are necessary but not sufficient. The lynchpin that is now in place and functioning to fully leverage the individual excellence described is the desire and infrastructure to allow productive win-win collaboration.

This report provides data that allows growth opportunities to be assessed for their fit with industry, academic and state goals.
Primary Conclusions

Ohio’s polymers and advanced materials industry is the largest manufacturing sector in the state and second to agriculture in total size.

There are 2,440 establishments in the industry, employing over 130,000 people. Growth prospects are very attractive based on the industries supply position with growth markets such as electronics, biomedical applications, and alternative/renewable energies.

There is a strong connection between agriculture and polymers as the world moves toward renewable input materials and a stable sustainable position that is not dependent on regional relationships and/or single material availability. Biomass that is produced here in Ohio has the potential to be an important feedstock for specialty chemicals and polymers produced by Ohio’s major companies.

The key to continued industry leadership is the rapid commercialization of technologies that provide materials with unique performance characteristics. Choosing to remain entrenched in current materials technology is the path to reduced use and sure obsolescence.

The report focuses on Global Polymer Markets and what that means in terms of Polymer Opportunity Areas for Ohio. The first set of criteria is a description of “What Is” and is independent of our plans and actions. The latter section, Opportunity Areas, demands a reasoned, responsive and robust set of strategies and actions that will allow Ohio’s manufacturing industries to grow and prosper.

An actionable and prioritized set of strategies and programs proposed by polymer and advanced materials industry leaders follows the section on opportunity areas. This is perhaps the most thought-provoking part of the update and should be the impetus for many readers to become more involved in their industry and/or state.

Below are the global polymer markets identified as representing significant opportunity for growth and profitability.
Global Polymer Markets

- Alternative/renewable Energy
- Automobiles, Aeronautics and Defense
- Biomedical
- Building Materials
- Electronics
- Packaging

The polymer opportunity areas, representing technology strengths and positioning, are

Polymer Opportunity Areas

- Conductive and Electronic Polymers
- Polymer Nanocomposites
- High Performance Polymers
- Bio-based Polymers and Feedstock
- Degradable and Recyclable Polymers
- Additive Manufacturing (Direct Digital Manufacturing)

The strategies developed to assure the Ohio polymer industry capitalizes on its industry leadership position, strong university and laboratory/institute structure, and the states intent to establish a healthy growing economy are shown below.
**Enabling Technologies Critical To Growth**

**Industrial Biotechnology and Bio-refining in Ohio (Collaboration between Agriculture and Polymers)**

Specialty chemicals and polymers have traditionally been petroleum-based but major companies are making significant commitments to the use of renewable resources and this is creating an opportunity for Ohio’s agriculture and polymer industries. Ohio’s agriculture industry can provide renewable starting materials and its polymer industry forms the customer base for the input feedstock. An operational biorefinery is needed to demonstrate the process feasibility and economics for producing bio-fuels and bio-materials from the same input stock and machine configuration.

Support from the state will be required to supplement investments from private companies because of the broad set of unknowns involved in the biorefinery output and the infrastructure needed to provide stable continuous operation.

Competition is moving forward and Ohio risks losing a prime opportunity. France has a multi-billion dollar biorefining facility, DuPont plans a major purchase of Danisco to bring focus to their efforts on bio-technology and bio-materials, and Braskem operates a production plant making more than 400M pounds of bio-based polyethylene from sugar cane ethanol annually.

Ohio should be a leading force in forging collaborative efforts among private and public stakeholders to assure an operational biorefinery becomes a reality near term. Anything less will lead to an erosion of Ohio’s global leading position in materials.

**Advanced Computational Modeling and Simulation**

High Performance Computing allows virtual new product development by analyzing trillions of data points and returning valid prognostic results in a matter of hours. It is grossly underutilized but will become the standard method of product development.

Small to medium size enterprises (SME’s) have the most to gain through use of this technology but its adoption is being held back because of the limited available applications, human talent and the required capital investment.

The technology is in broad use in graphic design, video production, gaming and CAD/CAM applications and major laboratories, universities, and companies use it routinely for advanced calculations involving product and tool design and new materials design and formulation.
Additive Manufacturing Technologies (Direct Digital Manufacturing)

This technology originally involved using 3D printing machines to produce basic forms of prototypes quickly and inexpensively before scale-up to manufacturing quantities. However, it is now being used to produce final products, not simply prototypes.

The technology provides the ability to update designs frequently and P&G uses it to evaluate packaging designs before mass production. It provides a high degree of precision and customization and is used to produce dental crowns and miniature hearing aids within 48 hours. These are examples of directly manufacturing high value added components/products.

Its use in Ohio will likely be in response to medical/healthcare, aerospace and automotive industry needs.

**Primary Strategies**

<table>
<thead>
<tr>
<th>Four Major Thrusts / Pillars</th>
<th>Primary Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>New technology Commercialization</td>
<td>Upgrade the polymer technology infrastructure to pursue significant opportunity areas</td>
</tr>
<tr>
<td></td>
<td>Establish efficient mechanisms to increase the commercial success rates for emerging technologies</td>
</tr>
<tr>
<td></td>
<td>Increase the speed of new technology commercialization</td>
</tr>
<tr>
<td>Value Chain</td>
<td>Strengthen value chain in Ohio by improving competitiveness of small-to-medium-sized manufacturers</td>
</tr>
<tr>
<td></td>
<td>Increase the number of collaborative projects by identifying productive partnerships across the value chain, reducing the time to market for both new technologies and incremental advances in existing technologies.</td>
</tr>
<tr>
<td>Talent</td>
<td>Strengthen the existing infrastructure to assure the established manufacturing talent is capable of leveraging new technology.</td>
</tr>
<tr>
<td>Access to Capital</td>
<td>Increase access to state, federal and corporate funding</td>
</tr>
</tbody>
</table>
Introduction

Purpose of Effort

The purpose of this update to the 2004 Polymer Industry Roadmap is to assure key growth markets, technologies and business opportunities are recognized, evaluated and communicated to polymer, biomaterials and advanced materials industry stakeholders.

This report focuses on new and emerging markets and technologies important to Ohio’s polymer industry. The research, data gathering and analysis was conducted with a global perspective but the conclusions and actions are based on Ohio polymer industry opportunities, growth, and sustainability. Government and academia leaders were intimately involved to assure highly influential non-industry groups were represented.

The update is intended to complement the 2004 Polymer Strategic Opportunity Roadmap. The reader familiar with that report will readily see the consistency and enduring value of the initial roadmap, while noting the changes in opportunities and challenges.
Background

The Ohio polymer industry maintains an international leadership position based on size, technology capabilities, an extensive in-place value chain in close proximity and demonstrated workforce skills. According to a report compiled by the Policy Research and Strategic Planning Office at the Ohio Department of Development, Ohio:

- Ranks first among 50 states in employment within the polymer industry segments of plastics and rubber products
- Ranks first among 50 states in new capital expenditures: investments in buildings and equipment
- Ranks first in plastics and rubber products GDP (U.S. Bureau of Economic Analysis)
- Exports of plastics and rubber products alone grew 7 consecutive years from $1.07 billion in 2001 to $1.59 billion in 2008. Exports of these subsectors in 2009 were slightly down at $1.37 billion

The industry enjoys extensive and productive relationships with nearby academic and government organizations. Taken collectively, the capital, intellectual and collaborative strengths are unequalled.

Having said that, rapidly changing global business dynamics present ongoing challenges to the industry’s sustainability and growth. Maintaining global leadership will require awareness of and the willingness to capitalize on new opportunities and technologies.

Ohio’s leading role in the polymer industry is based on its record of material and process innovation, application development, and broad customer base, but others are working to expand their presence in polymer and composite material markets. South Carolina is actively pursuing Ohio companies to consider relocating and North Carolina recently announced a new composite materials initiative. The French and Portuguese governments have also provided significant resources to their plastics industries to expand markets in polymers, composites and tooling, and have expressed interest in forming partnerships with Ohio companies. Ohio’s multi-faceted and ongoing support to the industry is a crucial factor for long term success.

Polymers will serve as the foundation for Ohio’s future economy with impacts and contributions to a wide range of industries from health and energy to transportation and construction, and as an enabler to many other fields from the biosciences to sensors and controls. Specific actions by industry leaders and participating companies have positioned the industry for job and revenue growth, but, as always, the competition is tough and added effort is needed.
Proven Leadership

In 2001 polymer industry leaders formed two organizations to provide leadership and support to a fragmented industry with limited voice/influence with government and academic institutions. Those organizations were PolymerOhio, which became an Edison Center in 2008, and the Ohio Polymer Strategy Council. PolymerOhio was established to advocate for and provide service to the industry, while the Ohio Polymer Strategy Council provides overarching strategic direction and support.

Collaboration within the industry was enhanced by the 2004 roadmap, and coupled with academic/public sources, has provided a platform for the development of high value-added products and businesses that contribute solid economic impact. Participation in the Ohio Third Frontier program began early and built steadily, culminating in more than $205 million being awarded to the polymers and advanced materials industry. This sum has been buttressed by more than $550 million in associated innovation-directed industry spending.

Zyvex Performance Materials relocated to Columbus, from Texas, after PolymerOhio, CMPND, and the Ohio Department of Development encouraged the company to move and leverage their supply chain partners located in Ohio. Zyvex, and several supply chain partners, were recently awarded a $4.9M grant to fund ongoing development and commercialization of carbon nanotube (CNT) reinforcements for composites. Zyvex has a lead technology position and is expected to grow rapidly as joint ventures are formed with major Ohio polymer companies such as PolyOne.

The significant industry progress seen in the 2000’s can be attributed to the guidance provided by a 2004 study of the industry done by Battelle. Titled, the Polymer Strategic Opportunity Roadmap, this report documented key technologies and innovations required for growing the industry. The technologies with maximum potential included:

- Bio-based materials
- Nano-enhanced polymers
- Instruments, controls and sensors
- Biomedical devices
- Advanced energy
Major progress has been achieved in bio-based materials through the establishment of the Ohio Bio-based Innovation Center (OBIC), a $30 million research alliance of leading academic and industry scientists formed to develop renewable specialty chemicals, polymers and advanced materials. International bio-based product companies seeking a presence in the U.S. identify and use OBIC as an entry point, providing global visibility for Ohio in this area.

Nano-enhanced polymers present a similar case. The Center for Multi-functional Polymer Nanomaterials and Devices (CMPND) is a $60 million Wright Center of Innovation that involves several universities, more than 50 companies and four national laboratories. CMPND has leveraged its capabilities to (1) create and retain 241 jobs; (2) secure over $92M in collaborator funding; and (3) lead the creation of 7 new companies. These are impressive results, by any standard.

### Economic Impact of PolymerOhio, OBIC, CMPND and Nano-Network (2006 till present)

<table>
<thead>
<tr>
<th>Organization</th>
<th>New Sales ($M)</th>
<th>New Investments ($M)</th>
<th>Cost Reductions ($M)</th>
<th>Total Benefits ($M)</th>
<th>ODOD Ratio</th>
<th>Jobs Created &amp; Retained</th>
<th>Companies Created</th>
<th>Companies Attracted</th>
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<td>28.5</td>
<td>27.5</td>
<td>2.4</td>
<td>58.4</td>
<td>14</td>
<td>210 a</td>
<td>2</td>
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<tr>
<td>CMPND</td>
<td>338</td>
<td>33.5</td>
<td>371.5</td>
<td>16.8</td>
<td>241</td>
<td>7</td>
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<td>OBIC c</td>
<td>29.5</td>
<td>71.0</td>
<td>100.5</td>
<td>9</td>
<td>190</td>
<td>5</td>
<td>4</td>
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<tr>
<td>NanoNetwork</td>
<td>4.4 d</td>
<td>8.3</td>
<td></td>
<td></td>
<td>47</td>
<td>13</td>
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<tr>
<td>Total</td>
<td>$400.4</td>
<td>140.3</td>
<td>2.4</td>
<td>530.4</td>
<td>14</td>
<td>688</td>
<td>27</td>
<td>18</td>
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</table>

a PolymerOhio began tracking retained jobs in FY2010-11. PolymerOhio has played major role in many joint projects with OBIC & CMPND. (Does not include 20 jobs forecasted for PolymerOhio later this year)

b SPI data, new jobs was calculated by PolymerOhio by dividing New Sales by $137K

c OBIC data set is incomplete and understated at this time

d 8 responses from Survey of 53 in Jan2011. NanoNetwork was recently formed with membership accelerating from 35 to 300 in just 18 months, sales numbers from this emerging technology activity will take some time to materialize.
**Today**

The industry is now on the cusp of new growth through innovative polymers providing specialized functions. The Ohio Department of Development has designated polymers as a key “vertical” thrust; meaning it is a technology similar to information technology, whose growth also supports the growth of many other technologies. This dual positive impact provides increased benefit per dollar invested by the state, and increases the attractiveness of investments in polymers.

There is a groundswell of support for more collaboration and faster commercialization of high value-added technology-based materials. The Ohio Department of Development and the Third Frontier Program provide a platform for future growth. As the state strategy has evolved and matured, there has been a rebirth of innovation, and entrepreneurship, as evidenced by the number of companies involved and new products introduced. There are also clear signs that large and small companies have recognized the value of collaboration in moving towards commercialization. Summarizing, Ohio has the people, infrastructure and business climate to accelerate economic growth.

The polymer industry is actively renewing itself, recognizing that technology will increasingly drive growth and profitability. Further data regarding emerging technologies, leverage points, and critical mass formation (clusters) will direct near term efforts, while serving as a long-term roadmap for sustained prosperity. An updated strategy and action plan will provide leaders with the information to act decisively, allowing the polymer industry to remain nationally strong and internationally competitive.
### Defining the Industry

The broadly defined private sector polymer industry consists of 10 subsector groupings – each consisting of one of more NAICS code industries.

<table>
<thead>
<tr>
<th>Subsectors of the Polymer Industry Identified in Battelle’s 2004 Roadmap for Northeast Ohio</th>
<th>NAICS</th>
<th>Plastic Shapes, Plates, &amp; Laminated Sheet Manufacturing</th>
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<td>NACIS</td>
<td>Lubricants, Coatings, Paints, Colorants, &amp; Adhesives</td>
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<td>324122</td>
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<td>Custom Compounding of Purchased Resins</td>
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<td>Rubber Product Manufacturing</td>
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<td>Plastics Bag, Film, &amp; Unlaminated Sheet Manufacturing</td>
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<tr>
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<tr>
<td>326150</td>
<td>Urethane and Other Foam Product (ex. PS) Manufacturing</td>
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NAICS codes for nano or bio are not available and hence, data does not include such companies.
Several Businesses fall under the multiple NAICS codes (producing more than one type of product). However, using 2011 data from Hoover’s, duplicates were eliminated to get a true number of plastics, rubber and related establishments in Ohio for small, medium and large businesses based on employees. The cumulative number of establishments for Ohio Polymer Industry stands at 2,440 in 2011.

According to Hoover’s 2011, the breakdown of plastics, rubber and related establishments in Ohio is:

- 2,160 business in Ohio with <100 employees
- 273 business in Ohio which have between 100 to 999 employees
- 7 businesses in Ohio with > 999 employees

In the table below, the number of establishments includes both primary and secondary NAICS codes. Therefore, there will be some overlap in the column titled “Establishments” as a company could fall into multiple NAICS codes.
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<tr>
<th>NAICS</th>
<th>Description</th>
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<th>Medium (100-999 Employees)</th>
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<td>Industrial Mold Manufacturing</td>
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The map below offers a snapshot of the cluster concentration of Ohio’s polymer industry.
**Technology-based Economic Development – The Challenge**

Economic development is an overarching priority to most municipalities, states, and countries around the world. There are multiple, and often inter-related approaches to developing and sustaining a growing progressive economy. Examples include the attraction of growing companies to a specific region and incentives to encourage existing companies to invest and grow. While these approaches have been successful, technology-based economic development offers sustainable benefits that complement and strengthen other approaches.

Technology-based economic development is a complex, multi-faceted effort that requires commitment and contributions from a mix of industry, academic and government sources. In Ohio, the state and the Ohio polymer industry have been working together to effect a transformation to a higher value-added technology-based position for the past several years. Much has been accomplished, including new sales totaling $530M and more than 1200 new jobs.

These tangible visible achievements have been important to the state’s economy, but they represent a small fraction of the strategic vision of Ohio’s polymer industry. The foundation of that vision is a technology-based leadership position that rewards long term investment, risk taking and a commitment to economic prosperity and stability.

The successes to date serve as a preview of the changes required to maintain a position of technology and manufacturing leadership. What’s happened to date:

- Universities across the state continue to revamp their curricula and standards to reflect the importance of polymers and advanced materials in today’s ever changing business climate. Priority has been given to attracting world-class teachers, researchers, and students and providing a crucible for their intellectual exchange and experimentation.

- Industry participants have been active from a global perspective and recognize both the opportunity and challenge that polymers represent in terms of innovation and Ohio-based employment. External technology search and inclusion in a company’s strategy and tactics has become the norm, in many cases, replacing an internal focus that placed a high priority on protecting rather than expanding intellectual assets.

- The State of Ohio government has been instrumental in creating an atmosphere of innovation and entrepreneurship, taking the lead through the Ohio Third Frontier economic development program. This program alone has invested
$1.4 billion and another $700 million in investment funding over the next 4 years is planned. One of the more visible and tangible assets put in place is the National Polymer Innovation Center established on the University of Akron campus in 2010. Construction of this facility provides seven state of the art processes for industry and universities to use to move polymer technology forward. Creating new polymers with custom functionality will be the key to future growth. CMPND provided extensive and invaluable support to the university in their efforts to fund the facility. To date, the Third frontier Initiative has yielded an attractive leverage of 8.4 on each taxpayer dollar.

The Ohio Polymer Strategy Council believes the efforts to date have been on target and consistent with a 2004 Battelle-prepared Strategic Opportunity Roadmap for the Ohio polymer industry. This update reinforces the progress made, but more importantly calls for expanded efforts to move the industry to manufacturing technology-based products and processes that provide the desired and needed performance attributes.

Efforts to inform and assist industry companies in making the move to new technologies must be continued and expanded to assure the transition is broad-based, complementary to value-chain participants, and leads to overall stability and new Ohio jobs.

The programs and efforts recommended in this report will form the cornerstone for related activities that lead to success in growth markets like flexible devices, biomedical and alternative/renewable energy.
Development Speed

Why is speed the number one priority? Simple: We live in a time of exponential change.

Examples include:

- The top 10 jobs in demand in 2010 were not known in 2004
- New technical information is doubling every 2 years (note that means half of the new technical graduates’ education is obsolete)
- There were 31 billion uses of Google last month

The increasing rate of change in business and technology leaves one with no choice but to engage and excel. To do otherwise inevitably leads to stagnation and obsolescence.

The research and underlying basis for this industry update leads to the conclusion that the business winners will be externally focused, collaboratively inclined and committed to growth as the only means of remaining profitable and viable. More importantly, they will be activists who learn from multiple “failures”, understand the importance and recognize that the most compelling competitive advantage is speed to market.

In most cases, speed will come from leveraging one’s internal assets with external resources from the value-chain, customer, specific investments and/or government systems. The inter-locking mechanism must be manufacturing focused technology and the overriding priority must be speed.
The Economic Context

Ohio and the United States need to maintain, and where necessary, recapture manufacturing leadership to assure job stability and growth. The Ohio polymer industry is a visible and important asset for supporting existing industries and growing new industries and new manufacturing jobs. The economic drivers and structural challenges described have a primary influence on Ohio’s polymer industry and are often equally applicable to global opportunities.

Significant Economic Drivers

The requirement for and potential of developing polymer based solutions will be substantially impacted by how markets change to meet consumer and industry requirements. Application development will continue to evolve and the continued or extended use of polymers will depend on their functionality and ability to enable new and desired product performance, but it is clear that overall polymer material use will grow at a higher rate than other materials.

Aging and Healthcare

The continued aging and the increasing importance of healthcare availability and solutions is leading to increased technical sophistication and innovation in diagnostic, therapeutic and clinical technologies. Emerging polymer technologies are ideally positioned to capture major market segments by providing comfort and mobility through the lightweight and unique design capabilities of polymeric materials.

Physical Infrastructure

The nation’s infrastructure is being recognized as the foundation for moving forward to enhance many aspects of 21st century life. Buildings, roadways, bridges and water/gas/electric distribution are critical to the future of transportation and defense but are also major players in the efforts to use alternative and renewable energy sources to achieve a sustainable environmental position.

Older elements of the existing infrastructure will need to be replaced, and those roads/bridges/buildings that remain sound and efficient will need to be monitored in a proactive manner. Polymers and advanced materials offer many possibilities; including
coatings for structures, new additives and materials for construction and novel functionalities achieved through the use of innovative composites, sensors and functional materials.

**Consumer Demand and Tastes**

Consumer goods demand is exploding as the BRIC (Brazil, Russia, India and China) countries seek to match the use and availability of consumer products in more developed countries. Firms developing and marketing consumer goods are aware of increasing demands for added value, functionality and performance at an affordable end user price.

Recent advances in polymer materials will make it the material of choice for many, large volume, diverse applications. Also, the use of existing and development of new polymers often leads to product design innovation that creates a new class of product or capability. Note the use of thermoplastic elastomers (TPEs) in household appliances and power tools.

**Energy Alternatives and Efficiency**

With their strength, reliability, durability and lightweight, polymer materials are used throughout the transportation and aerospace industries to conserve energy and improve performance. Material substitution opportunities continue to grow as new and innovative solutions to energy requirements and sustainability are addressed through research and development.

Wind energy suppliers are using traditional and new functional polymers to provide reliable long-term performance in adverse weather and environmental conditions. Polymers are being used throughout the wind energy platform; in blades, turbine design, and supporting towers. Two examples are coatings to provide improved weatherability and resistance to degradation and materials that can sense structural deterioration and affect an in-place solution (self-healing polymers).

Polymers and the design flexibility offered by solar panels (see the DOW solar roof panels) provide a cost-effective alternative to petroleum-based energy and the unique structural and functional properties of polymers are a necessary and desirable part of many designs being considered and installed.

Fuel cell technology options include the use of polymer electron membranes (PEMs) and other advanced material components for their operation and performance attributes.
There is an urgent and growing market need for high-performance batteries that provide efficient and reliable energy storage for use in the defense, automotive, solar and wind industries. Functional polymers represent a potential component for designing the batteries needed but complementary materials, sensor, and transmission technology will also be required.

**Material Availability**

It is becoming increasingly clear that global demands for energy and consumer products will cause a shortage of key input materials, including polymers, unless innovative solutions to reduce the rate of usage are developed and implemented. One possible solution, as Michael Porter and Mark Kramer point out in a 2011 Harvard Business Review article, is the use of recycled materials and the development of bio-polymers.

The polymer industry’s reliance on oil/natural gas feedstocks competes with the energy industry demand and a significant reduction in the volume used for polymers could provide an incentive for new polymer development. At the time of writing this report (March, 2011), oil has again crossed the $100 per barrel threshold with unrest in the Middle East contributing to major uncertainties moving forward. The use of bio-materials as input for polymers is one alternative that is being successfully implemented on a commercial scale and the expansion of bio-based polymers and related additives appears certain.

Recycling of polymers is also a critical opportunity/challenge for the industry as polymers become more prominent in modern life. Whether it be the bottling industry or e-commerce (TV’s, phones, computers), massive efforts to increase the re-use of polymers are justified as the industry and world strive for increased sustainability and environmental stewardship.

The third leg of the stool to address material availability concerns is a change in design, development and life-cycle philosophy. Industry giants like Wal-Mart, Ford, DuPont and P&G have instituted sustainability initiatives that will mandate major changes in materials and use profiles for the products they produce and market. Caterpillar’s fastest growing division involves the refurbishment and re-use of major components (motors, blades, etc.) of their heavy equipment that have been designed and built specifically to allow re-use, conserve materials and use bio-based polymer materials. John Deere is on a similar path as the Virtual Cycle depicted below indicates.

The challenge and the opportunity is clear. Polymer materials can provide the desired functionality through new higher value-added products and material systems.
**Sustainability**

Polymeric materials are the second most prevalent consumer material (exceeded only by paper) in the waste stream and demand for a more sustainable position is actively increasing within and outside the industry. Recycling technologies will be important, as will the use of bio-mass inputs. Business as usual is not sustainable and the polymer industry must become proactive in developing and commercializing solutions that offer substantive reductions in polymer material waste.

On the opportunity side, unique polymeric properties offer advantages for a wide variety of applications. Membranes for environmental remediation, environment-friendly lubricants and coatings, and fertilizers and herbicides providing time release or reduced leaching are three of the more advanced technologies.

**Defense, Security and Safety**

Defense, security and safety are important to all types of consumers and world politics and dynamics serve to highlight the need for ongoing and improved functionality and protection. Materials that provide strength, flexibility and long-term reliability at attractive economics will rule the market. Many materials required by our military are not currently made in America and polymers offers a path to make substantial changes to that situation.
Structural Challenges

Global Competition

In 2009, as reported by the Society for Plastics International, the U. S. had a $13B trade surplus from the plastics industry due to value added advanced materials and engineered resins. The corresponding plastic product-side trade deficit with China was $3.8B while the total trade deficit with China, including those products that have plastic components (e.g. hair dryers), was $22B.

Historically, lower labor rates have been a principal driver in decisions to shift production geographically but that is changing as world markets change and consumer demands become increasingly important and short term oriented. The need to move production close to new markets (e.g. emerging economies) has been a factor in the location of many manufacturing sites outside the U. S. As major manufacturers move operations (i.e. appliances to Mexico), suppliers in the value chain are encouraged to follow to assure responsive service and lowest overall end-user product cost. The result has been a substantial flow of manufacturing jobs outside the U. S.

Tighter security measures and increased inspection requirements are added burdens that influence the choice of production locations. Imports and exports are now subjected to significant costs, scrutiny and time delays that make time-sensitive or low margin products more difficult to import or export.

A third hindrance to U. S. manufacturing global competitiveness is the regulatory costs imposed on manufacturers. According to the National Association of Manufacturers, the annual regulatory burden for the manufacturers was the highest in the country at $3,700 per employee per year in 2004.

On the positive side, there are recent indications that many polymer companies are re-thinking their decision to move manufacturing offshore. Reduced government aid and incentives, rising labor costs, management talent and control issues, and inconsistent logistics support are among the reasons causing the re-evaluation.
Improved Productivity Leads to Fewer Jobs

Global competition is not the only factor in U. S. manufacturing job losses. Many other countries have experienced higher percentage declines with Brazil, Japan, China and the UK having lost a higher percentage than the U. S. from 2000-2008. Automation based productivity improvements have been responsible for much of this job decrease and that trend is expected to continue.

Increasing productivity and quality through automation and increased efficiencies through new manufacturing approaches like “Lean” will be important to the survival of U. S. manufacturers. Higher value-added/higher margin products will necessarily require technologies that allow manufacturing flexibility and short batch runs without sacrificing quality or cost.

While the move to higher value-added technologies is critical, the key to increased employment will be to produce and market new or expanded product offerings that are able to garner an increased global market share.

The Bio-Economy is Here

Agricultural based feedstock for polymer and specialty chemicals’ production are increasing in appeal to consumers as the awareness of and concern about sustainability and the finite supply of petroleum based feedstock is understood and appreciated. Consumers are now willing to pay a premium when renewable resources are used. Walmart and P&G have recognized this market demand and responded with sustainability “scorecards” for products and packaging from their suppliers. Major polymer processors are also citing economic advantages made possible by the use of agricultural based feedstock.

Longer term, regulatory goals and actions will play a major role in the timing and extent of use agriculturally-derived chemistries achieve in the U. S. The federal Biomass and Energy Development Act established a goal for the chemical manufacturing of producing 25% of its output from agriculturally derived chemicals by 2030.

Complementing the bio-economic influence on polymer chemistries, polymers will be in the forefront of new developments in bio-medicine. New drug delivery systems, improved implant capabilities, orthopedic applications and accelerated wound recovery are a few of the more advanced application areas where polymers play a key role in the function of the product.
Increased Value through Materials and Design

Design expertise is a key component in linking manufacturing capability to customer needs and is often the differentiating factor that provides increased value to customers. This design expertise is important to both end user product manufacturers and supply chain firms. End user expectations and demands will increasingly require new modified, higher performing products and the supplier that can bring value to the part design process will enhance its competitive position.

Life Cycle Management and Increased Recycling

According to Consumers Electronics Association, Americans own approximately 24 electronic products per household. The environmental impact from discarded electronic equipment has provided the impetus for a worldwide effort to improve the recyclability of materials contained in these products. While hazardous materials and heavy metals receive considerable attention, the increased use of plastics also warrants serious attention to improving the rate of recycling these materials.

- More than 2.4 billion pounds of plastic bottles were recycled in 2008. Although the amount of plastic bottles recycled in the U.S. has grown every year since 1990, the actual recycling rate remains steady at around 27 percent.

- In recent years, the number of U.S. plastics recycling business has nearly tripled. More than 1,600 businesses are involved in recycling post-consumer plastics.

According to the EPA, 30 million tons of plastic wastes were generated in 2009, representing 12.3 percent of total Municipal Solid Waste. While the total amount of plastics available for recycling is considerably lower, the efforts must continue on developing the appropriate chemistries, uses and end markets to facilitate broad use of these materials.
Ohio’s Polymer Industry Strengths

The Industry Landscape

Large Companies
- Twenty-nine companies on Fortune magazine’s U.S.-1,000 or Global-500 lists have polymer industry operations in Ohio; including Goodyear, Sherwin Williams, Lubrizol, Momentive Performance Materials/Hexion, Ashland, and Milacron.
- Seven of the twenty-nine have their world headquarters here: A. Schulman, Cooper Tire & Rubber, Eaton, Goodyear Tire & Rubber, Owens-Illinois, Parker-Hannifin, and PolyOne.

Employment
- Ohio employs more than 130,000 within the polymer industry.
- 273 polymer companies employ between 100 and 999 employees in Ohio, according to Hoover’s 2011 data.
- More than 3,000 people in Ohio work for Goodyear, making the company the largest polymer industry employer in the state.
- Other companies employing at least 1,000 include Cooper Tire & Rubber, Eaton, and Yamashita Rubber, Owens Corning and Sherwin Williams.
- Eighty-four of the eighty-eight counties in Ohio have at least one industry establishment, with the majority in 12 counties: Ashtabula, Butler, Cuyahoga, Franklin, Geauga, Hamilton, Lake, Lorain, Montgomery, Portage, Stark, and Summit.

Ohio-based Companies with Polymer Operations on Fortune’s U.S.-1,000 List

Source: Fortune
Exports

- Exports are an important market for rubber and plastic product makers, rising from $1.07 billion in 2001 to $1.37 billion in 2009. NAFTA partners, Canada and Mexico, are the largest foreign markets, combining for $873.5 million of purchases in 2009. China (excluding Hong Kong and Macau) is the fastest growing market for Ohio’s exports.

Investments

- International investment in Ohio is important, with 44 companies from 13 foreign nations employing more than 8,000 people in Ohio making rubber and plastic products as well as resins and synthetic rubber. Five were on Fortune’s Global-500 list and Yamashita Rubber is the largest with more than 1,000 workers.
- Seventy-three companies announced 78 major industry investments* in Ohio from 2007 through 2009. Planned expenditures approached $1.5 billion, and over 2,500 new jobs are anticipated when the projects are completed, as reported by Policy Research and Strategic Planning (2010).

Trends

- Polymer based materials continue to replace other materials. For example, replacing metal and glass with polymers in automotive and composite polymer materials to replace metals in aircrafts.
- During the past few years, two trends in the polymer industry are the consolidation of producers (particularly resin makers) and the globalization of operations.
- While growth of rubber and plastic resins and products is expected in the near term, the industry’s expansion in production and capacity utilization levels is directly tied to the housing market, associated consumer durables and motor vehicle sales. Real growth in the output of plastics products is forecast to be higher than average over the decade of 2006 – 2016.
- High prices for oil and natural gas, which are both feedstock and energy source for the industry, will remain a major challenge for the industry.

(*) These counts are derived from a list of major investments compiled by Ohio Policy Research & Strategic Planning (2010). To be included, a major investment must meet at least one of the following criteria: 20,000 square feet of new space; $1 million to be spent for land, building(s), or equipment; or 50 new jobs.
Ohio Polymer Industry Employment & Wage Analysis

The overall employment in Ohio’s polymer and advanced materials industry is more than 130,000 making it to be the largest employment sector in Ohio. Since NAICS codes have not been established for nano-materials and bio-derived materials, the total does not include small companies or captive companies that are developing nano-materials or bio-derived materials.

According to the 2004 Battelle Roadmap, employment in the captive polymer sector, including companies such as Proctor & Gamble and Delphi, was reported to be approximately 30,000.

Based on a recent report done by Battelle for Ohio Department of Development, there has been 18% loss in employment over the period of 2002 and 2010, reducing the employment in the captive polymer segment to 24,600.

Since, recent data could not be obtained for polymer and related employment at Ohio universities and research institutions, this report uses employment data of 4,000 from the 2004 report. We believe the growth in nano-materials and biomaterials, and the increased number of people going back to universities to add education/training, the university employment is approximately the same if not higher.
According to Ohio Business Development Coalition, Polymer industry employment is greater in Ohio, with 8 percent of the U.S. industry jobs are located here, compared with 4 percent of all private sector employment in the U.S. Ohioans employed in the plastic and rubber industry earn above-average salaries. These salaries vary by industry sector.

The chart below provides data on average wages within the industry, with the greatest pay earned in resins and synthetic rubber production.

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<th>NACIS Code</th>
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<td>Asphalt Shingle and Coating Materials Manufacturing</td>
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<td>Lubricants, Coatings, Paints, Colorants, &amp; Adhesives</td>
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<td>Petroleum Lubricating Oil and Grease Manufacturing</td>
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<td>Lubricants, Coatings, Paints, Colorants, &amp; Adhesives</td>
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<td>333511</td>
<td>Industrial Mold Manufacturing</td>
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</tbody>
</table>

* Estimated

Source: BLS QCEW 2010 data for 2009
Capital Expenditures/Value-Added Analysis

- The chart depicts an upward trend in Capital Expenditures over the past three years in the polymer industry sub-sectors of rubber products and plastic products. For this report, “capital expenditures” are funds spent for building and equipment used for manufacturing”. Capital expenditures in rubber products alone have risen since 2003.

Source: U.S. Census Bureau
The previous two charts also indicate that the proportions of capital expenditures in Ohio between 1999 and 2008 nearly equal the proportions of value-added originating here. On average, 7.8 percent of national capital expenditures for plastics product manufacturers were made in Ohio, while 7.3 percent of the value added by the group came from Ohio. A similar correlation exists between capital expenditures and value-added at 12.5 and 12.7 respectively for rubber product manufacturers in Ohio.

The near equality of these ratios indicates industry companies’ continue to reinvest in plastics and rubber products in Ohio. (The Ohio Polymers Industry May 2010, ODOD)

The charts above also indicate that in spite of pricing pressures, the value-added component has not declined over the time period.
The Advantages of Locating in Ohio

Proximity to Customers/Suppliers – The Polymer Industry in Ohio is close to its major customers, often other manufacturers, and its supply chain. Manufacturing continues to be large part of Ohio’s economy, and industries that are large consumers of rubber and plastics products – automotive, aerospace, packaging and food processing, printing, industrial machinery and medical devices are concentrated in Ohio.

Top Universities, Commercial Research, Federal Laboratories – Below are few of the universities and research institutions in Ohio that offer nationally recognized programs in polymers and advanced materials.

<table>
<thead>
<tr>
<th>Universities</th>
<th>Commercial Research Institutions</th>
<th>Federal Labs</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Akron (Rubber, Polymer, Ad.Mat.)</td>
<td>Battelle</td>
<td>Wright Patterson Air Force Research Lab</td>
</tr>
<tr>
<td>University of Cincinnati (consumer products)</td>
<td>University of Dayton Research Institute</td>
<td>NASA Glenn Research Center</td>
</tr>
<tr>
<td>Case Western Reserve University (Materials Sci)</td>
<td>Plastics Technologies, Inc</td>
<td>EPA Lab (Cincinnati)</td>
</tr>
<tr>
<td>University of Dayton (Aerospace)</td>
<td>Cornerstone Research</td>
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<tr>
<td>Kent State University (Liquid Crystals)</td>
<td>METTS Corporation</td>
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<tr>
<td>The Ohio State University (Composites &amp; Nano)</td>
<td>Smithers Scientific</td>
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<tr>
<td>Shawnee State University (Plastics Engineering)</td>
<td></td>
<td>P&amp;G Packaging Design Center</td>
</tr>
<tr>
<td>University of Toledo (Alternative Energy)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wright State University (Nanotechnology)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Economic Development Organizations Serving Ohio’s Polymer Industry – Six primary organizations serve Ohio’s fast growing and rapidly evolving polymer industry; Ohio Polymer Strategy Council, PolymerOhio Inc, Center for Multifunctional Polymers Nano-materials and Devices (CMPND), Ohio BioProducts Innovation Center (OBIC), Ohio Nano-Network and National Composite Center (NCC). These organizations work to assure the industry is moving towards higher value-added products and applications serving growing markets. They also actively involved in aligning university research with industry and commercial goals. The collaborations formed to commercialize new products and technologies consistently reduce time to commercialization. See Appendix 1 for additional information on these organizations.
Logistics – Ohio offers a central location for distributing polymer products, nationally and globally, through extensive network of accessible rail, major highways and navigable waterways.

Workforce – There is a broad distribution of trained and experienced employees. Ohio has 187 institutions of higher education, more than any other state on a per capita basis, conferring 95,000 degrees each year to associate, bachelor and graduate candidates. Ohio has seven two-year technical colleges offering technical vocational training in polymer materials and manufacturing. The University of Akron’s Global Polymer Training Center and Shawnee State University’s program in Plastics Engineering Technology are notable for providing hands on training in the area of polymer processing.

State Supported Technology Development - Ohio’s Third Frontier (OTF) Program is nationally recognized for its successful linkage of the research capabilities of universities with entrepreneurial efforts in the development of new materials and technologies. To date, the program has awarded over $1 billion supporting a broad array of technology-based collaborative projects that have initially created many new jobs and substantial additions to that number are assured. The leverage factor for each dollar spent exceeds 8.4:1. The polymers and advanced materials sector received over $205 million in direct funding for projects and that was equaled or surpassed by similar indirect project funding (from stakeholders and recipients). This sector has consistently led the way in submitting a high number of quality Letters of Intent indicating the industries strong push for innovation and commercialization.
Resources and Opportunities – A Sampling

The following pages provide a list of resources and industry needs, obtained through visits and interviews of senior management. The intent is to identify specific capabilities of a large company that could be available and of value to the industry but not well known to the industry. Conversely, a technology or manufacturing need of a large polymer company may represent an opportunity for other industry members.

Lockheed Martin – Large Scale Spinning of PBO (polybenzoxazole) Fibers

Lockheed Martin is developing a High Altitude Airship (HAA). Working with Akron Polymer Systems and the University of Dayton Research Institute, LM has successfully demonstrated (in the laboratory) the performance required using PBO fibers. As the commercialization continues, the company is looking to collaborate with an organization that has the capability to do large scale spinning of PBO fibers. Due to the highly specialized nature of the fabric and low projected volumes needed, the large capital investment needs to be leveraged through other uses.

The project is a near-term opportunity, with strong support from DOD and high interest from Lockheed Martin.

University of Akron – Collaborative Projects Wanted

The university has the resources to provide meaningful support to industry and wants to establish additional and more in-depth collaborations with industry members. Both the National Polymer Innovation Center and the Center for Polymers and Advanced Materials have been established to strengthen the university’s linkages with industry. When fully operational, the NPIC will have seven individual processes available for collaborative efforts. These centers offer a number of different approaches to meet differing industry needs and are willing to tailor their efforts to support industry objectives.

One example of successful collaboration involves 3M and its program to award up to 9 faculty awards annually. The University of Akron has received 2 of these awards, indicating a productive alignment between the universities research and faculty team and 3M’s business objectives.
Goodyear – Opportunities to Collaborate on Natural Rubber Alternatives

Goodyear consumes over 1 billion pounds of natural rubber each year and the price of natural rubber has risen from $1/lb to $2.40/lb. in the last 18 months. Part of the cause is the expectation that there will be a shortage of rubber with the growth taking place in BRIC countries (Brazil, Russia, India, China) and emerging markets. Goodyear has been working on a range of alternatives, including isoprene, and is working with the state to build a small scale isoprene plant in Ohio.

The Andersons – Collaborative Opportunities for New Applications Development

The Andersons is an agricultural based company with one of its core expertise in dry or liquid material handling. It offers blending, mixing, packaging, storing, and shipping. The company is looking for complementary products using byproducts from their ethanol business which are currently sold into the animal feed business.

Lubrizol – New Specialty Chemicals Incorporating Bio-derived Feedstock

Lubrizol has strengthened their market position and grown margins and profits through the global recession. The company is now looking to capitalize on the higher margins and grow its two business sectors of additives and advanced materials. Lubrizol’s additives division includes engine, driveline and industrial additives. The Advanced Materials unit contains the three specialty segments of engineered polymers, consumer specialties and performance coatings.

Lubrizol sponsors research in the US and the UK, recently reached an agreement with CWRU, and are in negotiations with the University of Akron for sponsored work there.

Lubrizol is interested in buying feedstock from bio-derived sources and turning them into specialty chemicals. For example, bio-derived acrylic acid is a building block for several specialty products made by Lubrizol.
Ashland – *Exploring Collaborative Opportunities in Bio-refineries*

Ashland has an experienced technical service organization, with broad expertise and capabilities that services customers who use their resins in composites. Their analytical group is well equipped and does, for fee, chemical and physical analysis investigations.

Ashland actively searches for external technologies and maintains an active “needs list” of technologies that are required to meet their business goals. They also maintain a non-confidential list of technologies of interest and look for companies that can complement their internal capabilities.

They use multiple approaches and programs to surface external technologies, including:

- Consortiums with universities to pursue grant funding.
- Work with federal laboratory consortium looking for technologies within the federal lab system. OPSC is used as a way to network with companies.
- External technology network with the Industrial Research Institute.
- Occasionally use open innovation intermediaries such as Nine Sigma.

On a more local (Ohio) note, Ashland is very interested in finding bio-refinery partners who would be interested in making chemicals in addition to fuels like ethanol.

Ashland’s specific needs and interests are shown on a comprehensive chart in the Appendix.

**P & G – Sustainability as a Way of Doing Business**

Consumer products giant Proctor & Gamble has announced a sweeping sustainability effort – one likely to have far reaching impact on the plastics industry. Long term goals announced late last year in a webcast by Cincinnati-based P&G were:

- All packaging will be made from renewable or recyclable materials
- P&G’s manufacturing plants to be powered with 100 percent renewable energy
- Zero percent waste will go from P&G and its consumers to landfills
- Products will be designed to both please consumers and maximize available resources

Officials announced several goals to be reached by 2020, including:

- Replace 25% of all petroleum-based materials with “sustainably sourced” renewable
- Reduce packaging
- Engineer detergents so that all P&G products will work in cold water
- Reduce overall company waste to less than 0.5 percent
- Reduce truck transportation 20 percent

The company’s long-term vision is to eliminate all petroleum-based virgin plastic and they have started moving in that direction by using Braskem SA’s sugarcane-derived polyethylene in selected packaging.

P&G plans to install additional solar panels and wind turbines at its manufacturing plants in California and Europe. Also, they have launched a sustainability scorecard to assess and improve the environmental performance of key suppliers.

**DuPont Converting BioMass to Fuels, Food and Materials**

DuPont is actively pursuing the conversion of biomass into fuels, foods and materials. The company is moving ahead with the purchase of Danisco’s Genencor enzyme business which will put industrial biotechnology and bio-based materials at the center of DuPont. According to the company, the addition of enzymes and a stronger capability in fermentation allows DuPont to integrate across the entire industrial biotechnology value chain, from seeds and agricultural processing through food, fuels and materials production. “This parallels the beginnings of the petroleum refining industry 150 years ago, which took a low-valued input in crude oil and fractionated it to produce value-added fractions like kerosene and eventually gasoline,” said a spokesman.
Technologies Critical to Growth

According to the National Association of Manufacturers, 95% of the 300,000 manufacturers in the U.S. are small and medium sized enterprises (SMEs). While large manufacturers provide employment to millions of Americans, the SMEs historically have provided twice as many jobs. The national economic recovery is reliant on the revitalization of U.S. manufacturing and the most efficient way to spur rapid growth is to leverage the existing manufacturing base. Below are three enabling technologies that will play a critical role in the growth and sustainability of Ohio’s polymer industry.

Advanced Computational Modeling and Simulation

This new tool for manufacturing innovation exists in the digital domain, examining, simulating, and processing trillions of data points, then returning valid prognostic results in a matter of hours, not years. It is one of America’s greatest – and most underutilized – competitive assets.

According to the National Center for Manufacturing Sciences, in the future, 90 per cent of all products will be developed virtually. High Performance Computing (HPC) power will be required in some instances.

HPC tells you what you’d otherwise have to guess – and does it so fast, and with such accuracy, that traditional prototyping and over designing will soon be obsolete. If high performance computing methods were adopted throughout the U.S. manufacturing base, our global competitiveness would be enhanced.

There is an opportunity to capture a competitive advantage using HPC capabilities for product and tooling design, CAD/CAM, prediction of properties, advanced simulation and new materials design and
formulation. The leading barriers to HPC adoption by the SMEs are the availability of applications, talent and capital.

According to a report by the International Data Corporation (IDC), a global provider of market intelligence, nearly half of manufacturing SMEs would use HPC if they could and almost all of them don’t.

According to the Alliance for High Performance Digital Manufacturing, which is comprised of 25 members from academia, industry and government, public/private partnerships could provide catalyst investments to create scalable technology transfer mechanisms for the Advanced Computational Modeling and Simulation supply chain.

According to Hoover’s Database 2011, more than 2100 polymer companies have fewer than 100 employees. Their scale is a barrier to their innovating. It generally costs $30 - $100K for software and another $100K in talent to utilize the system.
Additive Manufacturing (Direct Digital Manufacturing)

The most successful innovators are the ones who innovate at high speed, bringing new products to manufacturing and to market in months rather than years. Through the use of Additive Manufacturing technologies, also known as Direct Digital Manufacturing (DDM), it is possible for innovators and manufacturers to print production quality parts and complete products straight from a 3D CAD file.

Additive manufacturing (AM), also referred to as additive fabrication, is a process of joining materials to make objects from 3D model data, usually in successive layers, as opposed to subtractive manufacturing methodologies. The parts produced can be models, prototypes, tooling components, and increasingly production parts. They are generated from 3D computer-aided design (CAD) data, medical scans, or data from 3D scanning systems. Based on thin horizontal cross sections taken from a 3D computer model, AM systems produce plastic, metal, ceramic, or composite parts, layer upon layer.

For more than a decade, engineers and scientists have been using 3D printing machines to produce basic forms of prototypes quickly and cheaply. Stereolithography, Fuse Deposition Modeling (FDM), Laser Sintering (LS), Selective Laser Sintering (SLS) are some of the additive manufacturing technologies. Over time, the technology has evolved to work with a broad range of metals and plastics and produce bigger and more complex shapes at a faster rate.

According to Terry Wohler, specializing in this field, more than 20% of the output of 3D printers today is final product, rather than prototypes, and growth in usage is forecast to reach 50% by 2020.

The market for additive manufacturing was $1.2 billion in 2007. While this is not large compared to other emerging technologies, it is important to consider the economic impact the technology is having on manufacturing organizations. For example:

- Graco Children’s Products is producing 7,000 – 10,000 parts per year – all with four AM systems and one person.
- Another large manufacturer of toys is producing a staggering 12,000 models per year with two people.

High Frequency in Design Changes –
The design team at Proctor & Gamble uses 3D printing technology to print and evaluate new design consumer laundry detergent bottles before the design is approved for mass production.

Nike’s design team utilizes 3D printing technologies to continuously improve its product line.

**High-Degree of Precision and Customization** - With additive manufacturing technologies, low-volume and highly customized products are produced within days. Examples include a laser scan of teeth being fed into a 3D CAD file, from which orthodontists can print crowns within 24 hours. Miniaturized hearing aids can be produced within 24 hours and medical implants for the knee or spine are routinely produced from a scan of the affected area.

**High Value Added Parts** – Prototype parts tend to be very expensive to make as one-offs by conventional means. With additive manufacturing technologies, companies turn to manufacturing high-value added components directly. EADS Innovation Works, a European defense and aerospace group best known for building Airbuses, uses additive manufacturing technologies to produce prototype parts for their wind-tunnel testing.

With industries in Ohio such as medical devices, aerospace and defense, and automotive, the supply chain of Ohio’s polymer industry (compounders, resin producers and equipment manufacturers) could be leveraged to play a significant role in driving innovation in new materials including but not limited to high-temperature, high-performance materials and nano-composites for additive manufacturing technologies. The Ohio State University and the University of Dayton Research Institute continue to lead research in new materials and additive manufacturing technologies. A growing number of Ohio companies are looking to make investments in these technologies to capitalize on the growth anticipated in the medical and defense area.

*Printing Blood Vessels One Layer at a Time (Source: Organovo Inc.)*

2011 Update: Ohio’s Polymer Strategic Opportunity Roadmap
Industrial Biotechnology & Bio-refining (Collaboration between Agriculture & Polymers)

A revolution is taking place in the supply chain for specialty chemicals and polymers. Until recently, these materials were petroleum-based. However, with concerns about the rising cost and uncertain availability of petroleum, and customer concerns about sustainability, a need has arisen to expand the supply chain by producing materials based on renewable resources. As a result, many companies have made strategic commitments to align their business with the bio-materials phenomena. Ohio has an opportunity to take advantage of this trend and gain a leadership position in the manufacture of such materials by putting in place one or more bio-refineries to manufacture these materials.

Ohio is well-positioned because its two largest industries, agriculture and polymers, can provide the starting materials and the customer base for the materials produced. It is likely that both bio-fuels and bio-materials would be produced in a bio-refinery. Bio-fuels and bio-materials are inextricably linked because bio-fuels often generate large amounts of by-products that can be used to make specialty chemicals and commodity polymers. A bio-refinery would be similar to petroleum refining which generates a host of different materials.

Bio-refineries will only be economically-feasible if by-products are utilized. Currently, the major bio-fuel processes to make ethanol or bio-diesel, generate huge volumes of by-products in the form of dried distiller grains (DDGs) and glycerol, respectively.

Beyond the Start-up Phase

Europe has made considerable progress with the concept of a bio-refining. For example, France has a multi-billion dollar facility that utilizes a number of agricultural inputs to produce fuel, specialty chemicals, and bio-polymer outputs (Ohio Polymer Summit Presentation, French Competitiveness Cluster, Industries and Agro-Resources, June, 2010).

BP predicts that bio-fuel production will reach 6.7 million bbls/day in 2030, a significant level when contrasted to the ~20 million bbls/day used currently in the US (Chemical Week, Feb. 7/14, 2011). Bio-fuel production has also lead to significant generation of by-products which can be the starting point for bio-material manufacture.
DuPont plans to purchase Danisco and their Gnencor enzyme business to focus on bio-technology and bio-materials. “This parallel’s the beginnings of the petroleum refining industry 150 years ago…..to produce value-added fractions like kerosene and eventually gasoline,” said Thomas Connelly, DuPont Executive VP (Chemical Week, January 17/24, 2011)

Braskem, a pioneer in making a bio-based polyethylene from sugar cane ethanol, has put in place a plant making 441 million lbs annually. They have announced a new initiative to put in place a facility that will make 66 million lbs annually of polypropylene homo- and copolymer (Plastic News, Nov. 1, 2010).

Coca Cola and H. J. Heinz Company recently announced a strategic partnership that allows Heinz to use Coca Cola’s PlantBottle™ to package ketchup. The PET PlantBottle is partially made from material derived from sugarcane ethanol in Brazil. The PlantBottle has been used since 2009 to package Coke, Sprite, Fresca, and other soft drinks (SpecialChem, Feb. 28, 2011).

Creating a New Bio-economy Sector

Biomass will come from bio-fuel processing by-products, agricultural crop components (oils, proteins, and fats) and residues (corn cobs, soy hulls, etc.), food processing wastes, and new sources such as algae and wood cellulose. Natural fibers, e.g. wood and straw, will increasingly be used in polymer composites.

Conversion processes will include bio-conversion (fermentation), physical treatment, and chemical modification to produce bio-based materials. Ohio has gaps in companies that practice these skill sets and there is a need to understand these gaps and proactively seek to attract these companies. Considerable opportunity exists for new chemistries and processes leading to intellectual property providing enhanced competitive positions.

Bio-based materials important to the polymer industry that are expected to be produced by a bio-refinery include specialty chemicals (additives, surfactants, etc.), bio-polymers, natural fibers and fillers, and composites from these materials. A strong market demand is emerging for these products.

The energy industry is substantially ahead of the materials industry in terms of securing commitments for bio-materials to be converted to fuels. Energy industry participants are more visible and active with both farmers and government. Increased
attention needs to be focused on feedstock type, availability, optimum use, current value to farmers, logistics, financing, and storage and handling.

Major Private/Public Initiative

Ohio has major polymer companies with strong interests in establishing a bio-refinery to produce the materials needed to manufacture bio-based materials and products. Ohio also has an aggressive agricultural community that shares this objective and has sponsored R&D in this area.

Several local economic development organizations have expressed interest in locating a bio-refinery in their area. One of these organizations is strategically located near Lake Erie providing an ideal waterway for importing biomass from surrounding states and exporting product to Europe and elsewhere.

A bio-refinery is a major initiative that will require private and public forces joining in its planning and implementation. The State of Ohio should lead the project team and federal support and funding will also be required. The importance of developing materials based on renewable resources and complementary to those produced from petroleum cannot be overestimated. Ohio has always been a “Materials” state with an economy that has historically relied on the polymers, glass, ceramics and metals industries. Positioning Ohio to be a major player in the bio-economy for materials manufacture should be a natural next step.
Vision / Mission / Major Thrusts

Ohio’s polymer industry leaders are guided by two principles: Build on Established Strengths and Leverage Collaborative Efforts. These two mind-sets serve as the foundation for multiple concurrent efforts to grow individual companies and maintain global leadership. Every effort is intended to reinforce those principles and strengthen our long term competitive position. Diagram on next page depicts those principles providing the foundation for growth.

There are four primary elements critical to Ohio’s polymer industry maintaining its global leadership. These areas are the focus for a large percentage of the efforts directed to meeting the current and future challenges and opportunities. These elements form the pillars in the diagram showing the industry at a glance on page 54.

The most important opportunity involves a transition to higher value-added applications and products through the use of new technology. The industry must put the building blocks in place to assure that new technology can be rapidly moved from the laboratory or bench to the marketplace. Significant effort and collaboration to identify and put in place, processes that facilitate the commercialization of new technology is underway and this effort must be sustained and expanded.

Ohio’s polymer industry has a significant competitive advantage over other areas because of its comprehensive and multi-talented value chain. Companies located in Ohio can readily use this advantage and maximize its effectiveness because of its nearby location, skilled workforce and operational capital equipment. No other region can match this capability and it is difficult to duplicate short term.

One of the significant contributors to Ohio’s leadership position is its talented and trained workforce located across the state. World-class universities and two-year colleges have a long history of educating and training scientists and technicians to lead the research, development and manufacturing of polymers. Technological advances are creating new knowledge at a rapid pace, changing countless jobs and workplaces, while redefining the essential knowledge and skills needed to succeed in the workplace. Record numbers of Ohioans are enrolling in college to raise their educational levels and sharpen their skills. The report State Higher Education Finance FY 2010 showed record classes at many public colleges and universities and total enrollment grew by 7.7 percent against a national average of 6.3 percent.
Raising educational levels on a broad scale is important because the availability of a reliable, skilled workforce is one of the most important factors for businesses planning to expand or relocate. That is why the state of Ohio is committed to continuously developing its workforce and creating jobs, ensuring that employers have a competitive advantage in the 21st century global marketplace.

To meet workforce requirements, institutions will need to teach in ways that link content, experience, knowledge and skills and that engage a new generation of learners, as well as adult learners who have not been in school for many years. The utilization of technology and online learning will play a critical role going forward. Ohio’s progress in the use of technology for student services has been notable as more than 100,000 students enrolled in online courses, an increase of 23% from 2007 to 2008. Adults (25 and older) make up half of the online enrollments with many seeking to upgrade their skills to be more marketable in the workplace.

The fourth pillar, funding, represents the enabling function that is necessary to sustain and grow the industry to its full potential. State, federal and private funds are used for various purposes and all are crucial to continued progress and stability within the industry.
2011 Update: Ohio’s Polymer Strategic Opportunity Roadmap

Awareness and Support to Ohio Polymer Industry from State and Federal Initiatives

- Build on Strengths
- Leverage Collaborative Efforts

- Four Major Thrusts
- Two Guiding Principles

New Technology Commercialization (Opportunity)
Value Chain (Advantage)
Talent (Sustainer)
- Train
- Retain
- Attract
Access to Funding (Enabler)
- State
- Federal
- Private

- Talent (Sustainer)
- Access to Funding (Enabler)
- Value Chain (Advantage)
- New Technology Commercialization (Opportunity)
Vision

Ohio’s polymer industry sustains global leadership in polymers, advanced materials and bio-based materials products, processes and services. Existing industry leaders transform their companies and grow and prosper through the adoption of emerging technologies. Growth companies and talented people are attracted to a model of collaborative excellence focused on commercial growth. Emerging technology commercialization, product and process innovation, and value chain collaboration have been institutionalized as business processes.

Mission

Build on Ohio’s strengths of proven innovators, research universities, access to value chains and markets, and technology capabilities to transform Ohio’s polymer industry to a position of global leadership in technology-based opportunities. Engage and mobilize industry innovators to transform existing companies (and form new companies) that provide high value-added products and services to growing markets. Attract and retain world-class talent through consistent evidence of emerging technology commercialization and industry growth.
## Polymer Opportunity Matrix

<table>
<thead>
<tr>
<th>Significant Global Polymer Markets</th>
<th>Polymer Opportunity Areas For Ohio</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative /Renewable Energy (wind, solar)</td>
<td>Electronic and Conductive Polymers, including Liquid Crystals</td>
<td>S</td>
</tr>
<tr>
<td>Automobile, Aeronautics &amp; Defense</td>
<td>Polymer Nano Composites</td>
<td></td>
</tr>
<tr>
<td>Biomedical</td>
<td>High Performance Polymers</td>
<td></td>
</tr>
<tr>
<td>Building Materials</td>
<td>BioPolymers and Feedstocks</td>
<td></td>
</tr>
<tr>
<td>Electronics</td>
<td>Degradable Recyclable Polymers</td>
<td></td>
</tr>
<tr>
<td>Packaging</td>
<td>Additive Manufacturing / Direct Digital Manufacturing</td>
<td></td>
</tr>
</tbody>
</table>

**ST** – Strongest/Primary/Create Synergies

**R** – Reinforcing/Build on Existing Synergies

**S** – Strong/Partnerships
Significant Global Polymer Markets

The OPSC commissioned the Battelle technology Partnership to provide an update on global polymer markets and the opportunities for technology-based high-value added polymers. Technology is evolving rapidly in important sectors of the polymer industry and the markets discussed below represent a sampling of the potential opportunities as the technology is commercialized and used to its full potential.

*Alternative/Renewable Energy*

*Automobile, Aeronautics & Defense*

*Biomedical*

*Building Materials*

*Electronics*

*Packaging*
Alternative/Renewable Energy

Market Trends Important to Polymer Industry Development

Recognizing the importance of alternative and renewable energy inputs, both the federal government and the State of Ohio have stated and complementary goals to stimulate the development and commercialization of renewable energy technologies. Aggressive federal and state mandates are in place to obtain part of energy through renewable resources.

The advancement of polymer-based solar photovoltaics will depend on industry-wide pursuits to drive down the cost of solar energy, achieve energy efficiency ratings of at least 10% for polymer-based solar photovoltaics, and simplify manufacturing for mass production.

A key determinant of market entry for polymers for use in renewable energy applications, especially wind energy and solar photovoltaics, is certification according to the International Electrotechnical Commission (IEC) standards.

Accumulation of dust and debris on solar photovoltaic modules can reduce efficiency ratings and requires manual cleaning of photovoltaic arrays. Clear nanocoatings that inhibit the build-up of dust and debris upon module surfaces have begun to enter the market.

The feasibility of “encapsulants” used in solar photovoltaic panels will be driven by the consistency and level of adhesion to the solar cells and glass. Encapsulants must also be weather resistant, flexible, and made from thermoplastic materials (for recyclability purposes).

The introduction of microinverters to the market has the potential to drive down costs, and increase efficiency and output. Traditional modules are connected to a central inverter in which inefficiencies of one panel will drag down the output level of all panels in an array. Microinverters, however, are attached to each panel in an array to isolate inefficiencies, are less costly to replace than a central inverter, and replacement can be scheduled when routine maintenance is required.
Weight reduction poses a significant challenge for the wind energy sector. Advances in carbon fiber composites (CFCs) provide opportunities for both the wind energy and fuel cell sectors. CFCs are light weight (which increases fuel consumption efficiency) and strong (impact resistant), however manufacturing costs must be reduced.

Offshore wind farms are becoming increasingly feasible due to more efficient and less costly turbines, equipped with tower elevators and direct-drive technologies. As a result, fast-drying, weather-resistant coatings and erosion-resistant advanced adhesives continue to enter the market. These coatings and adhesives will play an important role in reducing maintenance costs and allowing wind turbines to maximize seasonal productivity.

Polymeric insulated AC and DC cable lines with the capabilities to travel long distances underground and in seawater, and the ability to be remotely controlled, are essential components for wind farms in remote locations and offshore projects.

Polyurethane adhesives are primarily used by the wind power sector for blade bonding and blade repair. Wind turbines must be able to operate for as much as 20 years without significant repairs, thus adhesives must provide long-lasting bonds. Sealants, primarily polyurethane and silicone-based, are used for waterproofing blades and nacelles.

Current demand for proton-exchange membrane (PEM) fuel cells is significantly greater than demand for molten carbonate fuel cells (MCFC) or direct methanol fuel cell (DMFC) technologies due to the potential for PEM fuel cells in a variety of applications, such as automobiles and electronic devices. Demand for PEMs is forecast to rise by 31.2% between 2008 and 2013. Polymer electrolyte components are essential elements of PEM fuel cells and preferable to alternative materials because they can operate at low temperatures and can be produced in the small sizes ideal for electronic devices.

DMFCs use similar polymeric materials to PEM fuel cells and are ideal for applications with a limited amount of space. Adhesives and sealants can be used in fuel cell technologies to seal hydrogen, oxygen, and moisture within cells and must be heat and chemical resistant.
**Key Emerging and Future Polymer Applications**

Encasing silver particles within polymer layers in solar cells improves the overall efficiency. Researchers have found that the addition of silver nano-particles can be used in a variety of solar cells, and can make polymer solar cells commercially viable.

Silicon-based elastic polymers used as encapsulants for solar photovoltaic modules provide protection from mechanical failure, moisture damage, and are becoming easier and faster to manufacture.

Silicon impregnated polymers can increase efficiency ratings for polymer-based solar photovoltaics and a simplified synthesis process will facilitate mass production.

Nanoporous antireflective (AR) coatings for thin-film solar cells have the potential to capture more sunlight than traditional antireflective coatings from inorganic materials.

Solid-oxide fuel cell (SOFC) technologies have received significant attention because of their potential cost advantage but the technology is only suitable for a limited amount of applications.

Transmission and distribution (T&D) is a significant financial barrier for wind power and the permitting process can be slow. Planning for high voltage transmission lines and routes will require action from federal governmental agencies, including the Federal Energy Regulations Commission (FERC).
Automobile, Aeronautics & Defense

Market Trends Important to Polymer Industry Development

U.S. demand for automotive polymers will be driven by strong growth rates for sealants and adhesives. Trends include automotive manufacturers’ preference for light weight applications (e.g. adhesives rather than mechanical fasteners).

The growth of sealants in the automotive industry is driven by the demand for noise reduction applications in the cabin.

The market for rubber components for machinery in the automotive industry will grow significantly due to an increase in machinery output. Asia remains the fastest growing market for rubber.

Electronic and mechanical components, and low speed and light weight vehicles, continue to drive the expanding automotive market in China.

The emergence of electric vehicles and other energy efficient technologies in automobiles is driven by rising fuel costs and federal legislation that mandates average fleet-wide gas mileage to reach 35.5 mph by 2016. In 2013, European Union emission reduction standards go into effect for nitrogen oxide at 80% and particulate matter (PM) at 66%.

Researchers and firms specializing in composites for the aerospace industry continue to adapt new techniques and are focusing on defense applications, including ballistics composites. The performance of ballistic composites will be dependent on the elastic modulus of resins.

Due to rising fuel prices and the economic recession, order cancellations for Boeing and Airbus aircrafts increased substantially between 2008 and 2009. In 2008, Airbus had a total of 141 cancellations, primarily for narrow-body aircrafts, while Boeing received had 65 cancellations.

The conversion from radar surveillance systems used by air traffic controllers to the new ADS-B system creates opportunities for small aircraft avionics, which will demand equipment upgrades.

The market for hybrid systems in aircrafts is driven by reliability, weight and space reduction. Additionally, the continued growth of electronic components on aircrafts is also driven by the reliability of digital systems and the significant weight reduction of cabling.
The International Civil Aviation Organization (ICAO) has established a goal of 2% annual fuel efficiency improvement for aircraft fleets.

As evident with the assembly of the Boeing 787, aircraft manufacturers are becoming increasingly open to international suppliers including emerging markets in Asia. Potential growth opportunities exist for Very Light Jet (VLJ) technologies and Maintenance, Repair and Overhaul (MRO) of aircrafts with green technologies.

The airline trend toward regional carriers is primarily a response to demand rather than efficiency. However, with forecasted increases in fuel rates, expect the trend to maximize efficiency to continue.

**Key Emerging and Future Polymer Applications**

Unmanned Aircraft Systems (UAS) are expected to grow in the U.S. market. Significant challenges for commercial UAS are apparent. Nevertheless, researchers and airline manufacturers continue to pursue the long-term potential of UAS.

The Joint Strike Fighter requires over 1500 specific parts to be manufactured using high-temperature advanced materials such as PEEK, presenting a significant opportunity for those with the ability to produce these parts/components.

Transparent eyewear, composite materials for light weight helmets and protective gear, flame retardant fabrics, rubber materials and coatings that prevent interaction with hazardous chemicals, and portable energy storage and charging devices have tremendous growth opportunities in the defense market.

Multisensor systems that can synchronize information is an emerging market in the defense industry with great potential for cross-industry applications. Opportunities exist for electronic manufacturers of sensors and surveillance systems and composite materials for maritime and ballistics applications.

The use of bio-based engineering plastics is currently the highest in automotive markets, where PA11 has been dominant for many years. However, over the last few years, the automotive industry has placed increased emphasis on reducing its environmental footprint, and has promoted the use of bioplastics and other sustainable materials such as natural fiber reinforced composites. Bio-based engineering plastics are expected to continue to grow in automotive applications.

- High value, high performance polymers such as Sorona from DuPont and the polyamides from Arkema and other polyamide producers are in this space and ongoing improvements to the production process and process chemistries will add to the potential automotive applications for these polymers.
Biomedical

*Market Trends Important to Polymer Industry Development*

The aging population is a leading driver in the growth of biomedical devices, procedures and services.

In the U.S., the market for medical equipment is expected to expand from $145.4 billion in 2008 to $190 billion by 2013.

Growth in the use of biocompatible materials, in areas such as implantable devices and surface coatings, is expected through 2012 due to growing consumer awareness, aging population, and technological innovations. Commonly used biocompatible polymers include polylactic acid, polyglycolic acid, polyurethane and nylon.

The U.S. trade deficit for medical equipment grew by over 6% between 2003 and 2008, expanding to a $2.2 billion gap between imports and exports. Ireland, Mexico and Germany are leading exporters to the U.S. The emergence of China promises to shape trade dynamics in the future. Important destinations for U.S. exports include Japan, the Netherlands, Canada, and Germany.

Electromedical equipment, which made up 19% of demand for all medical equipment in 2008, is projected to be the fastest growing sector through 2013, driven by technology innovations in medical imaging.

A key determinant of U.S. market entry is the required Food and Drug Administration (FDA) approval. Medical devices are grouped into Classes I, II, and III. Class III devices, such as implantable pacemakers, receive the most scrutiny from the FDA and must undergo clinical trials.

Sterile medical packaging will rise annually by approximately 6% through 2012 and the fastest growing material used in medical packaging is plastic resins.

Demand for medical plastics in the U.S. will expand to $6.5 billion in 2012. The principal economic driver is the increase in use of disposable medical products.

Annual growth for pharmaceutical packaging in the U.S. is predicted to grow by 5.5% through 2012. Opportunities for growth include the markets for plastic dispensing bottles, prefillable inhalers and syringes, parenteral vials, and flip-top closures.
The market for medical disposables in the U.S. will grow to $58.9 billion in 2013. Growth opportunities include the markets for polymer sealants for wound closure, blood glucose test strips, and transdermal patches for the delivery of drugs. While there are many medical adhesive products available, large firms have significant marketing and brand advantages due to customer awareness, loyalty, and the ability to achieve economies of scale by producing goods at lower rates. Venture capital funding for medical devices between 2007 and 2008 dropped from over $3.9 billion and 393 deals made in 2007 to approximately $3.4 billion for 382 deals in 2008.

**Key Emerging and Future Polymer Applications**

Medical device and equipment manufacturers will continue to introduce environmentally-friendly products, especially injectible drugs, to the market. Manufacturers will demand less toxic chemicals, coatings, and sealants, and the use of renewable and/or recyclable materials.

Emerging applications for medical adhesives include the market for implantables, such as cardiac stents. However, approval from the FDA, under Class III categorization, will require clinical trials and testing which will significantly lengthen the certification process.

Trends for the medical adhesives market include a swing toward “light-curing” medical adhesives. The new technology may provide a breakthrough for balloon catheters.

Compatibility between blood and biocompatible materials pose challenges for the development of polymeric surface coatings.

Opportunities exist in the market for biofilms for devices that resist bacterial attachment, and surfaces that can slowly release antibiotics within the system.
Building Materials

Market Trends Important to Polymer Industry Development

Building and construction materials that increase energy efficiency continue to enter the market, driven by rising energy rates, federal tax incentives and changing social values of consumers.

The lagging residential construction market in the U.S. has prevented polymer based building products and materials from fully realizing the potential in the market.

Asphalt shingle roofing systems remain widely used in the residential market, driven by low costs relative to alternative systems. The market for waterproofing adhesives in the U.S. will grow in cold climate regions with aging housing stock (e.g. Great Lakes region), as home owners cannot afford to replace an entire roofing system.

Elastomeric roofing or waterproofing membranes have a somewhat limited market available to them since they are designed for a low slope or flat roof. However, they represent a major technology within “cool roofing” space due to their low emissive properties and high solar reflectance values when a light or white color is used.

Support for green building has slipped during the economic recession. In 2007, 77.4% of 1,600 surveyed designers, architects, and construction professionals believed it was worthwhile to obtain LEED certification. In 2009, 61.7% of respondents agreed.

Building materials constructed from waste byproducts, such as bricks made from fly-ash, is a growing trend in the market driven by cost saving measures, looming governmental regulations and environmental impact concerns of consumers.

In Europe, air conditioning units account for approximately 15% of total energy consumption of buildings and is forecast to grow substantially over the decade. As a result, demand exists for building materials and products that can efficiently cool buildings.

Composites and plastic materials that resemble the preferential material choice for consumers (e.g. plastic trim that resembles wood) have driven growth in the market for plastic building materials.

The largest market served by the adhesives industry in the U.S. is the construction industry at 35.4% of revenue.
Growth in home weatherization, including air and duct sealing, is partly driven by federal incentives. Air sealing incentives include the energy trust incentives which provide 40% of cost, up to $400 for electric heated homes and 50% of costs, up to $275 for gas-heated homes.

Tax incentives for energy efficient windows include the federal energy tax credit which provides 30% of costs up to $1,300. Energy incentives for energy efficient windows include $2.25 per square foot of windows installed for electric and gas heated homes and $3.50 per square foot of windows installed for electric and gas heated homes. These incentives, especially the tax credits, are driving interest in energy efficient windows.

**Key Emerging and Future Polymer Applications**

The emerging trend toward composite roofing shingles is driven by improved durability relative to asphalt shingles and greater design flexibility (e.g. shape and color).

The feasibility of adaptive windows that can automatically adjust the amount of transmitted light depending on the interior and exterior climate will grow with increased public interest in energy efficient products and lower cost.

As construction activity recovers from the global economic downturn, cast polymers will be used increasingly in residential and non-residential construction due to the material's durability, variety of applications, ease of customization and affordability.

Consumption of flame-retardant polymers is set to increase as the global standard of living rises and fire safety requirements improve worldwide. The market will move toward more environmentally compatible flame-retardant polymers in response to legislative pressures and growing social awareness.

Fiber-reinforced polymers will gain market share as they gain industry acceptance for their enhanced performance, sustainability and lower cost over conventional materials.
Electronics

Market Trends Important to Polymer Industry Development

The market for flexible chips, including products ranging from flexible “e-paper” to applications for the military, will be determined by the quality and cost of substitutes for expensive materials including silicon. Opportunities exist for plastics to replace these materials, but candidates must be highly durable and flexible. The market for flexible chips also provides opportunities to significantly reduce the cost of radio frequency identification.

Wisconsin enacted a law in October 2009 that restricts the disposal of electronics in landfills as of September 1, 2010. “E-Cycle Wisconsin” is a newly established program that requires manufacturers to make annual payments to offset the price of residential recycling. As additional states pursue the possibilities of similar legislation, electronics manufacturers continue to research environmentally sensitive components for electronic devices.

The $53M 2009 revenue market for printed electronics is expanding due to growing demand in Asia. Components such as polymer-based inks and flexible plastic materials are technologically limited and present challenges to manufacturers. Technology advances will be required to displace silicon because its consistent performance merits the high costs for applications in printed electronics.

The worldwide growth rate for solid state lighting devices, including light-emitting diodes (LEDs), liquid crystal displays (LCDs), and plasma display panels (PDPs), decreased between 2008 and 2009. LCD applications continue to find growth as a leader in the growing market for flat panel displays (FPDs).

Organic light-emitting diodes (OLEDs), consisting of polymer film layers, is a rising technology in the market for FPDs. OLEDs, in which backlighting is not required, have been introduced to small electronic device applications including mobile phones. However, a potential threat to the realization of OLED technology in larger scale FPDs, such as televisions, is the short lifetime of OLED devices.

Despite the downturn in the global economy, the engineering plastics market in Latin America continues to mature as multinational companies continue to grow. The market is dominated by Brazil and Mexico, and a continued growth rate will be highly dependent on access to credit for machinery acquisition and working capital.

Green manufacturing and regulations continue to play an increasingly vital role in electronics operations.
Drivers of green manufacturing include governmental regulations including emissions standards and worker exposure standards, improved corporate image and market value of the company, reduced liability, and advantages in resource consumption and the conservation of costly raw materials.

Electronic device manufacturers continue to pursue smaller products with efficient designs, thus reducing floor space needed for manufacturing, and transportation costs.

The most common practice in ecodesign is known as design for environment (DFE), which acts in collaboration with the Environmental Protection Agency (EPA). The guidelines encourage snap fits rather than adhesives, which poses a threat to the polymer adhesives sector.

The move away from incorporating hazardous materials including halogens, lead, and mercury is driven by environmental laws and marketing.

**Key Emerging and Future Polymer Applications**

Transparent OLED technology provides opportunities for military and energy efficient windows applications.

Technological innovations involving the ability to embed transistors within plastic can potentially reshape the electronic devices market and allow more versatile applications. Potential advantages of plastic electronics include lower manufacturing and raw material costs.

Product “take-back” programs that promote the recycling of electronics will depend on collaboration between electronics manufacturers, large retailers and service providers. Multinational firms cannot establish recycling programs and opportunities due to infrastructure costs; however opportunities exist for partnerships with retail firms.

Electronics manufacturers are seeking to differentiate their products in order to remain competitive in the market. Polymer materials (such as aliphatic TPU and polycarbonate) that offer easy coloration and durability will increase in demand.

Over the next three to five years high value applications in the areas of electronics, electrical equipment, and other household applications will be key growth areas for bioplastics.
Packaging

*Market Trends Important to Polymer Industry Development*

The global market for packaging reached approximately $400 billion in 2009. Plastic packaging is the largest sector in the packaging industry.

The trend of consumers using the internet for retail purposes is a key driver in the growing global demand for protective packaging.

The volume of packaging for frozen foods will continue to rise in the U.S. due to a preference for convenience and microwavable foods. The use of plastic, sealable and microwavable containers will continue to grow, though safety and health concerns exist.

The use of environmentally friendly packaging (e.g. biodegradable and compostable) is driven by corporate image improvements and social values of consumers. However, higher costs, lack of infrastructure (i.e. hauling programs for composting) and government regulations restricting residential composting have stunted the potential of such applications in the U.S..

An annual survey from Packaging Digest found that sustainability has become an important factor in decision-making among nearly two-thirds of packaging companies. 61% of the respondents also said that sustainability has become a priority among their customers. Companies are also formalizing sustainability practices and making them an integral part of the business.

The survey also found that roughly one quarter of packaging companies have codified their sustainability efforts and 35% have made their strategies public. The most popular sustainability guidelines involve: energy consumption (62%); recycled content specifications (54%); packaging design (49%); and bans or limits on certain materials usage (43%).

The emergence of “ready-to-eat” fruit and healthy diets are helping to drive high growth rates for plastic packaging for produce. The largest expansion in the market for food containers is found in the BRIC countries.

Flexible packaging is increasingly becoming the preferred choice given the trend toward single-serving packaging.

Opportunities exist for medical applications for sterile packaging, flip-top closures, and plastic dispensing bottles.
Polyethylene terephthalate (PET) is a key element in the production of carbonated beverage and water bottles. Carbonated soft drinks and water bottles account for over 60% of the total demand for PET. The fastest growing market for beverage containers is China and the primary application is for milk containers.

In the U.S. in 2010, plastic packaging accounted for approximately 13% of total plastic products in the market.

Packaging from recycled content, recyclability and source reduction are driven by the consumer’s growing appreciation for environmentally friendly products, firm brand image, and corporate financial savings.

Peelable polyester lid stocks have begun to replace mixed-polymer lid stocks. The key drivers for the shift are reduced costs (source reduction) capabilities and environmental advantages, as polyester lid stocks allow the entire package (lid and tray) to be 100% recyclable.

**Key Emerging and Future Polymer Applications**

The emergence of the QR code (a two dimensional bar code) on packaging products allows consumers, equipped with smartphones to link to a website for further information on products and corporations. ISO standards exist for the QR codes and plastic packaging manufacturers may be forced to adapt (e.g. flat surfaces) in order to implement the growing trend into package designs.

There is growing demand from packaging companies and their customers for resins that enable packaging to be more innovative in aesthetics and design as well as improved ecological and performance levels.

Worldwide expansion in the use of Retail Ready Packaging (RRP), which saves transportation and labor costs, is boosting demand for PE film.

Multi-layer film constructions are enabling packaging manufacturers to respond to demand for designs that meet requirements for low permeability. Two-polymer combination structures create effective barrier containers, but boost the demand for adhesives which are required to obtain sufficient cohesion between polymers.

The main application for bio-based plastics has been packaging, where their biodegradability is particularly useful in flexible and rigid food packaging.

- Flexible food packaging in particular will be an important application to follow in this market. However, it will not be possible for bioplastics to replace all the conventional plastics and other materials used in these applications.
This is mainly because these alternative systems offer low costs that will be difficult to replicate with bio-based plastics.

Public awareness has grown regarding solid waste disposal problems in the U.S., where many municipal landfills have been pushed to capacity. Because discarded packaging comprises nearly one-third of municipal solid waste in the U.S. (with packaging as a key market for many polymers, especially PE), containers and other packaging products have increasingly become a subject of environmental concern.

- As a result, consumer demand has grown for packaging that is perceived as environmentally friendly (i.e., ecologically harmless, recyclable, reusable, compostable or fabricated from recycled materials), fostering the expansion of municipal and industrial recycling programs.

- Cradle-to-cradle design is a principle of sustainable packaging that encourages the use of biodegradable materials or other packaging that can be reused or recycled in closed-loop systems.
Polymer Opportunity Areas for Ohio

Ohio has significant strengths and leadership positions in five Technology Opportunity Areas that span the Key Market Application Areas. These technologies offer clear opportunities within the growing markets cited in the previous pages and their growth appears certain. The boundaries on their use and applications are going to expand and will be defined by the technology advancements and commercial successes that can be achieved over the next several years.

*Conductive & Electronic Polymers*

*Polymer Nanocomposites*

*High Performance Polymers*

*Bio-polymers & Feedstocks*

*Degradable & Recyclable Polymers*

*Additive Manufacturing Technologies*
Conductive & Electronic Polymers

**Basis for Opportunity Selection**

**Current Involvement**

57% of Ohio industry respondents are currently engaged in functional polymer activities.

- 43% of Ohio industry respondents are currently engaged in Conductive & Electronic polymer activities.
- 17% are engaged in Liquid Crystal polymers.

There are numerous university research activities in key applications such as flexible electronics, renewable energy, and “smart” materials.

- University/research institute research efforts also extend this area into photonic polymers.

**Future Plans**

52% of Ohio Industry respondents have plans for continued and future conductive & electronic polymer activities.

**Detailed Market Information**

Conductive polymers offer a wide range of benefits compared to metals or other materials in terms of greater flexibility, lighter weight, and ease of handling. Current research is aimed at improving the conductivity and environmental stability characteristics of conductive polymers. Application development for conductive polymers is one of the most active product development areas in the polymer realm given the variety of characteristics that fall within the broad “conductive polymer” context. Application work ranges from more mature areas such as shielding and static dissipation to newer areas such as sensor, actuator, supercapacitor, and flexible lighting applications (Frost & Sullivan, 2010)

The U.S. conductive polymer market is forecast to increase by more than 3% annually from 2009-2014.

- During the next five years, new technological applications in electronics and materials such as carbon nanotubes and naturally derived conductive polymers will increase demand for conductive polymers.
In the last ten years, demand for conductive polymers peaked at 320 million pounds in 2000 and is estimated to have reached slightly less than 250 million pounds in 2009. The performance of the conductive polymer sector is correlated with the demand for durable goods, and as such the industry is relatively volatile. Competition in conductive polymers is very strong due to numerous producers and the availability of alternative materials and technologies.

- Industry leaders tend to be large, multinational corporations with access to capital.
- Small-to-mid size companies are able to compete within the sector, particularly those that focus on niche technologies or end-markets.

The electroactive polymers product market is forecast to be worth $2.8 billion in 2014 (Markets and Markets, 2010).

- The conductive plastics segment accounted for 84% of the total market in 2009, and it will likely retain a significant portion of the market due to its use in electrostatic discharge and interference applications.
- North America is the largest market for electroactive polymer products with a 64% share due to substantial R&D efforts, early product commercialization and a high absorption rate of electronic products. Europe is the second largest market accounting for a 22% share of market.
- The global market for electroactive polymers will increase from 290 million pounds in 2007 to 410 million pounds in 2012: a compound annual growth rate of 5.4%. Although they comprise a smaller share of the broadly-defined electroactive polymer market, inherently conductive polymers (ICPs) are projected to increase in market volume and dollar value through 2010. Capacitors are the primary application for ICPs, followed by electrostatic dissipators, sensors and textiles. (BCC Research, 2008)

Based on reports by SRI Consulting (2009), global consumption of liquid crystal polymers is expected to grow at an average annual rate of 9%.

- At this growth rate, demand will outpace the current supply; estimates state that capacity must grow approximately 5-6% per year to accommodate this increasing demand.
- Demand for liquid crystal polymers is expected to expand most in Asia, and China in particular.
According to PARC, the market for flexible printed electronics is currently about $1 billion but is forecast to reach nearly $45 billion by 2016.

- The majority of this increased activity will come from new markets that are enabled due to the use of flexible electronic substrates or that are possible due to significant cost advantages from “printable” electronics.

NanoMarkets projects the global market for Flexible and Printed Electronics (FPE) will expand to $300 billion by 2025.

- Growth in the FPE market will be primarily driven by demand for substitutes for toxic materials common in traditional electronics, energy-efficient technologies offered in FPE products, and applications in high growth markets such as mobile devices and renewable energy (e.g., photovoltaics).

- Technological advantages in organic light-emitting diodes (OLEDs) provide application opportunities in flexible electronics and mobile devices because OLEDs do not require backlighting and can be fabricated in flexible shapes. Energy-efficient and shatter resistant characteristics of OLEDs are also appealing features in battery-powered, portable devices.

OLED displays and lighting are projected to consume $500 million worth of transparent conductors by 2016 (NanoMarkets 2010)

- Alternative TCOs will comprise 21% of volume in electrode materials used in OLEDs by 2016.

Demand for electronic displays is expected to grow by 2.3% per year to $4.6 billion in 2013. (Freedonia 2010). Demand for mobile phones and portable devices are projected to increase to $1 billion at 3.7% growth per year to 2013.
Polymer Nanocomposites

**Ohio Basis for Opportunity Selection**

**Current Involvement**

49% of Ohio Industry respondents are engaged in nano-enhanced polymers and/or polymer nanocomposite activities. 60% of industry respondents consider feedstock price to be a major consideration in choosing markets to pursue. Nearly every Ohio research university has ongoing research in the areas of nano-enhanced polymers and/or polymer nanocomposites.

**Future Plans**

54% of Ohio Industry respondents have plans for continued and future nano-polymer related activities.

**Detailed Market Information**

Although packaging and automotive have been emerging markets for nanocomposites, electrical and electronic applications and construction will become important markets.

Global market revenue for composite nanoparticles is expected to reach nearly $75 million in 2010 and is forecast to exceed $140 million by 2013 (Frost & Sullivan, 2007). In 2008, global consumption of nanocomposites was equal to 68K metric tons with a market value of $467 million (BCC Research, 2010). The market will expand through 2014 at a compound annual growth rate of 27% and will reach 214K metric tons and $1.4 billion in revenue. Market growth is being driven by decreasing nanomaterial and composite prices and technological advances creating new applications.

The global market for nanomaterials is heavily dominated by the U.S. and Europe which collectively accounted for more than 80% of sales in 2008 (Global Industry Analysts, 2008). Overall U.S. nanomaterial demand is forecast to increase by more than 22% annually through 2013, reaching $1.5 billion, and is forecast to reach $3.7 billion by 2018. Conventional polymer
nanomaterials (clay, fibers, tubes) account for the majority of demand but emerging nanomaterials (e.g., carbon nanotubes) will have higher annual growth.

- Demand for nanoscale chemicals and polymers (representing approximately 44% of the overall nanomaterial market) is forecast to grow by nearly 24% per year through 2013 to total $695 million, and reach $1.7 billion by 2018. Gains will be fueled by rapid growth in applications such as pharmaceuticals, textile treatments, rubber and plastic additives, and energy storage devices.

- Nanomaterial demand in the energy market is forecast to advance by 42% per year from 2008 to 2013 and continue to grow rapidly through 2018 to $380 million. Demand will benefit as advanced batteries, fuel cells and photovoltaic modules rely heavily on nanoscale materials.

The market for nanocoatings and nanoadhesives is projected to experience significant growth through 2015.

- Global revenues will increase from $2.3 billion in 2009 to $19.1 billion in 2015, a CAGR of 39%. Nanocoatings accounted for $2.1 billion of market revenues in 2009 and are projected to account for $17.9 billion of market revenue in 2015.

Consumption of ceramic-containing nanocomposites suffered a minor decline in 2009 but demand is forecast to increase with the market growing at a CAGR of 12.5% through 2014, reaching a value of $145 million.

New functional applications will drive the growth of carbon nanotubes (CNTs).

- The current market global market for CNTs is estimated to be $247 million (Nanoposts.com, 2010).

- By 2015, the market is projected to reach global revenues of $2.7 billion in demand for electronics and data storage, defense, energy aerospace and automotive industries (Research and Markets, 2010).

- CNTs are forecast to gain more than 60% of the market in value terms by 2025 (Plastemart.com, 2009).

Recently, demand for carbon black in conductive composites has dominated the nanomaterial market. This will change as the price of clay-based nanocomposites falls. Clay-based nanocomposites are forecast to grow at a CAGR of 32% from 2009-2014, reaching a value of $692.3 million (BCC Research). By 2025, clays will comprise more than half of market demand by volume. (Plastemart.com, 2009)
High Performance Polymers

Ohio Basis for Opportunity Selection

Current Involvement

49% of industry respondents consider high-performance polymer characteristics (e.g., corrosion or heat resistance) critical to their current business.

43% of Industry respondents consider high strength-to-weight characteristics important to their market activities, with 14% specifying this is the single “most important” characteristic to their customers.

Future Plans

45% of Ohio industry respondents have interest in learning more about high “strength-to-weight” ratio polymers and 36% are interested in polymers for harsh environments.

Detailed Market Information

High-performance polymers, those that perform well under extreme thermal, mechanical, and chemical properties, are among the fastest-growing plastics product groups. New applications are being driven by innovation, product development, and increasing performance requirements (SpecialChem, 2010).

- Market interest in these materials is especially strong since they offer resin suppliers high margins, while much of the plastics industry is facing rising raw-material costs, declining profits and rigorous competition.
- High performance polymers cover a wide range of materials from the well established high performance polyamides to the more recently developed polymers such as liquid crystal polymer (LCP), polyphenylene sulphide (PPS), polyetherimide (PEI), polyether ether ketone (PEEK) and thermoplastic polyimide (PI). These materials are valued not only for their temperature resistance but also their dimensional stability, strength, and...
chemical resistance in highly demanding applications. Significant application areas include automotive, appliance, medical devices, and high heat electronics.

Industry trends have been moving towards higher-value, higher cost, high-performance materials. Major industry players have shifted activities away from highly commoditized polymer markets to newer technologies with greater potential such as solar cells and structural glass laminates.

The world high performance polymer market was valued at $6.1 billion in 2008 and growth is anticipated to occur at a CAGR of 6% through 2012. The full high performance polymer value chain, including polymerized resins to usable forms, is currently valued at approximately $14 billion (Principia Partners, 2008)

- The Medical Sector, and Computers and Peripherals end-markets will experience the highest rates of growth, each growing by a CAGR of more than 8%.
- New players are entering the market, increasing competition and stimulating market growth as the resulting economies of scale allow lower prices.

Among the market segments for high performance polymers (Principia Partners w/ Battelle calculations):

- Electrical and electronics, the largest end-market for high performance polymers, is valued at $1.8 billion and forecast to grow at 6.8% annually, to a value of $2.5 billion in 2012.
- The industrial sector, including chemical processing, oil & gas, food processing, power plants, and water treatment is estimated at $1.40 billion, growing at a CAGR of 5.6%. At this rate, this market segment will reach $1.84 billion by 2012.
- Automotive, an end-market that consumed $1.3 billion worth of high performance polymers in 2007, is forecast to grow at 5.7% over the next five years with continued metal replacement and to address increasing temperature performance requirements in engine compartments. This market is expected to reach $1.7 billion in 2012.
- Consumer goods, where high performance polymers are used in a wide range of applications such as appliances, cookware, sporting goods, and other household items, is valued at $420 million and growing at a CAGR of 5.2%. This market segment’s growth has been dampened by the economic slowdown but new application development continues at a rapid pace.
Aerospace and defense, an end-market valued at $290 million for high performance polymers, has ever-increasing requirements around flammability, smoke, and toxicity, and is projected to grow at a CAGR of 7.1% to reach $409 million in 2012.

Medical, valued at $290 million in 2007 is projected to reach $440 million by 2012 (CAGR of 8.7%) with high performance polymers being used in applications requiring strength, stiffness and biocompatibility.

Computers and peripherals accounted for $180 million of high performance polymers consumption and are projected to grow at a CAGR of 8.3%, reaching $268 million in 2012. Key issues include miniaturization and related heat management, and the increasing use of multi-function products that combine printers, copiers, and fax machines in a single device.
Bio-Polymers & Feedstock

Ohio Basis for Opportunity Selection

Current Involvement

32% of industry respondents are currently engaged in bio-polymer-related activities.

60% of Industry respondents consider feedstock price to be a major consideration in choosing which markets to pursue.

Bio-based feedstock is emerging as a critical issue to Ohio’s polymer and resin manufacturers.

More than 50% of the university respondents are engaged in bio-polymer or bio-feedstock-related research.

Future Plans

43% of industry respondents see the availability of renewable feedstock as an important driver in their future product and market activities.

Detailed Market Information

Between 2009 and 2015, the global biopolymers market is forecast to grow at a compound annual growth rate of 27.3% and reach 2.7 million tons. By 2020, Toyota officials expect one-fifth of the world’s plastic will be bioplastic (BCC Research, 2008)

Demand for biopolymers is dominated by North America which accounted for 45% of global demand in 2009. This demand is being driven by oil dependency, global warming, health concerns, and legislation discouraging petroleum-based plastics.

Global biopolymer capacity was estimated to be less than 2 billion pounds in 2009 but capacity is expected to increase to 5 billion pounds in 2013 and nearly 8 billion pounds by 2020 (Plastics News, 2010).

All “natural polymer” products (directly derived from plant and/or animal sources) will continue to grow in demand. (Freedonia, 2010)
o Cellulose ethers comprise the largest segment of the biopolymer market and are expected to increase 4% per year to reach $1.5 billion.

o Starch & fermentation products will be the fastest growing subsector increasing by 14.6% annually to reach $1.2 billion.

o Protein-based polymers will reach $670 million in 2014 at an annual growth rate of 6.5%.

o Other natural polymer (including marine polymers, exudates and vegetable gums, natural phenolics, and waxes) demand will increase at an annual rate of 4% to reach $1 billion.

According to Frost & Sullivan (2009) the total global bio-based plastics market (bio-feedstock-based polymers and natural polymers) will increase to 396 kilo tons by 2012, a CAGR of 35.3%.

o Much of the growth will be driven by improved supply, with a number of critical expansion and new projects scheduled to become operational.

o Growth rates have been subdued recently because of the recession and the fact that some of the critical product types such as PHA and Polylactic Acid do not have enough capacity to meet demand.

The market is expected to cross the one billion euro mark over the forecast period in terms of revenues, reaching 1.1 billion euros in 2012 (Frost & Sullivan, 2009). Revenue growth rates will be lower at 24%, due to the expected decrease in prices that will occur as the market volume grows.

Globally, the automotive industry will consume nearly 4 billion pounds of engineering plastics in 2010, and bioplastics can be expected to make inroads in the short term forecast period. Already, natural fiber reinforced plastics are becoming preferred in the interiors of cars largely due to lighter weight compared to glass-reinforced composites. Soy-based foams are being introduced in seating systems for cars, and similar opportunities will begin to emerge for bioplastics in these unconventional high performance applications.

The electrical and electronic markets will also be important for bioplastics. PLA is being tested by major cell phone producers in casings and its use will expand over the forecast period. Cell phone housings is an 88 million pound per year market for plastics globally, representing a large opportunity for bio-plastic producers.
In 2009, PLA and starch based plastics completely dominated the market for bio-based plastics globally, accounting for more than 80% total volume. However, the market will get more diverse over the next three to five years, with particularly strong growth in plastics such as commodity bio-based plastics and PHA. Regardless, Cargill is starting additional production of 150M pounds of PLA, indicating their confidence in the market demand.

A key development path will be continued research into new additives and modifiers to enhance the performance characteristics of bio-based polymers. This research will extend into both traditional additive chemistries as well as bio-based chemistries.
Degradable & Recyclable Polymers

Ohio Basis for Opportunity Selection

Current Involvement

There is limited industry involvement in degradable polymers: 14% of Ohio industry respondents are working in this area. 31% of industry respondents consider recyclable polymers and recyclable feedstock to be important to future product and market activities. However, currently only about 10% consider polymer recycling to be a key component of their operations.

Future Plans

43% of industry respondents see the availability of recyclable feedstock as an important driver in their future business and 40% are interested in learning more about biodegradable polymers.

Detailed Market Information

The global market for biodegradable polymers is projected to grow at an annual rate of 13% from 2009-14 according to SRI Consulting (2010). Degradable polymers are gaining traction as consumers, producers, and lawmakers seek to reduce harmful environmental effects.

The biodegradable polymer market grew during the global economic recession while the larger chemical and plastics industry experienced reduced revenues. (Greener Package, 2010).

Europe is the largest consumer of biodegradable polymers with approximately half of global consumption. North American consumption has grown in recent years and is projected to grow further.

Key factors in the growth of biodegradable polymers include: increasing cost competitiveness (vs. petroleum-based products), legislative support, increasing public awareness, desire to improve corporate sustainability practices, and continued quality improvements.
Improvements in structural characteristics and application development are critical for an increase in the use of recycled polymers and plastics as feedstock. While numerous “recycled-content” products exist, ranging from park benches and picnic tables to shipping pallets, a continued emphasis on higher value added applications will be the key to future growth.

U.S. firms have recently developed, tested, and are now marketing applications such as 100% recycled plastic railroad ties and high-load bridges as a substitute for both wood and concrete components (Frost & Sullivan, 2009).

The e-waste stream is the fastest growing waste stream in the country—the U.S. EPA estimates nearly 3.2 million tons of e-waste entered the waste stream in 2007 & 2008.

The total pounds of plastic bottles recycled reached a record high 2,456 million pounds in 2009. The total plastic bottle recycling rate was 27.8%, up from 27.0% in 2008 while the total pounds of plastic bottles collected increased by 46 million pounds annually. The 20 year compounded annual growth rate for plastic bottle recycling was 9.4% (American Chemistry Council, 2010).

- PET bottles collected decreased by 7 million pounds for a total of 1,444 million pounds.
- HDPE bottles collected rose by nearly 45 million pounds to 982 million pounds.
- Polypropylene bottle recycling totaled 27 million pounds, an increase of 27% over 2008 with 48% of the total processed domestically as PP (polypropylene) material, as opposed to mixed material flake.

Recycled PET end use consumption was 937 million pounds in 2009. U.S. and Canadian reclaimers supplied 720 million pounds of flake and pellet from all feedstock sources and 42 million pounds of secondary material. U.S. reclaimers supplemented the domestic supply of PET by importing 98.5 million pounds of post consumer bottles from Canada, Mexico, South and Central America.

In 2009, light-weighting initiatives and unfavorable market conditions reduced the amount of PET resin used in bottles and jars by approximately 4% compared to 2008, bringing the total amount of PET bottles and jars available in the U.S. for recycling to 5.1 billion pounds. Recycled PET consumption in the strapping and carpet industries also declined. The amount of recycled PET used in food and beverage bottles increased 44% and usage in packaging applications increased 22% in 2009.
High demand and inadequate supply is likely to create higher prices for recycled PET. These prices may become competitive with, or higher than, virgin material. Estimates are that the recycling rate will need to double to achieve the PET supply level supported by current and future reclamation projects and infrastructure.

- High demand and short supply remains for good quality granulate, which commands a price premium of at least $.10 per pound over bales.
- In the U.S. new plants and expansions of existing plants added a net increase of 200 millions of pounds in reclamation capacity in 2009.

The use of recycled PET in the packaging industry is constrained by quantity limitations, leading companies that have not been able to secure an adequate supply of recycled PET to make investments in reclamation and conversion technologies.

The use of renewable raw materials in the production of PE creates a more environmentally friendly image and reduces dependence on petroleum-based feedstocks. In August 2010, Procter & Gamble (P&G) formed an agreement with Braskem (Brazil) that involves the supply of a green HDPE produced from ethanol derived from sugar cane. P&G will use the plastic in packaging for selected products beginning in 2011 (Freedonia, 2010).

Polymer material companies will be faced with important issues regarding the use of virgin materials versus recycled polymer feedstocks as collection/sorting capabilities improve the reliability of the recycled polymer supply. These firms will need to look to the development of high-value added additives to replace potential revenue declines from customers turning to recycled polymer feedstocks.
## Mapping of Strategies and Actions to the Polymer Opportunity Areas

<table>
<thead>
<tr>
<th>Pillars</th>
<th>Strategies</th>
<th>Actions</th>
<th>Opp. #1</th>
<th>Opp. #2</th>
<th>Opp. #3</th>
<th>Opp. #4</th>
<th>Opp. #5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. New Technology Commercialization</td>
<td>1. Upgrade polymer research infrastructure to pursue key opportunity areas</td>
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<td></td>
<td>2. Establish efficient mechanisms to increase the commercial success rates for emerging technologies</td>
<td>1. Increased support of $30 million for Akron Functional Material Center, an industrially-focused center designed to accelerate the technology commercialization of new polymeric materials to meet market needs in areas of water, sustainability, energy &amp; biomaterials</td>
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<td>2. Build on early achievements of CMPND &amp; increase the operational funding of CMPND, with added focus, driving applications development from the research/discovery phase to a feasibility stage that warrants further business investment, with a total support of $15-$30 million over 3 years.</td>
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<td>3. Enhance bio-based materials cluster formation through increased support for OBIC with $16-$20 million over 3 years</td>
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<td>4. Establish a Virtual Applications Development Lab with funding support of $11 million</td>
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<td>3. Increase the speed of new technology commercialization</td>
<td>1. Establish a U.S. Consortium on Direct Digital Manufacturing for polymers and advanced materials to develop a broad range of new high-performance functional materials and nano-composites for high-value added applications, with funding support from the state, federal and the industry</td>
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<td>2. Develop a web-clearinghouse of all applicants to Ohio Third Frontier Advanced Materials Program, linked to PolymerOhio’s industry database for efficient linkages</td>
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<td>3. Increase state and industry support of PolymerOhio</td>
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<td>2. Value Chain</td>
<td>1. Strengthen value chain in Ohio by improving competitiveness of small-to-medium-sized manufacturers</td>
<td>1. Develop a polymer portal, providing access to high-performance computing, advanced computational tools, and modeling &amp; simulation software to small and medium polymer manufacturers, with funding support of $7 million</td>
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<td>2. Increase the number of collaborative projects by identifying productive</td>
<td>1. Establish integrated bio-refineries to achieve sustainability in alternative materials with funding support of $30 million</td>
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partnerships across the value chain, reducing time to market for both new technologies and incremental advances in existing technologies.

| 3. Talent | 1. Strengthen existing infrastructure to assure the established manufacturing talent is capable of leveraging new technology. | 1. Increase number of polymer industry events promoting supply chain collaborations, hosted by PolymerOhio, with support from the industry and the State | 2. Increase number of polymer industry events promoting supply chain collaborations, hosted by PolymerOhio, with support from the industry and the State |
|  |  | 3. PolymerOhio to provide leadership role in collaborative multi-Edison center conferences designed around one or multiple large industry player such as Proctor & Gamble, Airbus | 3. PolymerOhio to provide leadership role in collaborative multi-Edison center conferences designed around one or multiple large industry player such as Proctor & Gamble, Airbus |

| 4. Access to Funding | 1. Increase access to State, federal and corporate funding. | 1. Expand online learning degree programs at universities offering polymer-related programs | 2. Create a pool of innovative workers that would support the needs of 21st century businesses, through incenting early linkages between students pursuing science degrees and the technology businesses within the polymer industry |
|  |  | 3. Develop innovative online tools and programs for the incumbent workforce training and development | 3. Develop innovative online tools and programs for the incumbent workforce training and development |
|  | 1. Increase availability of seed and venture capital to commercialize technologies in polymer and advanced material area | 2. Create a $30 million polymer and advanced material focused venture capital fund with funding support from state and industry corporate group | 3. Launch marketing campaigns to portray Ohio’s strengths and leadership in the industry |
|  | 2. Create a $30 million polymer and advanced material focused venture capital fund with funding support from state and industry corporate group | 4. Increase advocacy with federal agencies and increase their awareness of Ohio’s polymer industry, its strengths and capabilities | 4. Increase advocacy with federal agencies and increase their awareness of Ohio’s polymer industry, its strengths and capabilities |

The section below provides a more detailed write-up on some of the initiatives listed above.
**Strategy** - Establish efficient mechanisms to increase the commercial success rates for emerging technologies

**Action** – Increased support of $30 million for Akron Functional Material Center, an industrially-focused center designed to accelerate the technology commercialization of new polymeric materials to meet market needs in areas of water, sustainability, energy & biomaterials

**Rationale** – The Akron Functional Materials Center (AFMC) is a joint initiative between the College of Polymer Science and Polymer Engineering at The University of Akron and the Austen BioInnovation Institute in Akron (ABIA). The AFMC is committed to creating a collaborative ecosystem that facilitates talent development, industrial collaborations, and low cost technology transfer to industrial partners for increasing economic opportunities, global competitiveness and job growth, locally and nationally.

Transformational advances in technological areas of strategic importance to the United States and its economic security including water, sustainability, energy and biomaterials require solutions to fundamental barriers in materials and materials processing. The research activities of the AFMC are structured around elevating the technology readiness level of research discoveries using combinatorial and high-throughput (C&HT) methods, which facilitate the rapid optimization of multi-component materials designed to overcome these barriers and accelerate the translation of these discoveries into products and devices.

The AFMC is modeled after the highly successful 8-year “open source” consortia at the NIST Combinatorial Method Center (NCMC). NCMC was a collaborative research consortia with ~22 industrial, academic and national laboratory members focused on novel technology and measurement solutions focused on increasing US competitiveness in the global marketplace. A recent economic impact assessment by the US Department of Commerce found total benefits to the AFMC industrial members were estimated to be $210.4 million and yielded a benefit-to-cost ratio of 8.55 using an OMB approved formula.

The AFMC was launched by a large investment ($1.6 M) from the ABIA for initial infrastructure and work force development. Industry members of AFMC will have ‘open source’ access to experts and technological developments across areas of
research covering six technical working groups: Nanomaterials, Complex Fluids, Biomaterials, Adhesion, Membranes and Manufacturing. Additional mechanisms for participating at higher levels including Focus Projects, Sponsored Research and CRADAs are available including mechanisms for corporate entities to maintain IP that is developed.

The AFMC resides in the newly established National Polymer Innovation Center (NPIC), which also houses two additional industrially relevant centers including the ABIA’s Center for Biomaterials in Medicine, and the Wright Center for innovation in Roll to Roll Processing. It contains a suite of “resource” level facilities coupled with established “combi tools” dedicated to assisting researchers, industry and innovators with the design, fabrication and optimization of polymers and advance materials across six technical working groups. The other centers and laboratories include biological and imaging laboratories, clean rooms along with industrial scale, multiple field (UV, Thermal, EM) assisted roll-to-roll (R2R) film processing lines (3) located in an adjacent large high-bay area. Collectively, these make the NPIC a unique national resource for industrial research, prototyping and testing.

**Resource Requirements** - Total funding of $30 million over 10 years, with 30% for capital dollars. Current annual operating costs are estimated to be $1.5 million per year, with 80% or more coming from industry partners through membership, fees for services, sponsored research projects and royalties.

**Key Partners**

Strategy – Establish efficient mechanisms to increase the commercial success rates for emerging technologies

Action – Build on early achievements of CMPND & increase the operational funding of CMPND, with added focus, driving applications development from the research/discovery phase to a feasibility stage that warrants further business investment.

Rationale – Polymers and advanced materials are Ohio’s largest industry with more than 2,400 companies and 127,000 employees representing a major driving force of the Ohio economy. Yet, for technical and financial reasons, there are relatively few successful entrepreneurial ventures within the polymer domain in the state. The missing link between the critical mass of polymers and advanced material technologies at seven of the country’s top research institutions (in Ohio) and Ohio’s largest industry cluster is the limited availability and investment of angel and seed capital in polymers and advanced material deals.

CMPND has developed an integrated system with the seven Ohio research institutions, understands the technologies and marketplace, and has the ability to connect the supply chain collaborators. This puts it in a unique position to better align and leverage university research in polymer and advanced materials with the region’s existing industrial assets. CMPND can facilitate the advancement of key technologies from the incubation stage to the feasibility stage; thereby establishing its readiness for demonstration and market entry.

With funding of $1 million per year for 3 years, CMPND will lead industry and university collaborative efforts driving towards RCP and Federal grant type proposals; develop supporting data and prototypes; conduct project demonstrations for technologies with near-term commercialization potential (18 months or less); and provide seed grants of up to $10K with a 1:1 match from the industry to support demonstrations of university technologies and secure follow-on industry investment.

Priority and Timing

Critical and near-term
**Resource Requirements** – The overall level of effort would be near $15-30 million in combined state, federal, university and industry partner funds over a 3-yr period. Potential funding sources include the Wright Center of Innovation/Ohio’s Third Frontier Program funds, interested federal agencies, industry stakeholders and participating universities.

**Key Partners**

The Ohio Department of Development, The Ohio State University, University of Dayton Research Institute, University of Akron, University of Toledo, Kent State University, Case Western Reserve University, Wright State University, Industry Partners, PolymerOhio Inc
**Strategy** – Establish efficient mechanisms to increase the commercial success rates for emerging technologies

**Action** – Enhance bio-based materials cluster formation through increased support for OBIC with $16 - $20 million over 3 years

**Rationale** – OBIC was established in 2005 as a Wright Center of Innovation in response to a strategic need defined in the 2002 Polymer Roadmap. The mission of OBIC was/is to establish Ohio as a leader in the commercialization of bio-based polymers, specialty chemicals, and advanced materials. OBIC links Agriculture & Food Processing ($93 billion) with Chemicals, Polymers & Advanced Materials ($89 billion), two of Ohio’s largest industries and major drivers for economic development.

With targeted direction from industry, OBIC has deployed proven strategies and services to support entrepreneurial ventures including enhancing the effectiveness of interactions between industry and the research assets which best fit the needs of the respective venture. OBIC employs proven cluster development practices to promote and nurture formation of regional industries around technologies that deliver sustainable, bio-based materials meeting defined market needs.

OBIC has developed a unique ability to accelerate the development and integration of technologies, services, resources, supply chains, and skills required for a product to reach commercialization. OBIC’s uniqueness stems from its ability to provide a range of critical capabilities not found in combination elsewhere. These cluster support activities include situational analysis, value proposition development, networking, collaboration-building, a range of assessment capabilities, acquisition of resources, advocacy, project oversight, and workforce development activities.

With proven capabilities in place and increased funding going forward, OBIC is ideally positioned to accelerate and improve the rate of success of commercialization ventures. Access to University assets in support of industry initiatives is a key factor, and other activities would include materials flow analysis, prototype development, techno-economic analysis, developing pilot-scale demonstration facilities, and application development to support industry-led initiatives.

**Priority and Timing**

Near-term and critical

**Resource Requirements**

2011 Update: Ohio’s Polymer Strategic Opportunity Roadmap
With funding of $2 million per year for 3 years, OBIC will continue to deploy proven practices to support and leverage industry and academic assets in support of entrepreneurial ventures. Funding will be leveraged through state and federal grants, industry grants, contracts that include match cost sharing and industry-led seed grants. Potential funding sources include Third Frontier Programs (including the WCI Success Fund), other state and federal agencies, industry stakeholders, industry-based organizations, and universities.

The overall level of effort would require a $16-$20 million investment in combined state, federal, universities and industry over a 3-year period. Strategic initiatives will include materials flow analysis, bio-refining demonstrations and applications development facilities.

**Key Partners**

Ohio Soybean Council, Ohio Department of Development, OBIC Board of Advisors, Ohio Polymer Strategy Council, PolymerOhio, Battelle, Ohio Farm Bureau Federation, Industry Partners, Ohio Chemistry Technology Council, Ohio Department of Agriculture, USDA Agricultural Research Service, NorTech, University of Akron, and The Ohio State University
Strategy – Increase the speed of new technology commercialization

Action – Establish a U.S. Consortium on Direct Digital Manufacturing for polymers and advanced materials to develop broad range of new high-performance functional materials and nano-composites for high-value added applications

Rationale – Direct Digital Manufacturing (DDM) is used interchangeably with additive manufacturing. Additive manufacturing (AM) technologies such as the fuse deposition modeling (FDM), stereolithography (SL), laser sintering (LS), selective laser sintering (SLS) and 3-D printing, are revolutionizing the U.S. manufacturing sector. Techniques once used to develop solid-state block-type table-top models, are increasingly used to print functional prototypes and production quality parts directly from a digital file, reducing lead time, costs and material wastes for the manufacturers. In addition, AM technologies are enabling improved product designs not producible with conventional subtractive processes. These technologies also allow manufacturers to design for manufacturing within the U.S., offsetting jobs being lost as a result of off-shoring.

Limited range of polymers and advanced materials available for AM technologies, higher price of select materials for value-added parts, reliability and the inability to produce larger parts and faster are among the challenges that are driving rapid growth in this area. Europe has a head start in establishing cooperative efforts to address these limitations and as a result lead in many of the critical AM technology areas. One such effort is lead by U.K. Currently, U.S. lacks a similar effort.

The overall objective of the U.S. Consortium on Direct Digital Manufacturing for polymers and advanced materials to improve awareness of DDM within the polymers and advanced materials industry of Ohio, and to advance research and commercialization of technologies developed at universities and companies that will address the limitations in AM manufacturing technologies including choice of materials, part production speed, quality, size limitations for parts produced etc.

The consortium comprising of polymer and advanced material related organizations from industry, academia and government will establish a U.S. Center of Excellence in Direct Digital Manufacturing leveraging Ohio’s polymers and advanced materials industry to:

- develop new materials including but not limiting to high-temperature functional materials and nano-composites,
- create new high growth high value added opportunities for Ohio manufacturers,
- transform the manufacturing sector by leveraging benefits of AM technologies for certain applications,
- enable the manufacturing sector to design and produce products not previously possible with conventional subtractive processes, and
- maintain competitiveness of Ohio’s polymer industry

**Priority and Timing** –

Critical and near-term

**Resource Requirement** – The total cost of overall effort $9 million - $15 million, with funding support coming from industry, academia and government.

**Key Partners** – University of Dayton Research Institute, PolymerOhio Inc, Edison Welding Institute, Air Force Research Lab, ManTech Program, Federal agencies, EOS, Stratasys, industry stakeholders
Strategy – Strengthen value chain in Ohio by improving competitiveness of small-to-medium-sized manufacturers

Action – Develop a polymer portal, providing access to high-performance computing, advanced computational tools, and modeling & simulation software to small and medium polymer manufacturers, with funding support of $7 million

Rationale –

To foster Manufacturing Extension Partnership’s (MEP) vision of next generation manufacturing, we must raise the awareness of manufacturing companies, small- and medium-sized companies in particular, of the benefits of modeling and simulation through applications of practical, cost-effective, productivity-enhancing computational methods. The impact would be significant by helping raise the levels of more than 300,000 SMEs that are the backbone of the country.

The polymer portal will look to provide access to a range of sophisticated tools including access to high-performance computing capabilities to more than 1,600 polymer SMEs at affordable prices. It will provide access to expertise in polymer science and engineering, computational resources and software for modeling and simulation, databases with relevant material properties, training, business intelligence and strategy, vendor relevant material, advanced instrumentation and measurements, and research results and directions. For example, for composite material simulation, user will define matrix, fiber, distribution and geometry and in seconds, the portal will generate mechanical properties such as tensile, bending or torsion, and also offer information on thermal, electrical and magnetic properties.

The polymer portal will target small to medium polymer companies to assess their needs and methods that will be most effective for them, train their incumbent staff in applying these methods and provide access to a range of sophisticated tools at an affordable price.

Priority and Timing – Critical and near-term

Resource Requirements – Total project cost of $7 million will cover portal development, access to high-performance computing capabilities, design e-learning training programs for SMEs, software licenses, access to database of range of...
materials, properties, etc with an annual operating cost of $500K per year for four years before becoming self-sustaining. Additional funding from the federal MEP is possible since they have a vested interest in taking our Polymer ePortal national.

**Key Partners** – PolymerOhio Inc, Ohio Supercomputer Center, U.S. Council on Competitiveness, Ohio Department of Development, Federal Manufacturing Extension Partnership (MEP) program, polymer industry SMEs
Sources

A variety of printed and electronics information resources were used to provide information, insights, market trends, and background for this update. The sources include (citation information if available is included within the document):

- Specific firms’ websites and materials
- Articles and website information from industry/press publications: Plastics News, Plastics Engineering, Chemical Week, et al
- Press releases and website materials from market research firms including: Freedonia Group, Frost and Sullivan, SRI Consulting Business Intelligence, etc
- Data Provided by SPI
- OPSC membership: meetings and interviews
- PolymerOhio, Center for Multifunctional Polymers Nanomaterials and Devices (CMPND), Ohio BioProducts Innovation Center (OBIC)
- *The Ohio Polymers Industry: Rubber and Plastics Resins and Products, and Related Machinery*, May 2010 by Ohio Department of Development
- “Northeast Ohio Polymer Strategic Opportunity Roadmap”, September 2004, by Battelle
APPENDICES
## Appendix 1 - Economic Development Organizations Serving Ohio’s Polymer Industry

<table>
<thead>
<tr>
<th>CMPND</th>
<th>OBIC</th>
<th>NCC</th>
<th>PolymerOhio</th>
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<tr>
<td><strong>Background</strong></td>
<td><strong>Mission</strong>: Build link between basic research &amp; material suppliers / manufacturers in nano-technology</td>
<td><strong>Mission</strong>: Accelerate commercialization of bioproducts that enhance Ohio’s economic growth</td>
<td><strong>Mission</strong>: Focused on enhancing Ohio’s polymer industry companies’ global competitiveness and growth</td>
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<td><strong>Formed</strong>: May, 2005</td>
<td><strong>Formed</strong>: May, 2005</td>
<td><strong>Formed</strong>: Established in 1996 by UDRI, Dayton Development Coalition, EMTEC, AFRL, &amp; ODOD</td>
<td><strong>Formed</strong>: 2001</td>
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<td><strong>Funded</strong>: $19.5M capital; $3M operating; $44M from industry collaborators</td>
<td><strong>Funded</strong>: $11.5M plus $23M from industry collaborators</td>
<td><strong>Funded</strong>: Designated as an Edison Technology Center in 2008; $600K from ODOD, $300K from Industry</td>
<td><strong>Funded</strong>: Designated as an Edison Technology Center in 2008; $600K from ODOD, $300K from Industry</td>
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<tr>
<td><strong>Size &amp; Scope</strong>: 70 member companies &amp; 10 companies in residence</td>
<td><strong>Size &amp; Scope</strong>: 15 member companies &amp; 10 companies in residence</td>
<td><strong>Size &amp; Scope</strong>: 70 member companies &amp; 10 companies in residence</td>
<td><strong>Size &amp; Scope</strong>: 70 member companies &amp; 10 companies in residence</td>
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### Successes

**CMPND**
- Provided earliest funding to 3 projects that later received OTF grants at the maximum level
- Provided critical early networking to 6-10 other OTF awards.
- Cutting edge research required for success
- Extensive collaboration solely due to CMPND
- Capital equipment operational
- New jobs created: 206
- Companies started/attracted: 7/2
- National Polymer Innovation Center constructed

**OBIC**
- Collaborate with industry, academia, and government to link the innovation process.
- Facilitated formation of new clusters with common goals.
- Assist collaborators on grant preparation.
- Establish strong connection to polymers/specialty chemicals markets.
- Provide project management

**NCC**
- 15 year history
- Support to local high-tech organizations (AFRL, UDRI)
- Collaboration efforts in wind energy, materials development, automotive, and aerospace
- Capital equipment operational & available to members

**PolymerOhio**
- The model for “how to” connect and collaborate across technologies and industries
- Designated a “vertical” technology indicating its efforts affect many other industries/markets across Ohio
- Conducts numerous events – Emerging Technology Forums, Ohio Polymer Summit, Legislators Lunch, et al
- Has created an international presence and contacts
- Spurred the rapid growth of Nano-Networks; a quasi social nanotechnology network (220
## CHALLENGES
- Operational funds need to be 40% of total funding.
- Mission to move technologies through the “valley of death” unlikely to be independently sustainable
- Securing the needed pre-seed funds for materials, prototypes, et al.
- Cluster strength and growth
- Difficult economic model to sustain; high capital needs & costs.
- Emerging technologies require new investment
- Must provide “expert” process & product services at competitive price
- Supporting the real & broad variety of needs in the industry
- Annual funding mechanism
- Generating funds through programs to finance growth in services offered
- Time for advocacy efforts at state and federal level

## CHANGE
- Secure additional operations funding
- Increased focus on federal funding/programs
- State and/or federal funding highly desirable
- Update to strategic opportunities roadmap will direct changes in emphasis, if appropriate
- Role as “vertical” integrator will require broader suite of programs

## FUTURE
- Funding for 2011/2012 requested
- Evolve to the recognized networking and “one stop” demo platform for nano and advanced materials
- Role in supporting polymer growth in Ohio
- Vision to become self-sustainable
- Funding for 2011/2112 requested
- Evolve to National Center of Excellence
- Role in supporting polymer growth in Ohio
- Vision to become self-sustainable
- Maintain role in supporting polymer industry growth in Ohio
- Active participant in industry strategy update
- Continue major role in industry health and growth

## GROWTH AREAS
- Markets include wind energy, transportation, defense & aerospace
- Technologies include: nano & nanoscience at interface and novel foams; affordable & high-strength fibers; integrated and precision manufacturing for composites
- Biorefineries
- Waste stream to energy
- Green materials for building
- Use state/local/federal funding to build unique expertise that allows growth in current technologies
- Leverage international to benefit Ohio
- Growth in revenue generating services, leveraging increased state support
- Position as “vertical” technology
### Appendix 2 – Business Incentives For Expansion in Ohio
(Source: [www.development.ohio.gov](http://www.development.ohio.gov))

<table>
<thead>
<tr>
<th>State of Ohio Business Incentives</th>
<th>Purpose</th>
<th>Name</th>
<th>Loan/Grant/Tax Credit</th>
<th>Available for</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure Development Incentives</td>
<td>Making Your Site Ready for Business</td>
<td>Roadwork Development (629) Account</td>
<td>Grant Funds</td>
<td>Available for public roadway improvements, including engineering and design costs</td>
<td>Projects primarily involving manufacturing, R&amp;D, high technology, corporate headquarters and distribution activity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ohio Rail Development Commission</td>
<td>Loan and Grant Funds</td>
<td>Available for public and private rail improvements, including engineering and design works</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ohio Water Development Authority</td>
<td>Low-interest Financing</td>
<td>Available to local communities for public water and sanitary sewer improvements</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Community Development Block Grant</td>
<td>Federal Grant Funds</td>
<td>Available through state to assist with public road, water and sanitary sewer improvements benefitting ED projects</td>
<td>Hire at least 51% from low-to moderate-income populations in county of project location</td>
</tr>
<tr>
<td>Low Interest Financing</td>
<td>Building Your Facility and Buying Equipment</td>
<td>166 Direct Loan</td>
<td>Loan</td>
<td>Available to help finance manufacturing facilities with eligible uses: new building construction, building acquisition, machinery &amp; equipment acquisition</td>
<td>Capped at 30% of project cost to a max of $1M USD. Min loan amount of $350,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ohio Enterprise Bond Fund</td>
<td>Revenue Bond Financing</td>
<td>Available through S&amp;P AA-rated fund, proceeds from sale of bonds are loaned to companies for fixed rate, long-term capital asset financing</td>
<td>Rates are fixed depending on type of bond issued with terms: 7-10 yrs for equipment, 15-20 yrs for real estate. $10M USD available through program</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R&amp;D Investment Loan Fund</td>
<td>Direct Loan financing</td>
<td>$1M USD to $25M USD available for projects primarily engaged in R&amp;D activity</td>
<td>Rates are fixed with terms similar to those of commercial financing. Cos receive $ for $ non-refundable Ohio corporate</td>
</tr>
<tr>
<td>Workforce Development Financing</td>
<td>Finding and Training Your Employees</td>
<td>Pre-employment Recruitment, Testing and Screening Services</td>
<td>ODJFS provides a skills testing and employee recruitment services to companies at no cost, while company retaining control on selection and hiring process</td>
<td>Cost savings to employers up to $1,000 per employee hired</td>
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</tr>
<tr>
<td>Ohio Workforce Guarantee</td>
<td></td>
<td></td>
<td></td>
<td>Formerly known as Ohio Investment in Training Program</td>
<td></td>
</tr>
<tr>
<td>State and Local Tax Incentives</td>
<td>Reducing Your Long-Term Costs</td>
<td>Ohio Job Creation tax Credit</td>
<td>For certain high-wage industries creating 10 or more full time jobs in 3yrs</td>
<td>Also, for companies creating 25 new FT jobs within 3 yrs.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>R&amp;D Investment Tax Credit</td>
<td>Non-refundable tax credits against franchise (income) tax credit</td>
<td>For qualified research expenses by Ohio eligible C-corp. Credit calculated on 7% of qualified investment in a specific year</td>
<td>Other criteria required by program. Credit can be carried forward for up to 7 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Local Property Tax Exemptions</td>
<td>Tax Abatements</td>
<td>Local communities can elect to abate a portion of property taxes owed by a company</td>
<td>Abatements are 50-75% of taxes exempted for 10-15 yrs on real or tangible property</td>
</tr>
</tbody>
</table>
### Appendix 3 – Technology Needs Identified by Large Polymer Companies

<table>
<thead>
<tr>
<th><strong>Ashland’s Business Group-Specific Needs and Interests</strong></th>
<th><strong>Adhesives</strong></th>
<th><strong>Aqualon Functional Ingredients</strong></th>
<th><strong>Valvoline</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Composites</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Bio-based resin building blocks</td>
<td>- Structural adhesives</td>
<td>- Cost-effective sources of pure cellulose</td>
<td></td>
</tr>
<tr>
<td>• For unsaturated polyester (UPE) and vinyl ester (VE) resins</td>
<td>• Higher heat resistance – for wood, composites</td>
<td>- Modification / etherification of cellulose</td>
<td></td>
</tr>
<tr>
<td>- Styrene replacement / reduction in UPE and VE resins</td>
<td>• Improved impact resistance</td>
<td>- Rheological control of aqueous systems</td>
<td></td>
</tr>
<tr>
<td>- Resins with improved fire resistance</td>
<td>• Pressure-sensitive adhesives (psa)</td>
<td><strong>Valvoline</strong></td>
<td></td>
</tr>
<tr>
<td>• Lower smoke and toxicity</td>
<td>• 100% solids</td>
<td>- Low wear, high thermal conductivity fluids</td>
<td></td>
</tr>
<tr>
<td>- Low density composites</td>
<td>• Emulsion-based psa’s with performance comparable to solvent-based</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Natural fiber-based</td>
<td>- Robust flexible packaging adhesives</td>
<td>- Low cost base oil feedstocks</td>
<td></td>
</tr>
<tr>
<td>- Antifouling gel coats</td>
<td>- Replacements for Bis Phenol A</td>
<td>- Bio-based lubricants</td>
<td></td>
</tr>
<tr>
<td>- New uses of composites</td>
<td>- Adhesives for low surface energy surfaces</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Pressure-sensitive adhesives</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Structural adhesives</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Improved impact resistance</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Urethanes, acrylcs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Water Technologies</strong></th>
<th><strong>Aqualon Functional Ingredients</strong></th>
<th><strong>Valvoline</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Disassembly of biomass</td>
<td>- Cost-effective sources of pure cellulose</td>
<td></td>
</tr>
<tr>
<td>- Formation of uniform, aqueous slurries of fibers</td>
<td>- Modification / etherification of cellulose</td>
<td></td>
</tr>
<tr>
<td>- Non-woven sheet formation</td>
<td>- Rheological control of aqueous systems</td>
<td></td>
</tr>
<tr>
<td>- Paper-like matrices with novel performance properties</td>
<td><strong>Aqualon Functional Ingredients</strong></td>
<td></td>
</tr>
<tr>
<td>- Amphiphilic polymers &amp; oligomers</td>
<td>- Low wear, high thermal conductivity fluids</td>
<td></td>
</tr>
<tr>
<td>- Non-chemical methods for water treatment</td>
<td>- Low cost base oil feedstocks</td>
<td></td>
</tr>
<tr>
<td>• For corrosion inhibition, scale inhibition and biofilm inhibition</td>
<td>- Bio-based lubricants</td>
<td></td>
</tr>
<tr>
<td>- Sensors for system performance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Scale, biofilm formation; corrosion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ashland’s More Basic Needs and Interests</td>
<td></td>
<td></td>
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<td>-----------------------------------------</td>
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</tr>
<tr>
<td><strong>Bio-based Materials</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Bio-derived alternatives to petroleum-based raw materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- For composite resins, adhesives, lubricants, water treatment chemicals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Polyols, acids, acrylics, aromatics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Formation, isolation, reactivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Biomimetic materials for adhesives, composites</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Catalysis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Novel room temperature cure chemistry for thermosets</td>
<td></td>
<td></td>
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<tr>
<td>- Organometallic catalysts</td>
<td></td>
<td></td>
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<tr>
<td>- UV cure systems</td>
<td></td>
<td></td>
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<tr>
<td>- Encapsulated catalysts &amp; reactants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Enzymatic catalysis</td>
<td></td>
<td></td>
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<tr>
<td><strong>Resins &amp; Additives</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Reactive diluents</td>
<td></td>
<td></td>
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<tr>
<td>- UV-stable resins, UV stabilizers</td>
<td></td>
<td></td>
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<tr>
<td>- Low shrinkage thermosets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Thermoset resins with improved thermal stability</td>
<td></td>
<td></td>
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<tr>
<td>- Block copolymers</td>
<td></td>
<td></td>
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<tr>
<td>- New tackifiers</td>
<td></td>
<td></td>
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<tr>
<td>- New impact modifiers, tougheners</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Engineering</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Consistency, predictability in batch reactors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Continuous (heterogeneous) synthesis of thermoset resins</td>
<td></td>
<td></td>
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<tr>
<td>- On-line process monitoring</td>
<td></td>
<td></td>
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<tr>
<td><strong>New Test Methods / Method Development</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Weatherability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Accelerated testing methods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Toughness tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- High throughput testing methods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Characterization of composites</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Recycling, re-use of thermosets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Waste minimization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Utilization of waste streams</td>
<td></td>
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</tbody>
</table>