Polymer Industry Cluster
Strategic Framework

Sponsored by:

Greater Akron Chamber

City of Akron

County of Summit

Team NEO

The University of Akron

GAR Foundation

Prepared by:

Greater Akron Chamber

And

Partners

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Acknowledgement

I would like to express my sincere thanks to the Steering Committee for giving me the opportunity to work on this wonderful Polymer Industry Cluster initiative. It has potential for significant impact on the future economic growth of the region. I would like to thank sponsors (Greater Akron Chamber, City of Akron, County of Summit, Team NEO, GAR Foundation and The University of Akron) for their financial support.

My specials thanks to the esteem members of the Polymer Industry Advisory Council for their commitment and support throughout the year. Their advice, input and feedback have been invaluable in the development of the vision, mission, ecosystem, and strategy frame work. I cannot express enough thanks to this group of leaders for their continued support and encouragement.

I would like to express my sincere gratitude to my partners on the project and Greater Akron Chamber associates Brian Anderson, Gregg Cramer and Alyssa Carpenter for their support and making connections with local industry and Government agency leaders. They have a very impressive network of businesses that can be leveraged for the greater good of the Polymer Industry Cluster and the region.

Last but not the least, I would like to thank Heather Flohr for her administrative support throughout the year.

Surendra Chawla

1. Introduction

1.1. Background

Surviving in a global economy, "the knowledge era", is all about speed, flexibility, adaptability, quality, innovation, network, and critical mass. This new style of doing business demands a team approach at a local level – a clustering approach.

The Greater Akron Region (GAR) has been the center of the world's polymer industry, rubber and plastics, for decades. Northeast Ohio has the largest concentration of plastic and rubber plants in North America; more than half of the total US plastics consumption occurs within 500 miles of Northeast Ohio. Ohio ranks as the #1 state in the nation for the manufacture of plastics machinery. Initial research sponsored by the Elevate Greater Akron team concluded that a cluster of polymer companies within the region certainly exists, and that there is opportunity for much more collaboration among companies and with local universities for the economic growth of the region.

With that in mind, the Elevate Greater Akron team including Greater Akron Chamber has initiated a "Polymer Industry Cluster" initiative. The goal of the initiative today is to explore and advance opportunities for collaboration among polymer companies in the region and with globally recognized University of Akron, Kent State and Case Western Reserve University.

From the economic development perspective, the regions that have a high industry density like ours, and whose companies collaborate with each other more often, have seen significant positive economic impact for not only the individual companies, but for the region as a whole. In this polymer industry cluster initiative, we have committed to undertaking a deep dive investigation of the polymer industry to explore what kind of specific challenges, trends and opportunities exist that could drive profitable collaboration with in the industry and for the region.

1.2. What is Polymer?[1-9]

The term *polymer* is commonly used in the plastics and composites industry, often as a synonym for *plastic* or *resin.* Polymers include a range of materials with a variety of properties and are found in common household goods, in construction materials, and in numerous other products.

A ***Polymer*** is a substance or material consisting of very large molecules, called macromolecules, composed of many repeating simpler chemical units called monomers. The word polymer designates an unspecified number of monomer units. When the number of monomer units is very large, the compound is sometimes called a high polymer. Polymers are not restricted to monomers of the same chemical composition. Some natural polymers are composed of one kind of monomer. Most natural and synthetic polymers, however, are made up of two or more different types of monomers - such polymers are known as co-polymers.

Polymers are both man-made and naturally occurring. Rubber, for example, is a natural polymeric material that has been used for thousands of years. It has excellent elastic qualities, the result of a molecular polymer chain created by nature. The most common natural polymer on earth is cellulose, an organic compound found in the cell walls of plants. It is used to produce paper products, textiles, and other materials such as cellophane.

Synthetic or man-made polymers include materials such as polyethylene, the most common plastic in the world. Polyethylene, composed of repeating ethylene monomers, is an addition polymer. It may have as many as 10,000 monomers joined in long coiled chains. Polyethylene is crystalline, translucent, and thermoplastic – ie, it softens when heated. It is used for coatings, packaging, molded parts, and manufacture of bottles and containers.

Other addition polymers include polybutadiene, polyisoprene, and polychloroprene, which are all important in the manufacture of synthetic rubbers. Some polymers such polystyrene, are glassy and transparent at room temperature, as well as being thermoplastic. It is used to make disposable cups. Other well-known industrial application polymers include, polyester, polyvinyl chloride (PVC), polyamides (nylon), polyurethanes and silicones. Polymer scientists around the world continue to conduct research in the areas of synthesis of new polymers, the investigation of polymerization processes, and the characterization of the structure and properties of polymeric materials to address global needs, challenges and opportunities.

1.3. What is Polymer Industry?[10-12]

Polymer industry is the collection of all companies that manufacture and research natural and synthetic polymers such as plastics, elastomers, and chemicals. It makes use of these polymers in manufacturing processes for many different products included in the NAICS codes 325 and 326. These products range from everyday items that are commonly used by the average person to highly specialized tools utilized by professionals. The industry includes a collection of companies operating in research, design, development, and manufacturing of new polymers, polymer compounds, and industrial and consumer goods. The polymer industry markets include industry sectors such as aerospace, health care, automotive, additive manufacturing, energy, packaging, building & construction, and electronics & communication.

For example, in the automotive industry, 50% of today's new cars are made of plastic (polymer) materials in addition to rubber industry use of tires, belts, and hoses. Most of these products are contained in the interior of a car, e.g. dashboard, gauges, door handles, seat belts, air bags etc. An increased number of auto manufacturers are starting to include high performance plastics in the body. In the aerospace industry, a modern airplane, e.g. Boeing 787 Dreamliner, consists of 50% polymer composites; fighter aircraft like Eurofighter contain 70% of polymer composites. Development of high temperature polymer composites will replace existing metal engine parts, e.g. jet compressor blades.

A variety of polymeric materials are used in 3D printing. They include; polycarbonate (PC), acrylonitrile butadiene styrene (ABS), poly ether ester ketone (PEEK), nylon, PET (T-Glass), high performance thermoplastics e.g. carbon fiber. The future of 3D printing materials opens many opportunities for polymer innovations, especially where materials can be tailored to leverage the process and end-use applications. The health care

industry is investing in the development of smart materials for PPE design and innovation to combat COVID-19.

1.4. What is Polymer Industry Cluster?[13-15]

The Polymer Industry Cluster (Northeast Ohio) is a concentration of polymer companies and institutions in the region that complement each other thru exchange of ideas and activities along one (several) value creation chains. Clustering is a philosophy based on the core principles of **integration (of activities) and collaboration (of members) for mutual benefit**. Cluster benefits come at three levels: individual firm level, regional level, and the wider economy level.

At the firm level, clusters help companies take advantage of **market** opportunities that they could not achieve alone. Firms benefit from being part of large and dense **supply chains**. The presence of many customers allows suppliers to specialize and become more productive, while presence of more suppliers is efficient for customers. The interaction between suppliers and customers supports rapid learning and joint innovation. Firms benefit from being in labor markets with an abundance of specific types of **skills**. Firms benefit from being close enough to **technology/innovation** that they can capture "knowledge spillovers".

The regional benefits from clustering derive from the ability of a cluster to raise the profile of the region locally, nationally and internationally. This will lead to an increase in the investment attractiveness as an indicator of a 'business friendly' environment with necessary policy support and governance.

Clusters add value to the development of an economy by creating groups of networked businesses in specific sectors. They improve competitiveness, innovation and adoption of 'best practice'. They enable economic specialization of a particular region, in a range of related activities. Clusters can contribute to an increase in economy-wide competitiveness, fostering private-public dialogue and becoming a catalyst for wider private sector development initiative.

An integrated, collaborative and systemic approach described as "*The Triple Helix Model*" is being adopted and implemented to create a competitive Polymer Industry Cluster.

The Triple Helix Model[1-18] promotes three principles: (1) a more prominent role for academia and centers for education/learning in innovation, (2) collaborative relationships among the three major institutional spheres, and (3) in addition to fulfilling their traditional functions, each institutional sphere also "takes the role of the other" performing new roles as well as their traditional function. Institutions taking non-traditional roles are viewed as a major potential source of innovation in innovation. The Polymer Industry Cluster of Northeast Ohio has all the necessary elements to be a very successful and competitive industry cluster.

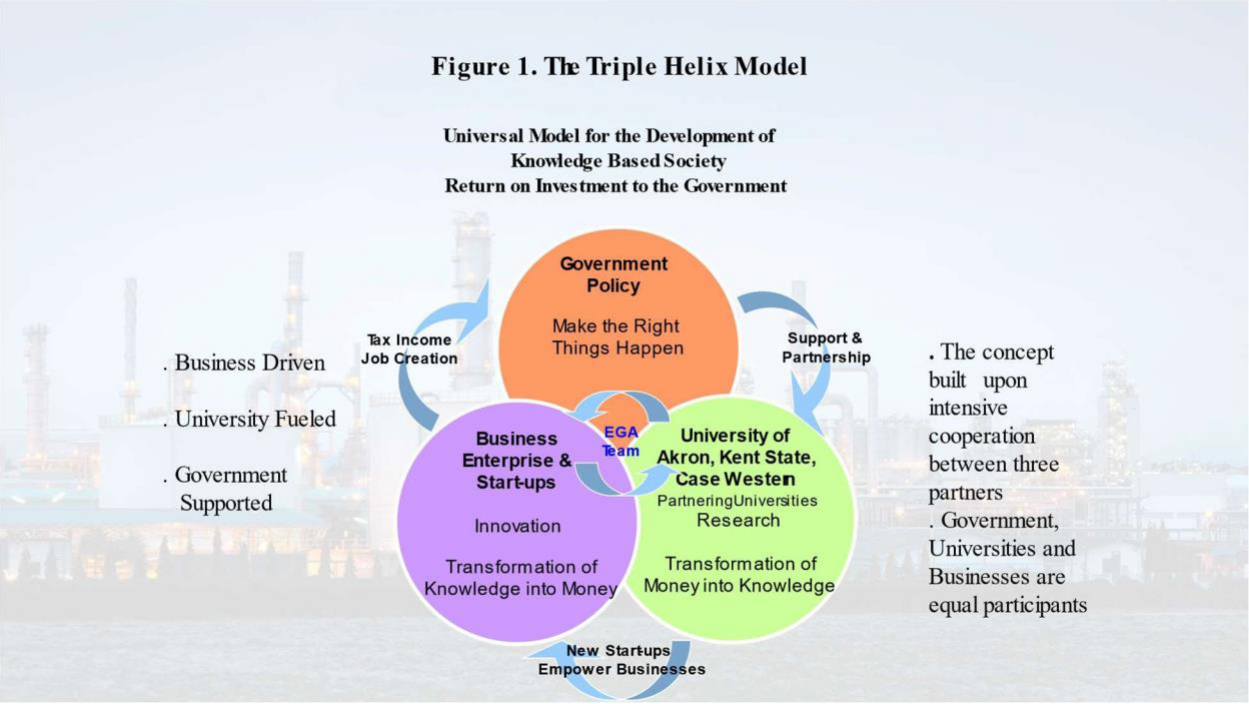


Figure1. The Triple Helix Model

2. Scope of Work

The purpose of the Polymer Industry Cluster initiative is to create clear vision, strategy and a roadmap for the integration and collaboration among Polymer Industry Cluster members in Northeast Ohio. A primary component of this vision is to capitalize on the technology advancements for all and leverage the advantage of "power of cluster" for the benefit of individual businesses and collectively for the region.

> "*Areas with strong clusters produce more economic growth, more jobs, stronger wage growth, increased entrepreneurial activity, and more intellectual property – such as patents – than other areas".*
>
> Institute for Strategic and Competitiveness, Harvard Business School

Figure 2 shows the scope of work and the time line for the Polymer Industry Cluster initiative.

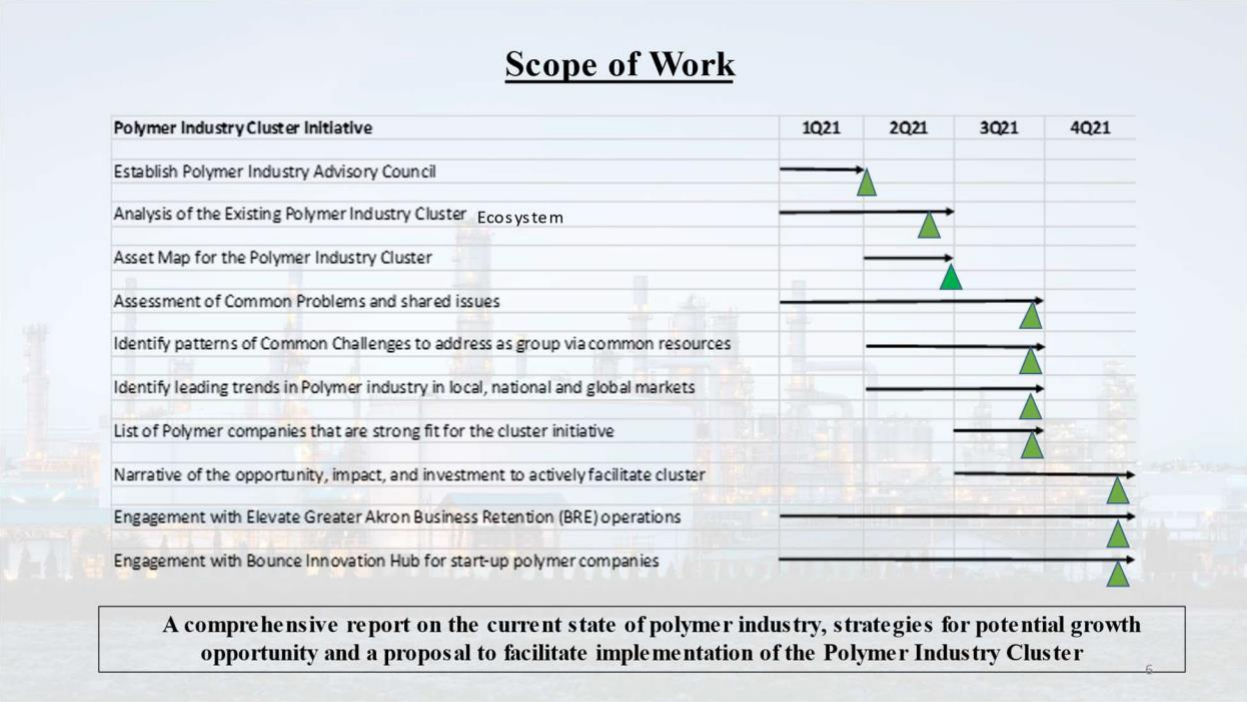


Figure 2. Polymer Industry Cluster Initiative Scope of Work for year 2021

The specific tasks to be performed include i) analysis of the current cluster ecosystem identifying gaps and opportunities, ii) development of inventory of the asset/resources available to the polymer industry, iii) identification of shared challenges and opportunities affecting polymer companies and trends in global, national and local markets, iv) identification of list of polymer companies that are a strong fit for the growth and further development of the cluster, v) preparation of narrative of the opportunity and impact resulting from additional investment in actively facilitating a polymer cluster in Greater Akron and Northeast Ohio region.

2.1. Polymer Industry Advisory Council

The challenges identified in the previous section are big, broad and globally impactful and cannot be answered in isolation. To this end significant effort was put forth into the formation of the Advisory Council.

Polymer Industry Advisory Council (January 10, 2022)

First Name	Last Name	Organization	Role
Steve	Barber	Parker-Hannifin Corporation	VP, Technology & Innovation
Paul	Boulier	Team NEO	VP, Industry and Innovation
Bob	Bradley	Novation SI	President
David	Butler	Roechling Automotive Inc.	Director, Operations
Eric	Castner	The Goodyear Tire & Rubber Co.	Manager, Global Materials
James	Eagan	The University of Akron	Asst. Professor, SPSPE
Dan	Fernback	JuggerBot 3D	Vice President
Peter	Geise	Focus CFO	President, Akron Chapter
Albert	Green	AMG Consulting Group	Founder & CEO
Josh	Guilliams	Polymer Valley Chemical	VP, Technical Operations
Harry	Harris	LTA Galactic	Director of Operations
Wayne	Hawthorne	Case Western Reserve University	Sr Licensing Manager, Tech Transfer
Torsten	Hegmann	Kent State University	Director, AMLCI
James	Hilton	Bounce Innovation Hub	Sr Director, Entrepreneurial Services
Sadhan	Jana	The University of Akron	Assoc. Dean Res. and Graduate Study
Letha	Keslar	ARPM	Managing Director
Jean-Claude	Kihn	The Goodyear Tire & Rubber Co.	Ret.-CTO, President EMEA/LA Business
Tianbo	Liu	The University of Akron	Interim Director, SPSPE
Joao	Maia	Case Western Reserve University	Professor & Director, CAPP
Carla	McBain	Synthomer	VP, Innovation Functional Solutions
Darrel	McNair	MVP Plastics Corporation	President & CEO
Lakisha	Miller-Barclay	American Chemical Society	Executive Director, Rubber Division
James	Popio	Smithers Group	VP of Operations North America
Ernie	Pouttu	Harwick Standard Distribution Co	President & CEO
Larry	Rhodes	Promerus LLC	General Manager
Barry	Rosenbaum	The University of Akron	Senior Fellow, UARF
Gordon	Schorr	The University of Akron	Senior Fellow, UARF
Erick	Sharp	ACE Products & Consulting LLC	President
Mark	Smale	Bridgestone Americas Inc.	Director, Core Polymer Science
Andre	Thornton	ASW Global	CEO
Kevin	Westgate	Continental ContiTech	Director, R&D

Table 1. List of the Polymer Industry Advisory Council

As of January 10, 2022, the Advisory Council consisted of 32 eminent leaders with diverse background from the industry, academia, service organizations, and scientific journals. Their advice, input and the feedback have been invaluable. Table 1 shows the list of the Advisory Council along with their roles in the organizations they serve. All the work of the Polymer Industry Cluster initiative is and will continue to be driven by this esteemed group of leaders ensuring that the outcome will be truly industry driven.

2.2. Process[19,20]

The process employed was the Team NEO In-Seven Road Mapping Process (Figure 3). This model is designed to identify key regional strengths as the basis of long-term cluster development opportunities.

The first stage of the process included extensive review of the current state of the polymer industry at global, national, state and local regional level. The purpose was to accurately assess the landscape and future market/growth opportunities. With the assistance of associates from the Greater Akron Chamber, City of Akron, County of Summit, Team NEO and the University of Akron, virtual meetings with more than 3 dozen companies were held to understand their needs, areas of opportunities, and shared challenges the polymer industry faces today. Interviews were also conducted with companies from the surrounding regions. The information gathered was useful in assessing Northeast Ohio's competitive position. The second half of the process, "What is Possible" deals with outlining the potential for growth opportunities in the target polymer market segment. Based on this feedback from the industry, a set of recommendations and path forward roadmap is proposed.

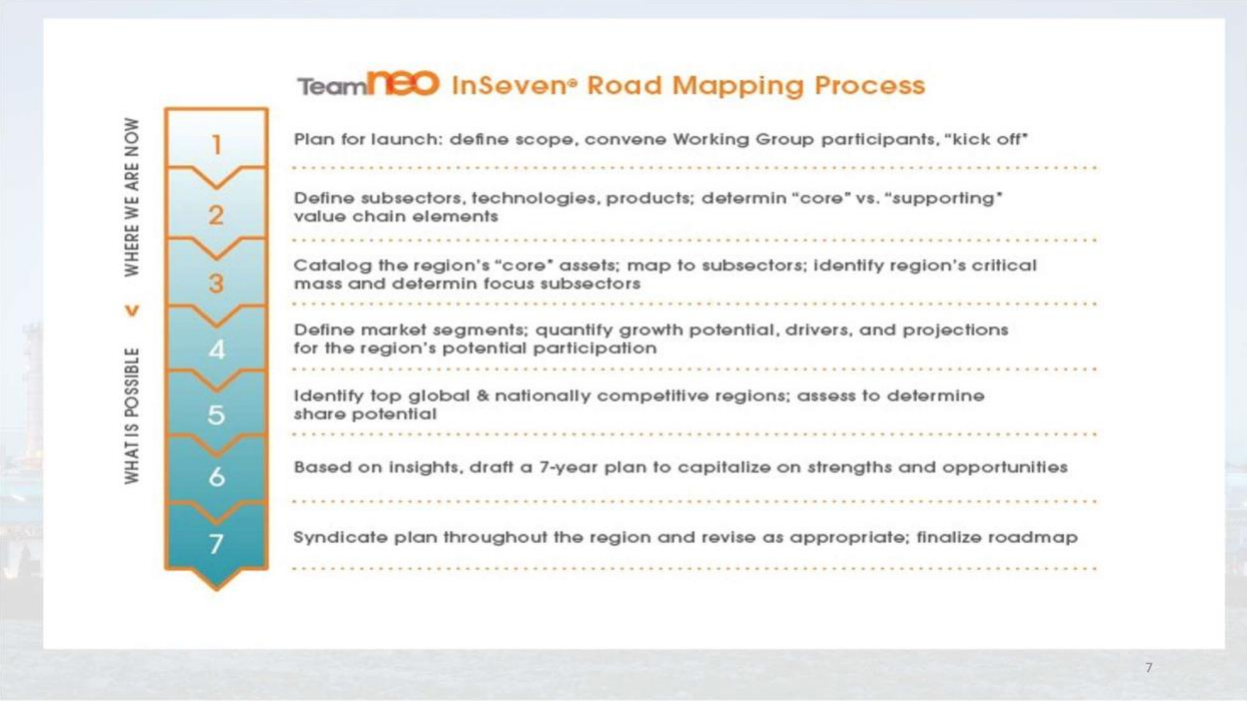


Figure 3. The Team NEO InSeven Road Mapping Process

3. Value of Work

The polymer industry in Northeast Ohio has the characteristic of a cluster that has the ability to put the regional economy on a new trajectory. The opportunity this polymer industry cluster presents within Northeast Ohio includes building on the already robust polymer industry base to aid the region's ability not only to remain competitive but leap forward with more than the average industry growth. The polymer industry cluster will not only positively impact the economic growth of the region, it will provide individual companies with advantages that will impact their bottom line through innovation, production efficiency, reduction in time to market, and market development globally.

The polymer industry cluster mission is to increase growth and competitiveness of Ohio's companies whose businesses are based on polymer technology. The key aspect of polymer industry cluster's effort is to know the polymer research and researchers at universities and individual research labs e.g. Centre for Multifunctional Polymer Nanomaterials Devices (CMPND) and Ohio Bioproducts Innovation Center (OBIC). Commercialization of biobased material products is already emerging in Northeast Ohio companies. Ohio's polymer industry has huge potential and in combination with the Ohio agriculture industry can place NEO in a world leading position with a large increase in jobs and a significant impact of the supply of biobased polymer materials. Products derived from soy beans and corn are now clearly showing they can offer many performance advantages plus better economics.

Additionally, this effort will have significant impact on major industry sectors, with a substantial polymer component, of the region including aerospace, automotive, health care, construction, and additive manufacturing to name a few.

3.1. Why Northeast Ohio?

The polymer industry is Ohio's largest industry cluster and manufacturing hub with more than 72,000 employees in 996 companies contributing $40+ billion to the Ohio GDP[23]. The Northeast Ohio counties (16) account for more than half (516) of polymer companies in Ohio. Accounting for all secondary/supporting businesses, there are 42,000 jobs with 800+ establishments in Northeast Ohio that contribute $22 billion dollars to the local economy. Leading the pack is the Greater Akron region with 174 of polymer companies employing 10,743 of polymer industry workforce.

The suppliers and major customers are close. It is the largest supplier of plastics–and rubber-working machinery in the nation. Ohio is the 6th ranked producer of natural gas mostly due to the development of Utica shale and close proximity to secondary sources for resin and synthetic rubber production. Northeast Ohio's location close to rail, major highways, and major waterways make it well suited for distribution of raw materials, intermediate and final products to customers by truck, rail, water, and air as appropriate for the product form.

Northeast Ohio region is the center of globally recognized research capabilities, intellectual property (IP) generation and skilled workforce from the School of Polymer Science and Polymer Engineering at the University of Akron, Advanced Materials and Liquid Crystal Institute at Kent state, and the Department of Macromolecular Science and Engineering at Case Western Reserve University.

Northeast Ohio is a perfect location for polymer compounders. Compounders play an important role in the polymer business. While there have not been a large number of new polymers invented since 1970, compounders have created many new materials by combining two or more polymers, rubbers, and other materials. Northeast Ohio is the place where polymer compounded polymers are developed and produced. Compounding and blending are very important for nano-enhanced high performance advanced materials for applications in high technology industries.

The existing fabric of manufacturers, end-use markets, professional associations, higher education, and regional economic development and entrepreneurial support organizations make Northeast Ohio a hotbed of the polymer industry. The regional organizations dedicated to business and entrepreneurial growth in Northeast Ohio include Team NEO's expertise in public/private collaboration, Bio-enterprise's biotech business formation, recruitment and acceleration, JumpStart's support of diverse entrepreneurs, MAGNET, a center for manufacturing growth in Northeast Ohio, and Bounce Innovation Hub as incubator.

4. The Polymer Industry Landscape and Market Opportunity

4.1. Global Landscape and Market Opportunity

The **global polymer industry** is forecasted to remain on a sizable growth trajectory over next several years. The global polymers market valued at $533.6 billion dollars in 2019 is projected to reach $838.5 billion by 2030 at CAGR of 5.1% during 2020-2030 timeframe. The global market for industrial rubber products valued at $135 billion in 2020 is projected to reach $190.5 billion by 2027 at CAGR of 5.0% during 2020-2027 timeframe. Tires are a major global product and it is estimated that over 1.5 billion tires are currently produced each year with a total value of about $190 billion. This is expected to rise to 2.2 billion units by 2025, at a healthy compounded growth of 4.6%, with a total value of about $270 billion. The **total global market of all polymer products is in the upwards of $1 trillion** – a huge opportunity for Northeast Ohio region to capitalize based on its history, knowledge and capabilities that exist in this region.

4.2. National Landscape and Market Opportunity

The source of information for this section is IBISWorld Industry Reports of 2018, 2019 and 2020[24-46]. IBIS World specializes in industry research with coverage on thousands of global industries. The comprehensive data and in-depth analysis have been very helpful to gain quick and actionable insights on the polymer industry around the world. The US polymer industry is comprised of companies that are involved in the manufacture of broad range of plastic, rubber and chemical products represented by NAICS codes 325 and 326. Table 2 and Table 3 show polymer industry sector breakdown of NAICS codes 325 and 326, respectively.

No.	Polymer Industry Sector	NAICS Code
1.	Petrochemical Manufacturing in the US	32511
2.	Dye & Pigment Manufacturing in the US	32513
3.	Inorganic Chemical Manufacturing in the US	32518
4.	Organic Chemical Manufacturing in the US	32519
5.	Plastic-Resin Manufacturing in the US	32521
6.	Synthetic Fiber Manufacturing in the US	32522
7.	Paint Manufacturing in the US	32551
8.	Adhesives Manufacturing in the US	32552
9.	Soap – Cleaning Compound Manufacturing in the US	32561
10.	Cosmetic – Beauty Products Manufacturing in the US	32562
11.	Chemical Product Manufacturing	32599

Table 2. Polymer Industry Sector represented in NAICS Code 325

The US market for NAICS code 325 valued at $518 billion in 2015 was reduced to $429 billion in 2020 at an average CAGR of -3.9% during 2015–2020 timeframe. However, it is projected to recover to $489 billion by 2025 at an average CAGR of +2.65% over a 5-year period of 2020-2025.

The US market for NAICS code 326 valued at $251 billion in 2015 was reduced to $249 billion in 2020 at an average CAGR of -0.14% during 2015-2020 timeframe. However, it is projected to recover to $271 billion in 2025 at an average CAGR of +1.4% during 2020-2025 timeframe.

No.	Polymer Industry Sector	NAICS Code
1.	Plastic Film Sheet – Bag Manufacturing in the US	32611
2.	Plastic Pipe – Part Manufacturing in the US	32612
3.	Laminated Plastics Manufacturing in the US	32613
4.	Polystyrene Foam Manufacturing in the US	32614
5.	Urethane Foam Manufacturing in the US	32615
6.	Plastic Bottle Manufacturing in the US	32616
7.	Plastic Products Miscellaneous Manufacturing in the US	32619
8.	Tire Manufacturing in the US	32621
9.	Hose-Belt Manufacturing in the US	32622
10.	Rubber Products Manufacturing in the US	32629

Table 3. Polymer Industry Sector represented in NAICS Code 326

The US total market for the polymer industry (NAICS Codes 325+326) valued at $756 billion in 2015 was reduced to $678 billion in 2020 at an average CAGR of -2.2% during 2015-2020. It is projected to recover to $750 billion in 2020 at an average CAGR of +2.04% during 2020-2025, still short of 2015 market value. Figure 4 shows the polymer industry forecast for NAICS codes 325, 326 and (325+326), respectively.

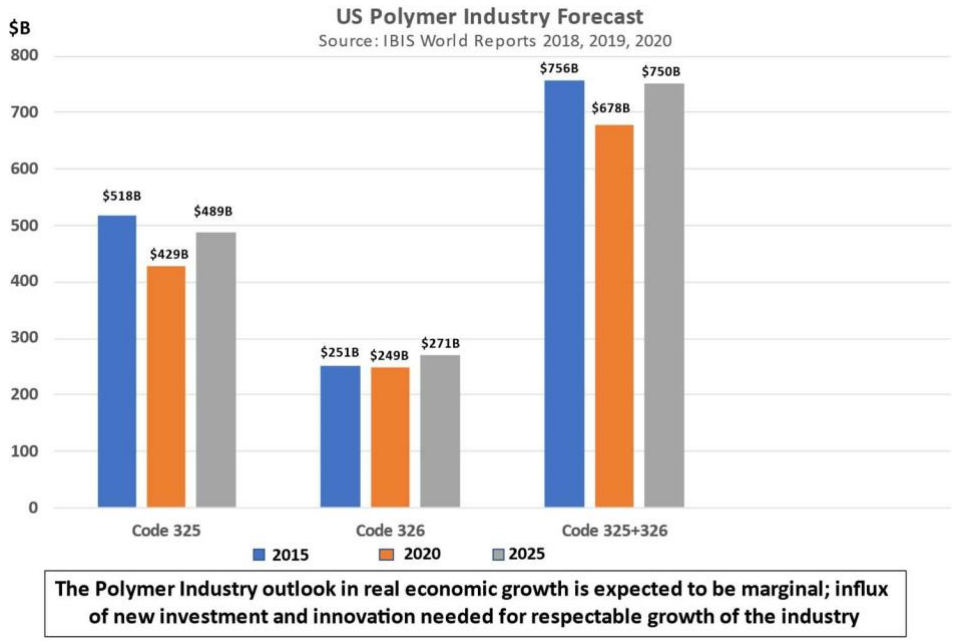


Figure 4. US Polymer Industry Forecast – NAICS Codes 325, 326 and (325+326)

Industry clusters identified by high density and interdependence have a catalytic nature to infuse new investments and innovation that drive serious growth. The polymer industry cluster of Northeast Ohio

has all the elements to crystalize much needed more than average growth for the US polymer industry (Figure 5).

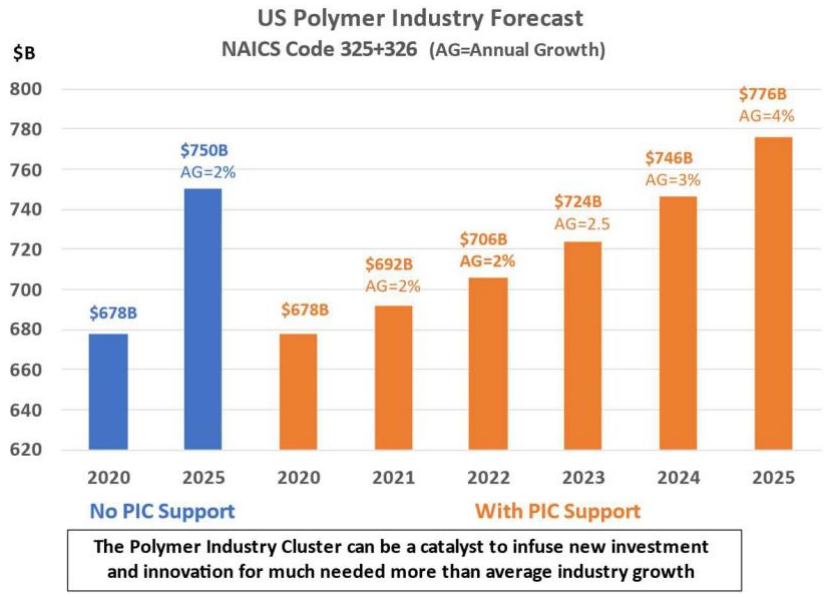


Figure 5. Projected impact of the Polymer Industry Cluster on the US polymer industry growth

In Figure 5, assumption is made that the implementation of a polymer industry cluster will bring new investment, drive collaboration and innovation resulting in a gradual increase in annual growth from 2% to 4% by year 2025 and potential net positive impact of $26 billion to the US polymer industry. Starting in 2030, net positive impact of the cluster on US polymer industry will be around $16 billion annually.

4.3. Ohio State Landscape and Market Opportunity

The source of information for this section was IBIS World Reports of 2018, 2019, and 2020, and Ohio Development Service Agency report on Polymers – Plastics Resins, Synthetic Rubber and Related Products, June 2019. The Ohio's polymer industry at 6.25% of the US polymer industry is among the top three states with annual revenue of $42.3 billion. It is projected to grow to $46.9 billion at average CAGR of 2% well below the projected average industry growth around 3%. However, with support from the Polymer Industry Cluster the CAGR can gradually increase from 2% to 4% by year 2025 with projected revenue of $48.4 billion in 2025 and growing at a steady pace to $58.9 billion by 2030. The net positive impact of the polymer industry cluster to Ohio's economy will be $7.1 billion through 2030 as shown in Figure 6. Starting 2030, net positive impact of cluster on Ohio's economy will be in excess of $1.3 billion annually.

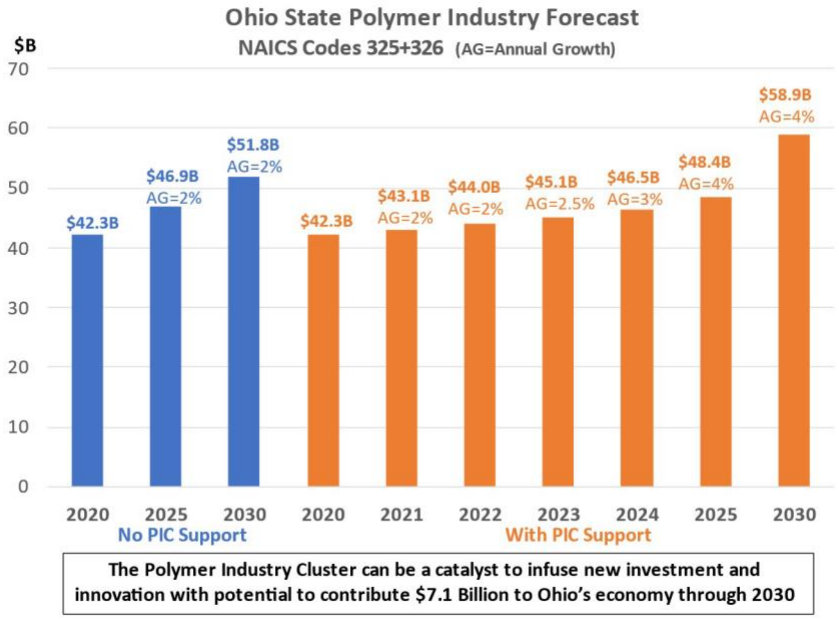


Figure 6. Projected impact of the Polymer Industry Cluster on Ohio's polymer industry growth

4.4. Northeast Ohio Landscape and Market opportunity

There are 996 polymer industry establishments across Ohio. There are 16 counties in Northeast Ohio that account for more than half (516) of all polymer companies in Ohio, contributing $22 billion to the region's economy. It is projected to grow to $ 26.8 billion at a nominal CAGR of 2% by 2030. However, with implementation of a polymer industry cluster the CAGR can gradually grow from nominal 2% to 4% by year 2025 contributing $30.5 billion annually to the region's economy by 2030 (Figure 7). The net positive impact of the cluster to Northeast Ohio's economy is projected to be $3.7 billion through 2030. Starting 2030, the net positive impact of a cluster on Northeast Ohio's economy will be around $700 million annually.

4.5. Greater Akron Region (GAR) Landscape and Market Opportunity

Three counties of Greater Akron Region (Summit, Medina, Portage) account for 174 or 17% of all polymer companies in Ohio, contributing $7.4 billion to the region's economy projected to grow to $9.3 billion at a nominal CAGR of 2% by 2030. A polymer industry cluster can be a catalyst to grow the CAGR from nominal 2% to 4% by year 2025 contributing $10.3 billion annually to the region's economy by 2030 (Figure 8). The net positive impact of the cluster to Greater Akron Region's economy is projected to be $1 billion through 2030. Starting 2030, net positive impact of cluster on Greater Akron Region's economy will be around $225 million annually.

The concentration of polymer companies combined with economic contribution and local universities as well as the supporting infrastructure lend credence to Northeast Ohio polymer industry. New innovative technologies such as bio-derived/inspired materials, recyclable polymers, smart/intelligent materials for automotive, aerospace, health care, and additive manufacturing offer opportunities of above average,

robust, and sustainable growth for the industry. It is projected that the influx of these innovations will contribute to the gradual growth of CAGR from a nominal 2% to 4% by 2025.

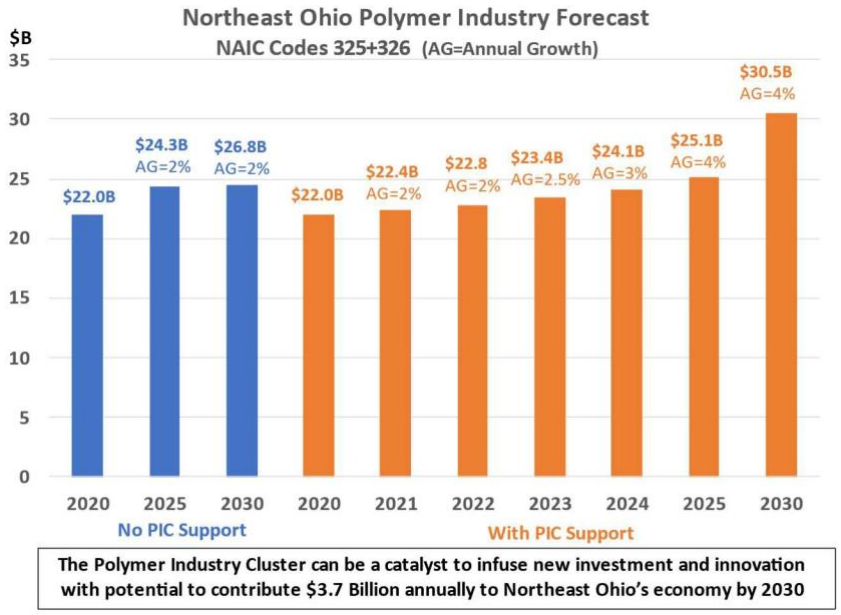


Figure 7. Projected impact of Polymer Industry Cluster on NE Ohio's polymer industry growth

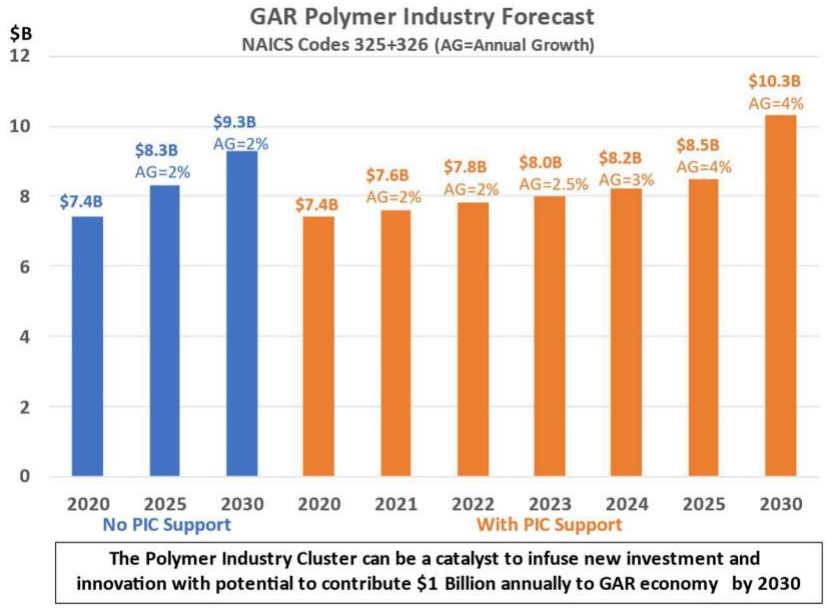


Figure 8. Projected impact of Polymer Industry Cluster on GAR's polymer industry growth

5. Benchmarking Analysis[14,15,47-51]

Clusters are environments where enterprises can develop a competitive and global advantage, while at the same time generating wealth and local economic development in the process. In the United States cluster building is already an advanced and accepted tool in economic development. The following are few well known successful examples:

- **Internationally renowned Silicon Valley Regional Cluster**[52] **-** home to 7000+ high tech companies, is a model everyone aspires to. The region is characterized by having had amazing and unexpected growth, technological and economic progress. Silicon Valley has experienced five remarkable stages that led to its development. These stages include:
    1. Technological innovations achieved during the first half of the twentieth century.
    2. High technology industry formed at the Stanford Industrial Park in the 1950s.
    3. The growth of innovative microelectronic firms supported by the Department of Defense in the 1960s.
    4. The consolidation of microprocessors based on semiconductors and the launch of the personal computer era in the 1970s.
    5. The domination of the computer industry, its innovative spin-offs, and the internationalization of the industrial structure, in the 1980s.

  The unprecedented success of Silicon Valley today is a result of fostering and the creation of venture capital, know-how, talent, and a modern and efficient physical infrastructure such as science parks, incubators and accelerators.
- **Pittsburgh Life Sciences/BioTech Cluster**[53,54]- known as Pittsburgh Life Sciences Greenhouse. Pittsburgh metro is an area consisting of seven counties and has 2.3 million residents. Pittsburgh is viewed as a model for post-industrial transformation and is positioned to provide sustainable careers and high standard of living for its residents. One of the contributing factors has been the development of Life Sciences/BioTech Cluster. Five key elements in the regional strategy included: i) analysis and planning, ii) targeted cluster development strategy, iii) public policy and support from the state, iv) unique collaboration between two premier research and educational institutions, and v) the cooperation and support of the local economic development organizations. Together they provided a unique and effective strategy for targeted cluster development.

  Analysis and Planning: In the early 90's, it was becoming apparent that traditional industries in Pittsburgh would not be able to sustain region's economy. Regional leaders engaged Michael porter and his team from the Harvard Business School and local leaders from businesses, academia, philanthropy and government to conduct analysis, identify strengths and weaknesses of various segments of the Pittsburgh economy and potential growth opportunities. The result was identification of **five** clusters that included **three** traditional sectors and **two** potential new sectors of Pittsburgh economy. The two potential new sectors were tech-based and included ***information technology and the life sciences/biotech sectors.*** It led to the launch of life science/biotech cluster initiative known as Pittsburgh Life Sciences Greenhouse.

  Pittsburgh Life Sciences Greenhouse[55]: The Pittsburgh Life Sciences Greenhouse was created in 2001 to drive the development of the cluster. The operational plan included a small

experienced multi skilled team supplemented by local business leaders. Initial funding commitment of $33 million came from the state. The Greenhouse staff, board and local business and government leaders raised additional funds bringing the total amount to $100 million to support 5 years of operation. The current team consists 8 members that include:
Ms Diana Cugliari, President & Chief Executive Officer
Mr Alan West, Executive-in-Resident
Ms T. Marlise Manzetti, Executive Administrative Assistant
Ms Dana McGrath, Program Manager, Health IT
Ms Diana Hill, Executive -in-Resident
Mr Tim Bosse, Senior Vice President, Talent Solutions System
Mr Jason Baim, Advisor, Health IT
Mr Christopher R. Evans, Venture Partners – Founder & CEO Toolkit
The Greenhouse business plan called for the development of technology with the intent to accelerate technology commercialization with support from seed and early-stage companies, connect those companies to investors and to relocate Life Sciences companies from outside the region. The plan also called for significant funding to go to the universities to enhance research and development capabilities and support technology transfer. Additional $60 million was set aside for venture capital investment in the Life Sciences and over $20 million a year was set aside to invest in expanding research capabilities at the universities.

University of Pittsburgh/ Carnegie Mellon University Collaboration: One of the hallmarks of Pittsburgh's overall recovery is the collaboration model it uses to address major public policy issues. This model of collaboration was exemplified in a unique collaboration between the leaders and staff of the University of Pittsburgh and the Carnegie Mellon. The basis of this close working relationship is the natural overlap of research and expertise at the two institutions; the University of Pittsburgh has deep capabilities in the Bio world and Carnegie Mellon's depth in the Digital world. The combination of the two brings unique solutions to modern life sciences treatments and patient care. This resulted in an increase of startup activity from 2-3 new companies to 20-30 companies achieving one of the key objectives of the cluster.
Overall, the cluster is larger and stronger; the research base has grown significantly and hundreds of new products have been developed and put into the market. The rate of startup activity is an order of magnitude larger than 20 years ago and thus the business side of the cluster is larger and more robust.

- **Syracuse Unmanned Aerial Systems (UAS or Drones)[49,56]:** Drawing on long-standing expertise in radar and sensors, central New York is positioning itself as a leading center for drone testing and innovation.

Geography: Central New York is a 12-county region including the Syracuse, Ithaca, Utica/Rome, and Watertown metro areas with 1.5 million residents (The Syracuse alone has 650,000 residents).
Cluster Size and Growth Trajectory: The "data to decisions" (D2D) cluster, of which the drone industry is key, includes 50 firms and 90,000 direct jobs. The entire drone supply chain is estimated to account for nearly 22,000 jobs in the region.
Cluster Type: Part of the broader and quickly evolving "internet of things" (IoT) industry, the D2D cluster is a group of firms that "collect, analyze, interpret, and protect

data" and whose technological capabilities lie primarily in sensing and sensor systems as well as adjacent fields like cybersecurity and predictive analytics. In the Syracuse region today, the drone industry is the most prominent way in which these technologies are applied.

Organizational Structure: The cluster consists of collaborative implementation by the regional EDO (**Economic Development Office**) and an industry organization NUAIR (**Northeast UAS Airspace Integration Research Alliance, Inc)**, with approximately four to eight dedicated staff between the two organizations. The state EDO is a key partner and funder, providing in excess of $50 million.

Resources and Key Assets: Primary cluster initiative investments relate to infrastructure and high growth start-up accelerator, with a secondary focus on policy research, facilitation of collaborative Research & Development, and basic economic development services (including attraction and expansion incentives) for firms. At the core of the cluster is a set of large defense contractors also focused on the civilian market, including Lockheed Martin, Syracuse Research Corporation, Saab and United Technologies Corporation Aerospace. These strengths are backed by major federal investment/presence (Air Force Research Laboratory, Airforce Reserves, Army and operation facilities).

- **Upstate South Carolina Automotive Cluster**[49,57]**:** The Clemson University International Center for Automotive Research (CU-ICAR) is a 50-acre research and technology campus that anchors Upstate South Carolina's thriving Automotive Cluster – home to the largest BMW production facility, recently established Volvo and Mercedes-Benz assembly plants and a cluster of automotive companies.

Geography: Upstate South Carolina is a 10-county region that includes the Greenville metropolitan area and the Spartanburg metropolitan area (approximately 1.4 million people).

Cluster size and Growth Trajectory: The automotive cluster contains 22,000 employees in 223 automotive-related companies and 3.3 percent annual employment growth (1998-2015).

Cluster Type: Clemson University International Center for Automotive Research is an automotive cluster that is industry based defined by the concentration of 223 automotive-related companies including BMW, Volvo, Mercedes-Benz, Michelin and mix of small, medium and large businesses.

Organizational Structure: Concentrated on a 250-acre campus, CU-ICAR focuses on university-based talent development and an applied research center associated with automotive industry. CU-ICAR is operated by a center within Clemson University's office of External Affairs in partnership with the College of Engineering and the Clemson University Real Estate Foundation. It works in tandem with Greenville Technical College and Upstate Alliance to support the automotive cluster.

Resources and Key Assets: CU-ICAR offers North America's first advanced degree in automotive engineering and is uniquely industry-relevant, featuring endowed industry faculty chairs in addition to significant co-investment from university, industry, and state government. The center has 14 dedicated staff with an additional 46 staff at Clemson's Department of Automotive Engineering, along with $300 million in total public and private investment.

- **The Water Cluster, Milwaukee**[49,58-61]**:** At the start of the 21st century, Milwaukee's brewing and leather tanning industries were in sharp decline. By mid-2000s, local leaders,

convinced they were at critical point in the region's economy, began to search for economic rebirth. One of the surprising potential answers was WATER. Left in the wake of decimated brewing and leather tanning industries, there was an abundance of companies in the region specializing in water technologies. Milwaukee's water cluster came into being based on the realization that by organizing themselves under the theme of water, these companies, and the region, could reimagine their role and partner in the start of a new economic trajectory. The confirmation of water technologies as a cluster took place over a three years period from 2007 to 2010 through action-forcing events that resulted in a vision to position Milwaukee as the "Silicon Valley of water technologies."

Geography: The water cluster covers eight counties in southeast Wisconsin, including four that comprise the official Milwaukee metro area, with a population of 1.57 million, and four neighboring counties that bring the regional population total to 2.15 million.

Cluster Size and Growth Trajectory: The water cluster is composed of 200+ companies with about $12 billion in revenues and employing over 20,000 in the region. The global market for water technologies was estimated to be over $600 billion in 2016.

Cluster Type: The water cluster is technology-based, focused on companies in water technologies involving instruments, equipment, and services.

Organizational Structure: The water cluster is led by a staffed, well-resourced, and self-described *industry cluster driver* (The Water Council), with core collaboration and investment from academic institutions (University of Wisconsin-Milwaukee and Marquette University), the state (Wisconsin Economic Development Corporation), the city of Milwaukee, and Milwaukee Metropolitan Sewerage District. The early support also came from the Greater Milwaukee Committee and M7 (regional economic development organization).

Resources and Key Assets: Key resources include a strong mix of firms, a location on the world's largest body of freshwater, The Water Council (11 full-time staff, 238 members, about $3 million operating budget), and a robust array of associated programs, such as a $50 million School of Fresh Water Sciences at the University of Wisconsin-Milwaukee, the $22 million Global Water Center building, and a city water district funded through an $11.2 million grant.

The Water Council Membership Model: The Water Council offers its members access to an unparalleled network of water industry thought leaders, policymakers and innovators, aligned with one of the most influential freshwater technology hubs in the world.

As a non-profit, membership-based organization, The Water Council is committed to convening, connecting and showcasing its 200+ members from 20 US states and 11 countries by providing a full range of business development services, networking opportunities throughout the year and opportunities to collaborate with a network of global water leaders.

Membership Benefits: Membership levels are organized into a tier system (Table 4) based on the level of engagement and value the organization would like to achieve. No matter what tier an organization selects, all members receive:

1. Access to event and meeting space in the Global Water Center
2. Customized member profile in the Global Directory
3. Use of The Water Council Member logo
4. Connections to a pipeline of talent, startups and entrepreneurs
5. Networking opportunities throughout the year

6. B2B Matchmaking

Member Category	Tier 1	Tier 2
Industry	$6,500	$1,000
Academic Partners	$2,500	$1,000
Non-Profits/Associations		$300
Municipal Utilities		$1,000
Public Sector	$6,500	$2,500
Startups	$800	$300

Table 4. The Water Council membership model

The Water Council Team:

Dean Amhaus, President & CEO
Beverley Ferrara, European Representative
Karen Frost, VP Economic Development & Innovation
Matt Howard, VP Water Stewardship
Amy Jensen, CFO & COO
Dr Barry Liner, Technical Advisor
Angela May, Executive Assistance & Office Manager
Laura Mullen, Member Engagement Member
Stacy Vogel Davis, Communication Director
Dylan Waldhuetter, Director of Water Stewardship Solutions

The approach Milwaukee took to the water cluster has led to exactly the kinds of outcomes envisioned from the start. New innovations and products are being developed; startups are being launched; large companies are mentoring and investing in promising young companies; cluster members are growing, collaborating, and becoming more competitive; new companies and talents have moved in; growth is occurring around the water district; and Milwaukee has positioned itself as an undisputed global water hub.

Polymer Industry Cluster of Northeast Ohio: A review of 6 cluster initiatives, offers lessons in how best to organize, launch and sustain cluster-based economic development. Two basic models emerge: Cluster Hub in which one organization acts as the clear lead and driver (e.g. Pittsburgh Life Sciences Greenhouse and The Water Council (Milwaukee)); Shared Leadership, in which two or three organizations act as a highly collaborative joint leads (e.g. Unmanned Aerial Systems (Syracuse)). The best cluster initiatives do not focus on attracting outside investment rather spend more time and money on boosting the competitiveness of existing companies by addressing R&D, capital investment, skill & infrastructure development, and collaboration among cluster members including educational and research institutions.

Geography: The Polymer Industry Cluster covers 16 counties of Northeast Ohio with total population of 4.12 million people that is 35% of the state's population.

Cluster Size: The Polymer Industry Cluster is composed of 516 companies with about $22 billion in revenue and employing 42,000 people in the region. Leading the pack is Greater Akron Region, comprised of Summit, Portage and Medina counties, with 174 companies and about $7.4 billion in revenue employing in excess of 10,000 people.

Cluster Type: The Polymer Industry Cluster is manufacturing/technology base cluster; focus is on the development and commercialization of new polymer materials, polymer compounds, and polymer processing including recyclability.

Organizational Structure: In 2021, the organizational structure of the Polymer Industry Cluster included:

1. Steering Committee (5)
2. Advisory Council (28) - consisting of local leaders with diverse background
3. Core Team (2): Senior Research Director at Greater Akron Chamber and a Consultant
4. Supporting Team – associates of the Greater Akron Chamber and Team NEO

The operating budget for year 2021 was $115,000. It is proposed to increase the size of the core team to 3 and the operating budget to $250,000 in 2022.

6. Asset Map and Value Chain

6.1 Asset Map[62-70]

Definition: An inventory of the strengths and gifts of the community and the region. Asset mapping reveals the assets of the entire region and highlights the interconnections among them.

Asset Mapping[65-70]: represents the process of identifying, connecting, promoting and mobilizing the strengths, resources, skills, opportunities, passions and experiences that exist within a region, in order to build upon and enhance positive outcomes. The five most important aspects of the asset mapping process are to:

1. Discover and learn – see the resources in new light
2. Build Relationships – make connection and build relationships
3. Connect – people to assets and projects
4. Promote and celebrate – reveal asset richness
5. Mobilize – link resources for productive future actions

Asset mapping is about connecting businesses to each other and their local economy and network within an ecosystem. There are six key asset categories, namely: i) economic/business assets, ii) institutional assets, iii) people assets, iv) physical assets, v) local associations, and vi) cultural assets, histories and stories.

Northeast Ohio Assets:

The purpose of asset mapping is to identify assets that are critical and must be protected and sustained with in the Greater Akron and surrounding Northeast Ohio region. The stakeholders including members of the advisory council were solicited to identify assets as well as their role in support of the polymer industry. For example, 258 companies/organizations were identified that are directly engaged with the polymer industry just in the Greater Akron region. The breakdown segments include:

. Elastomer = 42 companies
. Plastics = 45 companies
. Adhesive & Coatings = 12 companies
. Specialty Chemicals = 7 companies
. Health Care =7 companies
. Logistics = 26 companies
. Engineering & Design = 32 companies
. Civil Engineering = 32 companies
. Career Centers = 15 organizations
. Miscellaneous = 40 companies (tire molds, rubber mixing, testing, bio-polymers, recycling etc.)

Northeast Ohio (16 counties) account for more than half (516) of polymer companies in Ohio.

Economic Business Assets: Following are few of the most prominent assets:

1. The Goodyear Tire & Rubber Company[71]: Goodyear is one of the world's leading tire companies with operations in most regions of the world. Goodyear manufactures its products in 46 facilities in 21 countries. It employs approximately 63,00 people around the world including 3000 in Akron Ohio. Goodyear with its headquarter and innovation center in Akron is one of the most critical assets for the polymer industry cluster and the region. Goodyear is pushing the future of mobility (Connected, Autonomous, Shared and Electrical

vehicles) and "Sustainability" with investments in technologies and startups through its venture program.

2. Bridgestone Americas Technology Center[72]: A Research & Development arm of the world's No.1 tire company Bridgestone, the technology center in Akron is home to more than 700 associates dedicated to developing design, specification and materials used in tires produced in both North and South Americas. It houses multiple labs and testing technologies to develop solutions for the future of mobility. Bridgestone Americas Technology Center is providing valuable support to the Bridgestone Corporation in its transformation to a "Sustainable Solutions Company". It has an impressive program on "Sustainability" with aspirational targets of 100% carbon neutral and 100% renewable resources in tire products by 2050. The Technology Center's support of the University of Akron and Bounce Innovation hub is very valuable to the polymer industry cluster and the region.
3. Continental ContiTech[73]: ContiTech, one of the five Continental divisions, is primarily engaged in manufacturing of industrial rubber goods including conveyor belt systems, drive belts and hoses for industrial oil and gas, passenger and commercial vehicles, and power transmission. It is headquartered in Fairlawn, Ohio, employing 130 employees in Northeast Ohio. ContiTech is providing valuable support to the polymer industry cluster initiative.
4. Promerus LLC[74]: Promerus is a technology driven organization providing advanced material solutions for the next generation of applications in markets such as semi-conductors, opto-electronics, and electronic packaging. Formed as a wholly owned subsidiary of the Sumitomo Bakelite Co Ltd of Japan, Promerus represents a significant presence in North America for both research and commercial activities related to polycylic olefins. Its parent company is a leader in development of materials for product applications in the transportation industry, electrical and electronics equipment, functional packaging materials, and bio-based products. Promerus is focused on growing its business through innovation and development of advanced materials right here in Akron, Ohio.
5. ASW Global[75]: ASW Global is a leading 3PL (3rd Party Logistics) provider for local, national, and multinational companies. ASW Global, strong supporter of the polymer industry cluster, offers a range of supply chain solutions, material handling, fulfillment, and asset management services and has experience operating 2.5 million square feet of dedicated and flexible warehouse space in North America. ASW Global's shared service environment, located in Mogadore, Ohio, occupies 500,000 square feet of warehousing and distribution space dedicated to a diverse group of global clients. This facility located within Foreign Trade Zone # 181 and regulated by Homeland Security is a very valuable asset for the supply chain.
6. Lubrizol Corporation[76]: The Lubrizol Corporation, a Berkshire Hathaway Company, with headquarters in Wickliffe, Ohio, has annual revenues of more than $6 billion, 8,800 employees, more than 100 facilities and customers in over 100 countries. Lubrizol supports its global customers through two business segments: i) Lubrizol Additives – address a wide variety of vehicle needs, including improving energy efficiency, reducing emissions, and enhancing engine reliability and durability; creating new formulations for application to electrical vehicle market; industrial applications include hydraulic, turbine, food processing and many more; ii) Lubrizol Advanced Materials: used in a wide variety of consumer and

industrial applications in a wide variety of industries that include health care, hygiene and beauty, sports and recreation, home cleaning and construction; recyclable and durable polymers are used in mobile phones, auto interiors, and surface protection applications. The Lubrizol Corporate Ventures group, established in 2020, partners with industry game changers to solve emerging complex challenges, develop, test, commercialize and scale breakthrough opportunities in emerging high-tech industries.

7. Parker Hannifin[77]: Parker Hannifin is a global leader in motion and control technologies with annual sales of $14+ billion and with its headquarters in Mayfield Heights, Ohio. Parker Hannifin is comprised of six product groups spanning the core motion technologies – electromechanical, hydraulic, and pneumatic – with a full complement of fluid handling, filtration, sealing and shielding, climate control, process control and aerospace technologies. Parker is located in 50 countries around the world supporting 100 divisions with 336 manufacturing locations. Parker Parflex Division plant located in Ravenna, Ohio manufactures polymer-based hose and tubing for fluid transfer/fluid power companies. From general hydraulic hoses that operate in temperatures as low as -70degF to subsea hoses that reach 10,000 feet down to the ocean floor, their comprehensive line includes low, medium and high pressure pneumatic and hydraulic hoses. Parker Parflex has agreed to join the polymer industry advisory council.
8. Smithers Group[78]: Founded in 1925 and headquartered in Akron, Ohio, Smithers is a multinational provider of testing, consulting, information, and compliance services. With laboratories and operations in North America, Europe, and Asia, Smithers supports customers in several industries including transportation, life science, food and packaging, materials, consumer goods and energy. Smithers offers independent testing services that include chemical, physical, and product testing for a wide range of industries, products, materials, and formulations. Smithers experts can design custom testing programs to meet unique needs or meet specific requirements for the customer's industry. Combining over 100 years of knowledge and experience across a wide range of industries, Smithers' renowned market reports provide exclusive market forecasts, critical industry analysis, and insights into key drivers and trends. Companies use these market reports for their strategic planning.
9. Sherwin-Williams Company[79]: A global leader in paints and coatings was founded in Cleveland in 1866. It primarily engages in the manufacture, distribution, and sale of paints, coatings, floorcoverings, and related products to professional, industrial, commercial, and retail customers worldwide. The company operates through three segments: i)The Americas Group with 4,758 stores, including more than 135 floorcovering centers, ii) Consumer Brands Group – develops, manufactures, and distributes various paints, coatings and related products under the brand names of Cabot, Duron, Dutch Boy, Geocel, Kool Seal Thompson's Waterseal, Uniflex and many more, and iii) Performance Coatings Group – sells coatings and finishes to industrial, wood furniture manufacturing, marine, packaging, and automotive markets in more than 120 countries. Sherwin-Williams has 61,031 employees and annual revenue of $18.4 billion for the year 2020. Sherwin-Williams is committed to keeping its headquarters in a new building complex in Downtown Cleveland, and a new R&D facility in Brecksville, both expected to open in 2023.

10. NASA Glenn Research Center[80]: Located next to the Cleveland International Airport, NASA Glenn Research Center performs research, engineering, development, and testing to advance aviation, enable exploration of the universe, and improve life on earth. Its scientists and engineers deliver advanced technology and flight systems for spacecraft and improve efficiency in aircraft, often in partnership with U.S. companies, universities, and other government institutions. The centers core capabilities concentrate on in-space propulsion, power systems, aerospace communications, materials for extreme environments, biomedical technologies, and high-value space experiments in the physical sciences – all focused on solving important, practical aerospace problems and opening new frontiers (scientific, technological, and economical) for our nation. In addition, NASA Glenn is leading the aeronautic research that includes managing the Advanced Air Transport Technology Project, defining the most compelling technical challenges facing the air transport industry as envisioned for the 2030-2040-time horizon. The research explores and advances knowledge, technologies, and concepts to enable giant steps in energy efficiency and environmental compatibility, resulting in less fuel burn and less direct impact with the atmosphere. Since its groundbreaking on January 3, 1941, more than **$1.04 trillion** has been invested in the construction of NASA Glenn's campuses. In Fiscal Year 2020, NASA Glenn's **$540.7 million direct spending in Northeast Ohio,** resulted in in output (sales) of **$1.7 billion** across all industry sectors. The value added increased by **$1.1 billion** as a result of NASA Glenn's operation. In addition, 8,514 jobs were created and supported in the region, and labor income in Northeast Ohio increased by **$770.7 million.** NASA Glenn's activities in Northeast Ohio also generated **$148.1 million** in local, state and federal taxes.

Institutional Assets: We have three world renowned institutions in our backyard that have been the backbone of the rubber, polymer, and liquid crystal industry. They offer opportunities for the polymer industry to regain its global leadership role offering world class education, breakthrough research and innovation in joint collaboration with the industry. The Following are brief highlights of each institution:

The University of Akron[81]: is a public research university in Akron, Ohio. As a STEM-focused institution, it focuses on industries such as polymers, advanced materials, and engineering.

The University of Akron offers about 200 undergraduate and more than 100 graduate majors and has an enrollment of approximately 18,000 students with 1542 academic staff. Research at the University of Akron involves all colleges, numerous self-disciplinary centers and labs. The University of Akron is perhaps best known for polymer and advanced materials expertise in the field of manufacturing, medical devices, emerging green technologies, advanced energy, microelectronics and optical devices. Its prominent research centers include:

Goodyear Polymer Center: a 146,000 sq. ft. research facility that comprises two 12-story and nine-story towers connected by glass-enclosed walkways. It contains eight polymer synthesis groups, computer simulation and modeling capabilities, a microscopy suite, molecular and morphological characterization labs, surface analysis facilities, and thermal analysis and mechanical properties testing equipment. The Goodyear Polymer

Center houses both the Department of Polymer Science and the School of Polymer Science and Polymer Engineering.

National Polymer Innovation Center (NPIC): a contract services facility at the leading edge of advanced manufacturing and materials characterization. Supporting industry, national laboratories and the School of Polymer Science and Polymer Engineering, NPIC offers solutions in pilot-scale processing, surface and structural analysis, and physical and chemical characterization. Pilot scale processing includes multi-layer cast film extrusion, electromagnetic alignment solution casting, hybrid solution casting with electro-spun nanofibers, UV/IR co-curing, and small batch traditional plastics and rubber processing.

The National Center for Education and Research on Corrosion and Materials Performance (NCERCAMP): Originally funded by the U.S. Department of Defense, NCERCAMP is the only center of its kind providing multi-disciplinary approaches to help government and industry develop solutions for corrosion and materials performance challenges.

CenTire, Center for Tire Research: a National science Foundation/University Cooperative Research Center and consortium of tire and tire-related industry members with two world class universities, the University of Akron and Virginia Tech. CenTire conducts leading-edge, precompetitive research in materials, tire physics, testing, manufacturing and sustainability at the two universities that is of interest and directed by the industry members. The current industry members are global tire manufacturers, material suppliers, vehicle manufacturers, and test equipment and service suppliers. Virginia Tech is well known for its expertise in tire and vehicle mechanics and dynamics, road pavement characterization, simulation, and testing. The University of Akron is world-class in polymer science and polymer engineering. Faculty at the universities provide their technical expertise and guidance to the graduate student(s) performing the research, and interact with industry members.

University of Akron Research Foundation (UARF): Its mission is to transform and expand the regions innovation economy through entrepreneurship, education, technology commercialization, application of the University of Akron research, and creation of new entrepreneurial ventures. Since its creation in 2001, UARF has become a significant source of support for both University of Akron innovators and Northeast Ohio's entrepreneurs. UARF is home to one of the nation's first I-Corps sites, Ohio's first student-run venture fund (NEOSVF) and Akron's first angel network (ARCHAngels). In its I-Corps program, more than 150 entrepreneurial teams and 630 individual participants have completed UARF's 7-week I-Corp program, which focuses on using direct customer interactions to validate a business idea. I-Corps provide training, mentorship and accountability.

Kent State University[82]**:** a public research university in Kent, Ohio. The university has seven regional campuses in Northeast Ohio and additional facilities in the region and internationally. Kent State is the third-largest university in Ohio with an enrollment of 35,883 in the eight-campus system and 26,804 students on the main campus in Kent. Kent State offers over 300 degreed programs, among them 250 baccalaureate, 40 associate, 50 Master's, and 23 doctoral programs of study, which include programs such as aeronautics,

business, nursing, architecture, history, journalism, fashion design, library science and the Liquid Crystal Institute.

The Kent State University has 11 academic colleges. The university also has interdisciplinary programs in Biomedical Sciences, Digital Science, Financial Engineering, and Information Architecture and Knowledge Management. The College of Aeronautics and Engineering offers four aeronautics degrees: Aeronautical Engineering, Aviation Management, Air Traffic Control and Aeronautical Engineering. The Liquid Crystal Institute, founded in 1965, is engaged in research and development of liquid crystal optoelectronic materials, technology, and consumer products.

Advanced Materials and Liquid Crystal Institute (AMLCI): Building on the foundation of the Glenn H. Brown Liquid Crystal Institute's 50-year legacy of cutting-edge science, the AMLCI embraces all materials research on campus with an initial emphasis on materials that respond to changes in their respective environment. The AMLCI engages a large interdisciplinary team of liquid crystal researchers, and experts in nanoscience and technology, biomaterials, organic semiconductors and organic electro-optics. The AMLCI reaches well beyond the traditional STEM disciplines to engage faculty and students who use the advanced materials developed at Kent state. Examples of this reach include faculty from the School of Fashion and the College of Podiatric Medicine., who are pushing the boundaries of wearable technology, and faculty from the College of Aeronautics and Engineering, who are developing the next generation of fuel cells. The AMLCI builds collaboration with institutions, individual researchers with complimentary skills, as well as industries that apply its discoveries.

Case Western Reserve University (CWRU)[83]**:** a private research university in Cleveland, Ohio. Case Western Reserve University was established in 1967, when Western Reserve University ("Yale of the West") founded in 1826 and Case Institute of Technology, founded in 1880 formally federated. It joined the Association of American Universities in 1969. CWRU undergraduate and graduate schools include the College of Arts and Sciences, Case School of Engineering, Weatherhead School of Management, Case School of Dental Medicine, School of Law, and School of Nursing. CWRU has number of programs taught in conjunction with other institutions, including the Cleveland Clinic, the University Hospitals of Cleveland, Cleveland Institute of Music, and the Cleveland Institute of Art. Seventeen Nobel laureates have been affiliated with CWRU faculty and alumni. *Albert A. Michelson of Case School of Applied Science was the first American to win a Nobel Prize in Science in 1907*. Eric Baer, in 1967, pioneered the materials science of polymers and created the first comprehensive polymer science and engineering department at a major U.S. university. CWRU is noted for research in electrochemistry, electrochemical engineering, and polymer science and engineering. Prominent research Centers at Case Western Reserve include:

The Yeager Center for Electrochemical Sciences (YCES)[84]: conducts workshops on electrochemical measurements. Related laboratories at CWRU include the Electrochemical Engineering and Energy Laboratory (EEEL), the Electrochemical Materials Fabrication Laboratory (EMFL), the Case Electrochemical Capacitor Fabrication Facility and the ENERGY LAB. In July 2018, the university was awarded $10.75 million by the U.S. Department of Energy to establish the Energy Frontier Research Center to explore "Breakthrough Electrolytes for Energy Storage".

Sears Think[box][85]: Larry Sears and Sally Zlotnick Sears think[box] is a public-access design and innovation center that allows students and other users to access prototyping equipment and other invention resources. Many projects and startup companies have come out of this center.

Center for Advanced Polymer Processing (CAPP)[86]: The Center for Advanced Polymer Processing, stems from a partnership between Case Western Reserve University, Thermo Scientific and leading plastics and rubber companies. It is a state-of-the-art center for advanced polymer blending and compounding, and reactive extrusion to perform basic non-competitive research in the area of materials development and manufacturing in support of the polymer industry. The main objective of CAPP is to develop new advanced and functional multiphase complex materials or optimize the performance of existing ones by integrating the most advanced experimental and computational capabilities.

CAPP is directed by Professor Joao Maia, at the Department of Macromolecular Science and Engineering of Case Western Reserve University.

Artificial Intelligence Supercomputer Center[87]: National Science Foundation and Ohio Department of Education partnered to support a $1 million supercomputer system, expected to be installed and in use by summer 2022. More than 250 researchers across nearly two dozen research groups – from computer science to materials science to robotics – will benefit from the faster and larger computing power of a new "Artificial Intelligence SuperComputer". It is expected to accelerate machine learning and artificial intelligence (AI) tasks by at least 10 times compared to existing campus system.

People Assets: Our region has a very rich history of producing prominent leaders in all aspects of society including industrial entrepreneurs, educators, scientists, innovators, artists, sport athletes, and many more. Following is a list of few prominent globally recognized scientists and innovators from three eminent universities:

1. **Dr Joseph P. Kennedy**[81,88,89], Distinguished Professor of Polymer Science and Chemistry, School of Polymer Science and Polymer Engineering, University of Akron: Joseph P. Kennedy has had a long and accomplished career as a researcher, scientist, educator, and inventor, both in industry and academia. Additionally, he is active in commercialization of his research, the most notable example being the invention of the polystyrene – polyisobutylenepolystyrene thermoplastic elastomer (SIBS). SIBS is the biocompatible polymer used by Boston Scientific as a coating on the world's most popular cardiovascular stent, which has been implanted in over 6 million patients worldwide. Dr Kennedy is author of 4 scientific books, author of well over 700 original publications and inventor of more than 130 issued U.S. patents on various aspects of polymer science and technology. He is the recipient of many national and international awards. Dr Kennedy's current research concerns the synthesis of novel biomaterials.
2. **Dr Eric Baer**[83,86,90], Distinguished University Professor, Herbert Henry Dow Chair in Science and Engineering, and Director of Center for Layered Polymeric Systems, Department of Macromolecular Science and Engineering, Case Western Reserve

University: Dr Eric Baer is recognized as one of the widely known research engineer/scientist in the world in the area of polymeric materials. His pioneering research has served to provide the very foundation for the materials science of polymers. His international recognition stems from his prolific work on solid state structure-property relationships in polymers and their composites. He has published over 350 research papers, and has edited five technical books, and has served as editor of the prestigious Journal of Applied Science. He joined the engineering faculty at Case Institute of Technology in 1962. His goal at CWRU was to develop a major program in advanced polymer education and research which, under his leadership, became the current Department of Macromolecular Science and Engineering. Over last twenty years, Baer has led a large team in the creation of polymer layered systems. Focus on both micro and nanolayered structures has inspired the development of novel gradient index layered dielectric films for energy storage. Today, new layered systems are being developed under his direction for use in food packaging, ballistic resistant layered structures, and security features. He is recognized as one of the founders of emerging field of Biomimicry. He is the recipient of many national and international awards.

3. **Dr Mietek Jaroneic**[82,91]**,** Professor, Department of Chemistry and Biochemistry, Kent State University: Dr Mietek Jaroneic is ranked among top 1% of chemists and materials scientists. His area of research expertise is in absorption, chemical separation, and chemistry of nanomaterials – an "exciting and important research field, especially in design and synthesis of well-defined nanostructures with tailored porosity, surface properties and morphology for energy-related environmental applications." He is also member of the Advanced Materials Liquid Crystal Institute at Kent State. He has been among the world's top 100 materials scientists since 2001. He has edited several books and published more than 1000 scientific articles in international journals. Dr Jaroniec earned several honors and awards from all over the world. In 2016, the Polish Chemical Society awarded Dr Jaroniec with the Medal of "Marie Sklodowska-Curie" for scientific achievements. The prestigious medal is awarded to outstanding chemists for exceptional scientific achievements of international significance.
4. **Dr Ali Dhinojwala**[81,92], H.A. Morton Professor of Polymer Science, School of Polymer Science and Polymer Engineering, University of Akron: Dr Ali Dhinojwala has been a part of the School of Polymer Science and Polymer Engineering (SPSPE) for over 20 years, first serving as a professor, and then as Department Chair from 2002-2012 and Interim Director, SPSPE from 2020-2021. He has served as the co-Principal Investigator of the Biomimcry Research and innovation Center (BRIC) since its inception in 2011. Dr Dhinojwala's research is focused in the area of interfacial science. His group is using infrared-visible Sum Frequency-generation Spectroscopy (SFG) techniques to study fundamental problems in adhesion, wetting, and friction. They have developed approaches to couple SFG and mechanics together to relate macroscopic properties such as adhesion and friction with the structure and dynamics of interfacial molecules. His group is applying this fundamental knowledge of interfacial science to design new materials inspired by nature. His

research work is supported by the National Science Foundation, Airforce Office of Scientific Research and industries.

5. **Dr Torsten Hegmann**[82,93]**,** Professor, Ohio Research Scholar, and Director of Advanced Materials Liquid Crystal Institute, Kent State University: Dr Hegmann joined Kent State as an Associate Professor and Ohio Research Scholar in Science and Technology of Advanced Nanomaterials in 2011. He previously worked as a professor at the University of Manitoba for eight years following a post-doctoral fellowship at Queens University in Canada. He earned his doctorate in 2001 from Martin Luther University in Germany. He has organized or co-organized several symposia or conferences including the Chirality at the Nanoscale Symposium, and Gordon Research conferences on Liquid Crystals. He has served on the editorial board of the journal *Crystals* and is the Chief Scientific Officer of Blood Brain Biotransport LLC. He is recipient of many national and international awards. Dr Hegmann was named Fellow of Royal Society of Chemistry (FRCS) in 2016. The Royal Society of Chemistry, founded in 1841, is the United Kingdom's professional body for chemical scientists and the largest organization in Europe for advancing the chemical sciences. Dr Hegmann's admittance was based on his contributions in the field of chemistry and specifically advanced nanomaterials. His research group focuses on multiple projects funded by the National Science Foundation, NASA, Merck (Germany), LG Display, and the Canadian Institute for Health Research. Dr Hegmann has authored in excess of 100+ technical papers and holds about dozen active patents.
6. **Dr Sadhan Jana**[81,94], BF Goodrich Endowed Professor, Department of Polymer Engineering, and Associate Dean for Research, College of Engineering and Polymer Science: Sadhan Jana received his Ph.D. in Chemical Engineering from Northwestern University in 1993 and worked at GE Corporate Research before joining the University of Akron in 1998. His research interests include polymer processing, polymer nanocomposites, aerogels for nanoparticle filtration from air and water, materials solution for reduction of hysteresis and rolling resistance of tire-tread compounds, filler dispersion, shape memory polymers, ionogels for high temperature lithium-ion batteries. He served as chair of the Department of Polymer Engineering from 2004 to 2011 and then again from 2015 to 2019. He has authored in excess of 140+ technical papers and holds five active patents. He serves in editorial boards of scientific journals and is an executive committee member in professional societies. Dr Jana has received several honors and awards from national and international scientific organizations. In 2008 he was admitted as a Fellow into the Society of Plastics Engineers, and named Fellow of Royal Society of Chemistry (FRCS) in 2021.
7. **Dr Joao Maia**[83,86], Associate Professor and Director of the Center of Advanced Polymer Processing, Department of Macromolecular Science and Engineering, Case Western Reserve University: Dr Joao Maia earned his Ph.D. degree in Rheology from the University of Wales in 1996. He was a faculty member at the University of Minho, Portugal from 1996 to 2009. In October 2009, Dr Maia joined the Department of Macromolecular Science and Engineering at Case Western Reserve

University. Since 2011 he is the Director of CAPP – Center for Advanced Polymer Processing of CWRU. His main research interests lie in the areas of rheology applied to polymer processing, with an emphasis on the development of new functional multiphase polymeric materials e.g. blends and composites, on-line sensing of extrusion and compounding, and extensional rheology. He has published more than 300 scientific articles, including 8 patents, more than 80 papers in international refereed journals and more than 200 communications to international conferences. He was a Fulbright Fellow in 2007 and received the 2010 annual award of the British Society of Rheology and the 2011 Morand Lambla Award of the Polymer Processing Society. He currently leads five scientific R&D projects and another twelve in cooperation with industries for a total funding of $5 million. His research group currently consists of three post-doctoral researchers, fifteen PhD students and several undergraduate students.

8. **Dr Tianbo Liu**[81,95], A Schulman Professor, and Interim Director, School of Polymer Science and Polymer Engineering: Tianbo Liu received his Ph.D. in Chemistry from the Stony Brook University in 1999. After serving as a postdoctoral associate at Stony Brook, he started his independent research career in the Physics department of Brookhaven National Laboratory. In 2005 he transitioned to Lehigh University as an assistant professor of chemistry, promoted to associate professor in 2009 and full professor in 2012. During his time at Lehigh, he received the NSF Career Award and was named Alfred P. Sloan Foundation Fellow. In 2013, Dr Liu joined University of Akron as A. Schulman Professor of Polymer Science and was chair of the Department of Polymer Science from 2018 to 2020. Dr Liu was named Fellow of the American Association for the Advancement of Science. Dr Liu's progressive research focuses on the physical chemistry of complex polymer solution systems including macroions, inorganic-organic hybrids, colloids/nanoparticles, surfactants, polyelectrolytes, block copolymers and bio-macromolecules.
9. **Dr Thien Kyu**[81,96], Distinguished Professor, School of Polymer Science and Polymer Engineering, The University of Akron: Kyu received his Ph.D. in Polymer Chemistry from Kyoto University, Japan, in 1980. Prior to joining the Department of Polymer Engineering at the University of Akron in 1983, he was a post-doctoral research fellow at the Department of Chemistry, McGill University, Montreal, Canada in 1980-81 and a research associate at the Polymer Research Institute, University of Massachusetts, Amherst in 1981-83. Dr Kyu's research interest encompasses phase equilibria and kinetics of phase separation in polymer blends, phase field modeling on pattern formation aspects of crystalline polymers, molecular composites, secondary rechargeable lithium-ion batteries, phase transitions of liquid crystals, electro-optical properties of liquid crystal and photonic crystals, and bio-degradable polymers. His research has culminated in some 230 refereed papers, five patents and three books.
10. **Dr James Eagan**[81,97], Assistant Professor, School of Polymer Science and Polymer Engineering, The University of Akron: Dr James Eagan develops synthetic methodologies for the synthesis of new polymers, with a focus on polyolefin materials. He joined the University of Akron in 2019 as an Assistant Professor after

working at Aramco Performance Materials and Ascribe Bioscience. He received his Ph.D. degree in Chemistry from Columbia University in 2014. Following doctoral studies, Dr Eagan studied the synthesis and properties of polyolefin block copolymers. This research focused on combining the two most abundant plastics, polyethylene and polypropylene, into mechanically robust blends through the use of multiblock copolymers. Plastics are essential to modern life. However, the pervasive use and careless disposal of these materials has created an environmental catastrophe.

Research in the Eagan lab is focused on how plastics can be deployed to address the needs of today, without compromising the future; conducting research on synthesizing new polymeric materials for sustainable applications. Dr Eagan along with Dr Wang, also of the School of Polymer Science and Polymer Engineering were awarded $2.05 million by the U.S. Department of Energy for plastics recycling research and development.

Local Associations: There are currently three technical associations that the polymer industry leverages to address its work force skill development and technology/innovation needs for business sustainability and growth:

1. **Rubber Division, ACS**[99]: The Rubber Division of the American Chemical Society is an international association of chemists, engineers, technicians, scientists, plant managers, sales and marketing professionals and others in the rubber, polymer or related fields within industry, academia and government. Rubber Division's mission is to educate, connect and grow the evolving elastomer industry. The Rubber Division, ACS is over 100 years old.
2. **The Tire Society**[100] - *Driving innovation in Tire Science*: The Tire Society was established with the mission to disseminate knowledge and simulate the innovation of tires as it pertains to tire science, engineering and technology. The Society fulfills its mission through seminars, technical meetings and publication of the authoritative journal *Tire Science and Technology*.
3. **Akron Society of Plastic Engineers (Akron SPE)**[101]: The Akron SPE section has a long history of being one of the premier sections for SPE International. Akron SPE aims to continue spreading knowledge, strengthening skills, promoting education and promoting the industry to technicians, scientists, marketers, retailers and other plastics professionals. The Akron section brings innovation to members by offering creative and educational monthly programs, as well as partnering with other local professional groups and educational foundations.

Support Organizations: Following are a few key state supported organizations that provide service, support and guidance for workforce, manufacturing and innovation needs of the polymer industry:

1. **MAGNET (Manufacturing Advocacy and Growth Network)**[102]: The mission of MAGNET is to support, educate and champion manufacturing in Ohio with the goal of transforming the region's economy into a powerful global player. MAGNET is an organization dedicated to helping manufacturers grow and

compete in 21 counties in Northeast Ohio. MAGNET provides consulting and engineering services to Northeast Ohio's small and mid-sized manufacturers. These services include process innovation, automation, product design and development, quality management, employee development and much more. It assists early-stage, product-focused businesses reach market entry faster with reduced technical risks. The incubator at Magnet offers subject matter expertise, access to regional technical assets, partnership and connections with professionals in Northeast Ohio.

2. **Team NEO**[102]: a business and economic development organization focused on accelerating economic growth and job creation throughout the 18 counties of Northeast Ohio. Team NEO's work is driven by robust data analysis that helps create a clear picture of what is and what is not working across our regional economy and uses these insights to influence solutions and impact regional growth. Team NEO's highly experienced staff is guided by a board of business, economic development and civic leaders. Regionalism and collaboration are at the heart of everything Team NEO does as the regional Akron, Canton, Cleveland and Youngstown economic development organization.
3. **Bounce Innovation Hub**[103]: Founded in 2018, Bounce serves northeast Ohio entrepreneurs, start-ups and small businesses. Located in downtown Akron, the nonprofit organization comprises 300,000 sq. ft. of coworking, event, meeting and professional office space. With more than 50 organizations in the building, Bounce accounts for more than 250 people working and creating. Through entrepreneurial programs and community partnerships, Bounce currently serves more than 100 entrepreneurs and start-ups in northeast Ohio. Services include several programs such as technology incubator, software accelerator, MAGNET iterator program and GROW (Generating Real Opportunity and Wealth).
4. **JumpStart**[104]: Jumpstart was created in 2003 to address Northeast Ohio's declining economy, loss of jobs and lack of entrepreneurial growth. The region's civic, community and philanthropic leaders explored these issues, and as a result. NorTech and Case Western Reserve University launched this venture development organization. Jumpstart's mission is to unlock the full potential of entrepreneurship to transform entire communities. JumpStart is a venture development organization, combining the principles of venture capital and economic development to help entrepreneurs start and grow companies. JumpStart's work is focused on three core areas: i) Make Investments: JumpStart funds tech entrepreneurs with the capital they need to grow their startup businesses quickly, ii) Deliver Services: provide technical assistance to help high-potential businesses solve problems, drive growth and create jobs, and iii) act as a Value-Added Partner: work on behalf of private, public and philanthropic funders who want to assist entrepreneurs. JumpStart has a very impressive track record that includes a return on investment of a little over 6.5X. JumpStart portfolio include: 131 tech start-ups, $62 million capital invested to date, $1.4+ billion follow-on funding, $2+ billion exit value from

portfolio. JumpStart has recently signed an agreement with NASA to find entrepreneurs to commercialize NASA developed technologies

6.2 Value Chain[105-109]

What is Value Chain?[105,106,109]

"*A value chain is a concept describing the full chain of business's activities in the creation of a product or service – from the initial reception of materials all the way through the delivery to market, and everything in between.*"

Wesley Chai, Technical Writer, Tech Target

The value chain framework is made up of five primary activities. Primary activities contribute to a product or service's physical creation, sale, maintenance and support. These activities include the following:

1. **Inbound Operations:** The internal handling and management of resources coming from outside sources – such as external vendors and other supply chain sources. These outside resources flowing in are called "inputs" and may include raw materials.
2. **Operations:** Activities and processes that transform inputs into "outputs" – the product or service being sold by the business that flow out to customers. These "outputs" are the core products that can be sold for a higher price than the cost of materials and production to create a profit.
3. **Outbound Logistics:** The delivery of outputs to customers. Processes involve systems for storage, collection and distribution to customers. This includes managing a company's internal systems and external systems from customer organizations.
4. **Marketing and Sales:** Activities such as advertising and brand-building, which seek to increase visibility, reach a marketing audience and communicate why a customer should purchase a product or service.
5. **Service:** Activities such as customer service and product support, which reinforce a long-term relationship with customers who have purchased a product or service.

The value chain framework of a typical enterprise is shown in Figure 9. The five primary activities are identified in this framework. As inefficiencies are relatively easy to identify in this framework, well-managed primary activities are often the source of a business's cost advantage. This means the business can produce a product or service at a lower cost than its competitor – and that is the value of the value chain framework.

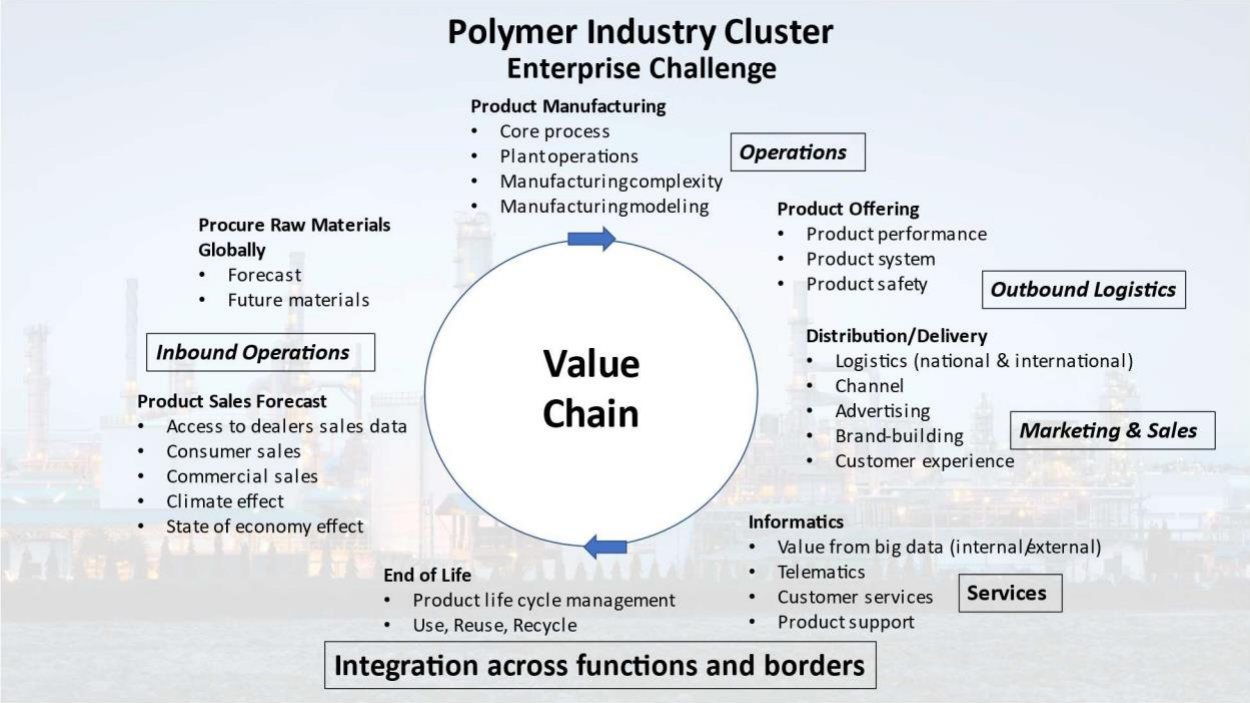


Figure 9. The value chain framework

7. Ecosystem[111-121]

Definitions:

Ecosystem: From ecology science perspective (Biology 2012)
"A system that includes all living organisms (biotic factors) in an area as well as its physical environment (abiotic factors) functioning together as a unit."

Economic Ecosystem: Moore (1993)[121] innovatively used ecosystem to describe an economic community which is supported by a foundation of interacting organizations and individuals. "An economic ecosystem is an organic combination of organizations, individuals and other actors that co-evolve their capabilities and resources and integrate their dedications so as to form additional value and/or enhance efficiency." Similar to ecology studies, economic ecosystems not only refer to the *biotic* factors, such as individuals and organizations, but also include the *abiotic* factors, such as policy, resource, capital, and culture.

What is Business Ecosystem?

A **business ecosystem** is the network of organizations – including suppliers, distributors, customers, competitors, universities, government agencies, and so on – involved in the delivery of a specific product or service through both competition and collaboration. The idea is that each entity in the ecosystem affects and is affected by the others, creating a constantly evolving relationship in which each entity is flexible and adaptable in order to survive as in a biological ecosystem.

Understanding a Business Ecosystem: In 1930s, British botanist Arthur Tansley introduced the term ecosystem to describe a community of organisms interacting with each other and their environments: air, water, earth etc. In order to thrive, these organisms compete and collaborate with each other on available resources, co-evolve, and jointly adapt to external disruptions.

Advances in technology and increasing globalization have changed ideas about the best ways to do business, and the idea of business ecosystem is thought to help companies understand how to thrive in this rapidly changing environment. Moore (1996) defined the **business ecosystem** as follows:

"An economic community supported by a foundation of interacting organizations and individuals – the organisms of the business world. The economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organisms also include suppliers, lead producers, competitors, and other stakeholders. Over time, they co-evolve their capabilities and roles, and tend to align themselves with directions set by one or more central companies. Those companies holding leadership roles may change over time, but the function of ecosystem leader is valued by the community because it enables members to move toward shared visions to align their investments, and to find mutually supportive roles."

In effect, the business ecosystem consists of a network of companies that dynamically interact with each other through competition and collaboration to grow revenue and survive. When an ecosystem thrives, it means that the participants have developed

patterns of behavior that streamline the flows of ideas, talent, and capital throughout the system.

What is Entrepreneurial Ecosystem (E-ecosystem)?

The **entrepreneurial ecosystem** is a special economic community of talented pioneers such as entrepreneurs, investors, engineers, researchers, as well as related resources, opportunities, capitals, policies, dedicated to create entrepreneurial firms. Notable characteristics of the E-ecosystem include: i) very diverse and has high mobility inside, ii) contrast with other ecosystem, E-ecosystem places entrepreneurs in focal point and iii) an aim to create new ventures, add new value, or improve efficiency, or advance the economics.

Why Ecosystem Matters?

Ecosystems are rapidly becoming ubiquitous across the business landscape. We are entering an era of ecosystem where most companies/regions will utilize ecosystem business models to drive innovation, entrepreneurship, and the pace and capital efficiency to create customer value. It is expected that businesses will increasingly favor for "partner" option in the "build, buy, partner" decision framework. The pace of change, demand for innovation and democratization of capital almost necessitates collaboration and partnerships. 'Building' can take too long and 'buying' can take too much capital. A robust Polymer Industry Cluster Ecosystem can be a path for venture creation and economic advantage for the polymer industry of Northeast Ohio.

Analysis of the current Polymer Industry Cluster Ecosystem:

A comprehensive analysis of the existing polymer industry cluster ecosystem was conducted to understand connections between and among businesses/resources and identify gaps and/or opportunities in the ecosystem. Figure 10 shows the representation of our current polymer industry cluster ecosystem covering environment and economic attributes. The environment attribute includes *infrastructure*, *policy* and *culture*, whereas economic attribute cover *capital*, *education* and *organizations*. The key elements and supporting organizations are further identified as shown in the figure. During the analysis of the contribution of each element in the ecosystem, several gaps, shortcomings and potential opportunities were identified. Following are key takeaways from the analysis:

1. The source of capital and venture funding is a big gap in the current ecosystem – the analysis of the *capital* attribute shed some light on the struggle Northeast Ohio region faces in attracting sources of capital investment. There appears to be very marginal private venture capital activity in polymers/materials in the region. JumpStart and North Coast Ventures use their funds mostly on high tech start-ups. President Biden's administration is making big bets on global warming that will have significant impact on the polymer industry and hence an opportunity for federal grants to support research and innovation for a new generation of polymers. Another potential source for capital investment can be venture funds from local large companies.

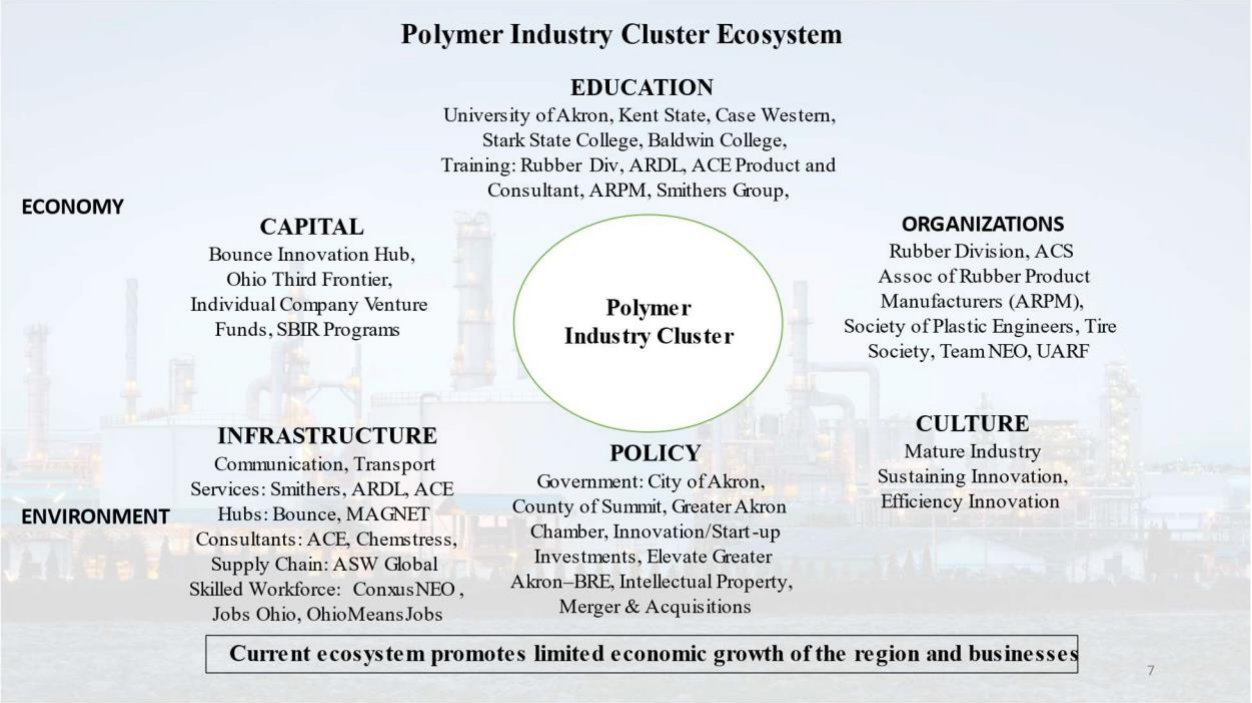


Figure 10. The current Polymer Industry Cluster Ecosystem

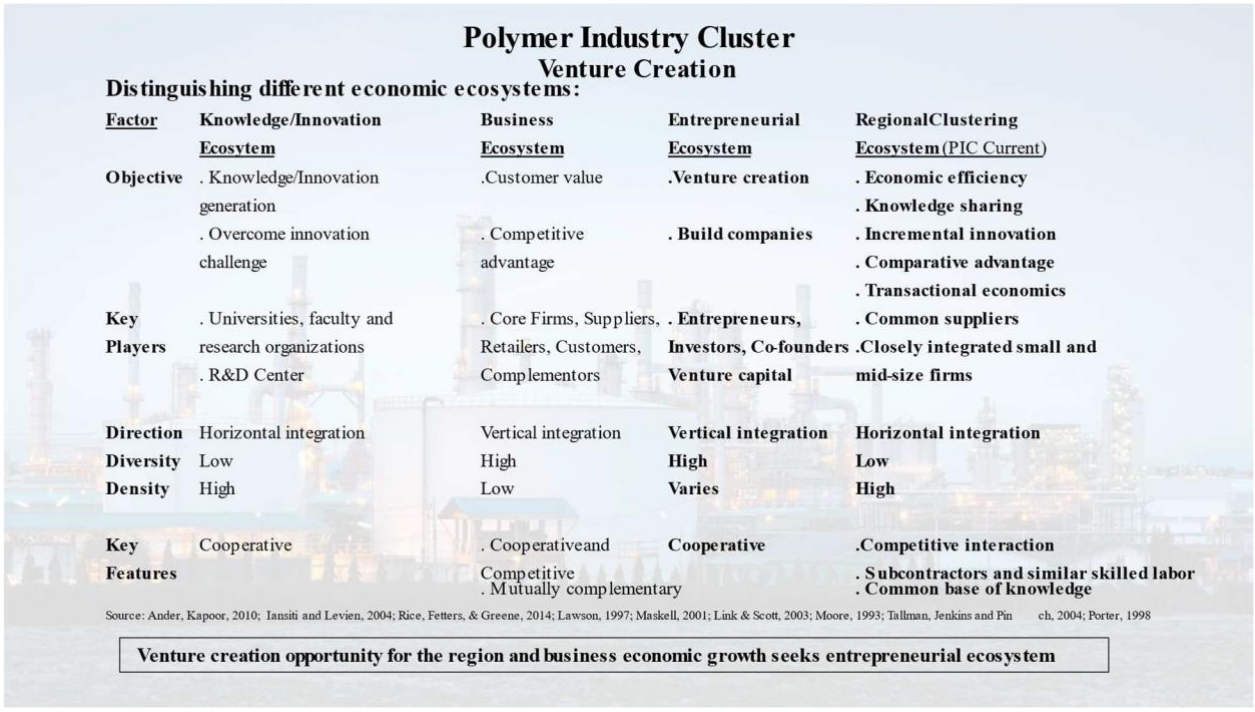
2. Workforce skill development and training is a gap for the polymer industry – the regional universities and colleges offer excellent source of professional hires, however, they lack in providing hands-on skill workforce to operate laboratory equipment and manufacturing machinery, a critical need of the industry.
3. Absence of a Polymer Processing Society – support professional organizations such as Rubber Division, Society of Plastic Engineers, Tire Society, Association of Rubber Products Manufacturing, Team NEO, and the University of Akron Research Foundation are outstanding assets to the polymer industry. The local presence of the Polymer Processing Society division will further strengthen the support system.
4. Infrastructure: Workforce Development Center- establishment of workforce development center will address the most challenging need of skilled workforce for the industry.
5. Lack of strong entrepreneurial culture – the polymer industry culture of today is that of a mature industry and therefore constrained to marginal growth opportunities. In general, industry does very well in promoting i) *sustaining innovation* ie making good products better, and ii) *efficiency innovation* ie improving effectiveness and efficiency of its operations. However, it falls short in creating new jobs or capital essential for the strong growth ie *empowering innovation*.

Building Entrepreneurial Ecosystem: Perspective on regional venture creation

The aim of the Polymer Industry Cluster initiative is to explore and create an environment for the launch of the striking phenomenon of **venture creation** in Northeast Ohio region. **Venture Creation** is *'the process of turning new ideas or technology into a business that can*

succeed and attract investors.' It is a complex and multidimensional process that demands i) entrepreneurs to watch out for entrepreneurial opportunities, ii) organize stream of entrepreneurial resources, iii) be aggressive with their competitors, iv) collaborate with founders, academic institutions, and government. From the resource perspective, human and social capital are critical for start-ups. Universities with a great pool for talent and new knowledge are found to boost venture emergence and foster new ventures with intellectual property.

One of the important topics in the ecosystem realm is **E-ecosystem**. The E-ecosystems' biotic factors such as entrepreneurs, investors, researchers, engineers co-evolve with abiotic factors such as capital, resources, culture, policy to be effective and efficient source of value creation. To conceptualize the role of E-ecosystem in venture creation, a comparative analysis of four proximate systems: knowledge ecosystem, business ecosystem, E-ecosystem and regional cluster ecosystem is shown in Table 5. It is proposed



Polymer Industry Cluster

Venture Creation

Distinguishing different economic ecosystems:

Factor	Knowledge/Innovation Ecosytem	Business Ecosystem	Entrepreneurial Ecosystem	RegionalClustering Ecosystem (PIC Current)
Objective	. Knowledge/Innovation generation . Overcome innovation challenge	.Customer value . Competitive advantage	.Venture creation . Build companies	. Economic efficiency . Knowledge sharing . Incremental innovation . Comparative advantage . Transactional economics
Key Players	. Universities, faculty and research organizations . R&D Center	. Core Firms, Suppliers, Retailers, Customers, Complementors	. Entrepreneurs, Investors, Co-founders Venture capital	. Common suppliers .Closely integrated small and mid-size firms
Direction	Horizontal integration	Vertical integration	Vertical integration	Horizontal integration
Diversity	Low	High	High	Low
Density	High	Low	Varies	High
Key Features	Cooperative	. Cooperativeand Competitive . Mutually complementary	Cooperative	.Competitive interaction . Subcontractors and similar skilled labor . Common base of knowledge

Source: Ander, Kapoor, 2010; Iansiti and Levien, 2004; Rice, Fetters, & Greene, 2014; Lawson, 1997; Maskell, 2001; Link & Scott, 2003; Moore, 1993; Tallman, Jenkins and Pin ch, 2004; Porter, 1998

Venture creation opportunity for the region and business economic growth seeks entrepreneurial ecosystem

Table 5. Comparative analysis of four proximate ecosystems[121-136]

that E-ecosystem with a good fit, match and interaction among key components would speed up the entrepreneurial opportunity identification and development raising the region's venture creation efficiency. Figure 11 shows the proposed polymer industry cluster entrepreneurial ecosystem (E-ecosystem). The new key elements identified in red, when implemented, will transform the Polymer Industry Cluster ecosystem of today to the entrepreneurial ecosystem of tomorrow with potential to create new ventures, add value and advance economic growth of the region.

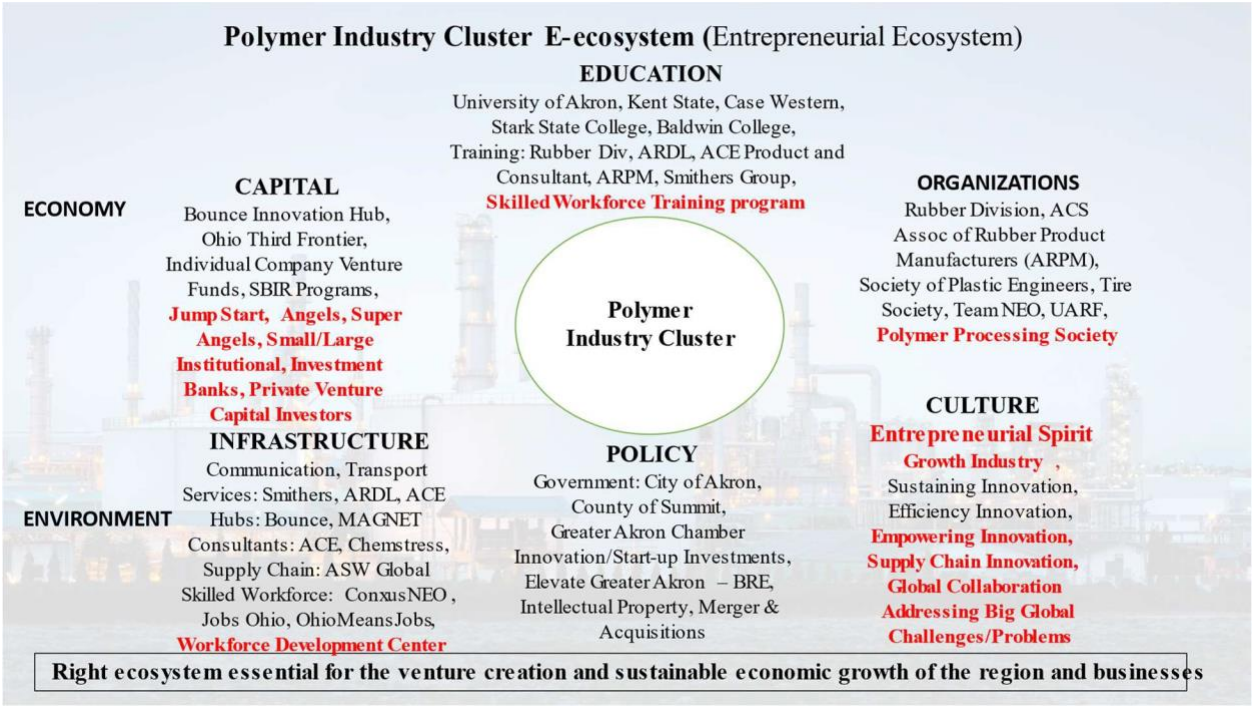


Figure 11. The proposed Polymer Cluster E-ecosystem

8. Voice-of-the-Customer[137-140]

8.1 Introduction

Definition:

"Voice-of-the-Customer (VOC)" is the manifestation of customer needs, wants, expectations and preferences".

Importance of Voice-of-the-Customer: The quality of customer experience is a key differentiating factor for any organization. Therefore, deployment of the 'Voice-of-the-Customer' program is important for ensuring that i) customer input is requested and valued, ii) customer feedback ensures that organizations deliver features that customer wants and needs, and iii) VOC program will increase customer loyalty and help organizations create more valuable product offering.

Voice-of-the-Customer Data Collection Methods:

There are multiple channels from which organizations collect direct feedback from customers. These methods include:

1. Customer Focus Groups
2. Customer Advisory Councils that meet with customers to receive their feedback
3. Customer feedback questionnaires
4. Phone surveys/data collection
5. Social media monitoring tools

Once customer feedback is collected, the next step is to develop a strategy for using the data.

1. **Analyze data to spot patterns and trends** - qualitative input may identify customer service processes that need to improvement.
2. **Share information across the organization** – this is an important step to coordinate a comprehensive collaborative response to customer needs.
3. **Act on customer insights from VOC data** – actions include improving customer support and launching new products and services.
4. **Measure success** – establish key performance indicators.
5. **Make revisions** – customer feedback is always evolving; it's necessary to make changes to ensure customer satisfaction.

8.2 Polymer Industry Cluster Initiative Approach:

The future success of the polymer industry in Northeast Ohio depends on identifying shared challenges and shared opportunities. For this reason, the VOC feedback approach identified in the previous section was followed which included i) customer focus group, ii) customer advisory council, and iii) developing and sharing feedback questionnaire.

We were fortunate to partner with Greater Akron Chamber's Economic Development team led by Gregg Cramer, Alyssa Carpenter and Sherri Shields. Their business portfolio included all polymer companies in the region. This team, for all practical purposes, served as customer focus group/council to collect direct feedback from these companies. In addition, the Polymer Industry Advisory Council consisting of 25 prominent leaders from the industry, served as a very significant source of VOC feedback. We also partnered with the University of Akron Research Foundation's Voice-of-the-Customer program to collect feedback using "Feedback Questionnaire" approach. Feedback responses were received from many

small, mid and large size corporations. The "Voice-of-the-Customer Feedback Questionnaire" is shown in Table 6.

Polymer Industry Cluster Initiative

"Voice-of-the-Customer Feedback Questionnaire"

1. What are your businesses challenges?
2. What are the barriers preventing you from addressing these challenges?
3. Do you have any supply chain issues?
4. What are your technology challenges, if any?
5. Can the University of Akron provide help to overcome your technology challenges?
6. Have you worked with the University of Akron before? What has been your experience?
7. If not, would you be interested in exploring a joint program with the University of Akron?
8. Are your hiring needs met through local universities and colleges?
9. Have you worked with the Rubber Division, ACS for training and education of your workforce?
10. If not, would you be interested in exploring training program with Rubber Division, ACS?
11. Do you have any questions or comments on the Polymer Cluster Initiative?
12. How are you addressing megatrends affecting polymer industry?
    - Sustainability: Reuse/Recyclability of materials, End-of-Life Cycle Analysis.
    - Mobility of the Future impacted by CASE (**C**onnected, **A**utonomous, **S**hared, **E**lectrical) vehicles.

Table 6. "Voice-of-the-Customer" Feedback Questionnaire

8.3 Voice-of-the-Customer Feedback:

Following are the key takeaways from the feedback received from industry member companies:

1. Businesses are experiencing serious challenges in hiring skilled workforces both in salary as well as hourly workers.
2. Education, skilled workforce, workforce development and training programs are the most urgent needs of the industry. Following are a few examples of education and training opportunities:
    - Rubber Division, ACS offers range of training program for the industry.
    - The University of Akron's certified training program.
    - However, there is need for more structured training program.
    - Industry has shown interest for the University of Akron to launch i) two-year associate degree program and ii) four-year bachelor's degree program in the School of Polymer Science and Polymer Engineering (four-year bachelor's degree program is scheduled to be launched in Fall 2022) .
    - The University of Akron continues to be the source of new employment force for the local businesses.
3. For the plastic industry, there is a serious shortage of injection molding operators and there is no training offered in our region. The nearest training center is in Eerie PA.
4. COVID-19 pandemic had significant adverse impact on the industry supply chain, workforce, and the businesses revenue generation. Many companies were barely able to manage its operations

in year 2020. 'Distributed Workforce' i.e., working remotely is becoming a norm and not the exception. Expect 2021 and beyond to be much better.

5. Industry relies on university research for new and innovative technologies. Many large and mid-size companies have worked with the University of Akron on technology challenges with positive results. However, a concern was raised that sometimes priorities of the university may not be in alignment with priorities of the industry and that results in limited opportunity for collaboration. The cluster would be an effective tool to overcome this challenge.
6. The concept of consortium is suggested as a means to encourage collaboration between the university and the industry. A consortium can be a catalyst for advance applications of polymers in high tech industry products such as sensors, 5G antenna, and high technology medical devices.
7. Global Trends: In general, there is universal agreement that sustainability, mobility solutions, and health of society are three global megatrends that will have significant impact on the future of the industry and must be addressed. 'Distributed workforce' i.e., working remotely is the 4th big trend that will dominate "Factories of the Future".
8. Sustainability and circular economy along with product life cycle management are top technical challenges and priorities of almost all businesses in the industry. There is opportunity to leverage federal funds under the Build Back Better program to address challenges of global warming, greenhouse gas emissions, and development of renewable advanced materials.
9. Lack of waste management infrastructure in the region to take full advantage of research efforts at our local universities is a gap that must be addressed.
10. Infrastructure Support – critical need for a polymer pilot facility to produce new and innovative materials in quantities required by industry and investors.
11. Entrepreneurial Support – there is very small amount of active capital available in our region due to limited resources and inability to leverage industry venture funds.
12. Industry including NASA Glenn Research would prefer to work with the University of Akron research community on "Big Technology Platforms" that promise future economic growth of the region and where there is a good fit. Examples of technology platforms include:
    - Digital Transformation[141-143]: Data Analytics, Artificial Intelligence, Machine Learning, Human Machine Interface, Digital Twin Concept, Virtual Reality
    - Recyclability, Upcycling, Recyclable polymers[144]
    - Mobility Revolution: **C**onnected, **A**utonomous, **S**hared, **E**lectrical vehicle solutions
    - Cybersecurity

8.4 Summary:

Following is the summary of key challenges, gaps and opportunities as identified from the "Voice-of-the-Customer" feedback.

8.4.1 Key Findings – Challenges & Gaps:

- **Workforce**: the most urgent common problem facing industry – i) strong demand for injection molding technicians, machine operators, analytical technicians, ii) create environment to remove barriers for diverse workforce
- **Research:** alignment with industry needs and long lead time are challenges that should be addressed – i) research is heart of the catalytic growth, introducing new breakthrough materials and processes, ii) region is blessed with world-class research

community dedicated to new materials innovations that should be leveraged to address major global challenges .

- **Entrepreneur Support:** need to boost both financial and non-financial resources – lack "patient capital" given long lead-times in developing new materials; limited concept commercialization capacity exist in the region.
- **Infrastructure:** must enhance regional offerings specific to industry needs – lack pilot scale facility to iterate and produce materials at "scale-up" quantities for maximum impact.
- **Cluster Focal Point:** lack permanent, dedicated, independent cluster leadership – lack of consistent cluster-focused capacity and programming leads to low level of inter-cluster interaction.
- **Communication** of cluster assets and capabilities – lack of clear messaging on cluster assets and capabilities lead to missed opportunities.

8.4.2 Key Findings – Opportunities[144-154]:

- **Sustainability**: across all business sectors – i) circular economy – life cycle analysis/management of materials and products, ii) new recyclable polymers – plastic and rubber, iii) recycling/upcycling of thermoplastics and carbon fiber reinforced composites, iv) recycling of rubber products (e.g., 2 billion tires sold annually, $200+ billion global industry), v) bio-derived/bioinspired materials, vi) advanced materials – smart polymers/sensors, carbon fiber reinforced structural composites, flexible electric-conducting polymers, vii) multiscale molecular modeling for development of new materials, viii) entrepreneurial ecosystem – empowering innovation, global collaboration, IP generation and commercialization.
- **Mobility Revolution:** world is in the middle of a mobility revolution driven by **Zero Emissions**, **Zero Accidents** and **Zero Ownership** – i) **C**onnected, **A**utonomous, **S**hared and **E**lectrical (CASE) vehicles, ii) light weight, durable, strong plastic components (electrical vehicles), iii) light weight, cost effective carbon-fiber reinforced composites (electrical vehicles), epoxy resin encapsulation materials for automotive use (e.g., rotor magnet fixation on e-motors, electronic control unit).
- **Health of the Society:** especially after COVID-19 Pandemic – i) smart materials for Personal Protective Equipment (PPE) design and innovation, ii) new biostable and biocompatible polymers for implantable material devices.

9. Outcome

9.1 SWOT Analysis[155-158]:

Definition:

"A study undertaken by an organization to identify its internal strengths and weaknesses, as well as its external opportunities and threats".

SWOT analysis is a strategic planning and strategic management technique used to help an organization identify strengths, weaknesses, opportunities, and threats related to business competition or project planning. It is sometimes called situational assessment or situational analysis.

Northeast Ohio is ideally suited to be a global leader in polymers. There is an unusually high concentration of polymer industry; a historically strong manufacturing base and workforce; a strong presence of global leaders with headquarters and innovation/technology centers; and globally recognized the University of Akron, Case Western Reserve University and the Kent State University for advance research in polymers and advanced materials. The respective strengths, weaknesses, opportunities, and threats of the polymer industry in Northeast Ohio region are shown in Figure 12.

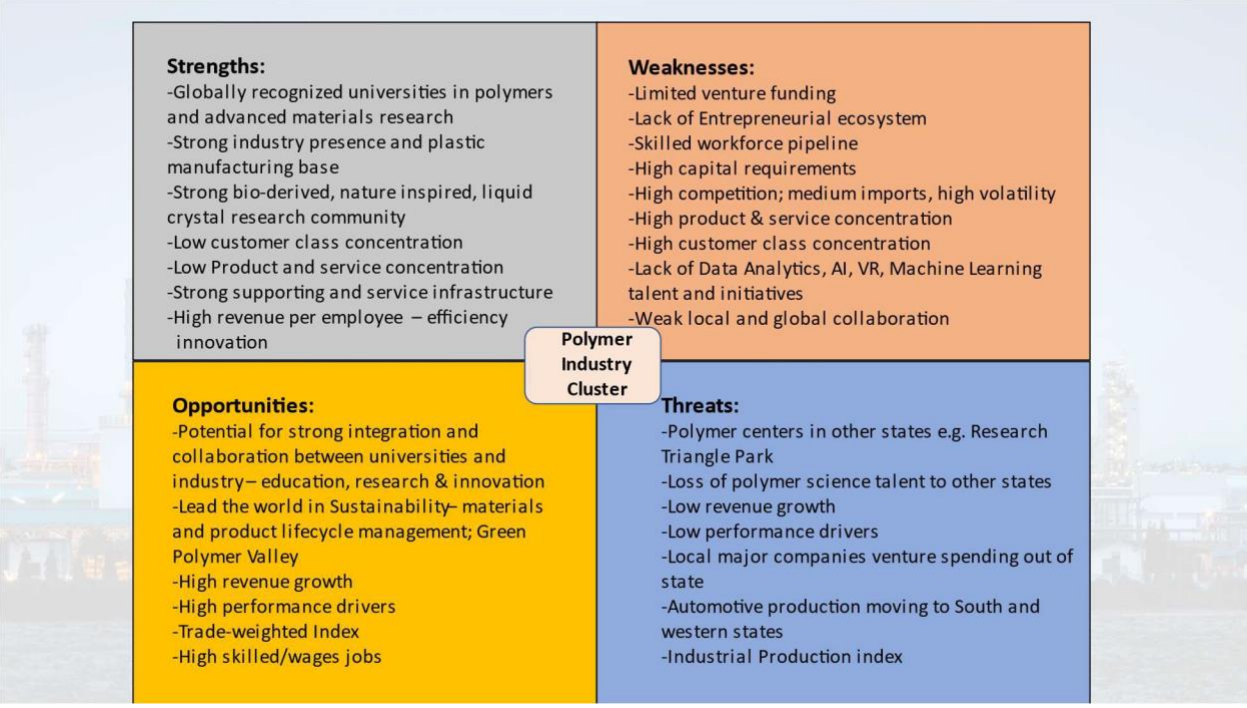


Figure 12. The SWOT Analysis of the Polymer Industry Cluster in NEO Region

9.2 Vision and Mission

Drawing on the strengths identified in the Asset Map, the SWOT analysis with an emphasis on existing regional programs, the advisory council articulated Vision and Mission for the transformative growth of the polymer industry in Northeast Ohio. The polymer industry cluster can be a catalyst to infuse opportunities for innovation, expansion and venture creation.

Vision:

Aspire to become a world-class Polymer Industry Cluster that attracts employers, innovators, entrepreneurs, and investors with an aim to create new ventures, solve big global problems, and elevate economic growth for Northeast Ohio.

Mission[159]**:**

(1) create collaboration and action on shared polymer industry challenges and opportunities that will grow investment, sales, exports, talent and jobs for Northeast Ohio's polymer industry; (2) leverage our rich heritage of polymers research, development, manufacturing, and innovation across industry, academia, and user groups to achieve shared goals; and (3) attract businesses and talent to the region, and grow sales, exports, and jobs.

9.3 Goal and Objective:

To realize the vision, the goal and the objectives of the polymer industry cluster are:

Goal:

Elevate Northeast Ohio's polymer industry into a truly dynamic enterprise that is better positioned for strong sustainable growth in an ever-changing global economy.

Objective:

1. The objective of the Polymer Industry Cluster initiative is to advance collaboration among cluster members and with the School of Polymer Science & Polymer Engineering at the University of Akron, Advanced Materials Liquid Crystal Institute at the Kent State University and the Center of Advanced Polymer Processing at the Case Western Reserve University.
2. Leverage the advantage of the Power of Cluster:
   "Areas with strong clusters produce more economic growth, more jobs, stronger wage growth, increases entrepreneurial activity, and more intellectual property – such as patents – than other areas."
   Institute for Strategy and Competitiveness
   Harvard Business School

9.4 Strategy Framework[160-165]

9.4.1 What is Strategy[162,163]?

Strategy is defined as *"A general direction set for the organization and its various components to achieve a desired state in the future. Strategy results from the detailed strategic planning process."*

Strategy can also be defined as knowledge of goals, uncertainty of events, and need to take into consideration the likely behavior of others. Strategy, in short, bridges the gap between "where we are" and "where we want to be".

Features of Strategy:

1. Strategy is significant because it is not possible to foresee the future; the organizations must be ready to deal with uncertain events.
2. Strategy deals with long term developments i.e. it deals with probability of innovations, new products, new methods of production, or new markets to be developed in the future.
3. Strategy takes into account probable response of customers and competitors.

9.4.2 What is Strategic Framework[161]?

"A strategic framework is an outline of activities that make up an organization's overarching strategy. A framework serves as the foundation for internal and external messaging, organizing all priorities and initiatives into strategic drivers that add up to high level goal or purpose. A strong framework is aspirational, designed to inspire stakeholders and demonstrate how the organization is working towards the vision, purpose, or goals".

A strategic framework typically includes the following elements:

1. Theme – alluding to overall goal or purpose.
2. Strategic Drivers – aligned with business priorities, aspirational goals, and research.
3. Programs or initiatives – supporting strategic drivers.

9.4.3 Polymer Industry Cluster: Strategic Framework

Desired outcomes: reflect measure of success

1. New Innovations and products developed.
2. Start-ups are launched.
3. New ventures created.
4. Large firms are mentoring and investing in promising young firms.
5. Interns and graduates being placed in local companies.
6. Cluster members growing, collaborating and becoming more competitive.
7. Infrastructure including supply chain and services continue to grow.
8. Cluster members addressing and solving global challenges and problems.
9. Growth occurring around Northeast Ohio region.
10. **Northeast Ohio has positioned itself as the undisputed polymer industry leader.**

Strategic priorities: The PIC has identified five strategic priorities:

1. **Foster Conditions for growth in Polymer Industry Cluster** – ensuring that the foundations for growth are in place. These foundational factors include the regulatory structures and environment, workforce program, support networks, and ecosystems
2. **Actively encourage growth in Polymer Industry Cluster** – with strong foundation in place encourage growth among businesses and new ventures promoting diversification and internal collaboration.

3. **Communicate the importance and successes of the Polymer Industry Cluster** – a communication strategy will be integral to building stakeholder support for the cluster. It will also be essential in creating a regional brand in front of a wider global audience of corporate decision makers.
4. **Promote Diversity, Equity and Inclusion (DEI)** – a strategy to support organizations, large and small, with developing transformative, sustainable solutions for diversity, equity and inclusion.
5. **Incorporate the Polymer Industry Cluster as a non-profit organization** – a non-profit organization dedicated to solving global polymer challenges for industrial and consumer goods industry.

Execution of Strategic Priorities: For each strategic priority, the PIC will ensure that the right expertise in the right place at the right time are made available for successful execution of strategic priorities. The relevant actions for each strategic priority are listed below.

Strategy 1: Foster conditions for growth in Polymer Industry Cluster

Ensuring that the foundations for growth are in place. These foundational factors include the regulatory structures and environment, workforce program, support networks and ecosystems.

Actions:

1.1 Build technical expertise and knowledge among regional partners.
1.2 Ensure the talent pipeline is aligned in a way that can support growth.
1.3 Develop entrepreneurial ecosystem to foster innovation, create new venture, and entrepreneurial growth
1.4 Monitor environment, infrastructure, business climate and policies that affect cluster growth.

Strategy 2: Actively encourage growth in Polymer Industry Cluster

With strong foundation in place encourage growth among businesses and new ventures promoting diversification and internal collaboration.

Actions:

2.1 Conduct ongoing strategic outreach to employers for business engagement and relation building.
2.2 Facilitate connecting employers with skilled workers in the region.
2.3 Strengthen the development and retention of entrepreneurial talent.
2.4 Diversify the regional economy and cluster through selective lead and business assistance.

Strategy 3: Communicate the importance of success of the Polymer Industry Cluster

A communication strategy will be integral to building stakeholder support for the cluster. It will also be essential to creating a regional brand in front of a wider global audience of corporate decision-makers.

Action:

3.1 Communicate importance of the Polymer Industry Cluster to community leaders and stakeholders.
3.2 Celebrate the *successes* as well as *the failures* of the cluster initiatives.
3.3 Establish and promote the brand.
3.4 Build awareness of career opportunities to strengthen talent pipelines and alignments.

Strategy 4: Promote Diversity, Equity and Inclusion

A strategy to support organizations, large and small with developing transformative sustainable solutions for diversity, equity and inclusion.

Action:

4.1 Foster a diverse, equitable and inclusive regional labor force.

4.2 Connect buyers to local suppliers of diverse background.

4.3 Avoid bias in job posting, hiring, onboarding, retention and other practices.

Strategy 5: Incorporate the Polymer Industry Cluster as a non-profit organization

A non-profit organization dedicated to solving global polymer challenges for industrial and consumer goods industry.

Action:

5.1 Incorporate the Polymer Industry Cluster a member based non-profit organization.

5.2 Ensure legal and ethical integrity.

5.3 Foster the cluster's mission and purpose – dedicate to solving global challenges by driving innovation.

5.4 Monitor and strengthen cluster programs and services.

5.5 Promote national and international collaborations.

9.5 Project Proposal and Project Roadmap

9.5.1 Project Proposal

As identified in the "Voice-of-the Customer" section, workforce is the most urgent common problem facing Northeast Ohio polymer industry. Initiatives to develop strategies for i) strengthening pipeline of students enrolling in programs from the high school level all the way up to graduate level, and ii) filling training gaps that exit in training programs offered by regional institutions are being formulated. The University of Akron is considering the development of a two-year Polymer Technology Apprenticeship Program (PTAP) leading to associate degree in polymer technology. This initiative will go a long way in addressing the urgent workforce needs of the industry.

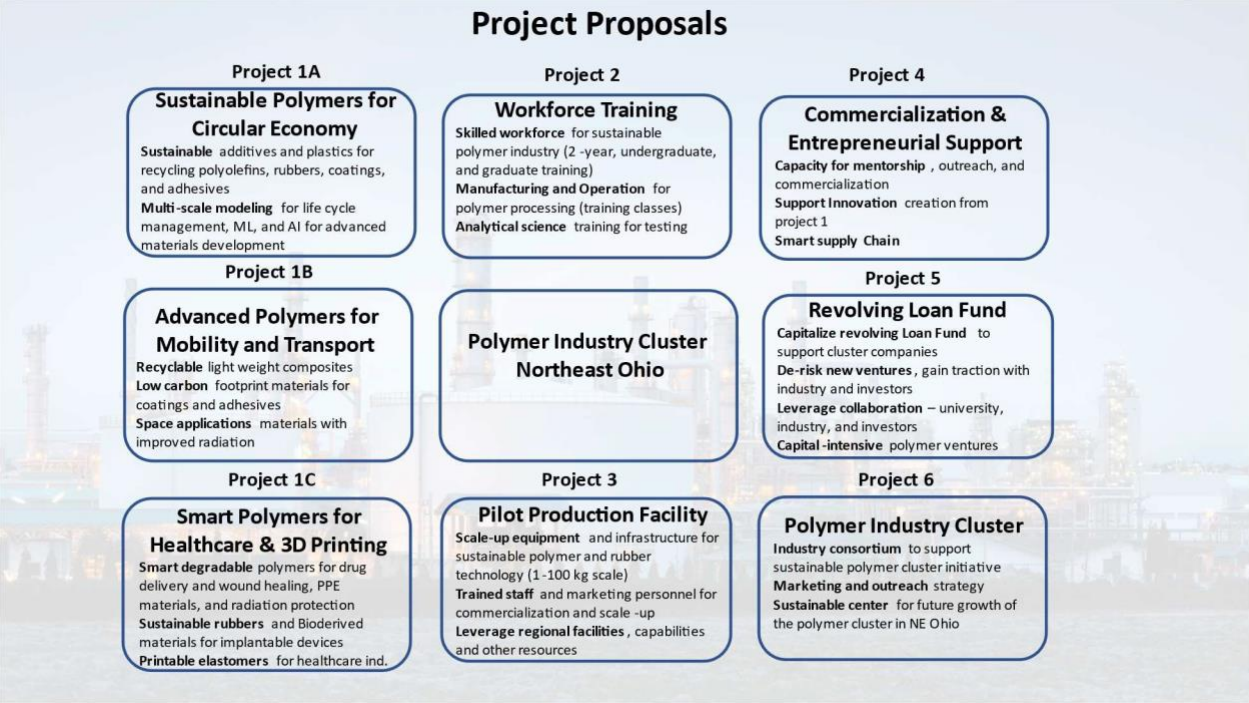


Figure 13. The project proposals to address global challenges and polymer industry needs

The challenges and opportunities facing the global polymer industry are sustainability, the future of mobility, and health care. As global industries adopt to increasingly aggressive sustainable goals, the development, production and use of commercial products should be sustainable, recyclable and be environmentally friendly. With the future of mobility, there are increasing opportunities to integrate and contribute to connected, autonomous, shared and electrical vehicles. And, polymers have an important role to play in the health care industry by developing biocompatible and biostable materials. In view of these tremendous opportunities, we are proposing a matrix of projects shown in Figure 13 to create economic growth opportunities for the industry and the region.

9.5.2 Project Roadmap: Polymer Industry Cluster Horizon Model

What is horizon Model[166]?

The horizon model is a growth strategy framework developed by McKinsey. The horizon model helps to manage vision and guide conversations by showing innovation plan and goals of that plan over time – including when to expect results. It is great for portfolio management and growth strategy.

Horizon 1 innovations are generally short-term projects that generate results in 1-3 years. Easier to justify because tangible results are within sight.
Horizon 2 innovations take a bit longer. From conception to completion, one could expect to see results in 2-5 years.
Horizon 3 ventures are long-term innovation projects that generally produce results in 5-12 years They are typically associated with disruptive or radical innovations.
Polymer Industry Cluster project roadmap is shown in Figure 14. The elements of the project proposals shown in Figure 13 are represented in Horizon 1, Horizon 2 or Horizon 3 depending upon the complexity

of the project. Significant investment from the industry, state and federal agencies will be needed to execute project proposal roadmap.

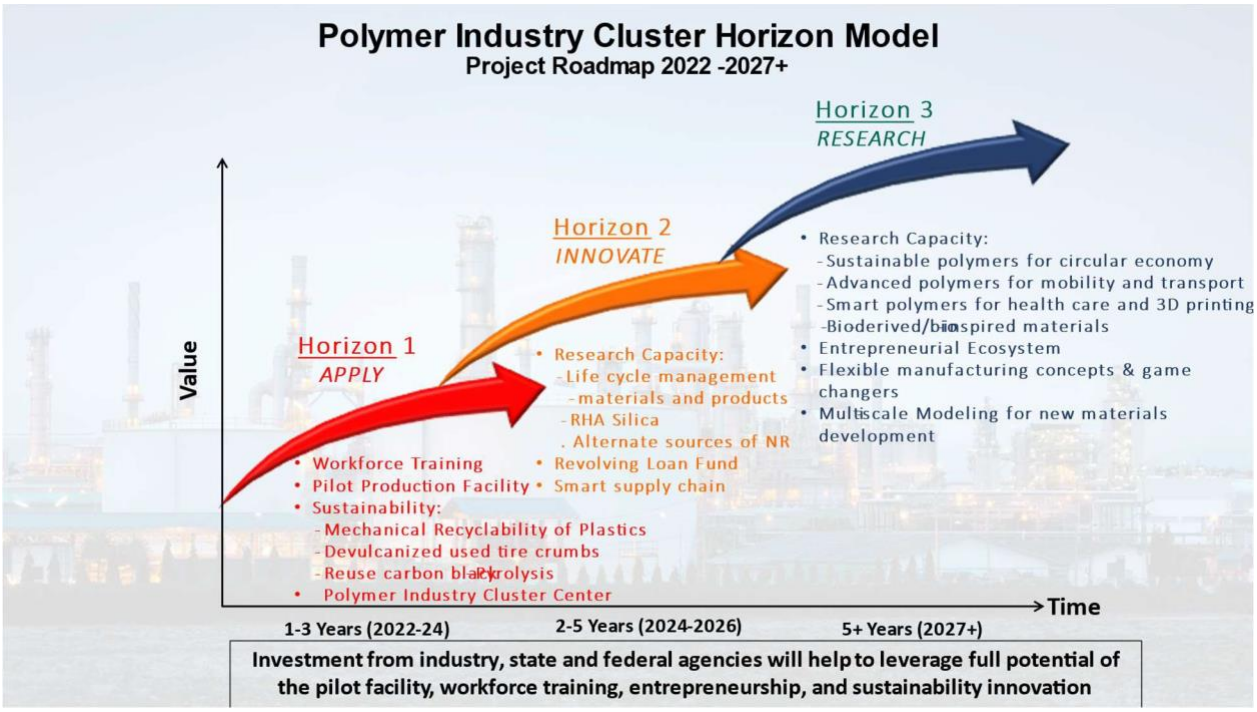


Figure 14. Polymer Industry Cluster project roadmap

9.6 Commercialization Strategic Framework

The Northeast Ohio polymer commercialization strategic framework shown in Figure 15 address three key areas: i) implementation of polymer solution, ii) polymer innovation and iii) workforce skill training development. The ultimate goal is coordinated integration of polymer solutions into polymer industry.

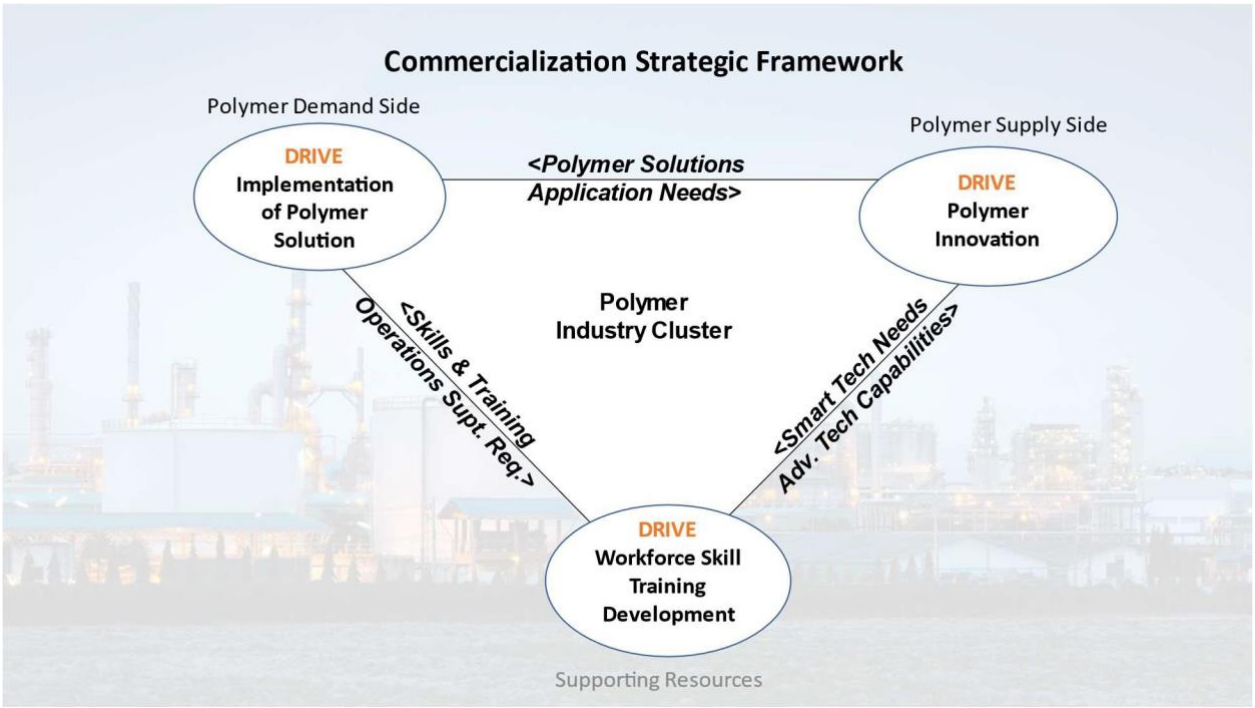


Figure 15. The Commercialization Strategic Framework

10. Path Forward – 2022

10.1 Polymer Industry Advisory Council Structure

Our work in year 2021 included the benchmark analysis (Chapter 5) of a few other established industry clusters that have built a structure and established continuity. These cluster organizations operating in other regions keep a modest staff of highly talented, connected, and creative individuals that are dedicated to advance, expand, and execute on research, supply chain, entrepreneurship, and workforce. The cluster organizations serve as a focal point both listening to industry leaders to learn their needs and at the same time providing an unparalleled network of industry leaders, connections and facilitate collaborations.

This is the direction for the polymer industry cluster to follow with a modest investment. The path forward is to expand engagement of the industry cluster leaders among themselves and with the region's universities. The Polymer Industry Advisory Council (PIAC) started with 17 members that had grown to 26 by the end of year 2021. The goal is to expand the PIAC to 50 by the end of 2022. It is proposed to create four distinct working groups to focus on four key need areas of the industry. The Figure 16 shows the recommended structure of the PIAC in 2022.

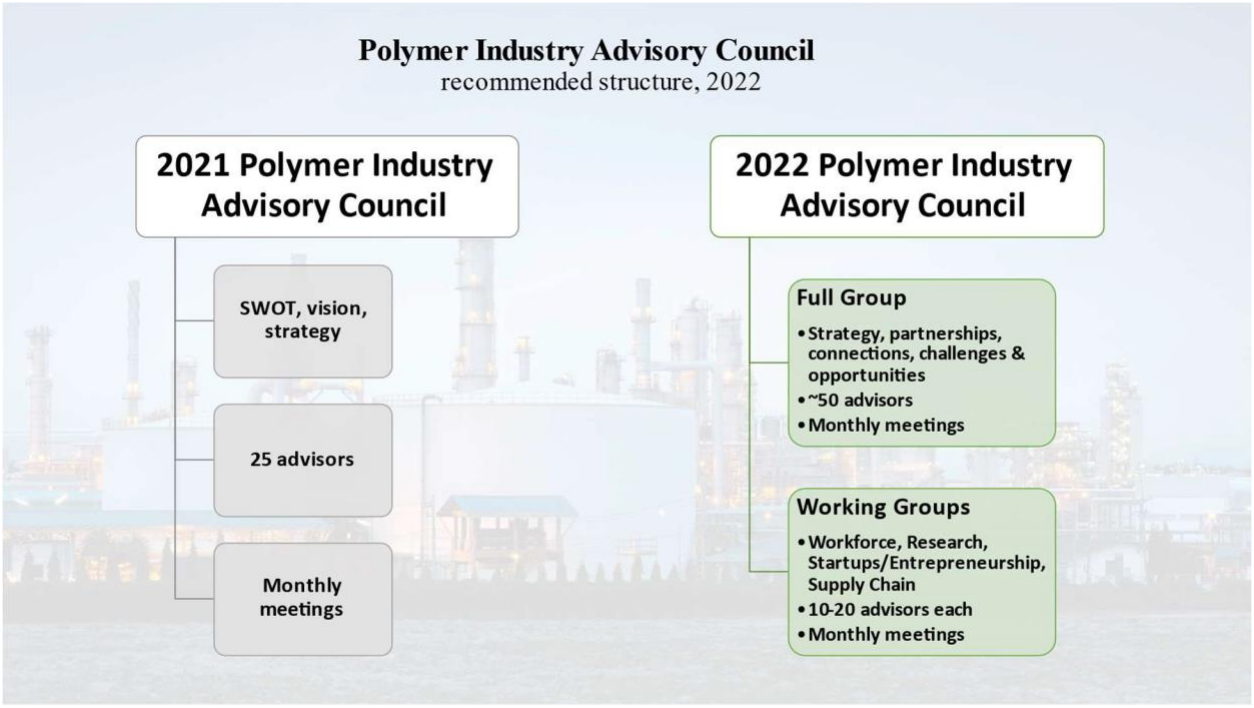


Figure 16. The recommended structure of the Polymer Industry Advisory Council

Four New Working Groups:

1. **Workforce:**

   Purpose: Design and implement workforce development strategies specific to the polymer industry; support outreach efforts to increase STEM enrollment and graduate retention; identify and address regional curriculum gaps.

   Quick Wins: Create/support engagement opportunities for polymer companies with local mid- and high schools; establish and grow a state-sponsored polymer industry sector partnership; educate employers on On-the-Job-Training (OJT) and other resources.

Metrics of Success: Number of student engagements, increase OJT utilization, increase enrollment in critical education/training programs.
Long-Term Focus: Forecast industry employment needs, and proactively drive enrollment to meet demand; make polymers a visible choice for students to pursue career; establish a clear and efficient set of training programs.

2. **Research & Development:**
Purpose: Promote empowering innovation, address global challenges and shared opportunities: i) environment for open innovation and collaboration, ii) deployment of pilot production facility, iii) sustainability – circular economy, iv) advanced materials – multiscale modeling for new materials development, v) mobility solutions – Connected Autonomous Shared Electrical (CASE) vehicles, and vi) health care solutions.
Quick Wins: Deployment of pilot production facility; enhanced collaboration among cluster members and educational and research institutes; sustainability solutions - expanded use of known technologies, mechanical recyclability, new bio-based materials.
Metrics of Success: Number of collaborations, number of new patents/trade secrets, innovation impact on business growth, number of new start-ups, number of commercialized successes.
Long-term Focus: Northeast Ohio as Green Polymer Valley; advanced materials development: smart materials, carbon fiber reinforced structural composites (use & reuse); upcycling of polymers/plastics; digital transformation – big data, machine learning, artificial intelligence; smart/additive manufacturing.

3. **Supply Chain:**
Purpose: Provide information to suppliers on current and projected polymer industry needs; proactively identify potential supply gaps; support supplier innovation; identify potential supplier attraction targets for Northeast Ohio.
Quick Wins: Utilize economic data resources to present and verify regional supply gaps.
Metrics of Success: Identify and prioritize polymer industry supply gaps; increase engagements between suppliers and polymer companies.
Long-Term Focus: Establish a continuous process for identifying and address polymer industry supply needs.

4. **New Ventures:**
Purpose: Identify, support, and elevate high potential polymer start-ups; strengthen connections between Northeast Ohio organizations offering support to polymer-focused entrepreneurs.
Quick Wins: Identify current high-potential polymer start-ups; organize demand to create polymer EIR (Entrepreneur-In-Residence) at Bounce Innovation Hub.
Metrics of Success: Number of start-ups/ventures created; number of jobs created; venture capital investment.
Long-Term Focus: Northeast Ohio region's transformation to Entrepreneur Ecosystem (EEcosystem); Northeast Ohio destination of new venture capital investment in polymer and advanced materials; center of polymer recyclability solutions.

10.2 Polymer Industry Cluster Investment in 2022

The operating budget of the Polymer Industry Cluster for the year 2021 was $115,000. It is suggested that the operating budget be increased to $250,000 in order to cover the cost of 1 additional staff and 1 consultant in 2022. The goal of this effort is to secure investment in the Polymer Industry Cluster from a mix of Government, non-profit, philanthropic, and private sector companies. To secure an operating budget of $250,000, a Polymer Industry Cluster membership model along the lines of The Water Cluster of Milwaukee, Wisconsin is proposed. The membership contribution is organized by the size of annual revenue of the company. The suggested investment model for 2022 is shown in Figure 17.

Figure 17. The Polymer Industry Cluster Membership Model

Serving the Polymer industry[60]:

The Polymer Industry Cluster will offer its members:

- Access to an unparalleled network of industry thought leaders, policymakers and innovators.
- Cluster is committed to CONVENE, CONNECT and SHOWCASE members by providing full range of business development services, networking and collaborating opportunities with global polymer leaders.

Benefits to Polymer Industry Cluster Members:

- **CONVENE:**
  - Host Polymer Industry Cluster networking, events, workshops and webinars.
  - Access to pipeline of prospective employees from interns/entry-level to full year college degree talent.
  - B2B sessions/matchmakings.

    - Host global delegation visits.
- **CONNECT:**
    - Access to robust network of entrepreneurs and start-ups.
    - Connection to a network of academic and federal laboratories and researchers.
    - Connection to supply chain, distributors, engineering/manufacturing support, and professional services.
    - Access to funding programs.
    - Access to diverse network of global partners and national and international members.

- **SHOWCASE:**
    - Create polymer cluster website.
    - Alignment with relevant clusters including manufacturing, materials, automotive etc.
    - Guest speaking opportunities as subject matter experts.
    - Members upcoming events, news releases and open positions on PIC website.

Return on Investment for 2022:

- Expand Polymer Industry Advisory Council from 25 to 50; facilitate monthly meetings.
- Create & facilitate working groups for key areas of development.
- Pursue opportunities for outside funding to drive growth in the cluster.
- Develop communication tools/materials for the Northeast Ohio Polymer Industry Cluster.
- Retain responsive, connected ecosystem to help accomplish businesses goals.
- Create new global opportunities to develop contacts, partnerships, and investments.
- Serve as industry specific resource uniquely capable to provide broad services to members.
- Assist in adopting new technologies to create new products services and competitive advantage.
- Assist in addressing global challenges critical to the industry.
- Facilitate open innovation (Connect & Develop) opportunities for members.
- Promote collaboration and competitiveness among industry members.

The goal through all of this effort is to catalyze substantial and sustainable new growth. This can be achieved by strengthening the region's polymer workforce, creating new partnerships among businesses, and between region's universities and businesses; improve communications to market Northeast Ohio polymer industry assets and capabilities. Much can be done to demonstrate that the Northeast Ohio is where polymer companies want to locate and grow.

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